International Civil Aviation Organization

Twenty Fifth Meeting of the Communications/ Navigation and Surveillance Sub-group (CNS SG/25) of APANPIRG

Video Tele-Conference, 18 – 22 October 2021

Agenda Item 4: Aeronautical Mobile Communications Service and Aeronautical electromagnetic spectrum utilization

4.3 Other issues related to aeronautical communications service and aeronautical radio spectrum management,

HANDBOOK ON RADIO FREQUENCY SPECTRUM REQUIREMENTS FOR CIVIL AVIATION (DOC 9718, VOLUME I and II)

(Presented by the Secretariat)

SUMMARY

This paper presents the latest revision of the Handbook on Radio Frequency Spectrum Requirement for Civil Aviation (DOC9718), Volume I and Volume II, which are to be formally published in early 2022.

1. INTRODUCTION

1.1. ICAO developed this Handbook on Radio Frequency Spectrum Requirements for Civil Aviation and the first edition was published in 1998.

1.2. This handbook contains the ICAO spectrum strategy and policy statements relevant to the aviation requirements for radio frequency spectrum, as approved and amended by the ICAO Council. The handbook is intended to assist States and ICAO in preparing for ITU conferences.

1.3. The material in this handbook is supplementary to the Standards and Recommended Practices (SARPs) contained in Annex 10 to the Convention on International Civil Aviation — Aeronautical Telecommunications, which continue to have precedence and applicability for those aspects covered by their provisions.

1.4. The handbook consists of two volumes: Volume I contains the **ICAO spectrum strategy, policy statements and related information**. Volume II contains **Frequency assignment planning criteria for aeronautical radio communication and navigation systems**.

2. DISCUSSION

2.1. Amendments to this handbook will be made on a regular basis so that the material will represent the latest position on the spectrum requirements for civil aviation. Towards this end, the

recommendations of divisional-type meetings and air navigation conferences as well as the findings and Recommendations of ICAO panels and other (e.g. regional) bodies, as approved by the Air Navigation Commission and Council as appropriate, are expected to be among the main sources of information. Changes may also be necessary as a result of decisions taken at ITU WRCs.

2.2. Results of ongoing activities in ICAO on spectrum management are available on the website for the Frequency Spectrum Management Panel (FSMP) at https://www.icao.int/safety/fsmp. FSMP is undertaking the activities on preparation and coordination of material, including the development of the draft ICAO Position, in particular for ITU WRCs, ITU-R study group meetings and meetings of regional telecommunication organizations.

2.3. There are 2 chapters and 3 appendices in the original Handbook Volume II, including Chapter 1. General Methodology for compatibility Analysis, and Chapter 2. Aeronautical VHF air-ground radio communication system operating in the band 117.975-137MHz.

2.4. The ICAO Secretariat initiated the revisions to the Handbook Volume II in 2018. The outcome was reviewed by the Navigation Systems Panel (NSP) in 2018 and circulated to CNS experts in the regions.

2.5. The overall revisions were presented to APAC CNS SG/23 through IP/10 in 2019 and to APAC SRWG/4 through IP/02 in 2020, including a review to Chapter 1, new Chapters 3 - ILS, Chapter 4 - VOR, Chapter 5 – DME, Chapter 6 - GBAS/VDB and Appendix A with conversions and formulas relevant to frequency assignment planning.

2.6. On 30th July 2021, the "UNEDITED ADVANCE REVISION" of Doc 9718, Volume I and Volume II is available at the FSMP website, which includes all amendments resulting from FSMP WG/11 (1-12 March 2021, VTC). Doc 9718 Vol I includes updates to Chapters 7 and 8 as well as Appendix F (ICAO Position). Doc 9718 Vol II includes the new material as received from NSP/6 (2 - 13 November 2020, VTC). The "UNEDITED ADVANCE REVISION" of Doc 9718, Volume I and Volume II is provided in **Appendix A** and **Appendix B** to this paper respectively.

2.7. The planning requirements contained in the revision for compatibility assessment of frequency assignments to NAV systems (ILS, VOR, DME and GBAS/VDB) have been incorporated in the new release of **Frequency Finder** tool.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information in this paper and in the **Appendix A** and **Appendix B**; and

b) discuss any relevant matter as appropriate.

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Doc 9718
AN/957

Handbook on Radio Frequency Spectrum Requirements for Civil Aviation

Volume I
ICAO spectrum strategy, policy statements and related information

Second Edition — 2018 – including updates in 2021

NOTICE TO USERS

This ***special*** **UNEDITED ADVANCE REVISION** includes u**pdates** to Chapters 7 and 8 **by FSMP WG/11 (**March **2021)** and the ICAO Position for WRC-23, as approved by ICAO Council on 16 June 2021.

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International Civil Aviation Organization

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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
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The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of ICAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

FOREWORD

Historical background

ICAO's Special Communications/Operations Divisional Meeting held in 1995 (Special COM/OPS/95) noted that the International Telecommunication Union (ITU) had begun to convene its World Radiocommunication Conferences (WRCs) every three to four years. While divisional-type ICAO meetings had traditionally developed positions on WRC agenda items related to aviation, it was evident that it was not feasible to convene such meetings frequently enough to keep pace with this schedule of WRCs. The Special COM/OPS/95 meeting recognized the importance of keeping up with the rapid development in telecommunications and consequently recommended that a new mechanism be developed to enable civil aviation to record its agreed requirements for aeronautical radio frequency spectrum in an adequate and timely manner.

The meeting accordingly recommended that an ICAO radio frequency (RF) document be developed and maintained (Recommendation 7/1). The Air Navigation Commission, at its meeting on 19 June 1995 (ANC 139-10), approved the recommendation for action. Subsequently, ICAO developed this *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation* and the first edition was published in 1998.

Recommendation 7/1 — ICAO radio frequency (RF) policy document on the aeronautical utilization of the RF spectrum

That ICAO develop and maintain a document (rolling plan) containing policy statements and other elements relevant to the utilization of the frequency spectrum with a view to assisting States and ICAO in their preparation for future ITU world radiocommunication conferences.

Status of the handbook

This handbook contains the ICAO spectrum strategy and policy statements relevant to the aviation requirements for radio frequency spectrum, as approved and amended by the ICAO Council.

The handbook is intended to assist States and ICAO in preparing for ITU conferences. The ICAO Position on matters of interest to aviation on the agenda of ITU WRC-19 is included in Attachment F. The approach for establishing and promoting the ICAO Position for future ITU WRCs is in Attachment E.

The material in this handbook is supplementary to the Standards and Recommended Practices (SARPs) contained in Annex 10 to the Convention on International Civil Aviation — *Aeronautical Telecommunications*, which continue to have precedence and applicability for those aspects covered by their provisions.

Amendments to this handbook will be made on a regular basis so that the material will represent the latest position on the spectrum requirements for civil aviation. Towards this end, the recommendations of divisional-type meetings and air navigation conferences as well as the findings and Recommendations of ICAO panels and other (e.g. regional) bodies, as approved by the Air Navigation Commission and Council as appropriate, are expected to be among the main sources of information. Changes may also be necessary as a result of decisions taken at ITU WRCs.

Results of ongoing activities in ICAO on spectrum management are available on the website for the Frequency Spectrum Management Panel (FSMP) at http://www.icao.int/safety/fmsp. FSMP is undertaking the activities on preparation and coordination of material, including the development of the draft ICAO Position, in particular for ITU WRCs, ITU-R study group meetings and meetings of regional telecommunication organizations.

Organization of the handbook

The handbook consists of two volumes:

Volume I contains the ICAO spectrum strategy and policy statements. It updates and replaces the material previously contained in the first edition of Doc 9718, Volume I, published in 2014.

Volume II contains technical material on the utilization of radio frequency spectrum by aviation.

Volume I is structured as follows:

— Chapter 1 introduces the subject of radio frequency spectrum management and aspirations.

— Chapter 2 defines the objectives and purpose of the handbook.

— Chapters 3 to 5 describe the institutional aspects and the relationships between the main participants (ITU, ICAO, national authorities, etc.).

— Chapter 6 contains an overview of the spectrum management process.

— Chapter 7, which is divided into four sections, contains the principal elements of the handbook. Each frequency band and its uses are described in detail, together with the approved ICAO policy statements for the civil aviation spectrum requirements in that band. Also included are relevant provisions (Regulations), Resolutions and Recommendations which are contained in the ITU Radio Regulations.

— Chapter 8 contains the ICAO spectrum strategy and vision and addresses future requirements of frequencies for civil aviation.

— Chapter 9 describes the elements of a framework of rules and preventative measures for the regulation and control of interference.

— Attachment A provides a selection of relevant ITU definitions.

— Attachment B contains acronyms and abbreviations used in the handbook.

— Attachment C gives an overview of the regulatory aspects of radio equipment in aircraft.

— Attachment D addresses the processes and sequence of actions for the review and updating of the handbook.

— Attachment E contains the ICAO approach for improving support for the ICAO Position.

— Attachment F contains the ICAO Position for ITU WRC-19, as approved by the Council on 19 June 2017.

— Attachment G contains technical information and frequency-sharing criteria.

— Attachment H references relevant ITU Resolutions and Recommendations which are incorporated in the ITU Radio Regulations.

Action by Member States and ICAO

States are requested to use the material in this policy document, as it is necessary and opportune, in their national discussions on matters relating to the use of the radio frequency spectrum by international civil aviation. In particular, the ICAO spectrum

strategy, the ICAO policy statements and the ICAO Position for ITU WRCs should be utilized and incorporated in proposals from States for ITU WRCs, meetings of the ITU-R sector (ITU-R study groups) and meetings of regional telecommunication organizations as the up-to-date agreement within ICAO on the reference subject. ICAO observers at these conferences and meetings may also, as necessary, use the material from the document as the agreed ICAO policy for international civil aviation purposes.

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Note 1.— Although this handbook includes relevant provisions from the ITU Radio Regulations, these extracts are not complete and the handbook should therefore be used in conjunction with the full text of the ITU Radio Regulations and the relevant ITU-R Recommendations.

Note 2.— Throughout this handbook, extracts from the ITU Radio Regulations are presented against a shaded background.

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Chapter 1

INTRODUCTION

1.1 The radio frequency spectrum is a scarce natural resource with finite capacity limits and for which demand is constantly increasing. Predictions of future demand for spectrum indicate a continuing rate of increase for all users and radio services and facilities that utilize radio waves as the world economies progressively expand. The competition among all users for the spectrum available is hence expected to intensify in the years ahead. In this competitive situation, even a user holding a spectrum allocation will not have an automatic right to retain that radio frequency spectrum, as a decision by an International Telecommunication Union (ITU) conference may require that spectrum be removed from any radio service to meet a superior justified demand for other radio services. Aviation is only one of many such competitors, albeit with the significant benefit of a worldwide cooperative forum, namely the International Civil Aviation Organization (ICAO), to coordinate and support its case.

1.2 Aeronautical services are recognized internationally to be prime users of radio frequencies without which aircraft operations would not be capable of meeting the global demand for safe, efficient and cost-effective transport. The prominent safety-of-life element, present during all phases of an aircraft's flight, is accorded special treatment internationally and is granted protection from harmful interference through agreed measures. Spectrum allocated to aeronautical services in the main frequency bands is divided into two main functions: air-ground communications and radionavigation. The gradual introduction of satellite-based services in accordance with the communications, navigation and surveillance/air traffic management (CNS/ATM) policies agreed at the Tenth Air Navigation Conference (1991) and approved by the ICAO Council is progressing.

1.3 Radio frequency spectrum congestion imposes on all users the duty of spectrum-efficient operation. The process of channel splitting, as employed in some aeronautical communication and navigation frequency bands, is an example of technological development helping to achieve spectrum-efficient operation and meeting future requirements without requiring additional spectrum. Modern sophisticated systems employing complex modulation techniques are another facet of efficient spectrum use when transmitting more information within the same bandwidth. Extending radio services and systems into higher frequency bands is yet another. These measures need to continue for the foreseeable future.

1.4 The process of international competition between expanding radio services obliges all existing users (i.e. aeronautical and non-aeronautical) to continually defend and justify the retention of frequency bands or the addition of new bands to those already allocated to their service, subject to the same conditions as apply in other services. Civil aviation operations are expanding globally, requiring more navigation and communication facilities and thus creating additional pressures on the already stressed and limited spectrum availability. The civil aviation community must accordingly develop and present, as necessary, its agreed policies and its quantified and qualified statements of requirement for radio frequency spectrum so as to ensure the continuing availability of adequate radio spectrum and, ultimately, the ongoing viability of air navigation services throughout the world.

1.5 Aeronautical systems utilize frequency bands that are attractive to many users due to their propagation characteristics, their generally worldwide allocations and resultant benefits in equipment design. Many of these users are global industries delivering significant economic benefits that are well understood by governments. The potential revenues for such sectors are often directly quantifiable in terms of their overall spectrum bandwidth allocation. However, unlike other spectrum users, the amount of spectrum used by aeronautical safety systems is not directly related to revenue and thus the quantification of the cost benefit of aviation spectrum bandwidth can become challenging.

1.6 Competition among spectrum users is becoming more severe and each ITU/WRC cycle sees increasing demand for new allocations to meet industry and societal demands for improved communications and new applications. Spectrum availability is now a key issue, and potentially a critical constraint, to delivering innovation and growth in all sectors. This has resulted in significant economic pressure on radio regulators and governments to ensure spectrum can be managed in a way that can adapt to meeting these changing needs.

1.7 This document contains a balanced and justified presentation of aviation needs, and it will be made available to all aviation interests involved in the frequency management process. It will be updated through regular amendments based on technological developments in communication, navigation and surveillance systems for aviation and changing operational requirements on the utilization of these systems. These updates also consider the decisions in the ITU, including amendments to the ITU Radio Regulations and the development of relevant ITU-R Recommendations and reports.

Chapter 2

OBJECTIVES AND PURPOSE

2.1 The ITU is the specialized agency of the United Nations for telecommunication matters where international agreements are made on the use of the radio frequency spectrum. At World Radiocommunication Conferences (WRCs), convened about every four years, changes are made to the ITU Radio Regulations, including the Table of Frequency Allocations (Article 5 of the ITU Radio Regulations), on the basis of proposals made by States. This mechanism was introduced in 1992 in order to better adapt the Table of Frequency Allocations to rapid technological developments and spectrum requirements for all users of the radio frequency spectrum.

2.2 A consequence of this process is that a coordinated aeronautical position (the ICAO Position) must be established for every ITU WRC and finalized well in advance of the ITU conference itself, in order to be of maximum use to aviation authorities. The ICAO Position is intended to be used by civil aviation authorities in their national discussions with the radio regulatory authorities when developing proposals for submission by their administrations to meetings of regional telecommunication organizations which prepare regional positions for ITU conferences as well as to the ITU conferences themselves and to brief the delegations at these meetings. In addition, it is to be used by aviation experts at these conferences and is submitted by ICAO to the ITU conferences in the form of an information paper. The ICAO Position contains the agreed radio frequency allocation requirements for aeronautical radio services, including the necessary protection from harmful interference, that are provided to support safety-critical aeronautical communication, navigation and surveillance systems. The ICAO Position, the ICAO spectrum strategy and the ICAO policy statements in this handbook are developed by the Air Navigation Commission, with the assistance of the Frequency Spectrum Management Panel (FSMP), and approved by the ICAO Council. In developing the ICAO Position, all ICAO Member States and relevant international organizations are consulted.

2.3 With this background, the prime objectives of this document are:

a) to provide a consolidated and up-to-date statement of agreed spectrum requirements for aeronautical services and the ICAO policy in the frequency bands used by international civil aviation for the communication, navigation and surveillance systems that are to be provided for air traffic purposes, taking into account all future needs;

b) to provide a source of reference for relevant ITU regulations, resolutions, recommendations and associated ITU-Radiocommunication Sector (ITU-R) material;

c) to provide a convenient record for important frequency management material, such as the criteria applied in the planning of radio frequency assignments, and the protection from interference; and

d) to provide background information on the international spectrum management institutional framework and the main ITU elements.

Chapter 3

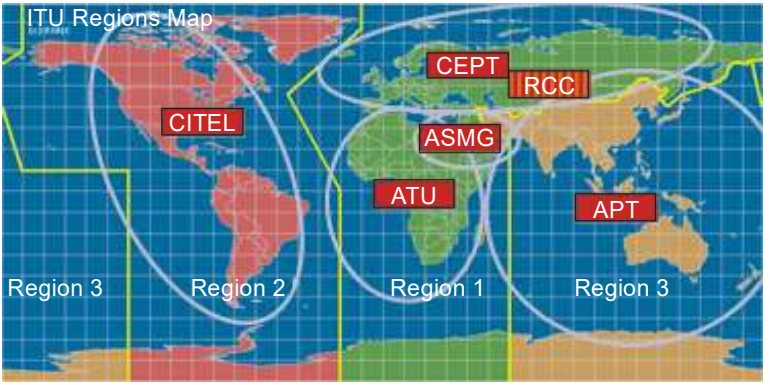
THE INTERNATIONAL TELECOMMUNICATION UNION

3.1 The ITU was founded in Paris on 17 May 1865 as the International Telegraph Union and took its present name in 1934 at the International Telegraph Conference in Madrid. In August 1947, the United Nations recognized the ITU as a specialized agency in the field of telecommunications, while acknowledging also that other specialized agencies, such as ICAO, would not be barred from any kind of work touching upon aeronautical telecommunications including standardization activities. The recognized competence of the ITU embraces all aspects of telecommunications, whether by line or by radio transmission, for which it has authority to set standards for systems, technical parameters and procedures. A prime and highly important area for aviation concerns the regulation and use of the radio frequency spectrum for which ITU is the recognized international body. The agreements made under its auspices for these matters and incorporated in the Final Acts of World Radiocommunication Conferences (which prior to 1993 were known as World Administrative Radio Conferences) are accorded treaty status and have full mandatory force without any possibility for variation in regard to their scope or their substance except by agreement at a further conference.

3.2 The basic treaty documents of the ITU (the ITU Constitution and the ITU Convention) may be amended at Plenipotentiary Conferences which are held every four years. Between these conferences, the Council, with a membership not exceeding 25 per cent of the total number of members of the Union, performs a policy and management function. The Council normally meets once per year for a duration of two weeks. The representation from member administrations to ITU conferences and meetings is drawn from national telecommunication authorities representing all the radio services and users in their State. Consequently, policy and decisions at a national level are matters for these authorities.

3.3 The internationally agreed regulation of the radio frequency spectrum is provided through the ITU Radio Regulations, parts of which are reviewed at WRCs. Within the Radio Regulations, the finite useable radio spectrum, from approximately 8.3 kHz to 275 GHz, is allocated to user services (see Figure 3-3) in response to their recognized demands, and among three ITU world Regions (see Figure 3-1) in accordance with the major regional spectrum requirements for these services in the relevant region. The allocations are contained in Article 5 of the Radio Regulations; together with other provisions on licensing, interference resolution, safety and

distress procedures and other aspects, the Radio Regulations are the treaty requirements to be observed at all times by all radio services.



Approximate coverage of ITU Regions
by regional telecommunication organizations

Figure 3-1. Map of ITU world Regions

3.4 Within ITU Member States, the telecommunication authorities (or telecommunication administrations) normally control and operate the mechanism which develops the national proposals for amending the Radio Regulations for submission to the ITU WRCs. National and international (regional) preparatory committees function as the coordination medium to which the aviation requirements, either ICAO coordinated or nationally derived, are presented by the national aviation authorities for consideration. National policies take into account all of the competing interests of radio frequency spectrum users to determine the States' proposals to the conference. It is essential that aeronautical participation in these national and regional activities be ensured in order to support and defend aviation requirements.

3.5 Aviation services are recognized important users of radio spectrum to create safe and expeditious conditions to support air operations. The aeronautical mobile (route) service (AM(R)S), the aeronautical radionavigation service (ARNS) and their satellite service counterparts are important components in the mobile and radiodetermination families of users (see Figure 3-3) with (normally) exclusive allocations made on a worldwide basis to ensure global harmonization. A summary

overview of the use of spectrum by aviation is in Figure 3-2. Worldwide allocations enable international standardization of equipment and systems to support safe and global air traffic. The Radio Regulations are used as the framework for the relevant ICAO Annexes and the Standards and Recommended Practices (SARPs) contained therein.

3.6 The Radio Regulations also regulate the prevention and removal of interference, whether between services, countries or regions, between frequency assignments, or from other sources of radiation such as industrial or medical equipment. Particular attention is accorded to services that have a predominant critical safety-of-life function, such as aeronautical and radionavigation services. This is reflected in special measures for rapid elimination of interference by national telecommunication authorities or, in case interference is affecting two or more States, through bilateral negotiations with authorities in these States. Other special measures such as the use of radio in distress and emergency situations or for search and rescue operations, in collaboration with maritime and land services as necessary, are also given prominent treatment.

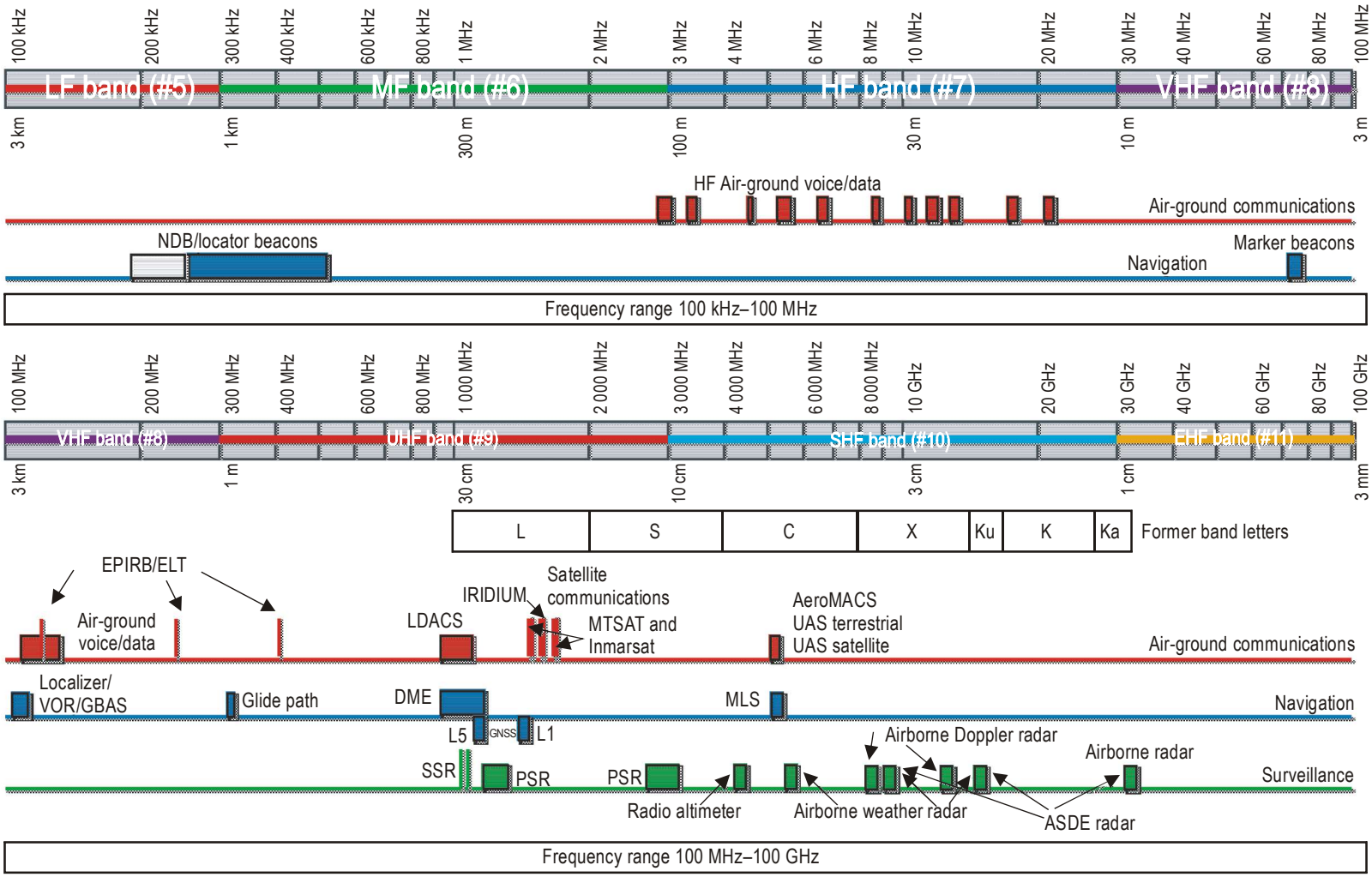
3.7 In the radio field, the technical work of the ITU is performed on an ongoing basis by the ITU Radiocommunication Sector (ITU-R) and the ITU Radiocommunication study groups (ITU-R SG). The ITU-R study groups support this technical work through the development of relevant ITU-R Recommendations, or reports and handbooks. Most aviation related issues are addressed in ITU-R Study Group 5 which deals with terrestrial services including mobile and radiodetermination. ITU-R Study Group 4 deals with satellite services including those used for aeronautical purposes. This work is important to aviation, particularly in relation to the development of ITU-R Recommendations addressing compatibility between aeronautical and non-aeronautical services with the view to preventing harmful interference to aeronautical use of radio frequency spectrum. In addition, the detailed technical preparations for the WRCs which are undertaken under the auspices of the Radiocommunication Bureau by the Conference Preparatory Meeting (CPM) are delegated to these STUDY Groups. The CPM functions as a permanent body using material developed by the ITU-R study groups and presented by administrations in developing the CPM Report to the WRC. The CPM Report provides information on the technical, operational and regulatory/procedural issues relevant to the WRC agenda items.

3.8 In response to its specialized responsibility and competence in civil aviation, ICAO has been accorded observer status (*"Observer in an advisory capacity"*, see Section 7-III.2) at all conferences and meetings held under ITU auspices, including ITU-R meetings. This enables ICAO to submit its internationally agreed statements on telecommunication policies and frequency use and ensures that the ICAO Position and policy is propagated at these conferences and meetings and, to the maximum extent

possible, to ensure that aeronautical allocations and frequency use, including future requirements, are safeguarded.

3.9 In order to coordinate frequency use and spectrum requirements within specific regions of the world, a number of regional bodies have been set up in a cooperative arrangement between telecommunication administrations. These are: the European Conference of Postal and Telecommunications Administrations (CEPT) for Europe, the Asia-Pacific Telecommunity (APT) for the Asia-Pacific region, the Comisión Interamericana de Telecomunicaciones (CITEL) for the Americas region, the African Telecommunications Union (ATU) for Africa, the Regional Commonwealth in the field of Communications (RCC) for Eastern Europe and Asian countries belonging to ITU Region 1, and the Arab Spectrum Management Group (ASMG) for the countries in the Middle East and North Africa. These regional bodies have the capability, where agreed and necessary, to present commen proposals to ITU conferences, which would include, where appropriate, proposals addressing aeronautical allocations. A trend is appearing also where these bodies exercise joint influence on policies to promote their regional interest, often with a strong commercial motivation.

3.10 The ITU forum is of great importance to civil aviation interests and is increasing in importance with the emergence of new philosophies on spectrum sharing between different services and on jointly operated services, such as mobile-satellite services. In order to secure adequate spectrum for aviation, it is essential that the aviation position be rational, well considered and well presented in discussions that are becoming increasingly diverse, complex and commercial in their character and scope. The ITU, for its part, is expected to give due consideration to the globally coordinated civil aviation requirements and positions submitted by ICAO and to act accordingly in order to ensure the continued safety of the air transport operations worldwide.



Notes:
1. Drawing not to scale.
2. Not all regional or sub-regional allocations are shown.
3. Band identification (e.g. VHF) and band # per Radio Regulations.
4. The satellite communication bands used by MTSAT and Inmarsat are not allocated to the aeronautical mobile satellite (R) service.

Figure 3-2. Overview of spectrum allocation to aeronautical services

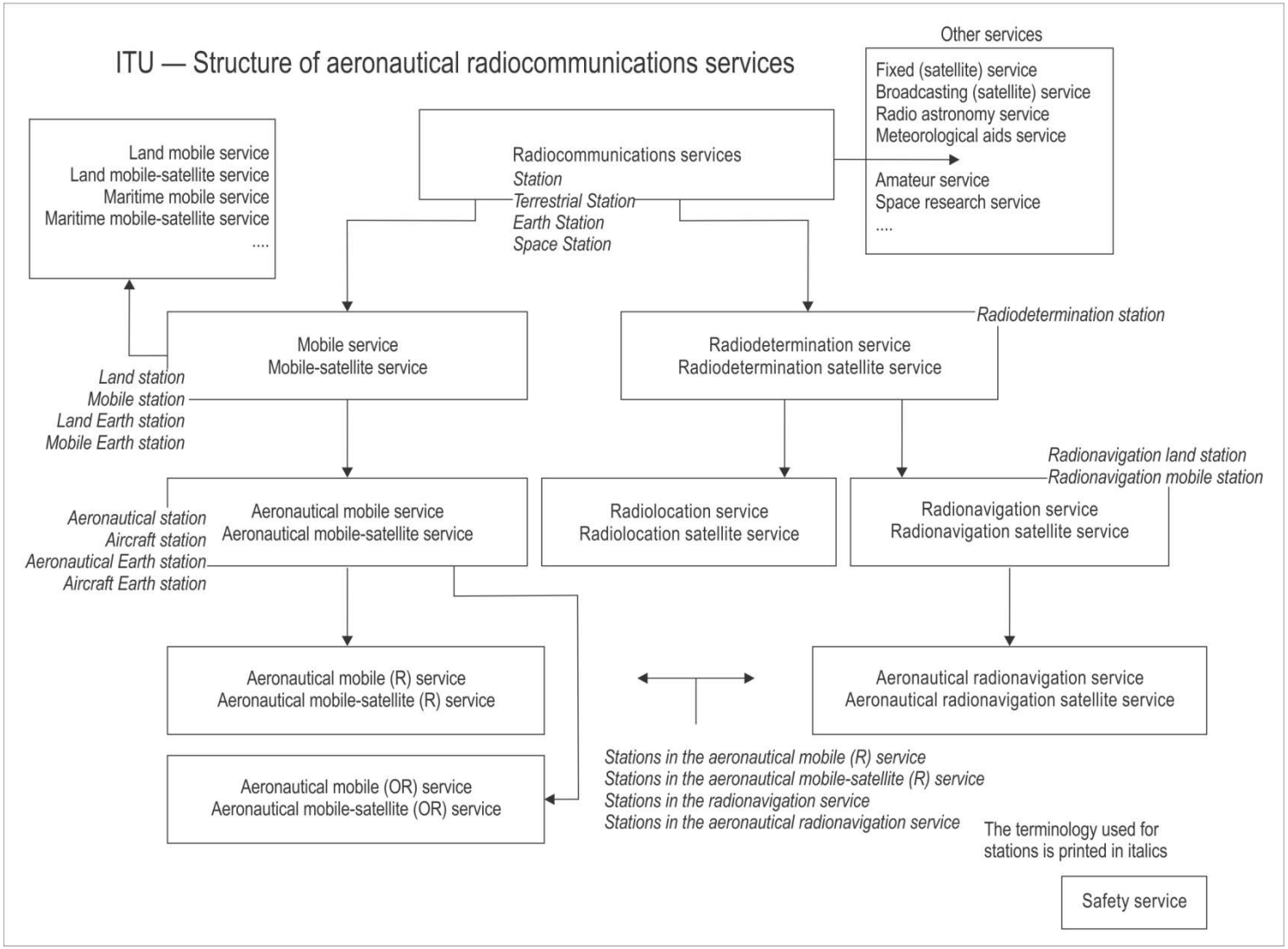


Figure 3-3. Radio services

Note.— Allocations are made to services; frequency assignments are made to stations.

Chapter 4

THE ITU REGULATORY FRAMEWORK FOR AERONAUTICAL RADIO SERVICES

4.1 THE ITU RADIO REGULATIONS

4.1.1 The ITU Radio Regulations recognize aeronautical mobile and radionavigation services as separate services within the mobile services family and the radiodetermination family, respectively (see Figure 3-3). The distress and safety provisions in Chapter VII (Article 30) and the regulatory and operational aspects of the aeronautical mobile service in Chapter VIII (dealing with aeronautical services), as well as various other regulations of the Radio Regulations, establish aeronautical services as a distinct and important component within the radio service hierarchy with a high importance being placed on safety aspects.

4.1.2 For the purpose of allocating spectrum, three regions are defined in the Radio Regulations as in Figure 3-1. Allocations in the Table of Frequency Allocations (Article 5 of the Radio Regulations) can be made on a worldwide or regional basis. Sub-regional or country allocations are normally made through footnotes to this table. These “footnote” allocations have the same status as allocations appearing in the Table of Frequency Allocations.

4.1.3 A distinctive designation has been created between aeronautical mobile services provided for safety and regularity of flight (aeronautical mobile route (R) services) and those for other (non-safety) purposes (aeronautical mobile off-route (OR) services) to ensure the necessary protection of air traffic operations (safety and regularity). The convention employed in the Radio Regulations of according worldwide exclusive allocations to these services facilitates and promotes the development of globally agreed system specifications and interoperability as required in Article 37 of the ICAO Convention on International Civil Aviation. The ICAO SARPs, notably those in Annex 10, are the practical realization of this requirement.

4.1.4 This section of the handbook identifies elements of the Radio Regulations which define the context and status of aeronautical services incorporated in the Radio Regulations. Reference should be made, as appropriate, to the hierarchical organization of radio services at Figure 3-3 and to the extracts in Attachment A (definitions and terms used in the Radio Regulations).

4.2 COMMUNICATIONS

4.2.1 Aeronautical communications services according to Article 44 of the Radio Regulations are classified into 1 of 10 orders of priority where those in priority order 1 to 6 are regarded as safety and the remaining 4 non-safety. In practical terms, this relates to the following:

a) safety communications requiring high integrity and rapid response:

   1) safety-related communications carried out by the air traffic services (ATS) for air traffic control (ATC), flight information and alerting; and

   2) communications carried out by aircraft operators, which also affect air transport safety, regularity and efficiency (aeronautical operational control (AOC)); and

b) non-safety related communications:

   1) private correspondence of aeronautical operators (aeronautical administrative communications (AAC)); and

   2) public correspondence (aeronautical passenger communications (APC)).

4.2.2 Allocations in the Table of Frequency Allocations (Article 5 of the Radio Regulations) are made to the:

a) aeronautical mobile service (AMS) defined in RR 1.32 — this service is not appropriate for safety-of-life operations and is not considered further in this handbook;

b) aeronautical mobile (route) service (AM(R)S) defined in RR 1.33 — with allocated band segments in the frequency range 2 850–22 000 kHz, and the frequency bands 108–117.975 MHz, 117.975–137 MHz, 960–1 164 MHz, 5 030–5 091 MHz and 5 091–5 150 MHz;

c) aeronautical mobile (off-route) service (AM(OR)S) defined in RR 1.34 — this service is not appropriate for safety-of-life operations and is not considered further in this handbook;

d) no allocations have been made to the aeronautical mobile-satellite service (AMSS) defined in RR 1.32 — this service is not appropriate for safety-of-life operations and is not considered further in this handbook; instead, the AMSS may operate under the (generic) mobile-satellite service;

e) aeronautical mobile-satellite (route) service (AMS(R)S) defined in RR 1.36 in the frequency bands 1 610–1 626.5 MHz and 5 000–5 150 MHz;

f) aeronautical mobile-satellite (off-route) service (AMS(OR)S) defined in RR 1.37 — this service is not appropriate for safety-of-life operations and is not considered further in this handbook.

Note.— For further information see Section 7-II, mobile-satellite bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz.

4.2.3 All voice and data communications between aircraft and ground stations, with priority 1 to 6 as defined in RR 44.1, use frequencies from the bands under b) and e) above. The (R) designation (see RR 43.1) signifies the use along national and international civil air routes. The (OR) designation (RR 43.2) signifies uses other than along national or international civil air routes and typically includes national defence. Public correspondence is not permitted in bands allocated exclusively to the aeronautical mobile service or the aeronautical mobile-satellite service.

4.2.4 In the 1 545–1 555 MHz and 1 646.5–1 656.5 MHz bands, the spectrum requirements of the AMS(R)S (i.e. all aeronautical communications with priorities between 1 and 6 in Article 44 of the Radio Regulations) shall be given priority. These categories of messages are the same as those in Annex 10, Volume II, Chapter 5, 5.1.8 a) to f). These AMS(R)S communications also have priority and immediate access over any other mobile-satellite communication operating within a network in these bands (see RR 5.357A and RR 5.362A, as well as Chapter 7-II (1 525–1 559 MHz and 1 626.5–1 660.5 MHz) on mobile-satellite bands).

4.2.5 Chapter VIII of the Radio Regulations deals with certain licensing, regulatory and service operation aspects of the aeronautical mobile service and applies to all of the aeronautical mobile-satellite services, including the (R) and the (OR) components. A special mention at RR 35.1 and RR 35.1.1 recognizes the role which ICAO carries out through the SARPs in Annex 10 by according these superior status to that of the regulations mentioned in RR 35.1 which they may replace.

4.2.6 Appendix 27 to the Radio Regulations contains the frequency allotment plan for the AM(R)S in the HF bands between 2 850 kHz and 22 000 kHz. This appendix contains the plan for HF frequency allotments to major world air route

areas and to regional and domestic air route areas as well as VOLMET areas. It also includes worldwide frequency allotments, which are for the use of aircraft operating agencies for AOC, to be assigned in accordance with RR 27/217.

4.2.7 Article 39 of the Radio Regulations requires the operators of aircraft to produce, on request, the radio licence for the installations on board an aircraft and the operator's certificate. These regulations are in line with Article 30 of the ICAO Convention.

4.3 NAVIGATION AND SURVEILLANCE

4.3.1 Allocations in the Table of Frequency Allocations (Article 5 of the Radio Regulations) for navigation and surveillance purposes are made to the:

— radiodetermination-satellite service: defined in RR 1.41. This service is not appropriate for safety-of-life operations and hence is not considered further in this handbook;

— radionavigation service: defined in RR 1.42;

— aeronautical radionavigation service: defined in RR 1.46;

— radionavigation-satellite service: defined in RR 1.43;

— aeronautical radionavigation-satellite service: defined in RR 1.47.

4.3.2 The definition for radionavigation services also includes those systems, such as radar, which contribute to the navigation of aircraft for ATC or which support other air navigation functions, such as radio altimeters and airborne weather radar.

4.3.3 Radionavigation services receive specific mention in the definition of harmful interference at RR 1.169, and in that of a safety service at RR 1.59. Radio Regulation 4.10 ensures that such harmful interference to radionavigation services receives the highest priority in measures to control and clear its effects.

4.3.4 Radiodetermination services, the generic service which includes radionavigation, are the subject of Article 28 of the Radio Regulations. Protection requirements for the planning of aeronautical radio beacons operating in the low frequency (LF) and medium frequency (MF) bands are contained in Appendix 12 of the Radio Regulations.

4.3.5 The practice in the aeronautical service of removal of the station identification to indicate a failure of service is expressly provided for in RR 19.10, and the requirements for call signs, including the formation of call signs, are contained in Article 19, Sections III and IV of the Radio Regulations. These call signs are also used in aviation for the registration of aircraft.

4.4 RELATIONSHIP BETWEEN ITU RADIO REGULATIONS AND OTHER MATERIAL AND ICAO SARPS

4.4.1 Under its Constitution and Convention, the ITU is recognized as the authoritative international body for telecommunications. The Radio Regulations are the instrument through which this specialization is expressed in internationally agreed terms for radio matters. These Radio Regulations, as presently constituted, lay down the agreed apportionment of the radio frequency spectrum to the various user services, including the aeronautical services. The Radio Regulations also define maximum radiation limits (e.g. for spurious or unwanted emissions) to support an interference-free radio environment. When necessary, this material is supplemented by ITU-R Recommendations. These, together with a broad regulatory framework covering, in particular, licensing of radio stations, personnel, provisions for inspection on demand, and procedures for safety, distress, resolving harmful interference, coordination and notification of frequency assignments, create the basis for a universal system of order in the use of radio frequencies.

4.4.2 The Radio Regulations have treaty status, and there is an inherent obligation on States to comply, unless an exception is stated and embodied in the Final Acts of the Conference which created the regulation. Such statements appear in the published version of the Final Acts. Aeronautical services are obliged to operate within the framework established by the Radio Regulations.

4.4.3 The ICAO SARPs in Annex 10 are developed in accordance with Article 37 of the ICAO Convention for the purpose of ensuring the safety and regularity of air navigation. In addition to the Radio Regulations, the SARPs specify interface and performance standards for internationally agreed aeronautical systems which have been developed by aviation to meet the specific operational requirements of aeronautical services. ICAO is recognized internationally as the competent international body to carry out this work and to coordinate a worldwide policy for the operational use of the specified systems. Furthermore, the ICAO Annexes contain procedures for regular and emergency communications that are specifically developed for aviation purposes, taking account of the operational conditions. These procedures supplement the basic requirements of the Radio

Regulations for procedures in aeronautical communications.

4.4.4 The Radio Regulations and ICAO SARPs together thus form a complementary set of regulatory provisions without any overlap. The Radio Regulations must evolve within the general telecommunications environment with its many and diverse users of the radio frequency spectrum, while the ICAO SARPs respond to the operational safety aspects of air navigation and are developed and agreed by aviation within the ICAO organizational framework.

4.5 FREQUENCY COORDINATION AND REGISTRATION

4.5.1 The coordination and registration of frequency assignments is the prerogative of the ITU and must be performed in accordance with procedures laid down in the Radio Regulations. Frequencies are registered in the Master International Frequency Register (MIFR) maintained at ITU Headquarters in Geneva. With the increasing practice of the sharing of frequency bands by more than one service, coordination assumes an increasing importance in ensuring compatible use.

4.5.2 In exclusive aeronautical bands, actual (day-to-day) coordination of frequency assignments is being undertaken by ICAO, through the ICAO Regional Offices. To support this coordination, the ICAO Regional Offices have developed the necessary procedures, including the relevant frequency assignment planning criteria. A global frequency assignment plan, based on the frequency assignment planning in the ICAO Regional Offices, is being developed. Coordination of frequency assignments is taking place (in most cases) with the national civil aviation authorities.

4.5.3 This procedure, however, does not dispense with the more general requirement for the coordination of a frequency assignment within the ITU and the registration of this frequency assignment in the MIFR, if international protection of that assignment is necessary. Such coordination and registration needs to take place through the radio regulator authorities in each country. Although in some cases aeronautical frequency assignments, notably those in HF and LF/MF bands, are registered by the countries operating these services, other frequency assignments, particularly those in bands above 100 MHz, tend to be recorded only in national registers or in the ICAO Regional Air Navigation Plans. Because of this, de facto, the ICAO frequency register is the authoritative internationally agreed (within ICAO) list of coordinated frequency assignments for aviation in the following frequency bands:

190–535 kHz	NDB, locator
108–117.975 MHz	ILS localizer, VOR, GBAS, VDL Mode 4
117.975–137 MHz	Air-ground voice (DSB/AM), VDL Mode 2 and 4
960–1 215 MHz	DME (SSR)
5 030–5 091 MHz	MLS

Nevertheless, even for the exclusive aeronautical bands it is considered beneficial to register the relevant frequency assignments within the ITU in order to obtain the status of international recognition and assist in protection of aeronautical applications from other services at future WRCs by declaring actual usage of these frequency bands. To this end, countries could use the system parameters recorded in the ICAO frequency register to update the ITU MIFR, as it was encouraged by the World Radiocommunication Conference, Geneva, 2012 (WRC-12).

4.5.4 Coordination and registration of frequency assignments in the HF bands (between 2 850 kHz and 22 000 kHz) is only taking place through the ITU. However, ICAO is considering developing, in parallel, a relevant ICAO list of HF frequency assignments.

4.5.5 Coordination and registration of frequency assignments for radar stations and on-board autonomous radionavigation systems is however NOT being coordinated through ICAO.

Note.— See also Chapter 5.

4.6 ITU STANDARDS

In the case of system and equipment standards, those contained in ICAO Annexes are obligatory (although a difference is allowable in matters of non-major detail). On the other hand, ITU standards, as published in ITU-R or ITU-T specification documents, exist as recommendations only, except for the very few instances where an ITU-R Recommendation is incorporated in the Radio Regulations, included in Volume 4 of the Radio Regulations and compliance is mandatory. The technical characteristics for HF aviation equipment in Appendix 27 of the Radio Regulations, since they form part of the Radio Regulations, enjoy the same status as compulsory treaty obligations.

4.7 ITU RESOLUTIONS AND RECOMMENDATIONS

ITU WRC Resolutions, included in Volume 3 and referenced in Volumes 1 (Articles) and 2 (Appendices) of the Radio Regulations using mandatory language, form part

of the Radio Regulations and express a mandatory agreement among all of the ITU members to follow a particular course of action. ITU Recommendations, which are also part of the Radio Regulations, have no mandatory force and usually address matters of limited concern.

4.8 RADIO EQUIPMENT IN AIRCRAFT

Proper regulation and control of the use of radio equipment is important for the safe operation of the aircraft. Correct operation of equipment in approved frequency bands and on assigned, operational frequencies must be assured throughout an aircraft's flight on national or international journeys. Performance standards for both telecommunication and air safety requirements are the means used to achieve conformity with international rules. The processes to achieve this are explained in detail in Attachment C.

Chapter 5

ICAO INVOLVEMENT IN FREQUENCY AND SPECTRUM PLANNING

5.1 ICAO is the United Nations specialized agency with recognized competence in matters related to aviation safety. Under Article 37 of the Convention on International Civil Aviation, ICAO is empowered to adopt and amend international SARPs for all aviation matters including aeronautical communications systems and air navigation aids. Under Article 37, the highest practicable degree of uniformity is seen as essential to facilitate and improve the safety of air navigation. Characteristics for aeronautical radio communication and navigation systems are laid down in Annex 10 to the ICAO Convention, and the requirement for interoperability of systems on a global basis demands that frequency allocations be available worldwide and, preferably, also exclusive.

5.2 ICAO coordinates the input to ITU discussions on aeronautical radio frequency spectrum matters. In pursuance of this role, ICAO is accorded observer status at relevant ITU WRCs and also participates at meetings of the ITU-R study groups, including the Conference Preparatory Meetings (CPMs) which prepare the technical and regulatory basis for WRCs. The range of this involvement includes aspects of common system technical standards, maximum levels of tolerable interference and measures to control and resolve interference incidents, frequency planning criteria, the preparation of frequency plans, and distress and safety procedures. The outcome of these discussions normally results in material being incorporated in the ITU Radio Regulations or in ITU-R Recommendations and subsequently being applied through national regulation by national telecommunication authorities.

5.3 Within ICAO, the necessary activity to support these ITU-generated functions exists at two levels:

a) at the worldwide level, through the work of the Air Navigation Commission, with the assistance of the FSMP (and communication divisional meetings or air navigation conferences, as required), to prepare the coordinated ICAO policies, spectrum estimates and technical inputs for ITU conferences and ITU-R study groups. The ICAO spectrum strategy, policy statements and the ICAO Position for WRCs are approved by the Council; and

b) at the regional level, by the ICAO Regional Offices, through coordination of frequency assignment plans with States, using agreed ICAO planning criteria. This activity is supported by the Regional Planning and Implementation Groups (PIRGs).

5.4 Aviation representatives are generally included in States' delegations to ITU conferences where they have the important role of safeguarding the aviation position during the conference discussions. States' cooperation in this supporting role is an essential factor in securing the aviation requirements.

5.5 The repetitive (now three to four-year) cycle for ITU WRCs means that the ICAO Position on the conference agenda must be prepared within the same time frame as national/regional inputs to the conference. This process is described in Attachment D to this handbook.

5.6 This handbook, which is updated through a rolling system of amendment action, provides the record of agreed ICAO policies, including the ICAO spectrum strategy and the ICAO policy statements.

5.7 The relationship between the radio regulatory activities and those of ICAO and civil aviation authorities (CAAs) is given in Figure 5-1.

5.8 The approach to improve States' support of the ICAO Position at WRCs has been approved by the ICAO Council. This approach is in Attachment E.

5.9 The ICAO Position for WRC-19, as approved by the Council, is in Attachment F.

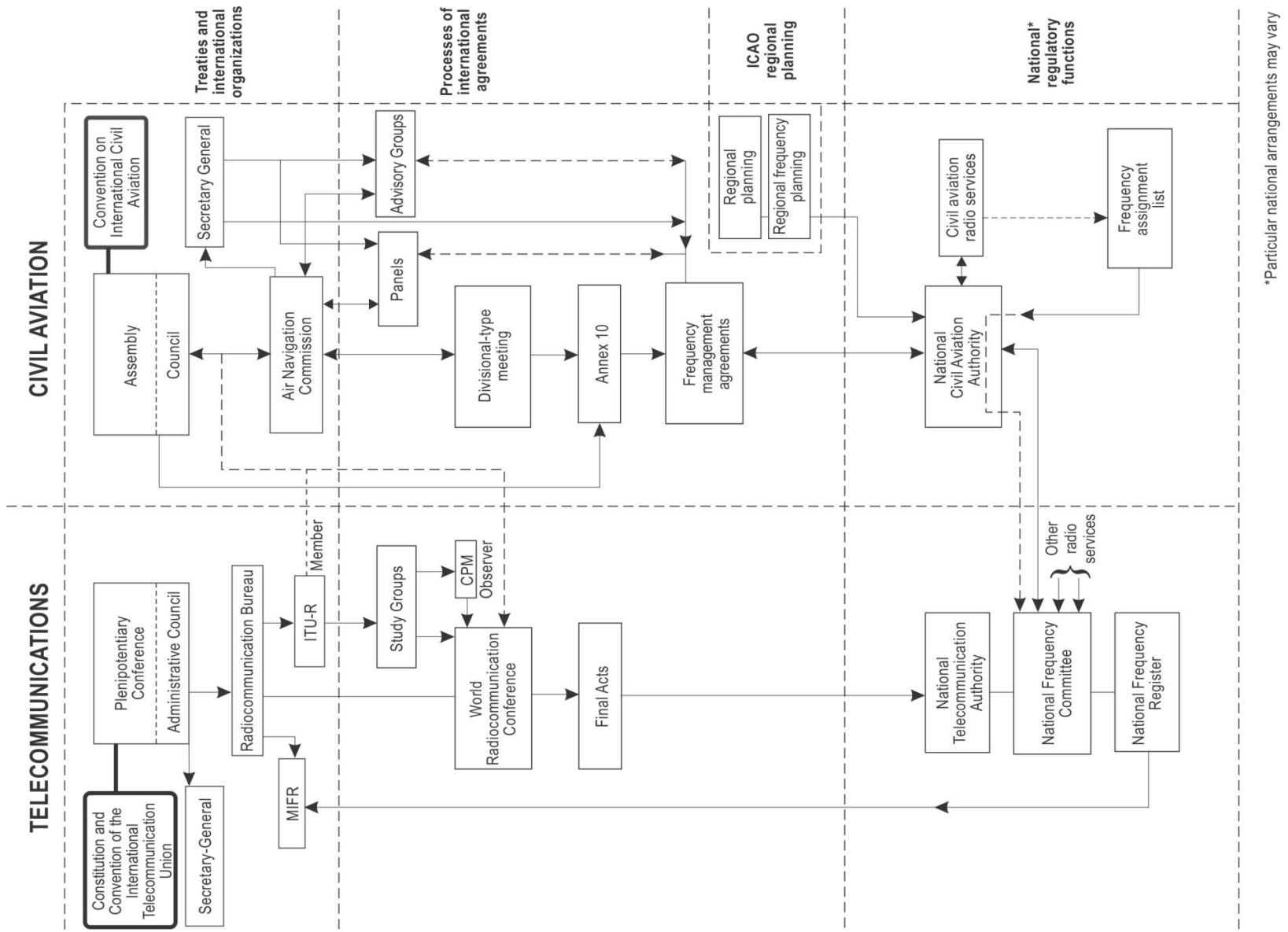


Figure 5-1. Frequency management institutional relationships

Chapter 6

OVERVIEW OF THE SPECTRUM MANAGEMENT PROCESS

6.1 GENERAL ASPECTS OF THE PROCESS

6.1.1 Civil aviation use of the radio frequency spectrum accounts for less than 14 per cent of the total, comparable to maritime use, but considerably less than other uses such as broadcast or national defence. The spectrum management process is designed to make the optimum use of this scarce spectrum resource. One of its main objectives is to create a universally agreed framework in which the demands for radio frequencies from individual countries are balanced with the interests of different service users to produce a planned radio environment incorporating an effective and efficient spectrum use. It has a necessary international dimension, which must be flexible and responsive to changing patterns of demand or to new technology, having scope for additional forms of transmissions and modulation methods.

6.1.2 With new technology, the useable spectrum expands over time, particularly in the higher frequency region, creating new possibilities and options. Spectrum expansion has limitations of scale and scope, however. Demand for spectrum continues to increase at a much faster rate than the frequency availability created from either extended spectrum boundaries or improved efficient use of the spectrum that is available (e.g. through reduced channel spacing). In its essentials, spectrum management combines separate disciplines, such as regulatory and control measures and technical (frequency assignment) planning, to achieve a reasonable compromise in dealing with the increasing demand for more spectrum. The current decade is expected to see this increase in demand rise sharply, particularly for broadband mobile applications and spectrum management problems will hence increase in complexity and scale.

6.1.3 In the context of this handbook, the management of the spectrum may be characterized by four main domains or areas of activity: the regulatory domain, the technical domain, the licensing domain and the registration domain, which are described below.

The regulatory domain

6.1.4 In this domain, the international agreements made within the ITU lay down a set of principles, rights and procedures, together with an institutional framework for their effective operation, which create the basis for an orderly international use of radio frequencies. The mechanism of the ITU (periodic radiocommunication conferences, the Radio Regulations Board and the Radiocommunication Bureau) maintains the permanent documents responsive to, and in line with, modern conditions.

6.1.5 The Radio Regulations, which have treaty status, are the cornerstone of the process. They contain the internationally agreed Table of Frequency Allocations and the agreed rules for its implementation, as well as the important international obligations for the operation of radio stations, licensing and other control measures for ensuring an effective regime of operation within the framework of the Radio Regulations.

6.1.6 The Radio Regulations primarily address regulatory aspects; technical material, usually of a more volatile character, is relegated to the Appendices to the Radio Regulations or to ITU-R Recommendations. Amendments to the Radio Regulations can only be made through a WRC, the Final Acts of which are agreed and signed at the conference, with the instrument of ratification to be deposited within the given time as specified in the Final Acts themselves. This regulatory basis, as contained in the ITU Constitution, Convention and Radio Regulations, is the starting point for the existence of a framework of stable international order and practical utility which is adhered to by all countries of the world.

The technical domain

6.1.7 In the final analysis, the effective use of the radio frequency spectrum is dependent on the expert technical planning of the frequency assignments used by the various services and systems. The main technical tools at the disposal of the spectrum manager are those in the hierarchical order of allocation planning, service sharing planning and, at the station level, the planning of assignments to particular locations.

6.1.8 The processes here are quantitative and exact, requiring careful examination and agreement between countries and service users. The concepts of acceptable interference and harmful interference, as contained in the regulatory rules, must be translated into practical limits and applied to achieve a service which meets all of its operational requirements. Different services require different amounts of bandwidth and can tolerate different levels of interference. Also, propagation

conditions vary widely throughout the useable spectrum. Careful assessment and balancing of these degrees of freedom have to be applied to achieve optimum results. The ITU-R is the focus for the studies which lead to refined and workable criteria for sharing among services and for the development of international and national frequency plans.

6.1.9 Due to safety implications, however, civil aviation is, through ICAO, developing and planning most of the use of worldwide exclusive aeronautical frequency bands within its organizational structures, utilizing technical standards that have been adopted or approved within ICAO.

The licensing domain

6.1.10 Implementation of the basic ITU obligations for certification of system and personnel, licensing of stations, monitoring the observance of licence conditions and clearing interference are functions carried out at the national level under national law. These duties are normally exercised by national telecommunication administrations, which also provide the spectrum management expertise for national frequency planning and participate in international discussions on spectrum matters. Coordination among administrations is the usual mechanism for bilateral and multilateral discussions. The licensing actions generally also include equipment type approval against national or other specifications. The parameters checked include those having an effect on other users, such as frequency stability and spurious emissions, and system interoperability features. In the case of aviation equipment, conformity with Annex 10 may also be a licensing condition.

6.1.11 The licensing process is the controlling mechanism for the use and change of use of frequency bands, or for the exercise of sanctions in the case of licence infringements. It also provides the opportunity to levy such charges as are necessary to support the spectrum management and regulation activity or to control demand.

6.1.12 Article 18 of the Radio Regulations requires that all stations be licensed by the government having authority over their operations. For aircraft, dispensations are granted in 18.8 for the specific instance of first delivery, and in 18.11 for wet and dry lease. Article 39 requires the station licence to be available for inspection on demand at any time. Article 37 addresses operators' certificates for personnel in the aeronautical services. These basic telecommunications requirements have been included in Articles 29, 30 and 32 of the ICAO Convention.

The registration domain

6.1.13 The registration by countries of their assignments in an internationally agreed database is fundamental to the ITU principle of prior rights gained by earlier registration (first come, first served), and the important obligation not to derogate the protection of existing registered assignments of other countries. The procedural rules are laid down in the Radio Regulations and the process of consultation and recording in the Master International Frequency Register (MIFR) is administered by the Radiocommunication Bureau. A comprehensive procedure for coordination, especially for space services, is a particular feature of these important provisions which have been developed and refined over many years.

6.1.14 The MIFR thus serves the dual purpose of a formal record and a planning guide for new assignments.

6.1.15 The predominant emphasis in all of these processes is that of the freedom of countries to use frequencies as they wish, provided they do not affect other existing services and uses of other countries, which have been established in accordance with the Radio Regulations and registered in the MIFR. In keeping with these liberal principles, the ITU Convention contains no provisions for arbitration or for the referral of disputes to international adjudication. The settling of problems is hence treated as a matter for bilateral or multilateral resolution in the first instance, calling on informal assistance from the permanent organs of the ITU should this fail. Cases of failure, however, remain an insignificant proportion of the millions of operating radio services.

6.1.16 For the role of ICAO in frequency coordination and registration (in ICAO) see Chapter 4, 4.5, and Chapter 5.

6.2 ELEMENTS OF THE TECHNICAL DOMAIN

6.2.1 The technical planning of frequency assignments is the single most important element in the use of the spectrum. Advances in technology supporting more efficient use of the available radio frequency spectrum and in planning methods enable a more effective and efficient use of radio frequencies. Frequencies are technically managed and planned in accordance with a hierarchical process that involves the planning of allocations to radio services, the determination of sharing conditions (with other services operating in the same or adjacent frequency bands) co-frequency and the actual frequency assignment planning.

Planning of frequency allocations

6.2.2 At the highest level is the planning of allocations of frequency bands to radio services, which are agreed internationally within ITU at WRCs and incorporated in the Table of Frequency Allocations (Article 5 of the Radio Regulations (RR); see also Section 7-II). Allocations in the form of frequency bands are made to "services", with the choice of grouping of services adopted in ITU (see Figure 3-3). Allocations are classified as primary or secondary, with the primary allocation taking precedence at all times over a secondary allocation should a conflict arise in registration or in implementation (see Section 7-II).

6.2.3 Allocations may be worldwide, as is the case with the majority of aeronautical services, or made to one or two of the three ITU regions (see Figure 3-1). Countries may make specific requests for sub-regional or country allocations, usually coordinated in advance with their neighbours. These allocations are normally incorporated in footnotes to the Table of Frequency Allocations.

6.2.4 In addition to the allocations concept, in which frequency bands are allocated to different radio services, specific ITU WRCs may distribute frequencies to geographical areas or radio stations, thus establishing frequency allotment or assignment plans, respectively, and incorporating them in ITU documents. Examples of such ITU documents are Appendix 27 to the RR containing a frequency allotment plan for the AM(R)S in HF bands, Appendix 30 to the RR containing a frequency assignment plan for broadcasting-satellite service or ITU Regional Agreement GE85 containing a frequency assignment plan for stations of the aeronautical radionavigation service in the MF bands in Region 1. It is more usual, however, for allocations to provide the basis for regional, area (sub-regional) or national frequency assignment planning.

6.2.5 Frequency assignment plans for aeronautical communications and navigation systems (with the exception of the HF bands) are usually developed and agreed regionally within ICAO, through the ICAO Regional Offices, using the planning criteria contained in the attachments to ICAO Regional Air Navigation Plans (see also Chapter 4, 4.5).

Service sharing

6.2.6 Increasing pressure on the spectrum has led to an increased sharing of frequency bands by compatible primary services to the extent that sharing has become commonly used. ITU-R studies, which determine the sharing conditions between different services, may include technical and operational limitations or procedures for coordination purposes. Sharing between low-signal-level space

services and other services, including on occasion aeronautical services, is often proposed. The results of the ITU-R studies are normally published in ITU-R Recommendations or ITU-R Reports.

Planning of frequency assignments

6.2.7 This activity follows on from allocation planning or sharing studies. Its purpose is to prepare frequency assignment plans between cooperating countries for their region or area, or by countries for application within national boundaries, or to identify individual assignments on a case-by-case basis. For terrestrial services, it employs the dimensions of frequency, distance and time separation in calculations which would use some or all of the following parameters:

— location of required service;

— frequency of operation and transmission bandwidth;

— power and directive gain of antenna;

— propagation characteristics;

— protection required by proposed service;

— protection required by other existing services on same or adjacent frequencies;

— time of day, season or year of operation.

A frequency assignment can be made when each new (or modified) frequency assignment simultaneously satisfies the protection requirement for each direction of transmission (the new/modified frequency assignment will not cause harmful interference to existing frequency assignments and in turn, existing frequency assignments shall not cause harmful interference to the new/modified frequency assignment). The task of creating and maintaining a frequency assignment plan for a region is usually extensive, requiring computer-based tools. Assignments are made to transmitting stations subject to the requirement to protect the received signal in a given area (designated operational coverage) from harmful interference.

6.2.8 For space services, Article 9 of the Radio Regulations lays down comprehensive coordination procedures operated by the Radiocommunication Bureau. Acceptability is assessed using calculation methods and criteria contained in agreed ITU-R Recommendations. ICAO is normally not involved in the

coordination of frequency assignments for space services.

6.2.9 Further guidance on frequency assignment planning and other technical material is in Volume II of this handbook.

6.3 THE ROLE OF TECHNOLOGY IN SPECTRUM MANAGEMENT

6.3.1 Technology plays a vital role in spectrum management in two ways:

a) it provides automated (computer-based) assistance to the frequency assignment planning process, facilitating better analysis, performing more complex or repetitive calculations, maintenance and access to information and data on frequency use, and many other applications; and

b) through system improvements, it leads to improved utilization of radio frequency (RF) spectrum.

6.3.2 Modern communication and navigation systems, employing sophisticated RF modulation techniques, tighter system design parameters and improved interference rejection circuitry, promote more efficient frequency use and are now commercially available at economical prices. For example, the actual spectral occupancy of a single VHF communication channel in the AM(R)S band has been significantly improved by channel splitting on four occasions in the past fifty years, which has resulted in the availability of many extra channels in that band. The use of digital modulation techniques to replace analogue modulations may provide for another practical system improvement measure which, coincidentally, may lead to more efficient spectrum use.

6.3.3 Technology improvements remain the best possibility for meeting the anticipated demand for frequencies in the future.

6.4 AERONAUTICAL SERVICES

6.4.1 Aeronautical services are subject to all of the processes described above in the same general way as any other radio service. The allocations to the aeronautical mobile and aeronautical radionavigation services are part of the common spectrum resource for aviation and are required to be justified on a continuous basis, requesting additions when necessary and releasing frequencies

which are no longer required.

6.4.2 The areas where the special role of radio in air operations is fully recognized, as noted above, are:

a) the technical control and management of the exclusive allocations to aeronautical services is carried out by aeronautical experts, both internationally and nationally, in a majority of countries. In these activities, ICAO performs a central coordinating function, providing the international forum for the review of needs for spectrum, the development of technical planning standards and the registration of global use. National aviation experts participate fully in these activities;

b) equipment and system approval by aviation authorities, recognizing that ground systems must meet operational standards based on safety, and aircraft equipment must obtain type approval and airworthiness certification also based on safety requirements under national responsibilities emanating from the ICAO Convention; and

c) cases of interference to aeronautical radio services are treated in the Radio Regulations as requiring special measures. National telecommunications administrations are required to take particular care in the licensing and operation of other services and industrial processes using radio waves which have the potential to endanger safety-of-life functions. In cases where harmful interference is experienced, ICAO can offer assistance in eliminating the interference.

6.5 SPECTRUM MANAGEMENT IN THE FUTURE

6.5.1 The worldwide demand for frequencies continues to increase, placing considerable pressures on the spectrum management process. Growth patterns vary between world regions, with developed economies experiencing expansion in (generic) mobile communications, both terrestrial and satellite, and in sound and television broadcasting. Elsewhere, fixed links for point-to-point communications are important in areas without an extensive ground-based (cable) infrastructure, or where radio services in large areas with difficult terrain have to be developed. Bandwidth efficient technologies can provide substantial gains in the amount of information processed per unit of bandwidth. Attention is also strongly focused on the release of spectrum no longer needed, or inefficiently used, or where the service concerned fails to argue the case for retention.

6.5.2 A result of this new trend is that spectrum earmarked for use at some

point in the future, or where no plans exist for use, can no longer be retained, effectively creating a situation in which it may never be possible to successfully reinstate a claim. In this process, the aeronautical industry, with its long timescales for international agreement and coordination, is at a serious disadvantage compared to other users, particularly to those users where commercial considerations are prime. Instances of arbitrary forcible release of spectrum to such commercial services are expected to increase.

6.5.3 Demand is unlikely to be satisfied solely by the application of the procedures of administrative negotiation and agreement used in the past, in which majority support at ITU conferences has been the criterion for change. Further, there are practical limits to the technical sharing of frequencies between services (i.e. shared allocations) which in the final analysis often merely advances eventual saturation. Spectrum managers are therefore seeking fresh initiatives to provide more effective ways of awarding and recovering frequencies.

6.5.4 In some countries, procedures are being introduced in which the recognition of economic forces would play a controlling role. Spectrum award to the highest bidder and licensing costs are the parameters in which market forces will be applied to restrict demand, ration allocations, and affect the speedy return of frequencies no longer needed. While this is initially applicable to high-profile services, such as land mobile and broadcasting, and in congested areas, it will in the longer term affect aeronautical allocations, increasing the cost of licences and applying pressure to release under-used frequencies. Although there is some recognition that for any methodology to be completely viable it must take into account essential social and community services and protect their interests, this reasoning has not yet been extended to include aviation, which spectrum managers are coming to regard as just another type of commercial operation, albeit with some special safety connotations. Spectrum pricing, which is a levy on the use of radio frequency spectrum, is in some countries being extended to spectrum allocated to aeronautical services.

6.5.5 Future aeronautical radio services are anticipated to make much greater use of bandwidth efficient systems through the application of modern technology for reduction of channel spacing, and increased channel capacity and digital technology. The overall effect of these technological improvements is to meet the expected increase in air traffic around the world in the years ahead, which in some areas is expected to double, and perhaps up to and beyond the year 2030 without any significant increase in spectrum. Introduction of new aeronautical systems or services may require additional frequency bands to be made available for aviation.

6.6 SPECTRUM MANAGEMENT SUMMARY

The objective of radio frequency spectrum management is to create a rational, controlled regime whereby the scarce radio frequency resource is planned in such a manner as to meet the competing and conflicting demands of all of the radio services intending to make use of it. It is characterized by an international treaty agreement within the ITU on the principles and objectives to be adhered to in pursuance of agreed international policies, which include, in particular, the following:

a) a complementary set of domains addressing the separate aspects of allocations, supporting regulations, technical planning, service licensing and frequency registration, embodied within an enabling set of agreed Radio Regulations;

b) the application of these agreed principles and measures within national territories by national telecommunication authorities. This process also includes the national coordination role for both implementation of international agreements and for the development of coordinated national proposals for the purpose of international negotiation and agreement;

c) the recognition that radio plays a vital role in the safe operation of aircraft, and the acceptance that aviation, through ICAO, may create standards for equipment and for frequency plans; and

d) the realization that technical and regulatory measures alone cannot meet all future demands of radio services for access to scarce frequencies. Present trends are leading to consideration of other means, including in particular the restriction of demand through the application of economic measures, such as administrative pricing and auction of frequency bands to the highest bidder.

Chapter 7

STATEMENT OF FREQUENCY ALLOCATIONS, TECHNICAL DETAILS AND ICAO POLICY

This chapter addresses the main subject matter in detail, structured as follows:

Section 7-I. List of frequency bands.

Section 7-II. Civil aviation frequency allocations — ICAO policy statements and related information (including a composite statement for each frequency band):

- allocation table;
- footnotes;
- ICAO policy;
- aviation use; and
- commentary.

Section 7-III. Radio Regulations and other ITU material of importance to aeronautical services including:

- identification of Regulations of importance to civil aviation; and
- ICAO policy.

Section 7-IV. Review of ITU Resolutions and Recommendations.

SECTION 7-I. LIST OF FREQUENCY BANDS

Band	*Service*	*Aviation use*	*Section 7-II page no.*
*130–535 kHz	ARNS	NDB	7-17
*2 850–22 000 kHz	AM(R)S	Air-ground communications (HF voice and data)	7-27
3 023 and 5 680 kHz	AM(R)S	Search and rescue	7-39
74.8–75.2 MHz	ARNS	Marker beacon	7-41
*108–117.975 MHz	ARNS AM(R)S	VOR/ILS localizer/ GBAS/VDL Mode 4	7-43
*117.975–137 MHz	AM(R)S	Air-ground and air-air communications (VHF voice and data)	7-53
121.5, 123.1 and 243 MHz	AM(R)S	Emergency frequencies	7-59
328.6–335.4 MHz	ARNS	ILS glide path	7-61
406–406.1 MHz	MSS	Search and rescue	7-63
*960–1 164 MHz	ARNS/RNSS AM(R)S	Air-ground communications/ DME/SSR/ACAS/UAT/ LDACS	7-67
1 030 and 1 090 MHz	ARNS	SSR/ACAS/ADSB	7-67
*1 164–1 215 MHz	ARNS/RNSS	DME/GNSS	7-67
*1 215–1 400 MHz	RLS/ RNSS ARNS	GNSS Primary surveillance radar	7-79
*1 525–1 559 MHz	MSS (s-E)**	Satellite communications	7-87
*1 610–1 626.5 MHz	AMS(R)S (s-E, E-s)	Satellite communications	7-87
*1 626.5–1 660.5 MHz	MSS (E-s)**	Satellite communications	7-97
*1 559–1 626.5 MHz	ARNS/RNSS/ MSS	GNSS	7-97
*2 700–3 300 MHz	ARNS/RNS/ RLS	Primary surveillance radar	7-109

Band	*Service*	*Aviation use*	*Section 7-II page no.*
*4 200–4 400 MHz	ARNS/ AM(R)S	Radio altimeter WAIC	7-115
*5 000–5 250 MHz	ARNS AM(R)S AMS(R)S	MLS/UAS command and non-payload communication/airport surface communication	7-119
*5 350–5 470 MHz	ARNS	Airborne weather radar	7-127
8 750–8 850 MHz	ARNS/RLS	Airborne Doppler radar	7-129
9 000–9 500 MHz	ARNS/RNS	Precision approach radar/ airborne weather radar/ ASDE	7-131
13.25–13.4 GHz	ARNS	Airborne Doppler radar	7-143
15.4–15.7 GHz	ARNS/RLS	ASDE/other systems	7-149
24.25–24.65 GHz	RNS	ASDE	7-159
31.8–33.4 GHz	RNS	ASDE/airborne radar enhanced flight vision system (EFVS)	7-165

AM(R)S: Aeronautical mobile (route) service
AMS(R)S: Aeronautical mobile-satellite (route) service
ARNS: Aeronautical radionavigation service
MSS: Mobile-satellite service
RLS: Radiolocation service
RNS: Radionavigation service
RNSS: Radionavigation-satellite service

* A graphical presentation of the allocations of the aeronautical services, together with other services and relevant footnotes to which these bands are also allocated, is in Figures 7-1 to 7-7.

** In the frequency bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz (and also in the band 1 555-1 559 MHz and 1 656.5-1 660.5 MHz in the United States under RR 5.362A), priority is to be given to accommodating the spectrum requirements of the aeronautical mobile-satellite (R) service providing transmission of messages with priority 1 to 6, as defined in Article 44 of the Radio Regulations; no allocation to AMS(R)S has been made in this frequency band.

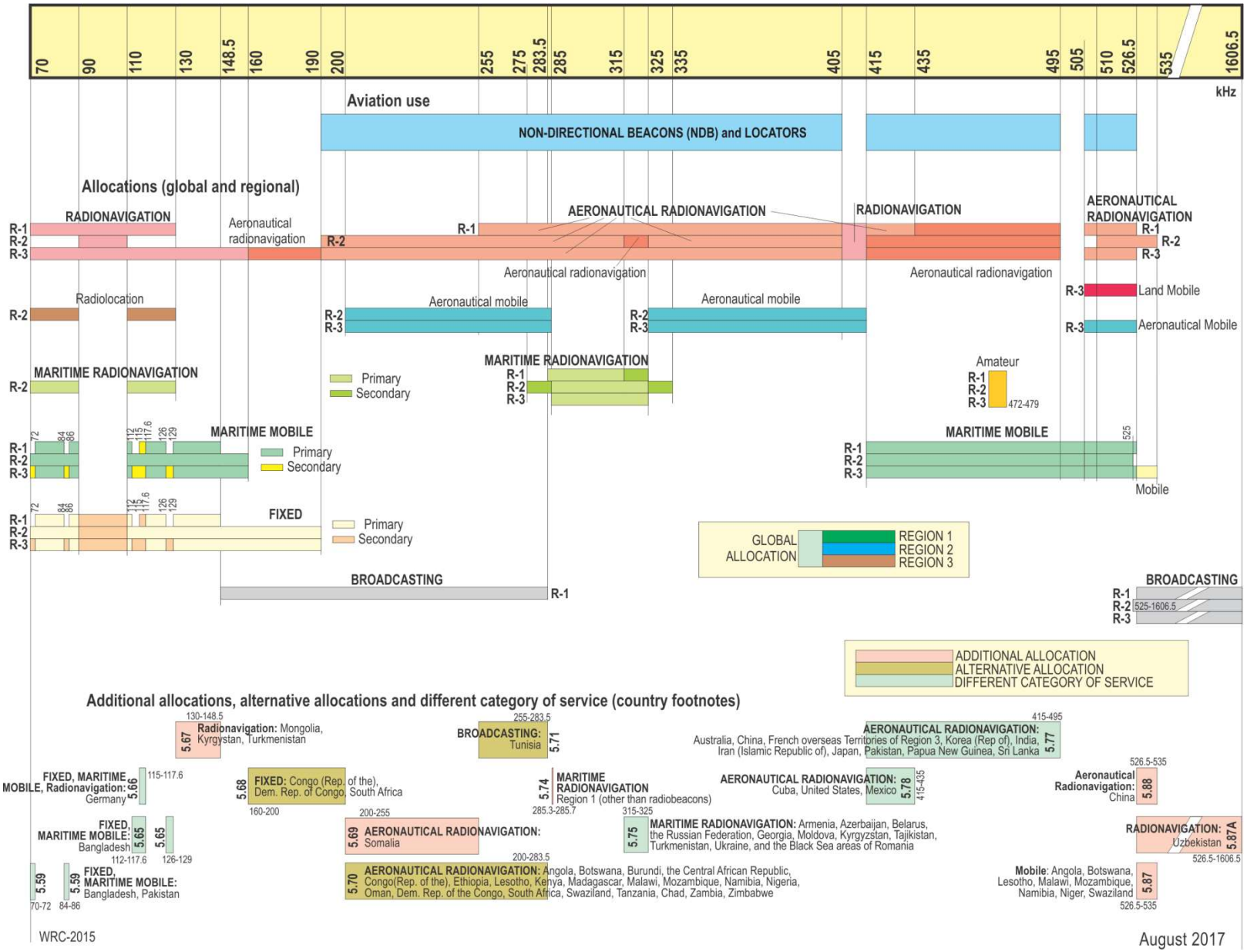


Figure 7-1. 70–1 606.5 kHz

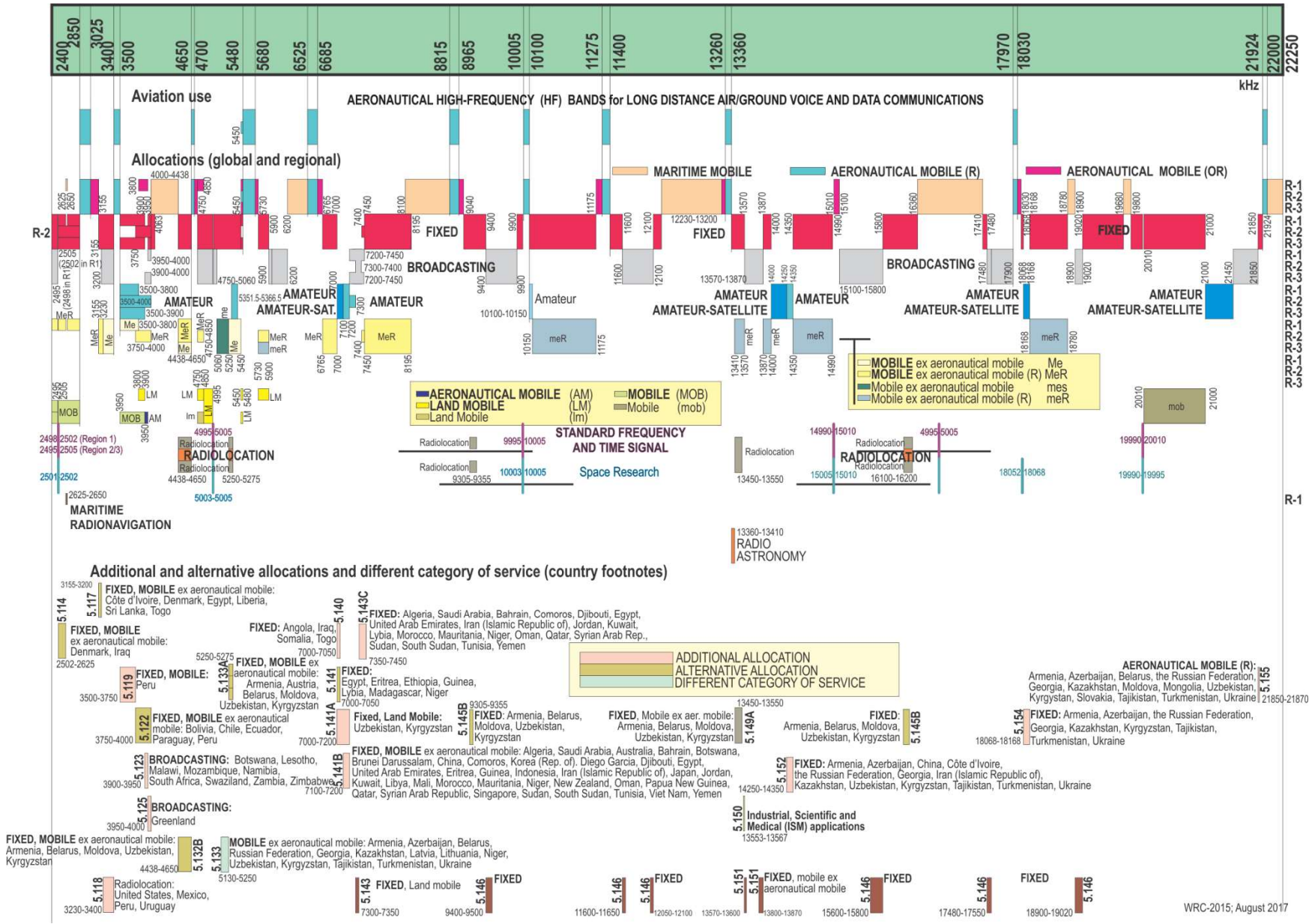


Figure 7-2. 2 400–22 250 kHz

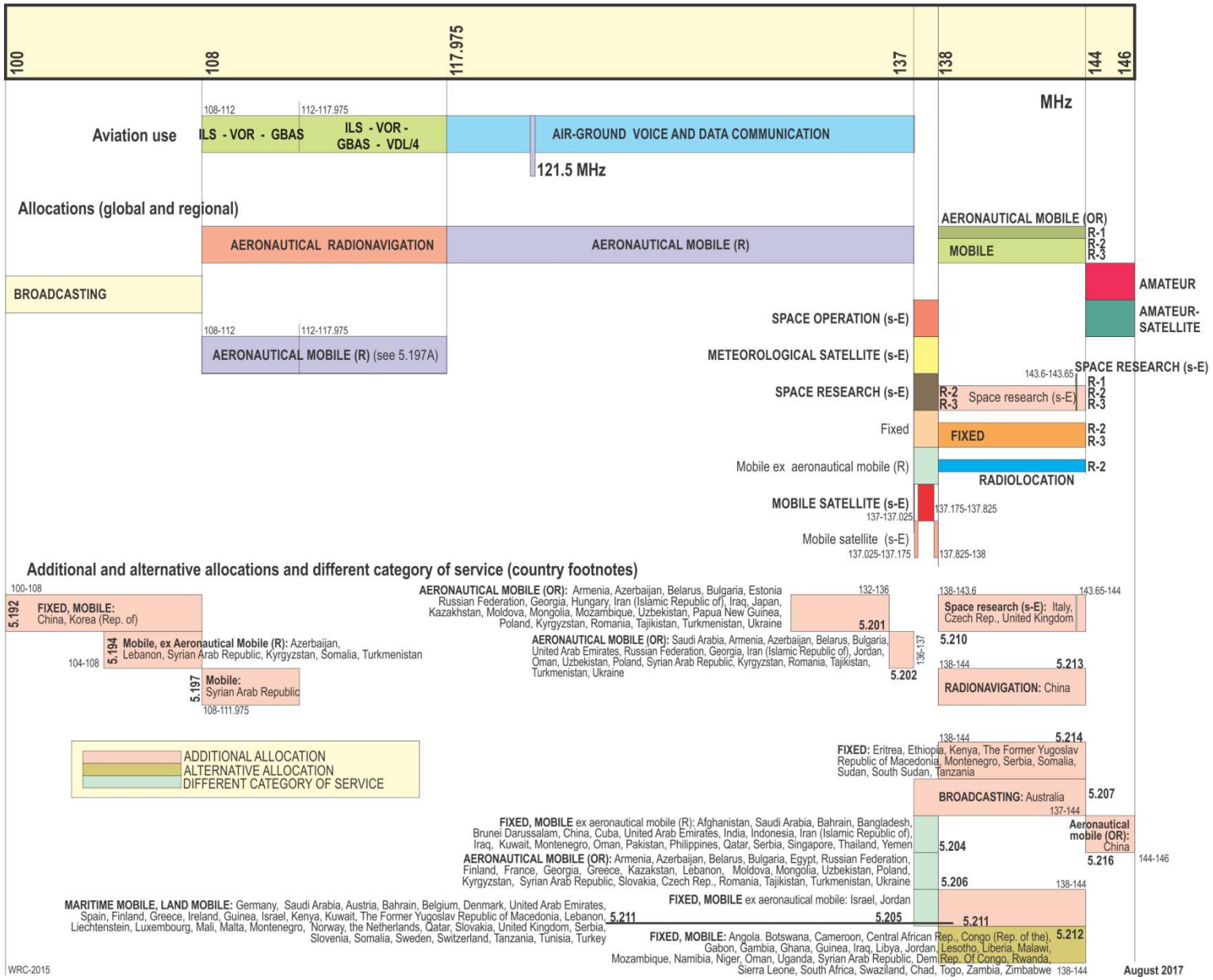


Figure 7-3. 100–146 MHz

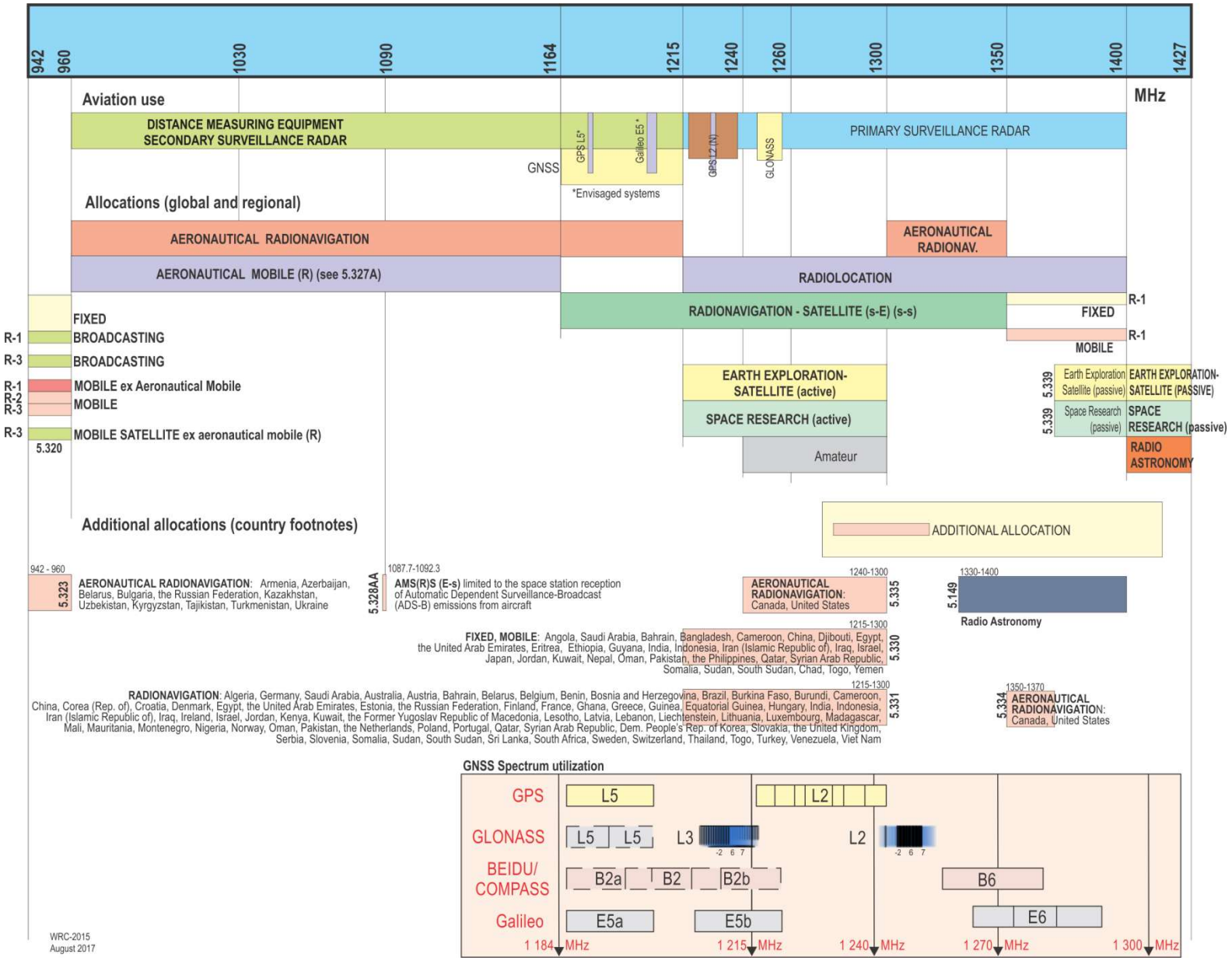


Figure 7-4. 942–1 427 MHz

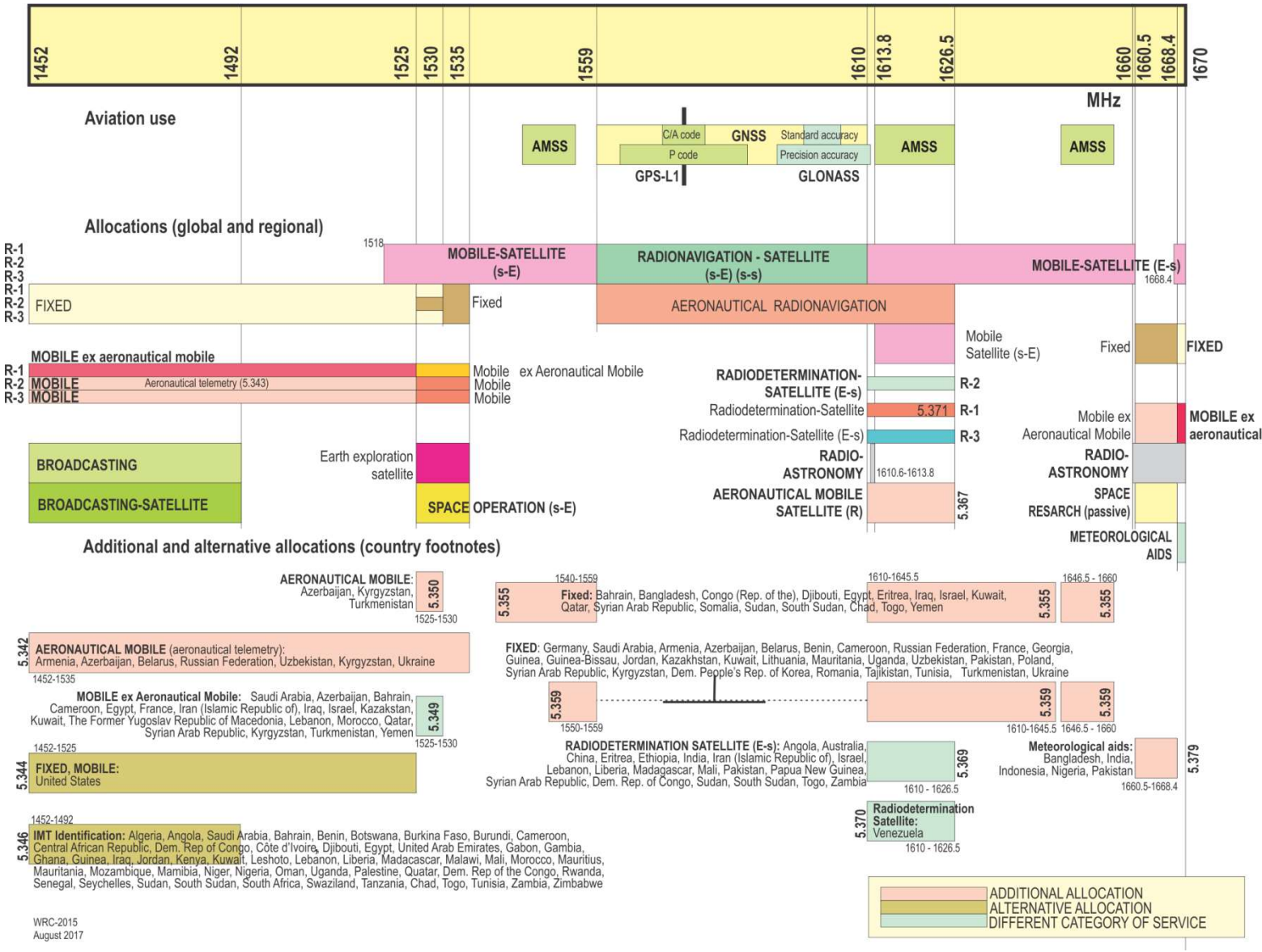


Figure 7-5. 1 452–1 670 MHz

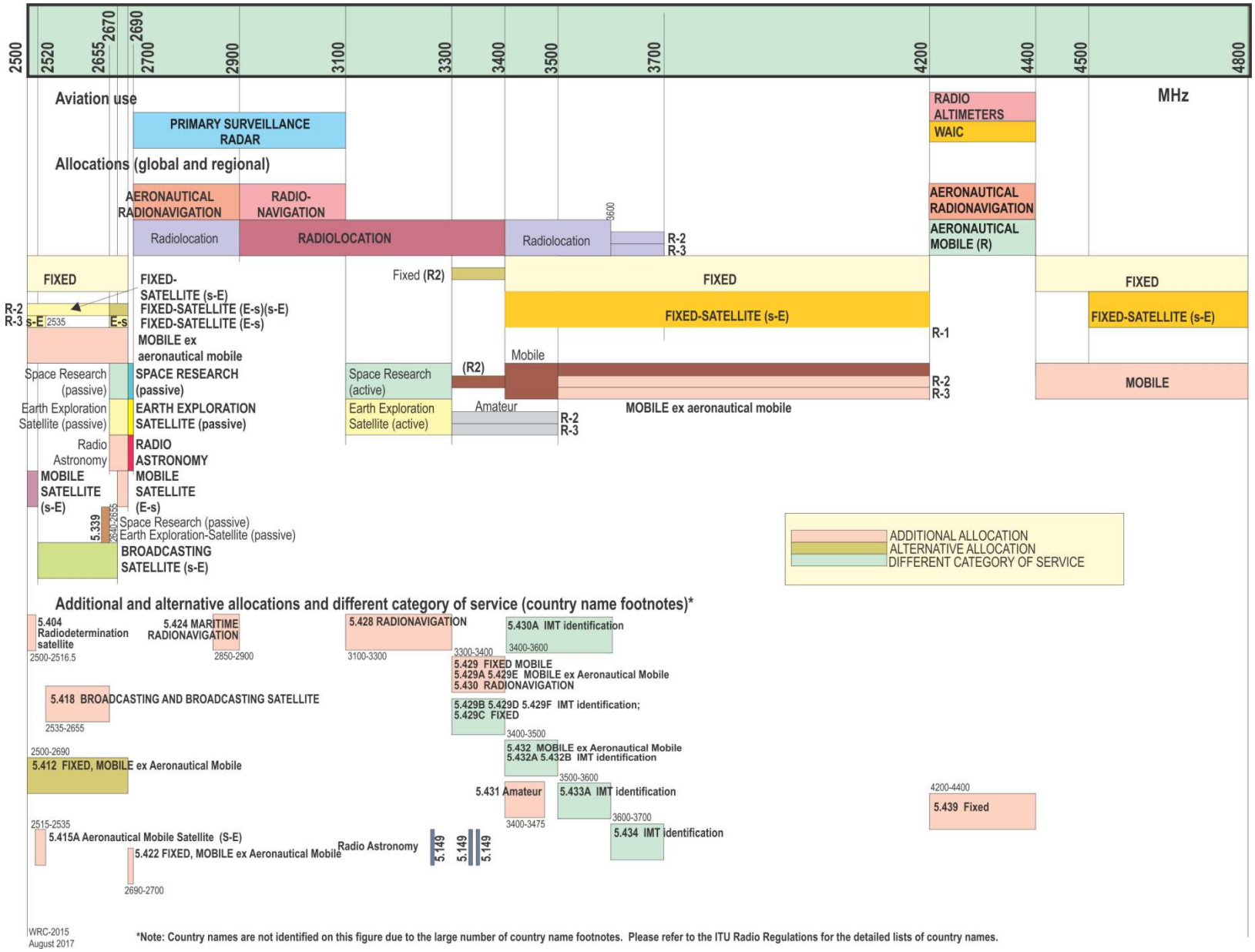


Figure 7-6. 2 500–4 800 MHz

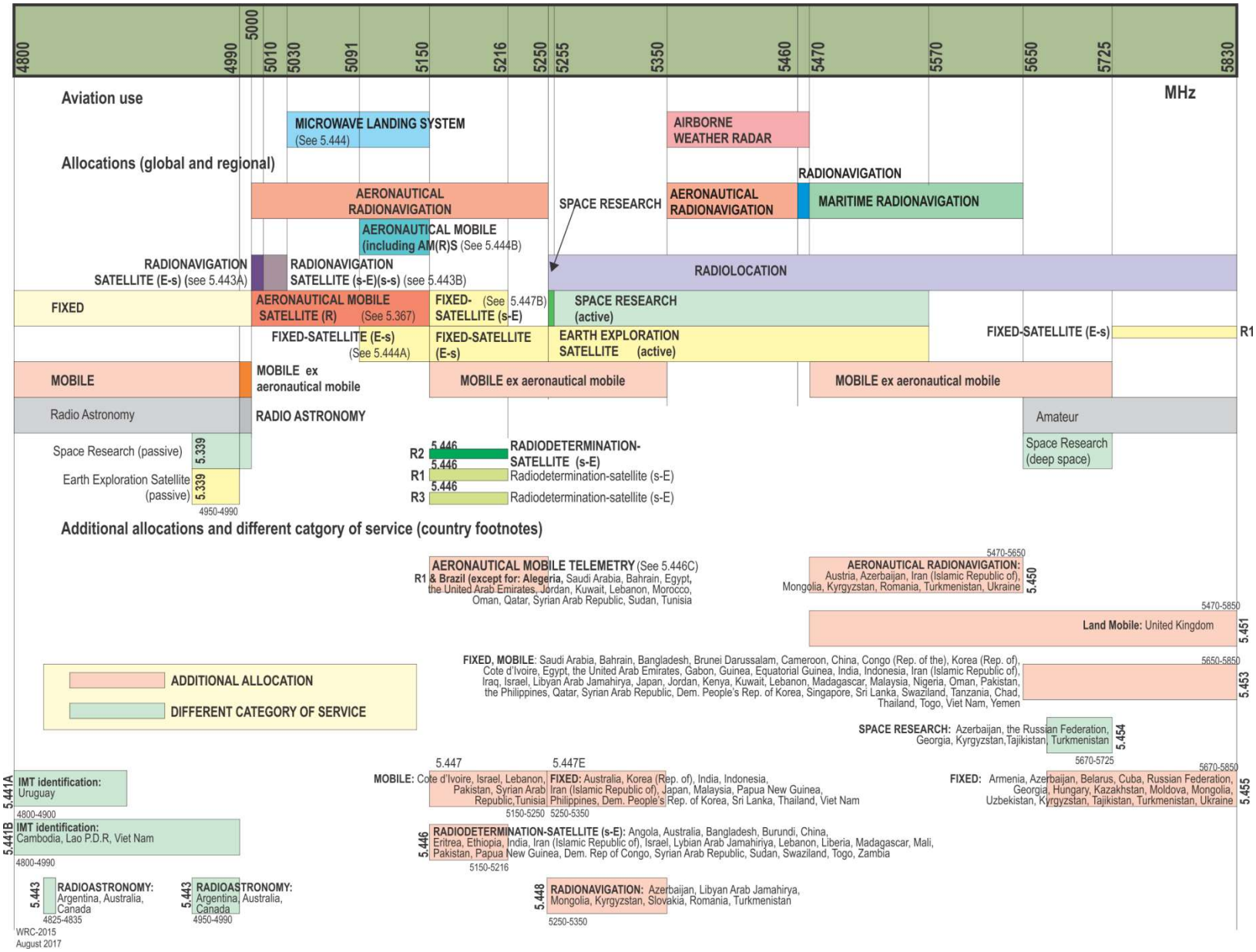


Figure 7-7. 4 800–5 830 MHz

SECTION 7-II. CIVIL AVIATION FREQUENCY ALLOCATIONS — ICAO POLICY STATEMENTS AND RELATED INFORMATION

(including a composite statement for each frequency band)

The following material is reproduced from Article 5 of the ITU Radio Regulations to provide necessary information on the regulatory basis of the Table of Frequency Allocations.

Note 1.— Extracts from the ITU Radio Regulations are presented against a shaded background.

Note 2.— This edition incorporates the changes to the Radio Regulations adopted at WRC-15.

ARTICLE 5
FREQUENCY ALLOCATIONS

5.1 In all documents of the Union where the terms allocation, allotment and assignment are to be used, they shall have the meaning given them in Nos. **1.16 to 1.18**, the terms used in the three working languages being as follows:

Frequency distribution to	French	English	Spanish
Services	Attribution (attribuer)	Allocation (to allocate)	Atribución (atribuir)
Areas or countries	Allotissement (allotir)	Allotment (to allot)	Adjudicación (adjudicar)
Stations	Assignation (assigner)	Assignment (to assign)	Asignación (asignar)

Section I. Regions and areas

5.2 For the allocation of frequencies the world has been divided into three Regions* as shown on the following map and described in Nos. **5.3** to **5.9**.

Note 1.— The map is reproduced in Figure 3-1 of this handbook.

*Note 2.— RR Nos. **5.3** to **5.22** are not included in this handbook.*

***5.2.1** It should be noted that where the words “regions” or “regional” are without a capital “R” in these Regulations, they do not relate to the three Regions here defined for purposes of frequency allocation.

. . .

Section II. Categories of Services and Allocations

5.23 *Primary and secondary services*

5.24 1) Where, in a box of the Table in Section IV of this Article, a band is indicated as allocated to more than one service, either on a worldwide or Regional basis, such services are listed in the following order:

5.25 a) services the names of which are printed in “capitals” (example: FIXED); these are called “primary” services;

5.26 b) services the names of which are printed in “normal characters” (example: Mobile); these are called “secondary” services (see Nos. **5.28 to 5.31**).

5.27 2) Additional remarks shall be printed in normal characters (example: MOBILE except aeronautical mobile).

5.28 3) Stations of a secondary service:

5.29 a) shall not cause harmful interference to stations of primary services to which frequencies are already assigned or to which frequencies may be assigned at a later date;

5.30 b) cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date;

5.31 c) can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later date.

5.32 4) Where a band is indicated in a footnote of the Table as allocated to a service “on a secondary basis” in an area smaller than a Region, or in a particular country, this is a secondary service (see Nos. **5.28 to 5.31**).

5.33 5) Where a band is indicated in a footnote of the Table as allocated to a service "on a primary basis", in an area smaller than a Region, or in a particular country, this is a primary service only in that area or country.

5.34 *Additional allocations*

5.35 1) Where a band is indicated in a footnote of the Table as "also allocated" to a service in an area smaller than a Region, or in a particular country, this is an "additional" allocation, i.e. an allocation which is added in this area or in this country to the service or services which are indicated in the Table (see No. **5.36**).

5.36 2) If the footnote does not include any restriction on the service or services concerned apart from the restriction to operate only in a particular area or country, stations of this service or these services shall have equality of right to operate with stations of the other primary service or services indicated in the Table.

5.37 3) If restrictions are imposed on an additional allocation in addition to the restriction to operate only in a particular area or country, this is indicated in the footnote of the Table.

5.38 *Alternative allocations*

5.39 1) Where a band is indicated in a footnote of the Table as "allocated" to one or more services in an area smaller than a Region, or in a particular country, this is an "alternative" allocation, i.e. an allocation which replaces, in this area or in this country, the allocation indicated in the Table (see No. **5.40**).

5.40 2) If the footnote does not include any restriction on stations of the service or services concerned, apart from the restriction to operate only in a particular area or country, these stations of such a service or services shall have an equality of right to operate with stations of the primary service or services, indicated in the Table, to which the band is allocated in other areas or countries.

5.41 3) If restrictions are imposed on stations of a service to which an alternative allocation is made, in addition to the restriction to operate only in a particular country or area, this is indicated in the footnote.

5.42 *Miscellaneous provisions*

5.43 1) Where it is indicated in these Regulations that a service or stations in a service may operate in a specific frequency band subject to not causing harmful interference to another service or to another station in the same service, this means also that the service which is subject to not causing harmful interference cannot claim protection from harmful interference caused by the other service or other station in the same service.

5.43A 1 bis) Where it is indicated in these Regulations that a service or stations in a service may operate in a specific frequency band subject to not claiming protection from another service or from another station in the same service, this means also that the service which is subject to not claiming protection shall not cause harmful interference to the other service or other station in the same service.

5.44 2) Except if otherwise specified in a footnote, the term "fixed service", where appearing in Section IV of this Article, does not include systems using ionospheric scatter propagation.

5.45 Not used.

Section III. Description of the Table of Frequency Allocations

5.46 1) The heading of the Table in Section IV of this Article includes three columns, each of which corresponds to one of the Regions (see No. **5.2**). Where an allocation occupies the whole of the width of the Table or only one or two of the three columns, this is a worldwide allocation or a Regional allocation, respectively.

5.47 2) The frequency band referred to in each allocation is indicated in the left-hand top corner of the part of the Table concerned.

5.48 3) Within each of the categories specified in Nos. **5.25 and 5.26**, services are listed in alphabetical order according to the French language. The order of listing does not indicate relative priority within each category.

5.49 4) In the case where there is a parenthetical addition to an allocation in the Table, that service allocation is restricted to the type of operation so indicated.

5.50 5) The footnote references which appear in the Table below the allocated service or services apply to more than one of the allocated services, or to the whole of the allocation concerned.

5.51 6) The footnote references which appear to the right of the name of a service are applicable only to that particular service.

5.52 7) In certain cases, the names of countries appearing in the footnotes have been simplified in order to shorten the text.

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Band: 130–535 kHz
Service: Aeronautical radionavigation (NDB)
Allocation:

<table>
<tr><th colspan="3">kHz
130–255</th></tr>
<tr><td colspan="3">Allocation to services</td></tr>
<tr><td>Region 1</td><td>Region 2</td><td>Region 3</td></tr>
<tr><td>130–135.7
FIXED
MARITIME MOBILE

5.64 5.67</td><td>130–135.7
FIXED
MARITIME MOBILE

5.64</td><td>130–135.7
FIXED
MARITIME MOBILE
RADIONAVIGATION
5.64</td></tr>
<tr><td>135.7–137.8
FIXED
MARITIME MOBILE
Amateur 5.67A

5.64 5.67 5.67B</td><td>135.7–137.8
FIXED
MARITIME MOBILE
Amateur 5.67A

5.64</td><td>135.7–137.8
FIXED
MARITIME MOBILE
RADIONAVIGATION
Amateur 5.67A
5.64 5.67B</td></tr>
<tr><td>137.8–148.5
FIXED
MARITIME MOBILE

5.64 5.67</td><td rowspan="2">137.8–160
FIXED
MARITIME MOBILE

5.64</td><td rowspan="2">137.8–160
FIXED
MARITIME MOBILE
RADIONAVIGATION

5.64</td></tr>
<tr><td rowspan="2">148.5–255
BROADCASTING

5.68 5.69 5.70</td></tr>
<tr><td>160–190
FIXED</td><td>160–190
FIXED
Aeronautical radionavigation</td></tr>
<tr><td colspan="2">190–200
AERONAUTICAL RADIONAVIGATION</td></tr>
</table>

<table>
<tr><th colspan="3">kHz
255 (200)–405</th></tr>
<tr><td colspan="3">Allocation to Services</td></tr>
<tr><td>Region 1</td><td>Region 2</td><td>Region 3</td></tr>
<tr><td rowspan="2">255–283.5
BROADCASTING
AERONAUTICAL
RADIONAVIGATION

5.70 5.71</td><td>200–275
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td><td rowspan="2">200–285
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>275–285
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile
Maritime radionavigation
(radiobeacons)</td></tr>
<tr><td>283.5–315
AERONAUTICAL
RADIONAVIGATION
MARITIME
RADIONAVIGATION
(radiobeacons) 5.73

5.74</td><td colspan="2">285–315
AERONAUTICAL RADIONAVIGATION
MARITIME RADIONAVIGATION
(radiobeacons) 5.73</td></tr>
<tr><td>315–325
AERONAUTICAL
RADIONAVIGATION
Maritime radionavigation
(radiobeacons) 5.73

5.75</td><td>315–325
MARITIME
RADIONAVIGATION
(radiobeacons) 5.73
Aeronautical
radionavigation</td><td>315–325
AERONAUTICAL
RADIONAVIGATION
MARITIME
RADIONAVIGATION
(radiobeacons) 5.73</td></tr>
<tr><td rowspan="2">325–405
AERONAUTICAL
RADIONAVIGATION</td><td>325–335
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile
Maritime radionavigation
(radiobeacons)</td><td rowspan="2">325–405
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>335–405
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td></tr>
</table>

<table>
<tr><th colspan="3">kHz
405–505</th></tr>
<tr><td colspan="3">Allocation to Services</td></tr>
<tr><td>Region 1</td><td>Region 2</td><td>Region 3</td></tr>
<tr><td>405–415
RADIONAVIGATION
5.76</td><td colspan="2">405–415
RADIONAVIGATION 5.76
Aeronautical mobile</td></tr>
<tr><td>415–435
MARITIME MOBILE
5.79
AERONAUTICAL
RADIONAVIGATION</td><td colspan="2" rowspan="2">415–472
MARITIME MOBILE 5.79
Aeronautical radionavigation 5.80</td></tr>
<tr><td>435–472
MARITIME MOBILE
5.79 5.79A
Aeronautical
radionavigation 5.77

5.82</td></tr>
<tr><td colspan="3">472-479
MARITIME MOBILE 5.79
Amateur 5.80A
Aeronautical radionavigation 5.77 5.80

5.82 5.80B</td></tr>
<tr><td>479–495
MARITIME MOBILE
5.79 5.79A
Aeronautical
radionavigation 5.77

5.82</td><td colspan="2">479–495
MARITIME MOBILE 5.79 5.79A
Aeronautical radionavigation 5.80

5.77 5.82</td></tr>
<tr><td>495–505</td><td colspan="2">MARITIME MOBILE</td></tr>
</table>

<table>
<tr><th colspan="3">kHz
505–535</th></tr>
<tr><td colspan="3">Allocation to Services</td></tr>
<tr><td>Region 1</td><td>Region 2</td><td>Region 3</td></tr>
<tr><td rowspan="3">505–526.5
MARITIME MOBILE
5.79 5.79A 5.84
AERONAUTICAL
RADIONAVIGATION</td><td>505–510
MARITIME MOBILE
5.79</td><td rowspan="2">505–526.5
MARITIME MOBILE
5.79 5.79A 5.84
AERONAUTICAL
RADIONAVIGATION
Aeronautical Mobile
Land Mobile</td></tr>
<tr><td>510–525
MARITIME MOBILE
5.79A 5.84
AERONAUTICAL
RADIONAVIGATION</td></tr>
<tr><td>525–535
BROADCASTING
5.86
AERONAUTICAL
RADIONAVIGATION</td><td>526.5–535
BROADCASTING
Mobile
5.88</td></tr>
</table>

Footnotes:

5.64 Only classes A1A or F1B, A2C, A3C, F1C or F3C emissions are authorized for stations of the fixed service in the bands allocated to this service between 90 kHz and 160 kHz (148.5 kHz in Region 1) and for stations of the maritime mobile service in the bands allocated to this service between 110 kHz and 160 kHz (148.5 kHz in Region 1). Exceptionally, class J2B or J7B emissions are also authorized in the bands between 110 kHz and 160 kHz (148.5 kHz in Region 1) for stations of the maritime mobile service.

5.67 *Additional allocation:* in Mongolia, Kyrgyzstan and Turkmenistan, the band 130–148.5 kHz is also allocated to the radionavigation service on a secondary basis. Within and between these countries this service shall have an equal right to operate. (WRC-07)

5.67A Stations in the amateur service using frequencies in the band 135.7–137.8 kHz shall not exceed a maximum radiated power of 1 W (e.i.r.p.) and shall not cause harmful interference to stations of the radionavigation service operating in countries listed in No. **5.67**. (WRC-07)

5.67B The use of the band 135.7–137.8 kHz in Algeria, Egypt, Iran (Islamic Republic of), Iraq, Lebanon, Syrian Arab Republic, Sudan, South Sudan and Tunisia is limited to the fixed and maritime mobile services. The amateur service shall not be used in the above-mentioned countries in the band 135.7–

137.8 kHz, and this should be taken into account by the countries authorizing such use. (WRC-12)

5.68 *Alternative allocation:* in Congo (Rep. of the), the Dem. Rep. of the Congo and South Africa, the frequency band 160–200 kHz is allocated to the fixed service on a primary basis. (WRC-15)

5.69 *Additional allocation:* in Somalia, the band 200–255 kHz is also allocated to the aeronautical radionavigation service on a primary basis.

5.70 *Alternative allocation:* in Angola, Botswana, Burundi, the Central African Rep., Congo (Rep. of the), Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Oman, the Dem. Rep. of the Congo, South Africa, Swaziland, Tanzania, Chad, Zambia and Zimbabwe, the band 200–283.5 kHz is allocated to the aeronautical radionavigation service on a primary basis. (WRC-12)

5.71 *Alternative allocation:* in Tunisia, the band 255–283.5 kHz is allocated to the broadcasting service on a primary basis.

5.73 The band 285–325 kHz (283.5–325 kHz in Region 1), in the maritime radionavigation service may be used to transmit supplementary navigational information using narrow-band techniques, on condition that no harmful interference is caused to radiobeacon stations operating in the radionavigation service.

5.74 *Additional allocation:* in Region 1, the frequency band 285.3–285.7 kHz is also allocated to the maritime radionavigation service (other than radiobeacons) on a primary basis.

5.75 *Different category of service:* in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Moldova, Kyrgyzstan, Tajikistan, Turkmenistan, Ukraine and the Black Sea areas of Romania, the allocation of the band 315–325 kHz to the maritime radionavigation service is on a primary basis under the condition that in the Baltic Sea area, the assignment of frequencies in this band to new stations in the maritime or aeronautical radionavigation services shall be subject to prior consultation between the administrations concerned. (WRC-07)

5.76 The frequency 410 kHz is designated for radio direction-finding in the maritime radionavigation service. The other radionavigation services to which the band 405–415 kHz is allocated shall not cause harmful interference to radio direction-finding in the band 406.5–413.5 kHz.

5.77 *Different category of service:* in Australia, China, the French Overseas Communities of Region 3, Korea (Rep. of), India, Iran (Islamic Republic of), Japan, Pakistan, Papua New Guinea and Sri Lanka, the allocation of the frequency band 415–495 kHz to the aeronautical radionavigation service is on a primary basis. In Armenia, Azerbaijan, Belarus, the Russian Federation, Kazakhstan, Latvia, Uzbekistan and Kyrgyzstan, the allocation of the frequency band 435-495 kHz to the aeronautical radionavigation service is on a primary basis. Administrations in all the aforementioned countries shall take all practical steps necessary to ensure that aeronautical radionavigation stations in the frequency band 435–495 kHz do not cause interference to reception by coast stations of transmissions from ship stations on frequencies designated for ship stations on a worldwide basis. (WRC-12)

5.78 *Different category of service:* in Cuba, the United States of America and Mexico, the allocation of the band 415–435 kHz to the aeronautical radionavigation service is on a primary basis.

5.79 The use of the bands 415–495 kHz and 505–526.5 kHz (505–510 kHz in Region 2) by the maritime mobile service is limited to radiotelegraphy.

5.79A When establishing coast stations in the NAVTEX service on the frequencies 490 kHz, 518 kHz and 4 209.5 kHz, administrations are strongly recommended to coordinate the operating characteristics in accordance with the procedures of the International Maritime Organization (IMO) (see Resolution **339 (Rev. WRC-07)**). (WRC-07)

5.80 In Region 2, the use of the band 435–495 kHz by the aeronautical radionavigation service is limited to non-directional beacons not employing voice transmission.

5.80A The maximum equivalent isotropically radiated power (e.i.r.p.) of stations in the amateur service using frequencies in the band 472–479 kHz shall not exceed 1 W. Administrations may increase this limit of e.i.r.p. to 5 W in portions of their territory which are at a distance of over 800 km from the borders of Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iran (Islamic Republic of), Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya,

Morocco, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia, Ukraine and Yemen. In this frequency band, stations in the amateur service shall not cause harmful interference to, or claim protection from, stations of the aeronautical radionavigation service.

5.80B The use of the frequency band 472–479 kHz in Algeria, Saudi Arabia, Azerbaijan, Bahrain, Belarus, China, Comoros, Djibouti, Egypt, United Arab Emirates, the Russian Federation, Iraq, Jordan, Kazakhstan, Kuwait, Lebanon, Libya, Mauritania, Oman, Uzbekistan, Qatar, Syrian Arab Republic, Kyrgyzstan, Somalia, Sudan, Tunisia and Yemen is limited to the maritime mobile and aeronautical radionavigation services. The amateur service shall not be used in the above-mentioned countries in this frequency band, and this should be taken into account by the countries authorizing such use.

5.82 In the maritime mobile service, the frequency 490 kHz is to be used exclusively for the transmission by coast stations of navigational and meteorological warnings and urgent information to ships, by means of narrow-band direct-printing telegraphy. The conditions for use of the frequency 490 kHz are prescribed in Articles **31** and **52**. In using the frequency band 415–495 kHz for the aeronautical radionavigation service, administrations are requested to ensure that no harmful interference is caused to the frequency 490 kHz. In using the frequency band 472–479 kHz for the amateur service, administrations shall ensure that no harmful interference is caused to the frequency 490 kHz. (WRC-12)

5.84 The conditions for the use of the frequency 518 kHz by the maritime mobile service are prescribed in Articles **31** and **52**. (WRC-07)

5.86 In Region 2, in the band 525–535 kHz the carrier power of broadcasting stations shall not exceed 1 kW during the day and 250 W at night.

5.87 *Additional allocation:* in Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Niger and Swaziland, the band 526.5–535 kHz is also allocated to the mobile service on a secondary basis. (WRC-12)

5.87A *Additional allocation:* in Uzbekistan, the band 526.5–1 606.5 kHz is also allocated to the radionavigation service on a primary basis. Such use is subject to agreement obtained under No. **9.21** with administrations concerned and limited to ground-based radiobeacons in operation on 27 October 1997 until the end of their lifetime. (WRC-97)

5.88 Additional allocation: in China, the band 526.5–535 kHz is also

allocated to the aeronautical radionavigation service on a secondary basis.

ICAO POLICY

- No change to RR Nos. **5.70**, **5.80** and **5.86**.
- In regions where the global navigation satellite system (GNSS) is implemented and non-directional radio beacon (NDB) assignments are withdrawn from international and national usage, aviation requirements for spectrum in these bands may be reduced.
- Until NDBs have been phased out, the current allocations to the aeronautical radionavigation service must be safeguarded.

On a global basis, the use of NDB beacons is expected to continue in the medium term and the long term subject to regional or sub-regional requirements. The use in general is stabilized and may be reduced over time as a result of ongoing GNSS and RNAV implementation. However, the use of NDB and locator beacons will continue subject to regional requirements (e.g. to provide a backup network to GNSS). No (significant) increase in frequency requirements for NDB and locator beacons is expected; the aeronautical requirements can be met in the currently available frequency bands. Outer locators which are used in conjunction with the instrument landing system (ILS) and marker beacons are, in a number of cases, being replaced with DME. Parts of the bands used for NDB/locator systems are shared with amateur, broadcasting, maritime radionavigation and maritime mobile services.

AVIATION USE: These bands support NDBs for short- and medium-range navigation. NDBs transmit non-directional signals in the low and medium frequency (LF/MF) bands, normally between 190 kHz and 535 kHz. With appropriate automatic direction finder (ADF) equipment on board an aircraft, the pilot can determine the bearing of the station or can "home" on the station. The ADF receiver tuning range is normally between 190 kHz and 1 750 kHz. NDBs are mainly used as a non-precision instrument approach aid, either in conjunction with an ILS (then designated as a "locator"), or to define air routes/airways. NDBs are extensively deployed at aerodromes for general aviation. Although NDBs are comparatively inexpensive navigation aids and relatively simple to install and maintain, bearing information derived from NDBs is not very precise and lightning, precipitation static, etc., cause intermittent or unreliable signals resulting in erroneous bearing information and/or large oscillations of the radio compass needle. NDBs are

assigned frequencies on the basis of daytime propagation conditions. Frequencies used for NDB are prone to night effects, whereby, due to ionosphere propagation (reflection), significant errors due to the reception of signals from distant NDBs may occur. This night effect increases with assigned frequency of operation.

Aeronautical NDBs at coastal locations are also used by the maritime service, and in the reverse sense, beacons provided for maritime purposes are potentially usable by aviation.

Frequency scarcity in ITU Region 1 (Europe and Africa) has been a cause for concern in the past. The 1979 ITU World Administrative Radio Conference (WARC-79) hence recognized a demand in Europe and Africa and allocated in ITU Region 1 the frequency band 415–435 kHz to the aeronautical radionavigation service, shared with the maritime mobile service, at that time on a permitted basis. An ITU frequency assignment plan for Region 1 was prepared for this band in 1985 giving priority access to the aeronautical radionavigation service (*Final Acts of the Regional Administrative Radio Conference for the planning of the MF Maritime Mobile and Aeronautical Radionavigation Services (Region 1)*, Geneva, 1985 refers). At present, the need for NDBs has stabilized and aviation can meet its requirement from the current allocations. Allocations made on a permitted basis were removed from the Radio Regulations in WRC-95 and replaced with an allocation on a primary basis.

Interference from broadcasting in the band 255–283.5 kHz has been reported, which renders parts of this band unusable in much of Region 1. (This band is not allocated to the broadcasting service in Regions 2 and 3.)

COMMENTARY: For international purposes, the future air navigation systems (FANS) scenario foresaw a reduction in the role of NDBs in the future due to, inter alia, the emergence of GNSS as the future system for a range of navigation services, including those for oceanic and low-density continental airspace.

At a national level where the majority of NDB services are provided, frequency demand for NDBs will depend to a large extent on national policies. The last worldwide ICAO review in 1985 (Appendix C to Agenda Item 8 of the *Report of the Communications/Operations (COM/OPS) Divisional Meeting (1985)* (Doc 9464)) considered the retention of NDB allocations essential, including the need for assignments for national purposes. General aviation use of NDBs is expected for at least the medium term (2035).

Recent developments include the need to retain NDB systems on a larger scale to provide backup for GNSS failures in areas where alternative backup systems, such as VOR/DME or DME-DME navigation, are technically or economically not

practicable.

Footnotes:

Footnotes to the Table of Frequency Allocations of particular importance are:

5.76: Designation of 410 kHz for radio direction finding.
5.80: The prohibition of the use of voice on NDB frequencies in Region 2 in the band 435–495 kHz.
5.84: Designation of 518 kHz for special use in the maritime mobile service.

More information on the use of spectrum for NDB as well as frequency assignment planning of these beacons relating to the provisions of Article **28** and Appendix **12** of the Radio Regulations is in paragraphs 7-III.3.6 and 7-III.4.2 of this handbook. Attachment G contains technical information and frequency-sharing criteria for NDB.

Band: 2 850–22 000 kHz
Service: AM(R)S (air-ground communications (HF voice and data))
Allocation: In several sub-bands

kHz **2 850–22 000**		
Allocation to Services		
Region 1	Region 2	Region 3
2 850–3 025	AERONAUTICAL MOBILE (R) 5.111 5.115	
3 400–3 500	AERONAUTICAL MOBILE (R)	
4 650–4 700	AERONAUTICAL MOBILE (R)	
5 450–5 480 FIXED AERONAUTICAL MOBILE (OR) LAND MOBILE	**5 450–5 480** AERONAUTICAL MOBILE (R)	**5 450–5 480** FIXED AERONAUTICAL MOBILE (OR) LAND MOBILE
5 480–5 680	AERONAUTICAL MOBILE (R) 5.111 5.115	
6 525–6 685	AERONAUTICAL MOBILE (R)	
8 815–8 965	AERONAUTICAL MOBILE (R)	
10 005–10 100	AERONAUTICAL MOBILE (R) 5.111	
11 275–11 400	AERONAUTICAL MOBILE (R)	
13 260–13 360	AERONAUTICAL MOBILE (R)	
17 900–17 970	AERONAUTICAL MOBILE (R)	
21 850–21 870	FIXED 5.155A 5.155	
21 924–22 000	AERONAUTICAL MOBILE (R)	

Footnotes:

5.111 The carrier frequencies 2 182 kHz, 3 023 kHz, 5 680 kHz, 8 364 kHz and the frequencies 121.5 MHz, 156.525 MHz, 156.8 MHz and 243 MHz may also be used, in accordance with the procedures in force for terrestrial radiocommunication services, for search and rescue operations concerning manned space vehicles. The conditions for the use of the frequencies are prescribed in Article **31**.

The same applies to the frequencies 10 003 kHz, 14 993 kHz and 19 993 kHz, but in each of these cases emissions must be confined in a band of ±3 kHz about the frequency. (WRC-07)

5.115 The carrier (reference) frequencies 3 023 kHz and 5 680 kHz may also be used, in accordance with Article **31** by stations of the maritime mobile service engaged in coordinated search and rescue operations. (WRC-07)

5.155 Additional allocation: in Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the band 21 850–21 870 kHz is also allocated to the aeronautical mobile (R) service on a primary basis. (WRC-07)

5.155A In Armenia, Azerbaijan, Belarus, the Russian Federation, Georgia, Kazakhstan, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the use of the band 21 850–21 870 kHz by the fixed service is limited to provision of services related to aircraft flight safety. (WRC-07)

ICAO POLICY

- Retain the current allocations in the HF bands to the aeronautical mobile (route) service (AM(R)S) bands and the provisions of Appendix **27** to the Radio Regulations for the foreseeable future for HF voice and data.
- Protect the use of the aeronautical HF bands in accordance with the provisions of Appendix **27**.
- No change to RR Nos. **5.111** and **5.115**.
- Support the measures and participate in the technical studies addressed in Resolution **207 (Rev. WRC-15)** concerning the unauthorized use of and interference to frequencies in the bands allocated to the AM(R)S.
- Consider technical solutions which can be implemented efficiently without changes to aircraft equipment or disruption of aeronautical services.

The global aviation HF frequency bands between 2 850 kHz and 22 000 kHz provide aviation with a means for long-distance (beyond the radio horizon) communications. HF communications consist of both air-ground voice, and HF data link (HFDL) communications. Both voice and HFDL enable aircraft to still communicate when moving outside of VHF coverage (e.g. oceanic, polar or remote areas) or during loss of satellite communications. Effective HF communication can be maintained up to thousands of kilometres between a ground station and the aircraft.

The extended range of HF operations is achieved through sky wave propagation, which uses the ionosphere and the Earth's surface to effectively "bounce" the signal beyond normal radio line of sight. As the ionosphere varies depending on the time of day and solar activity, a single HF ground station may cycle through multiple aeronautical frequencies from 2 MHz up to 22 MHz throughout the day to ensure communications.

HF is still required as a means for long-range communications for all aircraft operating in oceanic or remote regions, and is an integral part of the associated safety case. HFDL has continued to evolve to support more aeronautical operational control (AOC) and ATS applications, such as controller-pilot data link communication (CPDLC) and ADS-C reporting and as of 2017 over 3 000 aircraft are equipped with HFDL. Consequently, the HF channel capacity required for contingency planning continues to grow, though future requirements are expected to be met in the currently available frequency bands.

AVIATION USE: HF voice, HFDL

HF voice is used for both ATS and AOC communications worldwide. Using an upper single sideband (suppressed carrier) amplitude modulation (USB) for 3 kHz channels, HF ground stations transmit up to 6 kW of power. Use of the selective calling (SELCAL) notification system by ground stations reinserts the carrier for the duration of the SELCAL message to ensure reception by the aircraft.

HFDL also uses 3 kHz USB upper sideband channels, using a half-duplex digital transmission to communicate between the HF ground station and the aircraft on the same frequency. Its adaptive modulation rate provides resilience to interference, while also regularly scanning the other HF frequencies to select the most efficient channel as the ionosphere conditions change.

Appendix **27** to the Radio Regulations contains the Frequency Allotment Plan and system parameters and was agreed at the ITU WARC-Aer2 (1978). The ICAO Communications Divisional Meeting (1976) carried out the ICAO coordination prior to the ITU conference. The ICAO Communications Divisional Meeting (1981) agreed to the necessary amendments to Annex 10, which included the change of modulation specification from double sideband (DSB) to single sideband (SSB) upper sideband.

The registration of assignments in the ITU Master International Frequency Register (MIFR) is a mandatory requirement covered by the Radio Regulations and effected through ITU member administrations (national telecommunication administrations). Due to the provisions of the Radio Regulations, ICAO cannot play any role in this registration (see *Ref. 27/19* in the section below titled *Use of HF datalink in the HF AM(R)S*). However, ICAO encourages all administrations to maintain accurate and current information in the ITU MIFR to ensure additional frequency assignments are not constrained by legacy assignments no longer in use.

HF voice frequencies are used for international and domestic services:

- Allotments in the Appendix **27** Plan are made to major world air route areas (MWARA) for long-distance international services where more than one country is affected. Regional and domestic air route areas (RDARA) allotments are made in other cases. Both MWARA and RDARA voice services provide ATC and other ATS messages within the relevant flight information region (FIR). The structure of Appendix **27** conforms to the operational requirement for aeronautical HF voice communication for the foreseeable future.

- A number of frequencies in the HF bands have been allotted on a worldwide basis for AOC messages. Known as long-distance operational control (LDOC), many aircraft operating agencies use these frequencies intensively and, in many cases, operate their own HF networks to support LDOC for regularity of flight and aircraft safety purposes. (RR 27/217).

27/217 4. The world-wide frequency allotments appearing in the Tables at No. 27/213 and Nos. 27/218 to 27/231, except for carrier (reference) frequencies 3 023 kHz and 5 680 kHz, are reserved for assignment by administrations to stations operating under authority granted by the administration concerned, for the purpose of serving one or more aircraft operating agencies. Such assignments are to provide communications between an appropriate aeronautical station and an aircraft station anywhere in the world for exercising control over regularity of flight and for safety of aircraft. World-wide frequencies are not to be assigned by administrations for MWARA, RDARA and VOLMET purposes. Where the operational area of an aircraft lies wholly within a RDARA or Sub-RDARA boundary, frequencies allotted to those RDARAs and Sub-RDARAs shall be used.

Appendix **27** designates the carrier frequencies 3 023 kHz and 5 650 kHz (RR 27/232 to RR 27/238) for common use on a worldwide basis. RR 27/236 permits these frequencies to be used by other mobile services for air-surface search and rescue operations. RR Nos. **5.111** and **5.115 (WRC-07)** and Appendix **15** of the Radio Regulations also specify these frequencies for specific distress and safety purposes (coordinated search and rescue operations). The relevant provisions of Appendix **27** of the Radio Regulations are reproduced in *Section 7-II — Band 3 023 kHz and 5 680 kHz* of this handbook.

Appendix **27** RR 27/19 specifically recognizes the coordination role of ICAO, with reference to the operational use of frequencies in the Allotment Plan. This activity is coordinated at regional air navigation meetings where regional requirements and frequencies for long-range communications are agreed. Such agreements need to be registered with the ITU MIFR through the national telecommunication administrations.

Appendix **27** contains provisions for adaptation of the allotment and frequency assignment procedures. These provisions allow administrations to assign frequencies which are not identified in the Allotment Plan under the condition that such frequency assignments will not reduce the protection of frequencies which are in the Allotment Plan. After proper coordination by the national telecommunication authorities of such frequency assignments with other administrations, these frequency assignments can be recorded in the ITU MIFR with the same international protection as other frequencies.

These provisions provide for adequate flexibility in the regulatory procedures to implement changes in the use of the HF frequency bands by aviation, including the accommodation of new frequency assignments.

4. *Adaptation of allotment procedure*

27/20 It is recognized that not all the sharing possibilities have been exhausted in the allotment Plan contained in this Appendix. Therefore, in order to satisfy particular operational requirements which are not otherwise met by this allotment Plan, Administrations may assign frequencies from the aeronautical mobile (R) bands in areas other than those to which they are allotted in this Plan. However, the use of the frequencies so assigned must not reduce the protection to the same frequencies in the areas where they are allotted by the Plan below that determined by the application of the procedure defined in Part I, Section II B of this Appendix.

27/21 5. When necessary to satisfy the needs of international air operations Administrations may adapt the allotment procedure for the assignment of aeronautical mobile (R) frequencies, which assignments shall then be the subject of prior agreement between Administrations affected.

27/22 6. The coordination described in No. 27/19 shall be effected where appropriate and desirable for the efficient utilization of the frequencies in question, and especially when the procedures of No. 27/21 are unsatisfactory.

27/67 e) That, in accordance with the Radio Regulations, all details of the assignment(s), including the transmitting antenna characteristics shall be notified to the Radiocommunication Bureau.

COMMENTARY:

The present policy, in line with the findings of the ICAO Communications/ Meteorology/Operations (COM/MET/OPS) Divisional Meeting (1990), is that no change be made to the allocation of the bands between 2 MHz and 22 MHz allocated to the AM(R)S (Appendix A to the report of COM/MET/OPS/90 on Agenda Item 3, paragraph 2.3 — Future aviation use — refers). Although this policy recognized that requirements for HF frequency assignments were increasing, over the years few new frequency assignments have been made. The coverage of polar regions which cannot be accommodated by satellite systems utilizing geostationary satellites is a requirement for continued use of HF spectrum even after full implementation of satellite communication. Additionally, implementation of non-geostationary satellite systems (e.g. IRIDIUM) may also provide for the missing coverage over polar areas.

Use of HFDL in the HF AM(R)S

Data link on HF frequencies was considered by the Aeronautical Mobile Communications Panel (AMCP) and the Automatic Dependent Surveillance Panel (ADSP). A study on this matter, including the development of SARPs for Annex 10, was completed and relevant SARPs incorporated in Annex 10, Volume III.

SARPs for HFDL were incorporated in Annex 10, Volume III, in 1999. A global HFDL network/system (ARINC Global Link) for aviation, operating in accordance with ICAO SARPs, is currently in operation. HFDL is approved for full Future Air Navigation Systems (FANS) capability at RCP400.

The existing technical provisions in Appendix 27 permit data modulations, and the Rules of Procedure relating to this were approved by the ITU Radio Regulations Board at its meeting in July 1998. The relevant rules are referenced below:

Ref. 27/15:
This provision specifies that the use of channels derived from the frequencies indicated in No. 27/18 for the various classes of emissions other than J3E and H2B will be subject to special arrangements by the administrations concerned and affected. In this connection, and having in mind the spirit of Resolution **713** (WRC-95), the Board considers as a valid "special arrangement by the administrations concerned" any formal action by the International Civil Aviation Organization (ICAO) which results in Standards and Recommended Practices (SARPs), which are approved by the ICAO in accordance with its procedures and which are communicated to the ITU accordingly.

Ref. 27/19:
This provision specifies the role of ICAO in performing voluntary coordination ("should") in the operational use of the frequencies. The Board considers such a coordination as an internal ICAO activity, intended to concluding operational agreements between the international operators (e.g. timesharing arrangements). Therefore the Bureau will not take into account such agreements between operators, unless they are communicated to the Bureau by their national telecommunications administration.

Ref. 27/58:
This provision lists the permissible classes of emission on the channels of Appendix 27 and stipulates, amongst other emissions, the possibility of using "other transmissions such as data transmission, single sideband, suppressed carrier". The class of transmission listed against this latter description is JXX (former designation A9J). In this respect, the Board considers that any SSB

(suppressed carrier) class of emission is authorized on the channels in Appendix 27 (e.g. J2B, J2D, J7B, J7D, J9B, J9D, etc.), provided that the following conditions are satisfied:

- the reference frequency of the concerned transmission coincides with a reference frequency listed in the list of carrier (reference) frequencies (27/18);
- the occupied bandwidth of other authorized emissions does not exceed the upper limit of J3E emissions (No. 27/12), i.e. 2 700 Hz;
- the assigned frequency is at a value 1 400 Hz above the carrier (reference) frequency (27/75).

In frequency assignment planning, it is important to realize that the geographical disposition of allotments to MWARA and RDARA needs to be adjusted to accommodate the area of application of the new data services. In accordance with Appendix **27**, RR 27/56, the frequency assignments for data must be made so as not to cause harmful interference to the allotments in Appendix **27**. While some assignments may be identified using the possibilities covered by RR 27/20 (see above), the additional requirements for dedicated families for data, as specified by the AMCP, cannot be met from the present Appendix **27** Allotment Plan without affecting the provisions (allotments) for HF voice.

On the use of HF data link and to assist in the coordination and registration of frequency assignments by the ITU, Recommendation ITU-R M.1458 on the *Use of the frequency bands between 2.8 MHz and 22 MHz by the AM(R)S for data transmission using class of emission J2D* provides additional information.

Harmful interference to HF services in certain areas

The increase in harmful interference to air-ground communications (and to maritime communications) in the HF bands was discussed at ITU World Radiocommunication Conferences in 1997 and 2000. This problem is prevalent in some areas in the western part of the South Pacific and is believed to arise from the use of non-licensed, non-authorized equipment often installed on marine craft. The ITU discussions have encompassed both administrative measures, i.e. better control and regulation, and technical measures, which can reduce the effect. The latter are only regarded with favour in aviation if they can be implemented without changes to current operational aircraft equipment. Resolution **207 (Rev. WRC-15)** was amended at WRC-03 to draw attention to this threat and to ensure that studies by ITU-R continue.

Additionally, increasing environmental noise is being seen from unintentional and intentional radiators in the HF spectrum. New technologies such as Broadband over Power Lines (BPL) and Wireless Power Transmission (WPT) are being deployed worldwide into the consumer market with little control over the area of use, and have a high potential for raising the noise floor of aviation HF ground receivers. Furthermore, over the horizon HF radars are also a known source of interference when such use has not been fully coordinated internationally.

Appendix 27 provisions: Appendix **27** can only be amended by a competent ITU-R WRC where this subject is placed on the agenda. There are currently no requirements for a review of the Allotment Plan.

Some of the definitions relevant to the use of frequencies from the aeronautical HF bands, as given in Appendix **27**, are presented in the shaded box below.

Definitions

27/1 1. *Frequency allotment Plan:* A Plan which shows the frequencies to be used in particular areas without specifying the stations to which the frequencies are to be assigned.

27/2 2. The terms to express the different methods of frequency distribution as used in this Appendix have the following meanings:

Services	Attribution (attribuer)	Allocation (to allocate)	Atribución (atribuir)
Areas	Allotissement (allotir)	Allotment (to allot)	Adjudicación (adjudicar)
Stations	Assignation (assigner)	Assignment (to assign)	Asignación (asignar)

27/3 3. *A Major World Air Route* is a long-distance route, made up of one or more segments, essentially international in character, extending through more than one country and requiring long-distance communication facilities.

27/4 4. *A Major World Air Route Area (MWARA)* is an area embracing a certain number of Major World Air Routes, which generally follow the same traffic pattern and are so related geographically that the same frequency families may logically be applied.

27/5 5. *Regional and Domestic Air Routes* are all those using the Aeronautical Mobile (R) Service not covered by the definition of a Major World Air Route in No. 27/3.

27/6 6. Regional and Domestic Air Route Area (RDARA) is an area embracing a certain number of the air routes defined in No. 27/5.

27/7 7. A VOLMET Allotment Area is an area encompassing all points where an HF broadcast facility might be required to operate on a family of frequencies common to the area.

27/8 8. A VOLMET Reception Area is an area within which aircraft should be able to receive broadcasts from one or more stations in the associated VOLMET Allotment Area.

27/9 9. A World-Wide Allotment Area is one in which frequencies are allotted to provide long-distance communication between an aeronautical station within that allotment area and aircraft operating anywhere in the world.

27/10 10. Family of Frequencies in the Aeronautical Mobile (R) Service contains two or more frequencies selected from different aeronautical mobile (R) bands and is intended to permit communication at any time within the authorized area of use (see Nos. 27/213 to 27/231) between aircraft stations and appropriate aeronautical stations.

Current and future use of HF frequency bands

Current use of the HF frequency bands is still very significant. In the North Atlantic area, due to air traffic growth, use of HF communications is still a major component for adequate air traffic control. The NAT SPG (North Atlantic Systems Planning Group) has taken steps to increase the number of HF frequencies for use in the NAT region. It is expected that the necessary frequency assignments can be found within the current HF frequency bands and within the procedures as specified in Appendix **27** to the Radio Regulations. Similar steps (to increase the use of HF frequencies)

are also being considered in other regions. No amendments to the Radio Regulations are necessary as the current procedures include some flexibility for making new assignments and seeking their registration and protection within the ITU.

It should be noted that SATCOM voice trials conducted in 2007 showed, inter alia, that it could not be concluded if the existing satellite infrastructure, networks and telephone links to the radio stations have sufficient capacity to handle the volume of traffic currently supported by the NAT HF/VHF network. Since then, some countries have conducted additional studies to allow one HF communication system to be permanently replaced with a SATVOICE system, with several trials being implemented in certain FIRs.

Based on the ICAO Global Air Navigation Plan (GANP) fifth edition, the already employed HF systems are expected to continue operation beyond 2030.

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Band: 3 023 kHz and 5 680 kHz
Service: AM(R)S (search and rescue)
Aviation use: The frequencies 3 023 kHz and 5 680 kHz are intended for common use on a worldwide basis as indicated in Appendix **27**.

27/232 1. The carrier (reference) frequencies 3 023 kHz and 5 680 kHz are intended for common use on a worldwide basis.

27/233 2. The use of these frequencies in any part of the world is authorized:

2.1 aboard aircraft for:

a) communications with approach and aerodrome control;

b) communication with an aeronautical station when other frequencies of the station are either unavailable or unknown;

2.2 at aeronautical stations for aerodrome and approach control under the following conditions:

a) with mean power limited to a value of not more than 20 W in the antenna circuit;

b) special attention must be given in each case to the type of antenna used in order to avoid harmful interference;

c) the power of aeronautical stations which use these frequencies in accordance with the above conditions may be increased to the extent necessary to meet certain operational requirements subject to coordination between the administrations directly concerned and those whose services may be adversely affected.

27/234 3. Notwithstanding these provisions, the frequency 5 680 kHz may also be used at aeronautical stations for communication with aircraft stations when other frequencies of the aeronautical stations are either unavailable or unknown. However, this use shall be restricted to such areas and conditions that harmful interference cannot be caused to other authorized operations of stations in the aeronautical mobile service.

27/235 4. Additional particulars regarding the use of these channels for the above purposes may be recommended by the meetings of ICAO.

27/236 5. Frequencies 3 023 kHz and 5 680 kHz may also be used by stations of other mobile services participating in coordinated air-surface search and rescue operations, including communications between these stations and participating land stations. Aeronautical stations are authorized to use these frequencies to establish communications with such stations.

Note.— See also RR Nos. ***5.111*** *and* ***5.115*** *under band 2 850–22 000 kHz.*

Band: 74.8–75.2 MHz
Service: Aeronautical radionavigation (marker beacon)
Allocation:

MHz **74.8–75.2**		
Allocation to Services		
Region 1	Region 2	Region 3
74.8–75.2	AERONAUTICAL RADIONAVIGATION 5.180 5.181	

Footnotes:

5.180 The frequency 75 MHz is assigned to marker beacons. Administrations shall refrain from assigning frequencies close to the limits of the guardband to stations of other services which, because of their power or geographical position, might cause harmful interference or otherwise place a constraint on marker beacons.

Every effort should be made to improve further the characteristics of airborne receivers and to limit the power of transmitting stations close to the limits 74.8 MHz and 75.2 MHz.

5.181 *Additional allocation*: in Egypt, Israel and the Syrian Arab Republic, the band 74.8–75.2 MHz is also allocated to the mobile service on a secondary basis, subject to agreement obtained under No. **9.21**. In order to ensure that harmful interference is not caused to stations of the aeronautical radionavigation service, stations of the mobile service shall not be introduced in the band until it is no longer required for the aeronautical radionavigation service by any administration which may be identified in the application of the procedure invoked under No. **9.21**. (WRC-03)

ICAO POLICY

- No change to the current allocations.
- No change to RR No. **5.180**.
- Deletion of RR No. **5.181**.

Marker beacons are used in conjunction with ILS. On a global basis, the frequency band available for marker beacons satisfies the aeronautical requirements. In a number of cases, marker beacons (and outer locators) are being replaced with DME. As long as marker beacons are in operation, the band 74.8–75.2 MHz needs to be available for these systems.

AVIATION USE: The frequency of 75 MHz is assigned to marker beacons for use with ILS to define specific points on the approach path. The outer marker is nominally at 7.5 km from the runway threshold, the middle marker at 1 050 m from the threshold and, where installed, the inner marker is located just prior to the threshold. In addition, markers may also be used to mark significant points on air routes.

COMMENTARY: There is a continuing and essential requirement for this allocation (see also ILS localizer in band 108–111.975 MHz and ILS glide path in the band 328.6–335.4 MHz).

ILS will continue to be used for the foreseeable future. Marker beacons are normally an element of the ILS system.

RR No. **5.181** relating to the future use of this band by the mobile service was introduced at WARC Mob-87, primarily at the initiative of the European Conference of Postal and Telecommunications Administrations (CEPT) in the expectation that from 1995 onwards the ILS system, including the marker beacons, would be withdrawn from use by international civil aviation due to the firm plans in ICAO to transfer from ILS to MLS. Eventually, this transition did not take place and the need for continuing ILS operations (including the marker beacons) was re-established by ICAO. At WRC-2000, the aviation community was successful in removing fifteen European and Middle Eastern country names from this footnote. With the continuing use of ILS systems and markers, this footnote is not only ineffective but carries the risk of addition of new names at future conferences and should be deleted in its entirety. Any use of this band by the mobile service is incompatible with the allocation to the aeronautical radionavigation service.

The names of many countries, initially included in this footnote, have been deleted, leaving the concerns regarding compatibility and protection of marker beacons ILS/VOR limited to the three countries currently mentioned in this footnote.

Band: 108–117.975 MHz
Service: Aeronautical radionavigation (VOR/ILS localizer)
and AM(R)S (GBAS/VDL Mode 4)
Allocation:

MHz **108–117.975**		
Allocation to Services		
Region 1	Region 2	Region 3
108–117.975	AERONAUTICAL RADIONAVIGATION 5.197 5.197A	

Footnotes:

5.197 *Additional allocation*: in the Syrian Arab Republic, the band 108–111.975 MHz is also allocated to the mobile service on a secondary basis, subject to agreement obtained under No. **9.21**. In order to ensure that harmful interference is not caused to stations of the aeronautical radionavigation service, stations of the mobile service shall not be introduced in the band until it is no longer required for the aeronautical radionavigation service by any administration which may be identified in the application of the procedures invoked under No. **9.21**. (WRC-12)

5.197A *Additional allocation:* the band 108–117.975 MHz is also allocated on a primary basis to the aeronautical mobile (R) service, limited to systems operating in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **413 (Rev. WRC-12)**. The use of the band 108–112 MHz by the aeronautical mobile (R) service shall be limited to systems composed of ground-based transmitters and associated receivers that provide navigational information in support of air navigation functions in accordance with recognized international aeronautical standards. (WRC-12)

ICAO POLICY

- No change to the current allocation to the aeronautical radionavigation service and the aeronautical mobile (route) service (AM(R)S).
- Deletion of RR No. **5.197**.
- Ensure conformity with Recommendation ITU-R SM.1009-1 regarding compatibility with FM broadcast services in the band 87.5–108 MHz and ILS/VOR as well as with ITU-R Recommendation M.1841 for GBAS.

On a global basis, the frequency band 108–117.975 MHz is used for ILS (localizer) and VHF omnidirectional radio range (VOR). Implementation of the ground-based augmentation system (GBAS) under an allocation to the AM(R)S in this band is underway. Such implementation is subject to a satisfactory safety case with specific attention to interference into GNSS signals. In the longer term, GBAS may replace ILS in some areas. The spectrum vacated by future ILS decommissioning, if any, will be reused for GBAS systems. Some use of ILS is expected to continue for the foreseeable future.

On a global basis, the future use of VOR systems is expected to decline due to implementation of GNSS and RNAV. However, a residual number of VOR systems will continue to be in operation to meet specific requirements beyond 2030. The vacated spectrum, if any, will be reused for AM(R)S.

The frequency band 108–117.975 MHz is expected to meet the aeronautical requirements for ILS, VOR and GBAS until 2030 and beyond. Rationalization of GBAS technical characteristics (and frequency assignment planning criteria) may be necessary, in particular when being implemented in areas where VOR and ILS operations continue.

The allocation to the AM(R)S in the 112–117.975 MHz band can also be used for VDL Mode 4. The spectrum requirements for VDL Mode 4 are expected to be minimal (up to a maximum of 2 to 4 channels) and can easily be implemented in most areas. This frequency band is also considered to accommodate VHF air-ground voice and data link systems, subject to spectrum availability.

AVIATION USE: ILS localizer, VOR, GBAS and VDL Mode 4

ILS is one of the ICAO standard, non-visual aids to final approach and landing. The localizer transmitter, operating on one of the 40 ILS channels within the sub-band 108–111.975 MHz, emits signals which provide course guidance throughout the descent path to the runway threshold.

The VOR is the short/medium range navigation aid. The basic navigation guidance derived from a VOR is a radial line of position (magnetic) with respect to a known geographic point (the VOR site). The radial line is read in degrees of azimuth from magnetic North and is technically accurate to within approximately ±3.0 degrees. The overall system accuracy is approximately ±5.0 degrees. Bearing information may be used by aircraft to fly toward or away from the station at any azimuth selected by the pilot. The 180 degrees ambiguity in this indication is resolved by the provision of a "to/from" indicator in the aircraft avionics. A DME is a useful adjunct to, and is normally co-located with, a VOR. In such cases, the VOR is referred to as "VOR/DME". A DME provides a continuous digital readout of the slant range distance, in nautical miles, between the aircraft and the DME site. Because of the defined channel pairing scheme in Annex 10, when using a VOR/DME, the tuning of the airborne receiver to the VOR will automatically couple the DME receiver to the associated DME ground station. The VOR/DME is used to provide navigation guidance on ATS routes and specified tracks. Its accuracy allows ATS routes to be kept at reasonable widths and permits the application of comparatively small lateral separation minima between routes, resulting in a more efficient use of the airspace. The VOR/DME route structure is normally established so as to make it possible for aircraft to fly from one VOR direct to the next, or along intersecting radials of two adjacent VORs. Reporting points and/or other significant points are normally established along radials, either together with a given DME distance from an associated VOR, or by an intersection of radials from two different VORs. The VOR can also serve as a landing aid at locations where no precision approach facility is available.

The GBAS monitors GNSS signals at an aerodrome and broadcasts locally relevant integrity messages, pseudo-range corrections and approach data via a VHF data broadcast to aircraft within the range depending upon intended operations.

The frequency band 112–117.975 MHz is also planned for use by VDL Mode 4, in accordance with the provisions of the Radio Regulations and Annex 10. Frequency assignment planning criteria for VDL Mode 4 in this band have been developed in ICAO.

Use of the frequency band 108–117.975 MHz by the aeronautical radionavigation service

Note.— Technical details on the use of the frequency band 108–117.975 MHz by systems operating in the aeronautical radionavigation service (ILS, VOR) and the aeronautical mobile (R) service (GBAS, VDL Mode 4) is in Volume II of this handbook, which also includes provisions relating to harmful interference from FM broadcasting stations.

Figure 7-8 presents an overview of the channelling arrangements and use of the various aeronautical radionavigation and communication systems in the frequency band 108–117.975 MHz.

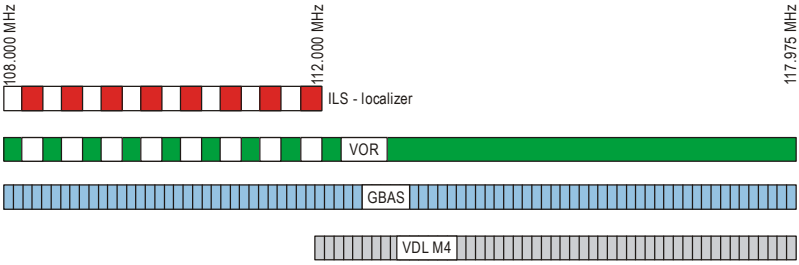

Figure 7-8. Channelling arrangements and use of systems in the frequency band 108–117.975 MHz

The sub-band 108–111.975 MHz is shared between ILS localizer and VOR in an interleaved frequency arrangement (108.1 and 108.15 MHz for ILS, 108, 108.05, 108.2 and 108.25 MHz for VOR, etc.). The channel spacing is either 50 kHz or 100 kHz, depending on regional agreements and requirements.

The sub-band 112–117.975 MHz is used for VOR, with 50 kHz or 100 kHz channel spacing, depending on regional agreements and requirements.

GBAS is standardized to operate in the band 108–117.975 MHz. GBAS/ILS and GBAS/VHF COM frequency planning criteria are currently under development. Until these criteria are defined and included in SARPs, GBAS frequencies should be selected from the band 112.050–117.900 MHz. The channel spacing for GBAS is 25 kHz.

VDL Mode 4 is standardized to operate also in the frequency band 112–117.975 MHz. The channel spacing for VDL Mode 4 is 25 kHz. The expected use of this band by VDL Mode 4 is limited to a few frequency assignments.

The ILS localizer is frequency paired with the glide path frequencies from the band 328.6–335.4 MHz (see Figure 7-9) and, where possible, with the microwave landing system (MLS) from the band 5 030–5 150 MHz. The ILS localizer is also paired with DME; implementation of DME associated with the ILS is increasingly replacing the use of marker beacons and the outer locater, mainly for economic reasons.

VOR is normally associated with DME and is frequency paired. Short-range airport VOR frequencies are usually taken from the sub-band 108–111.975 MHz.

Note.— The pairing of frequencies for the ILS localizer and the ILS glide path, as well as for the ILS/VOR with DME, is contained in Annex 10, Volume I.

Interference from FM broadcasting

ILS localizer, VOR, GBAS and VDL Mode 4 receivers are vulnerable to intermodulation and saturation effects from FM broadcast transmissions from the band 87–108 MHz. Guidelines for States, when assessing compatibility between assignments for FM broadcasting and aeronautical radionavigation (ILS/VOR), have been agreed in the ITU-R (Recommendation ITU-R SM.1009-1 refers). Recommendation ITU-R M.1841 addresses the issue of the compatibility between GBAS and FM sound broadcasting. Report ITU-R M.2147 addresses issues relevant to the compatibility between the ICAO standard VDL Mode 4 air-ground data link and FM sound broadcasting. The need to secure compatibility from the introduction of digital sound broadcasting in the frequency band 87–108 MHz has been addressed in Resolution **413 (Rev. WRC-12)**.

Note.— Additional information related to the effects of interference from FM broadcasting on aeronautical use of the band 108–117.975 MHz is contained in Attachment G and in Volume II of this handbook.

Use of the band 108–117.975 MHz by the aeronautical mobile (R) service

WRC-03 adopted Resolution **413** (which was amended at WRC-07 and again at WRC-12) to reflect the additional allocation to the AM(R)S as per RR No. **5.197A** (WRC-07) in the band 108–117.975 MHz and to provide for the conditions of using this band by the AM(R)S.

Resolution **413 (Rev. WRC-12)** invites ITU-R to study any compatibility issues between the broadcasting service and GBAS/VDL Mode 4 that may arise from the introduction of appropriate digital sound broadcasting systems.

Frequency congestion for ILS and VOR exists in some high-density areas, such as Western Europe and North America. This applies to ILS and VOR and arises, partially, from the frequency pairing and the frequency assignment planning constraints in the DME band (960–1 215 MHz).

The band has been used by aviation since 1947. The channel spacing was reduced from 200 kHz to 100 kHz in 1963 and from 100 kHz to 50 kHz in 1972 (at the Seventh Air Navigation Conference).

RR No. **5.197 (WRC-12)** was introduced at WARC-87 in anticipation that ILS would be withdrawn from international service in 1998 and the use of the ILS localizer would be terminated. At WRC-03 most countries removed their names from this footnote since ILS will continue operation for the foreseeable future.

COMMENTARY (ILS): The ICAO Special Communications/Operations Divisional Meeting held in 1995 (Special COM/OPS/95) examined the future of ILS in the context of transition to MLS and to GNSS as envisaged in the FANS scenarios. The transition to MLS has effectively been cancelled and the transition to GNSS/GBAS approach and landing has been much slower than predicted.

Most States indicated an intention to retain ILS in service (report of the Special COM/OPS/95 meeting on Agenda Item 1, paragraph 1.3.4 refers) for the foreseeable future. In this regard, it is noted that Annex 10 requires all ILS and VOR receivers (globally) to comply with the (improved) immunity standards against interference from FM broadcasts as from 1998.

ILS sustainability was addressed at the Special COM/OPS/95 meeting which agreed to review the ILS SARPs and guidance material to ensure adequate provision for ILS beyond the year 2000. Other recommendations have called for studies and examinations of various scenarios for transition from ILS to either MLS or GNSS, with important emphasis on the economics of operation.

The introduction of the mobile service, in accordance with the provision of RR No. **5.197 (WRC-12)**, is not possible in the foreseeable future. In light of the above, it is clear that the ILS allocation will be needed for the long term — until well beyond 2035.

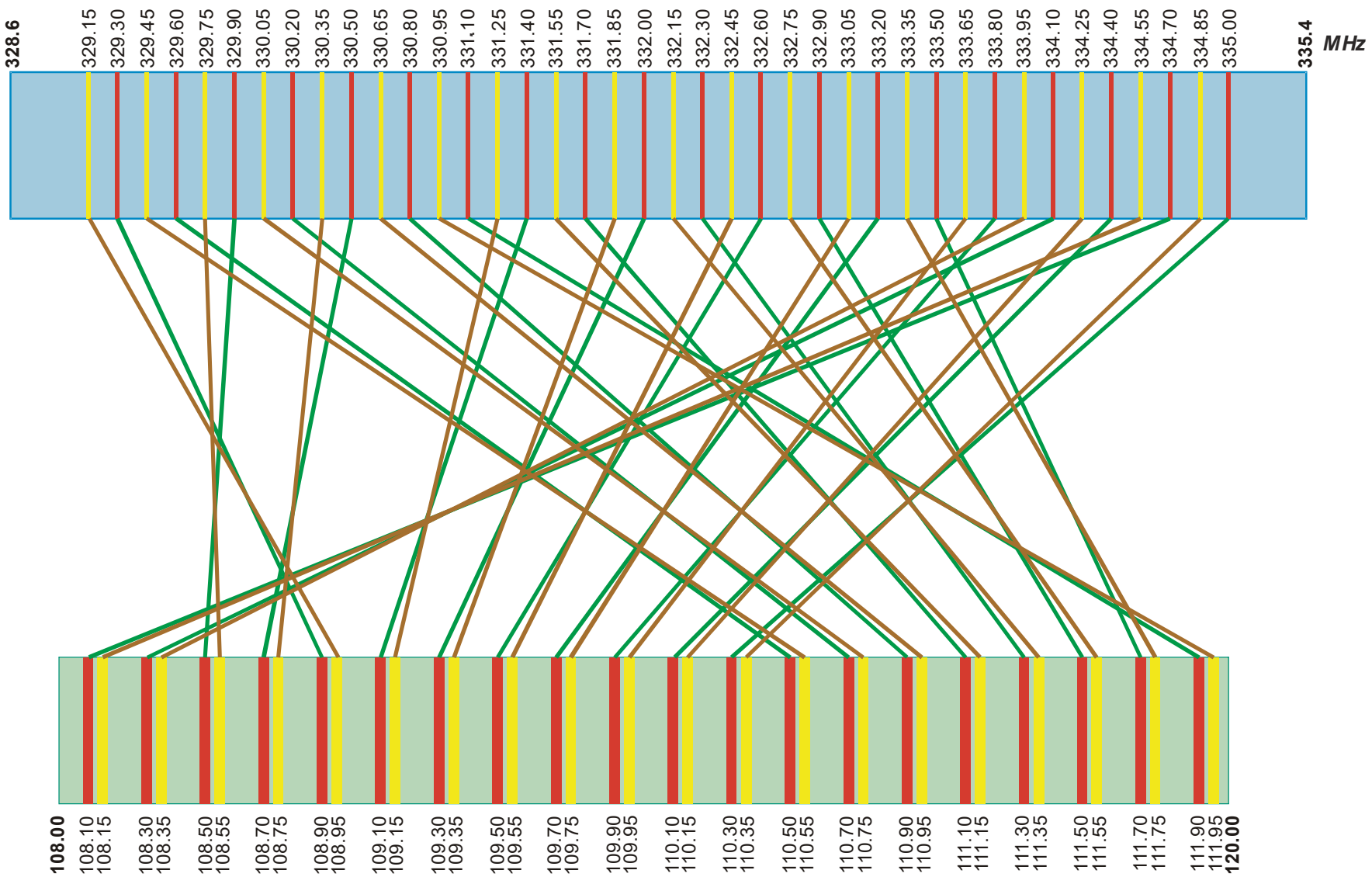

Figure 7-9. Channel pairing between ILS localizer and ILS glide path

COMMENTARY (VOR): The continuing deployment of VOR is dependent on the progress, development and implementation of GNSS; the aviation community may continue to require VOR for some time after implementing GNSS. ICAO has adopted SARPs for GNSS, and will continue, through the NSP, to develop the measures and principles necessary to evolve towards the use of GNSS as a means of en-route navigation.

Different world regions will have different emphasis on their need for GNSS in the near and medium terms, and decisions will be taken at a regional level.

No definite or tentative dates have been agreed for the GNSS programmes. In addition, safety requires a backup means of en-route navigation if all GNSS service is temporarily lost. Such backup facilities may include continued use of VOR/DME, DME/DME or NDB.

COMMENTARY (GBAS): ICAO has identified the band 108–117.975 MHz to support ground-based augmentation system/VHF data broadcast (GBAS/VDB) operations. WRC-03 and WRC-07 reviewed this band and introduced an allocation to the AM(R)S, which in the frequency band 108–112 MHz is limited to ground-based systems that transmit navigational information in support of air navigation and surveillance functions. This restriction was introduced to prevent aircraft systems using this frequency band which may cause interference to FM broadcast receivers. These systems shall not cause harmful interference to nor claim protection from international standardized systems operating in the aeronautical radionavigation service (RR No. **5.197A (WRC-12)** refers). This provision authorizes the operation of, in accordance with ICAO SARPs, GBAS/VDB systems in the frequency band 108–117.975 MHz.

COMMENTARY (VDL Mode 4): SARPs have also been developed for VDL Mode 4 which supports surveillance (e.g. ADS-B) and point-to-point communication applications. This system can also operate in the band 112–117.975 MHz. Provisions have been made for such use in Annex 10 and the Radio Regulations (RR No. **5.197A (WRC-12)** and Resolution **413 (Rev. WRC-12)** refer). The development of frequency assignment planning criteria for VDL Mode 4 to secure compatibility with the localizer, VOR and GBAS when operating in the frequency band 112–117.975 MHz has been completed.

Allocations to other services

RR No. **5.197 (WRC-12)** was added by the ITU WARC-87 for mobile services. The footnote introduced the mobile service in the band 108–111.975 MHz in a number of countries. Based on present expectations for the use of the band, it is improbable that this footnote can be considered for implementation for many years in the

country mentioned in the footnote. The footnote is not meaningful in practical terms and carries the risk that more country names will be added at future conferences. Hence, it should be deleted in its entirety. Furthermore, it should be noted that no guidance exists on how RR No. **5.197 (WRC-12)** would be applied, or what essential prior agreements are necessary within aviation for mobile service operations to commence on any single frequency or within particular sub-bands. This inexactness compounds the problem, as it leaves room for undesirable interpretations that could be used to allow entry of the mobile service in the band. The names of many countries initially included in this footnote have been deleted, leaving the concerns on compatibility and protection of ILS/VOR limited to the country that currently remains mentioned in the footnote.

At WRC-12, it was confirmed that all compatibility studies between AM(R)S systems and analogue broadcasting operating below 108 MHz had been completed. On the basis of this confirmation, Resolution **413 (Rev. WRC-12)** was amended to recognize access to the frequency band 108–117.975 MHz by AM(R)S systems under conditions laid out in Resolution **413 (Rev. WRC-12)**. In summary, these conditions stipulate:

- AM(R)S systems shall not cause harmful interference to the aeronautical radionavigation service.

- AM(R)S systems shall meet the FM broadcasting immunity requirements as per ICAO Annex 10 SARPs.

- GBAS is the only AM(R)S system that may operate in the band 108–112 MHz.

- Any AM(R)S system operating in the band 108–117.975 MHz shall meet ICAO SARPs.

Resolution **413 (Rev. WRC-12)** continues to call for studies to be undertaken to assess any compatibility issues with aeronautical radionavigation and communication systems operating in the band 108–117.975 MHz which are relevant to the introduction of digital broadcasting below 108 MHz.

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Band: 117.975–137 MHz
Service: AM(R)S (air-ground and air-air communications (VHF voice and data))
Allocation:

MHz **117.975–137**		
Allocation to Services		
Region 1	Region 2	Region 3
117.975–137	AERONAUTICAL MOBILE (R) 5.111 5.200 5.201 5.202	

Footnotes:

5.111 The carrier frequencies 2 182 kHz, 3 023 kHz, 5 680 kHz, 8 364 kHz and the frequencies 121.5 MHz, 156.525 MHz, 156.8 MHz and 243 MHz may also be used, in accordance with the procedures in force for terrestrial radiocommunication services, for search and rescue operations concerning manned space vehicles. The conditions for the use of the frequencies are prescribed in Article **31**.

The same applies to the frequencies 10 003 kHz, 14 993 kHz and 19 993 kHz, but in each of these cases emissions must be confined in a band of ±3 kHz about the frequency. (WRC-07)

5.200 In the band 117.975–137 MHz, the frequency 121.5 MHz is the aeronautical emergency frequency and, where required, the frequency 123.1 MHz is the aeronautical frequency auxiliary to 121.5 MHz. Mobile stations of the maritime mobile service may communicate on these frequencies under the conditions laid down in Article **31** for distress and safety purposes with stations of the aeronautical mobile service. (WRC-07)

5.201 *Additional allocation*: in Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, the Russian Federation, Georgia, Hungary, Iran (Islamic Republic of), Iraq, Japan, Kazakhstan, Moldova, Mongolia, Mozambique, Uzbekistan, Papua New Guinea, Poland, Kyrgyzstan, Romania, Tajikistan, Turkmenistan and Ukraine, the frequency band 132–136 MHz is also allocated to the aeronautical mobile (OR) service on a primary basis. In assigning frequencies to stations of the aeronautical mobile (OR) service, the administration shall take account of the frequencies assigned to stations in the aeronautical mobile (R) service. (WRC-15)

5.202 *Additional allocation:* in Saudi Arabia, Armenia, Azerbaijan, Belarus, Bulgaria, the United Arab Emirates, the Russian Federation, Georgia, Iran (Islamic Republic of), Jordan, Oman, Uzbekistan, Poland, the Syrian Arab Republic, Kyrgyzstan, Romania, Tajikistan, Turkmenistan and Ukraine, the frequency band 136–137 MHz is also allocated to the aeronautical mobile (OR) service on a primary basis. In assigning frequencies to stations of the aeronautical mobile (OR) service, the administration shall take account of the frequencies assigned to stations in the aeronautical mobile (R) service. (WRC-15)

ICAO POLICY

- No change to the allocations to the aeronautical mobile (route) service in this band.
- No changes to RR No. **5.200**.
- No changes to the provisions relating to the use of the emergency channels 121.5 and 123.1 MHz.
- Promote measures for the deletion of RR Nos. **5.201** and **5.202**.

The band 117.975–137 MHz is extensively used for VHF air-ground and air-air voice communications and VHF air-ground and air-air data. On a global basis, this band is expected to satisfy the aeronautical communication requirements due to full implementation of 25 kHz and/or 8.33 kHz channel spacing, where required. In Europe, however, saturation of this band, using 8.33 kHz channel spacing, was foreseen around 2020–2025. No plan has been developed yet to accommodate spectrum requirements beyond 2025 in Europe.

AVIATION USE: The band 117.975–137 MHz is the main communications band for line-of-sight air-ground voice and data communications and is used at all airports, for en-route, approach and landing phases of flight and for a variety of short-range tasks for general aviation and recreational flying activities (e.g. gliders and balloons). The use of this band is exclusively for air-ground communications relating to the safety and regularity of flight (ATC and AOC).

The band 118–132 MHz was first allocated to aviation in 1947. The extension of the band to 136 MHz was made in 1959 and the extension to 137 MHz in 1979.

To satisfy increased demand and to decrease frequency congestion in high-density traffic areas, the channel width has been reduced on four occasions (from 200 kHz to 100 kHz in the 1950s, to 50 kHz in the 1960s, to 25 kHz in 1972 (Seventh Air Navigation Conference) and finally to 8.33 kHz in 1995 (Special COM/OPS/95)). Frequency assignments and equipment standards may be chosen by regional agreement to suit local demand patterns. Currently, 25 kHz channel spacing is used in all regions; in parts of the EUR region 8.33 kHz channel spacing has also been implemented.

Single channel simplex is the mode of operation. Double sideband amplitude modulation voice is the major modulation method. Although FANS recommendations envisaged a transition to data in the future in this band for routine communications, still the main use is for air-ground voice communications. In cases where future data communications will become predominant, voice capability will still be required for non-routine communication.

ICAO has allotted the band to national and international services (see Annex 10, Volume V, Chapter 4, Table 4-1).

The AM(R)S is defined in RR Nos. **1.33** and **43.1** (see Attachment A and 7-III.3.8, Article 43 of this handbook) as "reserved for communications relating to safety and regularity of flight between any aircraft and those aeronautical stations and aeronautical earth stations primarily concerned with flight along national or international civil air routes". Public correspondence, as defined in RR No. **1.116**, is prohibited under RR No. **43.4** in the bands allocated exclusively to the aeronautical mobile service.

Frequencies for AOC use are covered by the Recommendation in Annex 10, Volume V, Chapter 4, 4.1.6.1.2, which prescribes that frequencies be selected for this purpose subject to regional agreement. Control of AOC communications content rests with the national licensing authority in accordance with Annex 10, Volume II, Chapter 5, 5.1.8.6 and 5.1.8.6.1 together with the note to 5.1.8.6.1. AOC communications are defined in Annex 10, Volume III, Part I, Chapter 1, as "communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight." AOC is part of the AM(R)S. Specific requirements for flight operations, including AOC, are contained in Annex 6.

The frequency 121.5 MHz is the aeronautical emergency frequency (Annex 10, Volume V, Chapter 4, 4.1.3.1) and is designated in the Radio Regulations (Chapter II) for general distress and safety and emergency locator transmitter (ELT) purposes. The frequency 121.5 MHz is no longer monitored by the International

Satellite System for Search and Rescue (COSPAS/SARSAT). Annex 10 requires that ELTs that are carried in compliance with the relevant provisions of Annex 6 operate on both 121.5 MHz and 406 MHz.

The frequency 123.1 MHz is designated as the frequency auxiliary to 121.5 MHz (Annex 10, Volume V, Chapter 4, 4.1.3.4, refers). This frequency is to be used as an auxiliary search and rescue frequency. The Radio Regulations also designate 123.1 MHz for general search and rescue purposes.

Frequency 123.450 MHz is the frequency designated for air-air communications between aircraft engaged in flights over remote and oceanic areas and while out of range of VHF ground stations.

To give low-level coverage over a large area, offset carrier operation is employed in some areas (see Annex 10, Volume III, Attachment to Part II, 1.2). Such systems, using up to five carriers in one channel, are possible with channel spacing of at least 25 kHz. Offset carrier systems could also be used with 8.33 kHz channel spacing, but cannot be implemented at this time due to lack of avionics equipage of 8.33 kHz offset carrier radios.

VHF receivers in the frequency band 117.975–137 MHz are susceptible to interference from FM broadcast signals in the band 87–108 MHz. Annex 10, Volume III, Part II, specifies performance requirements to provide protection from this possibility (see Section 7-III of this handbook). ITU-R SM.1009-1 provides technical planning guidance. Guidance on applying these performance requirements is in Volume II of this handbook.

COMMENTARY:

Channel spacing

The Special COM/OPS/95 discussed the shortage of assignable VHF channels necessary to support the growth in air traffic in the years ahead. This scarcity situation occurred in 1992 in the core area of Europe and is expected to expand into other areas or regions with the increase in air traffic.

Note.— The core area in Europe includes Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland and the United Kingdom.

The Special COM/OPS/95 agreed to a near-term improvement by using a VHF voice system based on 8.33 kHz channel spacing while recognizing that not all ICAO regions would need to apply this new Standard. Recommendation 6/1 from this divisional meeting, endorsed by the Air Navigation Commission, called for SARPs

for 8.33 kHz channel spacing DSB-AM to be incorporated in Annex 10 (Appendix B to the report on Agenda Item 6 refers). These SARPs were adopted by the ICAO Council in 1996. Implementation of 8.33 kHz channel spacing is subject to regional agreement.

Implementation of 8.33 kHz channel spacing in a limited form, i.e. for upper airspace services initially, started around 2000 in Europe under the aegis of ICAO, assisted by the European Organization for the Safety of Air Navigation (EUROCONTROL) in a coordination/planning role. The mandatory carriage of 8.33 kHz radio equipment was introduced for flights above FL 195 in the ICAO EUR region in 2007; this was further extended under EU mandate in 2014 and 2018.

Further expansion of the use of 8.33 kHz channel spacing to all airspace was completed around 2018 in Europe by EU regulation. Certain ground implementations remained as 25 kHz for wide area coverage, the accommodation of State aircraft and as a result of a safety requirement, e.g. 121.5 MHz. Further conversions are potentially foreseen around 2025 when non-8.33 kHz capable State aircraft are expected to have been retired, although 25 kHz offset carrier will be retained where it is spectrally efficient to do so.

Many other regions can continue to meet their requirements for VHF channels using 25 kHz channel spacing for some years without the compelling requirement to convert to 8.33 kHz channel spacing, although in some congested areas implementation of 8.33 kHz channel spacing may become necessary.

Use of data in air-ground communications

The CNS/ATM concept placed considerable reliance on the use of air-ground data for pilot/controller exchange of data to supplement the use of voice for certain categories of messages, primarily for routine communications between pilots and ATC. SARPs for VDL Mode 2, VDL Mode 3 and VDL Mode 4 have been incorporated in Annex 10. VDL Mode 2 will become the prime data system for the immediate future. VDL Mode 4 is foreseen to be regionally implemented. Frequency planning guidance material on VDL Mode 2 and VDL Mode 4 has been developed by the ACP for use in frequency assignment planning.

Band capacity issues

In high-density congested areas such as Europe and North America, the requirement for VHF channels continues to increase. In regular ATC use under normal circumstances, the maximum utilization of a channel dedicated to an ATC sector is around 10 to 20 per cent of the time due to other essential tasks performed by the

controller. The use of air-ground data should enable an improvement in utilization of the spectrum, which should be beneficial and delay the time point of spectrum exhaustion. Further expansion of spectrum for short-range, line-of-sight communications as demand increases will meet problems due to the general shortage of frequencies in all parts of the radio frequency spectrum. The strategy and options to deal with this situation require early attention.

Use of the band by other services

The band extensions at 132–136 MHz and 136–137 MHz were agreed to many years ago in ITU but continue to support other services (such as the AM(OR)S) which already existed at that time and now operate under footnote provisions (RR Nos. **5.201** and **5.202**). RR Nos. **5.201** and **5.202** relate to the use, for national purposes, for off-route (OR) services, which was widespread prior to the agreement in 1959 to release 132–136 MHz for exclusive use by the AM(R)S. In areas where the (OR) service operates on these frequencies, coordination procedures agreed to in the past have been satisfactory. With increasing and intensive use of the frequencies in the band for AM(R)S purposes, it is likely that this (OR) use may become a problem, in which case it will become essential to press for a cessation of this use.

Frequencies: 121.5 MHz, 123.1 MHz and 243 MHz (mobile)
Service: AM(R)S

Emergency frequency in mobile service (243 MHz)

The frequency 243 MHz (twice that of the aeronautical emergency frequency 121.5 MHz) is designated by the Radio Regulations (see Annex 10, Volume V, Chapter 2 — Distress frequencies and RR No. **5.256 (WRC-07)**) for use in distress situations. Survival craft stations using VHF are normally fitted with both 121.5 MHz and 243 MHz.

Footnotes: 5.256.

ICAO POLICY

No change to the provisions in Chapter VII relating to the use of 121.5 MHz, 123.1 MHz and 243 MHz.

AVIATION USE: Emergency frequencies for use in aircraft emergencies and in ELT (121.5 MHz) and for search-of-scene communication (123.1 MHz).

COMMENTARY: Standards relating to the mandatory carriage of ELTs operating simultaneously on 121.5 MHz and 406 MHz are contained in Annex 6. ELT equipment carried to satisfy the requirements of Annex 6 shall operate in accordance with the provisions of Annex 10, Volume III on the frequencies 121.5 MHz and 406.1 MHz.

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Band: 328.6–335.4 MHz
Service: Aeronautical radionavigation (ILS glide path)
Allocation:

MHz 328.6–335.4		
Allocation to Services		
Region 1	Region 2	Region 3
328.6–335.4	AERONAUTICAL RADIONAVIGATION 5.258 5.259	

Footnotes:

5.258 The use of the band 328.6–335.4 MHz by the aeronautical radionavigation service is limited to Instrument Landing Systems (glide path).

5.259 *Additional allocation:* in Egypt and the Syrian Arab Republic, the band 328.6–335.4 MHz is also allocated to the mobile service on a secondary basis, subject to agreement obtained under No. **9.21**. In order to ensure that harmful interference is not caused to stations of the aeronautical radionavigation service, stations of the mobile service shall not be introduced in the band until it is no longer required for the aeronautical radionavigation service by any administration which may be identified in the application of the procedure invoked under No. **9.21**. (Rev. WRC-12)

ICAO POLICY

- No change to current allocation to the aeronautical radionavigation service.
- No change to RR No. **5.258**.
- Deletion of RR No. **5.259**.

On a global basis, the frequency band 328.6–335.4 MHz is used for the ILS glide path, in conjunction with the ILS localizer (see section on 108–117.975 MHz). This frequency band is expected to meet the aeronautical requirements for ILS glide path for the long term. In areas where GBAS is implemented to replace ILS systems, the use of this band for glide path systems may be reduced.
AVIATION USE: The ultra-high frequency (UHF) glide path transmitter, operating

on one of the 40 ILS channels within the frequency band from 328.6 MHz to 335.4 MHz, radiates its signals in the direction of the ILS localizer front course. The term "glide path" means that portion of the glide slope that intersects the localizer. The signal provides descent information for navigation down to the lowest authorized decision height specified in the approved ILS approach procedure. The glide path projection angle is normally adjusted to 3 degrees above the horizontal plane so that it passes through the middle marker at about 60 m (200 ft) and the outer marker at about 426 m (1 400 ft) above the runway elevation. The glide slope is normally usable to a distance of 10 NM. However, at some locations, use of the glide slope has been authorized beyond this range. RR No. **5.258** limits the use of this band to ILS glide path. Frequencies are used at a spacing of 150 kHz (Annex 10, Volume I, Chapter 3, 3.1.6.1) and are paired with those of the ILS localizer (see Figure 7-8 in the section on 108–117.975 MHz).

COMMENTARY: ICAO policy for the future need and use of this allocation is described in detail in the general policy for the use of ILS (see commentary on ILS localizer at 108–117.975 MHz).

Use of the band by other services

RR No. **5.259** was introduced at WARC-87. This footnote uses the same text (except for the list of countries) as RR No. **5.197 (WRC-12)** for the ILS localizer and VOR band at 108–117.975 MHz. At WRC-2000, most of the countries listed removed their names from this footnote. The remaining country names must now also be deleted to protect ILS glide path services in these areas and to avoid the possibility of new names being added at a future conference.

Band: 406–406.1 MHz
Service: Mobile-satellite (Earth-to-space) (search and rescue)
Allocation:

MHz 406–406.1		
Allocation to Services		
Region 1	Region 2	Region 3
406–406.1	MOBILE-SATELLITE (Earth-to-space) 5.265 5.266 5.267	

Footnotes:

5.265 In the frequency band 403–410 MHz, Resolution **205 (Rev. WRC-15)** applies. (WRC-15)

5.266 The use of the band 406–406.1 MHz by the mobile-satellite service is limited to low power satellite emergency position-indicating radiobeacons (see also Article **31**). (WRC-07)

5.267 Any emission capable of causing harmful interference to the authorized uses of the band 406–406.1 MHz is prohibited.

ICAO POLICY

- No change to the allocation to the band 406–406.1 MHz and RR Nos. **5.265**, **5.266** and **5.267**.
- Secure protection of emergency locator transmitters (ELTs) which are used in aviation in this frequency band.

AVIATION USE: The use of ELTs offers the possibility of dramatically shortening the time required to alert rescue forces to the distress and to assist in final "homing" by the rescue team. In the ITU, such beacons are named emergency position-indicating radio beacons (EPIRBs). ELTs operating in this frequency band have the capacity to transmit a programmed digital message which contains information

related to the ELT and/or the aircraft on which it is carried. The COSPAS/SARSAT service, part of the global maritime distress and safety system (GMDSS) which receives the distress transmissions and relays back to Earth, is a joint enterprise operated on a multinational basis for the benefit of all users. SARPs on the use of ELTs operating in the frequency band 406–406.1 MHz are contained in Annex 10, Volume III, Part II, Chapter 5 and Volume V, Chapter 2. Carriage requirements for ELT are contained in Annex 6.

COMMENTARY: ICAO participates with the International Maritime Organization (IMO) and other international bodies in discussions on the global aspects of search and rescue which encompass the use and deployment of this frequency.

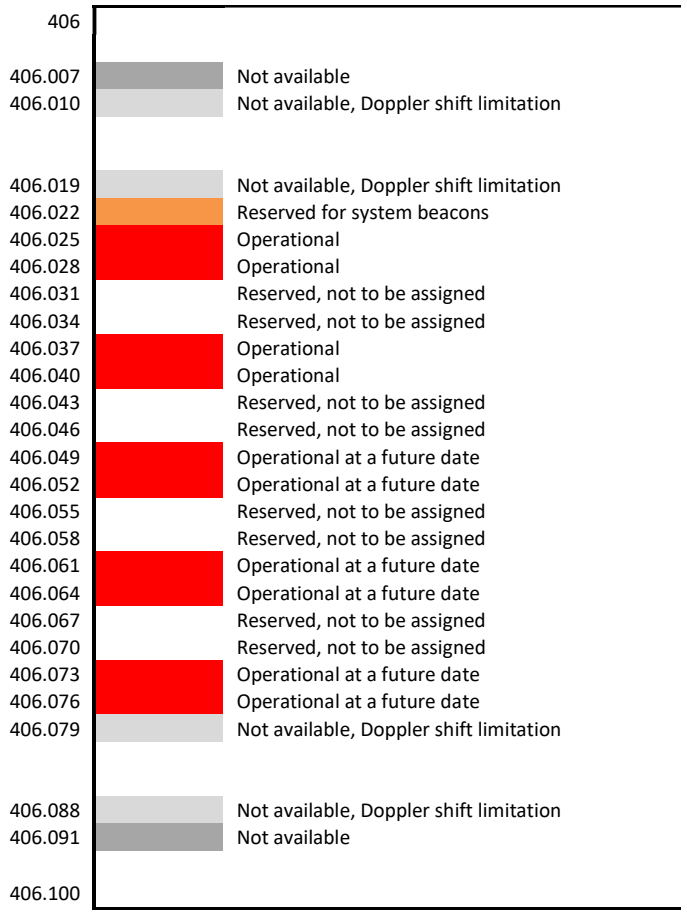
Recent cases of serious interference from non-emergency sources have caused concern regarding the effectiveness of COSPAS/SARSAT services. As a result, WRC-15 decided to reflect the need for providing protection of MSS systems in the frequency band 406-406.1 MHz taking into account the current and future deployment of services in adjacent bands. This was accomplished by including reference to revised Resolution **205 (Rev. WRC-15)** for the frequency band 403–410 MHz in Article **5**. The Resolution resolves the following:

1. to request administrations not to make new frequency assignments within the frequency bands 405.9–406.0 MHz and 406.1–406.2 MHz under the mobile and fixed services;

2. that administrations take into account frequency drift characteristics of radiosondes when selecting their operating frequencies above 405 MHz to avoid transmitting in the 406–406.1 MHz frequency band and take all practical steps to avoid frequency drifting close to 406 MHz.

COSPAS/SARSAT developed specifications for 406 MHz distress beacons (COSPAS/SARSAT Doc. C/S T.001 refers) and a frequency management plan for the band 406–406.1 MHz (see Figure 7-10) (COSPAS/SARSAT Doc. C/S T.012 refers).

ITU-R Recommendation M.633-4, which is incorporated by reference into the Radio Regulations (Article **34 (WRC-12)** refers), contains the transmission characteristics of a satellite EPIRB system operating through a satellite system in the 406 MHz band.



SAR processors will be able to receive signals in the band 406.01–406.09 MHz. With a Doppler shift of ±9 kHz and 1 kHz margin for spreading of beacon carrier frequencies, the channel plan should not include frequencies below 406.02 MHz and above 406.08 MHz.

Channels are made available on the basis of one pair of adjacent channels with a separation between the pair of 12 kHz in order to provide optimum capacity in both systems using geostationary satellites and low earth-orbiting satellites.

Figure 7-10. COSPAS/SARSAT frequency management plan (2013)

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Band: 960–1 215 MHz
Service: Aeronautical radionavigation/radionavigation satellite and AM(R)S (DME/SSR/ACAS/GNSS/1090ES/UAT)
Allocation:

MHz 960–1 215		
Allocation to Services		
Region 1	Region 2	Region 3
960–1 164	AERONAUTICAL MOBLE (R) 5.327A AERONAUTICAL RADIONAVIGATION 5.328 5.328AA	
1 164–1 215	AERONAUTICAL RADIONAVIGATION 5.328 RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.328A	

Footnotes:

5.327A The use of the frequency band 960–1 164 MHz by the aeronautical mobile (R) service is limited to systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **417 (Rev. WRC-15).** (WRC-15)

5.328 The use of the band 960–1 215 MHz by the aeronautical radionavigation service is reserved on a worldwide basis for the operation and development of airborne electronic aids to air navigation and any directly associated ground-based facilities.

5.328A Stations in the radionavigation-satellite service in the band 1 164–1 215 MHz shall operate in accordance with the provision of Resolution **609 (Rev. WRC-07)** and shall not claim protection from stations in the aeronautical radionavigation service in the band 960–1 215 MHz. No. **5.43A** does not apply. The provisions of No. **21.18** shall apply. (WRC-07)

5.328AA The frequency band 1 087.7–1 092.3 MHz is also allocated to the aeronautical mobile satellite (R) service (Earth-to-space) on a primary basis, limited to the space station reception of Automatic Dependent Surveillance-Broadcast (ADS-B) emissions from aircraft transmitters that operate in accordance with recognized international aeronautical standards. Stations operating in the aeronautical mobile-satellite (R) service shall not claim protection from stations operating in the aeronautical radionavigation service. Resolution **425 (Rev. WRC-19)** shall apply. (WRC-19)

5.328B The use of the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the provisions of Nos. **9.12, 9.12A** and **9.13**. Resolution **610 (WRC-03)** shall also apply; however, in the case of radionavigation-satellite service (space-to-space) networks and systems, Resolution **610 (WRC-03)** shall only apply to transmitting space stations. In accordance with No**. 5.329A,** for systems and networks in the radionavigation-satellite service (space-to-space) in the bands 1 215–1 300 MHz and 1 559–1 610 MHz, the provisions of Nos**. 9.7, 9.12A** and **9.13** shall only apply with respect to other systems and networks in the radionavigation-satellite service (space-to-space). (WRC-07)

See also:

*Art. 21/18: Administration operating or planning to operate radio- navigation-satellite service systems or networks in the 1 164-1 215 MHz frequency band, for which complete coordination or notification information was received by the Bureau after 2 June 2000, shall, in accordance with resolves 2 of Resolution **609 (Rev. WRC-07)**, take all necessary steps to ensure that actual aggregate interference into aeronautical radionavigation service systems caused by such RNSS systems or networks operating co-frequency in these frequency bands does not exceed the equivalent power flux-density level shown in resolves 1 of Resolution **609 (Rev. WRC-07)**.*

ICAO POLICY

- No change to the current allocation to the aeronautical radionavigation service or to RR No. **5.328** in the band 960–1 215 MHz.
- No change to RR No. **5.328A**.
- No change to the aeronautical mobile (route) service (AM(R)S) allocation or to RR No. **5.327A** in the band 960–1 164 MHz with the exception of possible changes to remove the restrictions on the use of the AM(R)S due to non-ICAO standardized systems from ITU-R Resolution **417 (Rev. WRC-15)**.
- No change to RR No. **5.328AA**
- Support further ITU-R studies relating to Resolution **425 (WRC-15).**

On a global basis, the band 960–1 215 MHz is used for DME systems; this use is expected to continue and increase well beyond 2030. In RNAV procedures, DME-DME navigation is planned to be one of the major navigation methods as an element of PBN. The band 960–1 215 MHz is expected to satisfy, on a global basis, the future requirements for DME, taking into account the protection given to aeronautical radionavigation (DME) in the ITU Radio Regulations. In some areas, the frequency band is heavily congested with DME assignments. Rationalization in this band of frequency assignments to DME stations, including a review of the technical characteristics of DME, may be necessary.

Two sub-bands of about ±10 MHz around the frequencies 1 030 MHz and 1 090 MHz are reserved for SSR. SSR provides, in addition to secondary surveillance radar, major functionality for ACAS and automatic dependent surveillance-broadcast (ADS-B). SSR is expected to continue to be required for surveillance; the frequency bands used for SSR satisfy, on a global basis, the aeronautical requirements to well beyond 2030.

The band 1 164–1 215 MHz is also used for GPS/Galileo/Beidou/GLONASS signals and is planned to be used by SBAS. In accordance with the Radio Regulations, the use of this band by GNSS systems needs to protect DME from interference and accept interference from DME. This frequency band is expected to meet the associated GNSS requirements, on a global basis, well beyond 2030.

The frequency 978 MHz is used for the universal access transceiver (UAT), which provides for ADS-B and up-linking of data messages.

The band 960–1 164 MHz is also planned to be used for an ICAO air-ground (and air-air) communications system, namely LDACS (L-band Digital Aeronautical Communications System). In this context, frequency assignment planning rules between DME, 1 030 & 1 090 MHz systems, UAT and LDACS are being developed to ensure compatibility among these aeronautical systems. This is being pursued through continuing coordination amongst ICAO Communications Panel, Navigation System Panel, Surveillance Panel and Frequency Spectrum Management Panel.

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AVIATION USE: The band 960–1 215 MHz is a prime radionavigation band which is used intensively, and extensively, to support a number of aviation systems, for both civil and military purposes. The band 960-1 164 MHz is also allocated to AM(R)S on a co-primary basis. The civil systems operating in the band 960–1 215 MHz are:

Distance measuring equipment (DME): DME is the ICAO standard system for the determination of the distance between an aircraft and a ground-based DME beacon within radio line of sight, using pulse techniques and time measurement. DME/N is the standard system used for en-route and terminal navigation. It can be co-located with VOR enabling the aircraft's position to be determined through a measurement of its bearing and the distance relative to the VOR/DME. Alternatively, the aircraft's position can be determined through measurement of the distances from two or three DMEs and the flight management system equipment in the aircraft. DME/P is a precision version of DME with enhanced precision measurement capability intended for use with MLS to provide accurate distance to touchdown. DME/N is a version of DME which is used in conjunction with ILS to provide accurate distance to touchdown. TACAN is the military equivalent of DME which also has a bearing capability and uses the same channel plan as DME.

The channel plan (Annex 10, Volume I, Chapter 3, Table A) employs discrimination in both pulse length and pulse spacing, generating four possible modes (X, Y, W and Z) as a means of creating additional channels.

Secondary surveillance radar (SSR): SSR is the ICAO standard system for secondary surveillance radar. It is used either as a stand-alone system or co-located and synchronized with primary radar. The ground equipment is an interrogator and the aircraft equipment is a transponder responding to signals from the interrogator. SSR employs Mode A for transmitting identification and Mode C for transmitting pressure-altitude information. Mode S employs selective addressing of the aircraft and has a limited data link capability. SSR Mode S is a continuing requirement, in

particular in high-density airspace.

All SSR installations operate on 1 030 MHz for the ground-to-air interrogation signal, and 1 090 MHz for the air-to-ground reply. Extensive use of pulse repetition frequency (PRF) discrimination and plot plan processing techniques assists in reducing the number of invalidated responses being processed by the ground receiving system.

Airborne collision avoidance system (ACAS): ACAS is the ICAO standard system for detection and avoidance of airborne conflict situations. ACAS aircraft equipment interrogates Mode A/C and Mode S transponders on aircraft in its vicinity and listens to the transponder replies. By processing these replies, the ACAS equipment determines which aircraft represent potential collision threats and provides appropriate display indication or advisories to the flight crew to avoid collisions. ACAS operates as a supplementary system to SSR using the same frequency pair of 1 030 MHz and 1 090 MHz. 1 030 MHz is used for the air-air interrogation and 1 090 MHz for the air-air reply. The three modes, I, II and III, provide increased capability at each level of functional implementation. Provision is made for air-ground communication with ground stations using the Mode S data link. Diagrams of the use of the frequencies 1 030 MHz and 1 090 MHz by air and ground elements of SSR and ACAS can be found in Figures 7-11 and 7-12. The traffic alert and collision avoidance system II (TCAS II) is the only currently available system capable of meeting the ACAS Mode II requirements, providing resolution advisories in the vertical sense (direction) telling the pilot how to regulate or adjust his vertical speed so as to avoid a collision.

1 090 MHz extended squitter (1090ES): 1 090 MHz extended squitter transmissions from Mode S transponders or other non-transponder devices are used to broadcast information relating to position of aircraft, aerodrome surface vehicles, fixed obstacles and/or other related information. The broadcast can be received by airborne or ground-based receivers and can contain ADS-B and/or traffic information service-broadcast (TIS-B) messages.

Automatic dependent surveillance — broadcast (ADS-B): ADS-B is an ICAO standardized cooperative surveillance technology in which a surveillance picture is built based on either a 1090ES signal triggered by an SSR or ACAS signal or via the periodic ADS-B broadcast from an aircraft or other obstruction. The signal can either be used by air traffic control as a supplement/replacement for SSR or by aircraft to provide situational awareness and allow self-separation. The ADS-B receivers can be located on the ground, in an aircraft or on a satellite.

Wide area multilateration: Wide area mutilateration systems take advantage of routine aircraft transmissions at 1 090 MHz by measuring the arrival of that signal at a number of receiving ground stations. Using the arrival time at the various ground stations and the geometry of those ground stations the aircraft's position is calculated. In areas where there are not enough 1 090 MHz emissions, a 1 030 MHz interrogator can be installed to elicit additional signals.

Universal access transceiver (UAT): ICAO has adopted SARPs and guidance material for UAT. This system is intended to support ADS-B data transmission as well as ground uplink services such as TIS-B and flight information service- broadcast

(FIS-B). UAT employs time division multiple access (TDMA) technique on a single 1 MHz channel at 978 MHz and is dedicated for transmission of airborne ADS-B reports and for broadcast of ground-based aeronautical information.

L-band digital aeronautical communications system (LDACS): Based on the AM(R)S allocation, LDACS is the L-band communications system supporting voice and data services. It provides the required capacity that cannot be achieved in the VHF band through VDL technologies. In particular, LDACS is intended to provide the required data link capacity, QoS and security means to support ATS-B2, ATS-B3 and services beyond, including trajectory planning in air traffic management. Work on the feasibility of implementing LDACS in the frequency band 960–1 164 MHz is currently (2021) ongoing and initial results indicate that the introduction of LDACS will require proper LDACS frequency assignment planning and LDACS ground station siting. Although those LDACS frequency assignment planning and ground station siting guidelines impose some constraints on the LDACS deployment, when completed the goal is that adherence to those requirements will ensure compatibility with the existing aeronautical systems (DME, 1 030 & 1 090 MHz systems, and UAT) in the L-band. . LDACS is being planned to operate in the bands 964-1 010 MHz (reverse link) and 1 110-1 156 MHz (forward link). LDACS forward link complies with the emission mask according to Resolution 417 (Rev. WRC-15) ensuring protection of RNSS in the band 1 164-1 215 MHz. In order to achieve this protection, frequencies up to 1 120 MHz may be used for LDACS ground stations which transmit with maximum EIRP, whereas frequencies above 1 120 MHz may only be used for LDACS ground stations which transmit with accordingly reduced EIRP.

The AM(R)S allocation in the 960–1 164 MHz frequency band can be used subject to the conditions contained in Resolution **417 (Rev. WRC-15)**. That Resolution requires that any communication system, with the exception of UAT, introduced into the frequency band 960–1 164 MHz must be coordinated when intended to operate within 934 km of a number of States (mainly in eastern Europe) using non-ICAO standard systems in this band. The Resolution also places a maximum e.i.r.p limit on the emissions from any AM(R)S system that is based on the frequency offset from 1 164 MHz and a fixed out-of-band limit above 1 164 MHz for the protection of the radionavigation-satellite service.

COMMENTARY: The present internationally agreed channel plans for DME occupy the full 960–1 215 MHz band. The DME channel plan is displayed at Table A of Annex 10, Volume I, Chapter 3. The arrangement of air-to-ground interrogations and ground-to-air replies showing the standard 63 MHz separation and the interleaving of X and Y channels is shown at Figure 7-11. Both X and Y channels are currently deployed together with 50 kHz VOR/ILS channel spacing in the higher density areas where the implementation of DME (and TACAN) is

extensive. W and Z channels are intended for use with MLS, employing an interrogation pulse pair with a different pulse length on the X and Y channels, respectively. In low-density areas, only DME X channels (paired with 100 kHz ILS/DME channel spacing) are used.

Some world areas are prone to frequency scarcity. Frequency pairing of DME with VOR or ILS, triple pairing of DME with ILS and MLS (a necessary operational technique for air safety or for the transition to MLS where this system is brought into use), and co-channel TACAN use are factors often creating difficulties in frequency planning which are not easily overcome.
To maintain the overall required safety levels, VOR/DME and DME/DME are foreseen as necessary navigation infrastructure in addition to GNSS for the foreseable future to take account of GNSS outages, such as jamming or spoofing. Specifically, where a terrestrial navigation capability is required, a DME network capable of supporting DME/DME area navigation needs to be provided, where possible. A residual capability based on VOR/DME will still need to be provided to cater to airspace users not equipped with suitable DME/DME avionics, where required. Accordingly, use of VOR and DME is expected to extend for the foreseeable future.

[Ref: Att H, Annex 10, Vol. I.]

SSR and SSR Mode S are the main techniques for surveillance in high traffic density areas (FANS II/4 refers). SSR Mode S is a tool for air traffic management mainly in high traffic density continental airspaces.

Carriage of ACAS systems by all aircraft over 5 700 kg or authorized to carry more than 19 passengers is mandatory globally.

The overall situation in this band is one of a continuing exploitation of current systems. It can be realistically expected that some important uses of the frequency band, such as ILS/DME, VOR/DME, DME/DME and SSR Mode S, will continue as essential ATS tools in high-density airspace and this will extend beyond 2030.

Use of the band for GNSS

Currently, a main component of GNSS is operating in the band 1 559–1 610 MHz. The frequencies in the band 1 164–1 215 MHz have been identified as suitable to support components for the future development of GNSS, in addition to GNSS components operating on other frequencies. Currently, a main component of GNSS is operating in the band 1 559–1 610 MHz.
Draft ICAO SARPs for dual-frequency GNSS core constellations and for dual frequency SBAS, operating both in the band 1 559–1 610 MHz and in the band

1 164–1 215 MHz, have been developed by the Navigation Systems Panel (NSP) and are expected to become applicable by 2023. They will introduce a second frequency of operation in the band 1 164–1 215 MHz for the GPS (USA) and GLONASS (Russia) constellations and for SBAS, already standardized by ICAO but only for operation in the band 1 559–1 610 MHz. Furthermore, they will introduce two new GNSS constellations, Galileo (European Union) and BeiDou (China), operating in both bands. Some of these new GNSS signals include higher signal levels and more robust interference rejection characteristics.

WRC-2000 adopted RR No. **5.328A** which includes an allocation to the radionavigation-satellite service (RNSS, the ITU terminology for GNSS systems) in the band 1 164–1 215 MHz. WRC-03 developed detailed regulatory provisions for the protection of the aeronautical radionavigation service in this band. Protection of the DME channels 77X to 126X, the use of which can be affected by this allocation, is to be assured by imposing an equivalent power flux-density limit of –121.5 dB(W/m^2) in any 1 MHz for the space-to-Earth signals produced by all satellites of all RNSS systems operating in this band, and by a regulatory provision requiring that RNSS shall not claim protection from the stations of the ARNS.

Protection of aeronautical systems in the 960–1 215 MHz Frequency band from harmful interference

Potential interference from ultra-wide-band (UWB) devices

Technological advances have resulted in the development of devices used in radar and communications applications. These emitters known as ultra-wide-band (UWB) devices radiate over very wide bandwidths, typically several gigahertz. Devices used in radar applications have many commercial and government uses, such as radar imaging through walls. Many of the frequency bands subject to UWB emissions are aeronautical.

Four ITU-R Recommendations (ITU-R SM.1754, 1755, 1756 and 1757) and one ITU-R report (ITU-R SM.2057) on the impact of UWB technology on radiocommunication services have been developed.

Considering especially the mobility of aircraft and the large "viewing" area to which aircraft are exposed, together with the variability and uncertainty of a significant number of factors (such as UWB emitter density, signal characteristics and activity factors) necessary for the interference analysis of devices using UWB technology with systems operating within safety services, UWB devices should in general not be operated in frequency bands allocated to safety services. In those cases where such use cannot be avoided, administrations should take all steps necessary to ensure that UWB devices do not cause harmful interference to the reception by stations operating under a safety service allocation. The level of harmful interference to safety systems needs to be determined on a case-by-case basis in the form of a safety analysis. This analysis would assess the use being made of the safety system and demonstrate that the required levels of integrity, reliability and availability are still maintained under all operational conditions. Factors such as the impact on safety service link budget margins and measures to preclude interference from UWB devices that malfunction need to be considered.

Potential interference from IMT unwanted emissions

By the decisions of WRC-12 and WRC-15, the frequency bands 694–790 MHz, 790–862 MHz and 1 427–1 518 MHz were identified for international mobile telecommunications (IMT) on a global or regional basis. Also, in several countries the band 470-694 MHz was identified for IMT in accordance with relevant footnotes of the Radio Regulations.

There are global navigation satellite systems operating in frequency bands below 3 GHz which have allocations for RNSS. Frequency bands identified for IMT do not overlap by their main emission with GNSS frequency bands. However, IMT can

impact on frequency bands of global navigation systems (1 164–1 300 MHz) by unwanted emissions including out-of-band and spurious emissions. In the GNSS frequency band 1 164–1 300 MHz, impact of the second harmonic of IMT stations that use frequency band 470–694 MHz is possible, as well as impact of spurious emissions from IMT stations that operate in the frequency band 1 427–1 518 MHz.

Current results of theoretical and experimental estimations indicate that the levels of unwanted emissions of IMT stations that are defined in ITU-R Recommendations M.2070 and M.2071 are not low enough to provide required protection level for RNSS receiving earth stations that operate in 1 164–1 300 MHz. Required separation distances are from 42 m to 2 446 m depending on the type of RNSS receiver, which makes impossible simultaneous application of these devices in one local spot without additional compatibility measures.

Potential interference from AM(R)S unwanted emissions

Resolution **417 (Rev. WRC-15)** provides the criteria to ensure that AM(R)S systems do not cause harmful interference to RNSS in the frequency band 1 164–1 215 MHz.

Use of the band by other services

In some countries, the band is also used by national communications systems (e.g. Joint Tactical Information Distribution System (JTIDS)/Multifunctional Information Distribution System (MIDS)). Such systems have no internationally recognized status in the band and therefore are only permitted to operate on a strict basis of non-interference to the radionavigation systems using the band in accordance with the ITU allocation (Article **4** of the Radio Regulations refers).

TACAN is a military development providing both the azimuth and distance components by equipment operating in the band 960–1 215 MHz. Where a TACAN transponder is co-located with a VOR, the distance measuring component of the TACAN substitutes for and fulfils any civil requirement for DME. The VOR is then referred to as “VORTAC”. As with DME, tuning to the VOR will automatically interlock with the associated TACAN distance measuring element. When used by civil aircraft, the guidance derived from a VOR/DME and a VORTAC is identical.

Certain airborne TACAN systems function as a standard TACAN interrogator system (measuring the slant-range distance and relative bearing to a selected ground station or an airborne TACAN beacon, and computing velocity and time-to-go to that station) and providing an air-air bearing transmit capability (beacon mode) used to provide rendezvous capability between aircraft.

Non-ICAO standard aeronautical radionavigation systems

The frequency band 960–1 215 MHz is also used for certain non-ICAO standard aeronautical radionavigation systems and mainly used in eastern-European countries. The technical characteristics and protection criteria for these systems are in ITU-R Recommendation M.2013. Use of the band 960–1 164 MHz by the aeronautical mobile (R) service (e.g. LDACS) needs to secure protection of these systems.

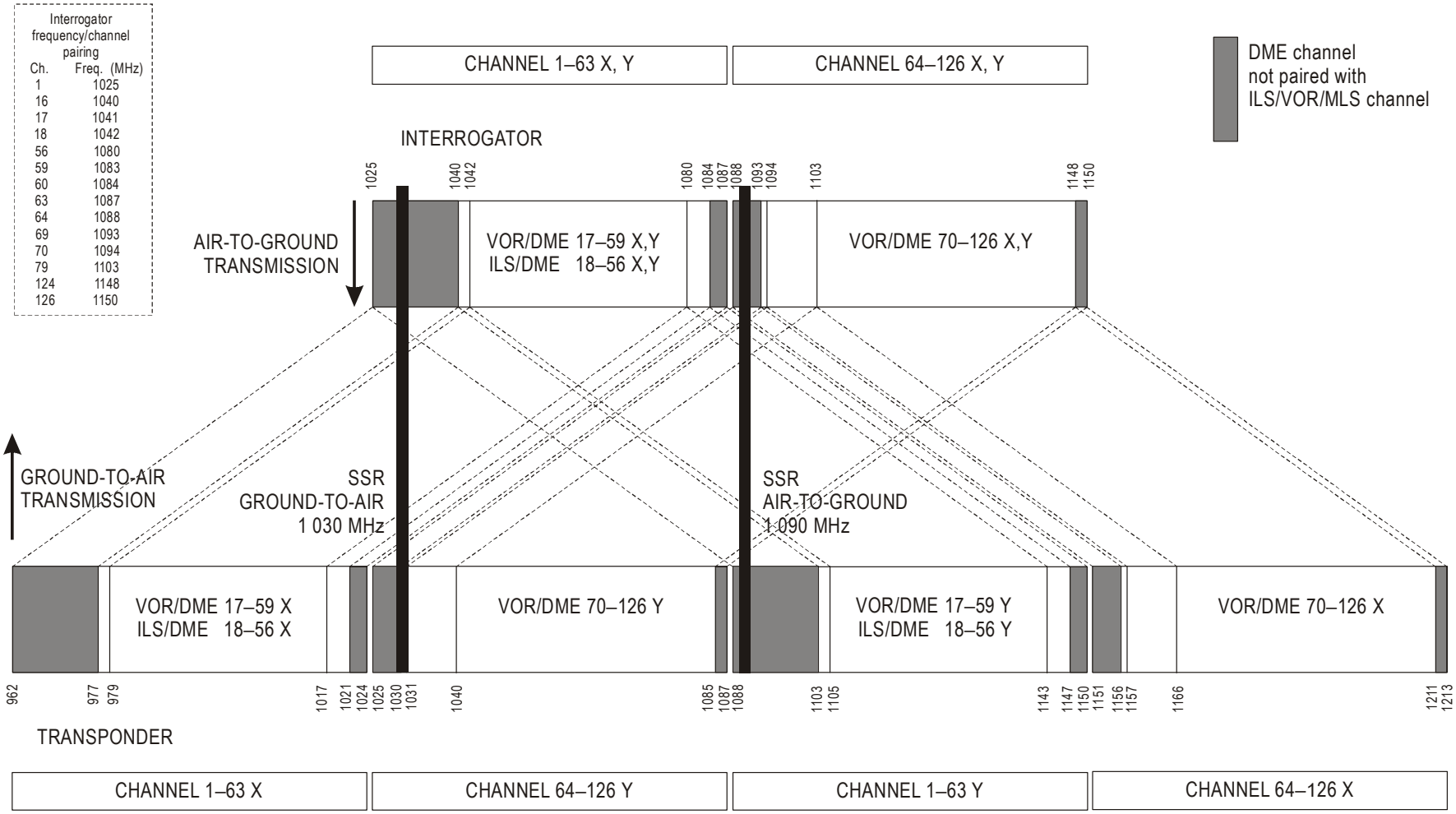

Figure 7-11. Channelling DME bank (960–1 215 MHz)

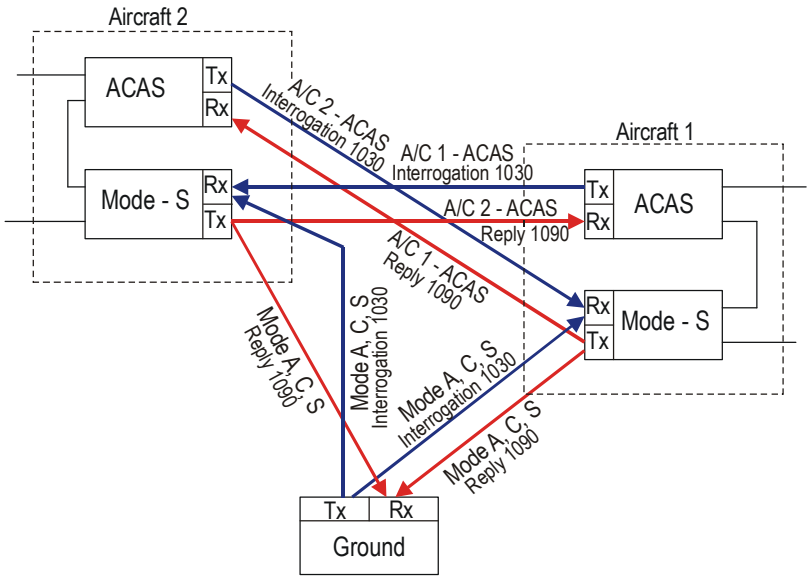

Figure 7-12. Use of frequencies 1 030 MHz and 1 090 MHz by SSR and ACAS air and ground elements

Band: 1 215–1 400 MHz
Service: Radionavigation/aeronautical radionavigation/ radiolocation/radionavigation-satellite (RNSS/primary surveillance radar)
Allocation:

MHz 1 215–1 400		
Allocation to Services		
Region 1	Region 2	Region 3
1 215–1 240	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) 5.330 5.331 5.332	
1 240–1 300	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.329 5.329A SPACE RESEARCH (active) Amateur 5.282 5.330 5.331 5.332 5.335 5.335A	
1 300–1 350	RADIOLOCATION AERONAUTICAL RADIONAVIGATION 5.337 RADIONAVIGATION-SATELLITE (Earth-to-space) 5.149 5.337A	
1 350–1 400 FIXED MOBILE RADIOLOCATION 5.149 5.338 5.338A 5.339	**1 350–1 400** RADIOLOCATION 5.338A 5.149 5.334 5.339	

Footnotes:

5.149 In making assignments to stations of other services to which the bands: ... 1 330–1 400 MHz, ... are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

5.282 In the bands 435–438 MHz, 1 260–1 270 MHz, 2 400–2 450 MHz, 3 400–3 410 MHz (in Regions 2 and 3 only) and 5 650–5 670 MHz, the amateur-satellite service may operate subject to not causing harmful interference to other services operating in accordance with the Table (see No. **5.43**). Administrations authorizing such use shall ensure that any harmful interference caused by emissions from a station in the amateur-satellite service is immediately eliminated in accordance with the provisions of No. **25.11**. The use of the bands 1 260–1 270 MHz and 5 650–5 670 MHz by the amateur-satellite service is limited to the Earth-to-space direction.

5.328B The use of the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the application of the provisions of Nos. **9.12**, **9.12A** and **9.13**. Resolution **610 (WRC-03)** shall also apply; however, in the case of radionavigation-satellite service (space-to-space) networks and systems, Resolution **610 (WRC-03)** shall only apply to transmitting space stations. In accordance with No. **5.329A,** for systems and networks in the radionavigation-satellite service (space-to-space) in the bands 1 215–1 300 MHz and 1 559–1 610 MHz, the provisions of Nos. **9.7, 9.12, 9.12A** and **9.13** shall only apply with respect to other systems and networks in the radionavigation-satellite service (space-to-space). (WRC-07)

5.329 Use of the radionavigation-satellite service in the band 1 215–1 300 MHz shall be subject to the condition that no harmful interference is caused to, and no protection claimed from, the radionavigation service authorized under No. **5.331**. Furthermore, the use of the radionavigation-satellite service in the band 1 215–1 300 MHz shall be subject to the condition that no harmful interference is caused to the radiolocation service. No. **5.43** shall not apply in respect of the radiolocation service. Resolution **608 (Rev**

WRC-19)* shall apply. (WRC-03)

5.329A Use of systems in the radionavigation-satellite service (space-to-space) operating in the bands 1 215–1 300 MHz and 1 559–1 610 MHz is not intended to provide safety service applications, and shall not impose any additional constraints on radionavigation satellite service (space to Earth) or on other systems or services operating in accordance with the Table of Frequency Allocations. (WRC-07)

5.330 *Additional allocation:* in Angola, Saudi Arabia, Bahrain, Bangladesh, Cameroon, China, Djibouti, Egypt, the United Arab Emirates, Eritrea, Ethiopia, Guyana, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Nepal, Oman, Pakistan, the Philippines, Qatar, the Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the band 1 215–1 300 MHz is also allocated to the fixed and mobile services on a primary basis. (WRC-12)

5.331 A*dditional allocation:* in Algeria, Germany, Saudi Arabia, Australia, Austria, Bahrain, Belarus, Belgium, Benin, Bosnia and Herzegovina, Brazil, Burkina Faso, Burundi, Cameroon, China, Korea (Rep. of), Croatia, Denmark, Egypt, the United Arab Emirates, Estonia, the Russian Federation, Finland, France, Ghana, Greece, Guinea, Equatorial Guinea, Hungary, India, Indonesia, Iran (Islamic Republic of), Iraq, Ireland, Israel, Jordan, Kenya, Kuwait, Lesotho, Latvia, Lebanon, Liechtenstein, Lithuania, Luxembourg, North Macedonia, Madagascar, Mali, Mauritania, Montenegro, Nigeria, Norway, Oman, Pakistan, the Kingdom of the Netherlands, Poland, Portugal, Qatar, the Syrian Arab Republic, Dem. People's Rep. of Korea, Slovakia, the United Kingdom, Serbia, Slovenia, Somalia, Sudan, South Sudan, Sri Lanka, South Africa, Sweden, Switzerland, Thailand, Togo, Turkey, Venezuela and Viet Nam, the frequency band 1 215-1 300 MHz is also allocated to the radionavigation service on a primary basis. In Canada and the United States, the frequency band 1 240-1 300 MHz is also allocated to the radionavigation service, and use of the radionavigation service shall be limited to the aeronautical radionavigation service. (WRC-19)

* *Note by the Secretariat:* This Resolution was revised by WRC-15.

5.332 In the band 1 215–1 260 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause harmful interference to, claim protection from, or otherwise impose constraints on operation or development of the radiolocation service, the radionavigation-satellite service and other services allocated on a primary basis.

5.334 *Additional allocation:* in Canada and the United States, the band 1 350–1 370 MHz is also allocated to the aeronautical radionavigation service on a primary basis. (WRC-03)

5.335 In Canada and the United States in the band 1 240–1 300 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause interference to, claim protection from, or otherwise impose constraints on operation or development of the aeronautical radionavigation service.

5.335A In the band 1 260–1 300 MHz, active spaceborne sensors in the Earth exploration-satellite and space research services shall not cause harmful interference to, claim protection from, or otherwise impose constraints on operation or development of the radiolocation service and other services allocated by footnotes on a primary basis.

5.337 The use of the bands 1 300–1 350 MHz, 2 700–2 900 MHz and 9 000–9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

5.337A The use of the band 1 300–1 350 MHz by Earth stations in the radionavigation-satellite service and by stations in the radiolocation service shall not cause harmful interference to, nor constrain the operation and development, of the aeronautical-radionavigation service.

5.338 In Kyrgyzstan, Slovakia and Turkmenistan, existing installations of the radionavigation service may continue to operate in the band 1 350–1 400 MHz. (WRC-12)

5.338A In the frequency bands 1 350-1 400 MHz, 1 427-1 452 MHz, 22.55-23.55 GHz, 24.25-27.5 GHz, 30-31.3 GHz, 49.7-50.2 GHz, 50.4-50.9 GHz, 51.4-52.4 GHz, 52.4-52.6 GHz, 81-86 GHz and 92-94 GHz, Resolution **750 (Rev.WRC-19)** applies. (WRC-19))

5.339 The bands 1 370–1 400 MHz, 2 640–2 655 MHz, 4 950–4 990 MHz and 15.20–15.35 GHz are also allocated to the space research (passive) and Earth exploration-satellite (passive) services on a secondary basis.

ICAO POLICY

- No change to the status of the allocation to the radionavigation service in RR Nos. **5.331** and **5.334**.
- No change to RR No. **5.332**.
- No change to the provisions of RR Nos. **5.329** and **5.337A** regarding the protection of radar stations from the radionavigation-satellite service.
- Support further ITU-R studies relating to Resolution **608 (Rev. WRC-19)**.

On a global basis, the band 1 300–1 350 MHz (and in many countries also the band 1 215–1 300 MHz) is extensively used for primary surveillance radar, mainly providing long-range independent non-cooperative airspace surveillance. This use is expected to continue to be required for the long term.

The use of this band for GNSS signals (GPS L2, GLONASS L2, Galileo E6 and Beidou B6) is not for civil aircraft applications.

A new development in radar technology is the multi-static primary surveillance radar (MSPSR). MSPSR may provide more spectrum-efficient use of this band and better coverage at lower altitudes. However, the implementation of MSPSR is dependent on the cost and improved spectrum efficiency that can be obtained.

AVIATION USE: These bands are used extensively for 23 cm (L-band) primary surveillance radar (PSR), for both en-route and terminal surveillance tasks. Modern systems employing digitized plot extraction often operate on multiple frequencies and use pulse repetition frequency (PRF) discrimination where up to four or even six frequencies may be used by a single radar spaced over a band of 100 MHz. For these requirements, the band from around 1 215 to 1 370 MHz (as for example in RR No. **5.334**) must be available. The band is also used extensively by other users for the long-range detection of aircraft targets. Co-located SSR and PSR are often employed with combined plot extraction, electronic processing and display. Electronically generated labels displaying flight number and other data, i.e. altitude reported from SSR Mode C, are often added to provide a complete radar data picture. Twenty-three centimetres is the preferred wavelength for long-range radar where a

sufficiently large antenna can be installed to provide narrow beams in azimuth and phased arrays for beam switching for multi-purpose mode operation.

COMMENTARY: Under FANS recommendations, the use of PSR is expected, in the long term, to diminish in both en-route and terminal areas (Agenda Item 7 of the *Report of the Tenth Air Navigation Conference (1991)* (Doc 9583) refers). The recommended replacement system is SSR Mode S or some form of ADS using air-ground data link. Future possible use of ADS or ADS-B may affect the requirements for primary or secondary surveillance radar. Primary surveillance radar with its high-level investment is, however, expected to continue to be utilized in civil aviation for many years into the future. One of the important features of PSR is the independent role it plays in the surveillance of airspace, allowing for the detection of non-cooperating aircraft.

The Communications/Meteorology/Operations (COM/MET/OPS) Divisional Meeting (1990) (Attachment 4 to Appendix B to the report on Agenda Item 1 refers) reported the wide use of this band (and also of the band 2 700–2 900 MHz) for en-route and terminal surveillance. Table 1 in Attachment 4 provides estimates of the use amounting to 583 radars worldwide. Paragraph 4 proposes the ICAO Position of no change to the allocation at 1 300–1 350 MHz and adjoining bands.

The conclusion of these considerations was that these bands should be retained and protected for the foreseeable future for the operation of radar systems.

Use of the band by the radionavigation-satellite service

The band 1 215–1 300 MHz is also used for GLONASS (operates on 14 frequencies spaced at 0.4375 MHz in the band between 1 242.9375 MHz and 1 248.6250 MHz). The frequency 1 227.6 MHz is used for the precise positioning service (PPS, L2) of GPS, extending the accuracy of GPS. A new signal, GPS L2C, remains pre-operational. Techniques have been developed for the use of ground stations to correct for ionospheric delays (see also commentary on GNSS usage of the band 1 559–1 610 MHz).

WRC-2000 introduced an allocation to the RNSS in the frequency bands 1 260–1 300 MHz for space-to-Earth and space-to-space directions, and 1 300–1 350 MHz for the Earth-to-space direction. The components in these bands are not being considered as a part of the ICAO GNSS system.

WRC-03 reviewed the allocation and decided that in the frequency band 1 215–1 300 MHz the radionavigation-satellite service shall be subject to the condition that no harmful interference is caused to, and no protection claimed from, the radionavigation service authorized under RR No. **5.331 (Rev. WRC-19)**.

Furthermore, the use of the radionavigation-satellite service in the frequency band 1 215–1 300 MHz shall be subject to the condition that no harmful interference is caused to the radiolocation service. Resolution **608 (Rev. WRC-15)** resolves that no constraints in addition to those in place prior to WRC-2000 shall be placed on RNSS (space-to-Earth) frequency assignments in the frequency band 1 215–1 260 MHz brought into use before 2 June 2000.

Studies in ITU-R have defined the interference environment that could be experienced by PSR.

Protection of aeronautical systems in the 1 215–1 300 MHz frequency band from harmful interference

Potential interference from ultra-wide-band (UWB) devices

Technological advances have resulted in the development of devices used in radar and communications applications. These emitters known as ultra-wide-band (UWB) devices radiate over very wide bandwidths, typically several gigahertz. Devices used in radar applications have many commercial and government uses, such as radar imaging through walls. Many of the frequency bands subject to UWB emissions are aeronautical.

Four ITU-R Recommendations (ITU-R SM.1754, 1755, 1756 and 1757) and one ITU-R report (ITU-R SM.2057) on the impact of UWB technology on radiocommunication services have been developed.

Considering especially the mobility of aircraft and the large "viewing" area to which aircraft are exposed, together with the variability and uncertainty of a significant number of factors (such as UWB emitter density, signal characteristics and activity factors) necessary for the interference analysis of devices using UWB technology with systems operating within safety services, UWB devices should in general not be operated in frequency bands allocated to safety services. In those cases where such use cannot be avoided, administrations should take all steps necessary to ensure that UWB devices do not cause harmful interference to the reception by stations operating under a safety service allocation. The level of harmful interference to safety systems needs to be determined on a case-by-case basis in the form of a safety analysis. This analysis would assess the use being made of the safety system and demonstrate that the required levels of integrity, reliability and availability are still maintained under all operational conditions. Factors such as the impact on safety service link budget margins and measures to preclude interference from UWB devices that malfunction need to be considered.

Potential interference from IMT unwanted emissions

By the decisions of WRC-12 and WRC-15, the frequency bands 694–790 MHz, 790–862 MHz and 1 427–1 518 MHz were identified for international mobile telecommunication (IMT) on a global or regional basis. Also, in several countries the band 470-694 MHz was identified for IMT in accordance with relevant footnotes of the Radio Regulations.

There are global navigation satellites systems operating in frequency bands below 3 GHz which have allocations for RNSS. Frequency bands identified for IMT do not overlap by their main emission with GNSS frequency bands. However, IMT can impact on frequency bands of global navigation systems (1 164–1 300 MHz) by unwanted emissions including out-of-band and spurious emissions. In the GNSS frequency band 1 164–1 300 MHz, impact of the second harmonic of IMT stations that use frequency band 470–694 MHz is possible, as well as impact of spurious emissions from IMT stations that operate in the frequency band 1 427–1 518 MHz.

Current results of theoretical and experimental estimations indicate that the levels of unwanted emissions of IMT stations that are defined in ITU-R Recommendations M.2070 and M.2071 are not low enough to provide required protection level for RNSS receiving earth stations that operate in 1 164–1 300 MHz. Required separation distances are from 42 m to 2 446 m depending on the type of RNSS receiver, which makes impossible simultaneous application of these devices in one local spot without additional compatibility measures.

Bands: Mobile-satellite bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz
Service: AMS(R)S (satellite communications)

1. Space-to-Earth

MHz **1 525–1 559**		
Allocation to Services		
Region 1	Region 2	Region 3
1 525–1 530 SPACE OPERATION (space-to-Earth) FIXED MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile except aeronautical mobile 5.349 5.341 5.342 5.350 5.351 5.352A 5.354	**1 525–1 530** SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354	**1 525–1 530** SPACE OPERATION (space-to-Earth) FIXED MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile 5.349 5.341 5.351 5.352A 5.354
1 530–1 535 SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile except aeronautical mobile 5.341 5.342 5.351 5.354	**1 530–1 535** SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354	
1 535–1 559	MOBILE-SATELLITE (space-to-Earth) 5.208B 5.341 5.351 5.351A 5.353A 5.354 5.355 5.356 5.357 5.357A 5.359 5.362A	

2. Earth-to-space

MHz **1 626.5–1 660.5**		
Allocation to Services		
Region 1	Region 2	Region 3
1 626.5–1 660	MOBILE-SATELLITE (Earth-to-space) 5.351A 5.341 5.351 5.353A 5.354 5.355 5.357A 5.359 5.362A 5.374 5.375 5.376	
1 660–1 660.5	MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY 5.149 5.341 5.351 5.354 5.362A 5.376A	

Footnotes:

5.149 In making assignments to stations of other services to which the bands: ... 1 660–1 670 MHz, ... are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

5.208B In the bands …1 525–1 610 MHz … Resolution **739 (Rev. WRC-15)** applies. (WRC-15)

5.341 In the bands 1 400–1 727 MHz, 101–120 GHz and 197–220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extraterrestrial origin.

5.342 *Additional allocation:* in Armenia, Azerbaijan, Belarus, the Russian Federation, Uzbekistan, Kyrgyzstan and Ukraine, the frequency band 1 429–1 535 MHz is also allocated to the aeronautical mobile service on a primary basis exclusively for the purposes of aeronautical telemetry within the national territory. As of 1 April 2007, the use of the band 1 452–1 492 MHz is subject to agreement between the administrations concerned. (WRC-15)

5.343 In Region 2, the use of the band 1 435–1 535 MHz by the aeronautical mobile service for telemetry has priority over other uses by the mobile service.

5.349 *Different category of service:* in Saudi Arabia, Azerbaijan, Bahrain, Cameroon, Egypt, France, Iran (Islamic Republic of), Iraq, Israel, Kazakhstan, Kuwait, The Former Yugoslav Republic of Macedonia, Lebanon, Morocco, Qatar, Syrian Arab Republic, Kyrgyzstan, Turkmenistan and Yemen, the allocation of the band 1 525–1 530 MHz to the mobile, except aeronautical mobile, service is on a primary basis (see No. **5.33**). (WRC-07)

5.350 *Additional allocation:* in Azerbaijan, Kyrgyzstan and Turkmenistan, the band 1 525–1 530 MHz is also allocated to the aeronautical mobile service on a primary basis.

5.351 The bands 1 525–1 544 MHz, 1 545–1 559 MHz, 1 626.5–1 645.5 MHz, 1 646.5–1660.5 MHz shall not be used for feeder links of any service. In exceptional circumstances, however, an earth station at a specified fixed point in any of the mobile-satellite services may be authorized by an administration to communicate via space stations using these bands.

5.351A For the use of the bands 1 518–1 544 MHz, 1 545–1 559 MHz, 1 610–1 645.5 MHz, 1 646.5–1 660.5 MHz, 1 668–1 675 MHz, 1 980–2 010 MHz, 2 170–2 200 MHz, 2 483.5–2 520 MHz and 2 670–2 690 MHz by the mobile-satellite service, see Resolutions **212 (Rev. WRC-07)**[*] and **225 (Rev. WRC-12)**[**]. (WRC-12)

5.352A In the frequency band 1 525–1 530 MHz, stations in the mobile-satellite service, except stations in the maritime mobile-satellite service, shall not cause harmful interference to, or claim protection from, stations of the fixed service in Algeria, Saudi Arabia, Egypt, France and French overseas communities of Region 3, Guinea, India, Israel, Italy, Jordan, Kuwait, Mali, Morocco, Mauritania, Nigeria, Oman, Pakistan, the Philippines, Qatar, Syrian Arab Republic, Viet Nam and Yemen notified prior to 1 April 1998. (WRC-15)

5.353A In applying the procedures of Section II of Article **9** to the mobile-satellite service in the bands 1 530–1 544 MHz and 1 626.5–1 645.5 MHz, priority shall be given to accommodating the spectrum requirements for distress, urgency and safety communications of the Global Maritime Distress and Safety System (GMDSS). Maritime mobile-satellite distress, urgency and safety communications shall have priority access and immediate availability

[*] *Note by the Secretariat.*— This Resolution was revised by WRC-07.
[**] *Note by the Secretariat.*— This Resolution was revised by WRC-15.

over all other mobile satellite communications operating within a network. Mobile-satellite systems shall not cause unacceptable interference to, or claim protection from, distress, urgency and safety communications of the GMDSS. Account shall be taken of the priority of safety-related communications in the other mobile-satellite services. (The provisions of Resolution **222 (Rev. WRC-12)** shall apply.) (WRC-12)

5.354 The use of the bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz by the mobile-satellite services is subject to coordination under No. **9.11A**.

5.355 *Additional allocation*: in Bahrain, Bangladesh, Congo (Rep of the), Djibouti, Egypt, Eritrea, Iraq, Israel, Kuwait, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the bands 1 540–1 559 MHz, 1 610–1 645.5 MHz and 1 646.5–1 660 MHz are also allocated to the fixed service on a secondary basis. (WRC-12)

5.356 The use of the band 1 544–1 545 MHz by the mobile-satellite service (space-to-Earth) is limited to distress and safety communications (see Article **31**).

5.357 Transmissions in the band 1 545–1 555 MHz from terrestrial aeronautical stations directly to aircraft stations, or between aircraft stations, in the aeronautical mobile (R) service are also authorized when such transmissions are used to extend or supplement the satellite-to-aircraft links.

5.357A In applying the procedures of Section II of Article **9** to the mobile-satellite service in the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz, priority shall be given to accommodating the spectrum requirements of the aeronautical mobile-satellite (R) service providing transmission of messages with priority 1 to 6 in Article **44**. Aeronautical mobile-satellite (R) service communications with priority 1 to 6 in Article **44** shall have priority access and immediate availability, by pre-emption if necessary, over all other mobile-satellite communications operating within a network. Mobile-satellite systems shall not cause unacceptable interference to, or claim protection from, aeronautical mobile-satellite (R) service communications with priority 1 to 6 in Article **44**. Account shall be taken of the priority of safety-related communications in the other mobile-satellite services. (The provisions of Resolution **222 (Rev. WRC-12)** shall apply.)

5.359 *Additional allocation*: In Germany, Saudi Arabia, Armenia, Azerbaijan, Belarus, Benin, Cameroon, the Russian Federation, France, Georgia, Guinea, Guinea-Bissau, Jordan, Kazakhstan, Kuwait, Lithuania, Mauritania, Uganda, Uzbekistan, Pakistan, Poland, the Syrian Arab Republic, Kyrgyzstan, the Dem. People's Rep. of Korea, Romania, Tajikistan, Tunisia, Turkmenistan and Ukraine, the frequency bands 1 550–1 559 MHz, 1 610–1 645.5 MHz and 1 646.5–1 660 MHz are also allocated to the fixed service on a primary basis. Administrations are urged to make all practicable efforts to avoid the implementation of new fixed-service stations in these frequency bands. (WRC-15)

5.362A In the United States, in the bands 1 555–1 559 MHz and 1 656.5–1660.5 MHz, the aeronautical mobile-satellite (R) service shall have priority access and immediate availability, by pre-emption if necessary, over all other mobile-satellite communications operating within a network. Mobile-satellite systems shall not cause unacceptable interference to, or claim protection from, aeronautical mobile-satellite (R) service communications with priority 1 to 6 in Article **44**. Account shall be taken of the priority of safety-related communications in the other mobile-satellite services.

5.374 Mobile earth stations in the mobile-satellite service operating in the bands 1 631.5–1 634.5 MHz and 1 656.5–1 660 MHz shall not cause harmful interference to stations in the fixed service operating in the countries listed in No. **5.359**.

5.375 The use of the band 1 645.5–1 646.5 MHz by the mobile-satellite service (Earth-to-space) and for inter-satellite links is limited to distress and safety communications (see Article **31**).

5.376 Transmissions in the band 1 646.5–1 656.5 MHz from aircraft stations in the aeronautical mobile (R) service directly to terrestrial aero- nautical stations, or between aircraft stations, are also authorized when such transmissions are used to extend or supplement the aircraft-to-satellite links.

5.376A Mobile earth stations operating in the band 1 660–1 660.5 MHz shall not cause harmful interference to stations in the radio astronomy service.

ICAO POLICY

- If required, modify RR Nos. **5.357A** and **5.362A** to strengthen AMS(R)S access to the bands.
- No change to RR Nos. **5.357** and **5.376**.
- Support the deletion of RR Nos. **5.355** and **5.359**.
- Provide support to the procedure to implement RR No. **5.357A** and Resolution **222 (Rev. WRC-12)**.
- Support the methodology for computing AMS(R)S spectrum requirements as contained in ITU-R Recommendation M.2091.

In the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz (and in the United States also the bands 1 555–1 559 MHz and 1 656.5–1 660.5 MHz as per RR No. **5.362A**), the provisions in ITU Radio Regulations stipulate that priority shall be given during the frequency coordination process to the spectrum requirements for the aeronautical mobile-satellite (R) service. Over a long period of time (prior to WRC-12), these provisions did not provide for the required access for aeronautical mobile-satellite (R) communications. In order to secure that the aeronautical requirements for, in particular, long-distance communications using satellite technology are met, the relevant radio regulatory provisions in Resolution **222** were amended at WRC-12 as an attempt to improve and secure, in all cases, access by aviation to those bands.

AVIATION USE: These frequencies are used for air-ground communications and, in the FANS scenarios, are expected to replace HF as the primary means of communication over oceanic/remote areas. In continental airspace, satellite communications may be used as a supplement to VHF. Some aeronautical satellite communications systems support voice and data for ATC or ADS-C purposes. AMS(R)S SARPs were adopted by ICAO in 1995.

Also included in the allocation table shown above are the mobile-satellite bands 1 544–1 545 MHz and 1 645.5–1 646.5 MHz which are to be used for any mobile service for distress and safety communications only.

AMS(R)S will be provided by service providers for both the space segment and the ground segment. The connection to ATC centres would normally be made by landline from the ground Earth station.

COMMENTARY: The use of satellites for communications (and navigation) was recommended as official ICAO policy by the Tenth Air Navigation Conference (Montreal, 5 to 20 September 1991), as part of the future CNS/ATM systems recommended by FANS. The Tenth Air Navigation Conference discussions

comprehensively covered all aspects of the subject. The ICAO Council endorsed the FANS recommendations at the twentieth meeting of its 134th Session on 29–31 October 1991. The prime use of satellites for communication and navigation would be in oceanic and continental low-density airspace. The CNS/ATM system supports voice and data, the latter being a support element for ADS.

At the above-mentioned conference, the role of ICAO in satellite communications with aircraft was explored (Agenda Item 8 of the *Report of the Tenth Air Navigation Conference (1991)* (Doc 9583) refers), and was seen to be basically that of a facilitator and coordinator. The complexities of the institutional and legal arrangements and interfaces between the concerned parties, such as air traffic service provider, space system provider and ground system provider, were addressed in Agenda Item 4 of the same conference. Appendix A to Agenda Item 4 sets out guidelines and recommendations for study on these aspects.

Generic allocations/access to frequencies

Until 1997, ITU allocations to the AMS(R)S were exclusive and worldwide in accordance with the definition at RR No. **1.36** and the rules at Chapter VIII for aeronautical mobile services. The exclusive condition ensured that ICAO SARPs could be applied, and the system operators would provide a service with the required integrity and reliability. Frequencies for mobile-satellite use were under intensive demand for other mobile applications, which led ITU to focus attention on the relatively unused AMS(R)S allocation.

WRC-97 discussed at great length the introduction of a generic allocation to the mobile-satellite service which replaced the exclusive allocations to the aeronautical, land and maritime mobile-satellite services, noting the dissenting views of the international civil aviation and maritime communities (see Section 7-III, paragraph 7-III.3.1.4 of this handbook). Frequencies in a generic allocation may be used for providing service to any class of mobile user (land, sea or air) and may carry any type of communication (safety, public correspondence, voice or data). Against the stated policies of ICAO and IMO, the introduction of generic allocations was approved, together with a new RR No. **5.357A** which was intended to provide a guarantee of future frequency access for aeronautical safety services. With this new generic allocation to the mobile-satellite service, aircraft have to share the 10 MHz in the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz with non-aeronautical systems, services and service providers (and an additional 4 MHz in the bands 1 555–1 559 MHz and 1 656.5–1 660.5 MHz in the United States).

RR Nos. **5.357A** and **5.362A**, inserted at WRC-97, provide the mechanism intended by radio regulatory authorities to compensate for the loss of the exclusive 10–14 MHz (each direction) of spectrum to the AMS(R)S and assure access in the future. It relied

on cooperation between administrations and satellite system operators and by itself had no apparent regulatory force. In a situation where there are no spare frequencies for aeronautical use in the bands quoted in the footnote, with some used for other (non-aeronautical) mobile-satellite systems, expansion of aeronautical use is only possible by a release of frequencies from a non-aeronautical user. In effect, there was no guarantee that such release could be made possible. Two important features of the footnote are that they address only the 10 MHz (14 MHz in the United States) of spectrum allocated to the AMS(R)S prior to WARC-92 (as quoted in the footnote) and that the priorities are Categories 1 to 6 of Article **44** of the Radio Regulations. These are identical to Annex 10, Volume II, Chapter 5, 5.1.8 (see Section 7-III, paragraph 7-III.3.8 of this handbook). This excludes public correspondence, a category which covers passenger and airline administrative communications.

The aviation concern on this point led to Resolution **222 (Rev. WRC-12)**. Resolves 3 of the Resolution states that administrations shall ensure that MSS operators yield capacity to accommodate AMS(R)S requirements, either through the coordination process described below or through prioritization and real-time pre-emptive access, where feasible. To give this Resolution a positive regulatory force, a linked reference has been placed in RR No. **5.357A**, which under present ITU rules gives it the same status as a Radio Regulation. This regulatory formula, while not fully meeting the ICAO policy calling for a recovery of the exclusive allocation to the AMS(R)S, is still a considerable improvement on the original.

The current practice of the application of RR No. **5.357A** is that all satellite service providers planning to operate in the bands 1 525–1 559 MHz and 1 626.6–1 660.5 MHz register the use of the whole band with the ITU. With this registration, the obligations of the Radio Regulations to internationally coordinate the frequency assignments are satisfied. However, the actual allotment of portions of this spectrum to satellite system operators is taking place under the auspices of a Memorandum of Understanding (MOU) between the concerned satellite system operators and relevant administrations. Under the MOU, satellite system operators are provided with spectrum on a yearly basis, using actual and predicted traffic characteristics, and satisfying their needs as long as these can be accommodated in the available spectrum. The results of these yearly consultations are not available in the public domain. ICAO is not invited to become a party to this MOU nor is it informed about the results. The frequency coordination and assignment process has been factually taken outside the traditional ITU frequency planning and coordination process. The secrecy around the results of the activities under the MOU does not give ICAO or the aviation community the possibility to assess if the aeronautical spectrum requirements will be met in the longer term. Furthermore, the process under the MOU does not provide for any alternative measures if it is no longer supported by administrations or satellite system operators. This creates serious concern about the practical ability to make frequency spectrum available for aeronautical communications, when required, which under the

MOU has already been assigned to a particular non-aeronautical satellite system operator.

Spectrum requirements for satellite communications

The amount of spectrum required for civil aviation has been a subject of study since 1971 when the first allocation of 15 MHz in both directions for safety communications only was made. Later (in 1987), with the realization that safety communications alone could not justify a satellite system with dedicated frequencies, and to meet airline needs, the scope was increased to include public correspondence. The WARC Mob-87 further reduced this exclusive allocation. Finally, WRC-97 concluded on the present 10 MHz (no longer exclusive) quoted in RR No. **5.357A**. The generic allocation permits public correspondence, subject to the priority terms for Categories 1 to 6 of Article **44** as quoted in the footnote.

ITU-R studies on AMS(R)S — Intersystem real-time pre-emption

To respond to the request by WRC-2000 with regard to Resolution **222 (Rev. WRC-12)**, the ITU-R has completed studies begun in 2000 to determine the feasibility and practicality of prioritization and real-time pre-emptive access (intersystem real-time pre-emption).

The concept of real-time pre-emption was proposed at WRC-97 as an expedient mechanism to open the sub-bands 1 545–1 555 and 1 646.5–1 656.5 MHz to generic MSS.

ITU-R considered various elements, such as characteristics of the aeronautical safety communications and aeronautical traffic, and applicability of real-time pre-emption and its practicality and effectiveness. The study also "identified a number of significant technical, operational and economic issues that would have to be overcome to make 'prioritization and intersystem real-time pre-emption' a reality." The results of this study are available from the ITU as Report M.2073 (*Feasibility and practicality of prioritization and real-time pre-emptive access between different networks of mobile-satellite service in the bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz*).

The study noted that although some mobile-satellite networks currently provide *intra*-system pre-emptive access functions, there are no actual MSS systems providing "prioritization and *inter*system real-time pre-emption" functions, and despite several years of study there are no methods yet developed.

The study further summarized that "prioritization and intersystem real-time pre-emption" would not necessarily increase the efficiency of spectrum use compared to the current situation, but it would certainly complicate substantially the

coordination process and network structure. Furthermore, it may not satisfy the operational and commercial requirements of AMS(R)S communications.

It was concluded that "prioritization and intersystem real-time pre-emption is not practical and, without significant advance in technology, is unlikely to be feasible for technical, operational and economical reasons."

Noting that the conclusions in ITU Report M.2073 identify that intersystem real-time pre-emption will not be effective to ensure spectrum availability and protection for AMS(R)S communications, WRC-12 was urged to provide appropriate regulatory provisions to ensure long-term and stable spectrum availability for AMS(R)S.

At WRC-12 the issue of recognized access for AMS(R)S systems to the frequency bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz was debated. As a result of that debate, it was agreed that the process for ensuring the enforcement of the priority access given by RR No. **5.357A** should be strengthened in a manner that also increased transparency within the process.

ITU-R Resolution 222 **(Rev. WRC-12)** was modified as follows:

- to place an obligation on administrations to ensure that their MSS operators who are not carrying AMS(R)S traffic yield capacity when a requirement for AMS(R)S traffic cannot be met otherwise;

- invite ICAO, where appropriate, to comment on the AMS(R)S traffic requirements;

- add an annex that details the procedure for the implementation of RR No. **5.357A**;

- ensure that an agreed methodology be used for the translation of traffic requirements into spectrum requirements;

- require notifying administrations to inform the ITU Bureau of the results with respect to AMS(R)S requirements of any coordination meeting;

- formalize dispute resolution meetings.

WRC-12, noting that there was not an agreed methodology for the translation of traffic requirements into spectrum requirements, also called for, through ITU-R Resolution 422, the development of such a methodology.
Band: 1 559–1 626.5 MHz

Service: Aeronautical radionavigation/
radionavigation-satellite (GNSS); AMS(R)S
Allocation:

MHz **1 559–1 613.8**		
Allocation to Services		
Region 1	Region 2	Region 3
1 559–1 610 AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.208B 5.328B 5.329A 5.341		
1 610–1 610.6 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	**1 610–1 610.6** MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) 5.341 5.364 5.366 5.367 5.368 5.370 5.372	**1 610–1 610.6** MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372
1 610.6–1 613.8 MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	**1 610.6–1 613.8** MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) 5.149 5.341 5.364 5.366 5.367 5.368 5.370 5.372	**1 610.6–1 613.8** MOBILE-SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space) 5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372

MHz **1 613.8–1 626.5**		
Allocation to Services		
Region 1	Region 2	Region 3
1 613.8–1 626.5 MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.371 5.372	**1 613.8–1 626.5** MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION- SATELLITE (Earth-to-space) Mobile-satellite (space-to-Earth) 5.208B 5.341 5.364 5.365 5.366 5.367 5.368 5.370 5.372	**1 613.8–1 626.5** MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B Radiodetermination- satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.372

Footnotes:

5.149 In making assignments to stations of other services to which the bands: ... 1 610.6–1 613.8 MHz, ... are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

5.208B In the frequency bands … 1 525–1 610 MHz … Resolution **739 (Rev. WRC-15)** applies. (WRC-15)

5.328B The use of the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010-5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the provisions of Nos. **9.12, 9.12A** and **9.13**. Resolution **610 (WRC-03)** shall also apply; however, in the case of

radionavigation-satellite service (space-to-space) networks and systems, Resolution **610 (WRC-03**) shall only apply to transmitting space stations. In accordance with No. **5.329A**, for systems and networks in the radionavigation-satellite service (space-to-space) in the bands 1 215–1 300 MHz and 1 559–1 610 MHz, the provisions of Nos. **9.7, 9.12, 9.12A** and **9.13** shall only apply with respect to other systems and networks in the radionavigation-satellite service (space-to-space). (WRC-07)

5.329A Use of systems in the radionavigation-satellite service (space- to-space) operating in the bands 1 215–1 300 MHz and 1 559–1 610 MHz is not intended to provide safety service applications, and shall not impose any additional constraints on radionavigation-satellite service (space-to-Earth) systems or on other services operating in accordance with the Table of Frequency Allocations. (WRC-07)

5.341 In the bands 1 400–1 727 MHz, 101–120 GHz and 197–220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extraterrestrial origin.

5.351A For the use of the bands 1 518–1 544 MHz, 1 545–1 559 MHz, 1 610–1 645.5 MHz, 1 646.5–1 660.5 MHz, 1 668–1 675 MHz, 1 980–2 010 MHz, 2 170–2 200 MHz, 2 483.5–2 520 MHz and 2 670–2 690 MHz by the mobile-satellite service, see Resolutions **212 (Rev. WRC-07)*** and **225 (Rev. WRC-07)****. (WRC-07)

5.355 *Additional allocation*: in Bahrain, Bangladesh, Congo (Rep. of the), Djibouti, Egypt, Eritrea, Iraq, Israel, Kuwait, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the bands 1 540–1 559 MHz, 1 610–1 645.5 MHz and 1 646.5–1 660 MHz are also allocated to the fixed service on a secondary basis. (WRC-12)

5.359 *Additional allocation:* in Germany, Saudi Arabia, Armenia, Azerbaijan, Belarus, Benin, Cameroon, the Russian Federation, France, Georgia, Guinea, Guinea-Bissau, Jordan, Kazakhstan, Kuwait, Lithuania, Mauritania, Uganda, Uzbekistan, Pakistan, Poland, the Syrian Arab Republic, Kyrgyzstan, the Dem. People's Rep. of Korea, Romania, Tajikistan, Tunisia, Turkmenistan and Ukraine, the frequency bands 1 550–1 559 MHz, 1 610–1 645.5 MHz and 1 646.5–1 660 MHz are also allocated to the fixed service on a primary basis. Administrations are urged to make all practicable efforts to avoid the

* *Note by the Secretariat.*— This Resolution was revised by WRC-15.
** *Note by the Secretariat.*— This Resolution was revised by WRC-12.

implementation of new fixed-service stations in these frequency bands. (WRC-15)

5.364 The use of the band 1 610–1 626.5 MHz by the mobile-satellite service (Earth-to-space) and by the radiodetermination-satellite service (Earth-to-space) is subject to coordination under No. **9.11A**. A mobile earth station operating in either of the services in this band shall not produce a peak e.i.r.p. density in excess of –15 dB(W/4 kHz) in the part of the band used by systems operating in accordance with the provisions of No. **5.366** (to which No. **4.10** applies), unless otherwise agreed by the affected administrations. In the part of the band where such systems are not operating, the mean e.i.r.p. density of a mobile earth station shall not exceed –3 dB(W/4 kHz). Stations of the mobile-satellite service shall not claim protection from stations in the aeronautical radionavigation service, stations operating in accordance with the provisions of No. **5.366** and stations in the fixed service operating in accordance with the provisions of No. **5.359**. Administrations responsible for the coordination of mobile-satellite networks shall make all practicable efforts to ensure protection of stations operating in accordance with the provisions of No. **5.366**.

5.365 The use of the band 1 613.8–1 626.5 MHz by the mobile-satellite service (space-to-Earth) is subject to coordination under No. **9.11A**.

5.366 The band 1 610–1 626.5 MHz is reserved on a worldwide basis for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities. Such satellite use is subject to agreement obtained under No. **9.21**.

5.367 *Additional allocation:* The frequency band 1 610–1 626.5 MHz is also allocated to the aeronautical mobile-satellite (R) service on a primary basis, subject to agreement obtained under No. **9.21**. (WRC-12)

5.368 With respect to the radiodetermination-satellite and mobile-satellite services the provisions of No. **4.10** do not apply in the band 1 610–1 626.5MHz, with the exception of the aeronautical radionavigation-satellite service.

5.369 *Different category of service:* in Angola, Australia, China, Eritrea, Ethiopia, India, Iran (Islamic Republic of), Israel, Lebanon, Liberia, Madagascar, Mali, Pakistan, Papua New Guinea, Syrian Arab Republic, the Dem. Rep. of the Congo, Sudan, South Sudan, Togo and Zambia, the allocation of the band 1 610–1 626.5 MHz to the radiodetermination-satellite

service (Earth-to-space) is on a primary basis (see No. **5.33**) subject to agreement obtained under No. **9.21** from countries not listed in this provision. (WRC-12)

5.370 *Different category of service*: in Venezuela, the allocation to the radiodetermination-satellite service in the band 1 610–1 626.5 MHz (Earth-to-space) is on a secondary basis.

5.371 *Additional allocation:* in Region 1, the bands 1 610–1 626.5 MHz (Earth-to-space) is also allocated to the radiodetermination-satellite service on a secondary basis, subject to agreement obtained under No. **9.21**. (WRC-12)

5.372 Harmful interference shall not be caused to stations of the radio astronomy service using the band 1 610.6–1 613.8 MHz by stations of the radiodetermination-satellite and mobile-satellite services. (No. **29.13** applies.)

ICAO POLICY

- No change to the allocation to the radionavigation-satellite service in the band 1 559–1 610 MHz.
- 1 559–1 610 MHz: No change to the use of this band for future GNSS elements, including GLONASS and GPS which must be protected.
- No new allocations to be made in the band 1 559–1 610 MHz.
- No change to RR Nos. **5.364**, **5.365**, **5.366**, **5.367** and **5.368**.
- Delete RR No. **5.371**.

The band 1 559–1 610 MHz is used by GNSS satellite systems as well as by GNSS satellite augmentation systems and is intensively used for aeronautical radionavigation applications. GNSS already plays a vital role in RNAV operations, ADS-B surveillance and the GBAS landing system (GLS). This band is used by GPS, GLONASS, Beidou, Galileo and the SBAS.

The band 1 559–1 610 MHz is however subject to intentional interference (GNSS jammers) and unintentional interference (potentially caused by an inadequate regulatory framework and improper implementation of systems such as pseudolites and GNSS repeaters). In addition, a proposed use of terrestrial cellular mobile

systems in the (adjacent) band 1 525–1 559 MHz in a few countries is expected to cause harmful interference to some GNSS receivers. Protection of GNSS signals is of paramount importance given the variety of GNSS applications for aeronautical navigation and surveillance.

The frequency band 1 610–1 626.5 MHz is used by IRIDIUM which is a standardized aeronautical mobile-satellite (R) system.

AVIATION USE: The bands between 1 559 MHz and 1 626.5 MHz are allocated to the aeronautical radionavigation service and the frequency band 1 559–1 610 MHz is allocated to the radionavigation-satellite service. At WARC-92, the allocation to the mobile-satellite service (Earth-to-space) in the band 1 610–1 626.5 MHz was introduced and currently provides the service link (to the mobile stations) for the Globalstar and the IRIDIUM mobile-satellite systems. The prime civil aviation interest is in the band 1 559–1 610 MHz which supports the main frequency components of the GPS, GLONASS, Beidou and Galileo radionavigation-satellite systems. In addition, in the frequency band 1 610–1 626.5 MHz IRIDIUM is providing aeronautical mobile (R) satellite communications in compliance with the relevant ICAO SARPs. The allocations of the band 1 610–1 626.5 MHz to the aeronautical radionavigation services and the radiodetermination satellite services are not supporting any civil aeronautical requirement. The satellites for Globalstar and IRIDIUM operate in a non-geostationary orbit.

Band 1 559–1 610 MHz: The radionavigation-satellite (space-to-Earth) allocation of 51 MHz is the main allocation available for GNSS. Other bands identified to support this main component and provide a more robust system with the possibility of compensation for ionospheric delay are at 1 164–1 215 MHz and planned for use by all radionavigation-satellite systems. GNSS provides the basis for many modern civil aviation radionavigation requirements. Present use of the band includes the standard positioning service of the GPS system as well as GLONASS,Galileo and Beidou.
Draft ICAO SARPs for the Galileo and Beidou systems operating in this band and in the 1 164–1 215 MHz band have been developed by the Navigation Systems Panel (NSP) and are expected to become applicable by 2023.

Band 1 610–1 626.5 MHz: The IRIDIUM non-geostationary satellite system provides AMS(R)S in this band in accordance with RR No. **5.367**. The IRIDIUM system provides for AM(R)S communications in accordance with the relevant SARPs as contained in Annex 10, Volume III, Chapter 4. Information on the IRIDIUM system and its compliance with ICAO SARPs is contained in the ICAO *Manual on the Aeronautical Mobile Satellite (Route) Service* (Doc 9925).

COMMENTARY:

Band 1 610–1 626.5 MHz. The allocations in this frequency band to the aeronautical radionavigation service and the radiodetermination service are not supporting requirements for international civil aviation. The allocation to the mobile-satellite service supports the Globalstar and the IRIDIUM mobile-satellite communication systems. The allocation to the mobile-satellite service is primary in the Earth-to-space direction and secondary in the space-to-Earth direction. However, RR No. **5.367** has allocated the frequency band 1 610–1 626.5 MHz to the aeronautical mobile-satellite (R) service on a primary basis in both the Earth-to-space and space-to-Earth directions. IRIDIUM uses this allocation to provide the service link for the aeronautical mobile (R) communications it provides.

Globalstar and IRIDIUM NGSO MSS systems are intended to provide a (near) global service of voice and data for commercial purposes to all classes of mobile users, including personal handset users. The Earth-to-space direction for a mobile-satellite service is the path between the mobile transmitting terminals, many of which will be hand-held devices, and the satellite. The potential for interference to aeronautical GPS and GLONASS receivers by hand-held devices operating in the Earth-to-space direction is hence high, particularly for mobile terminals operating on the lower frequencies in the band and especially in the vicinity of airports. This has led to the development of ITU-R Recommendation M.1343 which provides for maximum limits of unwanted emissions from these terminals into the GNSS band (see commentary for that band below).

RR No. **5.367** provides for an additional allocation to the AMS(R)S in the band 1 610–1 626.5 MHz subject to RR No. **9.21**, which requires coordination with other administrations before a registration in the MIFR can be made. The allocation to the AMS(R)S is on a primary basis in both directions of transmission. IRIDIUM, which operates in this band, has been validated to conform to the ICAO AMS(R)S SARPs.

The fixed service is allowed to operate in the band 1 610–1 626.5 MHz under RR Nos. **5.355** and **5.359**. This use conflicts with all the satellite services in the band and is undesirable.

The use of the band 1 610.6–1 613.8 MHz for aeronautical purposes is constrained by sharing with the radio astronomy allocation, which has primary status. RR No. **5.149** limits airborne use of this portion of the band. In practical terms, the band is of limited use for aviation services, in particular for aviation systems and services of international standard status.

RR No. **5.366** reserving the band 1 610–1 626.5 MHz for aeronautical purposes needs to be maintained.
The primary allocation to the radiodetermination-satellite service in Region 2, and

in Region 1 under RR No. **5.371** and, on a secondary basis in Region 3, was made to accommodate a position-fixing service for general use, which was originally proposed for use by aviation. This service is only implemented to a limited extent and has never been recognized internationally as an approved service for aviation purposes. RR No. **5.364** requires coordination of this service with the MSS. This system is not being used by international civil aviation.

Band 1 559–1 610 MHz. This band is the main allocation base for RNSS available for general use. (There are other RNSS systems which operate in other bands only for special purposes or for national defence purposes.) These systems (GPS, GLONASS, Beidou and Galileo) share the band in a complex sharing arrangement which is agreed by the respective service providers. Typically, RNSS requires 20–30 MHz or so of spectrum depending on the system's chipping rate and the accuracy requirement. Signal levels at the Earth's surface tend to be low, demanding an interference-free environment. To combat the effects of ionospheric delay and to provide a system with increased immunity to interference, another GNSS component, for civil use, in the frequency band 1 164–1 215 MHz has been accommodated. (See commentary for the DME band at 960–1 215 MHz.)

WRC-2000 added a (space-to-space) service to the (space-to-Earth) allocation to RNSS on a "no constraint to existing services" basis (see RR No. **5.329A**). This use is for the many operators of space services of all kinds who utilize the GPS system as a source of accurate timing or for position fixing of the satellites. This regularizes a practice which has existed for many years but gives the service no rights over the main class of GNSS user and other allocations.

Global navigation satellite system (GNSS)

GNSS was identified by the FANS Committee as a replacement for many of the existing terrestrial systems and is a main component of the CNS/ATM concept. The specifications for the ICAO GNSS presently recognize the GPS and GLONASS systems, and their augmentations. The required characteristics for GNSS are incorporated in SARPs. This forms the basis for satellite navigation as envisaged in the CNS/ATM concept and provides service for both en-route and airport approach and landing. SARPs and guidance material for GNSS are included in Annex 10, Volume I, Chapters 2 and 3 and Attachment D, and in the the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849).

Protection of GNSS signals from harmful interference

The protection of GNSS signals from harmful interference is of major concern to aviation. GNSS signal levels at the aircraft receiver are of very low level (in the order of –160 dBW) and, despite receiver signal processing having high interference rejection properties, the system is vulnerable to other in-band signals and to spurious

signals from non-aviation systems operating in adjacent bands. High power continuous signals in adjacent frequency bands also may cause GNSS receiver overload, impacting reception of desired GNSS signals. Additionally, the GNSS antenna placement on the aircraft and how its signal interfaces with other on-board radio systems require extreme care and careful design to ensure that the system can deliver the required performance on a continuous basis. The characteristics and protection of GNSS are addressed in a number of ITU-R Recommendations (see ITU-R Recommendation M.1903 and Attachment G) and specific studies have been made of the compatibility of GNSS with other systems to determine whether sharing is safe. In respect of the total radio environment in which GPS must operate, the aggregate sum of all interferences is of major importance. For this reason, aviation has pressed for the inclusion of a safety margin factor in all assessments for individual interfering systems. ICAO policy supports a factor of 6 to 10 dB for this feature. General details of some of the interference scenarios already identified are given below:

Hand-held devices in the band 1 610–1 626.5 MHz
and mobile terminals in the band 1 626.5–1 660.5 MHz

Problems with high levels of spurious emissions from hand-held mobile-satellite devices operating in the band 1 610–1 626.5 MHz have appeared and are the subject of European Telecommunication Standards Institute (ETSI) European Standards and ITU-R Recommendations. This work resulted in the approval of ITU-R Recommendation M.1343 and the adoption of Standards by ETSI, both of which recognize the ICAO requirements on the level of protection to be given to GNSS. Further work on the protection of the band 1 559–1 610 MHz from spurious emissions from mobile Earth stations operating in the band 1 626.5–1 660.5 MHz has been completed and resulted in ITU-R Recommendation M.1480.

Proposal for an allocation to MSS in band 1 559–1 567 MHz

A proposal to WRC-97 to allocate the frequency band between 1 559 MHz and 1 567 MHz to the mobile-satellite service in the space-to-Earth direction, strongly opposed by aviation interests, was eventually not adopted by that conference. The proposal was referred through Resolution **220 (WRC-97)** to the ITU-R for further study. The results of this study indicating that sharing is not feasible were included in the CPM Report to WRC-2000. WRC-2000 accepted these results, and Resolutions **226** and **227** of that conference, which address the question of additional spectrum for mobile-satellite services in the bands between 1 GHz and 3 GHz, specifically exclude the band 1 559–1 610 MHz from the study.

Potential interference from ultra-wide-band (UWB) devices

Recent technological advances have resulted in the development of devices used in radar and communications applications. These emitters known as ultra-wide-band (UWB) devices utilize very narrow pulses, typically less than 1 nanosecond, and radiate over very wide bandwidths, typically several gigahertz. Devices used in radar applications have many commercial and government uses, such as radar imaging through walls.

Developers of UWB devices anticipate extensive marketability due to the varied use and capabilities of these low power transmitter devices. Manufacturers of these devices are currently seeking approval to operate UWB systems on an unlicensed basis. Considering UWB device output power is low enough to operate unlicensed, their very wide bandwidth emissions would be present within restricted bands. Many of the restricted bands subject to UWB emissions include aeronautical bands reserved for safety-of-life services and, in particular, the 1 559–1 610 MHz band used by GNSS. The aggregate emission levels of UWB devices could interfere with many aeronautical systems; however, at this early stage of beginning to understand the potential degradation of aviation safety services, it is believed that GNSS receivers may be more vulnerable to interference from UWB devices. It must be realized, however, that many other aeronautical services are potentially at risk of interference from UWB devices.

In regard to growing concern with development of UWB devices which could operate as unlicensed applications causing harmful interference to aeronautical safety-of-life services, ICAO submitted a preliminary draft new question to the ITU-R Study Group 8 at its meeting in October 2000. Parallel to the concerns raised by ICAO, State regulatory and telecommunications authorities have undertaken active study and analysis of UWB emission characteristics and the potential effects on a variety of aeronautical services. Reports on the results of these ongoing activities by State authorities are currently available.

Four ITU-R Recommendations (ITU-R SM.1754, 1755, 1756 and 1757) and one ITU-R report on the impact of UWB technology on radiocommunication services have been developed. The comprehensive results may also be taken into consideration by ITU-R Study Group 5 to further advance necessary action to ensure protection of safety-of-life services.

Considering especially the mobility of aircraft and the large "viewing" area to which aircraft are exposed, together with the variability and uncertainty of a significant number of factors (such as UWB emitter density, signal characteristics and activity factors) necessary for the interference analysis of devices using UWB technology with systems operating within safety services, UWB devices should in general not be operated in frequency bands allocated to safety services. In those cases where such use cannot be avoided, administrations should take all steps necessary to ensure that UWB devices do not cause harmful interference to the reception by stations operating under a safety service allocation. The level of harmful interference to safety systems needs to be determined on a case-by-case basis in the form of a safety analysis. This analysis would assess the use being made of the safety system and demonstrate that the required levels of integrity, reliability and availability are still maintained under all operational conditions. Factors such as the impact on safety service link budget margins and measures to preclude interference from UWB devices that malfunction need to be considered.

It is recommended that State aviation representatives continue to actively participate in the ITU-R Study Group activities and provide knowledge of the potential impact to aeronautical services through liaison with their respective ITU administrations.

Potential interference from IMT unwanted emissions

By the decisions of WRC-12 and WRC-15, the frequency bands 694–790 MHz, 790–862 MHz and 1 427–1 518 MHz were identified for international mobile telecommunication (IMT) on a global or regional basis. Also, in several countries the band 470–694 MHz was identified for IMT in accordance with relevant footnotes of the Radio Regulations.

There are global navigation satellite systems operating in frequency bands below 3 GHz which have allocations for RNSS. Frequency bands identified for IMT do not overlap by their main emission with GNSS frequency bands. However, IMT can impact on frequency bands of global navigation systems (1 559–1 610 MHz) by unwanted emissions including out-of-band and spurious emissions. In the GNSS frequency band 1 559–1 610 MHz, impact of the second harmonic of IMT stations that use frequency bands 694–790 MHz and 790–862 MHz is possible, as well as impact of spurious emissions from IMT stations that operate in the frequency band 1 427–1 518 MHz.

Current results of theoretical and experimental estimations indicate that the levels of unwanted emissions of IMT stations that are defined in ITU-R Recommendations M.2070 and M.2071 are not low enough to provide required protection level for RNSS receiving earth stations that operate in 1 559–1 610 MHz. Required separation distances are from 42 m to 2 446 m depending on the type of RNSS receiver, which makes impossible simultaneous application of these devices in one local spot without additional compatibility measures.

Band: 2 700–3 300 MHz
Service: Aeronautical radionavigation/radionavigation/ radiolocation (primary surveillance radar)
Allocation:

MHz 2 700–3 300		
Allocation to Services		
Region 1	Region 2	Region 3
2 700–2 900	AERONAUTICAL RADIONAVIGATION 5.337 Radiolocation 5.423 5.424	
2 900–3 100	RADIOLOCATION 5.424A RADIONAVIGATION 5.426 5.425 5.427	
3 100–3 300	RADIOLOCATION Earth exploration-satellite (active) Space research (active) 5.149 5.428	

Footnotes:

5.149 In making assignments to stations of other services to which the bands: ... 3 260–3 267 MHz ... are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**) (WRC-07).

5.337 The use of the bands 1 300–1 350 MHz, 2 700–2 900 MHz and 9 000–9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

5.423 In the band 2 700–2 900 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the aeronautical radionavigation service.

5.424 *Additional allocation*: in Canada, the band 2 850–2 900 MHz is also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars.

5.424A In the band 2 900-3 100 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the radionavigation service. (WRC-03)

5.425 In the band 2 900–3 100 MHz, the use of the shipborne interrogator-transponder (SIT) system shall be confined to the sub-band 2 930–2 950 MHz.

5.426 The use of the band 2 900–3 100 MHz by the aeronautical radionavigation service is limited to ground-based radars.

5.427 In the bands 2 900–3 100 MHz and 9 300–9 500 MHz, the response from radar transponders shall not be capable of being confused with the response from radar beacons (racons) and shall not cause interference to ship or aeronautical radars in the radionavigation service, having regard, however, to No. **4.9**.

5.428 *Additional allocation*: in Azerbaijan, Kyrgyzstan and Turkmenistan, the frequency band 3 100–3 300 MHz is also allocated to the radionavigation service on a primary basis. (WRC-15)

ICAO POLICY

- No change to the frequency allocations to the aeronautical radionavigation service in these bands.
- No change to RR Nos. **5.423**, **5.424A**, **5.426** and **5.427**.
- Oppose any in-band or near-band allocation that would endanger the operation of radar services.
- Given the pressure on the use of this frequency band from non-aeronautical sources and in support of the ICAO overall policy statement:
  a) insist that any sharing studies carried out encompass the total technical and operational aspects of radar use, including possible impact on the safety case; and
  b) oppose any proposal that places undue or unreasonable economic penalty on radar systems presently in use.

The band 2 700–2 900 MHz, and to a lesser extent the band 2 900–3 300 MHz, is heavily used for primary surveillance radar (PSR) mainly providing medium range (to about 60 NM) independent non-cooperative surveillance. These radars typically provide surveillance in terminal and approach areas around major airports.

The band 2 700–2 900 MHz is also used for meteorological radar. This use is expected, on a global basis, for the foreseeable future.

Radar stations are subject to interference from out-of-band and fundamental emissions from cellular mobile systems operating in the band below 2 690 MHz. This interference can be mitigated in principle by improving RF selectivity in the radar stations and by reducing the mobile-system emissions that fall into the radar pass-band.

Another area of interference is by the use of the band 2 700–2 900 MHz for digital cordless cameras to support electronic news gathering (ENG). In Europe, such use is permitted by some administrations on the basis of CEPT/ECC Recommendation (02)09 and ECC Report 6. Digital cordless camera operation on a frequency within about ±10 MHz of the nominal frequency of the radar station can cause harmful interference to that PSR up to distances of about 250 NM. Such use may become globally harmonized. ECC Report 6 is based on an out-of-date version of ITU-R Recommendation M.1464 and should be revised to take into account proper protection of radar stations.

The use of this band by aviation may also become subject to “spectrum pricing”. (See also Chapter 8.)

AVIATION USE: These bands are extensively used for PSR (10 cm) for medium-range, en-route surveillance, and for terminal area and approach monitoring. The bands are also used by other radionavigation services (particularly maritime) and radiolocation as well as radars for national purposes on a shared basis. Airborne use is prohibited under the RR Nos. **5.337** and **5.426**. Civil aviation radars tend to be concentrated in the band 2 700–2 900 MHz, although the use of the band 2 900–3 400 MHz is increasing. The major users in the band 2 900–3 400 MHz are radionavigation radars for maritime purposes and radiolocation radars for national defence purposes.

Some countries are reviewing the long-term requirement for PSR. Until about the mid-seventies, PSR was the prime surveillance technology for air traffic management to support ATC. During the seventies and the eighties, ATC (SSR) transponders became increasingly important in supporting both ATC and the airborne collision avoidance system (ACAS). In the nineties, some countries adopted the philosophy to use only SSR (no PSR) for en-route flights, but to retain

PSR in terminal areas to detect potential violations of controlled airspace and to detect aircraft with faulty SSR transponders. However, in the future, some have suggested using SSR and ADS-B only in busy terminal areas. The cost of providing PSR may be high but can be considered the extra premium that needs to be paid in order to secure the required level of surveillance in the interest of safety and security. However, the consequences of undetected violation of controlled airspace could be catastrophic.

Ten-centimetre radar technologies and practices date from the 1940s and modern versions employ the latest radar techniques for plot extraction and display on formatted synthetic displays. Frequency diversity and pulse compression techniques are used to extract weak echoes from interference and to improve range resolution. Multiple frequency operation, commonly using two to four frequencies separated by 60–100 MHz, is necessary and requires careful frequency planning and separation of stations. More stable solid state transmitter frequency control is leading to a more effective use of spectrum than older magnetron systems, although the latter systems still have many years of useful life.

COMMENTARY: The *Report of the Communications/Meteorology/Operations Divisional Meeting (1990)* (Doc 9566) indicated considerable use of the band 2 700–2 900 MHz for surveillance purposes worldwide (Attachment 4 to Appendix B to the report on Agenda Item 1 refers). Table 1 indicated over 1 200 radars reported in response to an ICAO survey. Some use by meteorological radar was also reported.

The ICAO Position at paragraph 4 (page 1B-35) of the report was that no change was made to the allocation at 2 700–2 900 MHz or adjacent bands. This position recognized the considerable investment made in equipment, the suitability of the frequency band for the surveillance role and the long useful life of the equipment. Replacement systems will be required to prove their operational benefit over a long period of time.

While it is possible that SSR, GNSS and ADS will take over some of the functions of en-route surveillance, it is premature to derive a timescale for a reduction in the number of radars or the use of these bands. Airport use is likely to remain for many years.

S-band marine (shipborne) radar is concentrated at 3 050 ±30 MHz.

Proposals for other allocations in the band 2 700–2 900 MHz

To locate spectrum for the new global terrestrial/satellite multi-purpose communications service, radio regulators and mobile systems providers have focused on these radar bands to determine possible sharing with, or release of, spectrum allocated for use by aeronautical radar systems. At the outset, sharing does not seem possible since there appears to be a high probability of intolerable interference to both services. For example, strobing on radar displays and high-power pulse interference to mobile receivers are considered as highly probable, and unacceptable, risks. An additional problem is that the terrestrial broadband spectrum requirements appear to be for overflow purposes in high demand urban areas, which is the same location requirement as that for airport radar.

The precise use of the band 2 700–2 900 MHz was initially reviewed by ITU-R WP8B in 1999. Early research indicates that air traffic radars tend to be concentrated in the 2 700–2 900 MHz band, but this is not yet considered a conclusive result. Any suggestion of compressing the band into a smaller spectrum segment must be carefully examined to determine whether there is sufficient capacity and what are the economics of such spectrum re-farming.

Any decision on changes to the allocations in these bands, whether by reduction or by sharing, can only be taken after a full examination of current and future use. Present indications are that these radars will continue for the long term, and their numbers may increase as airport congestion becomes an even greater problem than it is now. Most use of 10 cm radars is at airports, and these are installed following a national decision to provide an independent surveillance support to the air traffic services at the airport. Increase in airport movements and congestion on runways at many major airports necessitates the provision of more effective monitoring of the airspace. Primary surveillance radar has the benefit that it does not require the carriage of equipment in the aircraft and it ensures comprehensive monitoring of all aircraft in the airspace.

Intensive studies are continuing in Europe to establish the possibility of an allocation to non-aeronautical users in this band. These studies include co-frequency and off-frequency sharing, and the efficient use of the band by radars. All sharing with mobile users is viewed with extreme concern due to the difficulty of tracing sources of interference, as well as the roaming and largely uncontrolled character of mobile use.

The firm ICAO policy is to insist on a full and comprehensive study programme, including not only the technical parameters for a compatible and safe operation of radar, but also the operational and financial implications of sharing frequencies with a use — such as that by mobile users — which is not amenable to effective control.

ITU-R studies

An intensive study has been carried out by ITU-R to document the characteristics and protection requirements of radars operating in these bands. It is difficult to carry out a comprehensive review of this kind because of the confidential nature of those systems used for national defence. Furthermore, ITU-R work has concentrated on PPI-type display radars, often used in maritime operations, and less work has been carried out on the modern plot extracted type systems now in extensive use in civil aviation.

Results indicate that co-frequency sharing is not practicable or feasible, requiring too large a geographic separation between radar stations and other users. Refinement and extrapolation to define the separation required at offset frequencies is expected to continue. Agreements on propagation models and protection ratios also require study and documentation.

At WRC-12 and WRC-15, one of the agenda items sought to identify additional spectrum that could be allocated to International Mobile Telecommunications/ mobile broadband. The frequency band 2 700–2 900 MHz was specifically mentioned as a band of interest.

A number of studies were conducted and all of those studies indicated that co-frequency operation would not be feasible between the mobile service and radar stations in the frequency band 2 700–2 900 MHz. Adjacent-frequency sharing would require removal of radars from certain frequencies and institution of frequency guardbands and geographic separations.

Band: 4 200–4 400 MHz
Service: Aeronautical radionavigation (radio altimeter)
Allocation:

MHz **4 200–4 400**		
Allocation to Services		
Region 1	Region 2	Region 3
4 200–4 400	AERONAUTICAL MOBILE (R) 5.436 AERONAUTICAL RADIONAVIGATION 5.438 5.437 5.439 5.440	

Footnotes:

5.436 Use of the frequency band 4 200–4 400 MHz by stations in the aeronautical mobile (R) service is reserved exclusively for wireless avionics intra-communication systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **424 (WRC-15).** (WRC-15)

5.4.37 Passive sensing in the Earth exploration-satellite and space research services may be authorized in the frequency band 4 200–4 400 MHz on a secondary basis. (WRC-15)

5.438 Use of the frequency band 4 200–4 400 MHz by the aeronautical radionavigation service is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground. (WRC-15)

5.439 *Additional allocation*: in Iran (Islamic Republic of), the band 4 200–4 400 MHz is also allocated to the fixed service on a secondary basis. (WRC-12)

5.440 The standard frequency and time signal-satellite service may be authorized to use the frequency 4 202 MHz for space-to-Earth transmissions and the frequency 6 427 MHz for Earth-to-space transmissions. Such transmissions shall be confined within the limits of ±2 MHz of these frequencies, subject to agreement obtained under No. **9.21**.

ICAO POLICY

- No change to the allocation to the radionavigation service in the light of the continuing requirement for radio altimeters to operate in this band and of the results of ITU-R studies indicating that the 200 MHz allocation is required to meet the stringent operational requirements for accuracy and integrity for radio altimeters.
- No change to RR No. **5.438** which could constrain the operation of radio altimeters.
- Oppose any in-band or near-band allocation that would endanger the operation of the aeronautical radionavigation service or aeronautical mobile (R) service.
- Delete RR No. **5.439**.
- No change to RR Nos. **5.436** and **5.437**.

The whole of the band 4 200–4 400 MHz is globally used for radio altimeters on board aircraft. Radio altimeters provide an essential safety-of-life function for all phases of flight, including the final stages of landing where the aircraft has to be manoeuvred into the flare position or attitude. Use of this band for radio altimeters is expected to continue for the long term. In addition, WRC-15 added an aeronautical mobile (R) service allocation limited to use for wireless avionics intra-communications (WAIC) systems.

AVIATION USE: The band is used extensively for airborne radio altimeters (also called radar altimeters) (see RR No. **5.438**), which have a vital task during all phases of flight, including being a prime component in automated landing for flare guidance, and as the sensor component in ground proximity warning systems. The basic function of radio altimeters is to measure the aircraft's absolute height above ground level. Considerable studies have been undertaken to identify the need for a 200 MHz-wide band for this system (see CCIR Report BL/8, Düsseldorf 1990). These studies show that the full band is required to meet the accuracy and integrity requirements of radio altimeters. As noted, these radio altimeters are operational during all phases of flight.

In addition, WRC-15 added an aeronautical mobile (R) service allocation limited to use for WAIC systems. These systems will be used in aircraft to connect safety-critical systems and sensors, enabling new functions and providing weight-reduction opportunities for fulfilling current functions.

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Band: 5 000–5 250 MHz
Service: Aeronautical radionavigation (MLS), aeronautical mobile (R) (airport communications, terrestrial UAS) and aeronautical mobile-satellite (R) (UAS)
Allocation:

MHz 5 000–5 250		
Allocation to Services		
Region 1	Region 2	Region 3
5 000-5 010	AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Earth-to-space)	
5 010-5 030	AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space) 5.328B 5.443B	
5 030–5 091	AERONAUTICAL MOBILE (R) 5.443C AERONAUTICAL MOBILE-SATELLITE (R) 5.443D AERONAUTICAL RADIONAVIGATION 5.444	
5 091–5 150	FIXED-SATELLITE (Earth-to-space) 5.444A AERONAUTICAL MOBILE 5.444B AERONAUTICAL MOBILE-SATELLITE (R) 5.443AA AERONAUTICAL RADIONAVIGATION 5.444	
5 150–5 250	FIXED-SATELLITE (Earth-to-space) 5.447A MOBILE except aeronautical mobile 5.446A 5.446B AERONAUTICAL RADIONAVIGATION 5.446 5.446C 5.447 5.447B 5.447C	

Footnotes:

5.328B The use of the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the provisions of Nos. **9.12, 9.12A** and **9.13**. Resolution **610 (WRC-03)** shall also apply; however, in the case of radionavigation-satellite service (space-to-space) networks and systems, Resolution **610 (WRC-03**) shall only apply to transmitting space stations. In accordance with No. **5.329A**, for systems and networks in the radionavigation-satellite service (space-to-space) in the bands 1 215–1 300 MHz and 1 559–1 610 MHz, the provisions of Nos. **9.7, 9.12, 9.12A** and **9.13** shall only apply with respect to other systems and networks in the radionavigation-satellite service (space-to-space). (WRC-07)

5.443AA In the frequency bands 5 000–5 030 MHz and 5 091–5 150 MHz, the aeronautical mobile-satellite (R) service is subject to agreement obtained under No. **9.21**. The use of these bands by the aeronautical mobile-satellite (R) service is limited to internationally standardized aeronautical systems.

5.443B In order not to cause harmful interference to the microwave landing system operating above 5 030 MHz, the aggregate power flux-density produced at the Earth's surface in the frequency band 5 030–5 150 MHz by all the space stations within any radionavigation-satellite service system (space-to-Earth) operating in the frequency band 5 010–5 030 MHz shall not exceed –124.5 dB (W/m^2) in a 150 kHz band. In order not to cause harmful interference to the radio astronomy service in the frequency band 4 990–5 000 MHz, radionavigation-satellite service systems operating in the frequency band 5 010–5 030 MHz shall comply with the limits in the frequency band 4 990–5 000 MHz defined in Resolution **741 (Rev. WRC-15)**. (WRC-15)

5.443C The use of the frequency band 5 030-5 091 MHz by the aeronautical mobile (R) service is limited to internationally standardized aeronautical systems. Unwanted emissions from the aeronautical mobile (R) service in the frequency band 5 030–5 091 MHz shall be limited to protect RNSS system downlinks in the adjacent 5 010–5 030 MHz band. Until such time that an appropriate value is established in a relevant ITU-R Recommendation, the e.i.r.p. density limit of −75 dBW/MHz in the frequency band 5 010–5 030 MHz for any AM(R)S station unwanted emission should be used.

5.443D In the frequency band 5 030-5 091 MHz, the aeronautical mobile-

satellite (R) service is subject to coordination under No. **9.11A**. The use of this frequency band by the aeronautical mobile-satellite (R) service is limited to internationally standardized aeronautical systems.

5.444 The frequency band 5 030–5 150 MHz is to be used for the operation of the international standard system (microwave landing system) for precision approach and landing. In the frequency band 5 030–5 091 MHz, the requirements of this system shall have priority over other uses of this band. For the use of the frequency band 5 091–5 150, No. **5.444A** and Resolution **114 (Rev. WRC-15)** apply. (WRC-15)

5.444A The use of the allocation to the fixed-satellite service (Earth-to-space) in the frequency band 5 091-5 150 MHz is limited to feeder links of non-geostationary satellite systems in the mobile-satellite service and is subject to coordination under No. **9.11A**. The use of the frequency band 5 091-5 150 MHz by feeder links of non-geostationary satellite systems in the mobile-satellite service shall be subject to application of Resolution **114 (Rev. WRC-15)**. Moreover, to ensure that the aeronautical radionavigation service is protected from harmful interference, coordination is required for feeder-link earth stations of the non-geostationary satellite systems in the mobile-satellite service which are separated by less than 450 km from the territory of an administration operating ground stations in the aeronautical radionavigation service. (WRC-15)

5.444B The use of the frequency band 5 091–5 150 MHz by the aeronautical mobile service is limited to:

— systems operating in the aeronautical mobile (R) service and in accordance with international aeronautical standards, limited to surface applications at airports. Such use shall be in accordance with Resolution **748 (Rev. WRC-15)**;

— aeronautical telemetry transmissions from aircraft stations (see No. **1.83**) in accordance with Resolution **418 (Rev. WRC-15)**. (WRC-15)

5.446 *Additional allocation*: in the countries listed in Nos. **5.369**, the frequency band 5 150–5 216 MHz is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis, subject to agreement obtained under No. **9.21**. In Region 2 (except Mexico), the frequency band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis. In Regions 1 and 3, except those countries listed in Nos. **5.369** and Bangladesh, the frequency band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a secondary basis. The use by the radiodetermination-satellite service is limited to feeder links in conjunction with the radiodetermination-satellite service operating in the frequency bands 1 610–1 626.5 MHz and/or 2 483.5–2 500 MHz. The total power flux-density at the Earth's surface shall in no case exceed –159 dB(W/m^2) in any 4 kHz band for all angles of arrival. (WRC-15)

5.446A The use of the bands 5 150–5 350 MHz and 5 470–5 725 MHz by the stations in the mobile, except aeronautical mobile, service shall be in accordance with Resolution **229 (Rev.WRC-12)**. (WRC-12)

5.446B In the band 5 150–5 250 MHz, stations in the mobile service shall not claim protection from earth Stations in the fixed-satellite service. No. **5.43A** does not apply to the mobile service with respect to fixed-satellite service earth stations. (WRC-03)

5.446C *Additional allocation:* in Region 1 (except in Algeria, Saudi Arabia, Bahrain, Egypt, United Arab Emirates, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Syrian Arab Republic, Sudan, South Sudan and Tunisia) and in Brazil, the band 5 150–5 250 MHz is also allocated to the aeronautical mobile service on a primary basis, limited to aeronautical telemetry transmissions from aircraft stations (see No. **1.83**), in accordance with Resolution **418 (Rev. WRC-12*)**. These stations shall not claim protection from other stations operating in accordance with Article 5. No. **5.43A** does not apply. (WRC 12)

5.447 *Additional allocation*: in Côte d'Ivoire, Egypt, Israel, Lebanon, the Syrian Arab Republic and Tunisia, the band 5 150–5 250 MHz is also allocated to the mobile service, on a primary basis, subject to agreement obtained under No. **9.21**. In this case, the provisions of Resolution **229 (Rev. WRC-12)** do not apply. (WRC-12)

* *Note by the Secretariat:* This Resolution was revised by WRC-15.

5.447A The allocation to the fixed-satellite service (Earth-to-space) is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to coordination under No. **9.11A**.

5.447B *Additional allocation*: the band 5 150–5 216 MHz is also allocated to the fixed-satellite service (space-to-Earth) on a primary basis. This allocation is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to provisions of No. **9.11A**. The power flux-density at the Earth's surface produced by space stations of the fixed-satellite service operating in the space-to-Earth direction in the band 5 150–5 216 MHz shall in no case exceed –164 dB(W/m^2) in any 4 kHz band for all angles of arrival.

5.447C Administrations responsible for fixed-satellite service networks in the band 5 150–5 250 MHz operated under Nos. **5.447A** and **5.447B** shall coordinate on an equal basis in accordance with No. **9.11A** with administrations responsible for non-geostationary-satellite networks operated under No. **5.446** and brought into use prior to 17 November 1995. Satellite networks operated under No. **5.446** brought into use after 17 November 1995 shall not claim protection from, and shall not cause harmful interference to, stations of the fixed-satellite service operated under Nos. **5.447A** and **5.447B**.

ICAO POLICY

- No change to RR Nos. **5.444, 5.444A** and **5.444B**.
- Apply the methodology contained in ITU-R Recommendation S.1342 on the coordination of microwave landing system (MLS) with fixed-satellite service (FSS) Earth stations in the band 5 091–5 150 MHz.
- Ensure that in addressing the future use of the frequency band 5 091–5 150 MHz by the FSS, current and intended future use by aeronautical systems are not adversely impacted.

Priority is given to the microwave landing system (MLS) in the band 5 030–5 091 MHz. Other applications for using this band (e.g. in the aeronautical mobile (R) service and aeronautical mobile-satellite (R) service to support unmanned aircraft) are emerging.

The aeronautical mobile (R) service in the band 5 091–5 150 MHz is reserved for ICAO-standard airport surface communication systems (AeroMACS). A tuning range of 5 000–5 150 MHz for AeroMACS is being considered to support either regional or sub-regional requirements.

The band 5 000–5 030 MHz is also planned for use by the radionavigation-satellite service.

AVIATION USE: The band 5 000–5 250 MHz was allocated to the ARNS in 1947 in anticipation of a future MLS as a replacement for ILS, and for other radionavigation uses for which the band would be particularly suited. At that time, it was estimated that 250 MHz of spectrum was required to support an MLS, and some of the later candidate systems occupied the full 250 MHz. RR No. **5.367** was added to allow use of the band for AMS(R)S as an option which could be taken up at a later date. Following the decision by ICAO, in 1978, to adopt the time reference scanning beam MLS as the future international standard system, RR No. **5.444** was added by WARC-79 giving precedence to this system over all other uses. The scanning beam system required 60 MHz for the initial channel plan, with the possibility of needing a further 60 MHz later. As of WRC-07, the MLS only has precedence in the portion 5 030–5 091 MHz, while 5 091–5 150 MHz has also been allocated to the aeronautical mobile service, limited to AM(R)S surface applications at airports and aeronautical telemetry. See RR No. **5.444B (WRC-15)**.

Annex 10, Volume I, Chapter 3, 3.11.4.1.1, was amended to include the channelling requirement for MLS of 200 channels based on capacity studies made by the All Weather Operations Panel (AWOP). The channelling plan for 200 channels, spaced 300 kHz apart between 5 030 MHz and 5 090.7 MHz, including the pairing with DME, is at Table A in Annex 10, Volume I, Chapter 3.

One ICAO region (EUR) has prepared a regional frequency assignment and implementation plan for MLS based on possible use at airports in the region in the years ahead. In this work, it was noted that the band 5 030–5 091 MHz could only support a portion of the foreseeable regional requirements if MLS were to become the standard for all non-visual needs. The Regional Air Navigation Plans for the other ICAO regions currently lack provisions for implementation of MLS.

The longer-term requirement for aids to precision approach to support all weather operations was discussed at the Special COM/OPS/95 meeting under Agenda Item 3. Recommendation 3/4 identifies some of the options for precision approach, and Appendix C to Agenda Item 3 provides a statement of the possible MLS implementation sequence. Under Agenda Item 5 (Appendix A), a strategy for the introduction of non-visual aids was developed and incorporated in Annex 10. Appendix B to Agenda Item 5 outlines the ICAO regional considerations for MLS,

which include a progression to MLS for CAT II and III requirements if GNSS is not available at the time of the ILS replacement.

It should be noted that the total ARNS use of this band will also include systems for national requirements, civil or military, as well as those for international civil aviation purposes.

The non-aeronautical uses (for mobile services and for fixed-satellite services) of the band 5 091–5 250 MHz, allowed by RR Nos. **5.444A**, **5.446**, **5.446A**, **5.446B**, **5.447**, **5.447A**, **5.447B** and **5.447C** should also be noted.

COMMENTARY: This important radionavigation frequency band has, in recent years, been the subject of close attention by other ITU radio services seeking worldwide exclusive spectrum. The very long delay in implementing the new ICAO standard system (MLS), and the prospect of GNSS offering equivalent capability, have accelerated this attention and have led to new allocations to non-aeronautical radionavigation uses for the frequencies in the bands 5 150–5 250 MHz, 5 091–5 150 MHz and 5 000–5 030 MHz. These were adopted by ITU conferences in 1987, 1992, 1995, 2003 and 2007.

At WRC-12, a new AM(R)S allocation was added in the frequency band 5 030–5 091 MHz to support terrestrial, unmanned aircraft (UAS; termed RPAS in ICAO) command and non-payload communications (termed “C2 Links” in ICAO).

A WRC-12 proposal to allocate the frequency bands 5 000–5 010 and 5 010–5 030 MHz to the AM(R)S for airport surface communication (i.e., AeroMACS) was rejected although it was demonstrated that AM(R)S and RNSS links can share these frequency bands. In order to ensure interoperability, ICAO has standardized the tuning range for AeroMACS in the ICAO SARPs to include the frequency band 5 000–5 030 MHz taking into account national/regional radio regulatory provisions for the use of this band.

An allocation to the AM(R)S in the band 5 091–5 150 MHz (MLS extension band), limited to airport surface operations was agreed at WRC-07 and updated at WRC-12. This is a shared allocation with the aeronautical radionavigation service (MLS), fixed-satellite service (FSS) and aeronautical mobile telemetry (AMT). AMT is a new allocation made during WRC-07 (see RR No. **5.444B** and Resolution **418 (Rev. WRC-15**). The precedence that was given to MLS in this band over other uses has been removed. For the use of the band by the AM(R)S and AMT, provisions to protect the FSS (feeder link), which operates in the same band, were introduced.

The frequency band between 5 150 MHz and 5 250 MHz is shared on a joint primary basis between the ARNS, the mobile (except aeronautical mobile) and the FSS. FSS use is specifically for feeder links for NGSO mobile-satellites (see RR No. **5.447A**) in the Earth-to-space direction. In practical terms, the spectrum between 5 150 MHz and 5 250 MHz can no longer support any international standard ARNS system.

The band 5 000–5 150 MHz is also allocated to the aeronautical mobile-satellite service on a primary basis under the provisions of RR Nos. **5.443AA** and **5.443D**. Particular consideration is being given to using the 5 030–5 091 MHz portion of this band for AMS(R)S control links in support of UAS/RPAS.

WRC-2000 approved the new RR No. **5.443A** for the RNSS in the band 5 000–5 010 MHz in the Earth-to-space direction, and RR No. **5.443B** for the RNSS in the band 5 010–5 030 MHz in the space-to-Earth direction. The latter footnote imposes power flux-density limitations on the space transmissions of the RNSS to protect MLS in the band 5 030–5 150 MHz and the radio astronomy in the band below 5 000 MHz. The addition of this RNSS allocation was not opposed by civil aviation. However, in the interest of protecting MLS, Resolution **603 (WRC-2000)** was agreed, which calls for study of the necessary technical, operational and regulatory measures necessary for the protection of MLS from the spurious emissions of the RNSS. For protection of MLS from unwanted emissions from RNSS Earth stations in the 5 000–5 010 MHz band, the preferred technical measure is likely to establish a minimum separation distance between these and MLS facilities, in the same way as applies to the operation of the FSS in the 5 091–5 150 MHz band under ITU-R Rec. S.1342.

Band: 5 350–5 470 MHz
Service: Aeronautical radionavigation (airborne weather and ground mapping radar)
Allocation:

MHz 5 350–5 470		
	Allocation to Services	
Region 1	Region 2	Region 3
5 350–5 460	EARTH EXPLORATION-SATELLITE (active) 5.448B SPACE RESEARCH (active) 5.448C AERONAUTICAL RADIONAVIGATION 5.449 RADIOLOCATION 5.448D	
5 460–5 470	RADIONAVIGATION 5.449 EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION 5.448D 5.448B	

Footnotes:

5.448B The Earth exploration-satellite (active) service operating in the band 5 350–5 570 MHz and space research service (active) operating in the band 5 460–5 470 MHz shall not cause harmful interference to the aeronautical radionavigation service in the band 5 350-5 460 MHz, the radionavigation service in the band 5 460–5 470 MHz and the maritime radionavigation service in the band 5 470–5 570 MHz. (WRC-03)

5.448C The space research service (active) operating in the band 5 350–5 460 MHz shall not cause harmful interference to nor claim protection from other services to which this band is allocated.

5.448D In the frequency band 5 350–5 470 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the aeronautical radionavigation service operating in accordance with No. **5.449**. (WRC-03)

5.449 The use of the band 5 350–5 470 MHz by the aeronautical radionavigation service is limited to airborne radars and associated airborne beacons.

ICAO POLICY

- No change to RR Nos. **5.448B**, **5.448C** and **5.448D**.
- These bands are used extensively, particularly for airborne weather radar, and are needed for the foreseeable future. No changes should be made which would restrict this aeronautical use.

The band 5 350–5 470 MHz is used for airborne weather radar. The airborne weather radar is a safety-critical instrument assisting pilots in deviating from potential hazardous weather conditions and detecting wind shear and microbursts. This use is expected to continue for the long term.

AVIATION USE: The band 5 350–5 470 MHz is used for airborne weather and ground mapping radar, which is in conformity with RR No. **5.449**.

COMMENTARY: Airborne weather radar equipment (a mandatory carriage item in many countries) supports the safe passage of an aircraft in the vicinity of turbulent weather conditions. It provides timely warnings of rapidly changing weather conditions as an aid to in-flight route planning. In addition, such equipment allows maintaining contact with geographic features, such as shorelines, as a supplement to navigational orientation. Annex 6, Part I, Chapter 6, 6.11, recommends that aircraft operating in areas with potentially hazardous weather conditions be equipped with airborne weather radar. The ICAO policy (Appendix C to the *Report of the Communications/Operations (COM/OPS) Divisional Meeting (1985)* (Doc 9464) refers) is to retain the allocation without changes. One of the uses of airborne weather radar is to avoid penetration of aircraft into hazardous weather.

WRC-97 added the Earth exploration service on a primary basis. At WRC-03, the Earth exploration-satellite service was also added, and the radiolocation service was upgraded to a primary service. These services can operate in this band under the express condition that they will not cause harmful interference to the (aeronautical) radionavigation service nor claim protection.

Band: 8 750–8 850 MHz
Service: Aeronautical radionavigation/radiolocation (airborne Doppler radar)
Allocation:

MHz 8 750–8 850		
Allocation to Services		
Region 1	Region 2	Region 3
8 750–8 850	RADIOLOCATION AERONAUTICAL RADIONAVIGATION 5.470 5.471	

Footnotes:

5.470 The use of the band 8 750–8 850 MHz by the aeronautical radionavigation service is limited to airborne Doppler navigation aids on a centre frequency of 8 800 MHz.

5.471 *Additional allocation:* in Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands, Qatar and Sudan, the frequency bands 8 825–8 850 MHz and 9 000–9 200 MHz are also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars only. (WRC-15)

ICAO POLICY

- No change since the requirement is a continuing one.
- No change to RR No. **5.470**.

The band 8 750–8 850 MHz is extensively used for airborne Doppler radar and ground mapping radar. These systems are used to determine ground speed, drift and distance travelled as well as ground mapping. The use of these radar systems is expected to continue for the long term. The band 8 750–8 850 MHz is shared with the radiolocation service and the maritime radionavigation service.

AVIATION USE: RR No. **5.470**.

Airborne Doppler navigation systems are widely used for specialized applications such as continuous determination of ground speed and drift angle information of an aircraft with respect to the ground. The information is derived by measuring the Doppler shift of signals transmitted from the aircraft in several narrow beams pointed towards the surface, backscattered by the surface and received by the Doppler radar receiver.

COMMENTARY: The ICAO policy is a continuing one of no change to the allocation, as expressed in the *Report of the Communications/Operations (COM/OPS) Divisional Meeting (1985)* (Doc 9464), page 8C-11. Hence, the current allocation to the aeronautical radionavigation service in this band must be retained.

Band: 9 000–9 500 MHz
Service: Aeronautical radionavigation/radionavigation (precision approach radar, airborne weather radar and ground mapping radar)
Allocation:

MHz **9 000–9 500**		
Allocation to Services		
Region 1	Region 2	Region 3
9 000–9 200	AERONAUTICAL RADIONAVIGATION 5.337 RADIOLOCATION 5.471 5.473A	
9 200–9 300	EARTH EXPLORATION-SATELLITE (active) 5.474A 5.474B 5.474C RADIOLOCATION MARITIME RADIONAVIGATION 5.472 5.473 5.474 5.474D	
9 300–9 500	RADIONAVIGATION EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION 5.427 5.474 5.475 5.475A 5.475B 5.476A	

Footnotes:

5.337 The use of the bands 1 300–1 350 MHz, 2 700–2 900 MHz and 9 000–9 200 MHz by the aeronautical radionavigation service is restricted to ground-based radars and to associated airborne transponders which transmit only on frequencies in these bands and only when actuated by radars operating in the same band.

5.427 In the bands 2 900–3 100 MHz and 9 300–9 500 MHz, the response from radar transponders shall not be capable of being confused with the response from radar beacons (racons) and shall not cause interference to ship or aeronautical radars in the radionavigation service, having regard, however, to No. **4.9**.

5.471 *Additional allocation:* in Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands, Qatar and Sudan, the frequency bands 8 825–8 850 MHz and 9 000–9 200 MHz are also allocated to the maritime radionavigation service, on a primary basis, for use by shore-based radars only. (WRC-15)

5.472 In the bands 8 850–9 000 MHz and 9 200–9 225 MHz, the maritime radionavigation service is limited to shore-based radars.

5.473 *Additional allocation:* in Armenia, Austria, Azerbaijan, Belarus, Cuba, the Russian Federation, Georgia, Hungary, Mongolia, Uzbekistan, Poland, Kyrgyzstan, Romania, Tajikistan, Turkmenistan and Ukraine, the bands 8 850–9 000 MHz and 9 200–9 300 MHz are also allocated to the radionavigation service on a primary basis. (WRC-07)

5.473A In the band 9 000–9 200 MHz, stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from, systems identified in No. **5.337** operating in the aeronautical radionavigation service, or radar systems in the maritime radionavigation service operating in this band on a primary basis in the countries listed in No. **5.471**. (WRC-07)

5.474 In the band 9 200–9 500 MHz, search and rescue transponders (SART) may be used, having due regard to the appropriate ITU-R Recommendation (see also Article **31**).

5.474A The use of the frequency bands 9 200–9 300 MHz and 9 900–10 400 MHz by the Earth exploration-satellite service (active) is limited to systems requiring necessary bandwidth greater than 600 MHz that cannot be fully accommodated within the frequency band 9 300–9 900 MHz. Such use is subject to agreement to be obtained under No. **9.21** from Algeria, Saudi Arabia, Bahrain, Egypt, Indonesia, Iran (Islamic Republic of), Lebanon and Tunisia. An administration that has not replied under No. **9.52** is considered as not having agreed to the coordination request. In this case, the notifying administration of the satellite system operating in the Earth exploration-satellite service (active) may request the assistance of the Bureau under Sub-Section IID of Article **9**. (WRC-15)

5.474B Stations operating in the Earth exploration-satellite (active) service shall comply with Recommendation ITU-R RS.2066-0. (WRC-15)

5.474C Stations operating in the Earth exploration-satellite (active) service

shall comply with Recommendation ITU-R RS.2065-0. (WRC-15)

5.474D Stations in the Earth exploration-satellite service (active) shall not cause harmful interference to, or claim protection from, stations of the maritime radionavigation and radiolocation services in the frequency band 9 200–9 300 MHz, the radionavigation and radiolocation services in the frequency band 9 900–10 000 MHz and the radiolocation service in the frequency band 10.0-10.4 GHz. (WRC-15)

5.475 The use of the band 9 300–9 500 MHz by the aeronautical radionavigation service is limited to airborne weather radars and ground-based radars. In addition, ground-based radar beacons in the aeronautical radionavigation service are permitted in the band 9 300–9 320 MHz on condition that harmful interference is not caused to the maritime radionavigation service. (WRC-07)

5.475A The use of the band 9 300–9 500 MHz by the Earth exploration-satellite service (active) and the space research service (active) is limited to systems requiring necessary bandwidth greater than 300 MHz that cannot be fully accommodated within the 9 500–9 800 MHz band. (WRC 07)

5.475B In the band 9 300–9 500 MHz, stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from, radars operating in the radionavigation service in conformity with the Radio Regulations. Ground-based radars used for meteorological purposes have priority over other radiolocation uses. (WRC-07)

5.476A In the band 9 300–9 800 MHz, stations in the Earth exploration-satellite service (active) and space research service (active) shall not cause harmful interference to, nor claim protection from, stations of the radionavigation and radiolocation services. (WRC 07)

ICAO POLICY

- Oppose any changes to the allocations that could adversely affect their use by aviation.
- No change to RR Nos. **5.337**, **5.427**, **5.473A**, **5.474**, **5.475**, **5.475A**, **5.475B** and **5.476A**.

The band 9 000–9 200 MHz is used for ground-based primary surveillance radar systems including precision approach radar (PAR) and airport surveillance detection equipment (ASDE). The main purpose of these systems is to provide surveillance to support precision approach to aircraft and to detect traffic at airports. This use is expected to continue to well beyond 2030. The use of the band is shared with the maritime radionavigation service and the radiolocation service.

The band 9 300–9 500 MHz is globally used for airborne weather radar and ground-based radar. This use is expected to continue to well beyond 2030. The airborne weather radar is a safety-critical instrument assisting pilots to avoid potential hazardous weather conditions and detecting wind shear and microbursts. The use of this band by the ground-based primary surveillance radar is similar to the use of the band 9 000–9 200 MHz. This band is shared with the Earth exploration-satellite service and the space research service.

AVIATION USE: These 3 cm radar bands are used extensively by aeronautical, maritime (land-based and shipborne) and national defence radar systems. They cater for shorter range surveillance and precision functions up to a 50 km range. In aviation, they find considerable application in precision monitoring and approach functions and in airborne weather radar (AWR) systems where their shorter wavelength is very suitable for the detection of storm clouds. One of the uses of AWR is to give warning of hazardous weather. In many countries the carriage of AWR is a mandatory requirement. AWR supports the safe passage of an aircraft in the vicinity of turbulent weather conditions. It provides timely warnings of rapidly changing weather conditions as an aid to in-flight route planning. In addition, such equipment could support maintaining contact with geographic features, such as shorelines, as a supplement to navigational orientation. This band is also used for surface detection radar. Some national uses employ transportable and mobile systems for national defence purposes.

The sharing of the bands with maritime coast and shipborne radar requires care and the application of modern technology to alleviate interaction effects. RR No. **5.475** draws attention to this sharing but does not alter the principle that both services have

equal access rights. It should be noted that AWR is categorized for aeronautical navigation, i.e. storm warning and avoidance in accordance with the definition in RR No. **1.10**, while meteorological radar for observation and recordings is in the category radiolocation (see last sentence in RR No. **5.475**).

COMMENTARY: The ICAO policy for these radar bands is based upon the requirement that these radars are likely to remain in service for many years into the future. Sharing with maritime radar is very manageable and practical because of the different geographical usage, and coordination between the two services is good. Sharing with other services in the areas of important operational use is not feasible.

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Band: 10.95–12.75 GHz

Note: The frequency bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.5 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Regions 1 and 3 and 19.7–20.2 GHz (space-to-Earth), and in the frequency bands 14-14.47 GHz (Earth-to-space) and 29.5–30.0 GHz (Earth-to-space) were identified by ITU WRC-15 for usage for command and non-payload communications of UAS (termed RPAS C2 link in ICAO), subject to being found suitable for meeting the requirements of ICAO, and completion of the requirements of Resolution **155 (Rev. WRC-19)**

Service: Fixed satellite service

Allocation:

GHz 10.95–12.75		
Allocation to Services		
Region 1	Region 2	Region 3
10.95–11.2 FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B (Earth-to-space) 5.484 MOBILE except aeronautical mobile	**10.95–11.2** FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B MOBILE except aeronautical mobile	
11.2–11.45 FIXED FIXED-SATELLITE (space-to-Earth) 5.441 (Earth-to-space) 5.484 MOBILE except aeronautical mobile	**11.2–11.45** FIXED FIXED-SATELLITE (space-to-Earth) 5.441 MOBILE except aeronautical mobile	
11.45–11.7 FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B (Earth-to-space) 5.484 MOBILE except aeronautical mobile	**11.45–11.7** FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B MOBILE except aeronautical mobile	

Region 1	Region 2	Region 3
11.7–12.5 FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE 5.492	**11.7–12.1** FIXED 5.486 FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.488 MOBILE except aeronautical mobile 5.485	**11.7–12.2** FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE 5.492
	12.1–12.2 FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.488 5.485 5.489	5.487 5.487A
5.487 5.487A	**12.2–12.7** FIXED MOBILE except aeronautical mobile BROADCASTING BROADCASTING-SATELLITE 5.492	**12.2–12.5** FIXED FIXED-SATELLITE (space-to-Earth) 5.484B MOBILE except aeronautical mobile BROADCASTING 5.484A 5.487
12.5–12.75 FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B (Earth-to-space) 5.494 5.495 5.496	5.487A 5.488 5.490	**12.5–12.75** FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B MOBILE except aeronautical mobile BROADCASTING-SATELLITE 5.493

Footnotes:

5.441 The use of the bands 4 500–4 800 MHz (space-to-Earth), 6 725–7 025 MHz (Earth-to-space) by the fixed-satellite service shall be in accordance with the provisions of Appendix **30B**. The use of the bands 10.7–10.95 GHz (space-to-Earth), 11.2–11.45 GHz (space-to-Earth) and 12.75–13.25 GHz (Earth-to-space) by geostationary-satellite systems in the fixed-satellite service shall be in accordance with the provisions of Appendix **30B**. The use of the bands 10.7–10.95 GHz (space-to-Earth), 11.2–11.45 GHz (space-to-Earth) and 12.75–13.25 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite service is subject to application of the provisions of No. **9.12** for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. **5.43A** does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)

5.484 In Region 1, the use of the band 10.7–11.7 GHz by the fixed-satellite service (Earth-to-space) is limited to feeder links for the broadcasting-satellite service.

5.484A The use of the bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.75 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Region 1, 13.75–14.5 GHz (Earth-to-space), 17.8–18.6 GHz (space-to-Earth), 19.7–20.2 GHz (space-to-Earth), 27.5–28.6 GHz (Earth-to-space), 29.5–30 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite service is subject to application of the provisions of No. **9.12** for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite

service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. 5.43A does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)

5.484B Resolution **155 (WRC-15)*** shall apply. (WRC-15)

* *Note by the Secretariat:* This Resolution was revised by WRC-19.

5.485 In Region 2, in the band 11.7–12.2 GHz, transponders on space stations in the fixed-satellite service may be used additionally for transmissions in the broadcasting-satellite service, provided that such transmissions do not have a maximum e.i.r.p. greater than 53 dBW per television channel and do not cause greater interference or require more protection from interference than the coordinated fixed-satellite service frequency assignments. With respect to the space services, this band shall be used principally for the fixed-satellite service.

5.487 In the band 11.7–12.5 GHz in Regions 1 and 3, the fixed, fixed-satellite, mobile, except aeronautical mobile, and broadcasting services, in accordance with their respective allocations, shall not cause harmful interference to, or claim protection from, broadcasting-satellite stations operating in accordance with the Regions 1 and 3 Plan in Appendix **30**. (WRC-03)

5.487A *Additional allocation:* In Region 1, the band 11.7–12.5 GHz, in Region 2, the band 12.2–12.7 GHz and, in Region 3, the band 11.7–12.2 GHz, are also allocated to the fixed-satellite service (space-to-Earth) on a primary basis, limited to non-geostationary systems and subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the broadcasting-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. 5.43A does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-03)

5.488 The use of the band 11.7–12.2 GHz by geostationary-satellite networks in the fixed-satellite service in Region 2 is subject to application of the provisions of No. 9.14 for coordination with stations of terrestrial services in Regions 1, 2 and 3. For the use of the band 12.2–12.7 GHz by the broadcasting-satellite service in Region 2, see Appendix **30**. (WRC-03)

5.489 *Additional allocation:* In Peru, the band 12.1–12.2 GHz is also allocated to the fixed service on a primary basis.

5.490 In Region 2, in the band 12.2–12.7 GHz, existing and future terrestrial radiocommunication services shall not cause harmful interference to the space services operating in conformity with the broadcasting-satellite Plan for Region 2 contained in Appendix **30**.

5.492 Assignments to stations of the broadcasting-satellite service which are in conformity with the appropriate regional Plan or included in the Regions 1 and 3 List in Appendix **30** may also be used for transmissions in the fixed-satellite service (space-to-Earth), provided that such transmissions do not cause more interference, or require more protection from interference, than the broadcasting-satellite service transmissions operating in conformity with the Plan or the List, as appropriate. (WRC-2000)

5.493 The broadcasting-satellite service in the band 12.5–12.75 GHz in Region 3 is limited to a power flux-density not exceeding –111 dB (W/(m^2·27 MHz)) for all conditions and for all methods of modulation at the edge of the service area. (WRC-97)

5.494 Additional allocation: in Algeria, Saudi Arabia, Bahrain, Cameroon, the Central African Rep., Congo (Rep. of the), Côte d'Ivoire, Djibouti, Egypt, the United Arab Emirates, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Madagascar, Mali, Morocco, Mongolia, Nigeria, Oman, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, Somalia, Sudan, South Sudan, Chad, Togo and Yemen, the frequency band 12.5–12.75 GHz is also allocated to the fixed and mobile, except aeronautical mobile, services on a primary basis. (WRC-15)

5.495 Additional allocation: in France, Greece, Monaco, Montenegro, Uganda, Romania and Tunisia, the frequency band 12.5–12.75 GHz is also allocated to the fixed and mobile, except aeronautical mobile, services on a secondary basis. (WRC-15)

5.496 *Additional allocation:* In Austria, Azerbaijan, Kyrgyzstan and Turkmenistan, the band 12.5–12.75 GHz is also allocated to the fixed service and the mobile, except aeronautical mobile, service on a primary basis. However, stations in these services shall not cause harmful interference to fixed-satellite service earth stations of countries in Region 1 other than those listed in this footnote. Coordination of these earth stations is not required with stations of the fixed and mobile services of the countries listed in this footnote. The power flux-density limit at the Earth's surface given in Table **21-4** of Article **21**, for the fixed-satellite service shall apply on the territory of the countries listed in this footnote. (WRC-2000)

ICAO POLICY

- To conduct studies within ICAO to determine if the implementation of C2 Links in this frequency band is suitable for meeting the requirements of RPAS.
- To support within the ITU-R the relevant studies of technical, operational and regulatory aspects in relation to the implementation of Resolution **155 (Rev. WRC-19).**

Band: 13.25–13.4 GHz
Service: Aeronautical radionavigation (airborne Doppler radar)
Allocation:

GHz 13.25–13.4		
Allocation to Services		
Region 1	Region 2	Region 3
13.25–13.4	EARTH EXPLORATION-SATELLITE (active) AERONAUTICAL RADIONAVIGATION 5.497 SPACE RESEARCH (active) 5.498A 5.499	

Footnotes:

5.497 The use of the band 13.25–13.4 GHz by the aeronautical radionavigation service is limited to Doppler navigation aids.

5.498A The Earth exploration-satellite (active) and space research (active) services operating in the band 13.25–13.4 GHz shall not cause harmful interference to, or constrain the use and development of, the aeronautical radionavigation service.

5.499 *Additional allocation*: in Bangladesh and India, the band 13.25–14 GHz is also allocated to the fixed service on a primary basis. In Pakistan, the band 13.15–13.75 GHz is allocated to the fixed service on a primary basis. (WRC-12)

ICAO POLICY

- No change to the allocations as there is a continuing aeronautical requirement for this band.
- No change to RR No. **5.497**.

The band 13.25–13.4 GHz is extensively used for airborne Doppler radar and ground mapping radar. These systems are used to determine ground speed, drift and distance travelled as well as ground mapping. The use of these radar systems is expected to continue for the long term. The band is shared with the Earth exploration-satellite service and the space research service.

AVIATION USE: RR No. **5.497** limits the use to Doppler navigation aids, which will continue to be used. Airborne Doppler navigation systems are widely used for specialized applications such as continuous determination of ground speed and drift angle information of an aircraft with respect to the ground. The information is derived by measuring the Doppler shift of signals transmitted from the aircraft in several narrow beams pointed towards the surface, backscattered by the surface and received by the Doppler radar receiver.

COMMENTARY: The Communications Divisional Meeting (1978) and the *Report of the Communications/Operations (COM/OPS) Divisional Meeting (1985)* (Doc 9464) (Appendix C to the report on Agenda Item 8 refers) both confirmed the need to retain this allocation. This requirement was confirmed in 1997.

Band: 14.4–14.47 GHz

Note: The frequency bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.5 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Regions 1 and 3 and 19.7–20.2 GHz (space-to-Earth), and in the frequency bands 14-14.47 GHz (Earth-to-space) and 29.5–30.0 GHz (Earth-to-space) were identified by ITU WRC-15 for usage for command and non-payload communications of UAS (termed RPAS C2 link in ICAO), subject to being found suitable for meeting the requirements of ICAO, and completion of the requirements of Resolution **155 (WRC-15)**

Service: Fixed satellite service

Allocation:

GHz **14.4–14.47**		
Allocation to Services		
Region 1	Region 2	Region 3
14.4–14.47	FIXED FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.484B 5.506 5.506B MOBILE except aeronautical mobile Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.509A Space research (space-to-Earth) 5.504A	

Footnotes:

5.457A In the frequency bands 5 925–6 425 MHz and 14–14.5 GHz, earth stations located on board vessels may communicate with space stations of the fixed-satellite service. Such use shall be in accordance with Resolution **902 (WRC-03)**. In the frequency band 5 925–6 425 MHz, earth stations located on board vessels and communicating with space stations of the fixed-satellite service may employ transmit antennas with minimum diameter of 1.2 m and operate without prior agreement of any administration if located at least 330 km away from the low-water mark as officially recognized by the coastal State. All other provisions of Resolution **902 (WRC-03)** shall apply. (WRC-15)

5.457B In the frequency bands 5 925–6 425 MHz and 14–14.5 GHz, earth stations located on board vessels may operate with the characteristics and under the conditions contained in Resolution **902 (WRC-03)** in Algeria, Saudi Arabia, Bahrain, Comoros, Djibouti, Egypt, United Arab Emirates, Jordan, Kuwait, Libya, Morocco, Mauritania, Oman, Qatar, the Syrian Arab Republic, Sudan, Tunisia and Yemen, in the maritime mobile-satellite service on a secondary basis. Such use shall be in accordance with Resolution **902 (WRC-03)**. (WRC-15)

5.484A The use of the bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.75 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Region 1, 13.75–14.5 GHz (Earth-to-space), 17.8–18.6 GHz (space-to-Earth), 19.7–20.2 GHz (space-to-Earth), 27.5–28.6 GHz (Earth-to-space), 29.5–30 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite service is subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. 5.43A does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)

5.484B Resolution **155 (WRC-15)*** shall apply. (WRC-15)

* *Note by the Secretariat:* This Resolution was revised by WRC-19.

5.504A In the band 14–14.5 GHz, aircraft earth stations in the secondary aeronautical mobile-satellite service may also communicate with space stations in the fixed-satellite service. The provisions of Nos. 5.29, 5.30 and 5.31 apply. (WRC-03)

5.504B Aircraft earth stations operating in the aeronautical mobile-satellite service in the frequency band 14–14.5 GHz shall comply with the provisions of Annex 1, Part C of Recommendation ITU-R M.1643-0, with respect to any radio astronomy station performing observations in the 14.47–14.5 GHz

frequency band located on the territory of Spain, France, India, Italy, the United Kingdom and South Africa. (WRC-15)

5.506 The band 14–14.5 GHz may be used, within the fixed-satellite service (Earth-to-space), for feeder links for the broadcasting-satellite service, subject to coordination with other networks in the fixed-satellite service. Such use of feeder links is reserved for countries outside Europe.

5.506A In the band 14–14.5 GHz, ship earth stations with an e.i.r.p. greater than 21 dBW shall operate under the same conditions as earth stations located on board vessels, as provided in Resolution **902 (WRC-03)**. This footnote shall not apply to ship earth stations for which the complete Appendix 4 information has been received by the Bureau prior to 5 July 2003. (WRC-03)

5.506B Earth stations located on board vessels communicating with space stations in the fixed-satellite service may operate in the frequency band 14–14.5 GHz without the need for prior agreement from Cyprus and Malta, within the minimum distance given in Resolution **902 (WRC-03)** from these countries. (WRC-15)

5.509A In the frequency band 14.3–14.5 GHz, the power flux-density produced on the territory of the countries of Saudi Arabia, Bahrain, Botswana, Cameroon, China, Côte d'Ivoire, Egypt, France, Gabon, Guinea, India, Iran (Islamic Republic of), Italy, Kuwait, Morocco, Nigeria, Oman, the Syrian Arab Republic, the United Kingdom, Sri Lanka, Tunisia and Viet Nam by any aircraft earth station in the aeronautical mobile-satellite service shall not exceed the limits given in Annex 1, Part B of Recommendation ITU-R M.1643-0, unless otherwise specifically agreed by the affected administration(s). The provisions of this footnote in no way derogate the obligations of the aeronautical mobile-satellite service to operate as a secondary service in accordance with No**. 5.29**. (WRC-15)

ICAO POLICY

- To conduct studies within ICAO to determine if the implementation of C2 Links in this frequency band is suitable for meeting the requirements of RPAS.
- To support within the ITU-R the relevant studies of technical, operational and regulatory aspects in relation to the implementation

of Resolution **155 (WRC-15).**

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Band: 15.4–15.7 GHz
Service: Aeronautical radionavigation
(ASDE/airborne weather radar, other systems)
Allocation:

GHz 15.4–15.7		
Allocation to Services		
Region 1	Region 2	Region 3
15.4–15.43	RADIOLOCATION 5.511E 5.511F AERONAUTICAL RADIONAVIGATION	
15.43–15.63	FIXED-SATELLITE (Earth-to-space) 5.511A RADIOLOCATION 5.511E 5.511F AERONAUTICAL RADIONAVIGATION 5.511C	
15.63–15.7	RADIOLOCATION 5.511E 5.511F AERONAUTICAL RADIONAVIGATION	

Footnotes:

5.511A Use of the frequency band 15.43–15.63 GHz by the fixed-satellite service (Earth-to-space) is limited to feeder links of non-geostationary systems in the mobile-satellite service, subject to coordination under **9.11A**. (WRC-15)

5.511C Stations operating in the aeronautical radionavigation service shall limit the effective e.i.r.p. in accordance with Recommendation ITU-R S.1340-0. The minimum coordination distance required to protect the aeronautical radionavigation stations (No. **4.10** applies) from harmful interference from feeder-link earth stations and the maximum e.i.r.p. transmitted towards the local horizontal plane by a feeder-link earth station shall be in accordance with Recommendation ITU-R S.1340-0. (WRC-15)

5.511E In the frequency band 15.4–5.7 GHz, stations operating in the radiolocation service shall not cause harmful interference to, or claim protection from, stations operating in the aeronautical radionavigation service.

5.511F In order to protect the radio astronomy service in the frequency band

15.35–15.4 GHz, radiolocation stations operating in the frequency band 15.4-15.7 GHz shall not exceed the power flux-density level of −156 dB(W/m^2) in a 50 MHz bandwidth in the frequency band 15.35–15.4 GHz, at any radio astronomy observatory site for more than 2 per cent of the time.

ICAO POLICY

- No change to the allocation to the aeronautical radionavigation service.
- No change to RR Nos. **5.511A** and **5.511C** which would introduce further restrictions to aeronautical use of this band.

The band 15.4–15.7 GHz is used for ground-based primary surveillance radar systems including precision approach radar (PAR) and airport surveillance detection equipment (ASDE). The main purpose of these systems is to provide surveillance to support precision approach to aircraft and to detect traffic at airports. This use is expected to continue to well beyond 2030. The use of the band is shared with the fixed-satellite service (Earth-to-space and space-to-Earth) and the radio location service (RLS). No FSS use has been registered with the ITU within this band.

AVIATION USE: This 20 mm band is used for a variety of civil and military systems using conventional radionavigation and radar techniques. An important civil use of this band is for ASDE for operational control of aircraft and vehicle ground movement at airports. This is an expanding requirement, as congestion at airports spreads and ground manoeuvring areas begin to saturate. Predictions made in Europe, for example, indicate a growing problem with surface movement, already affecting a number of major hubs, with saturation having occurred at major western European airports. ASDE radar is one preferred solution, and equipment operating in this frequency band, which offers a good compromise between antenna size and propagation characteristics, is presently in use at several main international airports. Typically, in Region 2, the band 15.6–16.6 GHz is used for ASDE radar.

Another civil use is that of height and obstruction measurement using radar techniques. This use is presently limited for general application to smaller aircraft operating into secondary and temporary landing areas. A forecast expansion in this use for specialized civil (as well as military) use has been predicted.

Both of these civil uses are ongoing for the foreseeable future.

The band 15.5–15.7 GHz is also used for airborne weather and ground mapping radar. These systems support the safe passage of an aircraft in the vicinity of turbulent weather conditions. It provides timely warnings of rapidly changing weather conditions as an aid to in-flight route planning. In addition, such equipment could support maintaining contact with geographic features, such as shorelines, as a supplement to navigational orientation.

This band is also available for use by civil or military radionavigation systems implemented for national purposes. The band offers the possibility for compact airborne systems which are light in weight and which have small antenna dimensions. High definition radar and precision landing systems are some examples of applications.

COMMENTARY:

Discussions and agreements at ITU conferences

WRC-95 discussed and agreed upon an allocation in the band 15.4–15.7 GHz for the FSS for feeder links to NGSO mobile satellites. The decision was made without full knowledge of the use made of the band by the ARNS. To identify and resolve any compatibility problem, Resolutions **116** and **117** were adopted calling for further study. These studies were undertaken by ITU-R WP4/1 — dealing mostly with the FSS — which identified a much more extensive use of the band than had originally been envisaged at CPM-95 and WRC-95. A range of applications, covering both airborne and ground systems, for both civil and military aviation purposes was identified. Sharing criteria were developed and are now fully documented in ITU-R Recommendations S.1340 and S.1341 which also recommend a partitioning of the band into three sections, which now appear in the Table of Frequency Allocations. Primarily, this was done to give added protection to the radio astronomy service in the band below 15.4 GHz and because the bottom 300 kHz and the top 700 kHz were too restrictive to be exploited by the FSS. The FSS allocation is for both Earth-to-space and space-to-Earth directions.

WRC-97 reviewed the results of studies, adopted the partitioning of the band, and modified RR Nos. **5.511A** and **5.511D** to provide a framework of control on the FSS to protect other services. RR No. **5.511B**, which prohibited airborne use in the 15.45–15.65 GHz section, was deleted in line with the agreed ICAO policies. RR No. **5.511C** is a restriction placed on the ARNS to limit the interference to FSS Earth stations and to impose a coordination distance on the FSS for the protection of ARNS stations.

WRC-97 also adopted Resolution **123** calling for studies of the protection required

for the radio astronomy service. The Resolution was reviewed at WRC-2000, which made further changes to the footnotes to make the control more effective, and was subsequently deleted.

The allocation of the FSS to this band has the potential to significantly affect the flexible use by aviation systems. At WRC-95, the FSS requirement was stated as for a "small number of stations". Despite the failure of one mobile-satellite system operator (at least) to proceed with an implementation to use the band, aviation has continued to meet a determined resistance within ITU to limit the allocation to a more realistic level. A country or regional footnote would be an example of an appropriate limitation measure.

The sequence of events which has taken place in the discussions on this band is indicative of the present intense pressure to find spectrum for the new NGSO services. Towards this purpose, the normal ITU processes of "study then allocate" have been reversed. Experience shows that it is considerably more difficult to remove an unjustified allocation once agreed to at a WRC than it is to allocate one in the first place. While a moderate amount of sharing with downlink space services is technically possible in this band, as determined by the ITU-R work, constraining the present use of this band by aviation and future exploitation of the allocation by aeronautical services and systems is not a satisfactory situation.

ARNS protection and planning implications

The ITU-R Recommendations quoted above have identified and calculated the sharing criteria necessary for the protection of all of the present ARNS systems known to use the band. These indicate, among other criteria, the need for coordination distances of between 310 km (landing and airborne radar measurement systems) and 600 km for general purpose airborne radar, referenced to the areas of operation. Coordination with the location of ground Earth stations prior to implementation is necessary to assess the potential for interference. These limitations and those of the power flux-density in the space-to-Earth direction create difficulties in terms of the siting of the FSS Earth station. Concern is expressed on the practicalities to maintain an exclusion zone around FSS stations for aircraft equipped with these systems.

The results of sharing studies (see Attachment G) to protect the aeronautical radionavigation services, which included ASDE and a radar altimeter, have been found unduly restrictive to the FSS — for example, very large dish sizes at Earth stations were necessary, and the distance separations from navigation facilities were large. The use of this band by the FSS appears to be minimal, and a worldwide allocation to the FSS is hence an inefficient deployment of scarce spectrum. Limited use in only a few countries in the future should be accommodated by a footnote. A footnote allocation is reasonable since the ITU-R Recommendation on sharing can be used as an effective

criterion for coordination between countries.

In FSS terms, this band is a supplementary band for feeder link operation for possible use as a backup or spill-over from the main FSS feeder link bands at 19 and 29 GHz. Resolution **117**, recognizing (b), indicates only a small number of stations, and ITU discussions show a limited interest among FSS operators (possibly only one country in North America and one in Europe). Provided that the ARNS has a flexible use of the band, based on an agreed set of clear and safe technical sharing conditions, there is a manageable sharing situation. As a service to be shared with the ARNS, the FSS is likely to be disciplined in its operations, highly stable in its implementation and technical characteristics, and hence be preferred as a sharing partner if sharing is necessary.

The future outlook for the band

The considerations above are the main elements in defining the aeronautical position on this matter. The band is in intensive use and will remain so. The short wavelength of operation permits the deployment of systems on the ground with a minimum of interference planning. Likewise, airborne use is highly practical and economical. The pressures on the spectrum are such that all worldwide exclusive bands above 1 GHz are very suitable for satellite services, and existing users, such as the ARNS, will continue to be pressured to share or vacate, especially in the situation where there is a perception of less than full use. This is a highly useful band for the exploitation of compact airborne radar and radio altimeter systems for use in civil aviation and needs to be preserved for possible future implementation. The ICAO policy is based on these principles and aims to coordinate efforts to preserve future use.

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Band: 19.7–20.2 GHz

Note: The frequency bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.5 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Regions 1 and 3 and 19.7–20.2 GHz (space-to-Earth), and in the frequency bands 14-14.47 GHz (Earth-to-space) and 29.5–30.0 GHz (Earth-to-space) were identified by ITU WRC-15 for usage for command and non-payload communications of UAS (termed RPAS C2 link in ICAO), subject to being found suitable for meeting the requirements of ICAO, and completion of the requirements of Resolution **155 (WRC-15)**

Service: Fixed satellite service

Allocation:

GHz 19.7–20.2		
Allocation to Services		
Region 1	Region 2	Region 3
19.7–20.1 FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.516B 5.527A Mobile-satellite (space-to-Earth) 5.524	**19.7–20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.516B 5.527A MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528 5.529	**19.7–20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.516B 5.527A MOBILE-SATELLITE (space-to-Earth) 5.524
20.1–20.2	FIXED-SATELLITE (space-to-Earth) 5.484A 5.484B 5.516B 5.527A MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528	

Footnotes:

5.484A The use of the bands 10.95-11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.75 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Region 1, 13.75–14.5 GHz (Earth-to-space), 17.8–18.6 GHz (space-to-Earth), 19.7-20.2 GHz (space-to-Earth), 27.5–28.6 GHz (Earth-to-space), 29.5–30 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite

service is subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. 5.43A does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)

5.484B Resolution **155 (WRC-15)*** shall apply. (WRC-15)

* *Note by the Secretariat:* This Resolution was revised by WRC-19.

5.516B The following bands are identified for use by high-density applications in the fixed-satellite service:

17.3–17.7 GHz (space-to-Earth) in Region 1,
18.3–19.3 GHz (space-to-Earth) in Region 2,
19.7–20.2 GHz (space-to-Earth) in all Regions,
39.5–40 GHz (space-to-Earth) in Region 1,
40–40.5 GHz (space-to-Earth) in all Regions,
40.5–42 GHz (space-to-Earth) in Region 2,
47.5–47.9 GHz (space-to-Earth) in Region 1,
48.2–48.54 GHz (space-to-Earth) in Region 1,
49.44–50.2 GHz (space-to-Earth) in Region 1,
and
27.5–27.82 GHz (Earth-to-space) in Region 1,
28.35–28.45 GHz (Earth-to-space) in Region 2,
28.45–28.94 GHz (Earth-to-space) in all Regions,
28.94–29.1 GHz (Earth-to-space) in Region 2 and 3,
29.25–29.46 GHz (Earth-to-space) in Region 2,
29.46–30 GHz (Earth-to-space) in all Regions,
48.2–50.2 GHz (Earth-to-space) in Region 2.

This identification does not preclude the use of these bands by other fixed-satellite service applications or by other services to which these bands are allocated on a co-primary basis and does not establish priority in these Radio Regulations among users of the bands. Administrations should take this into

account when considering regulatory provisions in relation to these bands. See Resolution **143 (WRC-03)***. (WRC-03)

5.524 Additional allocation: in Afghanistan, Algeria, Saudi Arabia, Bahrain, Brunei Darussalam, Cameroon, China, Congo (Rep. of the), Costa Rica, Egypt, the United Arab Emirates, Gabon, Guatemala, Guinea, India, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Lebanon, Malaysia, Mali, Morocco, Mauritania, Nepal, Nigeria, Oman, Pakistan, the Philippines, Qatar, the Syrian Arab Republic, the Dem. Rep. of the Congo, the Dem. People's Rep. of Korea, Singapore, Somalia, Sudan, South Sudan, Chad, Togo and Tunisia, the frequency band 19.7–21.2 GHz is also allocated to the fixed and mobile services on a primary basis. This additional use shall not impose any limitation on the power flux-density of space stations in the fixed-satellite service in the frequency band 19.7–21.2 GHz and of space stations in the mobile-satellite service in the frequency band 19.7–20.2 GHz where the allocation to the mobile-satellite service is on a primary basis in the latter frequency band. (WRC-15)

5.525 In order to facilitate interregional coordination between networks in the mobile-satellite and fixed-satellite services, carriers in the mobile-satellite service that are most susceptible to interference shall, to the extent practicable, be located in the higher parts of the bands 19.7-20.2 GHz and 29.5-30 GHz.

5.526 In the bands 19.7–20.2 GHz and 29.5–30 GHz in Region 2, and in the bands 20.1–20.2 GHz and 29.9–30 GHz in Regions 1 and 3, networks which are both in the fixed-satellite service and in the mobile-satellite service may include links between earth stations at specified or unspecified points or while in motion, through one or more satellites for point-to-point and point-to-multipoint communications.

5.527 In the bands 19.7–20.2 GHz and 29.5–30 GHz, the provisions of No. **4.10** do not apply with respect to the mobile-satellite service.

5.527A The operation of earth stations in motion communicating with the FSS is subject to Resolution **156 (WRC-15)**. (WRC-15)

5.528 The allocation to the mobile-satellite service is intended for use by networks which use narrow spot-beam antennas and other advanced technology at the space stations. Administrations operating systems in the

* *Note by the Secretariat.*— This Resolution was revised by WRC-07.

mobile-satellite service in the band 19.7–20.1 GHz in Region 2 and in the band 20.1–20.2 GHz shall take all practicable steps to ensure the continued availability of these bands for administrations operating fixed and mobile systems in accordance with the provisions of No. **5.524**.

5.529 The use of the bands 19.7–20.1 GHz and 29.5–29.9 GHz by the mobile-satellite service in Region 2 is limited to satellite networks which are both in the fixed-satellite service and in the mobile-satellite service as described in No. **5.526.**

ICAO POLICY

- To conduct studies within ICAO to determine if the implementation of C2 links in this frequency band is suitable for meeting the requirements of RPAS.
- To support within the ITU-R the relevant studies of technical, operational and regulatory aspects in relation to the implementation of Resolution **155 (Rev. WRC-19).**

Band: 24.25–24.65 GHz
Service: Radionavigation (ASDE)
Allocation: (NOC)
ICAO policy: (NOC)

GHz 24.25–24.65		
Allocation to Services		
Region 1	Region 2	Region 3
24.25–24.45 FIXED	**24.25–24.45** RADIONAVIGATION	**24.25–24.45** RADIONAVIGATION FIXED MOBILE
24.45–24.65 FIXED INTER-SATELLITE	**24.45–24.65** INTER-SATELLITE RADIONAVIGATION 5.533	**24.45–24.65** FIXED INTER-SATELLITE MOBILE RADIONAVIGATION 5.533

Footnote:

5.533 The inter-satellite service shall not claim protection from harmful interference from airport surface detection equipment stations of the radionavigation service.

ICAO POLICY

No change to the radionavigation allocations in Region 2 and Region 3.

AVIATION USE: These bands are used for airport surface detection equipment (ASDE). The higher frequency provides greater target resolution. RR No. **5.533** should be noted.

COMMENTARY: In 1997, the need to retain this allocation was reconfirmed. The ASDE requirement assumes greater priority with increasing airport congestion.

Band: 29.5–30 GHz

Note: The frequency bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.5 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in Regions 1 and 3 and 19.7–20.2 GHz (space-to-Earth), and in the frequency bands 14-14.47 GHz (Earth-to-space) and 29.5–30.0 GHz (Earth-to-space) were identified by ITU WRC-15 for usage for command and non-payload communications of UAS (termed RPAS C2 link in ICAO), subject to being found suitable for meeting the requirements of ICAO, and completion of the requirements of Resolution **155**. **(WRC-15)**

Service: Fixed satellite service

Allocation:

GHz 29.5–30		
Allocation to Services		
Region 1	Region 2	Region 3
29.5–29.9 FIXED-SATELLITE (Earth-to-space) 5.484A 5.484B 5.516B 5.527A 5.539 EARTH EXPLORATION-SATELLITE (Earth-to-space) 5.541 MOBILE-SATELLITE (Earth-to-space) 5.540 5.542	**29.5–29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.484B 5.516B 5.527A 5.539 MOBILE-SATELLITE (Earth-to-space) EARTH EXPLORATION-SATELLITE (Earth-to-space) 5.541 5.525 5.526 5.527 5.529 5.540	**29.5–29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.484B 5.516B 5.527A 5.539 EARTH EXPLORATION-SATELLITE (Earth-to-space) 5.541 MOBILE-SATELLITE (Earth-to-space) 5.540 5.542
29.9–30	FIXED-SATELLITE (Earth-to-space) 5.484A 5.484B 5.516B 5.527A 5.539	

Footnotes:

5.484A The use of the bands 10.95–11.2 GHz (space-to-Earth), 11.45–11.7 GHz (space-to-Earth), 11.7–12.2 GHz (space-to-Earth) in Region 2, 12.2–12.75 GHz (space-to-Earth) in Region 3, 12.5–12.75 GHz (space-to-Earth) in

Region 1, 13.75–14.5 GHz (Earth-to-space), 17.8–18.6 GHz (space-to-Earth), 19.7–20.2 GHz (space-to-Earth), 27.5–28.6 GHz (Earth-to-space), 29.5–30 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite service is subject to application of the provisions of No. 9.12 for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. 5.43A does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)

5.484B Resolution 155 (WRC-15)* shall apply. (WRC-15)

* *Note by the Secretariat:* This Resolution was revised by WRC-19.

5.516B The following bands are identified for use by high-density applications in the fixed-satellite service:

17.3–17.7 GHz	(space-to-Earth) in Region 1,
18.3–19.3 GHz	(space-to-Earth) in Region 2,
19.7–20.2 GHz	(space-to-Earth) in all Regions,
39.5–40 GHz	(space-to-Earth) in Region 1,
40–40.5 GHz	(space-to-Earth) in all Regions,
40.5–42 GHz	(space-to-Earth) in Region 2,
47.5–47.9 GHz	(space-to-Earth) in Region 1,
48.2–48.54 GHz	(space-to-Earth) in Region 1,
49.44–50.2 GHz	(space-to-Earth) in Region 1,
and	
27.5–27.82 GHz	(Earth-to-space) in Region 1,
28.35–28.45 GHz	(Earth-to-space) in Region 2,
28.45–28.94 GHz	(Earth-to-space) in all Regions,
28.94–29.1 GHz	(Earth-to-space) in Region 2 and 3,
29.25–29.46 GHz	(Earth-to-space) in Region 2,
29.46–30 GHz	(Earth-to-space) in all Regions,
48.2–50.2 GHz	(Earth-to-space) in Region 2.

This identification does not preclude the use of these bands by other fixed-satellite service applications or by other services to which these bands are allocated on a co-primary basis and does not establish priority in these Radio Regulations among users of the bands. Administrations should take this into account when considering regulatory provisions in relation to these bands. See Resolution **143 (WRC-03)** *. (WRC-03)

5.525 In order to facilitate interregional coordination between networks in the mobile-satellite and fixed-satellite services, carriers in the mobile-satellite service that are most susceptible to interference shall, to the extent practicable, be located in the higher parts of the bands 19.7–20.2 GHz and 29.5–30 GHz.

5.526 In the bands 19.7–20.2 GHz and 29.5–30 GHz in Region 2, and in the bands 20.1–20.2 GHz and 29.9–30 GHz in Regions 1 and 3, networks which are both in the fixed-satellite service and in the mobile-satellite service may include links between earth stations at specified or unspecified points or while in motion, through one or more satellites for point-to-point and point-to-multipoint communications.

5.527 In the bands 19.7–20.2 GHz and 29.5–30 GHz, the provisions of No. **4.10** do not apply with respect to the mobile-satellite service.

5.527A The operation of earth stations in motion communicating with the FSS is subject to Resolution **156 (WRC-15)**. (WRC-15)

5.529 The use of the bands 19.7–20.1 GHz and 29.–29.9 GHz by the mobile-satellite service in Region 2 is limited to satellite networks which are both in the fixed-satellite service and in the mobile-satellite service as described in No. **5.526**.

5.539 The band 27.5–30 GHz may be used by the fixed-satellite service (Earth-to-space) for the provision of feeder links for the broadcasting-satellite service.

5.540 *Additional allocation:* The band 27.501–29.999 GHz is also allocated to the fixed-satellite service (space-to-Earth) on a secondary basis for beacon transmissions intended for up-link power control.

5.541 In the band 28.5–30 GHz, the earth exploration-satellite service is

* *Note by the Secretariat.*— This Resolution was revised by WRC-07.

limited to the transfer of data between stations and not to the primary collection of information by means of active or passive sensors.

5.542 *Additional allocation:* In Algeria, Saudi Arabia, Bahrain, Brunei Darussalam, Cameroon, China, Congo (Rep. of the), Egypt, the United Arab Emirates, Eritrea, Ethiopia, Guinea, India, Iran (Islamic Republic of), Iraq, Japan, Jordan, Kuwait, Lebanon, Malaysia, Mali, Morocco, Mauritania, Nepal, Oman, Pakistan, Philippines, Qatar, the Syrian Arab Republic, the Dem. People's Rep. of Korea, Somalia, Sudan, South Sudan, Sri Lanka and Chad, the band 29.5-31 GHz is also allocated to the fixed and mobile services on a secondary basis. The power limits specified in Nos. **21.3** and **21.5** shall apply. (WRC-12)

ICAO POLICY

- To conduct studies within ICAO to determine if the implementation of C2 links in this frequency band is suitable for meeting the requirements of RPAS.
- To support within the ITU-R the relevant studies of technical, operational and regulatory aspects in relation to the implementation of Resolution **155 (Rev. WRC-19).**

Band: 31.8–33.4 GHz
Service: Radionavigation (ASDE), enhanced flight vision systems
Allocation:

GHz 31.8–33.4		
Allocation to Services		
Region 1	Region 2	Region 3
31.8–32	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547B 5.548	
32–32.3	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547C 5.548	
32.3–33	FIXED 5.547A INTER-SATELLITE RADIONAVIGATION 5.547 5.547D 5.548	
33–33.4	FIXED 5.547A RADIONAVIGATION 5.547 5.547E	

Footnotes:

5.547 The bands 31.8–33.4 GHz, 37–40 GHz, 40.5–43.5 GHz, 51.4–52.6 GHz, 55.78–59 GHz and 64–66 GHz are available for high-density applications in the fixed service (see Resolution **75 (WRC-2000)***). Administrations should take this into account when considering regulatory provisions in relation to these bands. Because of the potential deployment of high-density applications in the fixed-satellite service in the bands 39.5–40 and 40.5–42 GHz (see No. **5.516B**), administrations should further take into account potential constraints to high-density applications in the fixed service, as appropriate. (WRC-07)

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* *Note by the Secretariat:* This Resolution was revised by WRC-12.

5.547A Administrations should take practical measures to minimize the potential interference between stations in the fixed service and airborne stations in the radionavigation service in the 31.8–33.4 GHz band, taking into account the operational needs of the airborne radar systems. (WRC-2000)

5.547B *Alternative allocation:* in the United States, the band 31.8–32 GHz is allocated to the radionavigation and space research (deep space) (space-to-Earth) services on a primary basis. (WRC-97)

5.547C *Alternative allocation:* in the United States, the band 32–32.3 GHz is allocated to the radionavigation and space research (deep space) (space-to-Earth) services on a primary basis. (WRC-03)

5.547D *Alternative allocation:* in the United States, the band 32.3–33 GHz is allocated to the inter-satellite and radionavigation services on a primary basis. (WRC-97)

5.547E *Alternative allocation:* in the United States, the band 33–33.4 GHz is allocated to the radionavigation service on a primary basis. (WRC-97)

5.548 In designing systems for the inter-satellite service in the band 32.3–33 GHz, for the radionavigation service in the band 32-33 GHz, and for the space research service (deep space) in the band 31.8–32.3 GHz, administrations shall take all necessary measures to prevent harmful interference between these services, bearing in mind the safety aspects of the radionavigation service (see Recommendation **707**). (WRC-03)

ICAO POLICY

No change to the radionavigation allocations.

The band 31.8–33.4 GHz is used by aviation to support ground-based airport surface detection equipment (ASDE) radar, mainly to detect traffic at airports. The band is shared with the mobile, the fixed and the space research service.

The 31.8–33.4 GHz frequency range is also used for embedded systems that generate navigation information and a video image of the external scene and provide them to the pilot. The band offers a good compromise between resolution and atmosphere penetration in bad weather conditions.

AVIATION USE: Use of the band for ground movement radar detection equipment is reported.

COMMENTARY: The *Report of the Communications Divisional Meeting (1978)* (Doc 9239) (Appendix C to the report on Agenda Item 3 refers) reported some use of these bands for ASDE and for airborne precision approach mapping radar.

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SECTION 7-III. RADIO REGULATIONS AND OTHER ITU MATERIAL OF IMPORTANCE TO AERONAUTICAL SERVICES

7-III.1 GENERAL

7-III.1.1 The ITU, which is governed by its Constitution and Convention, is an important forum for aeronautical radio services, and ultimately, for the continued operation of aviation. The principal areas where the ITU organization exercises its influence are:

a) the radio frequency bands needed to sustain the radio services; these may only be obtained through agreements made at ITU World Radiocommunication Conferences (WRCs);

b) standardization of systems and equipment with other services, to the degree necessary, which are often only achievable within the technical organs of the ITU;

c) problems of radio interference;

d) important regulations relating to frequencies and procedures for distress and safety communications which also affect the maritime and land mobile services; these can only be agreed and formalized within a common international forum; and

e) provisions dealing with licensing of radio stations and personnel.

7-III.1.2 Through the exercise of its authority and competence over the full telecommunications field, the ITU provides a focus for discussion and agreement. For example, in the use of satellite navigation and communication services which usually is multinational, multi-purpose and commercial in character, the full range of representative interests may only be addressed in a common telecommunications forum such as the ITU.

7-III.1.3 The ITU Radio Regulations contain authoritative treaty provisions representing worldwide agreement on the telecommunications matters within the ITU areas of interest.

7-III.1.4 The ITU deals with all telecommunications matters, both for radio and for line transmission purposes, and is supported by its technical agencies ITU-R

and ITU-T for study and research in radio and line transmission, respectively. Their output is normally in the form of Recommendations for worldwide publication and dissemination. A small proportion of ITU-R Recommendations are validated to the same treaty status as that in the Radio Regulations through incorporation of such Recommendations in the RR by means of a linked reference.

7-III.1.5 Section 7-III-2 below highlights Regulations of special importance to aviation indicating their context and scope in relation to aeronautical use of the spectrum.

7-III.2 ITU CONSTITUTION AND CONVENTION

7-III.2.1 The ITU is governed by the agreements contained in its Constitution, which defines the objectives, composition and basic structure of the organization. The ITU Convention lays down the personnel procedures, working methods and other matters of a procedural character. The present Constitution and Convention were last amended at the Plenipotentiary Conference in 2010 (Guadalajara, Mexico) (PP-10). Some amendments were introduced as a consequence of extending participation of Observers and Sector Members of the ITU-R Sector to WRCs.

7-III.2.2 The need to ensure the safety of life is covered in Article 1 of the ITU Convention which states that one of the purposes of the Union is to "*promote the adoption of measures for ensuring the safety of life through the cooperation of telecommunication* services". Additionally, Article 40 of the ITU Constitution on the priority of telecommunications concerning safety of life states that "*International telecommunication services must give absolute priority to all telecommunications concerning safety of life at sea, on land, in the air or in outer space, as well as to epidemiological telecommunications of exceptional urgency of the World Health Organization*".

7-III.2.3 Of special importance is Article 50 of the Constitution, which deals with relations with other international organizations, and stipulates that "In furtherance of complete international coordination on matters affecting telecommunication, the Union shall cooperate with international organizations having related interests and activities".

7-III.2.4 The participation of ICAO in plenipotentiary conferences is regulated in Article 23 of the Convention, which states:

"...

No. 267 1 The following shall be admitted to plenipotentiary conferences:

…

No. 269 d) observers of the following organizations, agencies and entities to participate in an advisory capacity:

...

No. 269D iv) the specialized agencies of the United Nations and the International Atomic Energy Agency;

…"

7-III.2.5 The participation of ICAO in radiocommunication conferences is regulated in Article 24 of the Convention, which states:

"…

No. 276 1 The following shall be admitted to radiocommunication conferences:

...

No. 278 b) observers of organizations and agencies referred to in Nos. 269A to 269D of this Convention, to participate in an advisory capacity;

…"

7-III-2.6 The participation of ICAO in radiocommunication assemblies is regulated in Article 25 of the Convention, which states:

"…

No. 295 1 The following shall be admitted to the assembly or conference:

…

No. 297 c) observers, to participate in an advisory capacity, from:

…

No. 297bis i) the organizations and agencies referred to in Nos. 269A to 269D of this Convention;

…"

7-III.2.7 The *General Rules of Conferences, Assemblies and Meetings of the Union* state in GR 44 that "... observers that may attend conferences in accordance with the relevant provisions of the Convention, shall not be entitled to submit proposals".

7-III.2.8 The *General Rules of Conferences, Assemblies and Meetings of the Union* (GR 61) indicate that "It shall be the duty of the chairman to protect the right of each delegation to express its opinion freely and fully on the point at issue". The Annex to the Constitution defines a delegation as "The totality of the delegates ... sent by the same Member State". As a result, the right to express an opinion freely and fully is granted by the ITU solely to Member States.

7-III.2.9 The application and a peculiar interpretation of the above provisions at WRC-2000 severely restricted the ability of ICAO to express its view at WRCs. Later during that conference, the restrictions were partly lifted. Action taken by ICAO, supported by the IMO, triggered the ITU to revise the role of observers (including those observers from United Nations specialized Agencies like ICAO) at their Conferences and Meetings.

7-III.2.10 The Plenipotentiary Conference in 2002 (Marrakech, Morocco) (PP-02) considered the situation of observers in ITU conferences and meetings. Particular attention was given to the situation of observers from organizations and agencies within the United Nations system, several of which play an important role in relation to the use of the radio frequency spectrum and satellite orbits. It was recognized that the current provisions of the Constitution, Convention and General Rules support the furnishing of advice to conferences from these observers on matters within their competence. It was, however, noted that certain misunderstandings arose at WRC-2000 that resulted in a departure from the established practice of previous conferences concerning their participation. There was agreement at PP-02 that such misunderstandings must be avoided in the future.

7-III.2.11 Therefore, "the Plenipotentiary Conference decided to confirm to upcoming radiocommunication conferences that observers referred to in Nos. 259 (269A) and 262 (269D) of the Convention may submit to these conferences information documents relevant to their mandates to be noted by Member States.

These information documents will continue to be distributed to the conference as per past practice and shall be referenced for information on the relevant daily agendas. Further, observers referred to in Nos. 259 (269A) and 262 (269D) may, with the authorization of the Chairman and in accordance with the Rules of Procedures (i.e. RP 16 and 17) (GR 44), provide advice on points relevant to their mandates. The information documents and advice shall not include or be treated as proposals. The right to make proposals, either written or oral, to such conferences is clearly reserved to Member States."

7-III.2.12 PP-06 further analysed the role of observers in the ITU and agreed to various suggested modifications regarding observers to the ITU Convention and the General Rules, and agreed to plenipotentiary conference Resolution 145 on the participation of observers in conferences, assemblies and meetings of the Union. The amendments consolidate the references to observers in the basic texts of the ITU and set out guidelines for the participation of different observers in various types of ITU conferences, assemblies and meetings. The resolution also incorporates the decisions of PP-02 concerning the participation of certain "observers in an advisory capacity" (including United Nations specialized agencies such as ICAO) in an advisory capacity in WRCs. The resolution stipulates, inter alia, that observers in an advisory capacity, such as ICAO:

1) are admitted to participate in plenary meetings;

2) may, if not otherwise decided by the plenary meeting, be admitted to participate in committees and their subsidiary groups;

3) are entitled to receive all documentation;

4) may submit information documents. These documents shall be clearly referenced as information documents on the appropriate meeting agendas;

5) may request the floor in these meetings in order to provide advice or information on points relevant to their mandates. Such advice shall not include or be treated as proposals;

6) are to be given the floor by the chairman after the last Member State or Sector Member on the list of speakers;

7) may be asked by the chairman during the course of a meeting to make a statement or to provide relevant information in order to assist the proceedings.

7-III.2.13 Participation of ICAO in the work of the Radiocommunication Sector (ITU-R) is primarily governed by the provisions in Article 19 of the Convention on the participation of entities and organizations other than administrations in the ITU's activities as well as by Resolution 145 on the participation of observers in conferences, assemblies and meetings of the Union as adopted by PP-06.

7-III.2.14 Article 19, subparagraph 6 (No. 236) states that "Any request from an organization referred to in Nos. 269B to 269D of this Convention to participate in the work of a Sector shall be sent to the Secretary-General, and the organization concerned shall be included in the lists referred to in No. 237 below". No. 237 indicates that "The Secretary-General shall compile and maintain lists of all entities and organizations referred to in Nos. 229 to 231 and Nos. 269B to 269D of this Convention that are authorized to participate in the work of each Sector". ICAO, as a specialized agency of the United Nations, is qualified under No. 269D to be added to this list.

7-III.2.15 Under the provisions of Articles 19, 23, 24 and 25 of the Convention and Resolution 145 of PP-06, the full participation of ICAO in the work of the ITU (plenipotentiary conferences, radiocommunication conferences and assemblies as well as sector meetings), including the submission of contributions and the full participation in the debate, is secured.

7-III.2.16 Important to note here is that the ITU-R Sector Members are admitted as observers to radiocommunication conferences on the basis of provision No. 280 contained in Article 24 of the Convention, thus identifying a different status between a Sector Member and a specialized agency of the United Nations, such as ICAO. Pursuant to Annex 3 of Resolution 145 of PP-06, ITU-R Sector Members at radiocommunication conferences are admitted to attend plenary meetings and committees, and may be asked by the chairman during the course of a meeting to provide relevant information in order to assist the proceedings or to make a statement, but shall not be authorized to participate in the debates.

7-III.3 RADIO REGULATIONS

7-III.3.1 The Radio Regulations are the principal ITU document (with a treaty status) for radio matters. Parts of the Radio Regulations are discussed, agreed and embodied in the Final Acts of WRCs. WRCs are now held every four years in a rolling sequence in which each conference drafts the agenda for the next, and the provisional agenda for the second sequential WRC. The agenda for a WRC is approved by the ITU Council. The Radio Regulations lay down the framework for international spectrum

management and contain the Table of Frequency Allocations, which is effectively the worldwide agreement on the deployment and conditions of use of all radio frequencies in the radio frequency spectrum. ICAO develops its material (e.g. SARPs) for radiocommunication and radionavigation systems within the framework set by the Radio Regulations. This section of the handbook reproduces Radio Regulations of particular importance to aeronautical services, and presents them with background comments which highlight their context and significance.

7-III.3.1.1 Chapter I (Articles 1 to 3) — Terminology and technical characteristics

The three Articles in this chapter contain fundamental material addressing terminology and technical conditions relating to all of the radio services. The chapter defines the interpretations to be placed on the terms and definitions used later in the Regulations to prescribe allocations and their conditions of use. It is designed as follows:

— Article 1 contains terms and definitions;
— Article 2 deals with nomenclature; and
— Article 3 focuses on the technical characteristics of stations.

7-III.3.1.2 Article 1 — Terms and definitions

The terms and definitions of importance to aeronautical services are in Attachment A to this handbook. The following should be noted:

a) the hierarchical structure of radio services (see Figure 3-3) which is repeated in the definitions for stations;

b) the carefully worded definition for radionavigation, in particular the reference to “obstruction warning”. The latter is interpretable to apply to primary and secondary radar used for air traffic purposes, airborne weather radar, radio altimeters, ground proximity warning systems, etc., since they support the safe navigation of aircraft;

c) the definition for a safety service (RR 1.59) noting that a service can temporarily become such during periods when the communications fulfil the criteria of safeguarding of human life and property. All air traffic communications and radionavigation used in civil aviation fall under this classification;

d) the various definitions relating to interference (RR 1.166 to RR 1.169) noting that interference is only "harmful" when it is serious or where it endangers the functioning of a radionavigation service or other safety service;

e) the definition of public correspondence (RR 1.116) which is based on the concept of availability to the public of the service of transmission. This definition also appears in the ITU Convention. Air traffic communications do not fall within the classification of public correspondence;

f) the definition of an administration (RR 1.2) which is broad in scope covering any national entity in which the responsibility for discharging ITU obligations is vested. This definition is notable for its imprecision which constantly leads to problems in interpretation; and

g) the highly important definitions for allocation, allotment and assignment at RR 1.16, RR 1.17 and RR 1.18, together with the Table at RR 5.1 reproduced below:

Term	*Frequency distribution to*
Allocation	Service
Allotment	Area or country
Assignment	Station

The first two, "allocation" and "allotment", are for determination by an ITU conference. Article 5 contains the agreed allocations for the total spectrum. The concept of allotment is only applied in a few instances by ITU, of which Appendix 27, the HF Allotment Plan for the aeronautical mobile (R) service, is a notable example. The third, "assignment", is a matter for national administrations and results in the issue of a licence to an operator to authorize the operation or reception of a radio station.

7-III.3.1.3 Service merging

Recommendation 34 (Rev. WRC-12) puts forward the idea to allocate frequency bands to the most broadly defined services for consideration by administrations

(*Recommends 1*) and calls on ITU-R, in conjunction with ICAO and IMO, to undertake studies of the possibilities (*instructs the Director of the Radiocommunication Bureau and requests the ITU-R study groups 2*). In general, ICAO does not support replacing explicit aeronautical safety allocations with generic allocations.

7-III.3.1.4 Access to AMS(R)S spectrum

WRC-97 agreed to convert all spectrum in the bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz into an allocation to the mobile-satellite service. These bands are now available, primarily on a first-come, first-served basis, to all space system providers and service operators, and with services available to all mobile users, land, sea or air, as commercially practicable. The sub-bands 1 545– 1 555 MHz and 1 646.5–1 656.5 MHz were originally allocated to the AMS(R)S on an exclusive basis and were the key elements of the CNS/ATM system in relation to the implementation of long-distance communications for voice and data. The strong reservations of international civil aviation were not sufficient to stop this conversion process for the AMS(R)S allocations at 1 545–1 555 MHz and 1 646.5–1 656.5 MHz, and a new RR No. 5.357A was agreed which was intended to preserve a measure of assurance that sufficient frequencies for AMS(R)S needs would be available, as well as the requirement for a dynamic priority for ATC messages in a common system. In addition, Resolution 218 (WRC-97) requested ITU-R to study the feasibility of prioritization, real-time pre-emptive access and, if necessary, the interoperability between the mobile services.

This situation of generic allocations to the mobile-satellite services could have profound adverse effects on the provision and operation of satellite communications for ATC purposes in the years ahead. Apart from the practicability of non-aeronautical satellite systems to give priority to ATC satellite communications in a multi-user service, it is by no means certain whether aviation's growing needs for interference-free communications satisfying the integrity, reliability and availability requirements in Annex 10 can be met in the long term. Controlled evaluations and operational trials, with the results discussed in both ICAO and ITU-R, are necessary prerequisites to providing the short-term guarantees that are necessary. The aspect of long-term availability of sufficient frequencies is a more difficult question, which will call for new and corroborated estimates of future demand for ATC and AOC and an assessment of the available spectrum, taking into account the predicted total mobile-satellite situation at some point in the future. Aeronautical public correspondence (AAC and APC) would have access to the full mobile-satellite allocation available.

It is not probable that the allocation to the generic mobile service, as agreed at WRC-

97, can be easily changed into an exclusive aeronautical allocation, and the likelihood is that all of the spectrum in the generic mobile-satellite frequency band (33 MHz in each direction) will be rapidly implemented and shared between many non-aeronautical space system providers. A new strategy for the future is a priority subject for discussion, as is the careful monitoring and study of the practical situation as it enfolds.

7-III.3.1.5 Articles 2 and 3

Article 2: Nomenclature

This Article defines the convention for the description of frequency bands and other associated information.

Article 3: Technical characteristics of stations

This Article contains important guidelines which have to be observed in the engineering and design of radio stations. Of particular interest to aviation is RR 3.3 which places an obligation on services to take account of the services in adjacent bands. The full text of this Regulation is:

> 3.3 Transmitting and receiving equipment intended to be used in a given part of the frequency spectrum should be designed to take into account the technical characteristics of transmitting and receiving equipment likely to be employed in neighbouring and other parts of the spectrum, provided that all technically and economically justifiable measures have been taken to reduce the level of unwanted emissions from the latter transmitting equipment and to reduce the susceptibility to interference of the latter receiving equipment.

Aircraft receiving equipment is vulnerable to interference over a large geographic area and the requirement placed on transmitters in this Regulation is a beneficial statement of good practice. Conversely, aircraft receivers should be designed with good interference rejection characteristics as a prior condition of seeking emission control from other radio services. Radio Regulation 3.13 has a similar message which qualifies RR 3.3 and introduces a proximity condition implying that very close operation is a special case.

ICAO POLICY ON CHAPTER I

- No changes should be made to the Regulations of importance to aeronautical services as identified above.
- Service merging of aeronautical radionavigation in the worldwide allocations where an ICAO standard system operates with other radiodetermination services is not practicable without prejudicing the service of the aeronautical system.
- Service merging of aeronautical mobile service allocations with other services is not possible due to the radically different operational requirements.

7-III.3.2 Chapter II (Articles 4 to 6) — Frequencies

7-III.3.2.1 *Article 4: Assignment and use of frequencies*

This Article contains several very important provisions relating to the deployment of frequencies. The following are of special interest to aeronautical services.

4.4 Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.

The objective of this Regulation is to prevent registered assignments which are not in accordance with the Radio Regulations from causing interference to those which are in conformity. It also has the important secondary purpose of establishing rights for "non RR-conforming" registrations on a "non-interference" basis, which then establishes priority rights over those "non-interference" registrations that come later. It has a highly important conservation role in that it helps to promote and increase spectrum use. It introduces the fundamental ITU principle that individual administrations can use the spectrum in any way they wish, provided interference is not caused to services operating in conformity with the agreements in the Radio Regulations and which are registered in the Master International Frequency Register (MIFR).

4.10 Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies.

This Regulation establishes a long-standing major principle in the use of frequencies and originates from maritime practices, which were created in their own right with a set of discrete aeronautical radio services before aviation was established in ITU. The previous long-standing practice of not sharing radionavigation allocations with other services, whether primary or secondary, has been discarded and frequency sharing based on technical criteria is now a common, although not desirable practice. The principle of "special measures" in this Regulation still finds application in the action to be taken when interference occurs. This, together with the other provisions dealing with harmful interference, ensures that rapid attention is given by administrations when interference to a safety service takes place. Implicit in the wording of the Regulation is the fact that radionavigation is a safety service (see RR 1.59).

4.9 No provision of these Regulations prevents the use by a station in distress, or by a station providing assistance to it, of any means of radiocommunication at its disposal to attract attention, make known the condition and location of the station in distress, and obtain or provide assistance.

4.16 However, in circumstances involving the safety of life, or the safety of a ship or aircraft, a land station may communicate with fixed stations or land stations of another category.

4.22 Any emission capable of causing harmful interference to distress, alarm, urgency or safety communications on the international distress and emergency frequencies established for these purposes by these Regulations is prohibited. Supplementary distress frequencies available on less than a worldwide basis should be afforded adequate protection.

These Regulations address the situation of distress and safety, and permit and protect the necessary communications in these circumstances. In ITU, distress and safety messages have to be given special treatment in the maritime service, which is characterized by infrequent safety and distress communications on the same channel as public correspondence. These situations are comparable to that of emergency messages in the aeronautical service. Aeronautical procedures for emergency communications, as laid down in Annex 10, Volume II, are the valid rules for civil aviation.

4.19 In certain cases provided for in Articles **31** and **51**, aircraft stations are authorized to use frequencies in the bands allocated to the maritime mobile service for the purpose of communicating with stations of that service (see No. **51.73**). (WRC-07)

4.20 Aircraft earth stations are authorized to use frequencies in the bands allocated to the maritime mobile-satellite service for the purpose of communicating, via the stations of that service, with the public telegraph and telephone networks.

These Regulations are principally relevant to the transmission of public correspondence. The importance of RR 4.20 diminishes with the ITU agreement at WRC-97 to apply generic type allocations to all mobile-satellite communications.

7-III.3.2.2 *Article 5: Frequency allocations*

This Article contains the Table of Frequency Allocations and is the component of the Radio Regulations which receives the constant attention of ITU conferences. It records the agreed use of the entire useable spectrum by all defined radio services over the three ITU world regions. It is extensive (occupying well over 100 pages) and detailed.

Note.— Section 7-II of this handbook addresses the aeronautical aspects of the Table of Frequency Allocations in detail.

In addition to the material addressed in Section 7-II, the following two Regulations in Article 5 are important to aviation:

5.43 1) Where it is indicated in these Regulations that a service or stations in a service may operate in a specific frequency band subject to not causing harmful interference to another service or to another station in the same service, this means also that the service which is subject to not causing

harmful interference cannot claim protection from harmful interference caused by the other service or other station in the same service.

5.43A 1*bis*) Where it is indicated in these Regulations that a service or stations in a service may operate in a specific frequency band subject to not claiming protection from another service or from another station in the same service, this means also that the service which is subject to not claiming protection shall not cause harmful interference to the other service or other station in the same service.

Recent ITU conferences have agreed to the sharing of aeronautical allocations with other services either in a situation where the added service operates on an equal primary basis with the existing aviation service, or on a non-interference basis with the aviation service. However, both services must be protected with respect to any secondary allocation in the same band. A footnote applying to the added service usually contains the conditions to be observed. For example, see the band 960–1 215 MHz where the RNSS is added to the ARNS (DME, SSR, ACAS). Radio Regulations 5.43 and 5.43A address and clarify these situations, though in certain situations, 5.43 and/or 5.43A may be exempted through a footnote (e.g. 5.328A, 5.473A, 5.475B and 5.476A). This in effect creates a new category of services that falls between the categories of primary and secondary.

7-III.3.2.3 *Article 6: Special agreements*

Article 6 dealing with special agreements is of interest to aviation since some of the conditions on special agreements may be applied, in particular circumstances, to the agreements on frequency use coordinated within ICAO (see, for example, Nos. 6.2 and 6.3).

ICAO POLICY ON CHAPTER II

- Article 4: maintain these Regulations, particularly RR 4.10, without any change in substance.
- Article 5: see Section 7-II of this handbook.
- Article 6: maintain these Regulations without change.

7-III.3.3 Chapter III (Articles 7 to 14) — Coordination, notification and recording of frequency assignments and Plan modifications

7-III.3.3.1 The long-standing ITU procedure of introducing registration of frequency assignment in a central document (Master International Frequency Register (MIFR)), so as to obtain prior rights for protection against other registrations being introduced at a later time (see RR 8.3), is embodied in the terms and conditions laid down in this chapter. It may be noted that registration, which is not an absolute requirement, has as its main purpose the establishment of protection rights by countries for their assignments and is exercised at the discretion of each ITU member administration. These rights are dependent on a number of important conditions of which conformity with all of the requirements of the Regulations is the prime factor. Non-conformity provides no protection (RR 8.5) except, perhaps, against another non-conforming registration which appears later.

7-III.3.3.2 With the notable exception of high frequency (HF), non-directional radio beacon (NDB) and satellite communication (SATCOM), assignments to aeronautical services, in exclusive aeronautical bands, are normally coordinated within ICAO and entered in a register maintained under aviation auspices. This process may be considered to amount to a *de facto* form of compliance with the terms of Chapter III, although the consultation is wholly within aviation and technically does not meet the full ITU registration process requirement. HF assignments allotted to major world air route areas (MWARA), regional and domestic air route areas (RDARA) and worldwide use are obtained from Appendix 27 and are, as well as NDB assignments, normally registered in the MIFR.

7-III.3.3.3 Recording of frequency assignments that have been coordinated within ICAO through the Regional Offices with the MIFR represents a very important element of international regulations. Correct and up-to-date information in the MIFR may be critically important for frequency management, including the analysis of occupancy of frequency bands for sharing studies and allocation of spectrum at WRCs.

ICAO and its Regional Offices also maintain databases of coordinated aeronautical frequencies in a number of frequency bands allocated to the aeronautical mobile (R) service and aeronautical radionavigation service. A comparison of the ITU and ICAO databases has shown that only a small part of frequency assignments contained in ICAO's database is recorded in the MIFR. One possible reason for this situation is that ICAO's databases are updated by authorized aeronautical authorities of ICAO Contracting States, which could be different from ITU administrations notifying frequency assignments to the MIFR.

The Bureau and the ICAO Secretariat made preliminary consultations on the technical and regulatory feasibility of recording in the MIFR the frequency assignments contained in the ICAO databases. During these consultations, a number of technical matters requiring solutions were identified. These matters include handling differences in format and parameters of the ICAO and ITU databases, processing of changes in the ICAO database, which is frequently modified due to changing air traffic requirements, and ways of registration of aircraft systems which are not associated with ground-based stations. The initial evaluation of these issues indicates that the data conversion from ICAO to ITU format is feasible. In addition to the data handling, an urgent need to establish a regulatory basis for the relevant activities was emphasized.

WRC-12 reviewed the initiative of the ITU and ICAO and concluded, at the Seventh Plenary Meeting, the following:

> "It was suggested that the Bureau should urge administrations, through a Circular Letter, to notify aeronautical frequency assignments to the MIFR. At the same time, Committee 4 appreciated previous consultations between the ICAO Secretariat and the Radiocommunication Bureau on this matter and expressed the opinion that such consultations should continue with respect to a possible transfer of ICAO database information to the Bureau."

These consultations are ongoing, as necessary, with the involvement of the FSMP. In these consultations, both the technical and the (Radio) Regulatory aspects are reviewed.

ICAO POLICY ON CHAPTER III

- Maintain these Regulations without change.
- Continue the assessment on aligning the ITU database of frequency assignments with the ICAO global frequency lists.

7-III.3.4 Chapter IV (Articles 15 and 16) — Interferences

7-III.3.4.1 This chapter on interferences is important in aeronautical terms. It prescribes the conditions under which stations must operate to avoid causing interference, the measures to be applied when interference is detected and the actions to be taken when a resolution cannot be obtained by normal bilateral coordinative actions. The necessary actions prescribed contain a strong emphasis on the importance of removing interference in the case where it occurs to a safety service (RR 15.36 and RR 15.37), or where distress frequencies are involved (RR 15.28).

7-III.3.4.2 It is noted that the procedures in the Radio Regulations for clearing interference have no mandatory force, nor is there any procedure for the referral of disputes for arbitration. Thus, RR 15.22 mentions "goodwill and mutual assistance", and as a final attempt, an administration may request the Radio Regulations Board to help (RR 15.41, RR 15.42 and Section 1 of Article 13).

7-III.3.4.3 Regulations of particular importance to aeronautical service in this chapter are reproduced below.

15.8 Special consideration shall be given to avoiding interference on distress and safety frequencies, those related to distress and safety identified in Article **31**, and those related to safety and regularity of flight identified in Appendix **27**. (WRC-07)

15.28 Recognizing that transmissions on distress and safety frequencies and frequencies used for the safety and regularity of flight (see Article **31** and Appendix **27**) require absolute international protection and that the elimination of harmful interference to such transmissions is imperative, administrations undertake to act immediately when their attention is drawn to any such harmful interference. (WRC-07)

15.32 If further observations and measurements are necessary to determine the source and characteristics of and to establish the responsibility for the harmful interference, the administration having jurisdiction over the transmitting station whose service is being interfered with may seek the cooperation of other administrations, particularly of the administration having jurisdiction over the receiving station experiencing the interference, or of other organizations.

15.36 When a safety service suffers harmful interference the administration having jurisdiction over the receiving station experiencing the interference may also approach directly the administration having jurisdiction over the interfering station. The same procedure may also be followed in other cases with the prior approval of the administration having jurisdiction over the transmitting station whose service is being interfered with.

15.37 An administration receiving a communication to the effect that one of its stations is causing harmful interference to a safety service shall promptly investigate the matter and take any necessary remedial action and respond in a timely manner.

15.40 If there is a specialized international organization for a particular service, reports of irregularities and of infractions relating to harmful interference caused or suffered by stations in this service may be addressed to such organization at the same time as to the administration concerned.

ICAO POLICY ON CHAPTER IV

This chapter contains Regulations of importance to aeronautical services which provide for the rapid clearance of interference to these services. No changes of substance should be made, and the degree of attention accorded to safety services and distress frequencies should not be lessened.

7-III.3.5 Chapter V (Articles 17 to 20) — Administrative provisions

7-III.3.5.1 Several administrative provisions contained in Articles 18 and 19 of this chapter are of interest to aviation (action may either involve the telecommunications or the aviation authority, or both). Radio Regulations 18.8 and 18.11 have been included at the request of aviation to regularize the licensing of aircraft on delivery from the manufacturer, and aircraft leased to a country other than the country of registry. Radio Regulation 19.10 is a dispensation from the normal rule that radio stations must transmit an identification at all times, and regularizes the ICAO Annex 10 practice with navaids where removal of the identification is an indication of malfunction. In ITU, the term “radiobeacon” has a wider significance than in aviation and can include all ground-based navaids. The most important of these Regulations are reproduced below:

18.8 In the case of a new registration of a ship or aircraft in circumstances where delay is likely to occur in the issue of a licence by the country in which it is to be registered, the administration of the country from which the mobile station or mobile earth station wishes to make its voyage or flight may, at the request of the operating company, issue a certificate to the effect that the station complies with these Regulations. This certificate, drawn up in a form determined by the issuing administration, shall give the particulars mentioned in No. **18.6** and shall be valid only for the duration of the voyage or flight to the country in which the registration of the ship or aircraft will be effected, or for a period of three months, whichever is less.

18.11 In the case of hire, lease or interchange of aircraft, the administration having authority over the aircraft operator receiving an aircraft under such an arrangement may, by agreement with the administration of the country in which the aircraft is registered, issue a licence in conformity with that specified in No. **18.6** as a temporary substitute for the original licence.

19.10 All operational transmissions by radiobeacons shall carry identification signals. However, it is recognized that, for radiobeacons and for certain other radionavigation services that normally carry identification signals, during periods of malfunction or other non-operational service the deliberate removal of identification signals is an agreed means of warning users that the transmissions cannot safely be used for navigational purposes.

19.16 In transmissions carrying identification signals a station shall be identified by a call sign, by a maritime mobile service identity or by other recognized means of identification which may be one or more of the following: name of station, location of station, operating agency, official registration mark, flight identification number, selective call number or signal, selective call identification number or signal, characteristic signal, characteristic of emission or other clearly distinguishing features readily recognized internationally.

7-III.3.5.2 Sections III and VII of Article 19 deal with the formation of call signs in the aeronautical service. The Regulations do not define the distinction between an identification and a call sign very clearly, and both are transmitted essentially to provide others with a means of determining the identity of a radio transmission. The usual interpretation is that identification is primarily required on transmissions by radio beacons for the purpose of identifying interference sources, while call signs have the added purpose of facilitating two-way communications. The greater majority of the requirements laid down in Section III relate to maritime services, with dispensations (as indicated below) in the case of aeronautical stations. To a large extent Annex 10 (Volume II) has been aligned with these Regulations.

Section III — Formation of Call Signs

19.57 *Aircraft stations*

19.58 — two characters and three letters.

19.77 1) *Aeronautical stations*

— the name of the airport or geographical name of the place followed, if necessary, by a suitable word indicating the function of the station.

19.78 2) *Aircraft stations*

— a call sign (see No. **19.58**), which may be preceded by a word designating the owner or the type of aircraft; *or*

— a combination of characters corresponding to the official registration mark assigned to the aircraft; *or*

— a word designating the airline, followed by the flight identification number.

19.79 3) In the exclusive aeronautical mobile frequency bands, aircraft stations using radiotelephony may use other methods of identification, after special agreement between governments, and on condition that they are internationally known.

Section VII — Special Provisions

19.127 1) In the aeronautical mobile service, after communication has been established by means of the complete call sign, the aircraft station may use, if confusion is unlikely to arise, an abbreviated call sign or identification consisting of:

19.128 a) in radiotelegraphy, the first character and last two letters of the complete call sign (see No. **19.58**);

19.129 b) in radiotelephony:

— the first character of the complete call sign; *or*

— the abbreviation of the name of the owner of the aircraft (company or individual); *or*

— the type of aircraft;

followed by the last two letters of the complete call sign (see **No.19.58**) or by the last two characters of the registration mark.

19.130 2) The provisions of Nos. **19.127, 19.128** and **19.129** may be amplified or modified by agreement between administrations concerned.

ICAO POLICY ON CHAPTER V

Chapter V, which addresses identification signals and call signs, is the basic international document for these matters. Alignment with Annex 10 is essential and must be maintained either through similar text or by exemption (e.g. RR 19.10).

7-III.3.6 Chapter VI (Articles 21 to 29) — Provisions for services and stations

The Articles in this chapter address specific procedures and technical practices for radio services and stations that are essential for efficient and orderly operation and for efficient use of spectrum. One of the services of interest to aviation is detailed below.

Article 28: Radiodetermination services

Section I is general and is oriented towards the maritime service, which has no international document other than the Radio Regulations in which to prescribe obligatory requirements.

Section II contains a provision dealing with the aeronautical radionavigation-satellite service (which has not yet received an allocation in the Table of Frequency Allocations).

Section III deals with radio direction-finding stations. Such stations are no longer a standard feature in civil aviation on international services. However, where it applies, there is a dispensing regulation which permits aviation to use ICAO agreements as the rule. This is:

28.17 In the aeronautical radionavigation service, the procedure contemplated for radio direction-finding in this Section is applicable, except where special procedures are in force as a result of arrangements concluded between the administrations concerned.

Section IV deals with radio beacons in a general way. Radio Regulations 28.23 and 28.24 include reference to Appendix 12 which designates field strength and protection requirements for aeronautical radio beacons. The parameters and values defined in Appendix 12 are those used by ICAO in the frequency assignment planning for aeronautical NDB. The text of these Regulations is:

28.23 The power radiated by each radiobeacon properly so-called shall be adjusted to the value necessary to produce the stipulated field strength at the limit of the range required (see Appendix **12**).

28.24 Special rules applicable to aeronautical radiobeacons operating in the bands between 160 kHz and 535 kHz and to the maritime radio beacons operating in the bands between 283.5 kHz and 335 kHz are given in Appendix **12**.

ICAO POLICY ON CHAPTER VI

- The provisions in the chapter are necessary as broad principles for radiodetermination services. They should be maintained and improved, as necessary, by future amendments based on practical experience.
- Appendix 12, together with the enabling provisions 28.23 and 28.24, should be maintained unchanged.

7-III.3.7 Chapter VII (Articles 30 to 34) — Distress and safety communications

Primarily, this chapter addresses the operational use of the global maritime distress and safety system (GMDSS) intended for ships in distress situations. However, aircraft are not precluded from using the system. Radio Regulation 30.9 provides the dispensation for aeronautical radio services to conform to the provisions in Annex 10 in any case where provisions of the Radio Regulations diverge from aeronautical practices. Regulations of relevance are:

Article 30 — General provisions

Section III — Aeronautical Provisions

30.8 The procedure specified in this Chapter is obligatory for communications between stations on board aircraft and stations of the maritime mobile-satellite service, wherever this service or stations of this service are specifically mentioned.

30.9 Certain provisions of this Chapter are applicable to the aeronautical mobile service, except in the case of special arrangements between the governments concerned.

30.10 Mobile stations of the aeronautical mobile service may communicate, for distress and safety purposes, with stations of the maritime mobile service in conformity with the provisions of this Chapter.

30.11 Any station on board an aircraft required by national or international regulations to communicate for distress, urgency or safety purposes with stations of the maritime mobile service that comply with the provisions of this Chapter, shall be capable of transmitting and receiving class J3E emissions when using the carrier frequency 2 182 kHz, or class J3E emissions when using the carrier frequency 4 125 kHz, or class G3E emissions when using the frequency 156.8 MHz and, optionally, the frequency 156.3 MHz.

Article 33: Operational procedures for urgency and safety communications in the global maritime distress and safety system (GMDSS)

Medical transports are defined in the 1949 Geneva Convention and the definition is repeated in RR 33.19. They may be aircraft or ships involved in areas of armed conflict. Section III — *Medical transports* sets down the special identification measures, which include the use of secondary surveillance radar (SSR) for aircraft.

ICAO POLICY ON CHAPTER VII

Chapter VII concerns primarily the global maritime distress and safety system (GMDSS), but affects aircraft indirectly. These provisions (identified above) should be maintained, or improved as necessary, based on operational practices.

7-III.3.8 Chapter VIII (Articles 35 to 45) — Aeronautical services

7-III.3.8.1 This chapter deals exclusively with aeronautical matters and addresses licensing and regulatory aspects of allocations as well as service operational matters. These matters are applicable to all aircraft operations, whether for civil, national defence or governmental purposes. This chapter contains the following articles (with the type of regulation indicated in brackets):

Article 35 *Introduction*

Article 36 *Authority of the person responsible for the station* (operational)

Article 37 *Operator's certificates* (licensing)

Article 38 *Personnel* (licensing)

Article 39 *Inspection of stations* (licensing)

Article 40 *Working hours of stations* (operational)

Article 41 *Communications with stations in the maritime services* (regulatory)

Article 42 *Conditions to be observed by stations* (regulatory)

Article 43 *Special rules relating to the use of frequencies* (regulatory)

Article 44 *Order of priority of communications* (operational)

Article 45: *General communication procedure* (operational)

Radio Regulation 35.1.1 recognizes, with the exception of Articles 36, 37, 39, 42, 43 and 44.2, the application of ICAO Annexes to civil aircraft provided their implementation does not cause harmful interference to the radio services of other countries.

7-III.3.8.2 Particular regulations of interest and importance in Chapter VIII are:

Article 37: Operator's certificates

This important Article lays down the requirement for operator's certificates to be issued for aircraft personnel in relation to the control and use of the radio as a transmitting device. The requirement is also reflected in Article 30 (b) of the ICAO Convention, and the requirements for the air safety aspects are laid down in Annexes 1 and 10. Several of the provisions in this Article take account of practices in civil aviation as specified in ICAO Annexes. Of relevance to aviation are:

— RR 37.1 which requires that every aeronautical radio station be certified by an "operator holding a certificate issued or recognized by the government to which the station is subject". The wording of this Regulation permits the certificate to be issued by the authority with responsibility for civil aviation.

— RR 37.2 which provides a dispensation for the use of ICAO requirements in lieu of those in the Regulations in the aspects where ICAO has specified conditions, qualifications or other relevant material. The text of this Regulation is:

37.2 In order to meet special needs, special agreements between administrations may fix the conditions to be fulfilled in order to obtain a radiotelephone operator's certificate intended to be used in aircraft radiotelephone stations and aircraft earth stations complying with certain technical conditions and certain operating conditions. These agreements, if made, shall be on the condition that harmful interference to international services shall not result therefrom. These conditions and agreements shall be mentioned in the certificates issued to such operators.

— RR 37.4 and RR 37.5 which permit administrations to decide if a certificate is necessary for frequencies above 30 MHz, but not on frequencies assigned for international use.

— RR 37.14 which permits the issue of a restricted certificate in lieu of a general certificate where the frequencies used are from exclusive aeronautical bands, and operation of the equipment requires only the use of simple external switching devices. This applies to all HF and VHF radio equipment carried in modern civil aircraft.

Article 42: Conditions to be observed by stations

Of note in this Article is RR 42.4 which prohibits the operation of a broadcasting service by an aircraft station while over the sea. An associated RR 23.2 prohibits the establishment and use of broadcasting services outside national territory.

Article 43: Special rules relating to the use of frequencies

This Article lays down conditions of use for aeronautical frequencies.

RR 43.1 is often referred to in an aeronautical mobile and aeronautical mobile-satellite context in ITU discussions. It distinguishes the civil aviation use of frequencies from other aircraft uses, notably national defence use (i.e. the (OR) service). The inclusion of the words "safety and regularity" has been a deliberate transfer from the ICAO Convention. The service definitions at RR 1.33 and RR 1.36 were inserted recently to consolidate the concept insofar as the Table of Frequency Allocations is concerned. RR 43.4 prohibiting public correspondence is of long-standing and still is applicable to AM(R)S and AM(OR)S. There is no longer an exclusive allocation to the AMS(R)S.

43.1 Frequencies in any band allocated to the aeronautical mobile (R) service and the aeronautical mobile-satellite (R) service are reserved for communications relating to safety and regularity of flight between any aircraft and those aeronautical stations and aeronautical earth stations primarily concerned with flight along national or international civil air routes.

RR 43.4 has the objectives of maintaining civil aviation frequencies exclusively for safety messages, as well as preventing their exploitation for purposes which can lead to inefficient use of spectrum. It only applies to exclusive bands and is invalid for satellite services to aircraft operating in the generic mobile-satellite bands.

43.4 Administrations shall not permit public correspondence in the frequency bands allocated exclusively to the aeronautical mobile service or to the aeronautical mobile-satellite service.

Article 44: Order of priority of communications

The order of priority of communications in this Article (reproduced below) has been carefully aligned with that in Annex 10, Volume II, Chapter 5, 5.1.8 for Categories 1 to 6 below. These have been accorded priority over other communications by footnotes in the Table of Frequency Allocations, particularly in the allocations in the mobile-

satellite bands where other communications, e.g. public correspondence, are also transmitted on the same channel. RR No. 5.357A places only the priority Categories 1 to 6 of Article 44 as a condition to be observed by mobile-satellite service operators in the frequency bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz which are allocated to the (generic) mobile-satellite service.

44.1 §1. The order of priority for communications[1] in the aeronautical mobile service and the aeronautical mobile-satellite service shall be as follows, except where impracticable in a fully automated system in which, nevertheless, Category 1 shall receive priority:

1. Distress calls, distress messages and distress traffic.
2. Communications preceded by the urgency signal.
3. Communications relating to radio direction-finding.
4. Flight safety messages.
5. Meteorological messages.
6. Flight regularity messages.
7. Messages relating to the application of the United Nations Charter.
8. Government messages for which priority has been expressly requested.
9. Service communications relating to the working of the telecommunication service or to communications previously exchanged.
10. Other aeronautical communications.

44.2 §2. Categories 1 and 2 shall receive priority over all other communications irrespective of any agreement under the provisions of No. **35.1**.

[1] **44.1.1** The term *communications* as used in this Article includes radiotelegrams, radiotelephone calls and radiotelex calls.

ICAO POLICY ON CHAPTER VIII

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- Unless justified by studies under Resolution 427 (WRC-19)
  - Maintain Article 35 except for any consequential amendment.
- Maintain Article 43 without change.
- Maintain the order of priority in Article 44 for Categories 1 to 6 aligned with that in Annex 10.
-

Annex 10, Volume II, contains the order of priority of communications to be applied in the aeronautical mobile service (for voice communications). These priorities are aligned with the priorities as established by the ITU Radio Regulations in Article 44.

In addition, Annex 10, Volume III, contains a mapping of ATN network priorities to the mobile sub-network priorities. Essentially, these priorities are also aligned with those of the Radio Regulations. Some of the (air-ground data link) systems incorporate a slightly different order of priorities while meeting the general requirements placed by the Radio Regulations.

Note.— The order of priorities for the aeronautical mobile service do not apply to the order of priorities in the aeronautical fixed service (AFTN, ATN).

7-III.3.9 Chapter IX (Articles 46 to 58) — Maritime services

7-III.3.9.1 Articles 46 to 58 provide the regulatory framework for maritime services in a similar way to that in Chapter VIII for the aeronautical services.

7-III.3.9.2 Aeronautical services receive mention at isolated places within Chapter IX. The most important are identified below.

Article 51: Conditions to be observed in the maritime services

The provisions in Section III — *Stations on board aircraft communicating with stations of the maritime mobile service and the maritime mobile-satellite service* relate only to the situation where the frequencies used are those allocated to maritime services.

ICAO POLICY ON CHAPTER IX

Maintain the aeronautical provisions in this chapter without change.

7-III.4 APPENDICES TO THE RADIO REGULATIONS

7-III.4.1 Comments on Appendices of special significance to aeronautical services are given below.

7-III.4.2 Appendix 12. Section I — Aeronautical radiobeacons

The material in this Appendix defines the protection requirements for aeronautical radio beacons (non-directional beacons and locators). It achieves full Radio Regulation status through RR 28.24. (Prior to the VGE Report, the Appendix 12 provisions were contained within the main body of the Regulations.)

ICAO POLICY ON APPENDIX 12

No changes should be made to the provisions for aeronautical radio beacons in this Appendix.

7-III.4.3 Appendix 13. Distress and safety communications (non-GMDSS) (suppressed at WRC-07; see Chapter VII of the Radio Regulations)

7-III.4.4 Appendix 16. Documents with which stations on board ships and aircraft shall be provided

Appendix 16 was amended at WRC-07 to align its provisions with those of Chapter VII of the Radio Regulations. The section addressing documents with which stations on board aircraft need to be provided was amended as follows:

Section IV — Stations on board aircraft

These stations shall be provided with:

1. the documents mentioned in items 1 and 2 of Section I;

2. a log, unless administrations have adopted other arrangements for recording all information which the log should contain;

3. those published documents, in either printed or electronic formats, containing official information relating to stations which the aircraft station may use for the execution of its service.

The documents referenced in paragraph 1 are:

— the radio station licence (which is prescribed by Article 18 of the Radio Regulations)

— the certificates of the operator. These are normally included in the pilot licence.

ICAO POLICY ON APPENDIX 16

Retain without change.

7-III.4.5 Appendix 27. Frequency allotment plan for the AM(R)S and related information

7-III.4.5.1 Appendix 27 was agreed to at the World Administrative Radio Conference (WARC) for the Aeronautical Mobile (R) Service in 1978 when the use of the HF spectrum was converted from double sideband (DSB) to single sideband (SSB). The main technical provisions have been reproduced in Annex 10, Volume III, Part II, Chapter 2, 2.4. Appendix 27 is notable as the single case where aeronautical frequency planning is carried out in the ITU. The registration of HF frequencies in the MIFR is necessary. There is no established amendment procedure for Appendix 27, although it is recognized in provision 27/20, that frequencies not in conformity with the Allotment Plan may be selected and registered by ITU provided that they do not reduce the protection to the frequency allotments in the Plan.

7-III.4.5.2 Some frequency management aspects of importance are covered in Annex 10, Volume V, Chapter 3.

7-III.4.5.3 Of notable importance are the allotments made for aeronautical operational control (see Annex 10, Volume V, Chapter 3, 3.1.3) and the terms of No. 27/217 authorizing their use for this purpose. The full text of this important provision is at Section 7-II of this handbook under the band 2 850–22 000 kHz.

7-III.4.5.4 Appendix 27 is notable also for the recognition given to ICAO for its coordinating role in the operational use of radio frequencies (see No. 27/19 of the above-mentioned reference). In this context it has been clarified, however, that the registration of assignments in the MIFR as a requirement covered by the Radio Regulations is effected through ITU member administrations (national telecommunication administrations). Due to these provisions, ICAO cannot play any role in the registration of Appendix 27 frequencies.

ICAO POLICY ON APPENDIX 27

- Appendix 27 may only be amended by an ITU aeronautical conference or by an agenda item for a WRC to which aeronautical expertise is specifically invited. The present Allotment Plan is becoming incapable of meeting requirements, which appear to exceed the possibilities under provision 27/20.
- ICAO supports any action which could lead to an increase of the frequency bands for use by the aeronautical mobile (route) service (AM(R)S) in the bands between 2 850 kHz and 22 000 kHz.

SECTION 7-IV. REVIEW OF ITU RESOLUTIONS AND RECOMMENDATIONS

A standard item in the agenda of all WRCs is the review of past Resolutions and Recommendations and decision as to their continuing applicability. The review is normally made in the closing stages of WRC action and account is taken of the conference decisions and the new Resolutions and Recommendations agreed at the conference.

During its WRC preparation, ICAO reviews in accordance with ITU Resolution 95 (WRC-03) Resolutions and Recommendations of previous ITU conferences. The results are contained in Attachment F of this document.

Chapter 8

ICAO SPECTRUM STRATEGY AND VISION

8.1 INTRODUCTION

8.1.1 Air transport plays a major role in social and economic development of communities, regions and the world. The demand for passenger and freight operations is expanding geographically and growing in response to markets and demographics. Studies predict very similar patterns of activity in the years ahead. Since the mid-1970s and until the end of 2019, air traffic growth has consistently defied economic recessionary cycles, expanding two-fold once every 15 years. Notwithstanding the global COVID-19 pandemic, air traffic movements are expected to increase at an average annual rate of 5 per cent up to the year 2030.

8.1.2 The ICAO spectrum strategy presented in 8.2 is based on the recognition that adequate and appropriate spectrum availability is essential to aviation safety and to support efficient aircraft operations. This fundamental principle has been the long-standing basis for ICAO policy in spectrum matters, as recognized in Assembly Resolution 38-6 and in Recommendation 1/12 of the Twelfth Air Navigation Conference.

8.1.3 The ICAO spectrum strategy is consistent with the Fifth Edition of the ICAO *Global Air Navigation Plan* (GANP, Doc 9750), and in particular with the Technology Roadmaps contained in Appendix 5 of the GANP. Future developments of the plan will be taken into account as part of the strategy update process, as discussed in 8.3, which addresses future systems and strategy evolution.

8.1.4 Section 8.4 discusses a number of current and future challenges to civil aviation's use of the radio frequency spectrum.

8.1.5 The aviation spectrum long-term vision is detailed in section 8.5.

8.2. ICAO SPECTRUM STRATEGY

8.2.1 Purpose of the ICAO spectrum strategy

8.2.1.1 The safety aspects on the use of radio frequency spectrum by aviation require spectrum to be available on an exclusive basis or, when shared with non-

aeronautical radio services, with regulatory and technical conditions that recognize aeronautical safety requirements. The overall ICAO spectrum policy includes the ICAO spectrum strategy presented here and the ICAO policy statements contained in Chapter 7. Both the spectrum strategy and the policy statements are approved by the ICAO Council.

8.2.1.2 Implementation of the spectrum strategy will enable the advancement of technological developments and innovation to enhance safe and efficient global air transport. This is to be achieved through the development of ICAO SARPs as necessary.

8.2.1.3 The radio frequency spectrum capacity for aviation must be sufficient to meet the growing needs for aeronautical communication, navigation and surveillance systems, including any new systems that are being considered in ICAO to meet future CNS/ATM requirements. This is essential to adequately support changing trends in air traffic management such as foreseen in the GANP and the ICAO Regional Plans.

8.2.1.4 Spectrum for aeronautical radiocommunication and radionavigation (including surveillance) is allocated by the ITU with the recognition of the safety aspects identified above. The ICAO spectrum policy aims to ensure that aeronautical spectrum capacity requirements are satisfied during the frequency allocation process, taking into consideration the trends in future air traffic management.

8.2.2 Basis for the ICAO spectrum strategy

8.2.2.1 The ICAO spectrum strategy in this chapter has been developed on the basis of current global and regional plans for implementing CNS systems until about 2035. It identifies the spectrum necessary for each of the CNS elements and each relevant frequency band, including specific regional requirements which are part of the overall ICAO spectrum strategy.

8.2.2.2 It consists of a high-level ICAO spectrum strategy (8.2.3) and of a set of specific strategy statements for each frequency band (8.2.4). The high-level strategy is applicable to all frequency bands, and should be regarded as the basis for the band-by-band strategy statements, and for the relevant ICAO policy statements contained in Section 7-II.

8.2.2.3 In many cases, aeronautical radiocommunication, radiodetermination and radionavigation systems currently in use will continue to operate well beyond 2035, either on a global basis or in certain regions. The strategy identifies requirements for the medium term and until and beyond 2035. Spectrum requirements identified for the long term indicate that such spectrum is expected to be necessary for an undetermined

period, extending to well beyond 2035.

8.2.2.4 The strategy, including the timescale, will be updated on a regular basis taking into consideration developments in the use of current and new CNS systems, as reflected in the GANP Technology Roadmaps.

8.2.3 ICAO high-level spectrum strategy

ICAO HIGH-LEVEL SPECTRUM STRATEGY

- To secure the continuing availability of adequate radio frequency spectrum to support the current and planned aeronautical CNS infrastructure requirements as laid out in the Global Air Navigation Plan (GANP) and in the Regional Air Navigation Plans.
- To enable the advancement of technological innovation to maintain and enhance the safety of the global air transport system as well as increased efficiency in spectrum utilization.
- To ensure that proposals for new or modified allocations be supported by sharing studies on the use of frequency bands by aviation and take full account of the possible impact on the aeronautical safety case; these studies need to encompass the total technical, operational and economic aspects of aeronautical system use.
- To conduct ICAO studies on the compatibility of ICAO standard systems with other existing or planned ICAO standard systems.
- To support the ITU studies on the compatibility of ICAO standard systems with non-ICAO standard systems.
- To oppose proposals for new or modified allocations that place undue or unreasonable constraints on the continued use of current aeronautical CNS systems or affect the safety of aviation.
- To support efficient use of the frequency bands allocated to relevant aeronautical services by developing globally harmonized terrestrial-system frequency assignment planning criteria and a global frequency assignment plan in support of the GANP, while recognizing that the actual use of spectrum by aviation may vary between different regions where different system requirements and corresponding spectrum requirements exist.
- To ensure that aeronautical CNS systems, which provide safety-of-life services to aviation, operate in frequency bands that are properly allocated for use by aviation, with the objective of operating in spectrum allocated to an appropriate aeronautical safety service, and suitably protected from harmful interference that can be caused by other systems using the same or nearby frequency bands.

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8.2.4 ICAO specific band-by-band spectrum strategy for the frequency bands used by civil aviation

ICAO spectrum strategy for aeronautical communication systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
2 850–22 000 kHz (portions in accordance with RR Appendix **27**	HF air-ground communications (voice and data)	Long term	Secure the continuing availability of the HF frequency bands 2 850–22 000 kHz which are allocated to aeronautical mobile (R) service for use by air-ground communications on a global basis.	Current threats to aviation access in this band include emissions from wireless power transfer, power line communications and cable TV.	Initiate an action plan for the long-term use of HF communications
108–117.975 MHz	GBAS; VDL Mode 4	Long term	Secure the continuing availability of the frequency band 112–117.975 MHz (108–117.975 for GBAS), which is allocated to the aeronautical mobile (R) service, for use by GBAS and VDL Mode 4 on a global basis. Consider, subject to spectrum availability and spectrum requirements, the use of this band to accommodate VHF air-ground communication systems.	Current threats to aviation access in this band include emissions from new digital modulation types in the FM broadcast band, power line communications and cable TV.	
117.975–137 MHz	VHF air-ground; voice, VDL Mode 2 and VDL Mode 4	Long term	Secure the continuing availability of the frequency band 117.975–137 MHz, which is allocated to the aeronautical mobile (R) service, for use by VHF air-ground voice and data link on a global basis. Monitor progress on the development of the future air-ground data link and the implementation of 8.33 kHz channelization. Conduct regular capacity analysis of the existing band and, if necessary develop and evaluate strategies for a targeted extension of the band.	Current threats to aviation access in this band include emissions from power line communications and cable TV, and harmonics from industrial, science and manufacturing (ISM) systems.	Plan for the long-term replacement of 25 kHz Double-Sideband Amplitude Modulation (DSB-AM) voice communications with more spectrum efficient systems (e.g. 8.33 kHz DSB-AM). The severe congestion being experienced in core Europe could be overcome through the timely deployment of a future air-ground data link (probably operating in L-band).
960–1 164 MHz	Air-ground UAT LDACS 1090ES	Long term	Support the implementation of new systems in the aeronautical mobile (R) service in the frequency band 960–1 164 MHz (LDACS). Secure the continuing availability of the frequency band 960–1 164 MHz, which is allocated to the aeronautical mobile (R) service, for use by air-ground,air-air and air-satellite data link systems, by ADS-B via 1 090 MHz extended squitter and UAT. Implementation of these data links must take place under the express condition that no interference is	This band is extremely attractive to other (non-aviation) sectors (e.g. programme making and special events (PMSE)). However, because of the large and growing number of aeronautical services operating in this band, it is unlikely non-aeronautical allocations can be accommodated.	

ICAO spectrum strategy for aeronautical communication systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
			caused to the aeronautical radionavigation service operating in this frequency band (e.g. DME and SSR).		
1 525–1 559 MHz and 1 626.5–1 660.5 MHz	Air-ground satellite communications (Inmarsat)	Long term	Support retention of RR No. 5.357A in order to ensure sufficient access on a global basis by the aeronautical mobile-satellite (R) service in the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz to support the requirements for aeronautical satellite safety communications. *Note.— In these frequency bands, priority access should be provided for aeronautical safety communications within a network.* Ensure that any new or existing uses of these frequency bands will not cause harmful interference to the use of the bands by the aeronautical mobile-satellite (R) service. *Note.— In the United States in the bands 1 555–1 559 MHz and 1 656.5–1 660.5 MHz, the aeronautical mobile-satellite (R) service has priority and immediate access over other mobile-satellite communications within a network.*	This band is attractive to other sectors including PMSE and terrestrial broadband communications.	This band is extensively used for aeronautical satellite safety communications and should be safeguarded against the potential for interference from terrestrial services.
1 610–1 626.5 MHz	Air-ground satellite communications (IRIDIUM)	Long term	Support the continuing retention of the allocation to the aeronautical mobile-satellite (R) service (E-s, s-E) in the frequency band 1 610–1 626.5 MHz. *Note.— This frequency band has been allocated to the aeronautical mobile-satellite (R) service on a primary basis as per RR No. **5.367**.*		
3 400–4 200 MHz	VSAT for aeronautical networks and AMS(R)S feeder links	Long term	Support the continuing retention of the allocation to the FSS and adequate protection from other co-band and adjacent band services.	This band is attractive to other sectors including international mobile telecommunications (IMT).	
4 200–4 400 MHz	WAIC	Long term	Secure the continuing availability of the frequency band 4 200–4 400 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne radio altimeters on a global basis.		Develop SARPs. Identify opportunities to develop new radio altimeters that are spectrally efficient and

ICAO spectrum strategy for aeronautical communication systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
					resilient to interference.

ICAO spectrum strategy for aeronautical communication systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
5 000–5 150 MHz (5 000–5 030 MHz, 5 030–5 091 MHz, 5 091–5 150 MHz)	AeroMACS UAS terrestrial and satellite C2/C3 communications	Long term	Secure the continuing availability of the frequency band 5 091–5 150 MHz, which is allocated to the aeronautical mobile (R) service, for use by on-airport communications (AeroMACS) on a global basis. *Note.— While not in the Radio Regulations, some States may, on a national basis, allocate the 5 000–5 030 MHz band to the AM(R)S for use by AeroMACS.* Secure future implementation of the aeronautical mobile (R) service and the aeronautical mobile-satellite (R) service in the frequency band 5 030–5 091 MHz to support air-ground communications for unmanned aircraft systems while satisfying the spectrum requirements for MLS.		

ICAO spectrum strategy for aeronautical radio navigation service systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
130–535 kHz	NDB	Global: medium term Regional: long term	Secure the continuing availability of the frequency band 130–535 kHz, parts of which are allocated to the aeronautical radionavigation service, on a global basis for use by NDB systems for at least the medium term and, in the long term, on a regional basis. *Note.— Long-term use may be required to support national requirements.*		
74.8–75.2 MHz	Marker beacon	Long term	Secure the continuing availability of the frequency band 74.8–75.2 MHz, which is allocated to the aeronautical radionavigation service, for use by marker beacons on a global basis.	Current threats to this band include the increase of man-made noise due to, for example, PLC modems producing signal components as high as 300 MHz.	Consider a plan for the replacement of marker beacons by DME or other suitable technologies such as GNSS-based distance-to-threshold indicators.
108–112 MHz	ILS — localizer		Secure the continuing availability of the frequency band 108–117.975 MHz, which is allocated to the aeronautical radionavigation service, for use by ILS-localizer on a global basis.	An external threat to this band is compatibility with FM broadcasting operating in the band 88–108 MHz (see Resolution 413 (Rev. WRC 12)). It has been reported that FM broadcast transmissions are not in accordance with the assumptions set out in	Consider long-term (post 2030) replacement of ILS and protection of GBAS for use up to Cat III in the band 108–117.950 MHz.

ICAO spectrum strategy for aeronautical radio navigation service systems					
Frequency band	*Aeronautical use*	*Timescale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
				the standard compatibility assessment contained in ITU-R SM.1009-1.	
328.6–335.4 MHz	Glide path		Secure the continuing availability of the frequency band 328.6–335.4 MHz, which is allocated to the aeronautical radionavigation service, for use by ILS – glide path on a global basis.	There are no known threats to this band from other sectors seeking spectrum access. However, some States report that the increasing levels of man-made noise pose a threat to ILS deployment. The adjacent bands are used by military authorities for fixed and mobile services, including air-ground communications. There is a small guard band of around 400 kHz at each end of the aeronautical allocation.	
108–117.975 MHz	VOR	Long term	Secure the continuing availability of the frequency band 108–117.975 MHz, which is allocated to the aeronautical radionavigation service, for use by VOR on a global basis.	Identical to those for the ILS localizer.	Consider rationalization of VOR as an integral part of the PBN implementation plan and reuse by GBAS of any frequencies that may become available.
960–1 215 MHz	DME	Long term	Secure the continuing availability of the frequency band 960–1 215 MHz, which is allocated to the aeronautical radionavigation service, for use by DME on a global basis.	This band is extremely attractive to other sectors, particularly IMT. Because of the large and growing number of aeronautical services operating in this band, it is essential that changes to the existing allocations are strongly opposed.	Support studies to determine if there is a long-term optimization of the distance measuring function that could provide legacy support for use in those parts of the world where DME/VOR will remain, while also being implementable.
5 030–5 091 MHz	MLS	Long term	Secure the continuing availability of the frequency band 5 030–5 091 MHz, which is allocated to the aeronautical radionavigation service, for use by the microwave landing system (MLS) on a global basis to meet the spectrum requirements for the MLS. Assess, on a regional basis, requirements for the long-term implementation of MLS to establish the spectrum requirements for MLS.		

ICAO spectrum strategy for Global Navigation Satellite Systems (Reference: ICAO Doc 9750, Appendix 3, Roadmap 5)					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
1 164–1 215 MHz	GNSS (GPS, GLONASS, Galileo, Beidou, SBAS)	Long term	Secure the continuing availability of the frequency band 1 164–1 215 MHz, which is also allocated to the radionavigation-satellite service, for use by GNSS systems on a global basis, taking into consideration the radio regulatory conditions for using this band.	Concern about increase in numbers of DMEs, for example to improve area navigation or as a back-up to GNSS, impacting GNSS. In the GNSS frequency band 1 164–1 215 MHz, impact of the second harmonic of IMT stations that use frequency band 470–694 MHz is possible.	Dual-frequency, multi-constellation equipment should be encouraged. Contribute to the further strengthening of regulatory measures to reduce the risks of interference to GNSS.
1 559–1 610 MHz	GNSS (GPS, GLONASS, Galileo, Beidou, SBAS)	Long term	Secure the continuing availability of the frequency band 1 559–1 610 MHz, which is allocated to the aeronautical radionavigation and the radionavigation satellite services, for use by aeronautical GNSS systems, including augmentation systems, on a global basis. Support the development of regulatory measures to enforce prevention and removal of occurrences of in-band and out-of-band interference.	There is the ongoing risk of intentional interference (e.g. from GPS jammers and spoofers) and unintentional interference (e.g. from pseudolites and GNSS repeaters). Regulatory and enforcement measures may be necessary to contain these threats. In the GNSS frequency band 1 559–1 610 MHz, impact of the second harmonic of IMT stations that use frequency bands 694–790 MHz and 790–862 MHz is possible, as well as impact of spurious emissions of IMT stations that use frequency band 1 427–1 518 MHz.	Contribute to the further strengthening of regulatory measures to reduce the risks of interference to GNSS. Dual-frequency, multi-constellation equipment should be encouraged.

ICAO spectrum strategy for aeronautical surveillance systems (Reference: ICAO Doc 9750, Appendix 3, Roadmaps 3 and 4)					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
1 030 MHz and 1 090 MHz	SSR	Long term	Secure the continuing availability of the 1 030 MHz and 1 090 MHz frequencies, which are allocated to the aeronautical radionavigation service, for use by SSR on a global basis.	The popularity of these frequencies, in particular 1 090 MHz, make channel loading management necessary to ensure proper operation of SSR equipment. Introduction of remotely piloted aircraft systems (RPAS) are of particular concern if they were to try to use these channels.	To facilitate future growth and maintain system performance, it will become necessary to more carefully manage the signal-in-space. This will require further formal coordinated spectrum and frequency management processes.

ICAO spectrum strategy for aeronautical surveillance systems (Reference: ICAO Doc 9750, Appendix 3, Roadmaps 3 and 4)					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
1 215–1 350 MHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 1 215–1 350 MHz, which is allocated to the radionavigation and aeronautical radionavigation service, for use by primary surveillance radar on a global basis.		In the future, there is a probability that access to the band will be required by new technologies that are being developed for airport approach radar, such as multi-static primary surveillance radar (MSPSR) systems. These technologies may deploy new modulation techniques and high duty-cycle or continuous transmissions. MSPSR is being studied for use in terminal areas. Provision will need to be made for compatibility studies with PSR.
2 700–2 900 MHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 2 700–2 900 MHz, which is allocated to the aeronautical radionavigation service, for use by primary surveillance radar on a global basis. Where, in adjacent frequency bands, mobile systems are in use, secure protection of radar stations from harmful interference from mobile systems operating in adjacent bands.	This spectrum is attractive to the IMT sector for mobile broadband services. Compatibility studies have shown band sharing between PSR and mobile services not to be feasible. This is supported by experience of the roll-out of LTE in the band 2 670–2 690 MHz, which caused harmful interference to aeronautical PSRs operating in the band 2 700–3 100 MHz. The 2 700–2 900 MHz frequency band is also being considered in some countries for video PMSE.	Develop new non-cooperative surveillance techniques that are spectrally efficient and resilient to interference.
9 000–9 200 MHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 9 000–9 200 MHz, which is allocated to the aeronautical radionavigation service, for use by ground-based radar systems on a global basis.		
9 300–9 500 MHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 9 300–9 500 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne weather radar and ground-based radar on a global basis.		
15.4–15.7 GHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 15.4–15.7 GHz, which is allocated to the aeronautical radionavigation service, for use by ground-based radar systems on a global basis.		

ICAO spectrum strategy for aeronautical surveillance systems (Reference: ICAO Doc 9750, Appendix 3, Roadmaps 3 and 4)					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
24.25–24.65 GHz	Primary surveillance radar	Long term	Secure the continuing availability of the frequency band 24.25–24.65 GHz, which is allocated to the radionavigation service, for use by ground-based radar systems in Region 2 and 3.		
31.8–33.4 GHz	Primary surveillance radar Enhanced flight vision systems	Long term	Secure the continuing availability of the frequency band 31.8–33.4 GHz, which is allocated to the radionavigation service, for use by primary surveillance radar to support airport surveillance detection equipment (ASDE radar) on a global basis. This band is also used for enhanced flight vision systems (EFVS).		

ICAO spectrum strategy for aeronautical airborne (stand-alone) radar systems					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
4 200–4 400 MHz	Radio altimeter	Long term	Secure the continuing availability of the frequency band 4 200–4 400 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne radio altimeters on a global basis.	Current risks include potential for IMT identification in adjoining, or nearby, frequency bands.	To define an interference mask. Identify opportunities to develop new radio altimeters that are spectrally efficient and more resilient to interference.
5 350–5 470 MHz	Airborne weather radar	Long term	Secure the continuing availability of the frequency band 5 350–5 470 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne weather radar on a global basis.		
8 750–8 850 MHz	Airborne Doppler and ground mapping radar	Long term	Secure the continuing availability of the frequency band 8 750–8 850 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne Doppler radar and ground mapping radar on a global basis.		Develop Standards and specifications to support future compatibility and capacity studies.

ICAO spectrum strategy for aeronautical airborne (stand-alone) radar systems					
Frequency band	*Aeronautical use*	*Time scale*	*ICAO spectrum strategy*	*Risk factors*	*Vision statement*
9 300–9 500 MHz	Airborne weather radar	Long term	Secure the continuing availability of the frequency band 9 300–9 500 MHz, which is allocated to the aeronautical radionavigation service, for use by airborne weather radar and ground-based radar on a global basis.		Develop Standards and specifications to support future compatibility and capacity studies.
13.25–13.4 GHz	Airborne Doppler and ground mapping radar	Long term	Secure the continuing availability of the frequency band 13.25–13.4 GHz, which is allocated to the aeronautical radionavigation service, for use by airborne Doppler radar and ground mapping radar on a global basis.		Develop Standards and specifications to support future compatibility and capacity studies.

8.3 FUTURE SYSTEMS AND STRATEGY EVOLUTION

8.3.1 Growth in air traffic requires new ways of planning and enhanced ground, airborne and satellite infrastructure in order to reduce ATM costs, maintain safety, reduce the environmental impact of each flight and enhance the passenger experience. A process of international discussion and agreement, normally involving a minimum of five years for operational and technical finalization of system parameters followed by an adoption process taking several additional years (as prescribed in the ICAO Convention), is necessary to ensure that any new systems introduced as part of the infrastructure evolution are appropriate and safe. Other aeronautical systems not requiring international agreement to this degree can often be developed and implemented in a shorter timescale, but still require a minimum of several years to reach maturity and acceptance. In all these cases, the actual implementation of these systems requires additional time for implementation (e.g. regional agreement) in aircraft and on the ground, and a positive business case justifying the commitment of adequate financial resources.

8.3.2 In general, the standardization and the introduction of new systems will have to be consistent with the framework laid out in the GANP and may require updates to one or more of its Technology Roadmaps. This, in turn, may translate into updates to specific elements of the ICAO band-by-band spectrum strategy.

8.3.3 The impact on the ICAO spectrum strategy of the introduction of a new system will depend, inter alia, on which of the three following general categories the system falls into with respect to its spectrum requirements:

a) aviation systems that can be accommodated in existing allocations, with necessary footnote modifications, or less commonly, with modification to the allocation status or description;

b) aviation systems that require additional spectrum allocations for reasons of compatibility or frequency availability; and

c) other systems with multi-service application capability whose aviation requirements can be integrated with the other applications, entailing changes to allocation, modification of band limits or footnotes or, less commonly, a completely new allocation.

8.3.4 In any case, the allocation of spectrum for new services and systems in frequency bands already allocated for aeronautical use will have to be consistent with the high-level ICAO spectrum strategy and will need to take place within the framework set by the relevant ICAO SARPs for communication, navigation and

surveillance (CNS) systems, as well as other (industry) standards that apply to current operational systems.

Note.— Requirements for spectrum for meteorological radar and meteorological satellite systems are addressed by the World Meteorological Organization (WMO). However, specific requirements for airborne weather radar systems are included in the ICAO spectrum policy.

8.4 CHALLENGES

8.4.1 For many years, aeronautical radio frequency spectrum has been targeted for use by non-aeronautical services, in particular to satisfy requirements for mobile (terrestrial) and mobile-satellite communications. This has, for example, led to the loss of spectrum that was once allocated exclusively for aeronautical mobile-satellite communications (1.5/1.6 GHz) and to the introduction of non-aeronautical services in bands previously allocated for aeronautical use on an exclusive basis (e.g. the fixed-satellite service in the frequency band 5 091–5 250 MHz, the non-safety aeronautical mobile service for telemetry in the frequency band 5 091–5 150 MHz and the radionavigation-satellite service in the frequency band 5 000–5 030 MHz). This has created the potential for interference and/or loss of spectrum capacity to satisfy current and future aeronautical requirements for CNS systems.

8.4.2 There is currently pressure to release significant amounts of spectrum to support future commercial mobile communications and broadband wireless applications. While new systems can operate from UHF up to Ka and above, additional bandwidth has mainly been sought in the range from 300 MHz to 6 GHz. This range includes frequency bands used by a large number of safety-critical aeronautical systems, including ILS glide path, DME, primary and secondary radar, ACAS, AMS(R)S, GNSS, VSAT aeronautical networks and radio altimeters.

8.4.3 Another new element that may affect the future availability of radio frequency spectrum for aviation is the possible introduction of “spectrum pricing” which may have a significant economic impact on the aviation industry as a whole.

8.4.4 The ICAO spectrum strategy recognizes the challenges outlined above and provides the framework within which ICAO develops the international civil aviation position on issues of interest to international civil aviation to be decided at WRCs, which are the fora where these challenges typically face aviation.

8.5 THE AVIATION SPECTRUM LONG-TERM VISION

8.5.1 The need for a long-term vision

8.5.1.1 The availability of suitable radio spectrum is essential for meeting the global demand for safe, efficient and cost-effective air transport, particularly for enabling the provision of CNS. However, spectrum is a scarce and finite natural resource, and it is clear that aviation spectrum is under a global threat from other sectors that are seeking additional spectrum allocations. For this reason, it is vital that the aviation industry demonstrate good governance and efficient use of spectrum allocated to aeronautical services.

8.5.1.2 Spectrum management is the process of ensuring the availability of appropriately protected spectrum and the development and regulation of the use of radio frequencies to support aviation's operational and technical requirements. Assignment and use of spectrum is a sovereign issue within a State, and State radio administrations will remain responsible for spectrum policy and regulation.

8.5.1.3 However, unless aeronautical spectrum management evolves on a more coordinated basis, there is a risk that demand will continue to increase at a greater rate than that at which additional spectrum becomes available. Therefore, to prevent the potential lack of availability of sufficient spectrum becoming a serious risk, aviation stakeholders will need to work more cooperatively and proactively in sustaining aeronautical spectrum needs and demonstrating efficiency in the use of allocated spectrum.

8.5.1.4 The overall aim for the aviation spectrum vision is to secure the long-term availability of suitable radio spectrum to meet all of ICAO's future objectives for aviation through cooperative engagement in the global spectrum environment.

8.5.1.5 ITU WRC cycles are too short to deliver a strategy to support the overall long-term spectrum needs of the aviation sector. Currently, typical system development cycles far exceed this time frame. Although it is an objective to reduce the development and deployment lead-in time of new systems, as these are currently up to 20 to 25 years, and so a strategy and vision needs to support the entire in-service phase making provision for traffic growth, incremental development and operational evolution, etc. Innovative CNS systems may also need to consider integration timescale issues in relation to conceptual airframe designs.

8.5.2 Long-term vision for the future of aviation spectrum

8.5.2.1 General

8.5.2.1.1 The overall goal for the future of spectrum allocated to aeronautical services and aeronautical spectrum management is to ensure the perpetual

availability of spectrum through continual improvement in practices and processes. To achieve this goal, the ICAO spectrum vision focuses on the future that the aviation sector wishes to create for itself over an extended time frame.

8.5.2.1.2 While recognizing that there must be a strong drive towards reduced development cycles, the spectrum vision looks beyond those systems already in development towards the needs of conceptual systems. It should not be constrained by the timescales and technologies of existing strategic plans but should be developed on the expectation that existing spectrum allocated to aeronautical services will be under permanent pressure from other sectors and that new spectrum for aviation use is unlikely to be made available. This indicates a need to set out a vision looking forty years hence.

8.5.2.2 Vision statements

8.5.2.2.1 The ICAO spectrum vision is as follows:

a) *Establish and maintain an agreed spectrum strategy.* Civil aviation shall have a single, agreed spectrum strategy that is under continual development, and which is employed to create a sustainable environment for spectrum-efficient aeronautical systems;

b) *Improve collaboration.* Enhanced collaboration processes between aviation stakeholders shall be deployed for identifying, analyzing, coordinating and promoting aviation's spectrum needs in a collaborative manner. Through such collaboration, opportunities to maximize the effectiveness of existing spectrum allocated to aeronautical services and opportunities to share spectrum shall be fully explored and understood;

c) *Long-term view.* Aviation shall take a longer-term view of aeronautical spectrum requirements, i.e. forty years into the future. This shall not be constrained by the timescales and technologies of existing strategic plans;

d) *Holistic CNS and spectrum (CNS&S) approach.* A holistic CNS&S approach, taking into account any CNS&S strategy that is subsequently developed, shall be deployed as follows:

— an inter-disciplinary approach shall be taken to development, deployment and removal of aeronautical systems;

— development of spectrally efficient CNS systems shall be promoted to minimize the demand for additional spectrum to support future aviation growth; and

— withdrawal of obsolete and redundant systems shall be promoted in compliance with the future deployment programme.

e) *Financial decision making.* Aviation needs to take into account any spectrum impact on the financial decision making processes by:

— ensuring cost effective technological evolutions; and

— minimizing the impact and timescales of technological transitions.

8.5.2.3 Details of the spectrum vision

8.5.2.3.1 Realizing a long-term vision requires a strategy and an associated plan of action to deliver the strategy. Civil aviation needs to adopt a single spectrum strategy which has been agreed by national representation under specified collaborative arrangements. This strategy should set out the high-level principles to be applied in aviation spectrum management, including process improvements and interactions required to ensure that the necessary spectrum for current and planned CNS systems is secured and maintained. Such an agreed strategy should also be under continual development.

8.5.2.3.2 Improved collaboration (though interconnected, there is a need to keep separate the short-term WRC-driven strategy and the long-term strategy/vision, and a need to take into account Appendix E of this handbook.)

8.5.2.3.3 The identification of spectrum requirements entails the collaboration of a broad range of aviation expertise:

a) strategic policy makers to provide a full understanding of aviation operational strategic requirements, and what and when particular capabilities and operational improvements are required;

b) CNS developers to gain a full understanding of system performance targets;

c) spectrum experts to identify the impact on spectrum requirements through compatibility and capacity studies. In fact, these studies are likely to trigger an iterative process between developers and spectrum experts, and this is a further reason for initiating this interaction at an early stage.

8.5.2.3.4 Additionally, disparate aviation functions need to be fully appraised of the bigger picture and not work in isolation. In this way, opportunities to maximize the effectiveness of existing spectrum allocated to aeronautical services and opportunities to share spectrum will be fully explored and understood while assisting the identification and mitigation of risks around potential single points of failure. These opportunities are generally driven by the system design but must take into consideration related spectrum issues if they are to be exploited through deployment.

8.5.2.3.5 Coordination among aeronautical spectrum managers, frequency managers, CNS policy makers and developers, deployment managers, aviation economists, etc. to collaborate within an international team will ensure that the civil aviation position is strengthened in the international arena. Demonstrating to regulators an efficient and robust spectrum management regime will also help to seal support in obtaining and retaining future spectrum needs for civil aviation. In an environment where resource constraints and dilution of critical expertise can have an adverse impact, improved collaboration within aviation will provide an direct benefit to the sector.

8.5.2.3.6 *Longer-term view*

8.5.2.3.6.1 There must be a focus on the future that the aviation sector wishes to create for itself over the maximum realizable period and harmonized to deliver the long-term operational needs. This long-term view, by necessity, must be robust but sufficiently flexible to accommodate the constantly evolving needs of the sector. While recognizing that there must be a strong drive towards reduced development cycles, the spectrum vision looks beyond those systems already in development towards the needs of conceptual systems. This indicates a need to set out a vision looking forty years hence.

8.5.2.3.6.2 In general, the spectrum vision will be applicable to all new developments. To the maximum extent possible, it is set out to support spectrum requirements for conceptual CNS systems beyond the timeline of existing strategic programmes, such as the GANP and ICAO Regional Plans. As the level of certainty will be diminished as the time line extends, the ICAO spectrum vision focuses more

on generic principles rather than addressing the needs of specific equipment types and systems.

8.5.2.3.7 *Holistic CNS&S approach*

8.5.2.3.7.1 A major element of spectrum management is to provide the necessary support to the identification and promotion of systematic improvements designed to deliver greater spectrum flexibility and efficiency. Communications, navigation and surveillance all require spectrum and often require spectrum with identical or similar propagation properties. It is not appropriate for dedicated teams operating in isolation to identify their spectrum needs because their assumptions and actions may unwittingly impact on other teams' deliverables. For new systems, through the application of holistic arrangements, it will be possible to deliver spectrum efficiency in parallel with meeting the aspirations of CNS designers. Early identification of frequency band options, system bandwidth requirements and compatibility criteria will enable the identification and resolution of spectrum factors external to CNS. In this way, the associated spectrum-related risks can be mitigated and optimum choices for spectrum efficiency can be promoted for incorporation into the system design.

8.5.2.3.7.2 Therefore, there is a need for early, effective internal engagement with all responsible aviation and aerospace parties in the development of a holistic CNS&S strategy, which does not currently exist. Such a strategy is key to maximizing spectrum usage and availability, and it will strengthen aviation's position when dealing with regulatory authorities.

8.5.2.3.8 *Spectrum availability and financial decision making*

8.5.2.3.8.1 In understanding the impact of spectrum on revenue, aviation is in a different position from many other sectors. Many commercial sectors, for example mobile communications, are able to demonstrate that there is a direct relationship between available bandwidth and potential revenue.

8.5.2.3.8.2 For aviation safety purposes, the relationship between bandwidth and revenue is indirect. In general, making available additional spectrum will not deliver increased revenue, unless it results in increased airspace capacity. However, failure to make available sufficient spectrum will have a negative impact on aviation and its global economic revenues.

Chapter 9

INTERFERENCE PROTECTION CONSIDERATIONS

9.1 INTRODUCTION

The regulation and control of interference is essential to the safe and efficient operation of aeronautical radio services. An agreed framework of rules and preventative measures is thus an essential requirement. This framework is laid down in the Radio Regulations for observance by ITU members when cross-border cases of interference arise. National legislation then provides each State with the regulatory means to effect the discharge of the international obligation within its territory. This chapter describes the elements in this framework and contains the following specific sections:

— 9.2 Regulatory aspects

— 9.3 Management and control of interference

— 9.4 Assessment of protection for aeronautical radio services

— 9.5 Some special cases (e.g. VSAT, ISM)

— 9.6 General protection limits for aeronautical radio.

9.2 REGULATORY ASPECTS

The basic definitions of interference and harmful interference

9.2.1 The international framework of agreements for dealing with interference to radio services is contained in the ITU Radio Regulations. The provisions in these Regulations govern the circumstances and the procedures for seeking clearance action from other ITU administrations when interference occurs. The basic qualification for claiming protection is “conformity with the Radio Regulations” which implies that the radio service which is being interfered with is operating in an agreed frequency band and with characteristics which are specified in the Regulations, including its Appendices.

9.2.2 In the Radio Regulations the basic definition of interference is:

1.166 *interference:* The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

9.2.3 It is to be noted that interference is defined by the way in which the interfered system operation is affected. Thus, any performance degradation, misinterpretation or loss of information which would not occur in its absence constitutes interference. The definition does not imply that it is measurable in a quantitative sense, although it may well be in certain instances, but that there has been an adverse change of some detectable character. The change may be detectable by primary means, either aurally (voice signals) or visually (radar or TV), or by measurement (loss of data, inaccurate information, etc.). In some cases, it may be easier or preferable to instrument and record, or use the changed condition to give warning or to apply corrective measures. It is assumed also that interference in the sense employed in the Radio Regulations arises in all cases from sources outside the receiving system itself.

9.2.4 This basic definition of interference as stated in the Radio Regulations makes no reference to whether it is acceptable, but merely to the condition of its existence and its recognition. It is in the category of interference classed as harmful interference that the concept of unacceptability appears as a qualification or condition. This is clearly stated in the Radio Regulations as follows:

1.169 *harmful interference:* Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations (CS).

9.2.5 This regulation introduces the concept of unacceptability and defines criteria with which to make the decision. It is notable that the definition has two quite separate elements, one for radionavigation and safety services, and one for all other radio services. The former requires only proof of endangerment of the functioning, but the latter must demonstrate that a serious degradation or disruption has occurred which is at a higher level of disturbance. Again, as in the case of interference above, the means of assessment is not prescribed and could be either subjective or quantitative. It is important to observe that for interference to be considered harmful, it must be to a service that is operating in accordance with the

Radio Regulations. In this respect, accordance with the Radio Regulations means the totality of the Radio Regulations, including the Appendices. A service which does not operate in accordance with the Radio Regulations cannot claim protection as a right under the Radio Regulations, although administrations may often respond positively to the best of their ability**.** It is to be noted that all aviation safety services are operating on frequencies according to allocations to the service concerned, whether the aeronautical mobile (R) service, the aeronautical mobile-satellite (R) service or the (aeronautical) radionavigation service, and to agreed characteristics, and are operating in accordance with the Radio Regulations, as normally specified in Annex 10. This framework recognizes that interference, in its general sense, is a condition whereby a parameter of a received signal is affected in some way but not necessarily to the extent of being damaging to the reception. The interfering service must cease the interference when it creates a situation in which the operator of the interfered service decides that the service cannot be used for its intended purpose. The action to be taken is to remove interference which can include the reduction of radiated power or closing of the transmitter.

The treatment of harmful interference

9.2.6 Harmful interference is the condition recognized throughout the Radio Regulations as establishing a case for complaint and for the removal of the sources causing the problem. Procedures, obligations and rules related to interference are given detailed attention in **Chapter IV** of the Radio Regulations. The reporting and clearance of harmful interference to a radio service is one of the rights established by a registration in the MIFR and is a right conferred in general terms in RR **8.1** and RR **8.3**. In international terms, it creates an obligation for the country operating the interfering service to take action. The Regulations do not, however, carry mandatory force, and negotiation is the only course of action to resolve difficulties.

9.2.7 Safety services, such as a radionavigation service or an aeronautical mobile (R) service, or in certain cases the aeronautical mobile-satellite (R) service, are safety services as defined in:

1.59 *safety service:* Any radiocommunication service used permanently or temporarily for the safeguarding of human life and property.

9.2.8 Harmful interference to a safety service always requires urgent attention, and this is recognized by all ITU administrations. Safety services include not only the aeronautical services, but also maritime and land mobile services when the messages have safety-of-life content.

9.2.9 Of particular interest to aeronautical services in this context are the provisions mentioned at Section 7-III-3.4 of this handbook. Also, the permission to

operate without an identification for the testing of navaids is to be noted as at RR **15.16.** These measures provide a framework of regulatory actions which ensure that interference judged as harmful is cleared in an effective and expeditious manner.

Radiation and emission

9.2.10 The above terms are mentioned in the definition of interference, and it is important to understand their ITU interpretations in discussions on interference and its effects. Reference to RR **1.137** indicates that "radiation" is the generic category for any radio wave energy that is propagated either deliberately or inadvertently. As a subset, RR **1.138** states that "emission" is the case of radiation produced by a radio transmitting station and only by that source. Thus, radiation could either be the radio wave energy coming from a local oscillator in a receiver, or an instrument or machine used in medical or industrial purposes, while emission is exclusively the radio energy from a transmitting antenna.

Unwanted emissions

9.2.11 Generation of radio energy for RF transmission purposes generally includes signals other than those required for the efficient transmission and reception of the necessary information. When radiated, these have the potential to interfere. In the Radio Regulations, these unwanted emissions are defined as:

1.146 *unwanted emissions:* Consist of spurious emissions and out-of-band emissions.

The definitions of these two elements are given below.

1.145 *spurious emission: Emission* on a frequency or frequencies which are outside the *necessary bandwidth* and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic *emissions*, parasitic *emissions*, intermodulation products and frequency conversion products, but exclude *out-of-band emissions*.

1.144 *out-of-band emission: Emission* on a frequency or frequencies immediately outside the *necessary bandwidth* which results from the modulation process, but excluding *spurious emissions.*

9.2.12 The understanding of these definitions is completed by the definition of the term "necessary bandwidth":

1.152 *necessary bandwidth:* For a given *class of emission*, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

9.2.13 With increased congestion in spectrum utilization, this set of interlinking Regulations has become a highly important starting point for dealing with interactions between adjacent services, between services sharing the same frequency band, and in any other situation of frequency use conflict. A depiction of these relationships is in Figure 9-1.

9.2.14 The Regulations, in Appendix 3, specify a Table of Maximum Permitted Spurious Emission Power Levels. These refer to the power supplied to the antenna transmission line from the transmitter and are "never to be exceeded values". It is recognized that more stringent levels may be laid down by Conference agreement or by special agreement between administrations. For system performance reasons, ICAO SARPs often specify more stringent levels, in effect, meeting the spirit of the "special agreement" requirements of the Regulations.

Permissible interference and accepted interference

9.2.15 The Regulations specify these two further classes of interference:

1.167 *permissible interference*: Observed or predicted interference* which complies with quantitative *interference* and sharing criteria contained in these Regulations or in ITU-R Recommendations or in special agreements as provided for in these Regulations.

1.168 *accepted interference*: Interference* at a higher level than that defined as *permissible interference* and which has been agreed upon between two or more administrations without prejudice to other administrations.

***1.167.1** and **1.168.1** The terms "permissible interference" and "accepted interference" are used in the coordination of frequency assignments between administrations.

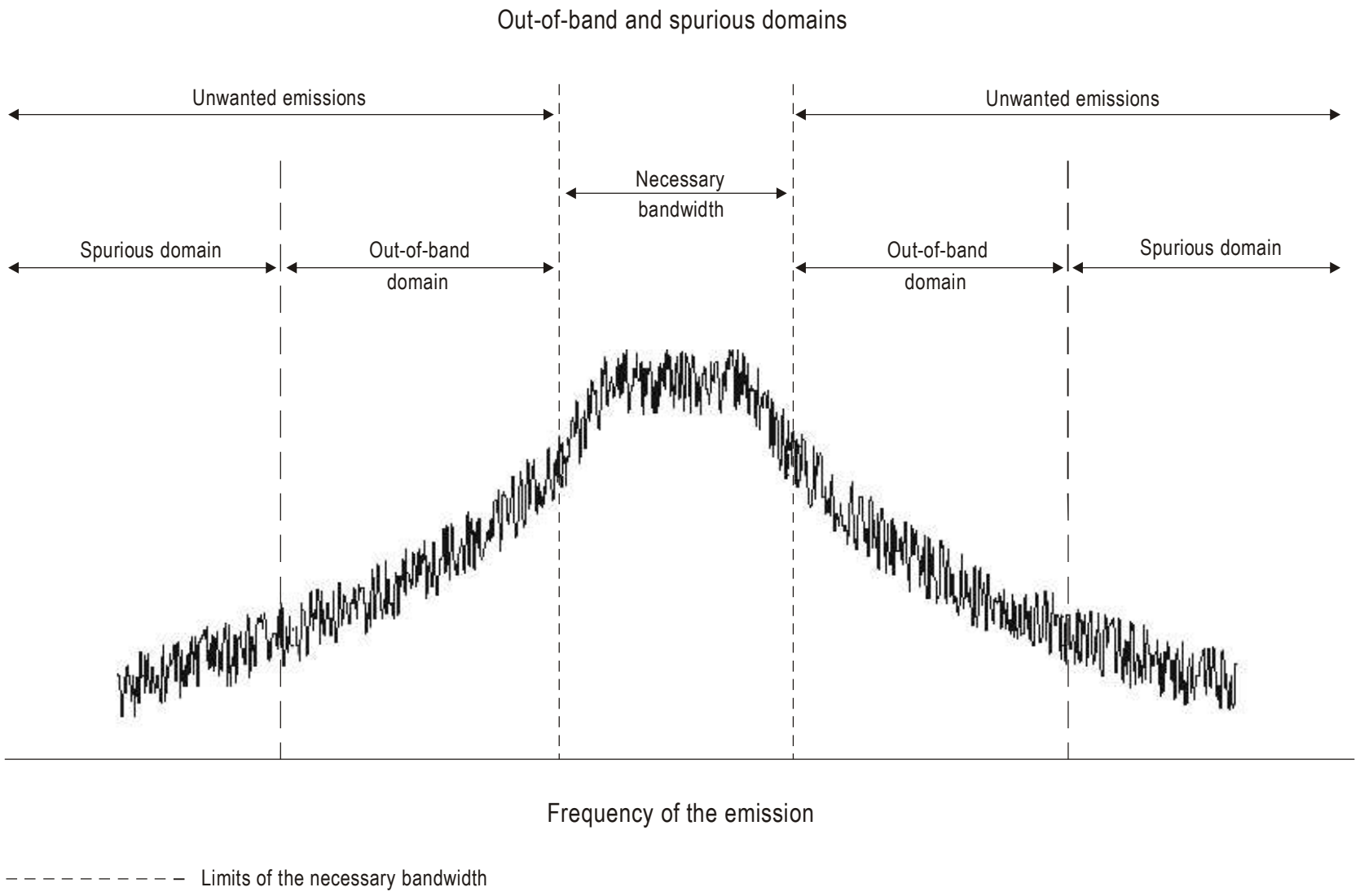

Figure 9-1. Unwanted emissions

9.2.16 These definitions have been developed to provide a basis for planning, and they highlight the fact that frequency planning is essentially a process involving the control of interference.

9.2.17 This concept of acceptability, based on quantitative criteria, can only be a conditional one since it cannot negate the freedom to state a complaint of harmful interference by a service suffering harmful interference. It would provide, nevertheless, a basis for review and adjustment of the criteria as a condition for the agreement to continue. In such a situation, it would be assumed that an aeronautical safety service would be permitted to continue to operate, with the prime obligation being on the interfering service to adjust, close down or take other immediate action to resolve the situation.

Frequency sharing

9.2.18 Assignment planning within a service is the most notable example of the concept of permissible interference and is the application of an agreed protection criterion to ensure that the strength of the unwanted signal from a like facility, or a similar facility in the same service (e.g. voice and data in the VHF communications band), is the agreed number of decibels below that of the wanted signal. In these cases, the acceptable performance change is normally minimal and quite often is a change in the noise floor or the received signal-to-noise ratio. This is highly important for systems such as VOR or ILS, or navigation systems in general, where the changes to the received signal are not easily detectable by the user. All of these quantitative criteria for in-service planning are developed by ICAO for harmonized worldwide application.

9.2.19 Non-safety-of-life services, willing to share a safety-of-life band, have to comply with the aviation safety requirements applicable in that band including certification of radio equipment, software and radio operators, as well as assumption of liability.

9.2.20 Frequency sharing has recently developed a new context with the addition of services other than aeronautical services to previously exclusive aeronautical bands. The criteria for acceptability in these cases are normally developed by the study groups of ITU-R and embodied in their recommendations. Bands where this procedure has already been applied are the aeronautical radionavigation bands at 5 000–5 250 MHz, 9 000–9 500 MHz and 15.4–15.7 GHz. As the spectrum is increasingly exploited and greater demands appear for further uses, the principle of sharing of allocations between two compatible services is likely to become more extensively relied on. In such discussions, the aviation service justifies its protection requirements. Final decisions are made at ITU conferences, sometimes against the best advice from the aviation community.

9.2.21 Sharing an allocation between two services normally places constraints on any future expansion and implementation of both services. This can ultimately be detrimental to aeronautical services whose expansion rate is slower than other, more commercially-based services, in effect resulting in a first-come, first-served situation. As mentioned above, the application of sharing criteria, whether covered by an ITU-R Recommendation or not, cannot negate the right to claim protection from harmful interference. Where the service interfered with has safety-of-life functions, harmful interference would normally require immediate termination or reduction of power of the interfering service until a permanent resolution has been found.

Multiple interference inputs

9.2.22 Assessments of interference effects and of acceptable levels tend to be conducted in isolation from one another. In any given practical situation, the net effect of many potentially interfering sources must be considered and due allowance made. An extra margin of at least 3 dB is recommended in general, with higher values in particular cases where a number of interference sources are known to exist (for example, see ITU-R Recommendation M.1343).

Aviation safety factor

9.2.23 Aeronautical safety applications are required to have continued operation through worst case interference, so all factors which contribute to harmful interference should be considered in analyses involving those applications. An aviation safety margin is included in order to address the risk that some such factors cannot be foreseen (for example impacts of differing modulation schemes). This margin is applied to the system protection criteria to increase the operational assurances to the required level. Traditionally for aviation systems/scenarios an aviation safety margin of 6–10 dB is applied. Until established on the basis of further study on a case-by-case basis, an aviation safety margin of not less than 6 dB should be applied.

Electromagnetic compatibility (EMC)

9.2.24 EMC is defined as the ability of a system to function satisfactorily in an electromagnetic environment without introducing intolerable electromagnetic disturbance to any other system in that environment.

9.2.25 Two elements, basically receiver rejection and transmitter unwanted emissions, are fundamental design parameters in the specification and engineering of radio systems to operate in their typical operating environment. They are normally addressed by national legislation, such as FCC Rules in the United States or ETSI

Standards in Europe. In many countries, they are a prerequisite to the approval of any equipment that generates radio frequency energy as a main functional source. This includes not only communications and navigation equipment but also computing equipment, industrial equipment, etc. The limiting values chosen are normally selected on the basis of best judgement and on the practical and economic factors applying in particular systems.

9.2.26 A good example of the essential need for EMC is in the case of the multiple radio systems (and, more recently, the digital control systems) used on board aircraft. In a modern transport aircraft, these can amount to systems operating in about 18 different frequency bands, with typically 35 antennas. Great care in the placement of antennas and in the internal cabling, and severe limitation of both output power and spurious products is necessary to maintain all installed systems within performance limits. Provisions addressing this point may be found in the specifications for airborne equipment produced by RTCA/EUROCAE and ARINC.

Other important radio regulations

9.2.27 Article **15** of the Radio Regulations lays down procedures and priorities for the actions to be taken in identifying, reporting and clearing interference. This material should be referred to for the detailed rules governing the circumstances, scope for reporting, and actions to be taken. Important provisions in the Radio Regulations are summarized below.

RR 15.16: Provides, in the aeronautical radionavigation service, for the removal of identification signals when tests or adjustments are being carried out.

RR 15.36: When the service being interfered with is a safety service, provides for direct communication to the administration having jurisdiction over the transmitting station causing the interference.

RR 15.40: Where there is a specialized agency (such as ICAO), reports of interference may be copied to that agency coincident with notifying the administration responsible for the station causing the interference.

RRs 15.41 to 15.46: Describe the procedure for the reference of disputes to the Radiocommunication Bureau. It should be noted that the Bureau has no power of enforcement, and its actions are solely those of investigation, reporting and arbitration.

The registration of frequencies

9.2.28 The Master International Frequency Register (MIFR) is held at the headquarters of the ITU in Geneva and is the document in which administrations may register their national frequency use. Following a request to the Radiocommunication Bureau, which is charged with the recording process, the assignment will be checked against the requirements of the Radio Regulations, and if in compliance, the frequency is recorded with the date of request. Later requests must protect any assignment with an earlier date. If a request is not in accordance with the Regulations, an entry may still be made, provided it does not interfere with a registered service, but the assignment will enjoy no protection from later registrations meeting the requirements. This is the so-called "non-interference basis". In the Radio Regulations, the status of recorded assignments is defined in Article **8,** and the notification procedure followed in the recording process is laid down in Article **11**.

9.2.29 Recorded assignments are the highest category of assignment and must always be protected. However, administrations normally accept an interference complaint provided the service is operating in accordance with the Regulations.

9.2.30 Apart from frequencies used for NDB or HF communications, aviation assignments are not registered with ITU on a systematic basis, although administrations may do so if they wish. The ICAO coordination, or the bilateral coordination in some world areas, has traditionally been accepted as a quasi-registration process. In these cases, the ICAO Regional Air Navigation Plan assumes the same role as the MIFR.

Summary of regulatory processes

9.2.31 The protection of aeronautical radio services is an end-to-end process, covered at all points by agreed technical protection criteria and by regulatory provisions, all of which are embodied in ITU Regulations, ITU-R Recommendations and aviation documents. Considerable attention is given in these to the needs of safety services, of which aeronautical services are examples. Exercise of the regulatory functions is the responsibility of national telecommunication administrations which have the necessary powers to license equipment which conforms to agreed specifications and to take action within their own jurisdiction, and with other administrations, to clear harmful interference. Important elements in these processes are:

— the existence of national and international agreements on safe planning criteria and practices;
— agreed mandatory equipment specifications which embody the necessary

control of unwanted emissions and radiations;

— an assignment planning process which is safely applied and which is coordinated to the extent necessary with other services and administrations;

— the efficient and effective monitoring and reporting of interference;

— immediate attention to clearing cases of harmful interference to aeronautical radio services.

9.3 MANAGEMENT AND CONTROL OF INTERFERENCE

9.3.1 Interference of all kinds is an ever-present feature of all radio frequency bands, arising from the transmissions from a multiplicity of different radio services, increasing in quantity and in power almost daily. The higher power services, such as broadcasting, radar and some specialized defence systems, have a potential to cause considerable disruption and must be carefully controlled. In addition to radio services, there are many other sources of interfering radio energy, such as industrial and medical machinery, motor vehicles, power transmission lines and many other electrical and electronic sources. Over cities and industrial areas particularly, the ambient radio noise can attain quite high levels making the detection of weak signals difficult, and on occasion impossible, affecting in particular the reception of radio in aircraft.

9.3.2 The management and control of the interference present in the radio environment is a highly important supplementary activity to that of the management of the radio spectrum itself. As with spectrum management, the overall process is a layered activity with international agreement on fundamentals in the upper layer, followed by national legislation and enforcing machinery. Good management and minimization of harmful products also increases the effective utilization of frequencies.

9.3.3 The basic elements in the process are:

International agreement on the regulatory basis. The elements of the basic regulatory framework are contained in the Radio Regulations and have been described above. These define a set of principles and actions which are designed to provide administrations with agreed understandings for use with other administrations and internally within their own countries. This activity is

international in character and is centred on the ITU in the first instance. ITU Regulations are treaty obligations and in respect of interference clearance are conscientiously followed. Where normal negotiation fails to resolve an issue, there is scope for reference of problems to the ITU Radio Regulations Board. However this is not a compulsory arbitration procedure, and in the unlikely event that this fails, the service suffering the interference may have to take independent action.

System and equipment standards. Development of standards and specifications for systems and equipment is the second step in the process. The standards and specifications must contain essential performance requirements relating to the maximum permitted levels of unwanted emissions. Internationally developed standards, such as those in aviation agreed by ICAO and RTCA or in ITU-R Recommendations, and in Europe those of Eureka and ETSI, have to incorporate clauses addressing these aspects. The Spurious Emission Limits at Appendix 3 of the Radio Regulations are "never to be exceeded" limits and negotiations are often necessary to analyse individual situations and specify levels below those in the Regulations. Most Annex 10 SARPs for adjacent channel frequency planning specify levels that are lower than those in Appendix 3. A recent example of individual negotiation may be found in the case of mobile-satellite equipment operating in bands adjacent to that of GNSS with the potential to interfere with approach and landing of aircraft. In this case, it was necessary to have agreement in both ITU-R and ETSI.

Licensing of radio services. Within national territory, legislation is necessary to provide the enforcement powers to manage and control the processes at the operating level. National telecommunication authorities hold this responsibility for the licensing of all radio services within their jurisdiction. In this process, the authority must ensure that the radio system is approved to agreed standards, that its EMC performance is adequate, and that it operates with characteristics which are in accordance with international agreements. The national telecommunication authority remains the regulating body for its operation in regard to interference with other radio services. The most important international obligation is to the Radio Regulations and ITU-R Recommendations; others may be regional standards such as those developed in Europe by ETSI. In the case of radio for civil aviation safety purposes, both ground and airborne, other requirements may be applied emanating from ICAO SARPs, RTCA and EUROCAE specifications, and for airworthiness purposes, the TSO laid down by the FAA in the United States and the JAA in Europe.

Control and clearance of interference. As with radio licensing, the responsibility for control and clearance of interference will normally rest with the national telecommunication authority under the same national legislation which addresses the detecting, the resolving and, if necessary, the closing down of sources of interference. This will include, in addition to radio stations, licensed or unlicensed, any equipment or system capable of radiating and causing interference. Many industrial, scientific, computer and line transmission systems have the potential for interference. If the service is a safety service, action must be taken on an urgent basis. Identification of an interference source is a difficult and often time-consuming activity. Some aviation authorities have found it beneficial in effecting a speedy clearance to assist the national telecommunication authority by local detection actions in which local knowledge is used to good advantage.

9.4 ASSESSMENT OF PROTECTION FOR AERONAUTICAL RADIO SERVICES

The nature of interference and its detection

9.4.1 Interference may not result in a change in the receiver output signal. Particular care is necessary with systems in which the output is neither aural nor visual, such as digital systems or systems where the output is used to operate control systems, where interference may not be detected for some time. The task of assessing the threat posed by other signals so as to make a decision of acceptability, for example in allocation sharing, must however have a basis which is logical and amenable to analysis.

9.4.2 For the assessment of compatible sharing with other radio services (a situation becoming more common), or where the threat is unwanted emissions from a known non-aviation system, a quantitative criterion has to be stated and used as a reference for decision making. For this purpose, a maximum interference threshold limit is normally chosen which has been selected on the basis of acceptable degradation, taking into account all other environmental conditions. In the absence of other data, the usual planning ratio for wanted-to-unwanted signals within the aviation service should be enhanced to give a margin for uncertainties which cannot be quantified (see 9.2.23).

9.4.3 At higher frequencies in the GHz ranges, and for wide-band low signal services, the criterion often used is the acceptable increase in the noise floor, or the noise temperature, of the receiving system. Antenna gains or losses are included to replicate real-life conditions. The final approach and landing phase is accepted as

being the most important of the safety-critical services. The model described below is recommended for this analysis.

The concept of a generalized assessment method

9.4.4 Many interference predictions have to be assessed on the basis of theoretical analysis. An agreed standard model and methodology is used as a basis for comparing the results of separate analyses and in formulating a conclusion on acceptability. The need to predict interference will arise in many different situations and, particularly, in the case where a decision on acceptable sharing of an allocation by two services is the issue. Real-life conditions are not accurately predictable, and theoretical analysis will invariably have to be verified under actual operational conditions before full acceptance is given to any proposal for sharing.

9.4.5 The effects of interference and the particular form of the signal degradation that it causes are usually dependent on the characteristics of the interfering signal. Pulsed and continuous-type signals often produce different results, with one or the other having more objectionable effects, or with more invasion of the demodulating process. Whenever data relating to the effects of specific modulations are available, these should be used to provide near realistic analyses of the interference situation. Tests and experiments should carefully replicate the actual interference situation as closely as possible, and quantitative analysis should clearly indicate the relevance of the criteria to the case in question.

Variables

9.4.6 In the minimization of the effects of interference there are four main areas on which to concentrate efforts to make improvements:

The source of the interfering signals. Control of the source is often the only practical means of protecting aviation radio services. This can take many forms depending on the nature of the potentially interfering signal. For radio transmitters, close control of unwanted emissions is essential, and the use of only necessary transmitting power to meet the requirements stated in RR **15.2** is also a discipline for operators of stations. Control at source is dependent on effective measures at a national licensing level, and these measures themselves should be aligned with standards agreed internationally, either globally or regionally.

A particular example is that of industrial, scientific and medical (ISM) equipment which use the heating effect of radio wave energy, are potential sources of interference, and are required to operate only in designated bands and exercise control and monitoring in accordance with RR **15.13** (see 9.5 below).

Another recent example is that of mobile-satellite terminals operating in bands close to GNSS services, for which ITU-R and ETSI standards have been developed.

Frequency separation. Where the interfering source operates on a discrete frequency, the provision of a frequency separation, or guard band, between the source and the receiver may be employed to provide the requisite protection. In using this, account can be taken of the receiver's rejection response to reduce the overall effect.

Distance separation between the interference source and the aviation receiver. Distance separation to reduce the energy of the potentially interfering signal to an acceptable level is a standard method of establishing the protection necessary in many practical applications. It is the method normally employed in assignment planning, for which purpose agreed protection and propagation path criteria are used in the calculation. In coordination between two services, a limiting value of separation, based on worst-case evaluation beyond which no coordination is required, is often employed. Another notable example is the analysis of final approach situations where a typical minimum separation distance between source and receiver may be chosen and used in calculations to establish the acceptability of proposed maximum spurious levels. (An ITU-R standard model for approach and landing has been developed.)

The aviation receiver. Receivers having a good interference rejection performance are now, in an ever-increasingly crowded spectrum, an essential requirement. No service user can claim protection until the receiving equipment employed in that service has been designed and built with full regard to this requirement. The Radio Regulations in RR **3.3** make mention of this obligation to take all measures which are economically and technically justifiable to minimize the effects of transmissions, particularly in adjacent bands, and RRs **3.12** and **3.13** require that radio receivers should have adequate performance to minimize the effects of signals outside the occupied bandwidth. The principle applied is based on the joint responsibility of both the service that is vulnerable and the potential interferer to share equally the burden of compatibility. Where the affected service is a safety service, such as aeronautical radionavigation or communications, the same general considerations apply, and receivers are expected to be resistant to expected interferences. An example of this is the case of VOR and ILS receivers operating adjacent to FM broadcasting.

9.4.7 Consideration of the above four elements leads to the concept of a "standard model" for use as a tool in theoretical assessments. This is described below.

The standard model

9.4.8 The source-path-receiver model is a three-element simulation of actual conditions that is commonly used for assessing on a quantitative basis the acceptability of specific limits on the production of interfering products. The analysis may be a single evaluation or an iterative simulation depending on the data and facilities available. The model is deterministic in its application to the analysis of aeronautical radio services protection. That is, the receiver susceptibility mask, the antenna losses or gains, and the propagation path and its variabilities are all considered at their worst-case limits. From these considerations the ideal radio frequency interference (RFI) source mask may be estimated and tested for practical realism. A process of adjustment of the variables, particularly distance separation, would follow to arrive at agreed standards, which if necessary may then be embodied in regulatory material.

9.4.9 Important points in the analysis are:

Service volume. The aeronautical protection point and the service volume chosen must take account of agreed and specified service volumes as stated in the ICAO Annexes or in other defining documentation. Normally, this would be the nearest service volume extremity to the interfering source. This is the case where the source is outside the service volume. Where the source is close to the receiver, such as during a landing operation, a carefully prepared scenario should be used. That recommended in ITU-R Recommendation M.1343 has been prepared by ICAO Panels and may be used in many cases.

Receiver susceptibility. The receiver criterion for acceptable degradation has to be carefully chosen. It must relate as appropriate to a detected change in a measurable parameter, or in perceived aural or visual reference, or in increase in error rate or other relevant characteristic, depending on the form and content of the receiver output. The receiver must under all conditions, with and without normal signal input, operate within its standard performance envelope, including measurement error limits, taking account also the real-life environment and other known interfering sources, in arriving at the limits for receiver susceptibility. Unacceptable change to the noise floor may be used as the datum for systems in the higher frequency bands, for example, in assessing interference to radar.

Propagation data. The best available propagation data, usually that documented in CCIR and ITU-R Reports, should be used. Account must be taken of the variability which applies to all propagation modes, and particularly where the separation distances are at the limits, near or beyond the radio horizon, or where seasonal phenomena, such as night effect at LF/MF, ducting at VHF, or ionosphere conditions at HF, exist. Natural features or shielding,

such as that provided by terrain or by the aircraft body, may be included if they are permanent features present in all cases of interest. In many cases, free space attenuation may be used as the reference level in calculations, especially above 1 GHz and where the distance separation exceeds 20 km.

Installation conditions. Variables such as antenna system losses, antenna gain in particular directions, terrain shielding or, in the case of aircraft installations, the effects of the aircraft body, may be included as variations from standard scenarios to produce more refined results in particular cases. Similarly, the interfering source conditions may be treated in the same way as a means to arrive at practical results.

The institutional processes for protection discussions and agreements

9.4.10 The ITU Radiocommunication Assembly adopts Recommendations dealing with all aspects of radio. This includes the interference aspects and sharing between services. Increasing congestion and sharing of two services on the same frequency has caused this activity to increase in intensity and depth. As spectrum congestion spreads, this activity is likely to increase further. Adjacent band services with a high differential in power levels, such as FM broadcast and mobile-satellite terminals, are typical real-life problem areas encountered by aviation services. The strategic siting of services in the Table of Frequency Allocations to minimize adjacent band problems is no longer practicable because of the pressures to meet requirements wherever they can be fitted in.

9.4.11 ITU-R Recommendations, resulting from the work of Study Groups, are the normal means of documenting the conclusions and agreements on technical bases. While these are generally only voluntary in their application, they are nevertheless applied conscientiously by administrations and by industry. The exceptions are a few special category subjects — NDB signal levels is one — where a linking reference placed in the Radio Regulations gives a Recommendation the same treaty status as a Regulation.

9.4.12 ITU-R Study Groups 4 and 5 are the most important for aviation and deal with all mobile services, satellite and terrestrial, and with radionavigation of all kinds. WP5B and WP4C are the principal subcomponents.

9.5 SOME SPECIAL CASES

Industrial, scientific and medical (ISM) equipment

Definition and description

9.5.1 The definition for ISM applications appears at RR **1.15** and is:

> **1.15** *Industrial, Scientific and Medical (ISM) applications* (of radio frequency energy): Operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of *telecommunications*.

9.5.2 This definition is intended to include a wide range of equipment in which the heating effect of RF energy is utilized to perform industrial and medical processes. High powers can be generated especially for such processes as metal hardening (e.g. car engine crankshafts), but the application area is local to the RF head. Measurement standards are often difficult to define, and this is particularly true in the case of large equipment assembled on site. Electromagnetic screening measures must be efficient in constraining the escape of energy and effective in maintaining that level of protection.

Radio Regulations

9.5.3 In the Radio Regulations, ISM does not fall within the definition of a radio service and is hence not subject to any of the provisions of the Regulations. Nevertheless, frequencies are designated for ISM use with the condition that radio services must accept interference if they are operated on the same frequencies. The text of the Regulation concerned is:

> **5.150** The following bands:
>
> **13 553–13 567 kHz (centre frequency 13 560 kHz),**
> **26 957–27 283 kHz (centre frequency 27 120 kHz),**
> **40.66–40.70 MHz (centre frequency 40.68 MHz),**
> **902–928 MHz in Region 2 (centre frequency 915 MHz),**
> **2 400–2 500 MHz (centre frequency 2 450 MHz),**
> **5 725–5 875 MHz (centre frequency 5 800 MHz), and**
> **24–24.25 GHz (centre frequency 24.125 GHz)**

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. **15.13**.

The text of RR **15.13** is:

15.13 9. Administrations shall take all practicable and necessary steps to ensure that radiation from equipment used for industrial, scientific and medical applications is minimal and that, outside the bands designated for use by this equipment, radiation from such equipment is at a level that does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations.

9.5.4 In the above list (RR **5.150**), particular attention has to be given to the frequencies in the 13 MHz and 27 MHz bands, since harmonics of these fall into both the ILS/VOR and the VHF COM bands with the potential in each case to affect a number of assignment points within each harmonic spread (as indicated in Figure 9-2).

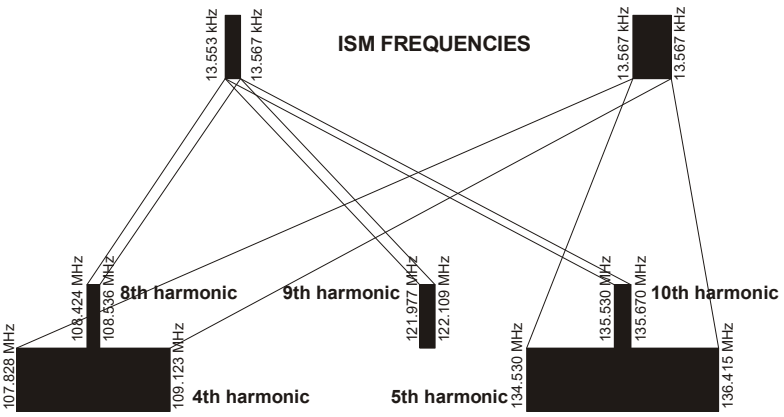

Figure 9-2. ISM frequencies

Control of ISM equipment

9.5.5 International action to agree on standards and conditions for the radio frequency radiations from ISM equipment takes place under the aegis of the International Special Committee on Radio Interference (CISPR), which is a component of the International Electrotechnical Commission (IEC). These standards are voluntary, and it is the responsibility of national authorities to decide on the extent and the nature of their national legislation required for the control of interference from these systems.

ITU-R Recommendations and CISPR publications

9.5.6 ITU-R Recommendation SM-1056 recommends the use of CISPR Publication 11 as a guide for the application of limits and methods of measurement for ISM equipment.

Very small aperture terminals (VSAT)

9.5.7 Aviation safety in certain regions of the world has been compromised by a lack of reliable fixed aeronautical telecommunications infrastructure used for providing air traffic services/direct speech (ATS/DS) and aeronautical fixed telecommunications network (AFTN) voice and data services. Service providers working together with air traffic and navigation services and civil aviation authorities have introduced C-band very small aperture terminal (VSAT) networks to resolve the lack of communications. The use of C-band allows for maintaining a reliable connection in all weather conditions; something that networks operating at higher frequencies would not support. The basic networks evolved with improving technology, and are currently used in a number of regions to support all aeronautical communications services including the extension of VHF aeronautical mobile, navigation and surveillance. VSAT networks are also used for data links for the meteorological services. VSAT networks constitute a real infrastructure, spanning, for example, the entire African continent and beyond. Aviation access to the entire 3 400–4 200 MHz FSS (space-to-Earth) band and the associated 5 850–6 725 MHz FSS (Earth-to-space) band (5 725–6 725 MHz in Region 1) is crucial to ensure the continued growth of traffic while maintaining the required level of safety in this region.

9.5.8 During WRC-07, the issue was addressed whether the band 3 400–4 200 MHz should be identified for the international mobile telecommunications (IMT) on a global basis. After study, global identification was rejected because of the recognized need to protect FSS communications from harmful interference. “Opt-in” footnotes were adopted however, in portions of the band in all of the ITU

Regions. In particular, allocations supporting IMT were adopted for eight-one countries in Region 1 for the band 3 400–3 600 MHz and fourteen countries in Region 2 for the band 3 400–3 500 MHz. The 3 500–3 600 MHz band has also been identified for IMT in countries that opt-in in Region 3. At WRC-15, the issue was revisited, and the band 3 400–3600 MHz was identified for IMT for the entirety of Regions 1 and 2 and for eleven Region 3 countries, and the band 3 600–3 700 MHz was identified for IMT in four Region 2 countries. The current situation is described in RR Nos. **5.430A**, **5.431B**, **5.432A**, **5.432B**, **5.433A** and **5.434**.

9.5.9 Interference cases from IMT into VSAT were experienced after the WRC-07 decision. Tests indicated that interference was not caused by co-channel IMT/VSAT assignments, but by the harmonic content in the side lobes of the radiated IMT signal into the VSAT. As a result, WRC-15 improved technical and regulatory conditions in order to support existing and future operations of VSAT within the frequency band 3 400–4 200 MHz as an aid for safe operation of aircraft. In particular, the conference modified Resolution **154 (Rev. WRC-15)** to underscore the protection needs of existing and planned aeronautical and meteorological VSAT stations. The modified Resolution also highlights the need to license the VSAT stations and register them in the MIFR to ensure that they are visible to all administrations concerned.

9.6 GENERAL PROTECTION LIMITS FOR AERONAUTICAL RADIO

The limits displayed in Table 9-1 are intended to give general guidance. For individual analysis, reference should be made to the complete definitive texts in the authoritative documents. Particular attention in these cases needs to be given to the specific spectral characteristics of the interfering systems.

These limits can ONLY be applied to assess intra-system interference and CANNOT be used to assess compatibility between systems with different RF or spectral characteristics.

Table 9-1. General protection limits

Not to be used for assessing compatibility with dissimilar systems

	Use	*Frequency band*	*Minimum signal dB (uV/m)*	*Intra-system planning protection ratio DB*
1	Omega	10–14 kHz		
2	NDB	190–850 kHz	37 (1)	15
3	HF communications	2.8–22 MHz		15
4	ILS marker beacon	74.8–75.2 MHz	46 (1)	20
5	ILS localizer	108–112 MHz	40 (1)	20
6	VOR	108–118 MHz	39 (1)	20
7	VHF communications	118–137 MHz	37 (1)	14
8	ILS glide path	328.6–335.4 MHz	52 (1)	20
9	ELT	406 MHz		
10	DME	960–1 215 MHz	71 (1)	8
11	SSR	1 030–1 090 MHz		
12	Primary radar (23 cm)	1 215–1 350 MHz		
13	Satcom (s-E)	1 525–1 559 MHz		
14	GPS	1 559–1 610 MHz	–160 dBW (2)	
15	GLONASS	1 559–1 610 MHz	–160 dBW (2)	
16	Satcom (E-s)	1 626.5–1 660.5 MHz		
17	PSR (10 cm)	2 700–3 300 MHz		
18	Radio altimeter	4 200–4 400 MHz		
19	MLS	5 030–5 150 MHz	58	20
20	Air weather radar	5 350–5 460 MHz		
21	Air weather radar	9 345–9 375 MHz		
22	Primary radar (3 cm)	9 000–9 500 MHz		

	Use	*Frequency band*	*Minimum signal dB (uV/m)*	*Intra-system planning protection ratio DB*
23	Air Doppler navigation	13.25–13.4 GHz		
24	ASDE	15.4–15.7 GHz		
25	RSMS	15.4–15.7 GHz		

Notes.—
1. *Signal levels specified in Annex.*
2. *At receiver terminals.*

Attachment A

DEFINITIONS AND TERMS USED IN THE ITU RADIO REGULATIONS RELEVANT TO AVIATION

1. INTRODUCTION

Article 1 of the Radio Regulations contains all of the definitions used in the Radio Regulations in relation to their interpretation. Some of the most important definitions for aeronautical services have been extracted and are reproduced in this attachment. Reference should be made to the full catalogue of definitions in Article 1 in cases where there is a need to appreciate their hierarchical structure.

1.1 For the purposes of these Regulations, the following terms shall have the meanings defined below. These terms and definitions do not, however, necessarily apply for other purposes. Definitions identical to those contained in the Annex to the Constitution or the Annex to the Convention of the International Telecommunication Union (Geneva, 1992) are marked "(CS)" or "(CV)" respectively.

Note.— If, in the text of a definition below, a term is printed in italics, this means that the term itself is defined in this Article.

SECTION I — GENERAL TERMS

1.2 *administration:* Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations (CS 1002).

1.3 *telecommunication:* Any transmission, *emission* or reception of signs, signals, writings, images and sounds or intelligence of any nature by wire, *radio*, optical or other electromagnetic systems (CS).

1.4 *radio:* A general term applied to the use of *radio waves*.

1.6 *radiocommunication: Telecommunication* by means of *radio waves* (CS)(CV).

1.7 *terrestrial radiocommunication:* Any *radiocommunication* other than *space radiocommunication* or *radio astronomy*.

1.9 *radiodetermination:* The determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of *radio waves*.

1.10 *radionavigation: Radiodetermination* used for the purposes of navigation, including obstruction warning.

SECTION II — SPECIFIC TERMS RELATED TO FREQUENCY MANAGEMENT

1.16 *allocation* (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space *radiocommunication services* or the *radio astronomy service* under specified conditions. This term shall also be applied to the frequency band concerned.

1.17 *allotment* (of a radio frequency or radio frequency channel): Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space *radiocommunication service* in one or more identified countries or geographical areas and under specified conditions.

1.18 *assignment* (of a radio frequency or radio frequency channel): Authorization given by an administration for a radio *station* to use a radio frequency or radio frequency channel under specified conditions.

SECTION III — RADIO SERVICES

1.19 *radiocommunication service:* A service as defined in this Section involving the transmission, *emission* and/or reception of *radio waves* for specific *telecommunication* purposes.

In these Regulations, unless otherwise stated, any radiocommunication service relates to *terrestrial radiocommunication*.

1.20 *fixed service:* A *radiocommunication service* between specified fixed points.

1.24 *mobile service:* A *radiocommunication service* between *mobile* and *land stations*, or between *mobile stations* (CV).

1.25 *mobile-satellite service:* A *radiocommunication* service:

— between *mobile earth stations* and one or more *space stations*, or between *space stations* used by this service; or

— between *mobile earth stations* by means of one or more *space stations*.

This service may also include *feeder links* necessary for its operation.

1.32 *aeronautical mobile service:* A *mobile service* between *aeronautical stations* and *aircraft stations*, or between *aircraft stations*, in which *survival craft stations* may participate; *emergency position-indicating radiobeacon stations* may also participate in this service on designated distress and emergency frequencies.

1.33 *aeronautical mobile (R)* service:* An *aeronautical mobile service* reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes.

1.35 *aeronautical mobile-satellite service:* A *mobile-satellite service* in which *mobile earth stations* are located on board aircraft; *survival craft stations* and *emergency position-indicating radiobeacon stations* may also participate in this service.

1.36 *aeronautical mobile-satellite (R)* service:* An *aeronautical mobile-satellite service* reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes.

1.40 *radiodetermination service:* A *radiocommunication service* for the purpose of *radiodetermination*.

1.42 *radionavigation service:* A *radiodetermination service* for the purpose of *radionavigation*.

1.43 *radionavigation-satellite service:* A *radiodetermination-satellite service* used for the purpose of *radionavigation*.

This service may also include *feeder links* necessary for its operation.

1.46 *aeronautical radionavigation service:* A *radionavigation service* intended for the benefit and for the safe operation of aircraft.

1.47 *aeronautical radionavigation-satellite service:* A *radionavigation-satellite service* in which *earth stations* are located on board aircraft.

1.59 *safety service:* Any *radiocommunication service* used permanently or temporarily for the safeguarding of human life and property.

* (R): Route

SECTION IV — RADIO STATIONS AND SYSTEMS

1.61 *station*: One or more transmitters or receivers or a combination of transmitters and receivers, including the accessory equipment, necessary at one location for carrying on a *radiocommunication service*, or the *radio astronomy service*.

Each station shall be classified by the service in which it operates permanently or temporarily.

1.62 *terrestrial station:* A *station* effecting *terrestrial radio- communication*.

In these Regulations, unless otherwise stated, any *station* is a terrestrial station.

1.63 *earth station:* A *station* located either on the Earth's surface or within the major portion of the Earth's atmosphere and intended for communication:

— with one or more *space stations*; or

— with one or more *stations* of the same kind by means of one or more reflecting *satellites* or other objects in space.

1.65 *survival craft station:* A *mobile station* in the *maritime mobile service* or the *aeronautical mobile service* intended solely for survival purposes and located on any lifeboat, life-raft or other survival equipment.

1.66A *high altitude platform station:* A station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth.

1.67 *mobile station:* A *station* in the *mobile service* intended to be used while in motion or during halts at unspecified points.

1.68 *mobile earth station:* An *earth station* in the *mobile-satellite service* intended to be used while in motion or during halts at unspecified points.

1.81 *aeronautical station:* A *land station* in the *aeronautical mobile service*.

In certain instances, an aeronautical station may be located, for example, on board ship or on a platform at sea.

1.82 *aeronautical earth station:* An *earth station* in the *fixed-satellite service*, or, in some cases, in the *aeronautical mobile-satellite service*, located at a specified fixed point on land to provide a *feeder link* for the *aeronautical mobile-satellite service*.

1.83 *aircraft station:* A *mobile station* in the *aeronautical mobile service*, other than a *survival craft station*, located on board an aircraft.

1.84 *aircraft earth station:* A *mobile earth station* in the *aeronautical mobile-satellite service* located on board an aircraft.

1.87 *radionavigation mobile station:* A *station* in the *radionavigation service* intended to be used while in motion or during halts at unspecified points.

1.88 *radionavigation land station:* A *station* in the *radionavigation service* not intended to be used while in motion.

1.92 *radiobeacon station:* A *station* in the *radionavigation service* the *emissions* of which are intended to enable a *mobile station* to determine its bearing or direction in relation to the radiobeacon station.

1.93 *emergency position-indicating radiobeacon station:* A *station* in the *mobile service* the *emissions* of which are intended to facilitate search and rescue operations.

1.94 *satellite emergency position-indicating radiobeacon:* An *earth station* in the *mobile-satellite service* the *emissions* of which are intended to facilitate search and rescue operations.

1.100 *radar:* A *radiodetermination* system based on the comparison of reference signals with radio signals reflected, or retransmitted, from the position to be determined.

1.101 *primary radar:* A *radiodetermination* system based on the comparison of reference signals with radio signals reflected from the position to be determined.

1.102 *secondary radar:* A *radiodetermination* system based on the comparison of reference signals with radio signals retransmitted from the position to be determined.

1.103 *radar beacon (racon):* A transmitter-receiver associated with a fixed navigational mark which, when triggered by a *radar*, automatically returns a distinctive signal which can appear on the display of the triggering *radar*, providing range, bearing and identification information.

1.104 *instrument landing system (ILS):* A *radionavigation* system which provides aircraft with horizontal and vertical guidance just before and during landing and, at certain fixed points, indicates the distance to the reference point of landing.

1.105 *instrument landing system localizer:* A system of horizontal guidance embodied in the *instrument landing system* which indicates the horizontal deviation of the aircraft from its optimum path of descent along the axis of the runway.

1.106 *instrument landing system glide path:* A system of vertical guidance embodied in the *instrument landing system* which indicates the vertical deviation of the aircraft from its optimum path of descent.

1.107 *marker beacon:* A transmitter in the *aeronautical radionavigation service* which radiates vertically a distinctive pattern for providing position information to aircraft.

1.108 *radio altimeter: Radionavigation* equipment, on board an aircraft or *spacecraft*, used to determine the height of the aircraft or the *spacecraft* above the Earth's surface or another surface.

1.109A *adaptive system:* A radiocommunication system which varies its radio characteristics according to channel quality.

SECTION V — OPERATIONAL TERMS

1.116 *public correspondence:* Any *telecommunication* which the offices and *stations* must, by reason of their being at the disposal of the public, accept for transmission (CS).

SECTION VI — CHARACTERISTICS OF EMISSIONS AND RADIO EQUIPMENT

1.137 *radiation:* The outward flow of energy from any source in the form of *radio waves*.

1.138 *emission: Radiation* produced, or the production of *radiation*, by a radio transmitting *station*.

For example, the energy radiated by the local oscillator of a radio receiver would not be an emission but a *radiation*.

1.144 *out-of-band emission*: Emission* on a frequency or frequencies immediately outside the *necessary bandwidth* which results from the modulation process, but excluding *spurious emissions*.

1.145 *spurious emission*: Emission* on a frequency or frequencies which are outside the *necessary bandwidth* and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic *emissions*, parasitic *emissions*, intermodulation products and frequency conversion products, but exclude *out-of-band emissions*.

1.146 *unwanted emissions*:* Consist of *spurious emissions* and *out-of-band emissions*.

1.147 *assigned frequency band:* The frequency band within which the *emission* of a *station* is authorized; the width of the band equals the *necessary bandwidth* plus twice the absolute value of the *frequency tolerance*. Where *space stations* are concerned, the assigned frequency band includes twice the maximum Doppler shift that may occur in relation to any point of the Earth's surface.

1.148 *assigned frequency:* The centre of the frequency band assigned to a *station*.

1.153 *occupied bandwidth:* The width of a frequency band such that, below the lower and above the upper frequency limits, the *mean powers* emitted are each equal to a specified percentage β/2 of the total *mean power* of a given *emission*.

Unless otherwise specified in an ITU-R Recommendation for the appropriate *class of emission*, the value of β/2 should be taken as 0.5%.

1.161 *equivalent isotropically radiated power (e.i.r.p.):* The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (*absolute or isotropic gain*).

1.162 *effective radiated power (e.r.p)* (in a given direction): The product of the power supplied to the antenna and its *gain relative to a half-wave dipole* in a given direction.

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* The terms associated with the definitions given by Nos. **1.144, 1.145** and **1.146** shall be expressed in the working languages as follows:

Numbers	In French	In English	In Spanish
1.144	Emission hors bande	Out-of-band emission	Emisión fuera de banda
1.145	Rayonnement non essentiel	Spurious emission	Emisión no esencial
1.146	Rayonnements non désirés	Unwanted emissions	Emisiones no deseadas

SECTION VII — FREQUENCY SHARING

1.166 *interference:* The effect of unwanted energy due to one or a combination of *emissions*, *radiations*, or inductions upon reception in a *radiocommunication* system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

1.167 *permissible interference*:* Observed or predicted *interference* which complies with quantitative *interference* and sharing criteria contained in these Regulations or in ITU-R Recommendations or in special agreements as provided for in these Regulations.

1.168 *accepted interference*: Interference* at a higher level than that defined as *permissible interference* and which has been agreed upon between two or more administrations without prejudice to other administrations.

1.169 *harmful interference: interference* which endangers the functioning of

a *radionavigation service* or of other *safety services* or seriously degrades, obstructs, or repeatedly interrupts a *radiocommunication service* operating in accordance with Radio Regulations (CS).

1.170 *protection ratio (R.F.):* The minimum value of the wanted-to-unwanted signal ratio, usually expressed in decibels, at the receiver input, determined under specified conditions such that a specified reception quality of the wanted signal is achieved at the receiver output.

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* **1.167.1** and **1.168.1** The terms “permissible interference” and “accepted interference” are used in the coordination of frequency assignments between administrations.

Attachment B

ACRONYMS AND ABBREVIATIONS

AAC	Aeronautical administrative communications
ACAS	Airborne collision avoidance system
ACP	Aeronautical Communications Panel (ICAO)
ADF	Automatic direction finder
ADS	Automatic dependent surveillance
ADS-B	Automatic dependent surveillance-broadcast
ADSP	Automatic Dependent Surveillance Panel (ICAO)
AEEC	Airlines Electronic and Engineering Committee
ALS	Aircraft landing system
AM(OR)S	Aeronautical mobile (off-route) service (ITU)
AM(R)S	Aeronautical mobile (route) service (ITU)
AMS(OR)S	Aeronautical mobile-satellite (off-route) service (ITU)
AMS(R)S	Aeronautical mobile-satellite (route) service (ITU)
AMSS	Aeronautical mobile-satellite service
AMT	Aeronautical mobile telemetry
ANC	Air Navigation Commission (ICAO)
AOC	Aeronautical operational control
APC	Aeronautical passenger communications
APT	Asia-Pacific Telecommunity
ARINC	Aeronautical Radio, Inc.
ARNS	Aeronautical radionavigation service (ITU)
AS	Aeronautical security
ASDE	Airport surface detection equipment
ASMG	Arab Spectrum Management Group
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic service
ATU	African Telecommunications Union
AWOP	All Weather Operations Panel (ICAO)
AWR	Airborne weather radar
CAT	Category (of landing)
CCIR	International Radio Consultative Committee
CDMA	Code division multiple access
CEPT	Conférence Européene des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunications Administrations)

CISPR	International Special Committee on Radio Interference
CITEL	Comisión Interamericana de Telecomunicaciones (Inter-American Telecommunication Commission)
CNS	Communications, navigation and surveillance
COSPAS/SARSAT	International satellite system for search and rescue
CPM	Conference Preparatory Meeting (ITU)
DGNSS	Differential global navigation satellite system
DME	Distance measuring equipment
DME/N	Distance measuring equipment-normal
DME/P	Distance measuring equipment-precision
DSB	Double sideband
DSB-AM	Double sideband-amplitude modulation
EASA	European Aviation Safety Agency
EESS	Earth exploration-satellite service
e.i.r.p.	Equivalent isotropically radiated power
ELT	Emergency locator transmitter
EMC	Electromagnetic compatibility
EPIRB	Emergency position-indicating radio beacon (ITU)
e.r.p.	Effective radiated power
ETSI	European Telecommunications Standards Institute
EUROCAE	European Organization for Civil Aviation Electronics
FAA	Federal Aviation Administration
FANS	Future air navigation systems
FCC	Federal Communications Commission
FDMA	Frequency division multiple access
FIS-B	Flight information service-broadcast
FM	Frequency modulation
FMSG	Frequency Management Study Group (ICAO) (now FSMP)
FSMP	Frequency Spectrum Management Panel (successor of ACP WG/F (frequency))
FSS	Fixed-satellite service (ITU)
GBAS	Ground-based augmentation system
GLONASS	Global orbiting navigation satellite system
GMDSS	Global maritime distress and safety system
GNSS	Global navigation satellite system
GPS	Global positioning system
GPWS	Ground proximity warning system
GSO	Geostationary orbit
HF	High frequency
HFDL	High frequency data link
IATA	International Air Transport Association
IEC	International Electrotechnical Commission

ILS	Instrument landing system
IMO	International Maritime Organization
IMT	International mobile telecommunications
ISM	Industrial, scientific and medical
ITU-R	International Telecommunication Union — Radiocommunication Sector
ITU-T	International Telecommunication Union — Telecommunication Standardization Sector
JAA	Joint Aviation Authorities
LADGPS	Local area differential global positioning system
LDACS	L-band data link aeronautical communication system
LF	Low frequency
MASPS	Minimum aviation system performance standards
MES	Mobile Earth station
MF	Medium frequency
MIFR	Master International Frequency Register
MLS	Microwave landing system
MOPS	Minimum operational performance standards
MOU	Memorandum of Understanding
MPR	Multi-purpose radar
MPS	Minimum performance specification
MSPSR	Multi-static primary surveillance radar
MSS	Mobile-satellite service (ITU)
MWARA	Major world air route area (ITU)
NDB	Non-directional radio beacon
NGSO	Non-geostationary orbit
NM	Nautical mile(s)
NSP	Navigation Systems Panel (ICAO)
OR	Off-route
PAR	Precision approach radar
PRF	Pulse repetition frequency
PSR	Primary surveillance radar
R	Route (or en route)
RAS	Radio astronomy service (ITU)
RCC	Regional Commonwealth in the Field of Communications
RDARA	Regional and domestic air route area (ITU)
RDSS	Radiodetermination-satellite service (ITU)
RF	Radio frequency
RLS	Radiolocation service
RNAV	Area navigation
RNS	Radionavigation service
RNSS	Radionavigation-satellite service
RPAS	Remotely piloted aircraft systems

RR	Radio Regulations (ITU)
RSMS	Radar sensing and measurement system
RTCA	RTCA Inc. (Radio Technical Commission for Aeronautics)
SARPs	Standards and Recommended Practices
SIT	Shipborne interrogator-transponder
SMGCS	Surface movement guidance and control system
SRD	Short-range device
SSB	Single sideband
SSR	Secondary surveillance radar
TACAN	Tactical air navigation
TIS-B	Traffic information service-broadcast
TSO	Technical Standard Order
UAS	Unmanned aircraft systems (equivalent ICAO acronym is RPAS)
UAT	Universal access transceiver
UHF	Ultra-high frequency
UWB	Ultra-wideband
VDL	Very high frequency digital link
VGE	Voluntary Group of Experts (ITU)
VHF	Very high frequency
VLF	Very low frequency
VOR	VHF omnidirectional radio range
VSAT	Very small aperture terminal
WAAS	Wide area augmentation system
WAIC	Wireless avionics intra-communications
WARC	World Administrative Radio Conference (ITU)
WP	Working Party (ITU)
WRC	World Radiocommunication Conference (ITU)

Attachment C

THE REGULATION OF RADIO EQUIPMENT IN AIRCRAFT

1. INTRODUCTION

This attachment describes the processes for the regulation of the radio equipment carried by civil aircraft. It identifies and highlights, in particular, the essential role of the agreements made in the ITU as they affect the radio systems carried by aircraft for air navigation. In this examination, it separates the two distinctive and complementary areas of regulation, the first for telecommunications, and the second for aviation safety. Compliance with both is necessary before any international flight can be undertaken. It shows that the constituent parts of these regulatory processes have some functions arrived at through the process of international agreements, which are then incorporated into national regulations, and others (particularly the development of performance standards) which are developed by voluntary agreement between all interested parties and then adopted by national law as the basis of the regulation.

2. BACKGROUND

2.1 Modern aircraft are equipped with many radio systems operating in a possible seventeen different frequency bands ranging from 9 kHz to 15 GHz. Approximately half of the systems have both transmit and receive functions, and the remainder are receive only. Three are for primary communications purposes, and up to twelve are for radionavigation functions, including three which have integral and complementary data links. In the course of a flight, an aircraft may traverse territory other than that of its State of Registry and must therefore be regulated within a systematic framework of internationally agreed rules. These rules must ensure that the flight is safe for passengers and crew, and free from risk of damage to persons and property on the ground. As a part of this regulatory process, the radio installations must conform to agreed performance standards, must operate in correct frequency bands, must be licensed by appropriate authorities, and be operated by licensed personnel.

2.2 The regulatory framework to ensure these requirements has, as its basis, two quite separate international agreements which are implemented at the national level by two sets of national regulatory bodies. An outline description of the organizational elements of this framework is given below.

3. THE REGULATORY FRAMEWORK

Telecommunications regulation

3.1 ITU World Radiocommunication Conferences agree upon the allocation of radio frequency bands to be used for aeronautical communications and radionavigation which are then incorporated in the Radio Regulations as part of Chapter II, Frequencies. In this chapter, Article 5, Frequency Allocations, contains the frequency allocation limits, the geographical scope and the status of the allocation, the sharing with other services, and any special conditions which apply. Chapter VIII of the Radio Regulations, on Aeronautical Services, deals with licensing, inspection, infringements, interference and related matters for aeronautical radio stations. The basic technical parameters for frequency stability, permitted levels of spurious emissions and other spectrum use parameters are agreed by ITU-R and embodied in ITU-R Recommendations which are then incorporated by reference in the main body of the Regulations. Taken together, these form a body of regulations for use by national telecommunications authorities to control ground and airborne radio stations in regard to their basic transmit and receive functioning and their use. The use of radio in an aircraft when outside its State of Registry must conform to these basic licensing conditions.

Aviation regulation

3.2 The safety aspects of the operation of civil aircraft are governed by the terms of the *Convention on International Civil Aviation* (Doc 7300). In the context of the carriage and operation of radio, Article 30 of the Convention requires an aircraft on international carriage to carry radio transmitting apparatus only if a licence to install and operate such equipment has been issued by the appropriate authorities of the State of Registry. The Convention does not define the national body to exercise the function, which is normally that body with responsibility for telecommunications. In addition, Article 31 requires that all of the radio equipment on board shall be covered by a certificate of airworthiness, invariably issued by the authority with responsibility for aviation safety. Article 37 calls for the adoption of international Standards and Recommended Practices (SARPs) dealing with, inter alia, communications and navigation aids. SARPs normally address all interface parameters, including radio frequency (RF), performance, coding, etc., to ensure worldwide interoperability. These provisions form the major part of the international framework for aviation safety in regard to the radio systems carried by aircraft. It should be noted that ICAO SARPs are only agreed for systems which are standardized on a worldwide basis, and hence do not include such self-contained systems as radio altimeters and airborne weather radar, carried as a mandatory requirement by many aircraft, and which also meet the certificate of airworthiness requirements.

National regulations

3.3 The respective national authorities for telecommunications and for aviation in the State of Registry of an aircraft are responsible for ensuring compliance with the international agreements within their competence and jurisdiction. It is common for the telecommunications licence to be issued by that authority only when the aviation safety requirements have been approved and a certificate of airworthiness has been granted by the aviation authorities. The total authorization thus embodies the permission to transmit and receive radio signals (the telecommunications part), and the certification that the systems are satisfactory for the navigation of the aircraft (the air safety part). Aircraft are frequently transferred from one country to another on delivery after manufacture or by wet or dry lease during their lifetime. The country of acceptance may agree to transfer the certificate of airworthiness with the aircraft as a practical means of compliance with international agreements. This latter procedure is recognized in Article 33 of the ICAO Convention and in Article 18 of the Radio Regulations.

4. AIRWORTHINESS APPROVAL AND THE ISSUE OF A CERTIFICATE OF AIRWORTHINESS

4.1 The process of airworthiness approval of the radio in aircraft includes requiring the assurance of the correct functioning of the equipment after its installation in the aircraft, which includes its performance as a working communications or radionavigation system, as well as its compatibility with other on-board radio and electronic systems. Prior to its installation, the equipment must have received approval under a Technical Standard Order (TSO) issued by a responsible body such as the Federal Aviation Administration (FAA) in the United States or the European Aviation Safety Agency (EASA) in Europe.

4.2 A TSO defines the performance and environmental requirements for the airborne radio system concerned and is traditionally based on the minimum performance specifications (MPS) developed in voluntary bodies such as RTCA in the United States and EUROCAE in Europe. This voluntary collaborative process, in which all the interested parties (administrators, radio system manufacturers, aircraft constructors, airlines, etc.) participate, has the advantage of facilitating the achievement of performance parameters that are realistic and which can be manufactured at economic cost levels.

4.3 Standardization of aircraft wiring and physical details (form and fit) is further carried out through the Aeronautical Radio, Inc. (ARINC) Characteristic — a document developed by the Airlines Electronic and Engineering Committee

(AEEC), an international body for which ARINC provides the secretarial service. The ARINC Characteristic also includes all the performance requirements, sometimes enhanced over those of the TSO, and is the specification that is generally used for the procurement of radio for commercial aircraft.

4.4 The processes of airworthiness for most aviation radio systems recognize that some environmental and performance requirements can be relaxed for aircraft used only for private or pleasure purposes, outside the airspace used by commercial aviation and on short flights. The telecommunications requirements remain the same as those for commercial aircraft.

4.5 Airworthiness requirements for radio not used for navigation or air traffic needs, e.g. passenger telephones, are usually limited to an assurance that it is not a safety hazard and does not, in any way, affect the correct functioning of the other radio and electronic systems carried for safety purposes.

5. SUMMARY

The above describes the main regulatory features which apply to the use of radio in aircraft. They are characterized by:

a) the requirement to observe two sets of international treaty obligations, ITU and ICAO;

b) the participation of two national regulatory bodies, one for telecommunications aspects and one for air safety approval requirements; and

c) a voluntary collaborative process for the preparation of performance specifications.

Attachment D

REVIEW AND UPDATE

1. Section 7-II identifies the prime objectives of this document, of which the most important is that of providing an up-to-date record of ICAO policy on the provisions in the ITU Radio Regulations for use by ICAO and its Member States. With ITU WRCs being held, in general, every four years, and numerous ITU-R preparatory activities and other studies taking place in the intervals, there is continuous activity in which aviation must actively participate. Appropriate responses to these activities include:

a) the timely development of the ICAO Position for WRCs; and

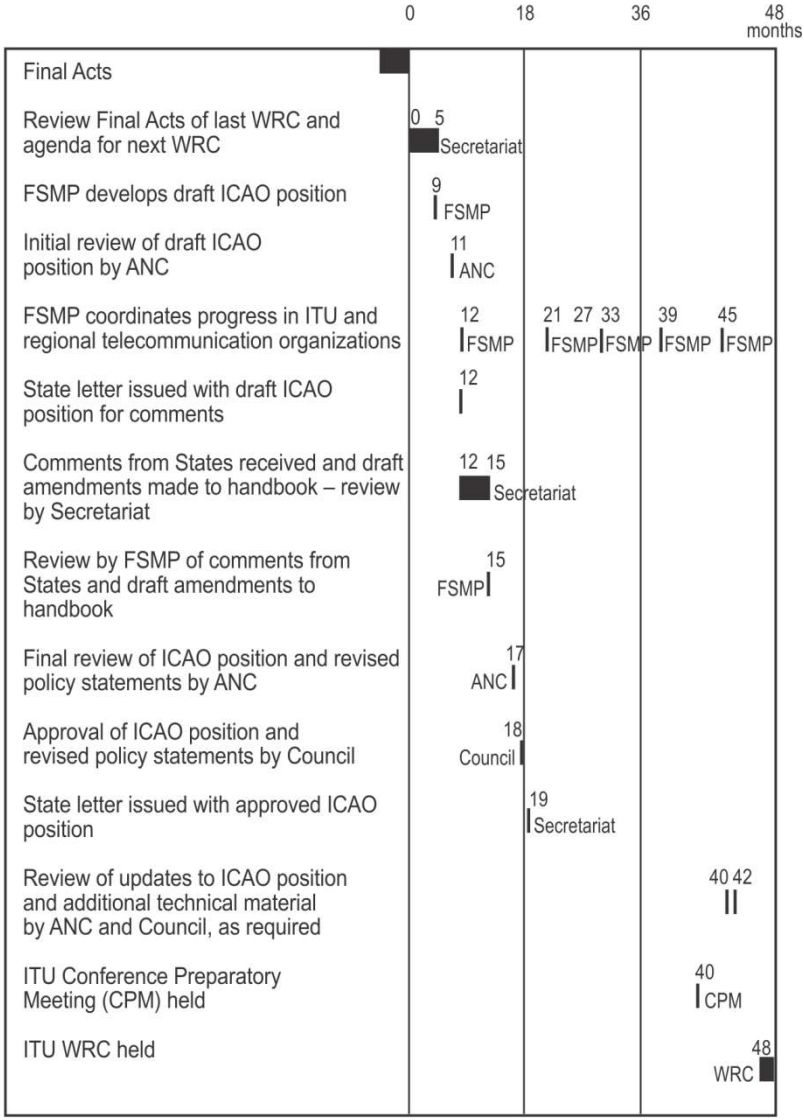
b) the development of updates to this handbook, including the relevant policy statements, in the light of the amendments to the Radio Regulations as agreed by ITU and the ICAO Position for future conferences.

A practical procedure for update of this handbook, including the policy statements and the development of the ICAO Position, is outlined below and sequenced to include the requirements for internal ICAO approval, consultation with States, divisional meetings when they occur and general publishing and dissemination requirements.

2. The review and update cycle, based on the four-year interval between WRCs, is believed to provide the best compromise between the twin goals of expediency and accuracy. It embodies important milestones such as the approval of the Air Navigation Commission (ANC) and Council of ICAO and the provision of advice to Member States in timescales that are achievable and suitable (see Figure D-1).

3. The sequence of events for the development of the ICAO Position for the next WRC, as well as necessary amendments to this handbook including the policy statements, in such a process incorporates the following:

- Review by ICAO of the Final Acts of the most recent WRC, including a review of the agenda for the next WRC and the preparation of policy proposals (ICAO Position for the next WRC and revised policy statements in this handbook by the appropriate ICAO body). In this process, the focal point for developing proposals in ICAO is the FSMP.



Note.— Bars indicate approximate timing of event.

Figure D-1. Review and update cycle of the ICAO Position and the RF handbook

- Update of the technical and regulatory material in this handbook;

- Initial review of the ICAO Position for the next WRC and policy statements in this handbook by the ANC;

- Issue of State letter with the draft ICAO Position for the next WRC inviting comments from States and international organizations on the proposals sent to States and international organizations;

- Final review of States' comments and consequential updated policy statements in this handbook by the ANC;

- Approval of the ICAO Position for the next WRC and updated policy statements by the Council. Shortly before the next WRC, a last review of any necessary update of the ICAO Position will be undertaken by the ANC and Council, as required;

- Final discussions and informal briefings on the latest information; and

- Commencement of the next WRC.

Attachment E

APPROACH FOR ESTABLISHING AND PROMOTING THE ICAO POSITION FOR FUTURE ITU WORLD RADIOCOMMUNICATION CONFERENCES

1. INTRODUCTION

This attachment presents a long-term approach for establishing and promoting the ICAO Position for future ITU World Radiocommunication Conferences (WRCs) with a view to securing support for the ICAO Position from ITU administrations and relevant international organizations.

2. BASIS FOR THE ICAO POSITION

2.1 The ICAO Position is developed on the basis of current and future aviation requirements for radio frequency spectrum, taking into account the expected growth in air traffic and the development of new technologies.

2.2 The long-term implementation strategy contained in the *Global Air Navigation Plan* (Doc 9750) forms the basis for the spectrum requirements.

2.3 The ICAO policy on radio frequency spectrum requirements, as approved by the Council, is contained in this handbook.

2.4 The framework for the development and support of the ICAO Position is contained in Assembly Resolution A38-6.

3. DEVELOPMENT OF THE ICAO POSITION

3.1 The ICAO Position for a WRC is established as early as possible after the agenda for that WRC is established. The position presents the ICAO views on all agenda items of interest to international civil aviation on the agenda of the WRC, with particular regard to the impact on safety, regularity and efficiency of flight. Technical and operational information is provided as required to support the position.

3.2 The focal point on all aspects related to the development of the ICAO

Position for WRCs is the Frequency Spectrum Management Panel (FSMP).

3.3 Throughout the development of the position, proper coordination with and involvement of the ICAO Regional Offices is required. Their involvement enables the incorporation of specific regional requirements and helps achieve improved support at the regional and national level.

3.4 The draft ICAO Position developed by the FSMP is reviewed by the ANC and sent to States and relevant international organizations for comment. The comments are reviewed by the ANC, and a consolidated ICAO Position is submitted by the ANC to the Council for approval.

3.5 After approval by the Council, the ICAO Position is sent to States for use in the coordination process leading to the development of national positions. The ICAO Position is also submitted as an information paper to the WRC.

3.6 Following the development of the ICAO Position, consequential amendments to policy statements contained in this handbook are developed for approval by the Council.

3.7 Any subsequent developments arising from ICAO and ITU activities in preparation for the WRC are considered by the Council with a view to updating the ICAO Position as necessary.

4. SUPPORT FOR THE ICAO POSITION

4.1 Assembly Resolution A38-6 shall be fully implemented so as to secure support from States for the ICAO Position and ensure that the resources necessary to support increased participation by ICAO to international and regional spectrum management activities are made available.

4.2 In addition to being submitted to States (paragraph 3.5 refers), the ICAO Position is also disseminated, as early as possible, to the regional telecommunication organizations involved in the development of regional positions for WRCs. Presentation of the position and follow-up is provided by the relevant ICAO Regional Offices, with assistance from Headquarters as required.

4.3 ICAO contributes to WRC preparatory activities conducted by ITU (meetings of relevant ITU-R Study Groups and ITU Conference Preparatory Meetings) by submitting additional technical papers supporting the ICAO Position.

4.4 Close coordination and cooperation with other aviation organizations participating in the conference, such as IATA, need to be maintained. Also, coordination with other specialized agencies of the UN on issues of common interest is required to broaden the support for specific elements of the ICAO Position.

4.5 Regional ICAO coordination meetings to present and discuss the ICAO Position should be organized as required. These meetings could be held in conjunction with the meetings of the FMSP.

5. NEW TRENDS IN SPECTRUM MANAGEMENT

5.1 In the application of the strategy outlined above, a number of new trends influencing the allocation of spectrum today and in the future need to be taken into account. Such trends, which may affect the availability of adequate and protected spectrum for aviation, include:

a) the increased role of the private sector in the work of the ITU;

b) the increased economic value of spectrum for certain applications;

c) the increased availability of radio devices that do not require licensing by radiocommunication authorities; and

d) the increased pressure for sharing spectrum allocated to aeronautical services with non-aeronautical services.

5.2 The increased role of the private sector in the ITU has had an adverse impact on the influence of inter-governmental bodies such as ICAO. This situation was addressed at the 2002 ITU Plenipotentiary Conference (PP-02) with a view to strengthening the role of ICAO in ITU.

5.3 The economic value of spectrum allocated to certain applications can exceed by far the economic value of aeronautical applications of the same spectrum. This has recently been demonstrated by the results of the “spectrum auctions” conducted in several countries to support future commercial mobile multimedia systems. This situation requires aviation to identify clearly the need and economic value of required spectrum in certain bands and to consider innovative approaches

to guarantee the required level of safety-service availability.

5.4 Technical trends such as the ones mentioned in sub-paragraphs 5.1 c) and d) have the potential of increasing interference levels to aeronautical systems and must therefore be carefully assessed on a case-by-case basis. A comprehensive investigation of interference levels and available margins in all aeronautical bands needs to be conducted urgently.

6. ASSEMBLY RESOLUTION A38-6

The ICAO Assembly approved Resolution A38-6 on the "Support of the ICAO policy on radio frequency spectrum matters" as follows:

Whereas ICAO is the specialized agency of the United Nations responsible for the safety, regularity and efficiency of international civil aviation;

Whereas ICAO adopts international Standards and Recommended Practices (SARPs) for aeronautical communications systems and radio navigation aids;

Whereas the International Telecommunication Union (ITU) is the specialized agency of the United Nations regulating the use of the radio frequency spectrum;

Whereas the ICAO Position, as approved by the Council, for ITU World Radiocommunication Conferences (WRCs) is the result of the coordination of international aviation requirements for radio frequency spectrum;

Whereas a comprehensive frequency spectrum strategy is required by aviation to support timely availability and appropriate protection of adequate spectrum;

Whereas a sustainable environment for growth and technology development is required to support safety and operational effectiveness for current and future operational systems and allow for the transition between present and future technologies;

Recognizing that the development and the implementation of the communications, navigation and surveillance/air traffic management (CNS/ATM) systems and the safety of international civil aviation could be seriously jeopardized unless requirements for appropriate aviation safety spectrum allocations are satisfied and protection of those allocations is achieved;

Recognizing that to ensure optimal use of the frequency spectrum allocated to

aviation, efficient frequency management and use of best practices are required;

Recognizing that support from ITU member administrations is required to ensure that the ICAO Position is supported by the WRC and that aviation requirements are met;

Considering the urgent need to increase such support due to the growing demand for spectrum and aggressive competition from commercial telecommunications services;

Considering the increased level of ITU WRC preparation activities associated with the growing demand for bandwidth from all users of the radio frequency (RF) spectrum, as well as the increased importance of the development of regional positions by regional telecommunication bodies such as APT, ASMG, ATU, CEPT, CITEL and RCC;*

Considering Recommendations 7/3 and 7/6 of the Special Communications/ Operations Divisional Meeting (1995) (SP COM/OPS/95), Recommendation 5/2 of the 11th Air Navigation Conference (2003) and Recommendation 1/12 of the 12th Air Navigation Conference (2012);

The Assembly:

1. *Urges* Member States, international organizations and other civil aviation stakeholders to support firmly the ICAO frequency spectrum strategy and the ICAO Position at WRCs and in regional and other international activities conducted in preparation for WRCs, including by the following means:

a) working together to deliver efficient aeronautical frequency management and "best practices" to demonstrate the effectiveness and relevance of the aviation industry in spectrum management;

b) supporting ICAO activities relating to the aviation frequency spectrum strategy and policy through relevant expert group meetings and regional planning groups;

* APT: Asia-Pacific Telecommunity; ASMG: Arab Spectrum Management Group; ATU: African Telecommunications Union; CEPT: the European Conference of Postal and Telecommunications Administrations; CITEL: Comisión Interamericana de Telecomunicaciones; RCC: Regional Commonwealth in the field of Communications.

c) undertaking to provide for aviation interests to be fully integrated in the development of their positions presented to regional telecommunications fora involved in the preparation of joint proposals to the WRC;

d) including in their proposals to the WRC, to the extent possible, material consistent with the ICAO Position;

e) supporting the ICAO Position and the ICAO policy statements at ITU WRCs as approved by Council and incorporated in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation* (Doc 9718);

f) undertaking to provide civil aviation experts to fully participate in the development of States' and regional positions and development of aviation interests at the ITU; and

g) ensuring, to the maximum extent possible, that their delegations to regional conferences, ITU study groups and WRCs include experts from their civil aviation authorities and other civil aviation stakeholders who are fully prepared to represent aviation interests;

2. *Requests* the Secretary General to bring to the attention of ITU the importance of adequate radio frequency spectrum allocation and protection for the safety of aviation;

3. *Instructs* the Council and the Secretary General, as a matter of high priority within the budget adopted by the Assembly, to ensure that the resources necessary to support the development and implementation of a comprehensive aviation frequency spectrum strategy as well as increased participation by ICAO in international and regional spectrum management activities are made available; and

4. *Declares* that this resolution supersedes Resolution A36-25.

Attachment F

ICAO POSITION FOR THE INTERNATIONAL TELECOMMUNICATION UNION (ITU) WORLD RADIOCOMMUNICATION CONFERENCE 2023 (WRC-23)

SUMMARY

This attachment reviews the agenda for the International Telecommunication Union (ITU) World Radiocommunication Conference 2023 (WRC-23), discusses points of aeronautical interest and provides the ICAO Position for these agenda items.

The goal of the ICAO Position is to ensure aeronautical access to appropriately protected spectrum for radiocommunication and radionavigation systems that support current and future safety-of-flight applications. In particular, it describes the safety considerations necessary to ensure adequate protection against harmful interference.

Support of the ICAO Position by ITU Member States is required to ensure that the position is supported at the WRC-23 and that aviation requirements are met.

1. Introduction
2. ICAO and the international regulatory framework
3. Spectrum requirements for international civil aviation
4. Aeronautical aspects on the agenda for WRC-23

Appendix to Attachment F:
Agenda for ITU WRC-23

1. INTRODUCTION

1.1 The ICAO Position on issues of interest to international civil aviation to be addressed at the 2023 ITU World Radiocommunication Conference (WRC-23) is presented below. The agenda of this Conference is contained in the attachment. The ICAO Position is to be considered in conjunction with sections 7-II and 8 of the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation,* Volume I — *ICAO spectrum strategy, policy statements and related information* (Doc 9718, Second Edition, 2018). Doc 9718 is available on http://www.icao.int/safety/fsmp (see webpage: Documents). It should be noted that the Handbook contains a long-term policy based on a snapshot in time and, as such, it may lag behind the ICAO WRC Position. As a result, when there is conflict between the Handbook and a current ICAO WRC Position, the Position should be seen as being the guiding document.

1.2 ICAO supports the working principle within the ITU, as established during studies for WRC-07, that ICAO will ensure the compatibility of ICAO standard systems with existing or planned aeronautical systems operating in accordance with international aeronautical Standards. Compatibility of ICAO standard systems with non-ICAO standard aeronautical systems (or non-aeronautical systems) will be addressed in the ITU.

2. ICAO AND THE INTERNATIONAL REGULATORY FRAMEWORK

2.1 ICAO is the specialized agency of the United Nations providing for the international regulatory framework for civil aviation. The *Convention on International Civil Aviation* is an international treaty providing required provisions for the safety of flights over the territories of the 193 ICAO Member States and over the high seas. It includes measures to facilitate air navigation, including international Standards and Recommended Practices commonly referred to as SARPs.

2.2 The ICAO Standards constitute the rule of law through the ICAO Convention and form a regulatory framework for aviation, covering personnel licensing, technical requirements for aircraft operations, airworthiness requirements, aerodromes and systems used for the provision of communications, navigation and surveillance, as well as other technical and operational requirements.

3. SPECTRUM REQUIREMENTS FOR INTERNATIONAL CIVIL AVIATION

3.1 Air transport plays a major role in driving sustainable economic and social development worldwide. Since the mid-1970s and until the end of 2019, air traffic growth has consistently defied economic recessionary cycles, expanding two-fold once every 15 years. It is estimated that in 2019 air transport directly and indirectly supported the employment of 87.7 million people, contributing U.S.$ 3.5 trillion to the global gross domestic product (GDP), and carried over 4.5 billion passengers and over 52 million tonnes of cargo.

3.2 While the COVID-19 outbreak has significantly impacted the global air transport industry, the industry continues to play a critical role in supporting humanity's fight against the global pandemic. The industry contributions include delivering medical equipment and medicines, supporting traveller repatriations and medical evacuations, and maintaining crucial global supply chains through increased air cargo operations.

3.3 The safety of air operations is dependent on the availability of reliable communication and navigation services. Current and future communication, navigation, and surveillance/air traffic management (CNS/ATM) systems are highly dependent upon the availability of sufficient, suitably protected radio spectrum that can support the high integrity and availability requirements associated with aeronautical safety systems. Spectrum requirements for current and future aeronautical CNS systems are specified in the ICAO Spectrum Strategy [1], as addressed by the Twelfth Air Navigation Conference, and as approved by the ICAO Council.

3.4 In support of the safety aspects related to the use of radio frequency spectrum by aviation, **Article 4.10** of the Radio Regulations states, "*ITU Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies."* In particular, compatibility of aeronautical safety services with co-band or adjacent band aeronautical non-safety services or non-aeronautical services must be considered with extreme care in order to preserve the integrity of the aeronautical safety services.

[1] The ICAO spectrum strategy is included in the ICAO *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I — *ICAO spectrum strategy, policy statements and related information* (Doc 9718).

3.5 The continuous increase in air traffic movements as well as the additional requirement for accommodating new and emerging applications such as unmanned aircraft systems (UAS[2]) and commercial sub-orbital vehicle flights are placing an increased demand on both the aviation regulatory and air traffic management mechanisms. As a result, the airspace is becoming more complex and the demand for frequency assignments (and consequential spectrum allocations) is increasing. While some of this demand can be met through improved spectral efficiency of existing radio systems in frequency bands currently allocated to aeronautical services, it is inevitable that these frequency bands may need to be increased or additional aviation spectrum allocations may need to be agreed upon to meet this demand.

3.6 In addition, it is noted that there is a general trend toward the development of new terrestrial mobile communications networks with higher radiated power base stations, in particular IMT base stations using active antennas. A review of unwanted emission levels of these stations should be considered to ensure continued compatibility with other systems and services, particularly aviation safety systems.

3.7 The ICAO Position for the ITU WRC-23 was initially developed in 2020 with the assistance of the Frequency Spectrum Management Panel (FSMP) and was reviewed by the Air Navigation Commission at the seventh meeting of its 215th Session on 27 October 2020. Following the review by the Commission, it was submitted to ICAO Contracting States and relevant international organizations for comment. After a further review of the ICAO Position in light of the comments received by the Commission on 29 April 2021, the ICAO Position was reviewed and approved by the ICAO Council on 14 June 2021.

3.8 States and international organizations are requested to make use of the ICAO Position, to the maximum extent possible, in their preparatory activities for the WRC-23 at the national level, in the activities of the regional telecommunication organizations[3] and in the relevant meetings of the ITU.

[2] For the purposes of this document, UAS is referred to in ICAO as remotely piloted aircraft systems (RPAS).

[3] African Telecommunication Union (ATU), Asia-Pacific Telecommunity (APT), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL), Arab Spectrum Management Group (ASMG) and the Regional Commonwealth in the Field of Communications (RCC).

4. AERONAUTICAL ASPECTS ON THE AGENDA FOR WRC-23

Note 1.— The statement of the ICAO Position on an agenda item is given in a text box at the end of the section addressing the agenda item, after the introductory background material.

*Note 2.— WRC-23 Agenda Items **1.6, 1.7, 1.8, 1.9**, **1.10** and **9.2** address issues where aviation is seeking action by the WRC.*

*Note 3.— WRC-23 Agenda Items **1.1, 1.2, 1.3, 1.4, 1.11, 1.13, 1.15, 1.16, 1.17, 4, 8,** and **9.1 topic b** could potentially affect aviation use of spectrum and hence aviation should participate in studies to ensure there is no undue impact. As a result, they are included in this position.*

*Note 4.— No impact on aeronautical services has been identified from WRC-23 Agenda Items **1.5**, **1.12**, **1.14**, **1.18, 1.19**, **2**, **3**, **5**, **6**, **7, 9.1 topic a, 9.1 topic c, 9.1 topic d** and **9.3** which are therefore not addressed in this position.*

*Note 5.— When in this document reference is made to "No. **X.YYY**", it means "No. **X.YYY** of the ITU Radio Regulations".*

WRC-23
Agenda Item 1.1

Agenda Item Title:

to consider, based on the results of the ITU-R studies, possible measures to address, in the frequency band 4 800-4 990 MHz, protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories, and to review the pfd criteria in No. 5.441B in accordance with Resolution 223 (Rev.WRC-19).

Discussion:

This agenda item seeks to study the technical and regulatory provisions necessary to ensure the protection of aeronautical and maritime mobile services, located either in or above international waters, from other stations located within national territories and operating in the frequency band 4 800-4 990 MHz. Additionally, the agenda item calls for the review of the pfd criteria contained in No.**5.441B**.

The frequency bands 4 800-4 825 MHz and 4 835-4 950 MHz are allocated to the aeronautical mobile service worldwide in accordance with the Table of Frequency Allocations and No. **5.442**. In addition, in parts of Region 2 and Australia as well as adjacent international airspace the frequency bands 4 400-4 940 and 4 825-4 835 MHz are used for aeronautical mobile telemetry for flight testing in accordance with the provisions of No.**5.440A**, **5.442** and Resolution **416 (WRC-07)**. According to Resolution **416 (WRC-07)** the aeronautical mobile telemetry emissions are limited to transmission from aircraft stations only.

Flight testing is key to maintaining and enhancing the safety of aircraft operation. Analysis of data gathered during flight testing is used to evaluate the aerodynamic flight characteristics of the vehicle and the performance of the systems onboard that vehicle in order to validate the design and its safety. The flight test phase allows any identified design issues to be addressed and resolved, as well as verifying and documenting the vehicle's performance for government certification and customer acceptance. It is key to ensure the integrity of the flight test data. Any interference to the transmission or reception of flight test data, if spotted, may invalidate the test data gathered during that flight and hence require a repetition of that flight test or if not spotted cause nugatory work to be carried out to address an issue that does not exist.

However, assignments to certain types of aeronautical systems, for example radio links between aircraft, are not registered in the MIFR. The absence of such recording together with No. **8.1**, which states that *rights and obligations of administrations in*

respect of frequency assignments shall be derived from the recording of those assignments in the MIFR, could lead to questions being raised as to why the protection of the aeronautical mobile service is required. Unfortunately, although the Radio Regulations require assignments to be registered in order to be internationally recognized (No. **11.2** & **11.8**), provision No. **11.14** precludes the notification and registration of frequency assignments to aeronautical mobile stations that do not have associated aeronautical land stations. This apparent discrepancy should be resolved in a manner that ensures recognition and protection of aviation systems when they are operated in international airspace.

Though this agenda item is limited to the frequency band 4 800-4 990 MHz, its considerations might have influence on a general regulatory mechanism of protection of the aeronautical mobile service in international airspace. It is essential to ensure that the proposed methods to satisfy this agenda item would not have a negative impact on the use of aviation systems in other frequency bands.

ICAO Position:

To support any measures taken to enhance the protection of flight testing in international airspace that are consistent with the results of agreed studies.

To oppose any proposed measure that is not in line with the results of agreed studies and reduces the level of protection afforded to flight test operations in international airspace and above international waters.

To ensure that the proposed methods to satisfy this agenda item do not have a negative impact on the use of aviation systems in other frequency bands.

WRC-23
Agenda Item 1.2

Agenda Item Title:

to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 245 (WRC-19);

Discussion:

The agenda item, based on the called for studies, seeks additional IMT identification, and possible new allocations to the mobile service identified for IMT on a primary basis in the frequency bands:

- 3 300-3 400 MHz (Region 1 & 2);
- 3 600-3 800 MHz (Region 2);
- 6 425-7 025 MHz (Region 1);
- 7 025-7 125 MHz (globally);
- 10.0-10.5 GHz (Region 2).

In parts of Region 2, as well as adjacent international airspace, the frequency band 5 925-6 700 MHz is used for aeronautical mobile telemetry for flight testing in accordance with the provisions of Resolution **416 (WRC-07)**.

Flight testing is key to maintaining and enhancing the safety of aircraft. Analysis of data gathered during flight testing is used to evaluate the aerodynamic flight characteristics of the vehicle and the performance of the systems onboard that vehicle in order to validate the design and its safety. The flight test phase allows any identified design issues to be addressed, as well as verifying and documenting the vehicles performance for government certification and customer acceptance.

It is key to ensure the integrity of the flight data. Any interference to the transmission or reception of flight test data, if spotted, may invalidate the test data gathered during that flight and hence require a repetition of that flight or if not spotted cause nugatory work to be carried out to address an issue that does not exist.

Also, the frequency bands 3 600-3 800 MHz and 6 425-7 025 MHz are allocated to the fixed satellite service (FSS), and parts of these bands are used for the provision of aeronautical services including the use of geo-stationary orbit (GSO) FSS very

small aperture (VSAT) systems for the transmission of critical aeronautical and meteorological information. Parts of these frequency bands are also used by FSS feeder links (downlinks and uplinks) of GSO mobile satellite service (MSS) networks to support the transmission of AMS(R)S communications in the 1.6/1.5 GHz bands, which is used to support ATC and aircraft operations by many ANSPs and airlines.

ITU-R studies identified under Resolution **245 (WRC-19)** will need to be completed to determine the potential for sharing of IMT with the FSS. In advance of results of these studies ITU-R Report S.2368 contains sharing studies between IMT-Advanced systems and GSO FSS in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15[4].

The report summarises the required separation distances presented in the individual technical studies to protect GSO FSS earth stations. The separation distances vary depending on the study and range from 10 km to around 100s km for protection of the FSS interference criteria.

Recently ICAO has received several studies regarding the interference potential to radio altimeters from new mobile service systems planned to operate in frequency bands adjacent/nearby to that used by those altimeters. The radio altimeter is a mandated critical aircraft safety system operating in the 4 200-4 400 MHz frequency band and used to determine the aircraft's height above terrain, enabling several safety related flight operations and navigation functions on all commercial aircraft and a wide range of other civil aircraft types. Such functions and systems include terrain awareness, aircraft collision avoidance, wind shear detection, flight controls, and functions to automatically land an aircraft. Harmful interference to the function of the radio altimeter during any phase of flight would pose a serious safety risk.

It is important to note, however, that the issues raised by the radio altimeter studies are not with the regulatory allocation and identification to the mobile service (i.e., it is not pertinent to WRC-23 Agenda Item 1.2 discussions), rather to how new systems are being authorized for deployment within that service. Work continues to assess any possible measures that might be needed, both near-term and in the future, to ensure compatible operation of radio altimeters and these new mobile service systems.

[4] Report ITU-R S.2368-0: Sharing studies between International Mobile Telecommunication-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15 (https://www.itu.int/pub/R-REP-S.2368)

ICAO Position:

To oppose any proposal in the frequency band 6 425-7 025 MHz in Region 1 that would reduce the level of protection below an acceptable level and hence compromise flight test operations.

To oppose any proposal in the frequency bands 3 600-3 800 MHz and 6 425-7 025 MHz that could lead to harmful interference or could constrain the use of these bands by the FSS for the provision of aeronautical services or GSO MSS feeder links.

WRC-23
Agenda Item 1.3

Agenda Item Title:

To consider primary allocation of the band 3 600-3 800 MHz to mobile service within Region 1 and take appropriate regulatory actions, in accordance with Resolution 246 (WRC-19);

Discussion:

The agenda item, based on the called for studies, seeks to upgrade the secondary allocation to the mobile service identified for IMT in the frequency band 3 600-3 800 MHz in Region 1.

Systems operating under the allocation to the fixed satellite service (FSS) in the frequency range 3 400-4 200 MHz provide ground infrastructure for the transmission of critical aeronautical and meteorological information. These systems are also used for feeder links to support systems providing an aeronautical mobile satellite (route) service. ITU-R Reports M.2109 & S.2199 contain sharing studies between systems operating under an allocation to the FSS and international mobile telecommunication (IMT) systems and broadband wireless access systems respectively in the frequency range 3 400-4 200 MHz. Studies show a potential for interference from IMT and broadband wireless access stations into Earth station in the FSS at distances of up to several hundred kilometres. Such large separation distances would impose substantial constraints on both mobile and satellite deployments. The studies also show that interference can occur when IMT systems are operated in frequency bands adjacent to those used by the FSS.

In addition, WRC-12 adopted Resolution **154** (revised at WRC-15) to support existing and future operation of Earth stations in the FSS within the frequency band 3 400-4 200 MHz, as an aid to safe operation of aircraft and reliable distribution of meteorological information in some countries, mainly in Africa, of Region 1.

Recently ICAO has received several studies regarding the interference potential to radio altimeters from new mobile service systems planned to operate in frequency bands adjacent/nearby to that used by those altimeters. The radio altimeter is a mandated critical aircraft safety system operating in the 4 200-4 400 MHz frequency band and used to determine the aircraft's height above terrain, enabling several

safety related flight operations and navigation functions on all commercial aircraft and a wide range of other civil aircraft types. Such functions and systems include terrain awareness, aircraft collision avoidance, wind shear detection, flight controls, and functions to automatically land an aircraft. Harmful interference to the function of the radio altimeter during any phase of flight would pose a serious safety risk.

It is important to note, however, that the issues raised by the radio altimeter studies are not with the regulatory allocation and identification to the mobile service (i.e., it is not pertinent to WRC-23 Agenda Item 1.3 discussions), rather to how new systems are being authorized for deployment within that service. Work continues to assess any possible measures that might be needed, both near-term and in the future, to ensure compatible operation of radio altimeters and these new mobile service systems.

ICAO Position:

To oppose any changes to existing regulatory provisions of the ITU Radio Regulations for the frequency bands 3 600-3 800 MHz that adversely affect the aeronautical use of systems operating in the FSS in Region 1.

WRC-23
Agenda Item 1.4

Agenda Item Title:

to consider, in accordance with Resolution 247 (WRC-19), the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level.

Discussion:

At WRC-2000, the frequency bands 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz in Regions 1 and 3, and the frequency bands 1 885-1 980 MHz and 2 110-2 160 MHz in Region 2 were identified in RR No. **5.388A** for possible use by high-altitude platform stations as international mobile telecommunications (IMT) base stations (HIBS) within the mobile service allocation. Resolution **221 (Rev.WRC-07)** referred to in RR No. **5.388A** stipulates technical conditions for HIBS necessary for the protection of ground-based IMT stations in neighboring countries and other services based on the sharing and compatibility studies with IMT-2000.

In view of increasing demand to provide mobile broadband services to underserved areas and noting the increase in the number of frequency bands within which ground based IMT is deployed, there is a need to review the existing regulations for HIBS with a view to providing flexibility for the operators to deploy HIBS in all frequency bands below 2.7 GHz that are identified for IMT. This review should include the fact that HIBS are expected to be used as a part of terrestrial IMT networks and may use the same frequency bands as ground-based IMT base stations. As a result, this agenda item considers appropriate technical conditions and regulatory actions for HIBS in certain frequency bands below 2.7 GHz that are already identified for IMT, i.e.:

- 694-960 MHz;
- 1 710-1 885 MHz (1 710-1 815 MHz to be used for uplink only in Region 3);
- 2 500-2 690 MHz (2 500-2 535 MHz to be used for uplink only in Region 3, except 2 655-2 690 MHz in Region 3).

In accordance with *resolves* 2 of Resolution **247** (WRC-19), the sharing and compatibility studies under this agenda item should ensure the protection of services having allocations in the same and adjacent frequency bands.

One of the frequency bands considered for HIBS is 694-960 MHz, which is adjacent to the band 960-1 164 MHz allocated to AM(R)S and ARNS and heavily used by aeronautical systems, e.g. ADS-B, DME, LDACS, SSR etc.

Another frequency band being considered is 2 500-2 690 MHz which is close to the frequency band 2 700-2 900 MHz used for the provision of primary approach radars. Regarding that latter band, in order to enable the deployment of ground based IMT below 2 690 MHz the existing radars had to be modified to increase the receiver front end filter rejection in order to cope with the power in the IMT fundamental signal. The design of those modifications was based on a specific set of assumptions about the deployment of IMT base stations, the antenna characteristics including height and directivity, and the use of a specific terrestrial propagation model (Recommendation ITU-R P.452). Placing the IMT base station on a high-altitude platform changes the assumptions used in determining the modifications required to the radar receiver front ends to accommodate ground based IMT. It is essential to ensure that by placing the base station on a high altitude platform the maximum level of signal received by the radar both in-band and out of band from IMT does not exceed those predicted during the studies on ground based IMT and on which the radar modifications were designed.

ICAO Position:

To ensure that high-altitude platform stations as IMT-base stations (HIBs) sharing and compatibility studies performed under Resolution **247 (WRC-19)** address the protection of aeronautical systems operating in the frequency bands 960-1 164 MHz and 2 700-2 900 MHz.

In particular, to oppose the use of HIBS within the frequency band 2 500-2 690 MHz or parts thereof where agreed studies have not demonstrated that the signal levels from the HIBS will be below the predicted levels from the ground based IMT studies.

WRC-23
Agenda Item 1.6

Agenda Item Title:

to consider, in accordance with Resolution 772 (WRC-19), regulatory provisions to facilitate radiocommunications for sub-orbital vehicles.

Discussion:

Sub-orbital vehicles have been developed to reach altitudes and velocities that are much higher than conventional aircraft. Re-usable sub-orbital vehicles that launch like traditional rockets have become routine. However, with the advances in technology, re-useable sub-orbital vehicles that take off and land on a traditional runway are close to becoming a reality with companies testing such vehicles. These vehicles are intended to perform various missions, such as deploying satellites, conducting scientific research, or carrying passengers and cargo, and then returning to the Earth's surface. As one example, such vehicles could lead to hypersonic travel from Europe to Australia in 90 minutes, down from the current 24 hours.

The introduction of sub-orbital vehicles will create numerous challenges for spectrum usage and frequency management. They must safely share airspace with conventional aircraft during certain portions of flight. Therefore, there is a need to track sub-orbital vehicles for the entire duration of the flight and for those vehicles to communicate with other airspace users and air traffic control.

With respect to spectrum for systems and applications related to aviation safety, ICAO standardized systems are necessary for harmonization and interoperability with the air traffic management system. However, sub-orbital vehicles are intended to achieve altitudes and velocities that are much higher than conventional aircraft and hence do not always perform as an aircraft. Also, the way that on-board ICAO-standard terrestrial or satellite systems operate may not necessarily be consistent with the definitions in the Radio Regulations. Therefore, there is not a clear regulatory understanding as to how stations on board sub-orbital vehicles should be addressed and hence no clear understanding as to the radio service(s) under which they should operate.

Studies have shown that in principle from a technical perspective, some of the current ICAO standardized systems should have the capability, although potentially not the capacity, to provide suitable radio links for sub-orbital vehicles to operate safely. Additional regulatory and technical analysis is required to address the questions and concerns raised in the studies called for by Resolution **772 (WRC-19)**.

ICAO Position:

To support ITU-R studies and the definition of relevant technical characteristics as called for by Resolution **772 (WRC-19)** to ensure aviation needs are satisfied.

To support, if identified as required by the studies called for in Resolution **772 (WRC-19)**, modifications to the Radio Regulations that help enable the integration of sub-orbital vehicles into the airspace structure.

To support, if studies show the need for access to additional spectrum, the establishment of a WRC agenda item at a future competent conference.

WRC-23
Agenda Item 1.7

Agenda Item Title:

to consider a new aeronautical mobile-satellite (R) service (AMS(R)S) allocation in accordance with Resolution 428 (WRC-19) for both the Earth-to-space and space-to-Earth directions of aeronautical VHF communications in all or part of the frequency band 117.975-137 MHz, while preventing any undue constraints on existing VHF systems operating in the AM(R)S, the ARNS, and in adjacent frequency bands.

Discussion:

In the past the level of aircraft traffic and separation in oceanic and remote areas has been limited due to either the geographical impracticality and/or prohibitive costs of providing and maintaining suitable terrestrial communication, navigation and surveillance (CNS) systems. However, with the existing availability of global navigation satellite systems and the implementation at WRC-15 of a satellite based surveillance broadcast systems in the frequency band 1 087.7-1 092.3 MHz, there has been progress in the areas of navigation and surveillance. However, in certain regions of the world there remains insufficient communications capability to complement these satellite navigation and surveillance functions.

One proposal currently being studied uses low-Earth orbiting satellites to relay regional air traffic control messages between the pilot and controller. Were the system to be operated in the frequency band 117.975-137 MHz, currently allocated to the aeronautical mobile (Route) service (AM(R)S), then it would be possible to avoid carrying out a prohibitively expensive aircraft retrofit programme as the system would utilize existing on-board radios.

Availability of VHF satellite communications in oceanic and remote areas, as noted above where terrestrial infrastructure is non-existent or impractical, would also enhance the efficiency and capacity of aircraft operations as well as supporting communications to RPAS (Remotely Piloted Aircraft Systems) flight operations. The primary intention of the VHF satellite concept is to provide bi-directional communications from ATC to aircraft, and aircraft to ATC. The satellite concept is not designed or intended to be a replacement for existing VHF terrestrial infrastructure due to limitations with the satellite payload.

Aeronautical VHF channel assignments are planned in accordance with the principles contained in ICAO Annex 10 to the Convention on International Civil Aviation Volume V and detailed in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation Volume II. These criteria have been designed to ensure that communications are free from harmful interference. Co-ordination is then undertaken prior to deployment, in line with ITU procedures, between the relevant aeronautical authorities including ICAO to ensure there are no objections to the proposed assignment with a master list of approved assignments normally being published regularly by the relevant ICAO regional office. The satellite VHF relay concept would be subject to the same scrutiny with planning criteria needing to be developed within ICAO to ensure that both the terrestrial and satellite aeronautical VHF frequencies are free from harmful interference and co-ordination procedures are established to ensure that all relevant entities are consulted before any frequency is used. Particular consideration should be given to the high current utilisation and future development of the terrestrial VHF band for voice and data communications in certain areas and the reduced channel bandwidth that is utilized in Europe.

The satellite system allocation to AMS(R)S shall operate in accordance with international standards, practices and procedures in accordance with the Convention on International Civil Aviation and not adversely impact or limit the operation of existing AM(R)S terrestrial VHF systems in the frequency band 117.975-137 MHz, nor require any changes to aircraft equipage or existing installations which do not participate in the provision of the link or service area provided by the satellite link.

ICAO Position:

To support ITU-R studies and the definition of relevant technical characteristics as called for by Resolution **428 (WRC-19)**.

To support a global allocation to the aeronautical mobile-satellite (route) service for both the Earth-to-space and space-to-Earth directions in the frequency band 117.975-137 MHz and that the use of the allocation be limited to the relaying of aeronautical VHF air traffic management communications.

To support that those systems shall operate in accordance with international Standards and Recommended Practices and procedures established in accordance with the Convention on International Civil Aviation.

To ensure that any change to the regulatory provisions and spectrum allocation resulting from this agenda item do not adversely impact the operation of existing VHF systems in the band 117.975-137 MHz operating in the AM(R)S, including regional usage of terrestrial VHF, nor require any changes to aircraft equipage or to existing installations.

WRC-23
Agenda Item 1.8

Item Title:

to consider, on the basis of ITU-R studies in accordance with Resolution 171 (WRC-19), appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution 155 (Rev.WRC-19) and No. 5.484B to accommodate the use of fixed-satellite service (FSS) networks by control and non-payload communications of unmanned aircraft systems.

Discussion:

Resolution **155 (Rev.WRC-19)** was initially developed at WRC-15 and modified by WRC-19, with the aim of enabling the use of geostationary-satellite networks operating in the fixed satellite service (FSS) to be used for the provision of unmanned aircraft control and non-payload communication (CNPC) in the following frequency bands:

- For downlink (space-to-Earth):
  - 10.95-11.2 GHz,
  - 11.45-11.7 GHz,
  - 11.7-12.2 GHz in Region 2,
  - 12.2-12.5 GHz in Region 3,
  - 12.5-12.75 GHz in Regions 1 and 3,
  - 19.7-20.2 GHz,
- For uplink (Earth-to-space):
  - 14-14.47 GHz,
  - 29.5-30.0 GHz.

Resolution **155 (Rev.WRC-19)**, in its resolves, contains the conditions under which an unmanned aircraft can use a satellite network operating in the FSS for CNPC. However, it was recognised when the Resolution was originally developed that:

- ICAO had yet to complete the development of the relevant international aeronautical Standards and Recommended Practices (SARPs),
- additional work would be required to assess the feasibility of using the satellite networks under the conditions contained in Resolution **155**,
- there may be inconsistencies between some of the **resolves**,
- Resolution **155 (Rev.WRC-19)** was originally developed during WRC 15, and modifications may be required once the further study work and

relevant ICAO SARPs material had been completed to ensure that the provisions of the Resolution meet the ICAO requirements.

Therefore, the Resolution as developed by WRC-15, contained a clause requiring WRC-23 "to consider the results of the above studies referred to in this Resolution with a view to reviewing and, if necessary, revising this Resolution, and take necessary actions, as appropriate". It also precluded operational use of the FSS by UAS CNPC before the review by WRC-23.

At WRC-19 Resolution **155** was revised and WRC-23 Agenda Item 1.8 adopted that through Resolution **171 (WRC-19)** *resolved to invite the ITU Radiocommunication Sector* to:

- continue and complete in time for WRC-23 relevant studies of the technical, operational and regulatory aspects, based on the frequency bands mentioned in *resolves* 1 of Resolution **155 (Rev.WRC-19)**, in relation to the implementation of Resolution **155 (Rev.WRC-19)**, taking into account the progress obtained by ICAO in the completion of SARPs on use of the FSS for the UAS CNPC links,
- review No. **5.484B** and Resolution **155 (Rev.WRC-19)** taking into account the results of the above studies.

Additionally, Resolution **171 (WRC-19)** *invites the 2023 World Radiocommunication Conference* to revise, if necessary, No. **5.484B** and Resolution **155 (Rev.WRC-19)** and take other necessary actions, as appropriate, on the basis of the studies conducted under Resolution **155 (Rev.WRC-19)** and **171 (WRC-19).** Work on the ITU-R studies is continuing, and the final outcome of the work has not yet been reached in order to allow WRC-23 to make decisions.

In this context, ICAO is invited to develop aeronautical Standards and Recommended Practices (SARPs) identifying how UAS CNPC operate under the existing FSS primary allocation, based on the Resolution **155 (Rev.WRC-19**). As a basis for developing these SARPs, since CNPC is a safety-of-life aeronautical system, ICAO is expecting that the decision of WRC-23 results in a Resolution that;

- clearly provides primary status to the various elements of the UAS CNPC link, including both the UAES and the UACS Earth station, taking into account the definitions contained within the radio regulations,
- removes the apparent inconsistency, in common frequency bands, between a) Resolutions **156, 169,** and any future Resolution that require that Earth stations in motion shall not be used or relied upon for safety-of-life applications and b) Resolution **155** that addresses the use of Earth stations in motion on board UA for safety-of-life applications,
- acknowledges that in accordance with the Annexes of the Convention of the International Civil Aviation Organization (ICAO) on international civil aviation it is the States that are responsible for ensuring the safety-of-life aspects of the use of UAS CNPC,

- provides operators, air traffic service providers and regulatory authorities sufficient information about the level of interference within the area of the UAS operation, including outside of the territory where they provide air traffic services, to support and/or validate supporting documentation for safety cases,
- ensures that safety cases or supporting documentation do not need to be revisited as a result of future satellite co-ordination agreements.

Within the ITU during the last study period work has made substantive progress but it has not been formally completed for the following two documents that addressed various resolves within Resolution **155**:

- ITU-R M.[UAS CNPC_CHAR] - Characteristics of unmanned aircraft system control and non-payload Earth stations for use with space stations operating in the Fixed Satellite Service,
- ITU-R M.[UA_PFD] - Review of power flux-density limits in accordance with resolves 16 of Resolution **155 (WRC-15)**.

It has to be noted that these documents will contain critical information that will be used for assessing the feasibility of UAS CNPC for different operational conditions, by ICAO, under Resolution **155**.

Within ICAO work has progressed on the development of Standards and Recommended Practices (SARPs) material. The first package of SARPs, dealing with the identification of frequency bands (including those listed in Resolves 1 of Resolution **155 (Rev.WRC-19)** and C2 Link procedures, has been adopted and became effective on 12 July 2021, following a review of comments received from States. The second package of SARPs, scheduled to be completed by 2022, will address the technical solutions for the FSS systems and the other relevant resolves of the Resolution **155**. ICAO will be responsible for the safety-of-life aspects of UAS CNPC under the existing RF environment given by the Resolution **155**. It should be noted that this work is still under development within ICAO.

The Director of the Radiocommunication Bureau will decide if the conditions included in the *instructs the Director of the Radiocommunication Bureau* 4 of Resolution **155 (Rev. WRC-19)** have been met. If they have, satellite network filings submitted by administrations with a new class of station can then be considered for processing.

It should be noted that work under Agenda Item 1.16 (Resolution **173 (WRC-19))** and Agenda Item 1.17 (Resolution **773 (WRC-19))** may have impacts on the use of the FSS by UAS CNPC during the WRC-23 cycle. The implications of any proposed amendment under these Agenda Items to the Radio Regulations need to be assessed and action taken, if necessary, to ensure that the radio regulatory provisions established during WRC-23 do not adversely impact the use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by unmanned aircraft for CNPC.

ICAO Position:

To support ITU-R studies, as called for by Resolutions **155 (Rev.WRC-19) and 171 (WRC-19)**.

To support the modification of No. **5.484B** and Resolution **155 (Rev.WRC-19)**.

ICAO is expecting that the decision of WRC-23 will result in a Resolution that:

- clearly provides primary status;
- removes any apparent inconsistencies;
- acknowledges that in accordance with the Annexes of the Convention of the International Civil Aviation Organization (ICAO), ensuring the safety-of-life aspects of the use of UAS CNPC is the role of the responsible States;
- provides sufficient information to support and/or validate safety cases; and
- ensures that safety cases do not need to be revisited as a result of future satellite co-ordination agreements.

WRC-23
Agenda Item 1.9

Agenda Item Title:

to review Appendix 27 of the Radio Regulations and consider appropriate regulatory actions and updates based on ITU-R studies, in order to accommodate digital technologies for commercial aviation safety-of-life applications in existing HF bands allocated to the aeronautical mobile (route) service and ensure coexistence of current HF systems alongside modernized HF systems, in accordance with Resolution 429 (WRC-19).

Discussion:

HF is the only terrestrial service with means of providing ubiquitous global communication coverage for aircraft, and is still the long-range system required by many aviation regulators for the provision of safety and regularity of flight communications in oceanic, polar and remote areas. Access to the various frequency bands in the range 2 850-22 000 kHz assigned to the aeronautical mobile (route) service (AM(R)S) is therefore essential. Since the last substantive review of Appendix **27** at the 1979 World Administrative Radio Conference, use of HF by aviation has continued to evolve and grow, especially with the introduction of HF datalink in the 1990s; now used by many airlines.

To date, operational capacity has been limited by the number of channels and channel bandwidths (maximum of 3 kHz) available in the HF band. However, the development of advanced digital techniques, including new waveforms, allows the aggregation of both contiguous and non-contiguous channels. This opens the possibly for simultaneous transmission of voice and data, thus improving capacity, connectivity, and quality of HF communication systems. Aviation would like to take advantage of these developments to provide aircraft with additional capabilities and to improve the reliability, availability and continuity of communications especially when used in conjunction with existing L-band aviation SATCOM systems.

In order to take advantage of the various benefits that a modern wideband HF communication system could offer, Appendix **27** of the Radio Regulations needs to be modified to allow the introduction of digital wideband systems in accordance with Resolution **429 (WRC-19)**.

ICAO Position:

To support ITU-R studies as called for by Resolution **429 (WRC-19)**.

To support, based on agreed studies, the necessary modification of Appendix 27 to the Radio Regulations that will enable the introduction of HF wideband aeronautical communication systems. Those systems shall be operated in accordance with international Standards and Recommended Practices and procedures established in accordance with the Convention on International Civil Aviation.

WRC-23
Agenda Item 1.10

Agenda Item Title:

to conduct studies on spectrum needs, coexistence with radiocommunication services and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications, in accordance with Resolution 430 (WRC-19).

Discussion:

As technology has developed and miniaturization has advanced, it has become possible to use aircraft as platforms for payload applications such as fire and border surveillance, air quality and environment monitoring, video surveillance, terrain mapping, and imagery such as film-making. As a result, the number of aircraft equipped with sensors and the demand for associated communication links to offload large amounts of data has also grown and is expected to continue to grow. Those communication links, whilst not associated with aeronautical safety, can be mission critical in providing data or sensor control for the application that they are supporting.

At the same time, there is no clear identification of the frequency bands in which non-safety aeronautical mobile applications can operate, due in-part to the limitations often placed on existing mobile allocations that either preclude or place technical/operational restrictions that are not compatible with aeronautical use. This has stifled further development due to a lack of confidence within the industry of long-term spectrum access and stability.

In consequence, there is a need for adaptation of the current regulatory framework in order to clearly identify spectrum that could only be used for aeronautical payload communication, giving the industry the stability it needs to allow it to develop innovative applications that can deliver tangible benefits. However, it is important that there is a clear distinction between such systems and those used to provide safety and regularity of flight communications, including UAS command and control functions.

The objective of this agenda item is to assess spectrum requirements for new non-safety aeronautical mobile applications and seek:

- possible new primary allocations to the aeronautical mobile service in frequency band 15.4-15.7 GHz for such non-safety aeronautical applications, and

- possible revision or deletion of the "except aeronautical mobile" in the frequency band 22-22.21 GHz, already allocated on a primary basis to the mobile, except aeronautical mobile, service.

ICAO Position:

To support ITU-R studies as called for by Resolution **430 (WRC-19)**.

To support, based on the agreed results of studies, new allocations to the aeronautical mobile service only for use by non-safety aeronautical mobile applications.

To ensure that any such modification does not adversely affect the status or provision of aeronautical safety services.

WRC-23
Agenda Item 1.11

Agenda Item Title:

to consider possible regulatory actions to support the modernization of the Global Maritime Distress and Safety System (GMDSS) and the implementation of e-navigation, in accordance with Resolution 361 (Rev.WRC-19).

Discussion:

Aircraft, of which helicopters are a subset, are an integral part of the global maritime distress and safety system, providing a rapid search capability that can affect a rescue or direct surface vessels to the scene of the incident. As such, they are fitted with appropriate global maritime distress and safety system (GMDSS) radio equipment to facilitate such activities. It is therefore essential to ensure that any change to the regulatory provisions and spectrum allocations resulting from this agenda item do not adversely impact on the capability of search and rescue aircraft to effectively communicate with vessels during disaster relief operations.

In addition, ICAO requires, inter alia, that satellite systems supporting aeronautical satellite safety communications (aeronautical mobile-satellite (route) service), must comply with priority requirements contained in ICAO Standards and Recommended Practices (SARPs). Therefore, if a system which already carries such communications were to be approved by the International Maritime Organization and identified to carry GMDSS, any resultant changes to the Radio Regulations should not adversely impact that, or other, system's SARPs compliance

ICAO Position:

To ensure that any change to the regulatory provisions and spectrum allocations resulting from this agenda item do not adversely impact on the capability of search and rescue aircraft, including helicopters, to effectively communicate with vessels during disaster-relief operations.

To ensure that any regulatory provisions in response to this agenda item do not adversely affect compliance of aeronautical mobile-satellite (route) service systems with international standards and recommended practices and procedures established in accordance with the Convention on International Civil Aviation.

WRC-23
Agenda Item 1.13

Agenda Item Title:

to consider a possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service, in accordance with Resolution 661 (WRC-19).

Discussion:

Under this agenda item, the following studies are to be conducted:

a) to investigate and identify all relevant scenarios between data relay satellites, non-geostationary satellites and manned flights in the space research service operating in the frequency band 14.8-15.35 GHz, to investigate and identify all relevant scenarios that need to be considered in compatibility and sharing studies, taking into account the latest relevant ITU Radiocommunication Sector (ITU-R) Recommendations,

b) to conduct and complete in time for WRC-23 sharing and compatibility studies in order to determine the feasibility of upgrading the SRS allocation to primary status in the frequency band 14.8-15.35 GHz, with a view to ensuring protection of the primary services,

c) to determine the technical and regulatory conditions according to the results of the studies necessary to ensure b) above.

Currently, the frequency band 14.8-15.35 GHz is allocated to the generic mobile and fixed services on a primary basis. According to Recommendations ITU-R M. 2089 mentioned in *noting a)* of Resolution **661** (**WRC-19**), systems operating in the aeronautical mobile service in the frequency range 14.5-15.35 GHz are used by airborne data links to support remote sensing applications on board either manned or unmanned aircraft. In addition, in some States systems operating under the fixed service allocation are used to support air traffic operations. Neither of these applications use ICAO standardized systems.

ICAO Position:

To support studies called for by Resolution **661** (WRC 19) ensuring that they take account of systems operating in the aeronautical mobile service.

To ensure that any radio regulatory action taken as a result of agreed studies does not adversely affect the provision of aeronautical services,

WRC-23
Agenda Item 1.15

Agenda Item Title:

to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally, in accordance with Resolution 172 (WRC-19).

Discussion:

This agenda item seeks to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on board an aircraft or vessel communicating with geostationary space stations in the fixed satellite service operating in accordance with the provisions of Appendix **30B** (No **5.441**). It resolves that such earth stations shall not be used or relied upon for safety-of-life applications nor result in changes or restrictions to existing Plan allotments and List assignments made under Appendix **30B**.

Resolution **172 (WRC-19)** calls for studies to:

- Identify the technical and operational characteristics and user requirements of earth stations on aircraft and vessels that communicate or plan to communicate with geostationary (GSO) space stations in the FSS in the frequency band 12.75-13.25 GHz (Earth-to-space) under the envelope of Appendix **30B** Article 6 recorded in the List or the Master International Frequency Register (MIFR) with favourable finding only,
- address the sharing and compatibility issues between earth stations on aircraft and vessels communicating with GSO space stations in the fixed satellite service with current and planned stations of existing services as well as services in adjacent frequency bands,
- to study the responsibility of the entities involved in the operation of the earth stations on aircraft and vessels,
- to develop the criteria to ensure that earth stations on aircraft and vessels, as a new FSS application in this frequency band, shall not claim more protection nor cause more interference than filed earth stations in Appendix **30B**.

Once consensus has been reached on those studies the Resolution calls on the ITU-R to develop technical conditions and regulatory provisions for the harmonised operation of earth stations on aircraft and vessels communicating with GSO space stations in the FSS operating in the frequency band 12.75-13.25

GHz (Earth-to-space). Those technical conditions and regulatory provisions shall ensure the protection of and not impose undue constraints on, the existing services in that frequency band. Additionally, they shall not adversely affect the criteria contained in Annex 4 to Appendix **30B** including the cumulative effect of multiple earth stations on aircraft and vessels nor limit access of other administrations to their national resources in Appendix **30B**.

WRC-23 should then consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period whilst ensuring that any action taken does not result in any additional status than that of the GSO satellite networks with which these stations are communicating.

The introduction of earth station in motion operations into a frequency band that is subject to Appendix **30B** restrictions could provide a welcome additional capacity for non-safety passenger/payload communication. Additionally, given the restriction that such use shall not be or relied upon for safety-of-life communication this agenda item should not adversely affect the provision of aeronautical safety service nor set a precedent for their provision. However, how this agenda item develops needs to be monitored to ensure that modifications are not introduced that change that expectation. For example, nothing should be introduced that implies that aeronautical safety communications can occur on a Secondary basis.

See also agenda item 1.16.

ICAO Position:

To ensure that any radio regulatory action, taken as a result of this agenda item, neither adversely affects the provision of aeronautical safety-of-life services nor sets an unwanted precedent.

WRC-23
Agenda Item 1.16

Agenda Item Title:

to study and develop technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-geostationary fixed-satellite service earth stations in motion, while ensuring due protection of existing services in those frequency bands, in accordance with Resolution 173 (WRC 19).

Discussion:

This agenda item seeks to extend the concept of earth stations in motion (ESIMs) communicating with geostationary space stations, to operation of ESIMs with non-geostationary space stations in the fixed satellite service (FSS) to the 17.7-18.6 GHz, 18.8-19.3 GHz, 19.7-20.2 GHz (space-to-Earth), 27.5-29.1 GHz and 29.5-30 GHz frequency bands.

Resolution **173 (WRC-19)** calls for studies to:

- identify the technical and operational characteristics and user requirements of the different types of ESIMs that plan to operate within non-geostationary (non-GSO) satellite systems operating in the FSS in the frequency bands or parts thereof identified,
- address the sharing and compatibility between ESIMs communicating with non-GSO FSS systems and current & planned stations of primary services allocated in the frequency bands identified as well as in the adjacent frequency bands.

The Resolution also calls on the ITU-R to develop technical conditions and regulatory provisions for the operation of aeronautical and maritime ESIMs communicating with non-GSO space stations operating in the FSS in the frequency bands identified. Those technical conditions and regulatory provisions shall ensure the protection of and not impose additional constraints on the existing services in the frequency bands identified.

ITU-R should also consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period.

It should be noted that the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz are identified within Resolution **155 (Rev. WRC-19)** for the provision of unmanned aircraft systems (UAS) control and non-payload communication (CNPC). However, both Resolution **156 (WRC-15)** that regulates the use of these frequency bands for ESIMs communicating to GSO satellites and Resolution **173 (WRC-19)** that seeks to facilitate the use of ESIMs

communicating to non-GSO satellites in these frequency bands preclude the use of the relevant ESIMs from being used or relied upon for safety-of-life applications. The implications of any proposed amendment under agenda item 1.16 to the Radio Regulations need to be assessed and action taken if they:

- could adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19)**,
- do not make a clear regulatory distinction between satellite networks or satellite network resources providing UAS CNPC and those providing non-safety ESIMs applications,
- set a precedent, such as giving the impression that safety communications can occur on a Secondary basis, that could adversely affect the provision of aeronautical safety-of-life services.

See also agenda item 1.8, 1.15 and 1.17.

ICAO Position:

To ensure that any radio regulatory action taken as a result of this agenda item:

- do not adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19)**;
- make a clear regulatory distinction between satellite networks or satellite network resources providing UAS CNPC and those providing non-safety ESIMs applications;
- do not set a precedent that could adversely affect the provision of aeronautical safety-of-life services.

WRC-23
Agenda Item 1.17

Agenda Item Title:

to determine and carry out, on the basis of ITU R studies in accordance with Resolution 773 (WRC 19), the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate.

Discussion:

Inter-satellite links have traditionally been used to relay communication between space stations, normally situated on non-geostationary satellites, and an earth station where direct communication is impeded for some reason such as being beyond visual line of sight. With the planned expansion in the use of low earth orbit satellites the demand for inter-satellite links and associated spectrum is also increasing. This agenda item seeks to develop the technical conditions and regulatory provisions, including potential new allocations to the inter-satellite service, by which the different types of space station can operate inter-satellite links in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz.

Resolution **773 (WRC-19)** calls for studies to:

- identify the technical and operational characteristics, including spectrum requirements, for transmissions between space stations in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz,
- address the sharing and compatibility between satellite-to-satellite links intending to operate between space stations in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz and current and planned stations of the FSS and other existing services allocated in same frequency bands and adjacent frequency bands,

Based on those studies the Resolution calls on the ITU-R to develop, for different types of space stations, the technical conditions and regulatory provisions for satellite-to-satellite operations, including potential new inter-satellite service allocations, in the frequency bands identified.

WRC-23 should then consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period whilst ensuring the protection of the fixed and mobile services allocated on a primary basis within the identified frequency bands.

It should be noted that the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz are identified within Resolution **155 (Rev. WRC-19)** for the provision of unmanned aircraft systems (UAS) control and non-payload communication (CNPC). It is therefore important that the implications of any proposed

amendment under agenda item 1.17 to the Radio Regulations are assessed and action taken if they could adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19)**,

See also agenda item 1.8 and 1.16.

ICAO Position:

To ensure that, given the overlap in frequency bands, any radio regulatory action taken as a result of this agenda item does not adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19),**

WRC-23
Agenda Item 4

Agenda Item Title:

in accordance with Resolution 95 (Rev.WRC-19), to review the Resolutions and Recommendations of previous conferences with a view to their possible revision, replacement or abrogation.

ICAO Position:

Resolutions:

Resolution No.	***Title***	***Action recommended***
18 *(Rev. WRC-15)*	Relating to the procedure for identifying and announcing the position of ships and aircraft of States not parties to an armed	No change
20 *(Rev. WRC-03)*	Technical cooperation with developing countries in the field of aeronautical telecommunications.	No change
26 *(Rev. WRC-19)*	Footnotes to the Table of Frequency Allocations in Article **5** of the Radio Regulations.	No change
27 *(Rev. WRC-19)*	Use of incorporation by reference in the Radio Regulations.	No change
63 *(Rev. WRC-12)*	Protection of radiocommunication services against interference caused by radiation from industrial, scientific and medical (ISM) equipment.	No change
76 *(Rev. WRC-15)*	Protection of geostationary fixed-satellite service and geostationary broadcasting-satellite service networks from the maximum aggregate equivalent power flux-density produced by multiple non-geostationary fixed-satellite service systems in frequency bands where equivalent power flux-density limits have been adopted.	No change

Resolution No.	***Title***	***Action recommended***
95 *(Rev. WRC19)*	General review of the resolutions and recommendations of world administrative radio conferences and world radiocommunication conferences.	No change
114 *(Rev. WRC-15)*	Studies on compatibility between new systems of the aeronautical radionavigation service and the fixed-satellite service (Earth-to-space) (limited to feeder links of the non-geostationary mobile-satellite systems in the mobile-satellite service) in the frequency band 5 091-5 150 MHz.	No change
140 *(Rev. WRC-15)*	Measures and studies associated with the equivalent power flux-density (epfd) limits in the band 19.7-20.2 GHz.	No change
154 *(WRC-15)*	Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1.	No change
155 *(Rev. WRC-19)*	Regulatory provisions related to earth stations on board unmanned aircraft which operate with geostationary-satellite networks in the fixed-satellite service in certain frequency bands not subject to a plan of Appendices 30, 30A and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces.	Subject to WRC-23 Agenda Item 1.8.

Resolution No.	***Title***	***Action recommended***
156 *(WRC-15)*	Use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service	Modify if necessary to ensure clear delineation between ESIMs and unmanned aircraft control and non payload communication covered in Resolution **155 (Rev. WRC-19)**.
160 *(WRC-15)*	Facilitating access to broadband applications delivered by high-altitude platform stations.	Suppress based on the results of studies carried out under WRC-19 Agenda Item 1.14.
165 *(WRC-19)*	Use of the frequency band 21.4-22 GHz by high-altitude platform stations in the fixed service in Region 2	No change
166 *(WRC-19)*	Use of the frequency band 24.25-27.5 GHz by high-altitude platform stations in the fixed service in Region 2	No change
167 *(WRC-19)*	Use of the frequency band 31-31.3 GHz by high-altitude platform stations in the fixed service	No change
168*(WRC-19)*	Use of the frequency band 38-39.5 GHz by high-altitude platform stations in the fixed service	No change

Resolution No.	***Title***	***Action recommended***
169 *(WRC-19)*	Use of the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service	Modify if necessary to ensure that the provisions for ESIMs do not limit the use of unmanned aircraft control and non payload communication covered in Resolution **155** ***(Rev. WRC-19)***.
171 *(WRC-19)*	Review and possible revision of Resolution **155 (Rev.WRC-19)** and No. **5.484B** in the frequency bands to which they apply	Subject to WRC-23 Agenda Item 1.8.
172 *(WRC-19)*	Operation of earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service in the frequency band 12.75-13.25 GHz (Earth-to-space)	Subject to WRC-23 Agenda Item 1.15.
173 *(WRC-19)*	Use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by earth stations in motion communicating with non-geostationary space stations in the fixed-satellite service	Subject to WRC-23 Agenda Item1.16.

Resolution No.	***Title***	***Action recommended***
176 *(WRC-19)*	Use of the frequency bands 37.5-39.5 GHz (space-to-Earth), 40.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) by aeronautical and maritime earth stations in motion communicating with geostationary space stations in the fixed-satellite service	Modify or suppress as necessary based on the results of studies carried out (preliminary WRC-27 Agenda Item 2.2).
205 *(Rev. WRC-19)*	Protection of the systems operating in the mobile satellite service in the band 406-406.1 MHz.	No change
207 *(Rev. WRC-15)*	Measures to address unauthorized use of and interference to frequencies in the bands allocated to the maritime mobile service and to the aeronautical mobile (R) service.	No change
217 *(WRC-97)*	Implementation of wind profiler radars.	No change
222 *(Rev. WRC-12)*	Use of the frequency bands 1 525-1 559 MHz and 1 626.5-1 660.5 MHz by the mobile-satellite service, and procedures to ensure long-term spectrum access for the aeronautical mobile-satellite (R) service.	No change
223 *(Rev WRC-19)*	Additional frequency bands identified for International Mobile Telecommunications	Modify or suppress *invites the ITU Radiocommunications Sector* 1 to Resolution **223**, as appropriate, based on the results of the studies called for by that provision.
225 *(Rev. WRC-12)*	Use of additional frequency bands for the satellite component of IMT.	No change

Resolution No.	***Title***	***Action recommended***
229 *(Rev. WRC-19)*	Use of the frequency bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks	No change
240 *(WRC-19)*	Spectrum harmonization for railway radiocommunication systems between train and trackside within the existing mobile-service allocations.	Monitor studies and ensure protection of aeronautical systems.
245 *(WRC-19)*	Studies on frequency-related matters for the terrestrial component of International Mobile Telecommunications identification in the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz	Subject to WRC-23 Agenda Item 1.2.
246 *(WRC-19)*	Studies to consider possible allocation of the frequency band 3 600-3 800 MHz to the mobile, except aeronautical mobile, service on a primary basis within Region 1	Subject to WRC-23 Agenda Item 1.3.
247 *(WRC-19)*	Facilitating mobile connectivity in certain frequency bands below 2.7 GHz using high-altitude platform stations as International Mobile Telecommunications base stations	Subject to WRC-23 Agenda Item 1.4.

Resolution No.	***Title***	***Action recommended***
249 *(WRC-19)*	Study of technical and operational issues and regulatory provisions for space-to-space transmissions in the Earth-to-space direction in the frequency bands [1 610-1 645.5 and 1 646.5-1 660.5 MHz] and the space-to-Earth direction in the frequency bands [1 525-1 544 MHz], [1 545-1 559 MHz], [1 613.8-1 626.5 MHz] and [2 483.5-2 500 MHz] among non-geostationary and geostationary satellites operating in the mobile-satellite service	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.8)
250 *(WRC-19)*	Studies on possible allocations to the land mobile service (excluding International Mobile Telecommunications) in the frequency band 1 300-1 350 MHz for use by administrations for the future development of terrestrial mobile-service applications	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.9)
251 *(WRC-19)*	Removal of the limitation regarding aeronautical mobile in the frequency range 694-960 MHz for the use of International Mobile Telecommunications user equipment by non-safety applications	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.12)
339 *(Rev. WRC-07)*	Coordination of NAVTEX services.	No change
354 *(WRC-07)*	Distress and safety radiotelephony procedures for 2 182 kHz.	No change
356 *(WRC-07)*	ITU maritime service information registration.	No change

Resolution No.	***Title***	***Action recommended***
361 *(Rev. WRC-19)*	Consideration of regulatory provisions for modernization of the global maritime distress and safety system and related to the implementation of e-navigation.	Subject to WRC-23 Agenda Item 1.11.
405 *(Geneva 1979)*	Relating to the use of frequencies of the aeronautical mobile (R) service.	Subject to WRC-23 agenda item 1.9.
413 *(Rev. WRC-12)*	Use of the band 108-117.975 MHz by aeronautical service.	No change
417 *(Rev. WRC-12)*	Use of the frequency band 960-1 164 MHz by the aeronautical mobile (R) service.	No change
418 (*Rev. WRC-15*)	Use of the band 5 091-5 250 MHz by the aeronautical mobile service for telemetry applications.	No change
422 *(WRC-12)*	Development of methodology to calculate aeronautical mobile-satellite (R) service spectrum requirements within the frequency bands 1 545-1 555 MHz (space-to-Earth) and 1 646.5-1 656.5 MHz (Earth-to-space).	Suppress as a result of the approval of Recommendation ITU-R M.2091.
424 *(WRC-15)*	Use of wireless avionics intra-communications in the frequency band 4 200-4 400 MHz.	No change
425 *(Rev. WRC-19)*	Use of the frequency band 1 087.7-1 092.3 MHz by the aeronautical mobile-satellite (R) service (Earth-to-space) to facilitate global flight tracking for civil aviation.	No change
428 *(WRC-19)*	Studies on a possible new allocation to the aeronautical mobile-satellite (R) service within the frequency band 117.975-137 MHz in order to support aeronautical VHF communications in the Earth-to-space and space-to-Earth directions	Subject to WRC-23 Agenda Item 1.7.

Resolution No.	***Title***	***Action recommended***
429 *(WRC-19)*	Consideration of regulatory provisions for updating Appendix 27 of the Radio Regulations in support of aeronautical HF modernization	Subject to WRC-23 Agenda Item 1.9.
430 *(WRC-19)*	Studies on frequency-related matters, including possible additional allocations, for the possible introduction of new non-safety aeronautical mobile applications	Subject to WRC-23 Agenda Item 1.10.
608 *(Rev. WRC-19)*	Use of the frequency band 1 215-1 300 MHz by systems of the radionavigation satellite service.	No change
609 *(Rev. WRC-07)*	Protection of aeronautical radionavigation systems from the equivalent power flux-density produced by radionavigation satellite service networks and systems in the 1 164-1 215 MHz band.	No change
610 *(Rev. WRC-19)*	Coordination and bilateral resolution of technical compatibility issues for radionavigation satellite networks and systems in the band 1 164-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz.	No change
612 (*Rev. WRC-12*)	Use of the radiolocation service between 3 and 50 MHz to support oceanographic radar operations.	No change
660 (*WRC-19*)	Use of the frequency band 137-138 MHz by non-geostationary satellites with short-duration missions in the space operation service.	No change
661 *(WRC-19)*	Examination of a possible upgrade to primary status of the secondary allocation to the space research service in the frequency band 14.8-15.35 GHz	Subject to WRC-23 Agenda Item 1.13.
705 *(Rev. WRC-15)*	Mutual protection of radio services operating in the band 70-130 kHz.	No change

Resolution No.	***Title***	***Action recommended***
729 *(Rev. WRC-07)*	Use of frequency adaptive systems in the MF and HF bands.	No change
748 (*Rev. WRC-19*)	Compatibility between the aeronautical mobile (R) service and the fixed satellite service (Earth-to-space) in the band 5 091-5 150 MHz.	No change
762 *(WRC-15)*	Application of power flux density criteria to assess the potential for harmful interference under 11.32A for fixed-satellite and broadcasting-satellite service networks in the 6 GHz and 10/11/12/14 GHz bands not subject to a plan.	No change
772 *(WRC-19)*	Consideration of regulatory provisions to facilitate the introduction of sub-orbital vehicles.	Subject to WRC-23 agenda item 1.6.
773 *(WRC-19)*	Study of technical and operational issues and regulatory provisions for satellite-to-satellite links in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8 20.2 GHz and 27.5-30 GHz	Subject to WRC-23 agenda item 1.17.
774 *(WRC-19)*	Studies on technical and operational measures to be applied in the frequency band 1 240-1 300 MHz to ensure the protection of the radionavigation-satellite service (space-to-Earth)	Subject to WRC-23 agenda item 9.1 topic b.

Recommendations:

Recommendation No.		***Action recommended***
7 *(Rev. WRC-97)*	Adoption of standard forms for ship station and ship earth station licences and aircraft station and aircraft earth station licences.	No change
9	Relating to the measures to be taken to prevent the operation of broadcasting stations on board ships or aircraft outside national territories.	No change
71	Relating to the standardization of the technical and operational characteristics of radio equipment.	No change
75 *(Rev. WRC-15)*	Study on the boundary between the out-of-band and spurious domains of primary radars using magnetrons.	No change
401	Relating to the efficient use of aeronautical mobile (R) worldwide frequencies.	No change
608 *(Rev. WRC-07)*	Guidelines for consultation meetings established in Resolution **609 (WRC-07)**.	No change

WRC-23
Agenda Item 8

Agenda Item Title:

to consider and take appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes, if no longer required, taking into account Resolution 26 (Rev.WRC-19).

Discussion:

Allocations to the aeronautical services are generally made for all ITU regions and normally on an exclusive basis. These principles reflect the global process of standardization within ICAO for the promotion of safety and to support the global interoperability of radiocommunication and radionavigation equipment used in civil aircraft. In some instances, however, footnotes to the ITU Table of Frequency Allocations allocate spectrum in one or more countries to other radio services in addition or alternatively to the aeronautical service to which the same spectrum is allocated in the body of the table.

The use of country footnote allocations to non-aeronautical services in aeronautical bands is generally not recommended by ICAO, on safety grounds, as such use may result in harmful interference to safety services. Furthermore, this practice generally leads to an inefficient use of available spectrum to aeronautical services, particularly when the radio systems sharing the band have differing technical characteristics. It also may result in undesirable (sub-) regional variations with respect to the technical conditions under which the aeronautical allocations can be used. This can have a serious impact on the safety of aviation.

The following footnotes in aeronautical bands should be carefully reviewed by administrations in order to preserve the safety and efficiency of aeronautical services for the reasons as discussed below:

a) In the frequency bands used for the ICAO instrument landing system (ILS), (marker beacons 74.8-75.2 MHz; localizer 108-112 MHz and glide path 328.6-335.4 MHz) and the VHF omnidirectional radio range system (VOR); 108-117.975 MHz, Nos. **5.181**, **5.197** and **5.259** allow for the introduction of the mobile service on a secondary basis and subject to agreement obtained under No. **9.21** of the Radio Regulations when these bands are no longer required for the

aeronautical radionavigation service. The use of both ILS and VOR is expected to continue. In addition, WRC-03, as amended by WRC-07, has introduced No. **5.197A** stipulating that the band 108-117.975 MHz is also allocated on a primary basis to the aeronautical mobile (R) service (AM(R)S), limited to systems operating in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **413 (Rev. WRC-12)**. The use of the band 108-112 MHz by the AM(R)S shall be limited to systems composed of ground-based transmitters and associated receivers that provide navigational information in support of air navigation functions in accordance with recognized international aeronautical standards. ICAO encourages administrations listed in Nos. **5.181**, **5.197** and **5.259** to review their use and if no longer required, to remove their country's name from these footnotes.

b) Nos. **5.201** and **5.202** allocate the frequency bands 132-136 MHz and 136-137 MHz in some States to the aeronautical mobile (off-route) service (AM(OR)S). Since these frequency bands are heavily utilized for ICAO-standard VHF voice and data communications, ICAO encourages those concerned administrations to review their use and if no longer required, to remove their country's name from these footnotes.

c) In the frequency band 1 215-1 300 MHz, which is used by civil aviation for the provision of radionavigation services through No. **5.331**. Footnote No. **5.330** allocates the band in a number of countries to the fixed and mobile service. Given the receiver sensitivity of aeronautical uses of the frequency band, ICAO does not support the continued inclusion of an additional service through country footnotes. ICAO would therefore encourage administrations to review their use and if no longer required, to remove their country's name from No. **5.330**.

d) in the frequency band 1 525-1 530 MHz, which is used by civil aviation for the provision of satellite services No. **5.352A** specifies that stations in the mobile-satellite service, except stations in the maritime mobile-satellite service, shall not cause harmful interference to, or claim protection from, stations of the fixed service in a number of countries that were notified prior to 1 April 1998. As of August 2020, the ITU Master International Frequency Register shows out of 20 administrations listed in this footnote, only 4 Administrations have fixed stations notified prior to 1 April 1998. ICAO would therefore encourage Administrations listed in the footnote to review their use of fixed service assignments in 1 525-

1 530 MHz, and if no longer required, to remove their country's name from No. **5.352A**.

e) In the frequency bands 1 540-1 559 MHz, 1 610.6-1 613.8 MHz and 1 613.8-1 626.5 MHz, within which some portions are assigned to or used by the aeronautical mobile-satellite (R) service, No. **5.355** also allocates the band on a secondary basis to the fixed service in a number of countries. Given that portions of these bands are utilized by a safety-of-life service, ICAO does not support the continued use of No **5.355** country footnote. ICAO encourages those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.355**.

f) In the frequency bands 1 550-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz which are assigned to mobile-satellite services, including in some portions assignment to or use by the aeronautical mobile-satellite (R) service, No. **5.359** also allocates the bands to the fixed service on a primary basis in a number of countries. Given that portions of these bands are utilized by a safety-of-life service, ICAO does not support the continued use of No. **5.359** country footnote. ICAO would therefore encourage those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.359**.

g) In the frequency band 4 200-4 400 MHz, which is reserved for use by airborne radio altimeters and wireless avionics intra-communications (WAIC), No. **5.439** allows the operation of the fixed service on a secondary basis in some countries. Radio altimeters are a critical element in aircraft automatic landing systems and serve as a sensor in ground proximity warning systems. WAIC provides aircraft safety communications between points on an airframe. Interference from the fixed service has the potential to affect the safety of both of these systems. ICAO would therefore encourage those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.439**.

ICAO Position:

To encourage administrations listed in the footnotes to review Nos. **5.181, 5.197** and **5.259**, as access to the frequency bands 74.8-75.2, 108-112 and 328.6-335.4 MHz by the mobile service is difficult and could create the potential for harmful interference to important radionavigation systems used by aircraft at final approach and landing as well as systems operating in the aeronautical mobile service in the frequency band 108-112 MHz.

To encourage administrations listed in the footnotes to review Nos. **5.201 and 5.202**, as use by the AM(OR)S of the frequency bands 132-136 MHz and 136-137 MHz in some States may cause harmful interference to aeronautical safety communications.

To encourage administrations listed in the footnote to review No. **5.330** as access to the frequency band 1 215-1 300 MHz by the fixed and mobile services could potentially cause harmful interference to services used to support aircraft operations.

To encourage administrations listed the footnote to review No. **5.352A** as access to the frequency bands 1 525-1 530 MHz by the fixed services could potentially constrain aeronautical use of this frequency band.

To encourage administrations listed in the footnote to review No. **5.355** as access to the frequency bands 1 540-1 559, 1 610.6-1 613.8 and 1 613.8-1 626.5 MHz by the fixed services could potentially constrain aeronautical use of these frequency bands.

To encourage administrations listed in the footnote to review No. **5.359** as access to the frequency bands 1 550-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz by the fixed services could potentially jeopardize aeronautical use of those frequency bands.

To encourage administrations listed in the footnote to review No. **5.439** to ensure the protection of the safety critical operation of radio altimeters and WAIC systems in the frequency band 4 200-4 400 MHz.

ICAO would encourage administrations to take appropriate actions under this agenda item to remove their country's name from these footnotes if no longer required.

Note 1.— Administrations indicated in the footnotes mentioned in the ICAO Position above which are urged to remove their country names from these footnotes are as follows:

*No. **5.181*** *Egypt, Israel and Syrian Arab Republic No.*

*No. **5.197*** *Syrian Arab Republic*

*No. **5.201*** *Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, the Russian Federation, Georgia, Hungary, Iran (Islamic Republic of), Iraq (Republic of), Japan, Kazakhstan, Mali, Mongolia, Mozambique, Uzbekistan, Papua New Guinea, Poland, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine*

*No. **5.202*** *Saudi Arabia, Armenia, Azerbaijan, Bahrain, Belarus, Bulgaria, the United Arab Emirates, the Russian Federation, Georgia, Iran (Islamic Republic of), Jordan, Mali, Oman, Uzbekistan, Poland, the Syrian Arab Republic, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine*

*No. **5.259*** *Egypt and Syrian Arab Republic*

*No. **5.330*** *Angola, Bahrain, Bangladesh, Cameroon, Chad, China, Djibouti, Egypt, Eritrea, Ethiopia, Guyana, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Nepal, Oman, Pakistan, the Philippines, Qatar, Saudi Arabia, Somalia, Sudan, South Sudan, the Syrian Arab Republic, Togo, the United Arab Emirates and Yemen*

*No. **5.355*** *Bahrain, Bangladesh, Congo (Rep of the), Djibouti, Egypt, Eritrea, Iraq, Israel, Kuwait, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen*

*No. **5.352A*** *Algeria, Saudi Arabia, Egypt, Guinea, India, Israel, Italy, Jordan, Kuwait, Mali, Morocco, Mauritania, Nigeria, Oman, Pakistan, the Philippines, Qatar, Syrian Arab Republic, Viet Nam and Yemen*

*No. **5.359** Germany, Saudi Arabia, Armenia, , Azerbaijan, Belarus, Cameroon, the Russian Federation, Georgia, Guinea, Guinea-Bissau, Jordan, Kazakhstan, Kuwait, Lithuania, Mauritania, Uganda, Uzbekistan, Pakistan, Poland, the Syrian Arab Republic, Kyrgyzstan, the Dem. People's Rep. of Korea, Romania, Tajikistan, Tunisia, Turkmenistan and Ukraine*

*No. **5.439** Iran (Islamic Republic of)*

WRC-23
Agenda Item 9.1

Agenda Item Title:

To consider and approve the report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Convention:

On the activities of the Radiocommunication Sector since WRC-19.

*Note.— The subdivision of Agenda Item **9.1** into topics, such as a), b), etc. was made at the first session of the Conference Preparatory Meeting for WRC-23 (CPM23-1) and is summarized in the BR Administrative Circular CA/251, 19th December 2019. In addition, a topic d) was added which was not part of Resolution 811 (WRC-19) (the WRC-23 agenda), however was agreed by WRC-19 (see WRC-19 document 573 §§ 35.2 to 35.4).*

Topic 9.1 (b):

Review of the amateur service and the amateur-satellite service allocations in the frequency band 1 240-1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite (space-to-Earth) service operating in the same band in accordance with Resolution 774 (WRC-19).

The amateur service has a secondary allocation in the frequency band 1 240-1 300 MHz (known as the "23 cm band" by the amateur community) and is currently used for amateur voice, data and image transmission. The frequency band is also allocated on a primary basis to the following services:

- Table Allocation
    - Earth exploration-satellite (active)
    - Radiolocation
    - Radionavigation Satellite (space-to-Earth) (space-to-space)
    - Space research(active)
- Footnote Allocation within various Countries
    - 5.330 Fixed

- 5.330 Mobile
- 5.331 Radionavigation

In the frequency band 1 240-1 300 MHz radionavigation satellite service (RNSS) systems such as GLONASS, Galileo, Beidou & QZSS are either operational, or becoming operational in various parts of the world with the expectation of enhancing the accuracy, reliability and positional accuracy of the current systems as well as offering additional features. However, there have been confirmed reports of harmful interference to the RNSS being caused by amateur service systems. This agenda item seeks to identify additional technical and operational measures that could be implemented to improve the protection of those RNSS from amateur and amateur-satellite systems operating under the secondary allocations to the amateur and amateur-satellite service without removing those amateur allocations.

Within the frequency band 1 240-1 300 MHz aviation currently operates primary surveillance radars used in the provision of air traffic control services. Past research has indicated that RNSS systems such as those indicated above can cause harmful interference to radars. The concern is that action taken under this agenda item could adversely affect the provision of those primary radar services with a consequential impact on air traffic control.

ICAO Position:

To ensure that ITU-R studies under Resolution **774 (WRC-19)** address whether potential mitigation measures will impact the protection of aeronautical radar systems operating under the existing aeronautical radionavigation or radiolocation service allocations.

WRC-23
Agenda Item 9.2

Agenda Item Title:

To consider and approve the report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Convention:

on any difficulties or inconsistencies encountered in the application of the Radio Regulations.

The relevant ITU-R working parties are invited to carry out the requested studies, indicated below, and to report the results of the studies to the Director of the Radiocommunication Bureau to be considered as the Director deems appropriate.

From Resolution **427 (WRC-19)** "Updating provisions related to aeronautical services in the Radio Regulations – resolves to invite ITU-R States "to study the Articles, limited to Chapters IV, V, VI and VIII of Volume I of the Radio Regulations and their associated Appendices, as appropriate, in order to identify outdated aeronautical provisions with respect to ICAO Standards and Recommended Practices and to develop examples of regulatory texts for updating these provisions, while ensuring that potential changes to such provisions will not impact any other systems or services operating in accordance with the Radio Regulations". (Responsible Group: WP 5B).

ICAO Position:

Participate in ITU-R studies to ensure any proposed changes to the Radio Regulations recommended in the Director's Report to the WRC do not impact current or planned aeronautical systems or applications.

APPENDIX TO ATTACHMENT F*

Agenda for the 2023 World Radiocommunication Conference

The World Radiocommunication Conference (Sharm el-Sheikh, 2019),

considering

a) that, in accordance with No. 118 of the ITU Convention, the general scope of the agenda for a world radiocommunication conference (WRC) should be established four to six years in advance and that a final agenda shall be established by the ITU Council two years before the conference;

b) Article 13 of the ITU Constitution relating to the competence and scheduling of WRCs and Article 7 of the Convention relating to their agendas;

c) the relevant resolutions and recommendations of previous world administrative radio conferences (WARCs) and WRCs,

recognizing

a) that this conference has identified a number of urgent issues requiring further examination by WRC-23;

b) that, in preparing this agenda, some items proposed by administrations could not be included and have had to be deferred to future conference agendas,

resolves

to recommend to the Council that a WRC be held in 2023 for a maximum period of four weeks, with the following agenda:

1 on the basis of proposals from administrations, taking account of the results of WRC-19 and the Report of the Conference Preparatory Meeting, and with due regard to the requirements of existing and future services in the frequency bands under consideration, to consider and take appropriate action in respect of the following items:

1.1 to consider, based on the results of ITU-R studies, possible measures to address, in the frequency band 4 800-4 990 MHz, protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories, and to review the power flux-density criteria in No. **5.441B** in accordance with Resolution **223 (Rev.WRC-19)**;

1.2 to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution **245 (WRC-19)**;

* The text of the resolution included in this Annex has been copied from the ITU Radio Regulations, Edition of 2020, Volume III.

1.3 to consider primary allocation of the frequency band 3 600-3 800 MHz to the mobile service in Region 1 and take appropriate regulatory actions, in accordance with Resolution **246 (WRC-19)**;
1.4 to consider, in accordance with Resolution **247 (WRC-19)**, the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level;
1.5 to review the spectrum use and spectrum needs of existing services in the frequency band 470-960 MHz in Region 1 and consider possible regulatory actions in the frequency band 470-694 MHz in Region 1 on the basis of the review, in accordance with Resolution **235 (WRC-15)**;
1.6 to consider, in accordance with Resolution **772 (WRC-19)**, regulatory provisions to facilitate radiocommunications for sub-orbital vehicles;
1.7 to consider a new aeronautical mobile-satellite (R) service allocation in accordance with Resolution **428 (WRC-19)** for both the Earth-to-space and space-to-Earth directions of aeronautical VHF communications in all or part of the frequency band 117.975-137 MHz, while preventing any undue constraints on existing VHF systems operating in the aeronautical mobile (R) service, in the aeronautical radionavigation service, and in adjacent frequency bands;
1.8 to consider, on the basis of ITU-R studies in accordance with Resolution **171 (WRC-19)**, appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution **155 (Rev.WRC-19)** and No. **5.484B** to accommodate the use of fixed-satellite service networks by control and non-payload communications of unmanned aircraft systems;
1.9 to review Appendix **27** of the Radio Regulations and consider appropriate regulatory actions and updates based on ITU-R studies, in order to accommodate digital technologies for commercial aviation safety-of-life applications in existing HF bands allocated to the aeronautical mobile (R) service and ensure coexistence of current HF systems alongside modernized HF systems, in accordance with Resolution **429 (WRC-19)**;
1.10 to conduct studies on spectrum needs, coexistence with radiocommunication services and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications, in accordance with Resolution **430 (WRC-19)**;
1.11 to consider possible regulatory actions to support the modernization of the Global Maritime Distress and Safety System (GMDSS) and the implementation of e-navigation, in accordance with Resolution **361 (Rev.WRC-19)**;
1.12 to conduct, and complete in time for WRC-23, studies for a possible new secondary allocation to the Earth exploration-satellite service (active) for spaceborne radar sounders within the range of frequencies around 45 MHz, taking into account the protection of incumbent services, including in adjacent bands, in accordance with Resolution **656 (Rev.WRC-19)**;

1.13 to consider a possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service, in accordance with Resolution **661 (WRC-19)**;

1.14 to review and consider possible adjustments of the existing frequency allocations or possible new primary frequency allocations to the Earth exploration-satellite service (passive) in the frequency range 231.5-252 GHz, to ensure alignment with more up-to-date remote-sensing observation requirements, in accordance with Resolution **662 (WRC-19)**;

1.15 to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally, in accordance with Resolution **172 (WRC-19)**;

1.16 to study and develop technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-geostationary fixed-satellite service earth stations in motion, while ensuring due protection of existing services in those frequency bands, in accordance with Resolution **173 (WRC-19)**;

1.17 to determine and carry out, on the basis of ITU-R studies in accordance with Resolution **773 (WRC-19)**, the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate;

1.18 to consider studies relating to spectrum needs and potential new allocations to the mobile-satellite service for future development of narrowband mobile-satellite systems, in accordance with Resolution **248 (WRC-19)**;

1.19 to consider a new primary allocation to the fixed-satellite service in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2, while protecting existing primary services in the band, in accordance with Resolution **174 (WRC-19)**;

2 to examine the revised ITU-R Recommendations incorporated by reference in the Radio Regulations communicated by the Radiocommunication Assembly, in accordance with *further resolves* of Resolution **27 (Rev.WRC-19)**, and to decide whether or not to update the corresponding references in the Radio Regulations, in accordance with the principles contained in *resolves* of that Resolution;

3 to consider such consequential changes and amendments to the Radio Regulations as may be necessitated by the decisions of the conference;

4 in accordance with Resolution **95 (Rev.WRC-19)**, to review the Resolutions and Recommendations of previous conferences with a view to their possible revision, replacement or abrogation;

5 to review, and take appropriate action on, the Report from the Radiocommunication Assembly submitted in accordance with Nos. 135 and 136 of the ITU Convention;

6 to identify those items requiring urgent action by the radiocommunication study groups in preparation for the next world radiocommunication conference;

7 to consider possible changes, in response to Resolution 86 (Rev. Marrakesh, 2002) of the Plenipotentiary Conference, on advance publication, coordination, notification and recording procedures for frequency assignments pertaining to satellite networks, in accordance with Resolution **86 (Rev.WRC-07)**, in order to facilitate the rational, efficient and economical use of radio frequencies and any associated orbits, including the geostationary-satellite orbit;

8 to consider and take appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes, if no longer required, taking into account Resolution **26 (Rev.WRC-19)**;

9 to consider and approve the Report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the ITU Convention;

9.1 on the activities of the ITU Radiocommunication Sector since WRC-19:

– In accordance with Resolution **657 (Rev.WRC-19)**, review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services;

– Review the amateur service and the amateur-satellite service allocations in the frequency band 1 240-1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite service (space-to-Earth) operating in the same band in accordance with Resolution **774 (WRC-19)**;

– Study the use of International Mobile Telecommunication systems for fixed wireless broadband in the frequency bands allocated to the fixed service on a primary basis, in accordance with Resolution **175 (WRC-19)**;

9.2 on any difficulties or inconsistencies encountered in the application of the Radio Regulations;[1] and

9.3 on action in response to Resolution **80 (Rev.WRC-07)**;

10 to recommend to the ITU Council items for inclusion in the agenda for the next world radiocommunication conference, and items for the preliminary agenda of future conferences, in accordance with Article 7 of the ITU Convention and Resolution **804 (Rev.WRC-19)**,

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[1] This agenda sub-item is strictly limited to the Report of the Director on any difficulties or inconsistencies encountered in the application of the Radio Regulations and the comments from administrations. Administrations are invited to inform the Director of the Radiocommunication Bureau of any difficulties or inconsistencies encountered in the Radio Regulations.

invites the ITU Council

to finalize the agenda and arrange for the convening of WRC-23, and to initiate as soon as possible the necessary consultations with Member States,

instructs the Director of the Radiocommunication Bureau

1 to make the necessary arrangements to convene meetings of the Conference Preparatory Meeting (CPM) and to prepare a report to WRC-23;

2 to submit a draft report on any difficulties or inconsistencies encountered in the application of the Radio Regulations referred in agenda item 9.2 to the second session of the CPM and to submit the final report at least five months before the next WRC,

instructs the Secretary-General

to communicate this Resolution to international and regional organizations concerned.

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Attachment G

TECHNICAL INFORMATION AND FREQUENCY-SHARING CRITERIA

1. INTRODUCTION

This attachment contains a repository of technical information for the various frequency bands relevant to aviation. This includes relevant references to other technical documentation, interference scenarios and frequency-sharing criteria.

Band: 130–535 kHz (selected bands)

Technical Information:

Service: Aeronautical radionavigation
Aviation use: Non-directional beacons, locator beacons
Annex 10:

SARPs: Annex 10, Volume I, Chapter 3, paragraphs 3.4 and 3.9
Frequency plan: Regional Plan
Channelization: 1 kHz spacing; in EUR region 0.5 kHz spacing may also be used
Planning criteria:

Annex 10, Volume V, Chapter 3, paragraph 3.2
Annex 10, Volume I, Attachment C, paragraph 6
Annex 10, Volume V, Attachment B
Air Navigation Plan: European Frequency Management Manual (EUR Doc. 11), Part 3, Chapter 1 (download from https://www.icao.int/EURNAT/Pages/EUR-and-NAT-Document.aspx

Note.— Reference to planning criteria for other regions to be added.

RTCA: DO-179, MOPS for ADF equipment (1982)
Eurocae: ED-51, MPS for Airborne ADF Equipment (1983), Amendment #1 (1987)
ARINC characteristic: 712-7, Airborne ADF System (1992)
ITU Res./Rec.:
ITU-R: Rec. P.368: Ground wave propagation curves for frequencies between 10 kHz and 30 MHz
Other material:

- CCIR Report No. 910-1 — Sharing between the maritime mobile service and the aeronautical radionavigation service in the band 415–526.5 kHz.

Note.— This report is published in Annex 3 to Volume VIII of the Report of the XVII Plenary Assembly of the International Radio Consultative Committee (CCIR) *(Düsseldorf, 1990).*

- *Final Acts of the Regional Administrative Radio Conference for the planning of the MF Maritime Mobile and Aeronautical Radionavigation Services (Region 1)*, Geneva, 1985

INTERFERENCE FROM NON-AERONAUTICAL SOURCES AND FREQUENCY SHARING BETWEEN NDB AND MARITIME MOBILE SERVICES IN BANDS BETWEEN 415 KHZ AND 435 KHZ

The medium frequency bands allocated to aeronautical radionavigation service between 415 kHz and 495 kHz are used for NDBs in all three ITU regions and shared with the maritime mobile service. In Region 1, in the band 415–435 kHz, the sharing is on a joint primary basis. In Regions 2 and 3, in the band 415–495 kHz (and in Region 1, in the band 435–495 kHz), the aeronautical radionavigation service is on a secondary basis although in some countries the aeronautical radionavigation service has a primary status (RR Nos. **5.77** and **5.78**). With careful planning and coordination, acceptable sharing arrangements can be achieved, facilitated by the geographically different areas of operation of the two services.

The protection of aeronautical beacons from transmissions of coast and ship stations of the maritime mobile service can be assured by the application of the criteria contained in Appendix **12** to the Radio Regulations. Additional guidance material is contained in Annex 10. Some ICAO regions, notably the European region, have also agreed to apply supplementary criteria to NDB frequency assignments in their areas. An overview of the relevant provisions is given below.

ITU Radio Regulations

Appendix 12

Special Rules Applicable to Radiobeacons
Section 1 — Aeronautical Radiobeacons

1) The assignment of frequencies to aeronautical radiobeacons operating in the bands between 160 kHz and 535 kHz shall be based on a protection ratio against interference of at least 15 dB for each beacon throughout its

service area.

2) The radiated power should be kept to the minimum value necessary to give the desired field strength at the service range.

3) The daylight service range of radiobeacons referred to in 1) above shall be based on the following field strengths:

4) *Regions 1 and 2*

— 70 microvolts per metre for radiobeacons north of 30° N;

— 120 microvolts per metre for radiobeacons between 30° N and 30° S;

— 70 microvolts per metre for radiobeacons south of 30° S.

5) *Region 3*

— 70 microvolts per metre for radiobeacons north of 40° N;

— 120 microvolts per metre for radiobeacons between 40° N and 50° S;

— 70 microvolts per metre for radiobeacons south of 50° S.

The above provisions have the status of Regulations through the linked reference at Article **28** (**28.23** and **28.24**), which specifies the above as special rules which must be complied with.

ICAO Annex 10

Frequency planning material relevant for NDB assignments is also contained in:

i) Annex 10, Volume I, 3.4 — Specification for non-directional radio beacon (NDB);

ii) Annex 10, Volume I, Attachment C — Information and material for guidance in the application of SARPs for ILS, VOR, PAR, 75 MHz marker beacons (en-route), NDB and DME; and

iii) Annex 10, Volume V, Attachment A — Considerations affecting the deployment of LF/MF frequencies and the avoidance of harmful interference.

The planning guidance in Attachment A of Annex 10, Volume V, is related to the RF-filtering characteristics of ADF receivers used in aircraft. These characteristics

are used for developing adjacent channel NDB planning parameters for establishing the required separation distance in the case where the NDB and maritime service frequencies operate on adjacent channels.

Propagation model

Daytime propagation at low frequency and medium frequency are greatly affected by the conductivity and permittivity characteristics of the ground. Night-time transmissions from NDBs are prone to ionospheric reflection. This condition does not generally provide a reliable service and such use is not recommended. The appropriate ground wave transmission model used for frequency assignment planning is contained in ITU-R Recommendation P.368. This recommendation provides ground wave propagation data for frequencies from 10 kHz up to 30 MHz. In the frequency range of interest for NDB, there are separate curves for the frequencies of 200, 300, 400 and 500 kHz. Separate propagation curves are provided for sea and for eight different values of ground conductivity and permittivity, which must be ascertained from local knowledge to enable accurate application.

CCIR Report 910-1 — Sharing between the maritime mobile service and the aeronautical radionavigation service in the band 415–526.5 kHz

Parts of the frequency band 415–526.5 kHz are allocated to both the maritime mobile service and the aeronautical radionavigation service. As a result of differences in operational use, i.e. frequency planning characteristics, radiated power, etc., the coexistence of these two radio services in the same bands may present problems. Particular attention is required with respect to the problems which have their origin in the power levels used. In general, the coast stations of the maritime mobile service operate at power levels in the order of 20 to 30 dB higher than short- and medium-range NDBs. For example, coast station operation at e.r.p. of 10 to 50 Watts is typical as is ship station operation at 40 Watts e.r.p., whereas an NDB with a range of 50 NM would have an e.r.p. of less than 1 Watt (taking into account the relative antenna efficiencies which may be as low as 10 to 30 per cent).

This highly important report examines in detail some of the important parameters to be addressed in any analysis of these situations. The required protection to both maritime (NAVTEX services on 518 kHz) and NDB is examined for the full range of conditions of propagation. Two annexes provide detailed analysis for particular cases: Annex I for protection of NAVTEX services and Annex II for protection of NDB services.

Band: 2 850–22 000 kHz (selected bands)

Technical Information:

Service: AM(R)S
Aviation use: Air-ground communications (HF voice and data)
Annex 10:
SARPs: Annex 10, Volume III, Part II, Chapter 2, 2.4
Frequency plan: Appendix 27 (see ITU below)
Channelization: 3 kHz spacing SSB
Planning criteria: see ITU below
RTCA:
- DO-163, Minimum Performance Standards-Airborne HF Radio Communications Transmitting and Receiving Equipment Operating within the Radio-Frequency Range of 1.5 to 30 Megahertz (1976)
- DO-265, Minimum Operational Performance Standards for Aeronautical Mobile High Frequency Data Link (HFDL) (2000)
- DO-277, Minimum Aviation System Performance Standards (MASPS) for the High Frequency Data Link Operating in the Aeronautical Mobile (Route) Service (AM(R)S) (2002)

Eurocae:
ARINC characteristic:
622-4, ATS Data Link Applications Over ACARS Air-Ground Network
634, HF Data Link System Design Guidance Material
635-4, HF Data Link Protocols
714-6, Mark 3 Airborne SELCAL System
719-5, Airborne HF/SSB System
753-3, HF Data Link System
ITU: Appendix 27 to Radio Regulations (Frequency Allotment Plan, Planning Criteria)
ITU Res./Rec.:
- Res. 207: Measures to address unauthorized use of and interference to frequencies in the frequency bands allocated to the maritime mobile service and to the aeronautical mobile (R) service (Rev. WRC-15)
- Res. 405: Relating to the use of frequencies of the aeronautical mobile (R) service
- Rec. 401: Relating to the efficient use of aeronautical mobile (R) worldwide frequencies
- Rec. 402: Relating to cooperation in the efficient use of worldwide frequencies in the aeronautical mobile (R) service

ITU-R: Rec. M.1458: Use of the frequency bands between 2.8 and 22 MHz by the AM(R)S for data transmission using class of emission J2D

Other material:

- The reports of AMCP/3, AMCP/4, AMCP/5 and ADSP/3 contain ICAO material relevant to the development of SARPs for HF data link.
- DO-258A, Interoperability Requirements for ATS Applications Using ARINC 622 Data Communications (2005)

Bands: 3 023 kHz and 5 680 kHz

Technical Information:

Service: AM(R)S
Aviation use: Search and rescue frequencies in HF
Annex 10:
SARPs:
Frequency plan: Annex 10, Volume V, Chapter 2, 2.2
Channelization:
Planning criteria:
RTCA: DO-163, Minimum Performance Standards-Airborne HF Radio Communications Transmitting and Receiving Equipment Operating within the Radio-Frequency Range of 1.5 to 30 Megahertz (1976), Errata
Eurocae:
ARINC characteristic:
ITU Res./Rec.:

- Rec. 401: Relating to the efficient use of aeronautical mobile (R) worldwide frequencies
- Res. 405: Relating to the use of frequencies of the aeronautical mobile (R) service

ITU-R:
Other material:

- Radio Regulations, Chapter VII
- Radio Regulations, Appendix 27

Band: 74.8–75.2 MHz

Technical Information:

Service: Aeronautical radionavigation
Aviation use: Marker beacon
Annex 10:
SARPs: Annex 10, Volume I, Chapter 3, 3.1.7 and 3.6
Frequency plan: Fixed frequency of 75 MHz
Channelization:
Planning criteria: Annex 10, Volume I, Attachment C, Section 5
RTCA: DO-143, MOPS for Airborne Radio Marker Receiving Equipment Operating on 75 MHz (1970)
Eurocae: 1/WG7/70, MPS for 75 MHz marker beacon receiving equipment (1970)
ARINC characteristic:
ITU Res./Rec.:
ITU-R:
Other material:

Band: 108–117.975 MHz

Technical Information:

Service: Aeronautical radionavigation

Aviation use:

VOR (108–117.975 MHz)
ILS localizer (108–111.975 MHz)
GBAS (112.050–117.900 MHz)

Annex 10:

SARPs: Annex 10, Volume I, Chapter 3, 3.1 (ILS), 3.3 (VOR), 3.7 (GBAS) and Volume III, Chapter 6 (VDL Mode 4)

Frequency plan: Annex 10, Volume I, Chapter 3, 3.1.6 (ILS), 3.7.3.5.4.1 (GBAS)

Channelization: 100 kHz/50 kHz spacing for ILS, VOR and 25 kHz for GBAS

Planning criteria:

Annex 10, Volume V, Chapter 4, 4.2
Annex 10, Volume I, Attachment C, 2.6 (ILS)
Annex 10, Volume I, Attachment C, 3.5 (VOR/ILS)
Annex 10, Volume I, Appendix B, 3.6.8.2.2 and Attachment D, 7.2.1 (GBAS)

RTCA:

ILS:

- DO-195, MOPS for Airborne ILS Localizer Receiving Equipment Operating within the Radio Frequency Range of 108–112 MHz (1986)

VOR:

- DO-180A, MOPS for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input (1990)
- DO-187, MOPS for Airborne Area Navigation Equipment Using Multi-Sensor Inputs (1984)
- DO-196, MOPS for Airborne VOR Receiving Equipment Operating within the Radio Frequency Range of 108–117.95 MHz (1986)

GBAS:

- DO-246C, GNSS Based Precision Approach Local Area Augmentation System (LAAS) — Signal-in-Space Interface Control Document (ICD) (2005)

Eurocae:

ILS:

- ED-46B, MOPS for Airborne Localizer Receiving Equipment
- ED-74, MOPS for Combined ILS and MLS Airborne Receiving Equipment, Amend. 1 (1997)
- ED-88, MOPS for MMR including ILS, MLS, and GPS used for Supplemental Means of Navigation

VOR:

- ED-22B, MPS for Airborne VOR Receiving Equipment (1988)

VOR:

- ED-27, MOPR for Airborne Area Navigation Systems Based on VOR and DME as Sensors (1979)
- ED-28, MPS for Airborne Area Navigation Computing Equipment Based on VOR and DME as Sensors
- ED-52, MPS for Conventional and Doppler VOR Ground Equipment (1984)

GBAS:

- ED-95, MASPS for GBAS to Support CAT 1 Operations (1999)
- ED-114, MOPS for GBAS Ground Facility to Support CAT 1 Approach and Landing (2003)

VDL Mode 4:

- ED-108, MOPS for VHF VDL Mode 4 Aircraft Transceiver for ADS-B (2001)

ARINC characteristic:

ILS: 578-4, Airborne ILS Receiver
ILS: 710-10, Mark 2 Airborne ILS Receiver
VOR: 579-2, Airborne VOR Receiver
VOR/ILS: 711-10, Airborne VOR ILS Receiver

ITU Res./Rec.: Res. 413 (Rev. WRC-12): Use of the band 108–117.975 MHz by the aeronautical mobile (R) service

ITU-R:

- Rec. M.44-1: Signal-to-interference ratios and minimum field strengths required in the aeronautical mobile (route) service above 30 MHz
- Rec. M.1841: Compatibility between FM sound-broadcasting in the band of about 87-108 MHz and the aeronautical ground-based augmentation system (GBAS) in the band about 108-117.975 MHz
- Rec. SM.1009-1: Compatibility between the Sound Broadcasting Service in the band 87–108 MHz and the Aeronautical Services in the band 108–137 MHz

Other material:

- Receiver susceptibility to FM broadcast:
  - DO-176, FM Broadcast Interference related to Airborne ILS, VOR and VHF Communications (1981)
  - Annex 10, Volume I, Chapter 3, 3.1.4 (ILS)
  - Annex 10, Volume I, Attachment C, 2.2.2 (ILS)
  - Annex 10, Volume I, Chapter 3, 3.3.8 (VOR)
  - Annex 10, Volume I, Attachment C, 3.6.5 (VOR)

- — Annex 10, Volume I, Appendix B, 3.6.8.2.2 (GBAS)
- — Annex 10, Volume III, Part I, 6.3.5.4 (VDL)

- RTCA DO-117, Standard Adjustment Criteria for Airborne Localizer and Glide Slope Receivers (1963), Errata
- RTCA DO-217, MASPS for DGNSS Instrument Approach System: Special Category 1 (SCAT-1) (1993), Change 1 to DO-217 (1994), Change 2 to DO-217 (1996)

INTERFERENCE FROM NON-AERONAUTICAL SOURCES AND COMPATIBILITY BETWEEN ILS/VOR AND FM BROADCASTING

General

The ITU WARC in 1979 allocated the band at 100–108 MHz to broadcasting services in Region 1. This band was previously allocated in that way only in Regions 2 and 3. The band is adjacent to the VOR/ILS band at 108–117.975 MHz, and interference effects have been experienced due to transmissions of broadcast stations, particularly those operating on frequencies close to the band edge and in areas where there is a high density of both FM stations and ILS or VOR. In many countries, FM sound broadcasting services of both low and high power are operated in this band. In some countries, the broadcast services also include analogue television transmissions. Compatibility problems due to intermodulation products, generated by both FM transmitter stations and in ILS/VOR receivers, as well as overloading of the front end of aircraft ILS/VOR receivers, became apparent when broadcast stations commenced use of the frequencies in the band 100–108 MHz in the mid-seventies in Region 2. Studies on a suitable planning methodology initiated by the CCIR (now ITU-R) in a joint aeronautical/ broadcasting group have documented a viable methodology for broadcast and aeronautical frequency assignment planning with a view to ensuring a safe situation for air operations.

Any resolution of this problem through planning and coordination automatically restricts both services. In high-density areas, such as Western Europe and North America, the full potential of the frequency band for either service cannot be realized. Both services tend to be at their greatest density in areas of high population, which places a severe constraint on the full utilization of the potential of the 40 channels available for use by ILS (see Annex 10, Volume I, 3.1.6). VOR services are also affected but not to the same critical degree. VHF communications, because of their greater frequency separation, are also affected, but to a lesser degree than ILS/VOR.

ITU-R studies

After many studies on the compatibility between ILS/VOR and FM broadcasting were initiated in ITU, ITU-R approved Recommendation SM.1009-1: *Compatibility between the Sound Broadcasting Service in the band 87–108 MHz and the Aeronautical Services in the band 108–137 MHz* in 1995.

The three annexes of Recommendation SM.1009-1 deal comprehensively with the subject and are:

Annex 1: Interference mechanism, system parameters and compatibility assessment criteria;

Annex 2: General assessment method; and

Annex 3: Detailed compatibility assessment and practical verification.

The Recommendation comprehensively covers the treatment of conflict situations for the four interference modes:

Type A: FM broadcasting-transmitter-generated interference products falling within the ILS/VOR bands. The two sub-types are:

Type A1: spurious or harmonic intermodulation products generated by one or more FM transmitters within the aeronautical band; and

Type A2: non-negligible components of the FM broadcasting signal, operating near the band edge 108 MHz, within the aeronautical band (affecting only aeronautical frequencies near the 108 MHz band edge).

Type B: ILS/VOR-receiver-generated interference caused by high-level broadcast signals operating outside the ILS/VOR band. The two sub-types are:

Type B1: interference that may be generated in the aeronautical receiver being driven into non-linearity due to high-power broadcasting signals outside the aeronautical band. The effect on the receiver resulting in the generation of intermodulation products in the receiver; and

Type B2: performance degradation due to high-power overload and desensitization without any frequency relationship.

This Recommendation, with its three detailed annexes, provides the essential requirements for the identification and analysis of interference situations and for the coordination between broadcasting and aeronautical interests within a country or between countries. The criteria and methods have been developed and reviewed by a group of experts and represent the best available information on the subject. Furthermore, the Recommendation is recognized by aeronautical and telecommunication authorities as the definitive guidance for planning and coordination purposes.

SARPs on FM-immunity for ILS, VOR, GBAS, VDL and VHF communications

Since 1984, Annex 10 has incorporated provisions covering the FM-immunity performance of airborne receivers. These performance requirements are a considerable improvement compared to those of unmodified receivers. In many cases, compliance with these SARPs will require equipment replacement. These SARPs were incorporated to standardize the FM-immunity performance of ILS, VOR and VHF communication receivers to FM broadcast signals. While the SARPs were incorporated in the Annex with Amendment No. 65 in 1984, implementation was not required until 1998, allowing fourteen years for modification or refit. In some areas of the world, implementation is not necessary due to the lower level of implementation of both ILS/VOR and FM broadcasting stations. Implementation of these SARPs took place in Europe by 2001 and is foreseen in other regions.

The FM-immunity SARPs are contained in:

for ILS: Annex 10, Volume I, Chapter 3, 3.1.4, Interference immunity performance for ILS localizer receiving systems and Annex 10, Volume I, Attachment C, 2.2.2, providing guidance material;

for VOR: Annex 10, Volume I, Chapter 3, 3.3.8, Interference immunity performance for VOR receiving systems;

for GBAS: Annex 10, Volume I, Appendix B, 3.6.8.2.2;

for VDL: Annex 10, Volume III, Part I, 6.3.5.4 (VDL); and

for VHF Com: Annex 10, Volume III, Part II, 2.3.3, Interference immunity performance and Annex 10, Volume III, Part II, Attachment, 1.3.

LEGBAC consultative arrangements

In Europe, the Limited European Group on Broadcasting Aeronautical Compatibility (LEGBAC) has developed a methodology, including software tools, to assess compatibility of assignments to FM broadcasting stations and ILS/VOR assignments. This methodology has been accepted as the European-wide assessment method. It is compliant with the provisions of the Final Acts of the 1984 ITU Broadcasting Conference, ITU-R Recommendation SM.1009-1 and the relevant SARPs.

Band: 117.975–137 MHz

Technical Information:

Service: AM(R)S
Aviation use: Air-ground and air-air communication (VHF voice and data)
Annex 10:

SARPs: Annex 10, Volume III, Part II, Chapter 2, 2.1, 2.2 and 2.3
Frequency plan: Annex 10, Volume V, Chapter 4, 4.1
Channelization: 25 kHz/8.33 kHz
Planning criteria: Doc 9718, Volume II

RTCA:

- DO-186A, MOPS for airborne radio communications equipment operating within the radio frequency range 117.975–137 MHz (1995), Change 1 (1998), Change 2 (2002)
- DO-207, MOPS for Devices that Prevent Blocked Channels Used in Two-Way Radio Communications Due to Unintentional Transmissions (1991)
- DO-209, MOPS for Devices that Prevent Blocked Channels Used in Two-Way Radio Communications Due to Simultaneous Transmissions (1992), Errata (1992)
- DO-219, MOPS for ATC Two-Way Data Link Communications (1993)
- DO-267A, MASPS for Flight Information Services Broadcast (FIS-B) Data Link (2004)
- DO-271B, Minimum Operational Performance Standards for Aircraft VDL Mode 3 Transceiver Operating in the Frequency Range 117.975–137.000 MHz (2003)
- DO-281, Minimum Operational Performance Standards for Aircraft VDL Mode 2 Physical, Link and Network Layer (2002)

Eurocae:

- ED-23B, MOPS for Airborne VHF Rx-Tx Operating in 117.975–136.975 (1995), Amendment #3 (1997)
- ED-67, MOPS for Devices That Prevent Unintentional or Continuous Transmissions
- ED-92A, MOPS for Airborne VDL Mode 2 Transceiver Operating in the Frequency Range 118–136.975 MHz (2003)

ARINC characteristic:

566A-9, Mark 3 VHF Communications Transceiver
622-4, ATS Data Link Applications Over ACARS Air-Ground Network
631-3, VHF Digital Link Implementation Provisions Functional Description
716-11, Airborne VHF Communications Transceiver

724-9, Mark 2 Aircraft Communications Addressing and Reporting System (ACARS)

750-4, VHF Data Radio

ITU Res./Rec.:

ITU-R: Rec. SM.1009-1: Compatibility between the sound broadcasting service in the band 87–108 MHz and the aeronautical services in the band 108–137 MHz

Other material:

- RTCA DO-165, Initial Report on Civil Aviation Frequency Spectrum Requirements 1980–2000 (1976)
- RTCA DO-169, VHF Air-Ground Communication Technology and Spectrum Utilization (1979)
- RTCA DO-176, FM Broadcast Interference Related to Airborne ILS, VOR and VHF Communications (1981)
- RTCA DO-224B, Signal-in-space MASPS for Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques (2000), Change 1 (2001), Change 2 (2002)
- RTCA DO-225, VHF Air-Ground Communications System Improvements Alternatives Study and Selection of Proposals for Future Action (1994)
- RTCA DO-264, Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by Data Communications (2000)
- RTCA DO-284, Next Generation Air/Ground Communication (NEXCOM) Safety and Performance Requirements (2003)
- RTCA DO-285, Next Generation Air/Ground Communication (NEXCOM) VDL Mode 3 Interoperability (2003)
- Eurocae ED-78A, Guidelines for the Approval of the Provision and Use of ATS Supported by Data Communications
- Eurocae ED-85A, Data Link Application System Document (DLASD) for the "Departure Clearance" Data Link Service
- Eurocae ED-89A, DLASD for the "ATIS" Data-link Service
- Eurocae ED-100A, Interoperability Requirements for ATS Applications Using ARINC 622 Data Communications
- Eurocae ED-106A, Data Link Application System Document for "Oceanic Clearance" (OCL) Datalink Service
- Eurocae ED-110A, Interoperability Requirements Standard for ATN Baseline 1 (Interop ATN B1)
- Eurocae ED-120, Safety and Performance Requirements Standard for Initial Air Traffic DLS in Continental Airspace

Frequency: 121.5 MHz, 123.1 MHz and 243 MHz

Technical Information:

Annex 10:

SARPs: Annex 10, Volume III, Part II, Chapter 5
Frequency plan: Annex 10, Volume V, Chapter 4
Channelization:
Planning criteria:

RTCA: DO-183, MOPS for Emergency Locator Transmitters-Automatic Fixed-ELT (AF), Automatic Portable-ELT (AP), Automatic Deployable-ELT (AD), Survival-ELT (S) Operating on 121.5 and 243.0 MHz (1983)

Eurocae: ED-62, MOPS for Aircraft Emergency Locator Transmitters (121.5/243 MHz and 406 MHz)

ARINC characteristic:

ITU Res./Rec.: Res. 18 (WRC-15): Relating to the procedure for identifying and announcing the position of ships and aircraft of States not parties to an armed conflict

ITU-R: Rec. M.690-1: Technical characteristics of emergency position- indicating radio beacons (EPIRBs) operating on the carrier frequencies of 121.5 MHz and 243 MHz (This ITU-R Recommendation is incorporated by reference in the Radio Regulations as per Appendix 15 (Table 15-2)

Other material:

- ITU Radio Regulations, Chapter VII
- RTCA DO-154, Recommended Basic Characteristics for Airborne Radio Homing and Alerting Equipment for Use with ELTs (1973)
- RTCA DO-182, ELT Equipment Installation and Performance (1982)

Band: 328.6–335.4 MHz

Technical Information:

Service: Aeronautical radionavigation
Aviation use: ILS glide path
Annex 10:
SARPs: Annex 10, Volume I, Chapter 3, 3.1.5
Frequency plan: Annex 10, Volume I, Chapter 3, 3.1.6
Channelization: 300 kHz or 150 kHz spacing
Planning criteria: as for ILS localizer
RTCA: DO-192, MOPS for Airborne ILS Glide Slope Receiving Equipment Operating within the Radio Frequency Range of 328.6–335.4 MHz (1986)
Eurocae: ED-47B, MOPS for Airborne Glide Path Receiving Equipment
ARINC characteristic: 551, Airborne Glide Slope Receiver — Mark 2
ITU Res./Rec.:
ITU-R:
Other material: RTCA DO-117, Standard Adjustment Criteria for Airborne Localizer and Glide Slope Receivers (1963), Errata

Band: 406–406.1 MHz

Technical Information:

Service: Mobile-satellite (Earth-to-space)
Aviation use: Search and rescue
Annex 10:
SARPs: Annex 6; Annex 10, Volume III, Part II, Chapter 5 and Appendix 1 to Chapter 5; and Annex 10, Volume V, Chapter 2.
RTCA: DO-204, MOPS for 406 MHz Emergency Locator Transmitters (ELT) (1989), Change 1 (1994), Change 2 (1997), Change 3 (2001)
Eurocae: ED-62, MOPS for Aircraft Emergency Locator Transmitters (121.5/ 243 MHz and 406 MHz)
ARINC characteristic:
ITU Res./Rec.: Res. 205 (Rev. WRC-15): Protection of the systems operating in the mobile-satellite service in the frequency band 406–406.1 MHz
ITU-R:
- Rec. M.633-4 Transmission characteristics of a satellite emergency position-indicating radio beacon (satellite EPIRB) system operating through a satellite system in the 406 MHz band
- Rec. M.1478 Protection criteria for COSPAS/SARSAT search and rescue instruments in the band 406–406.1 MHz
- Rep. M.2359 Protection of the 406–406.1 MHz band

Other material:
- COSPAS/SARSAT Doc. C/S T.001; Specifications for COSPAS/ SARSAT 406 MHz distress beacons
- COSPAS/SARSAT Doc. C/S T.012; 406 MHz frequency management plan

Band: 960–1 215 MHz

Technical Information:

Service: Aeronautical radionavigation, aeronautical mobile (R)
Aviation use: DME, LDACS
Annex 10:
SARPs: DME: Annex 10, Volume I, Chapter 3, 3.5
Frequency plan:
DME: Annex 10, Volume I, Chapter 3, Table A
DME: Annex 10, Volume V, Chapter 4, 4.3
Planning criteria:
DME, Annex 10, Volume I, Attachment C, Section 7
EUR ANP COM/3
RTCA:

- DO-152, Minimum Operational Characteristics — Vertical Guidance Equipment Used in Airborne Volumetric Navigational Systems (1972), Appendix D (1974)
- DO-180A, MOPS for Airborne Area Navigation Equipment Using a Single Collocated VOR/DME Sensor Input (1990)
- VOR: DO-187, MOPS for Airborne Area Navigation Equipment Using Multi-Sensor Inputs (1984)
- DO-189, MOPS for Airborne DME Operating within the Radio Frequency Range of 960–1 215 MHz (1985)

Eurocae:

- ED-27, MOPR for Airborne Area Navigation Systems Based on VOR and DME as Sensors (1979)
- ED-28, MPS for Airborne Area Navigation Computing Equipment Based on VOR and DME as Sensors
- ED-39, MOPR for Airborne Area Navigation Systems Based on Two DME as Sensors (1984)
- ED-40, MPS for Airborne Computing Equipment for Area Navigation Systems Using Two DME as Sensors (1984)
- ED-54, MPS for (DME/N and DME/P) Interrogators (airborne equipment) (1987)
- ED-57, MPS for distance measuring equipment (DME/N and DME/P) (ground equipment), (1986), Amendment #1 (1992)

ARINC characteristic: 709-8, Airborne DME Supplement 8, 709A-1, Precision Airborne DME
ITU Res./Rec.:

ITU-R:

- Rec. M.1639: Protection criterion for the aeronautical radionavigation service with respect to aggregate emissions from space stations in the radio-navigation-satellite service in the band 1 164–1 215 MHz
- Rec. M.1642: Methodology for assessing the maximum aggregate equivalent power flux-density at an aeronautical radionavigation service station from all radionavigation-satellite service systems operating in the 1 164–1 215 MHz band
- Rep. M.2121: Guidelines for AM(R)S sharing studies in the 960–1 164 MHz band
- Rep. M.2205: Results of studies of the AM(R)S allocation in the band 960–1 164 MHz and of the AMS(R)S allocation in the band 5 030–5 091 MHz to support control and non-payload communications links for unmanned aircraft systems
- Rep. M.2235: Aeronautical mobile (route) service sharing studies in the frequency band 960–1 164 MHz

Other material:

Band: 978 MHz

Technical Information (UAT):

Service: Aeronautical radionavigation
Aviation use: ADS-B, TIS-B, FIS-B, Universal Access Transceiver (UAT)
Annex 10:
SARPS: Annex 10, Volume III, Chapter 12
Frequency plan: Single frequency
Channelization: Single frequency
Planning criteria:
RTCA:

- DO-239, MOPS for Traffic Information Service (TIS) Data Link Communications (1997)
- DO-267A, MASPS for Flight Information Services Broadcast (FIS-B) Data Link (2004)
- DO-282A, MOPS for Universal Access Transceiver (UAT) Automated Dependent Surveillance-Broadcast (2004)
- DO-286A, MASPS for Traffic Information Services-Broadcast (TIS-B) (2005)

Eurocae:
ARINC characteristic:
ITU Res./Rec.:
ITU-R: Rep. M.2205: Results of studies of the AM(R)S allocation in the band 960–1 164 MHz and of the AMS(R)S allocation in the band 5 030–5 091 MHz to support control and non-payload communications links for unmanned aircraft systems
Other material: RTCA DO-232, Operations Concepts for Data Link Applications of Flight Information Services (1996)

Bands: 1 030 MHz and 1 090 MHz

Technical Information (SSR):

Service: Aeronautical radionavigation, aeronautical mobile (R)
Aviation use: SSR/ACAS
Annex 10:

SARPs: Annex 10, Volume IV, Chapters 3 and 4
Frequency plan: Two frequencies: 1 030 MHz for ground-to-air interrogations and 1 090 MHz for air-to-ground reply
Channelization: N/A
Planning criteria: Coordination of the pulse repetition frequency (PRF) on a national basis is required for overlapping coverage areas of SSR

RTCA:

- DO-144, Minimum Operational Characteristics-Airborne ATC Transponder Systems (1970), Change 1
- DO-181C, MOPS for ATCRBS/Mode S Airborne Equipment (2001), Change 1 (2002)
- DO-185A, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Airborne Equipment (1997)
- DO-197A, Minimum Operational Performance Standards for an Active Traffic Alert and Collision Avoidance System I (Active TCAS I) (1994), Change 1 (1997)
- DO-218B, MOPS for the Mode S Airborne Data Link Processor (2001)

Eurocae:

Mode S:

- MOPS for the Airborne Data Links Processor
- ED-86, Equipment Characteristics for Mode S Transponders with Extended Interface Functions
- ED-101, MOPS for Mode S Specific Service Applications
- ED-117, MOPS for Mode S Multilateration Systems for Use in A-SMGCS (2003) [Rx or Tx/Rx]

SSR:

- 1/WG7/71, MPS for Airborne Secondary Surveillance Radar Transponder Apparatus
- ED-43, MOPR for SSR Transponder and Alticoder
- ED-73B, MOPS for SSR Mode S Transponders (2003)
- ED-115, MOPS for Light Aviation SSR Transponders (2002)

ARINC characteristic:

718-4, Mark 3 ATC Transponder (ATCRBS/Mode S)
718A-1, Mark 4 ATC Transponder (ATCRBS/Mode S)
735-2, TCAS; 735A-1 Mark 2 TCAS

ITU Res./Rec.: Res. 18 (Rev. WRC-15): Relating to the procedure for identifying

and announcing the position of ships and aircraft of States not parties to an armed conflict

ITU-R: Rep. M.2205: Results of studies of the AM(R)S allocation in the band 960–1 164 MHz and of the AMS(R)S allocation in the band 5 030–5 091 MHz to support control and non-payload communications links for unmanned aircraft systems

Other material: RTCA DO-184, Traffic Alert and Collision Avoidance System (TCAS) I Functional Guidelines (1983)

Band: 1 090 MHz

Technical Information (1090ES):

Service: Aeronautical radionavigation, aeronautical mobile (R), aeronautical mobile-satellite (R)(E-s)
Aviation use: ADS-B, Mode S Extended Squitter
Annex 10:
SARPS:
Annex 10, Volume III, Part II, Appendix to Chapter 5
Annex 10, Volume IV, Chapter 3
Frequency plan: Single frequency
Channelization: Single frequency
Planning criteria:
RTCA:
- DO-242A, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B) (2002)
- DO-260 Change 1, MOPS for 1 090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B)
- DO-260A, MOPS for 1 090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services (TIS-B) (2003)
- DO-260B with Corrigendum 1, MOPS for 1 090 MHz Extended Squitter Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Services (TIS-B)

Eurocae: ED-102, MOPS for 1 090 MHz ADS-B (2000)
ARINC characteristic: 745-2, Automatic Dependent Surveillance
ITU Res./Rec.: Res. 425 (WRC-15): Use of the frequency band 1 087.7–1 092.3 MHz by the aeronautical mobile-satellite (R) service (Earth-to-space) to facilitate global flight tracking for civil aviation
ITU-R: Rep. M.2205: Results of studies of the AM(R)S allocation in the band 960–1 164 MHz and of the AMS(R)S allocation in the band 5 030–5 091 MHz to support control and non-payload communications links for unmanned aircraft systems
Other material:

Band: 1 164–1 215 MHz

Technical Information:

Service: Radionavigation-satellite
Aviation use: GNSS
ITU Res./Rec.:

- Res. 223 (Rev. WRC-15): Additional frequency bands identified for International Mobile Telecommunications
- Res. 224 (Rev. WRC-15): Frequency bands for the terrestrial component of International Mobile Telecommunications below 1 GHz
- Res. 610 (WRC-03): Coordination and bilateral resolution of technical compatibility issues for radionavigation-satellite service networks and systems in the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz

ITU-R:

- Rec. M.1318: Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz bands
- Rec. M.1787: Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.1831: A coordination methodology for radionavigation-satellite service inter-system interference estimation
- Rec. M.1901: Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz, 5 00–5 010 MHz and 5 010–5 030 MHz
- Rec. M.1904: Characteristics, performance requirements and protection criteria for receiving stations of the radionavigation-satellite service (space-to-space) operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.1905: Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 164–1 215 MHz
- Rec. M.2030: Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz frequency bands

- Rep. M.2220: Calculation method to determine aggregate interference parameters of pulsed RF systems operating in and near the bands 1 164–1 215 MHz and 1 215–1 300 MHz that may impact radionavigation-satellite service airborne and ground-based receivers operating in those frequency bands

PROTECTION OF GNSS IN BAND 1 164–1 215 MHz

Sharing and protection from other radio services

Potential interference from AM(R)S unwanted emissions

Resolution **417 (Rev. WRC-15)** provides the criteria in order to ensure that AM(R)S systems do not cause harmful interference to RNSS in the frequency band 1 164–1 215 MHz.

Protection of GNSS signals from potential interference of IMT unwanted emissions

Current results of theoretical and experimental estimations indicate that the levels of unwanted emissions of IMT stations that are defined in ITU-R Recommendations M.2070 and ITU-R M.2071 are not low enough to provide required protection level for RNSS receiving earth stations that operate in 1 164–1 300 MHz. Required separation distances are from 42 m to 2 446 m depending on the type of RNSS receiver, which makes impossible simultaneous application of these devices in one local spot without additional compatibility measures.

Band: 1 215–1 400 MHz

Technical Information:

Service: Radiolocation/aeronautical radionavigation/radionavigation-satellite
Aviation use: Medium- and long-range surveillance radar
Annex 10:
SARPs:
Frequency plan: Nationally produced
Channelization: Nationally produced
Planning criteria: Nationally produced
RTCA: DO-206, MASPS for Radiodetermination Satellite Service (RDSS) (1990)
Eurocae:
ARINC characteristic:
ITU Res./Rec.:

- Res. 608 (Rev. WRC-15): Use of the frequency band 1 215–1 300 MHz by systems of the radionavigation-satellite service (space-to-Earth)
- Res. 609 (Rev. WRC-07): Protection of aeronautical radionavigation service systems from the equivalent power flux-density produced by radionavigation-satellite service networks and systems in the 1 164-1 215 MHz frequency band
- Res. 610 (WRC-03): Coordination and bilateral resolution of technical compatibility issues for radionavigation-satellite service networks and systems in the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz

ITU-R:

- Rec. M.1318: Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz and 5 010–5 030 MHz bands
- Rec. M.1463: Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 1 215–1 400 MHz
- Rec. M.1584: Methodology for computation of separation distances between Earth stations of the radionavigation-satellite service (Earth-to-space) and radars of the radiolocation service and the aeronautical radionavigation service in the frequency band 1 300–1 350 MHz
- Rec. M.1787: Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.1831: A coordination methodology for radionavigation-satellite

service inter-system interference estimation

- Rec. M.1901: Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz, 5 000–5 010 MHz and 5 010–5 030 MHz
- Rec. M.1902: Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 215–1 300 MHz
- Rec. M.1904: Characteristics, performance requirements and protection criteria for receiving stations of the radionavigation-satellite service (space-to-space) operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.2030: Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz frequency bands
- Rep. M.2220: Calculation method to determine aggregate interference parameters of pulsed RF systems operating in and near the bands 1 164–1 215 MHz and 1 215–1 300 MHz that may impact radionavigation-satellite service airborne and ground-based receivers operating in those frequency bands
- Rep. M.2305: Consideration of aggregate radio frequency interference event potentials from multiple Earth exploration-satellite service systems on radionavigation-satellite service receivers operating in the 1 215–1 300 MHz frequency band

Other material:

Bands: 1 544–1 545 MHz and 1 645.5–1 646.5 MHz

Technical Information:

Service: Mobile-satellite
Aviation use: Distress and safety communications (satellite EPIRBs)
Annex 10:
SARPs:
Frequency plan:
Planning criteria:
RTCA:
Eurocae:
ARINC characteristic: 761-2, Second Generation Aviation Satellite Communications System, Aircraft Installation Provisions
ITU Res./Rec.: Radio Regulations: Article N38/Appendix 15
ITU-R: Rec. M.1731: Protection criteria for COSPAS/SARSAT local user terminals in the band 1 544–1 545 MHz
Other material:

Bands: 1 525–1 559 MHz and 1 626.5–1 660.5 MHz

Technical Information:

Service: AMS(R)S
Aviation use: Satellite communications
Annex 10:
SARPs: Annex 10, Volume III, Part I, Chapter 4
Frequency plan: Prepared by space segment provider
Channelization:
Planning criteria:
RTCA:

- DO-215A, Guidance on Aeronautical Mobile Satellite Service (AMSS) End-to-End System Performance (1995), Change 1 (1998)
- DO-210D, MOPS for Geosynchronous Orbit Aeronautical Mobile Satellite Services (AMSS) Avionics (2000), Change 1 (2000), Change 2 (2001)
- DO-270, MASPS for the Aeronautical Mobile-Satellite (R) Service (AMS(R)S) as Used in Aeronautical Data Links (2001)
- DO-343, MOPS for AMS(R)S data and voice communications supporting required communications performance (RCP) and required procedure performance (RSP) in procedural airspace

Eurocae:
ARINC characteristic:
741 P1, Aviation Satellite Communications System: Part 1 — Aircraft Installation Provisions;
741 P2, ASCS: Part 2 — System Design and Equipment Functional Description;
741 P4, ASCL: Part 4 — Specification and Description Language
781 Mark 3 Aviation Satellite Communications Systems
ITU Res./Rec.: Res. 222 (Rev. WRC-12): Use of the frequency bands 1 525–1 559 MHz and 1 626.5–1 660.5 MHz by the mobile-satellite service, and procedures to ensure long-term spectrum access for the aeronautical mobile-satellite (R) service
ITU-R:

- Rec. M.828-1: Definition of availability for communication circuits in the mobile-satellite service
- Rec. M.1037: Bit error performance objectives for the AMS(R)S radio links
- Rec. M.1089: Technical considerations for the coordination of mobile-satellite systems supporting the AMS(R)S
- Rec. M.1180: Availability of communication circuits in the AMS(R)S

- Rec. M.1233: Technical considerations for sharing satellite network resources between the MSS (other than AMS(R)S) and AMS(R)S
- Rec. M.1234: Permissible level of interference in a digital channel of a geostationary satellite network in the AMS(R)S in the bands 1 545–1 555 MHz and 1 646.5–1 656.5 MHz and its associated feeder links caused by other networks of this service and the FSS
- Rec. M.2091: Methodology to calculate spectrum requirements within the frequency bands 1 545–1 555 MHz (space-to-Earth) and 1 646.5–1 656.5 MHz (Earth-to-space) for aeronautical mobile-satellite (R) service communications related to the priority categories 1 to 6 of Article 44 of the Radio Regulations
- Rep. M.2396: Use of mobile-satellite service systems for flight tracking

Other material:

- AMCP/5 Report
- RTCA DO-231, Design Guidelines and Recommended Standards for the Implementation and Use of AMS(R)S Voice Services in a Data Link Environment (1996)
- RTCA DO-262, MOPS for Avionics Supporting Next Generation Satellite Systems (NGSS) (2000), Change 1 (2001)
- ICAO Doc 9925, Manual on the Aeronautical Mobile Satellite (Route) Service

Band: 1 559–1 626.5 MHz

Technical Information:

Service: Radionavigation-satellite/aeronautical radionavigation
Aviation use: GNSS
Annex 10:
SARPs: Annex 10, Volume I, Chapters 2 and 3
Frequency plan: GPS; GLONASS
Channelization:
Planning criteria:
RTCA:

- DO-208, MOPS for Airborne Supplemental Navigation Equipment using GPS (1991), Change 1 (1993) Errata (1995)
- DO-228, MOPS for GNSS Airborne Antenna Equipment (1999), Change 1 (2000)
- DO-229C, MOPS for Global Positioning System/Wide Area Augmentation System Airborne Equipment (2001), Errata (2002)

  Note.— DO-235A (not a Standard) is shown below under Other Material.
- DO-245A, Minimum Aviation System Performance Standards for Local Area Augmentation System (LAAS) (2004)
- DO-246C, GNSS Based Precision Approach Local Area Augmentation System (LAAS) — Signal-in-Space Interface Control Document (ICD) (2005)
- DO-253A, MOPS for GPS Local Area Augmentation System Airborne Equipment (2001)
- DO-261, NAVSTAR GPS L5 Signal Specification (2000)

Eurocae:

- ED-72A, MOPS for Airborne GPS Receiving Equipment Used for Supplemental Means of Navigation (1997)
- ED-88, MOPS for MMR including ILS, MLS, and GPS Used for Supplemental Means of Navigation
- ED-97, Interim Technical Performance Statement for EGNOS/WAAS Airborne Equipment (2000)

ARINC characteristic:
743, Airborne GPS Receiver, 743A, GNSS Sensor;
756-3, GNSS Navigation & Landing Unit
760-1, GNSS Navigation Unit (GNU)

ITU Res./Rec.:

- Res. 212 (Rev. WRC-15): Implementation of International Mobile Telecommunications in the bands 1 885–2 025 MHz and 2 110–2 200 MHz
- Res. 223 (Rev. WRC-15): Additional frequency bands identified for International Mobile Telecommunications
- Res. 224 (Rev. WRC-15): Frequency bands for the terrestrial component of International Mobile Telecommunications below 1 GHz
- Res. 225 (Rev. WRC-12): Use of additional frequency bands for the satellite component of IMT
- Res. 610 (WRC-03): Coordination and bilateral resolution of technical compatibility issues for radionavigation-satellite service networks and systems in the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz
- Res. 739 (Rev. WRC-15): Compatibility between the radio astronomy service and the active space services in certain adjacent and nearby frequency bands

ITU-R:

- Rec. M.823: Technical characteristics for differential transmissions for GNSS from maritime radio beacons in the frequency band 283.6–315 MHz in Region 1 and 285–325 MHz in Regions 2 and 3
- Rec. M.1318: Interference protection evaluation model for the radionavigation-satellite service in the 1 559–1 610 MHz band
- Rec. M.1343: Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz bands
- Rec. M.1480: Essential technical requirements of land mobile Earth stations for global GSO MSS systems providing voice and/or data communications in the band 1–3 GHz
- Rec. M.1787: Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.1831: A coordination methodology for radionavigation-satellite service inter-system interference estimation
- Rec. M.1901: Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz, 5 000–5 010 MHz and 5 010–5 030 MHz

- Rec. M.1903: Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) and receivers in the aeronautical radionavigation service operating in the band 1 559–1 610 MHz
- Rec. M.1904: Characteristics, performance requirements and protection criteria for receiving stations of the radionavigation-satellite service (space-to-space) operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz
- Rec. M.2030: Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz and 1 559–1 610 MHz frequency bands
- Rep. M.2396: Use of mobile-satellite service systems for flight tracking

Other material:

- GNSSP and NSP meeting reports
- RTCA DO-235A, Assessment of Radio Frequency Interference Relevant to the GNSS (2002)
- RTCA DO-292, Assessment of Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band (2004)

PROTECTION OF GNSS IN BAND 1 559–1 610 MHz

The radionavigation-satellite band at 1 559–1 610 MHz supports the operation of the GNSS which is expected to become the future all-purpose radionavigation system for aviation operations. GPS and GLONASS, presently in operation, have been identified as the initial components of the systems that will be used, possibly with ground augmentation. Both systems are also available for all purposes where a position fixing facility is required. This includes all mobile navigation needs for land, sea or air, survey, mineral exploitation, search and rescue, etc.

Very stringent integrity and reliability standards, and other performance characteristics have been developed by the ICAO NSP (see SARPs for GNSS in Annex 10, Volume I). Both GPS and GLONASS operate using multiple orbiting satellites (up to 24 in number) at around 20 000 km above the Earth's surface. Each satellite transmits exact orbital parameters (ephemeris data) with its corresponding highly accurate (atomic source) timing signal. Ground receivers solve four simultaneous equations for at least three sets of position data using the receivers' integral accurate time source to obtain a two-dimensional position. A minimum of four satellites is required to provide a three-dimensional position. The two systems use different methods of modulation and transmission, with GPS using pseudo-random coding transmitted on the same frequency and GLONASS using frequency division on a discrete frequency for individual satellites.

Brief spectrum details of the occupation of the 1 559–1 610 MHz frequency band, present and expected, are shown in Figure 7-5. The details of the two systems presently in operation are:

GPS. The centre frequency is 1 575.42 MHz. The occupied bandwidth is dependent on the type of receiver, and its tracking process coarse acquisition (C/A) code requires plus or minus 4 MHz and precision (P) code plus or minus 12 MHz.

GLONASS. GLONASS operates on 14 frequencies spaced at 0.5625 MHz in the band between 1 598.0625 and 1 605.3750.

GNSS augmentation. Proposals have been made for augmentation systems to improve GNSS integrity, which may operate in the lower end of the 1 559–1 610 MHz band. Protection requirements are tentative but early indications are that they would be similar to the systems already in use.

Aircraft receiving system protection

The performance requirements for the aircraft receiving system in regard to the projection from interference are contained in:

— Annex 10, Volume I;

— RTCA DO-229C, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System (GPS/WAAS) Airborne Equipment* (2001), Errata (2002);

— RTCA DO-228, *Minimum Operational Performance Standards for Global Navigation Satellite Systems (GNSS) Airborne Antenna Equipment* (1999), Change 1 (2000).

The document RTCA DO-235A, *Assessment of Radio Frequency Interference Relevant to the GNSS* (2002), addresses the specifics of the interference situation. This document contains basic material for protection calculations.

The maximum tolerable aggregate interference power levels measured at the antenna port for aircraft receivers, as contained in Annex 10, Volume I, are:

	Tracking	**Acquisition**
GPS		
Narrow-band signals	–150.5 dBW	–156.5 dBW
Wide-band signals	–140.5 dBW per 1 MHz	–146.5 dBW per 1 MHz
GLONASS		
Narrow-band signals	–149.0 dBW	–155.0 dBW
Wide-band signals	–140.0 dBW per 1 MHz	–146.0 dBW per 1 MHz

Wide-band signals are 1 MHz and wider, and narrow-band are nominally less than 700 kHz.

Sharing and protection from other radio services

Fixed links

No published characteristics are available for the fixed links which used to be operated under Footnotes 5.362B and 5.362C which were suppressed by WRC-15. Information from other work in connection with these fixed links indicates typical systems with characteristics as follows:

Frequency:	Anywhere in band 1 400–1 660 MHz at a bandwidth of 600 kHz
Output Power:	1.2 W
Antenna Gain:	up to 22 dB
Front/Back:	16 dB
Side Lobe Attenuation:	9 dB min

With these characteristics, unacceptable interference to GNSS services could exist at distances of 400 km and greater to an aircraft receiver in the main lobe of the fixed link transmitter. Ground station GNSS monitors used for augmentation may be affected within 80 km. The numbers, locations and operating frequencies of the equipment are only known to the licensing national administrations. National coordination with authorities in the countries concerned is necessary to establish the sharing possibilities on an individual site basis.

These links have the potential to inhibit GNSS operations over a wide area. The problem has been recognized internationally. ICAO Policy (Section 1 559–1 626.5 MHz of this handbook) supports the removal of the GNSS band at 1 559–1 610 MHz from both footnotes.

ICAO studies

The ICAO NSP has prepared material on the protection of GNSS to be used as ICAO input documentation to ITU-R and other discussions on this subject. This material contains the protection requirements for all GNSS and support systems that are expected to be utilized for aviation purposes.

The protection requirements for GNSS systems as stated by the NSP are:

— minus 137 dBW/m^2/MHz (wide-band signals); and

— minus 148 dBW/m^2/MHz (narrow-band signals).

Protection of GNSS from the spurious emissions of mobile Earth stations (MES)

Mobile-satellite terminals in the band 1–3 GHz

The band 1 610–1 626.5 MHz is allocated for use by mobile-satellite terminals for transmissions in the Earth-to-space direction to satellites in non-geostationary orbits (NGSO). The mobile terminals may either be fixed to a vehicle or other mobile unit, or be hand-held. The systems presently proposed may be either of CDMA (wide-band) or of FDMA (narrow-band) type. These systems generate unwanted emissions which can interfere with GNSS services in the band 1 559–1 610 MHz.

GSO mobile-satellite systems operating in other bands between 1 GHz and 3 GHz and particularly the Earth-to-space band at 1 660–1 660.5 MHz also have the potential to cause interference. The latter band is also used by AMS(R)S for transmissions from the aircraft (i.e. from an aeronautical Earth station) to the satellite. For this situation, special measures have to be applied by aircraft systems designers to maintain the AMS(R)S signal level at the GNSS antenna below the agreed protection value.

Any of these mobile terminals may be used in the vicinity of airports, which creates the need for an international agreement to control the manufacture and use of, and the cross-border controls relating to, such terminals. The Global Mobile Personal Communications by Satellite MOU, developed jointly by ITU and the World Telecommunications Policy Forum 1996, has been raised for signature by all participating countries as an agreement addressing the import and control of mobile-satellite equipment.

NGSO MES terminals

Protection of GNSS from NGSO MES is addressed by ITU-R Recommendation M.1343 (*Essential technical requirements of mobile Earth stations for global non-geostationary mobile-satellite systems in the band 1–3 GHz*).

The purpose of this recommendation, approved in 1997, is to provide a common technical basis to:

a) establish type approval requirements for MES terminals;

b) facilitate the licensing of MES terminal operations;

c) facilitate the development of mutual recognition arrangements of type approvals of MES terminals; and

d) facilitate the development of mutual recognition arrangements to facilitate the circulation and the use of MES terminals.

GSO MES terminals

Protection of GNSS from GSO MES is addressed by ITU-R Recommendation M.1480 (*Essential technical requirements of land mobile Earth stations for global GSO MSS systems providing voice and/or data communications in the band 1–3 GHz*).

This Recommendation has been developed from a European initiative which was approved by ITU-R.

The data for the "carrier-on" condition only have been extracted. For the "carrier-off" condition and all other relevant data, reference should be made to the Recommendation. The subject is complex and the information presented here is for general guidance only.

The limits relate to the level of unwanted emissions at the output of the MES in the frequency bands quoted. The first column is for terminals with antenna gain less than 8 dBi and e.i.r.p. less than 15 dBW. The measurement bandwidth is 1 MHz unless indicated otherwise.

Frequency range	**e.i.r.p. limit**	**e.i.r.p. limit**
(MHz)	(dBW)	(dBW)
1 559–1 600	–70	–70
1 600–1 605	–70	–70
1 605–1 612.5	–70 to –58.5 (1)	(2)

Notes.—
1. *Linear interpolation in dBW versus frequency.*
2. *Linearly interpreted from –70 dBW in 1 MHz at 1 605 MHz to –46 dBW at 1 610 MHz. Special conditions are applicable to GLONASS protection (see Recommendation).*

Protection of GNSS signals from potential harmful interference of IMT

Current results of theoretical and experimental estimations indicate that the levels of unwanted emissions of IMT stations that are defined in ITU-R Recommendations M.2070 and ITU-R M.2071 are not low enough to provide required protection level for RNSS receiving Earth stations that operate in 1 559–1 610 MHz. Required separation distances are from 42 m to 2 446 m depending on the type of RNSS receiver, which makes impossible simultaneous application of these devices in one local spot without additional compatibility measures.

Band: 2 700–3 300 MHz

Technical Information:

Service: Aeronautical radionavigation/radionavigation
Aviation use: Primary surveillance radar, surveillance radar element of precision approach radar (PAR) medium-range systems, ground-based weather radar
Annex 10:
SARPs: Annex 10, Volume I, Chapter 3, 3.2.4
Frequency plan:
Planning criteria:
RTCA:
Eurocae:
ARINC characteristic:
ITU Res./Rec.:
ITU-R:

- Rec. M.629: Use for the RN service of the frequency bands 2 900–3 100 MHz, 5 470–5 650 MHz, 9 200–9 300 MHz, 9 300– 9 500 MHz and 9 500–9 800 MHz
- Rec. M.1460: Technical and operational characteristics and protection criteria of radiodetermination and meteorological radars in the 2 900–3 100 MHz band
- Rec. M.1461: Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services
- Rec. M.1464: Characteristics of and protection criteria for radionavigation and meteorological radars operating in the frequency band 2 700–2 900 MHz
- Rec. M.1465: Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 3 100–3 700 MHz

Other material:

Band: 4 200–4 400 MHz

Technical Information:

Service: Aeronautical radionavigation
Aviation use: Radio altimeters
Annex 10
SARPs:
Frequency plan:
Planning criteria:
RTCA:
- DO-155, Minimum Performance Standards — Airborne Low-range Radar Altimeters (1974)
- DO-161A, Minimum Performance Standards — Airborne Ground Proximity Warning Equipment (1976)

Eurocae:
- ED-30, MPS for Airborne Low-Range Radio (Radar) Altimeter Equipment (1980), Amend. 1 (1980)
- ED-83, Recommendations on Ground Collision Avoidance Systems

ARINC characteristic:
594-4, Ground Proximity Warning System (GPWS)
723-3, Ground Proximity Warning System
707-6, Radar Altimeter (RALT) Supplement 6
ITU Res./Rec.: Rec. No. 606 (Mob-87): The possibility of reducing the band 4 200–4 400 MHz used by radio altimeters in the aeronautical radionavigation service
ITU-R:
- Report [BL/8] (Düsseldorf 1990)
- Question 94/8: Bandwidth required for radio altimeter

Other material:

PROTECTION ASPECTS OF RADIO ALTIMETERS IN BAND 4 200–4 400 MHz

General

The frequency band at 4 200–4 400 MHz has been allocated to the aeronautical radionavigation service (ARNS) and is reserved exclusively for radio altimeters by RR No. **5.438**. The radio altimeter, in one of its main applications, performs the highly important task of providing flare guidance in the last stages of automated approach to land. Equally critical is its use as an input to ground proximity warning systems (GPWS) in aircraft, which give a "pull up" warning at a predetermined altitude and closure rate.

For these applications, a good interference rejection performance is essential. Integrity standards of the order of one failure in 10^{19} operations are not uncommon. The use of a wide frequency band is an essential feature in effective designs to achieve high orders of interference rejection and freedom from disruptive effects due to the high levels of pollution of the radio environment which exist in densely populated areas.

Studies have determined the necessity for the retention of the existing 200 MHz of spectrum to meet the exacting requirements of high accuracy with good all-round performance.

ITU-R studies

CCIR Report 1186 discusses the technical background to meeting the operational performance required for modern conditions. It concludes that:

"The whole of the band 4 200 to 4 400 MHz currently allocated is required up to at least the year 2015."

In coming to this conclusion, Report 1186 reviews the accuracy requirements and the design features to meet those requirements as laid down in MOPS and MASPS. The relationship between frequency excursion and accuracy is particularly noted. Typical performance requirements are contained in ARINC Doc 707-1, Section 3.7 as follows:

— accuracy: within 1.5 ft., or 2 per cent if greater, in the range 20 to 2 500 ft;

— output noise: 0.25 ft;

— output Resolution: 0.125 ft.

Band: 5 000–5 250 MHz

Technical Information:

Service: Aeronautical radionavigation, aeronautical mobile (R), aeronautical mobile-satellite (R), aeronautical mobile (for aeronautical mobile telemetry), radionavigation-satellite
Aviation use: MLS, RPAS C2, AeroMACS
Annex 10:
SARPs: Annex 10, Volume I, Chapter 3, 3.11
Frequency plan: Annex 10, Volume I, Table A
Planning criteria:
Annex 10, Volume V, Chapter 4, 4.4
Annex 10, Volume I, Attachment G, Section 9
RTCA: DO-177, MOPS for MLS airborne receiving equipment (1981), Change 1 & 2 (1986)
Eurocae:
- ED-36, MOPS for MLS Airborne Receiving Equipment
- ED-53A, MOPS for MLS Ground Based Equipment
- ED-74, MOPS for Combined ILS and MLS Airborne Receiving Equipment, Amend. 1 (1997)
- ED-88, MOPS for MMR including ILS, MLS, and GPS used for Supplemental Means of Navigation

ARINC characteristic: 727-1, Airborne Microwave Landing System
ITU Res./Rec.:
- Res. 418 (Rev. WRC-15): Use of the frequency band 5 091–5 250 MHz by the aeronautical mobile service for telemetry applications
- Res. 610 (WRC-03): Coordination and bilateral resolution of technical compatibility issues for radionavigation-satellite service networks and systems in the bands 1 164–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz
- Res. 748 (Rev. WRC-15): Compatibility between the aeronautical mobile (R) service and the fixed-satellite service (Earth-to-space) in the frequency band 5 091–5 150 MHz

ITU-R:
- Rec. M.1318: Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz and 5 010–5 030 MHz bands

- Rec. M.1582: Method for determining coordination distances, in the 5 GHz band, between the international standard microwave landing system stations operating in the aeronautical radionavigation service and stations of the radionavigation-satellite service (Earth-to-space)
- Rec. M.1831: A coordination methodology for radionavigation-satellite service inter-system interference estimation
- Rec. M.1901: Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164–1 215 MHz, 1 215–1 300 MHz, 1 559–1 610 MHz, 5 000–5 010 MHz and 5 010–5 030 MHz
- Rec. M.1906: Characteristics and protection criteria of receiving space stations and characteristics of transmitting earth stations in the radionavigation-satellite service (Earth-to-space) operating in the band 5 000–5 010 MHz
- Rec. M.2031: Characteristics and protection criteria of receiving earth stations and characteristics of transmitting space stations in the radionavigation-satellite service (space-to-Earth) operating in the band 5 010–5 030 MHz
- Rec. S.1342: Method for determining coordination distances, in the 5 GHz band, between the international standard microwave landing system (MLS) in the aeronautical radionavigation service (ARNS) and non-geostationary mobile-satellite service stations providing feeder uplink services
- Rep. M.2219: Radionavigation-satellite service applications for the 5 000–5 010 MHz and 5 010–5 030 MHz bands
- Rep. M.2262: Potential interference between the ICAO standard microwave landing system (MLS) operating above 5 030 MHz and radionavigation-satellite service (RNSS) systems in the band 5 000–5 030 MHz

Other material: RTCA DO-226, Guidance Material for Evolving Airborne Precision Area Navigation Equipment with Emphasis on MLS (1995)

MLS COORDINATION WITH FSS IN BAND 5 090–5 150 MHz

Protection requirements for MLS (coordination with FSS Earth stations)

The band 5 000–5 250 MHz is allocated to the aeronautical radionavigation service (ARNS). RR No. **5.444** gives precedence in the band 5 030–5 150 MHz to the international standard system (microwave landing system) for precision approach and landing. RR No. **5.444A** allocates on a joint primary basis the band 5 091–5 150 MHz to the FSS (for mobile-satellite feeder links) in the Earth-to-space direction. This allocation was made by WRC-95. Resolution **114**, calling for studies of the compatibility between these two services, was approved.

The compatibility studies under Resolution **114** were carried out by ITU-R WP4A, which primarily deals with fixed-satellite systems, and it was found appropriate for the results of the work obtained in WP4A to be examined by the ICAO AWOP/16 held in 1997. AWOP/16 proposed numerous amendments, most of which were later adopted at the ITU Radiocommunication Assembly in 1997.

ITU-R Recommendations

The method for the determination of coordination distances between Earth stations in the mobile-satellite service (feeder links) in the band 5 091–5 150 MHz and MLS in the band 5 030–5 090 MHz which was agreed in ITU-R is contained in ITU-R Rec. S.1342 (Method for determining coordination distances, in the 5 GHz band, between the international standard microwave landing system (MLS) in the aeronautical radionavigation service (ARNS) and non-geostationary mobile-satellite service stations providing feeder uplink services).

This Recommendation addresses only the protection of MLS in the band 5 030–5 090 MHz. This band is displayed at Table A of Annex 10, Volume I, which specifies 200 channels for MLS installations. The Recommendation recognizes that the sharing between MLS in the band 5 091–5 150 MHz and the FSS in the band 5 091–5 250 MHz, and other new ARNS in the band 5 030–5 250 MHz and FSS in the band 5 091–5 250 MHz remains to be studied. (It should also be noted that AWOP/16 concluded that co-frequency sharing between the FSS and MLS is not feasible.) The band 5 091–5 150 MHz is required to satisfy future long-term requirements.

Band: 5 350–5 470 MHz

Technical Information:

Service: Aeronautical radionavigation
Aviation use: Airborne weather radar
Annex 10:
SARPs: Annex 6, Part I, Chapter 6, 6.11
Frequency plan:
Channelization:
Planning criteria:
RTCA:
- DO-173, Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars (1980), Corrigendum/ Errata/Change 1
- DO-220, Minimum Operational Performance Standards for Airborne Weather Radar with Forward-Looking Windshear Detection Capability (1993), Change 1 (1995)

Eurocae:
ARINC characteristic: No. 708A-3, Airborne Weather Radar with Forward Looking Windshear Detection Capability
ITU Res./Rec.:
ITU-R:
Other material:

Band: 8 750–8 850 MHz

Technical Information:

Service: Aeronautical radionavigation/radiolocation
Aviation use: Airborne Doppler radar
Annex 10:
SARPs:
Frequency plan:
Channelization:
Planning criteria:
RTCA:

- DO-158, Minimum Performance Standards-Airborne Doppler Radar Navigation Equipment (1975)
- DO-173, Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars (1980), Corrigendum/ Errata/Change 1
- DO-220, Minimum Operational Performance Standards (MOPS) for Airborne Weather Radar with Forward-Looking Windshear Detection Capability (1993)

Eurocae:
ARINC characteristic:
ITU Res./Rec.:
ITU-R:
Other material:

Band: 9 000–9 500 MHz

Technical Information:

Service: Aeronautical radionavigation/radionavigation

Aviation use: Primary radar 3 cm short-range applications including precision approach. Airport surface detection equipment (ASDE)

Annex 10:

SARPs: Annex 10, Volume I, Chapter 3, 3.2

Frequency plan:

Channelization:

Planning criteria:

RTCA: DO-173, Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars (1980), Corrigendum/ Errata/Change 1

Eurocae: ED-116, MOPS for Surface Movement Radar Sensor Systems for Use in A-SMGCS

ARINC characteristic: 708A-3, Airborne Weather Radar with Forward Looking Windshear Detection Capability

ITU Res./Rec.:

ITU-R: Rec. M.629: Use for the radionavigation service of the radio frequency bands 2 900–3 100 MHz, 5 470–5 650 MHz, 9 200–9 300 MHz, 9 300–9 500 MHz and 9 500–9 800 MHz

Other material:

Band: 13.25–13.4 GHz

Technical Information:

Service: Aeronautical radionavigation
Aviation use: Airborne Doppler radar
Annex 10:
SARPs:
Frequency plan:
Channelization:
Planning criteria:
RTCA:

- DO-158, Minimum Performance Standards-Airborne Doppler Radar Navigation Equipment (1975)
- DO-173, Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars (1980), Corrigendum/ Errata/Change 1
- DO-220, Minimum Operational Performance Standards (MOPS) for Airborne Weather Radar with Forward-Looking Windshear Detection Capability (1993), Change 1 (1995)

Eurocae:
ARINC characteristic:
ITU Res./Rec.:
ITU-R: Rec. M.496.3: Limits of power flux-density of radionavigation transmitters to protect space station receivers in the fixed-satellite service in the 14 GHz band
Other material:

Band: 15.4–15.7 GHz

Technical Information:

Service: Aeronautical radionavigation/radiolocation

Aviation use: Primary radar, particularly airport surface detection equipment (ASDE)

Annex 10:

SARPs:

Frequency plan:

Channelization:

Planning criteria:

RTCA: DO-173, Minimum Operational Performance Standards for Airborne Weather and Ground Mapping Pulsed Radars (1980), Corrigendum/Errata/ Change 1

Eurocae: ED-116, MOPS for Surface Movement Radar Sensor Systems for use in A-SMGCS (2004)

ARINC characteristic:

ITU Res./Rec.:

ITU-R:

- Rec. S.1340: Sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the Earth-to-space direction in the band 15.4–15.7 GHz
- Rec. S.1341: Sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the space-to-Earth direction in the band 15.4–15.7 GHz and the protection of the radio astronomy service in the band 15.35–15.4 GHz

SHARING IN THE BAND 15.4–15.7 GHz

General

The part of the band at 15.43–15.63 GHz of the aeronautical radionavigation band 15.4–15.7 GHz is shared with the fixed-satellite service (FSS), an allocation which was made by WRC-95 and later amended by WRC-97 (RR No. **5.511A**). The FSS use is restricted to feeder links for non-geostationary satellites in the mobile-satellite service. The conditions of use are covered by RR Nos. **5.511A** and **5.511C**, which place restrictions on both services as part of the protection requirements.

ITU-R studies

Aeronautical utilization of band

The band is utilized by the ARNS for a variety of systems:

— airport surface detection equipment (ASDE): radar systems used at civil airports for the control of surface movement;

— Radar sensing and measurement system (RSMS): sensing systems used in small aircraft and helicopters for height and other low-range measurement;

— aircraft landing system(s) (ALS): a transportable landing system used for temporary airfields;

— multi-purpose radar (MPR): an airborne surveillance radar.

Descriptions of these systems are given in Annex A of ITU-R Recommendations S.1340 and S.1341 (see below).

ITU-R Recommendations

Rec. S.1340: Sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the Earth-to-space direction in the band 15.4–15.7 GHz

This Recommendation contains the following limitations:

— limits the emissions from ALS and MPR at low angles (paragraph 2.1);

— limits horizontal emission by Earth stations to 54 dB (W/MHz);

— restricts RSMS to band 15.43 to 15.63 GHz;

— establishes coordination distances for the protection of ALS and MPR; and

— urges the limit of 42 dBW on all ARNS stations.

Rec. S.1341: Sharing between Feeder Links for MSS and the ARNS and the RAS in the space-to-Earth direction

This Recommendation contains the following limitations:

— limits the power flux-density of the FSS at the Earth's surface for various angles of arrival (paragraph 2.1);

— establishes coordination distances for ALS and MPR (paragraph 5);

— limits Earth stations to operate above 5 degrees; and

— makes provision for the protection of the radio astronomy service in the band 15.35–15.4 GHz.

Band: 24.25–24.65 GHz

Technical Information:

Service: Radionavigation
Aviation use: Primary radar: airport surface detection equipment (ASDE)
Annex 10:
SARPs:
Frequency plan:
Channelization:
Planning criteria:
RTCA:
Eurocae: ED-116, MOPS for Surface Movement Radar Sensor Systems for use in A-SMGCS (2004)
ARINC characteristic:
ITU Res./Rec.:
ITU-R:
Other material:

- ICAO Doc 9830, Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual
- ICAO Doc 9924, Aeronautical Surveillance Manual

Band: 31.8–33.4 GHz

Technical Information:

Service: Radionavigation
Aviation use: Airport surface detection equipment (ASDE), enhanced flight vision systems (EFVS)
Annex 10:
SARPs:
Frequency plan:
Channelization:
Planning criteria:
RTCA:
Eurocae:
ARINC characteristic:
ITU Res./Rec.: Rec. No. 707 (WARC-79): Relating to the use of the frequency band 32–33 GHz shared between the inter-satellite service and the radionavigation service
ITU-R: Rec. M.1466: Characteristics of and protection criteria for radars operating in the radionavigation service in the frequency band 31.8–33.4 GHz
Other material:

———————————

Attachment H

ITU RESOLUTIONS AND RECOMMENDATIONS

(as contained in the Radio Regulations)

1. INTRODUCTION

The ITU Resolutions and Recommendations contained in the Radio Regulations and referenced below are relevant to specific frequency bands used by aviation, specific aviation safety systems or certain WRC agenda items referenced in the ICAO Position.

Resolution	Footnotes/WRC-19 agenda item	Band description
18 (Rev. WRC-15)	—	Procedure for identifying and announcing the position of ships and aircraft of States not parties to an armed conflict
75 (Rev. WRC-12)	5.547	31.8–32.3 and 37–38 GHz
114 (Rev. WRC-15)	5.444; 5.444A	5 091–5 150 MHz
154 (Rev. WRC-15)	—	3 400–4 200 MHz; VSAT
155 (WRC-15)	5.484B	FSS bands; regulatory provisions for RPAS C2 links (UAS CNPC links)
157 (WRC-15)	**WRC-19 AI 9.1.3**	VSAT; radio altimeters
160 (WRC-15)	**WRC-19 AI 1.14**	Bands above 6 GHz, for high altitude platform systems (HAPS)
205 (Rev. WRC-15)	—	406–406.1 MHz
207 (Rev. WRC-15)	—	Aeronautical HF bands
215 (Rev. WRC-12)	—	L-band mobile-satellite/ AMS(R)S spectrum
222 (Rev. WRC-12)	5.353A; 5.357A	L-band mobile-satellite/ AMS(R)S spectrum
225 (Rev. WRC-12)	5.351A	L-band mobile-satellite; GNSS, 2 700–2 900 MHz
229 (Rev. WRC-12)	5.446A	5 150–5 250 MHz

Resolution	Footnotes/WRC-19 agenda item	Band description
236 (WRC-15)	**WRC-19 AI 1.11**	Any band. Railway radiocommunications
237 (WRC-15)	**WRC-19 AI 1.12**	Any band. Intelligent transport systems
238 (WRC-15)	**WRC-19 AI 1.13**	Ranges above 24.25 GHz for future IMT
239 (WRC-15)	**WRC-19 AI 1.16**	5 150–5 925 MHz, RLAN
359 (Rev. WRC-15)	**WRC-19 AI 1.8**	Maritime MF, HF, VHF and satellite bands, used by GMDSS
360 (Rev. WRC-15)	**WRC-19 AI 1.9.2**	Maritime VHF bands used by GMDSS
362 (WRC-15)	**WRC-19 AI 1.9.1**	Maritime VHF bands used by GMDSS
405	—	Aeronautical HF bands
413 (Rev. WRC-12)	5.197A	108–117.975 MHz; AM(R)S
417 (Rev. WRC-15)	5.327A	960–1 164 MHz; AM(R)S
418 (Rev. WRC-15)	5.444B, 5.446C	5 091–5 150 MHz (AMS)
422 (WRC-12)	—	L-band mobile-satellite/ AMS(R)S spectrum
426 (WRC-15)	**WRC-19 AI 1.10**	GADSS
608 (Rev. WRC-15)	5.329	1 215–1 300 MHz
609 (Rev. WRC-07)	5.328A	1 164–1 215 MHz
610 (WRC-03)	5.328B	1 164–1 300 MHz; 1 559–1 610 MHz; 5 010–5 030 MHz
659 (WRC-15)	**WRC-19 AI 1.7**	405.9–406.2 MHz
739 (Rev. WRC-15)	5.208B	1 525–1 559 MHz; 1 559–1 610 MHz
748 (Rev. WRC-15)	5.444B	5 091–5 150 MHz (AMS, FSS)
750 (Rev. WRC-15)	5.338A	1 350–1 400 MHz
763 (WRC-15)	**WRC-19 AI 9.1.4**	Potential frequency bands for stations on board sub-orbital vehicles

Resolution	Footnotes/WRC-19 agenda item	Band description
804 (Rev. WRC-12)	—	Establishment of WRC Agendas
958 (WRC-15)	**WRC-19 AI 9.1.6**	Wireless power transmission
Recommendation	**Footnotes**	**Band**
206 (Rev. WRC-12)	—	L-band mobile-satellite/ AMS(R)S spectrum
401	—	Aeronautical HF bands
608 (Rev. WRC-07)	—	1 164–1 215 MHz
707	5.548	31.8–33 GHz
724 (WRC-07)	—	Use of VSAT stations

— END —

Doc 9718
AN/957

Handbook on Radio Frequency Spectrum Requirements for Civil Aviation

Volume II
Frequency assignment planning criteria for aeronautical radio communication and navigation systems

~~Approved by the Secretary General and published under his authority~~

Second Edition - 2021~~First Edition — 2013~~

NOTICE TO USERS

This special **UNEDITED ADVANCE REVISION** includes amendments that were approved by the Sixth Meeting of the Navigation Systems Panel (NSP/6) and agreed by the Frequency Spectrum Management Panel Working Group 11 in March 2021. The material contained in this Handbook has been incorporated into the ICAO frequency assignment software Frequency Finder.

This document is an unedited advance version of an ICAO publication, rendered available to the public for convenience. The final edited version may still undergo alterations in the process of editing. Consequently, ICAO accepts no responsibility or liability of any kind should the final text of this publication be at variance from that appearing here.

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AMENDMENTS

Amendments are announced in the supplements to the *Catalogue of ICAO Publications;* the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by
1	29/9/17	ICAO

CORRIGENDA		
No.	Date	Entered by
1	13/9/13	ICAO

FOREWORD

Background and purpose

Volume II of this Handbook presents frequency assignment planning criteria for aeronautical radio communication and navigation systems.

This material was developed in response to requests from the ICAO Regions to provide updated frequency assignment planning criteria which can be implemented on a global basis to secure that aeronautical radio communication and navigation systems are protected from harmful interference on a uniform basis. The frequency assignment planning criteria were developed by the ICAO Aeronautical Communications Panel and the ICAO Frequency Spectrum Management Panel in cooperation with the ICAO Regional Offices.

Status of the Handbook (Volume II)

This volume contains detailed frequency assignment planning criteria for VHF air-ground communication systems (voice and data) operating in the frequency band 117.975 – 137 MHz, Instrument Landing Systems (ILS) (Localizer and Glide Path), VHF Omnidirectional Range (VOR), Distance Measuring Equipment (DME), Ground Based Augmentation System (GBAS) and VHF data broadcast (VDB), supplementing the relevant Standards and Recommended Practices (SARPs) in Annex 10 — *Aeronautical Telecommunications*, in particular Volume V — *Aeronautical Radio Frequency Spectrum Utilization*, and provides guidance for the application of these SARPs. In addition, it also provides the relevant background that led to the development of the detailed frequency assignment planning criteria.

In developing the frequency assignment planning criteria, careful attention was given to the material already available and used in the ICAO Regions and published through the relevant Regional Air Navigation Plans.

Implementation of frequency assignment planning criteria

The material contained in this volume is general in nature and should be applicable in all ICAO Regions. However, implementation in the Regions has to take place through relevant decisions by the Regional Planning and Implementation Groups (PIRGs), which are responsible for amending and updating provisions of the Regional Air Navigation Plans. Specific regional requirements on the use of radio frequencies have been accommodated as much as practicable. Future specific regional requirements can be implemented through relevant regional air navigation agreements and/or incorporated in future revisions to this Handbook.

It should be noted that the coordination of frequency assignments as well as the development of the regional frequency assignment plans rests with the ICAO Regional Offices and that these Offices should be consulted when amendment to these plans are being considered by ICAO Contracting States.

Note.— In some Regions, for administrative and practical purposes, different coordination mechanisms may be implemented.

Global Plan

The frequency assignment planning criteria as contained herein support the development of globally harmonized frequency assignment plans as an element of the Global Air Navigation Plan and the application of these criteria secures protection of frequency assignments on a globally harmonized and uniform basis.

Organization of this Handbook (Volume II)

Chapter 1 provides general principles and other material to be used in compatibility analyses of aeronautical radio communication and navigation systems. This material forms the technical basis for the frequency assignment planning criteria and can also be used when assessing compatibility of new systems planned to operate in frequency bands already used for aeronautical purposes.

Chapter 2 contains the background that was used when developing frequency assignment planning criteria for VHF air-ground communication systems (voice and data). This chapter gives due account to regional differences in using the VHF band while maintaining the basic principles for the protection of radio frequencies from harmful interference on the basis of globally accepted principles.

Chapter 3 (ILS), Chapter 4 (VOR), Chapter 5 (DME) and Chapter 6 (GBAS/VDB) contain the principles and guidance material for frequency assignment planning for these radio navigation systems.

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GLOSSARY

Acronyms

ACR.	Adjacent channel rejection
AM(R)S.	Aeronautical Mobile (Route) Service
ANP.	Air Navigation Plan
AOC.	Aeronautical operational control
AS.	Aerodrome surface
ATIS.	Automatic terminal information service
COM.	Communications
D/U.	Desired to undesired
DOC	**Designated Operational Coverage**
dB.	Decibel
dBi.	Decibels relative to an isotropic radiator
dBm.	Decibels relative to 1 milliWatt
dbW.	Decibels relative to 1 Watt
DME.	Distance measuring equipment
DSB-AM.	Double sideband — amplitude modulation
e.i.r.p.	Equivalent isotropically radiated power
EUR.	European
FMG.	Frequency Management Group
GP.	Glide Path
GBAS.	Ground-based augmentation system
ILS.	Instrument landing system
ITU.	International Telecommunication Union
LLZ.	Localizer
MSL.	Mean sea level
RF.	Radio frequency
RPDS	Reference Path Data Selector

RSDS. Reference Station Data Selector

SAR. Search and rescue

SARPs. Standards and Recommended Practices

UHF. Ultra-high frequency

VDB. VHF data broadcast (used with GBAS)

VDL. VHF digital link

VHF. Very high frequency

VOLMET. Meteorological information for aircraft in flight

VOR. VHF omnidirectional radio range

WRC-12. World Radiocommunication Conference — 2012

Terms and definitions

Designated operational range or height (DOR or DOH). The range or height to which an aid is needed operationally in order to provide a particular service and within which the facility is afforded frequency protection.

Note 1.— The designated value for range or height is determined in accordance with the criteria for the deployment of the aid in question.

Note 2.— The designated value for range or height forms the basis for the technical planning of aids.

Designated operational coverage (DOC). The combination of the designated operational range and the designated operational height (e.g. 200 NM/FL500 is the DOC for an aid with a designated operational range of 200 NM and a designated operational height of 50 000 ft .

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

Elevation. The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

Flight level (FL). A surface of constant atmosphere pressure which is related to a specific pressure datum, 1013.2hpa, and is separated from other such surfaces by specific pressure intervals.

Regional frequency allotment tables. The regional frequency allotment tables are contained in the supplement referenced in this Handbook (Volume II) and published separately. This supplement can be downloaded from the website of the Frequency Spectrum Management Panel at:http://www.icao.int/safety/fsmp/documents/doc9718

ICAO Regional Offices are encouraged to reference these frequency allotment tables in the Regional Air Navigation Plans when implementing the frequency assignment planning criteria, as contained in this Handbook (Volume II), into the Regional Air Navigation Plans.

Chapter 1

GENERAL METHODOLOGY FOR COMPATIBILITY ANALYSIS

1.1 INTRODUCTION

1.1.1 This chapter describes a general methodology that can be used in the analysis of interference between similar and dissimilar radio systems and provides the procedures for calculating the distance and frequency separation required to prevent harmful interference to systems used by aviation for communication and (radio) navigation purposes.

1.1.2 For a more detailed analysis, taking into account the aeronautical compatibility requirements, the method as described in ITU-R Recommendation SM.337 on "*Frequency and distance separations*" may be used in some cases. Also relevant are the provisions of ITU-R Recommendation SM.1535 on "*The protection of safety services from unwanted emissions*".

1.1.3 The material in this Handbook (Doc 9718, Volume II) can only be used for assessing compatibility between aeronautical radio communication and navigation systems with the conditions as specified in the various Chapters.

Note.— Material that can be used for assessing compatibility between non-aeronautical and aeronautical systems is in Doc 9718, Volume I, Chapter 9 and Appendix G.

1.1.4 The frequency assignment planning criteria in this Handbook (Volume II) are only valid for the assumptions as specified. When system implementation is different from these assumptions, a more detailed compatibility analysis is required taking into account actual system characteristics and radio wave propagation model(s).

1.1.5 Details on the allocation of frequency bands by the International Telecommunication Organization (ITU) are in Doc 9718, Volume I.

1.1.6 The material in this Handbook (Volume II) presents frequency assignment planning criteria for use by States and the Regional Offices when coordinating frequency assignments. Regions or States may supplement this material or use different frequency assignment planning criteria to meet regional requirements

1.1.7 Frequency assignment planning for aeronautical radio communication and navigation systems is based on the need to provide protection from harmful interference throughout the Designated Operational Coverage.

Note.— This concept excludes the need to provide protection for Communication or Navigation systems outside the DOC as promulgated by States.

1.2 COMPATIBILITY MODEL

1.2.1 Compatibility assessment

The electromagnetic compatibility of radio equipment should be calculated by the following method:

Step 1: determine the desired signal level (and spectral distribution) at the desired (victim) receiver input;

Step 2: determine the maximum undesired (interfering) signal level (and spectral distribution, including

noise) at the desired (victim) receiver input, taking into account the total (desired) receiving system performance requirements as per Annex 10;

Step 3: determine the interactive effects (e.g. the D/U ratio) among the desired and undesired signals for various frequency separations, while meeting the total (desired) receiving system performance requirements as per Annex 10. These effects can be determined through actual measurements or through analysis;

Step 4: determine from the data obtained in Step 3, the degree of frequency and/or distance separation required to provide the required level of service, while ensuring that any interference received by the victim receiver is not harmful; and

Step 5: determine, for establishing frequency/distance separation requirements, the appropriate propagation model.

Note.— In all cases, the co-frequency protection requirements have to be assessed, preferably through measurements. The procedures described in Recommendation ITU-R SM.337 would allow, under specific conditions, development of the frequency/distance separation when the interfering signal is not co-frequency with the desired signal while meeting the total system performance requirements.

1.2.2 Protection of the desired signal

1.2.2.1 Protection of the desired signal can be considered along two principles.

1.2.2.1.1 The first principle calculates the actual field strength of both the desired and the undesired signal at the receiver antenna, taking into account the distance to the (desired) transmitter. On the basis of the established desired to undesired (D/U) ratio, the maximum signal level of the undesired (interfering) signal determines, in turn, the maximum level of the interfering signal, before the interference becomes harmful as shown in formula (4) in 1.2.5. This principle is illustrated in Figure 1-1:

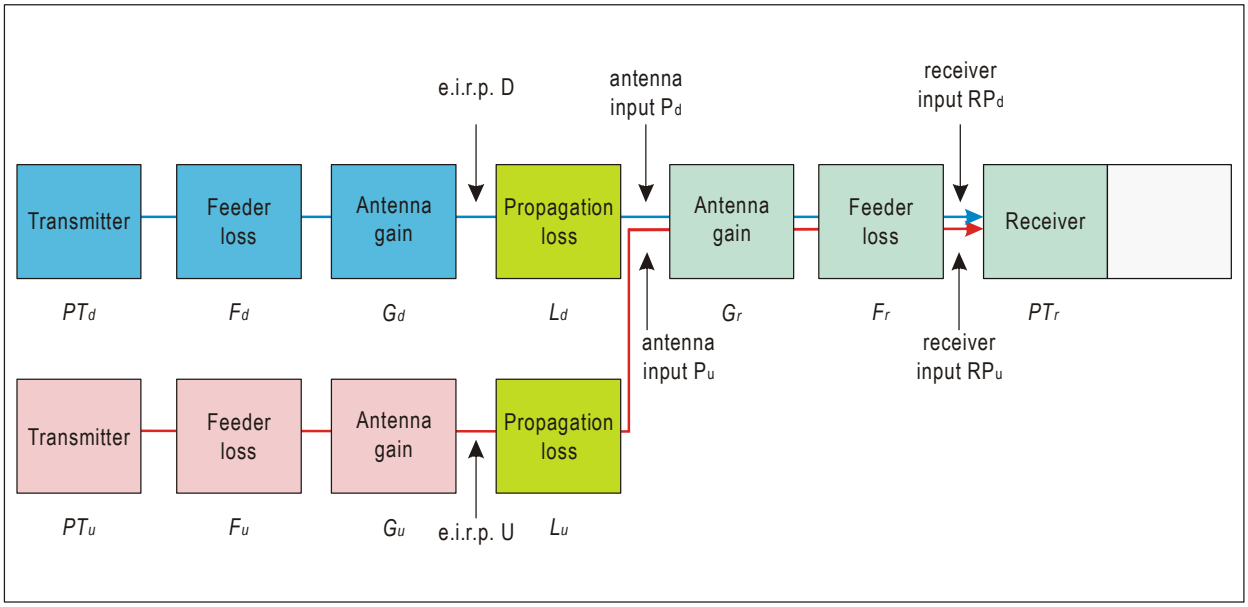

Figure 1-1. Schematic diagram of the complete scenario to be analysed

where:

F_d: feeder loss for the desired transmitter (dB)

F_r: feeder loss of the receiver (dB)

F_u: feeder loss for the undesired transmitter (dB)

G_d: gain of the antenna of the desired transmitter (dBi)

G_r: gain of the receiver antenna (dBi)

G_u: gain of the antenna of the undesired transmitter (dBi)

L_d: transmission loss for the desired signal (dB)

L_u: transmission loss for the undesired signal (dB)

PT_d: output power of the desired transmitter (dBm)

PT_u: output power of the undesired transmitter (dBm)

P_d: power of the desired signal at the antenna of the receiver (dBm)

P_u: power of the undesired signal at the antenna of the receiver (dBm)

RP_d: power of the desired signal at the input of the receiver (dBm)

RP_u: power of the undesired signal at the input of the receiver (dBm)

1.2.2.1.2 The second principle uses the minimum field strength at the receiver antenna (signal-in-space) as is specified by ICAO for all communication and navigation systems. This minimum field strength has to be assured throughout the DOC of the facility. Similar to the first principle described in 1.2.2.1.1, on the basis of the established D/U ratio, the maximum signal level of the undesired (interfering) signal can be determined, before the interference becomes harmful. This approach is more appropriate to establish protection throughout the DOC compared to the method in 1.2.2.1.1. This principle is shown in Figure 1-2.

Note.— States are responsible for securing that the minimum required field strength, as specified in Annex 10, is maintained throughout the Designated Operational Coverage.

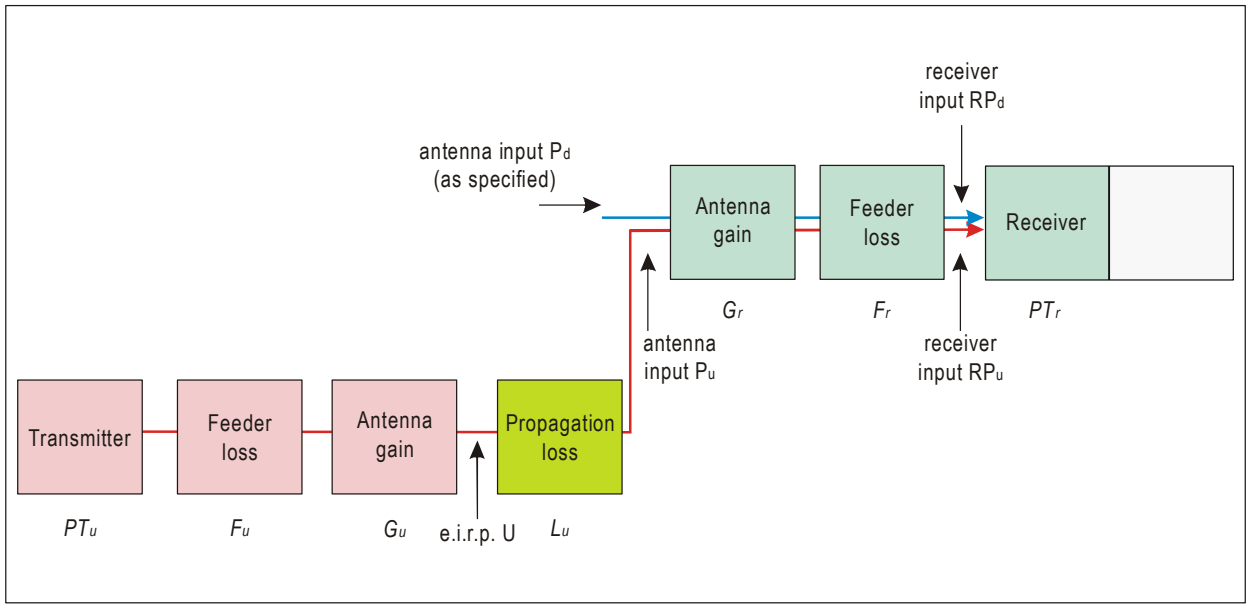

Figure 1-2. Schematic diagram of the minimum signal scenario

1.2.2.1.3 In cases where the interactions between the desired and the undesired signal have not been properly established (e.g. through actual measurements), protection of the desired (aeronautical) signal should be based on securing that the undesired signal is well below (6 – 10 dB) the noise floor of the aeronautical receiver.

1.2.3 Determination of the desired signal at the victim receiver antenna

1.2.3.1 Figure 1-3 illustrates the scenario to be analysed.

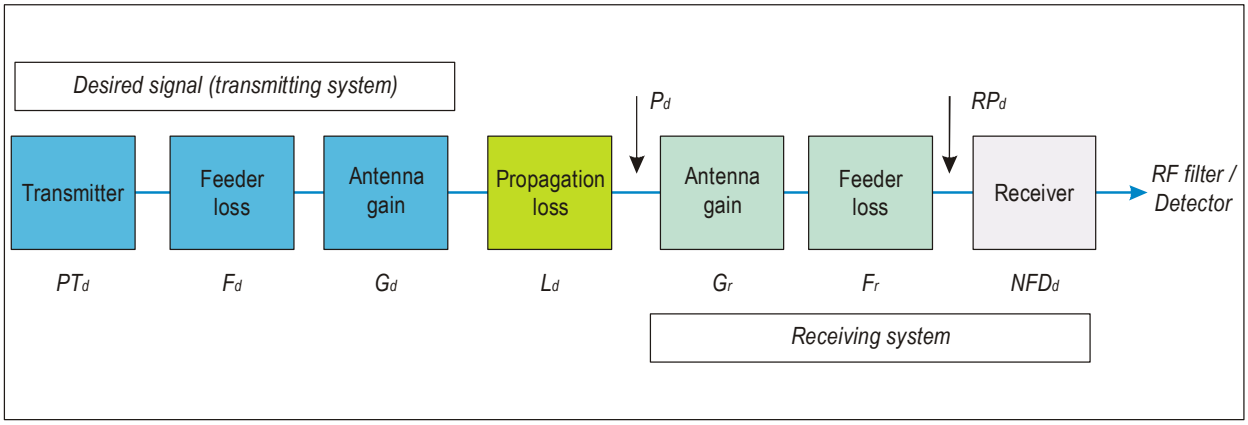

Figure 1-3. Schematic diagram of the desired signal path to the receiving antenna

1.2.3.2 The received power at the antenna of the receiver can be calculated by summing the transmitter power, antenna gains and feeder losses as shown in formula (1):

$$P_d = PT_d - F_d + G_d - L_d \quad (1)$$

where:

PT_d: output power of the desired transmitter (dBm)

F_d: feeder loss for the desired transmitter (dB)

G_d: gain of the antenna of the desired transmitter (dBi)

L_d: transmission loss for the desired signal (dB)

P_d: power of the desired signal at the antenna of the receiver (dBm)

The transmission loss L_d is calculated in accordance with the appropriate propagation model as developed by the ITU. See 1.3 on using the relevant propagation model to calculate the path loss.

When the minimum desired signal level at the receiver antenna is specified (e.g. in Annex 10, typically in the format of μV/m) and used in compatibility calculations, the scenario as shown in Figure 1-4 applies. In this case, P_d at the antenna of the receiver is the minimum required field strength as specified in the relevant provisions of Annex 10.

This modifies formula (1) into formula (2):

$$P_d = \text{xx dBm} \quad (2)$$

(xx is the minimum field strength is as specified by ICAO; for the conversion from μV/m to dBm, see Appendix A).

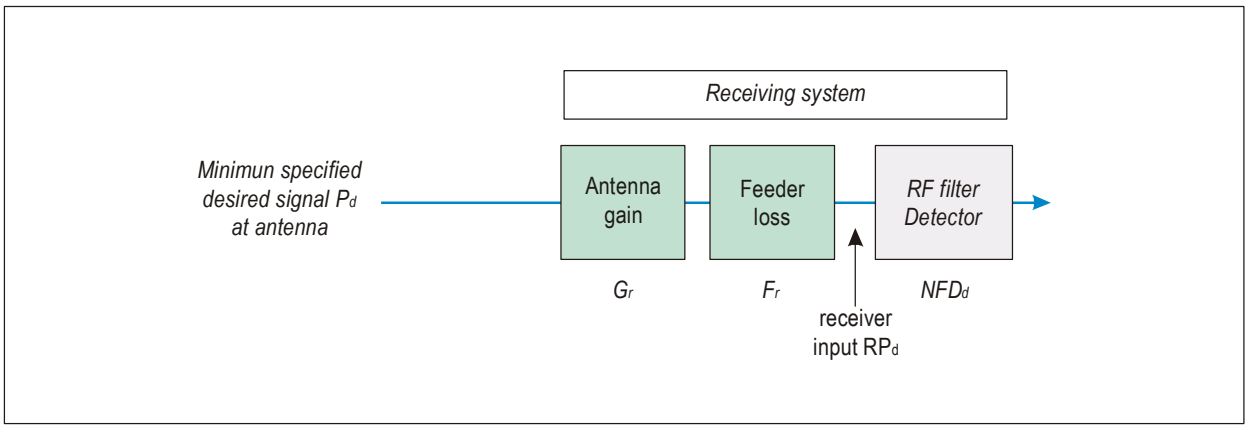

Figure 1-4. Desired signal path when minimum field strength is specified

1.2.4 Calculation of the undesired signal at the victim receiver antenna

Figure 1-5 illustrates the undesired signal path to be analysed.

Note.— The need for calculating the signal level of the undesired signal applies to both principles as identified in 1.2.2.1.1 and 1.2.2.1.2.

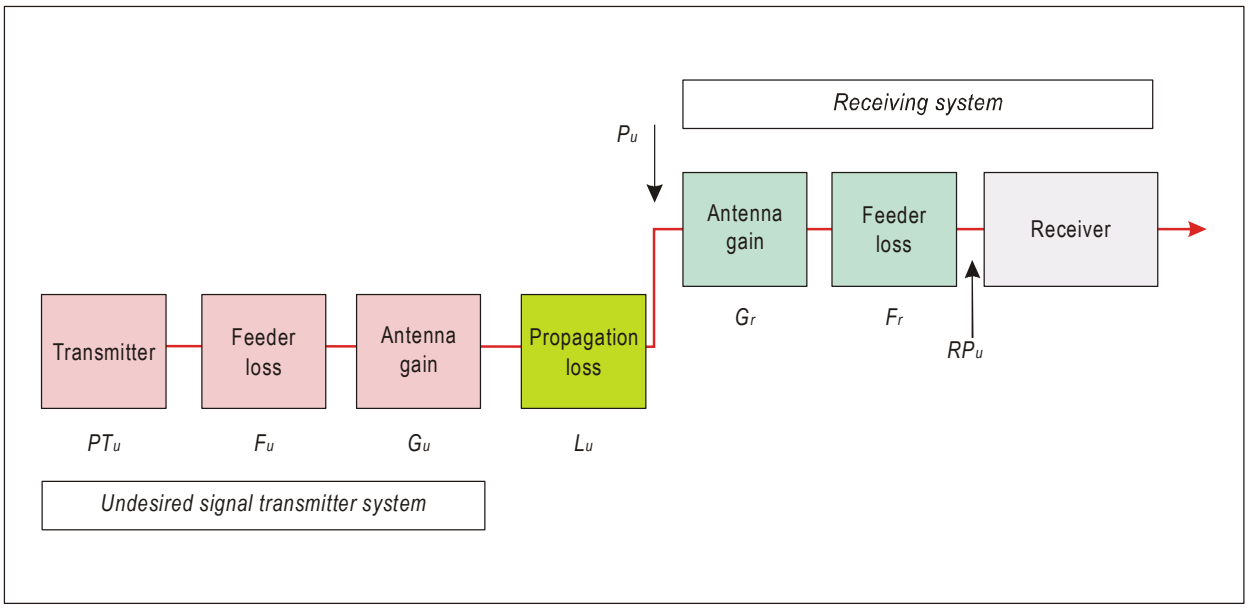

Figure 1-5. Schematic diagram of the undesired signal path

The received power at the input of the receiver antenna can be calculated by summing the various transmitter power, antenna gains and feeder losses as indicated in formula (3):

$$P_u = PT_u - F_u + G_u - L_u \quad (3)$$

where:

F_u: feeder loss for the undesired transmitter (dB)

G_u: gain of the antenna of the undesired transmitter (dBi)

L_u: transmission loss for the undesired signal (dB)

PT_u: output power of the undesired transmitter (dBm)

P_u: power of the undesired signal at an isotropic equivalent receiver antenna (dBm)

The transmission loss is calculated in accordance with the appropriate propagation model developed by the ITU. See 1.3 on propagation modelling and using the propagation model to calculate the path loss.

1.2.5 D/U ratio

After having calculated the values (or used the relevant ICAO standard value) for the desired signal and the undesired signals at the receiver antenna, these signal levels, in order to protect the desired signal from harmful interference from the undesired signal need to comply with formula (4):

$$P_d - P_u = D/U \quad (4)$$

where:

P_u: power of the undesired signal at the receiver (dBm)

P_d: power of the desired signal at the receiver (dBm)

D/U: Protection ratio (dB) as required by Annex 10 or established through measurements

Note.— If the compatibility analysis is for determining compatibility between an aeronautical system and a non-aeronautical system, then a safety margin in the order of 6 – 10 dB should be added to the required D/U ratio.

1.2.6 The effect of the adjacent channel rejection

When the frequencies are offset (i.e. the frequency of the desired signal differs from that of the undesired signal), the adjacent channel characteristics of the desired receiver will attenuate the desired signal before it is processed in the receiver. The factor with which these signals are attenuated is the adjacent channel rejection (ACR). The ACR is either the ACR as specified by ICAO (typically for intra system compatibility) or the ACR obtained by measurements (typically for inter system compatibility).

The power *Pu* at the antenna, as calculated using formula (3) and considering the ACR, becomes for adjacent frequencies:

$$P_u = PT_u - F_u + G_u - L_u - ACR \quad (5)$$

1.2.7 D/U ratio at the receiver input

For both the desired signal and the undesired signal at the receiver antenna, gain G_r and receiver feeder losses F_r are the same. Therefore, the D/U ratio at the receiver antenna is the same as the D/U ratio at the receiver input.

1.2.8 Interference immunity performance for digital systems

1.2.8.1 *Receiving function — interference immunity performance.* The standard measurement technique for digital systems provides that the desired signal field strength be doubled, and that the undesired signal be applied in increasing levels until the channel performance, i.e. the specified error rate, degrades to a value equal to the value found at the specified receiver sensitivity.

1.3 PROPAGATION MODELLING

1.3.1 Introduction

1.3.1.1 The ITU has developed a number of propagation models some of which are applicable to the study of the frequency assignment planning criteria for aeronautical systems and the protection of those systems from harmful interference from other radio systems that are either sharing the frequency band or operating in an adjacent frequency band.

1.3.1.2 The common propagation models used in aeronautical spectrum studies are described in 1.3.2 to 1.3.4.

1.3.2 Free-space propagation model

1.3.2.1 The free-space propagation model as defined in Recommendation ITU-R P.525 — Calculation of free-space attenuation, assumes an ideal propagation path where the transmitter and receiver antennas are considered isotropic antennas located in a perfectly dielectric, homogeneous, isotropic and unlimited environment with no obstructions. The free-space attenuation or transmission loss can be calculated using formula (6):

$$L_bf = 20 \log(4\pi d/\lambda) \quad (6)$$

where:

L_{bf}: free-space basic transmission loss (dB)

d: distance

λ: wavelength

Note that d and λ are expressed using the same unit of measurement.

The same formula can be rewritten using the frequency instead of the wavelength:

$$L_{bf} = 32.4 + 20\log f + 20\log d \quad (7)$$

where:

f: frequency (MHz)
d: distance (km)

or

$$L_{bf} = 37.8 + 20\log f + 20\log d \ (8)$$

where:

f: frequency (MHz)
d: distance (NM)

1.3.2.2 It should be noted that the propagation of radio waves in the very high frequency (VHF) and ultra-high frequency (UHF) frequency bands is subject to a number of additional conditions compared to the free-space transmission loss. Refraction and ducting, as described below, can extend the range over which this propagation model is applicable.

Note.— The radio refractive index is central to all theories of radio wave propagation through the lower atmosphere. The atmosphere causes a downward curvature of horizontally launched radio waves which is normally about one quarter of that of the earth. This applies in particular for radio waves propagating in the first kilometer (3000 ft) above ground. When the propagation path includes trajectories higher than one kilometer, the bending of the radio wave becomes less.

Refraction — Gradual changes in the refractive index of the (standard) atmosphere with altitude causes the bending of radio waves slightly towards (or in some cases away from) the Earth. The effect is that radio waves can propagate beyond the physical horizon and can be received up to a distance which is commonly referred to as the radio horizon as shown in Figure 1-6. Along this path, no (significant) losses other than the free-space propagation loss between the transmitter and the receiver have to be considered. Variations in the refractive index of the atmosphere, however, cause the radio horizon to vary as well. The bending effect of refraction is corrected in radio propagation by calculating the distance to the radio horizon using a 4/3 Earth radius. The 4/3 Earth radius approximation has been derived based on a standard atmosphere at sea level and is therefore not universally applicable. However, it is widely used and provides a good approximation of the effect of radio path propagation globally.

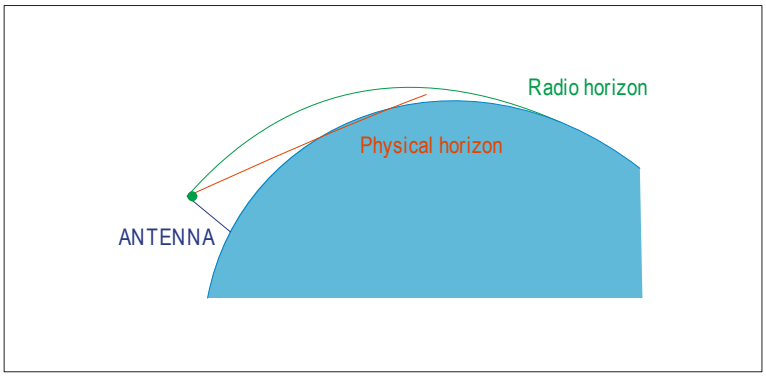

Figure 1-6. Radio horizon versus physical horizon

Ducting — The change in refractive index is normally gradual, but under certain atmospheric conditions a layer of warm air may be trapped above cooler air, often over the surface of water. The result is that the

refractive index will decrease far more rapidly with height than is usual. The rapid reduction in refractive index (and therefore dielectric constant) may cause complete bending down, as illustrated in the Figure 1-7. The unusual atmospheric condition traps the radio waves in a duct. Extreme bending of the radio waves between the top of the atmospheric duct and reflection of the radio waves from the surface of the Earth may propagate the radio waves over extreme long distances (e.g. more than 500 NM). Other phenomena such as sand storms may also cause ducting of radio waves.

Editorial Note.— *Replace* existing Figure 1.7 with the figure below:

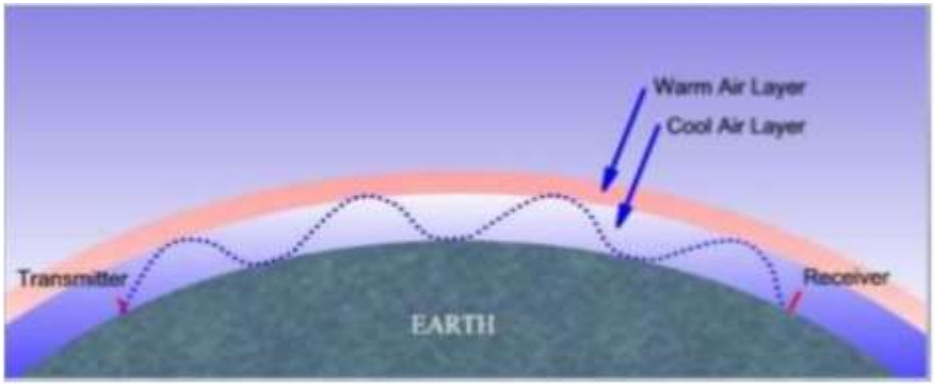

Figure 1-7. Propagation through ducting

1.3.2.2.1 **Sporadic E-layer –** The sporadic E (Es) layer is a layer in the ionospheric E region with a dense electron density and thin altitudinal thickness at altitudes around 100 km above the Earth. Sporadic E propagation bounces signals off smaller "clouds" or “patches” of unusually high density of accumulation of metallic ions in the lower E-region in the Earth’s ionosphere. This occasionally allows for long-distance communication at VHF frequencies not usually well-suited to such communication. Sporadic E-layer propagation has been observed in both the Northern and the Southern hemisphere.

These patches can cause anomalous propagation of VHF radio waves by reflecting radio waves which normally penetrate through the ionosphere. Figure 1 illustrates anomalous long-distance propagation of VHF radio waves by the Es layer. Signal levels were often observed to propagate over long distances (800 - 2000 km) and may be the source of potentially harmful interference. UHF and higher frequencies are not reflected by the Es layer.

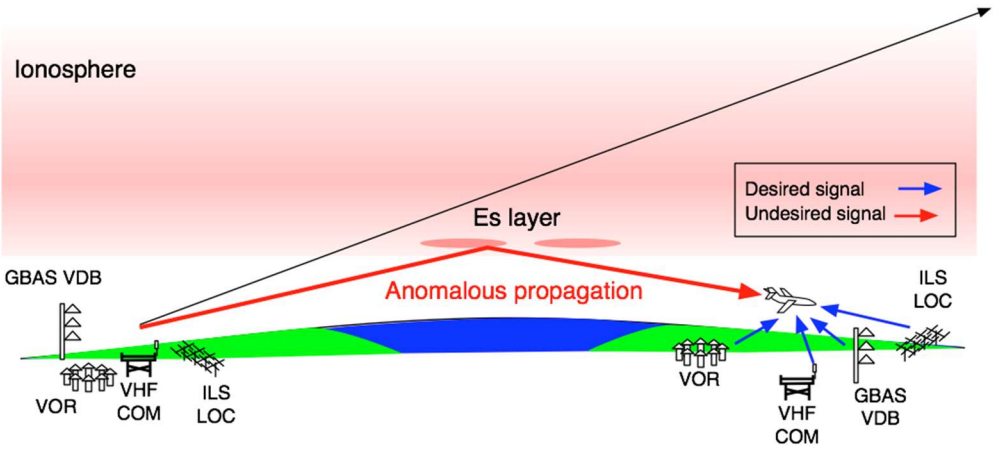

Figure 1-7A[1] – Propagation of VHF radio waves by the sporadic E-layer (Es layer).

Sporadic E-Layer propagation typically shows seasonal variations, with peaks at the summer solstice and smaller peaks at the winter solstice. Daily variations show larger peaks at noon and a secondary peak in the evening.

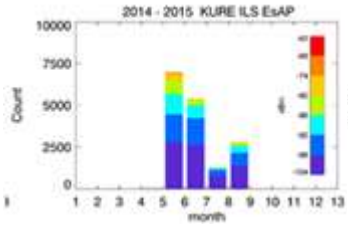

Figure 7B[1]- Sporadic E-layer propagation Seasonal variations observed in Japan

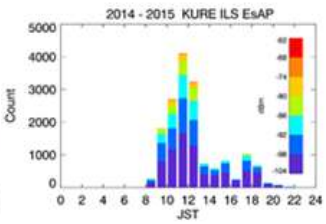

Figure 7C[1]- Sporadic E-layer propagation Daily variations observed in Japan

1.3.2.3 In aeronautical frequency assignment planning neither variations in the refractive index of the atmosphere (which causes variations in the distance to the radio horizon and effectively modify the 4/3 factor)) nor the effect of ducting is taken into account. In cases where these phenomena cause serious problems, consideration can be given to accommodate different criteria.

1.3.2.4 In the aeronautical standard propagation model free-space propagation conditions are assumed when the transmitter and the receiver are within the distance to the radio horizon (line of (radio) sight).

1.3.2.5 The distance to the radio horizon (4/3 Earth radius) can be calculated using equation (9):

$$d_{RH} = 1.23\left(\sqrt{h_{TX}}\right) \quad (9)$$

where:

d_{RH}: the distance of the station to the radio horizon (NM)

h_{Tx}: the height of the transmitter above the Earth's surface (feet)

Note.— The same formula can be used to calculate the radio horizon of the receiver by substituting the height of the transmitter with the height of the receiver.

1.3.2.6 In applying formula (9) to both the transmitter and the receiver (e.g. between an airborne transmitter and an airborne receiver), formula (10) can be used for the calculation of the distance to the radio horizon between the transmitter and receiver:

$$d_{RH} = 1.23\left(\sqrt{h_{TX}} + \sqrt{h_{RX}}\right) \quad (10)$$

where:

d_{RH}: the radio horizon separation distance between the transmitter and receiver (NM)

h_{Tx}: the height of the transmitter above the Earth's surface (feet)

[1] Source: Sakai, J., Hosokawa, K., Tomizawa, I., & Saito, S. (2019). A statistical study of anomalous VHF propagation due to the sporadic-E layer in the air-navigation band. Radio Science, 54, 426–439. https://doi.org/10.1029/2018RS006781

h_{Rx}: the height of the receiver above the Earth's surface (feet)

Editorial Note.— Replace 1.3.3 in its entirety with the following:

1.3.3 Aeronautical propagation curves

1.3.3.1 Recommendation ITU-R P.528-4 on "*A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands*" contains a method for predicting the transmission loss in the frequency range 125-15 500 MHz[2] for aeronautical and satellite services. The transmission losses presented in these curves are valid for ground-air and air-air radio links. The only data needed to predict the transmission loss are the distance between antennas, the heights of the transmitter / receiver antennas above mean sea level, the frequency, and the time percentage[3] for which the transmission loss is to be determined. A sub-set of the propagation curves in ITU-R Recommendation ITU-R P.528-4 relevant to the transmission loss for 5% of the time is contained in Appendix D. The ITU also makes these curves available in a tabular format. Recommendation ITU-R P.528-4 can be downloaded from the ITU website with the link https://www.itu.int/rec/R-REC-P.528-4-201908-I/en .

1.3.3.2 A description of the development and the application of the curves is in Annex 1 to ITU-R Recommendation P.528-4. The curves are based on data obtained mainly for a continental temperate climate. The curves give the basic transmission loss between ideal loss-free isotropic antennas.

1.3.3.3 These propagation curves are based on empirical data and include actual transmission losses for different time percentage availability. Within the radio horizon and at short distances, these curves are fairly consistent with free-space transmission path losses. Within the region "near" the radio horizon, the transmission loss was calculated using geometric optics to account for interference between the direct ray and a ray reflected from the surface of the Earth as well as the increased effect of the ground where the diffraction starts to manifest itself, and in general the transmission losses calculated using Recommendation P.528-4 are larger than free space loss at and beyond the radio line of sight.

1.3.3.4 Aeronautical frequency assignment planning is normally based on the curves for 5% of the time for assessing the level of the interfering signal and taking into account the protection of the minimum required field strength of the desired signal from harmful interference.

1.3.3.5 An example of ITU-R propagation curves for the frequency 108 MHz, a receiving antenna height of 45000 ft and a transmitter (interferer) antenna height of 20 ft is in Figure 1.8. The curves presented are valid for 5%, 50% and 95%of the time.

1.3.3.6 A program (P528 GUI.exe) that implements the propagation curves in ITU_R Recommendation P.528-4 can be downloaded from https://github.com/NTIA/p528-gui/releases . This program can be used to generate the propagation curves with the Graphical User Interface (GUI) and can export the curves in .csv format. A short description on the use of this program is in Appendix D. This program was developed by the U.S. based Institute for Telecommunication Sciences (NTIA/ITS).

1.3.3.7 When using the ITU propagation curves, a determination of the Radio Horizon in frequency assignment planning is no longer necessary since the curves themselves take this into account.

1.3.3.8 The application of these curves in frequency assignment planning for aeronautical radionavigation systems is described in paragraph 1.5.

[2] Extension of the frequency range for ITU-R Recommendation P.528-4 to include the band 108 – 124 MHz is in progress. This revision is expected to include material relevant for horizontally polarized radio signals.
[3] As an example, for the time percentage curve of 5%, the actual transmission loss will be less than the plotted value for 5% of the time

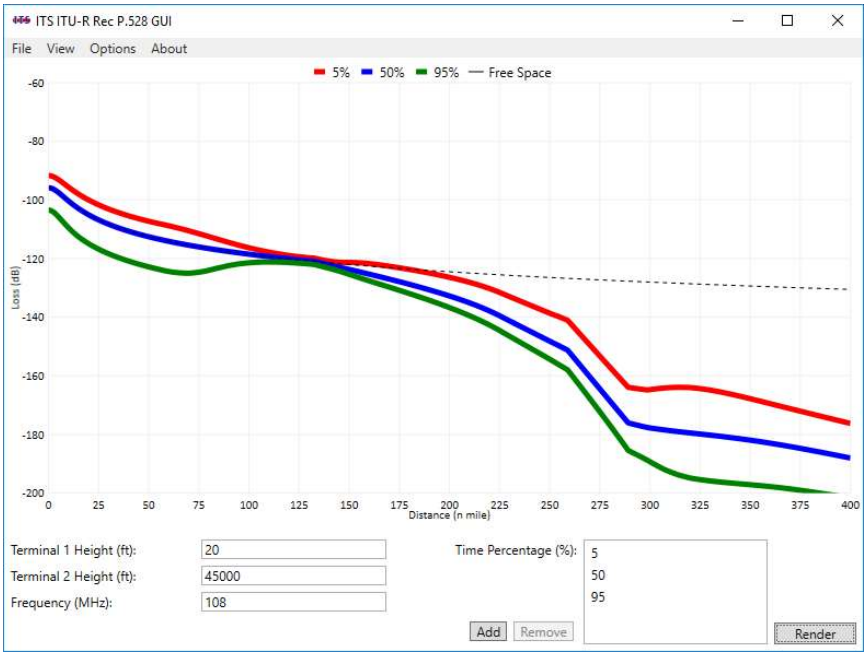

Figure 1.8 – ITU-R aeronautical propagation curves for a VOR 20 ft / 45000 ft/5% – 50% – 95 %

1.3.3.9.1 At about 100 NM, the curve starts to display increased transmission loss (compared to the free space transmission loss) while still within the Radio Line-of-Sight distance. This is caused by the increased effect of the ground where the effect of the reflected signal starts to manifest itself. At this range, the aircraft is about 4 degrees above the horizontal plane through the transmitter site.

1.3.3.9.2 From the radio line-of-sight distance of 260 NM, a sharp (almost linear) increase in transmission loss is observed. The propagation mode is here propagation by diffraction.

1.3.3.9.3 The propagation curves present the transmission loss for the slant range between the two terminals while keeping terminal 2 (the aircraft) at a constant altitude. However, at short distances between the two terminals, the aircraft may operate at a lower altitude which may result in a lower transmission loss. Therefore, an adjustment of the predicted transmission loss at short distances may be appropriate. Figure 1.8.A presents the transmission losses at a short distance between the terminals for different altitudes of the aircraft (Terminal 2).

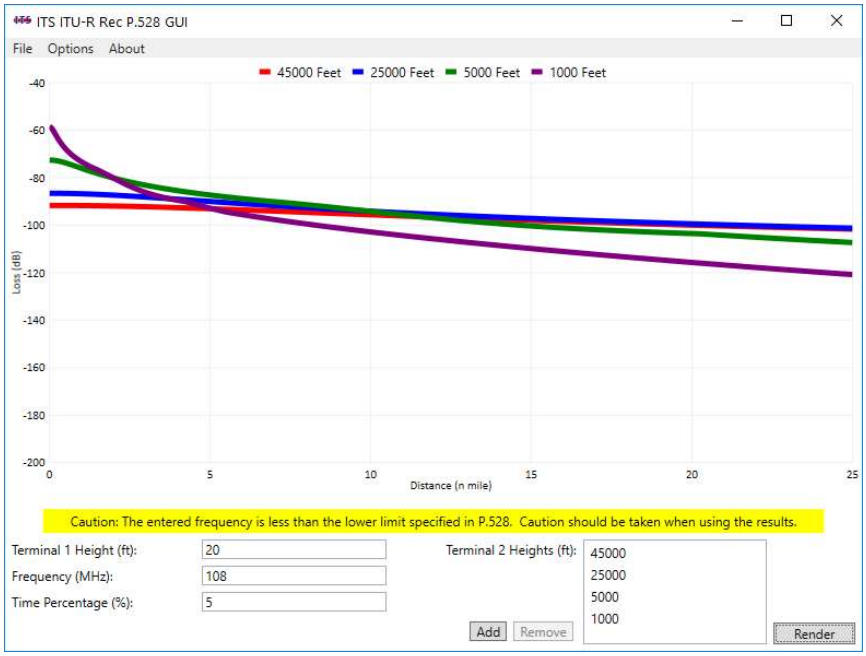

Figure 1.8. A Transmission loss for different altitudes at a short distance between Terminals 1 and 2.

1.3.3.9.4 This program can be used to estimate the transmission loss for antenna heights (for the undesired Terminal 1 and the desired Terminal 2) to down to 5 ft. The transmission loss is calculated taking into account the slant range between the (ground) and the (aircraft) terminals.

1.3.3.9.5 Within the range 108 – 118 MHz, the curves show a small increase in transmission loss with the higher frequency. As an example, at 108 MHz / 50 % of the time, a transmission loss of 150 dB is achieved at a distance of 256 NM, while the same transmission loss at 118 MHz is achieved at a distance of 155 NM. Or, at a distance of 250 NM, the transmission loss for 108 MHz is 148.17 dB and for 118 MHz 148.46 dB. (Curves for 50 % of the time). These differences do not significantly affect the results for calculating the minimum separation distance between a desired and an undesired facility. It is recommended to use the lower frequency of the band 108 – 117.975 MHz.

1.3.3.9.6 For the frequency range 960 – 1215 MHz (DME) these values are (50% of the time):

Transmission loss is 140 dB for 960 MHz at 130 NM and for 1215 MHz at 103NM
Transmission loss at 130 NM is for 960 MHz at 140 dB and for 1215 MHz at142 dB

If in this case for all DME facilities the propagation curve for 960 MHz is used, this results in a small over protection of facilities operating close to 1215 MHz.

1.3.3.9.7 The lower boundary of the ITU-R Recommendation P.528-4 is 125 MHz. The GUI that has been provided by the NTIA/ITS extends this down to 100 MHz.

End of new text.

1.3.4 Calculation of basic transmission loss when both the undesired transmitter and desired receiver are on the ground

1.3.4.1 In certain situations, both the undesired transmitter and the desired (victim) receiver can be located on the ground (e.g. the aircraft is on the surface of the airport and may interfere with a ground receiver station or a ground transmitter may interfere with an aircraft receiver). In this case, applying free-space transmission loss will result in

unrealistic low transmission losses. More realistic models that may be applied in these cases are either the two-ray (or flat Earth model) or the Egli model.

1.3.4.2 *Two-ray or flat Earth model*

To calculate the received power taking into account the effect of the ground, the two-ray ground reflection model or flat Earth model can be applied by the use of formula (12) and gives a more accurate prediction of the received power compared to the free-space model:

$$P_u = eirp_U + G_R - L_R - L_{pol} - 40\log d + 20\log H_T + 20\log H_R \quad (12)$$

where:

P_U: Received power (dBm) at the receiver input

$eirp_U$: e.i.r.p. (dBm) of the undesired (interfering) transmitter, including antenna gain and cable losses

d: distance (m) between (undesired) transmitter and (desired) receiver

H_T: transmitter antenna height (m)

H_R: receiver antenna height (m)

G_R: receiver antenna gain (dB)

L_R: receiver cable losses (dB)

L_{pol}: polarization discrimination (dB) (assumed to be 10 dB if direction of polarization differs by 90°)

Note.— This formula is an approximation of transmission loss at low angles and over a short distance (e.g. on the surface of an airport).

1.3.4.3 *Egli model*

The Egli model can be used to predict transmission losses taking into account the effect of the terrain, when both the transmitting and the receiving antenna are located relatively close to the ground. The Egli model offers a more accurate prediction of path loss compared to the free-space model. The Egli model is based on measured path losses and converted into the following mathematical model. It provides an alternative generic method to predict transmission losses when the antennas are close to the ground and includes an empirical frequency-dependent correction for frequencies greater than 30 MHz:

The received power from an undesired (interfering) transmitter can be calculated using the formula (13):

$$P_u = eirp_U + G_R - L_R - L_{pol} - 40\log d + 20\log H_T + 20\log H_R + 20\log 40 - 20\log f \quad (13)$$

where:

P_U: received power (dBm) at the receiver input

$eirp_U$: e.i.r.p. of the undesired (interfering) transmitter, including antenna gain and cable losses

d: distance (m) between (undesired) antenna and (desired) receiver

H_T: transmitter antenna height (m)

H_R: receiver antenna height (m)

G_R: receiver antenna gain (dB)

L_R: receiver cable losses (dB)

L_{pol}: polarization discrimination (dB) (assumed to be 10 dB if direction of polarization differs 90°)

f: frequency (MHz)

Note.— This formula is an approximation of transmission loss at low angles and over a short distance (e.g. on the surface of an airport).

Editorial Note.— Insert new Sections 1.4 and 1.5 as follows:

1.4 Generic model for calculating geographical separation distances between a desired and an undesired facility

1.4.1 The generic model establishes the minimum geographical separation distance between a desired and an undesired facility on the basis of the protection of the minimum field strength (as specified in Annex 10) that is required throughout the DOC of the desired facility. This model is described in paragraph 1.2.2.1.2. The undesired facility should be separated with a distance that protects the desired facility from harmful interference, taking into account the e.i.r.p of the undesired facility, the selectivity of the desired (aircraft) receiver and the transmission loss along the radio path. This generic model is used for calculating minimum separation distances between ILS, VOR, VDL Mode 4 and GBAS/VDB systems operating in the frequency band 108 – 117.975 MHz and 328.6 – 335.4 MHz (Glide Path) as well as for DME/TACAN systems operating in the frequency band 960 – 1215 MHz.

1.4.1.1 This model uses for the determination of the minimum distance between the location of an undesired radionavigation (transmitting) station to the location of the desired (aircraft) receiver the ITU-R propagation curves for aeronautical communication and radionavigation services as per ITU-R Recommendation P.528-4. These curves are described in section 1.3.3 of this Chapter. After the minimum required transmission loss between the desired and the undesired station has been determined, the corresponding separation distance can be derived from these curves.

1.4.1.2 This model provides for more conservative separation distances between facilities compared to models that are in use in the EUR/NAT and North-American Regions. Those models result in more efficient frequency assignment planning. In due course, when more detailed information is available on the overall frequency assignment planning, the generic model should be updated.

1.4.2 The geometry used in the generic model is in Figure 1-9

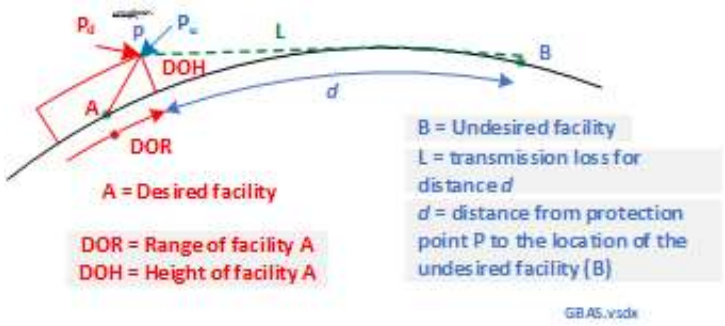

Figure 1-9 – Generic model for establishing minimum separation distance

1.4.2.1 The principle in this model is that, through frequency assignment planning, the maximum signal level from an undesired facility (Pu in Figure 1-9) does not cause harmful interference to the minimum signal (Pd in Figure 1-9) *throughout the DOC of the desired facility*. This is achieved by separating the undesired facility with a distance from the DOC of the desired facility that secures that the signal level (Pu) from the undesired facility at the protection point is [D/U] dB below the minimum signal level of the desired facility (Pd) at any location within the DOC of the desired facility. The D/U ratio is the protection ratio that need to be applied and can have a negative value when adjacent frequencies/channels are considered.
Note 1: This model considers the protection of the desired Signal-in-Space (SIS). It assumes an ideal loss-free isotropic antenna at the aircraft.
Note 2: The minimum signal level of the desired facility is specified in Annex 10

1.4.2.2 The steps for calculating the minimum separation distance between the desired facility A and the undesired facility B in Figure 1-9 are as follows:

a) Determine the minimum power P_d of the desired signal (facility A in Figure 1-9) at the location of the (receiving) aircraft (signal-in-space). This can be calculated with the formula:
$P_d = E - 20logf - 107.2$ (1.4-1)
where:
P_d is the isotropically received power at the antenna output(dB(W))
E is the minimum (desired) field strength (dB(μV/m)) as specified in Annex 10
f is the frequency (MHz)
Note.— $E = 20 \log FS$ where FS is the field strength in μV/m

b) Determine the maximum power Pu of the undesired signal (facility B in Figure 1-9) at the location of the aircraft. This can be calculated with the formula:
$Pu = Pd - D/U$ (1.4-2)
where:
Pu is the maximum allowed level of the undesired (interfering) signal (dBW)
Pd is the minimum level of the desired signal (dBW) as calculated in 1.4.2.2.a) above.
D/U is the protection ratio of the desired signal versus the undesired signal (dB)

c) Determine the minimum required transmission loss from the location of the undesired transmitter to the edge of the DOC of the desired facility with the formula:
$Pu = Tx - L$ (1.4-3)
where Pu is the maximum allowed level of the unwanted signal (dBW)
Tx is the e.i.r.p of the undesired transmitter (dBW)
L is the minimum total transmission loss (dB) from the undesired facility to the edge of coverage of the desired facility:
$L = Tx - Pd + D/U$ (1.4-4)
Note.— The location of the aircraft as in 1.4.2.2.a) and 1.4.2.2.b) is at the edge of the DOC of the desired facility

d) Once the minimum required transmission loss has been determined, the minimum separation distance between the location of the undesired transmitter and the (desired) aircraft can be established from the aeronautical propagation curves as per ITU-R Recommendation P.528-4.
A sub-set of the propagation curves is displayed in Figures 1-10 to 1-12.

1.4.3 The minimum distance between the location of the desired facility and the location of the undesired facility is established by adding to the separation distance as established with 4.2.2.2.d) the Designated Operational Range (DOR) of the desired station. When the DOR of the desired facility is described by a polygon, it is necessary to ensure that for each point on the boundary of the polygon the minimum separation distance between the undesired facility and the aircraft receiver as obtained with 4.2.2.c) is met.

1.4.4 The generic method does not take into consideration the on-board antenna characteristics. The ITU-R propagation curves give the basic transmission loss between ideal loss-free isotropic antennas. In specific cases the antenna characteristics can be taken into account. This can be accommodated by adding a margin to the minimum required D/U ratio. This also applies if the onboard transmission line loss for the desired and the undesired signal are not the same. The addition of such margins results in definition of the minimum required D/U ratio for the Signals in Space (SIS)

1.4.5 Compatibility calculation examples are in Chapter 3 (ILS), Chapter 4 (VOR), Chapter 5 (DME) and Chapter 6 (GBAS/VDB).

1.5 Utilization of the ITU-R aeronautical propagation curves[4]

1.5.1 For the assessment of interference between Aeronautical Radionavigation Systems in the band 108 – 117.987 MHz ICAO uses the ITU-R Recommendation P.528-4 on *A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands*. For the interference assessment, the curves for 5 % of the time are used to analyze the effect of the undesired signal.

1.5.2 Propagation curves, based on ITU-R Recommendation P.528-4 can be calculated with the program P.528 GUI that can be downloaded from https://github.com/NTIA/p528-gui/releases. A short description on the use of this program is in Appendix D. A sub-set of these curves is presented in Figure 1-10 (for the frequency 108 MHz; VOR), Figures 1-11a/b (108 MHz and 328 MHz; Localizer and Glide Path) and Figure 1-12 (for the frequency 960 MHz; (DME/TACAN) below. .

1.5.2.1 The curves in Figure 1-10 can be used to assess the transmission loss for VOR systems, operating at 108 MHz. These curves apply to the undesired (potentially interfering) signal, 5% of the time, an antenna height of the (undesired) transmitter of 15 ft and a height of the (desired) aircraft receiver at
45000 ft.

[4] Note.— Currently ITU-R Recommendation P.528-4 provides propagation curves only for radio signals with vertical polarization. An amendment to this Recommendation is being developed that includes propagation curves for radio signals with horizontal polarization. When this amendment has been agreed in the ITU, an adjustment to the calculations presented below (and in Chapters 3, 4, 5 and 6 may be necessary

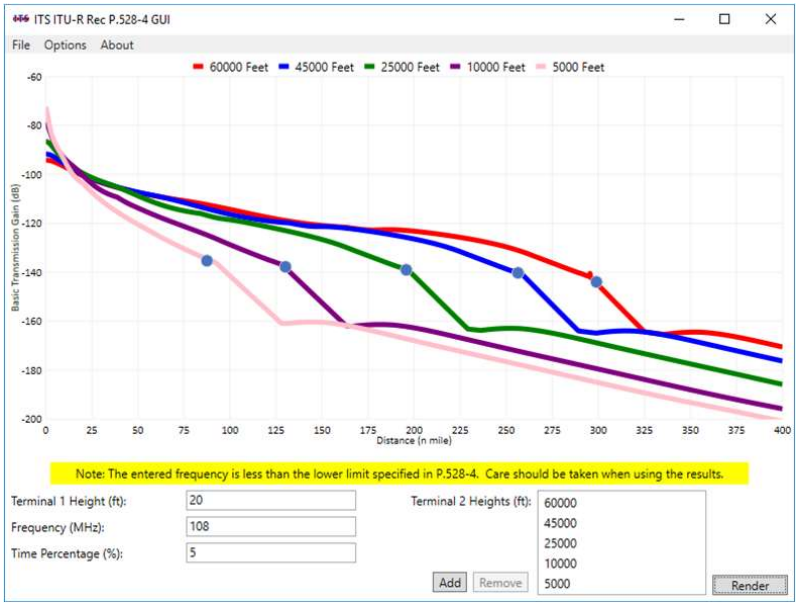

Figure 1-10 – ITU Propagation curves for the frequency 108 MHz (5% availability).

Note.— The blue dots in Figure 1-10 present the distance to the radio horizon with 4/3 Earth radius

These curves show that the transmission loss at the line-of-sight distance (which is almost similar to the radio horizon that can be calculated with a 4/3 Earth radius) is significantly larger compared to the free space transmission loss.

Using the 5 % of the time curves means that the actual transmission loss is less than shown with the curve for transmission for 5% of the time. For the remaining 95% of the time, the actual transmission loss is larger than shown with the curves.

Additional curves can be generated with the program P528 GUI as described in paragraph 1.3.3.

1.5.2.2 The curves in Figure 1-11a and 1-11b can be used to assess the transmission loss for ILS/Localizer at 108 MHz and the ILS-Glide Path at 328 MHz. These curves apply to the undesired (potentially interfering) signal, 5% of the time, an antenna height of the (undesired) localizer transmitter of 6 ft and a height of the (desired) aircraft receiver is 6250 ft. For the Glide Path the antenna height is 10 ft and the height of the aircraft receiver is 2500 ft.

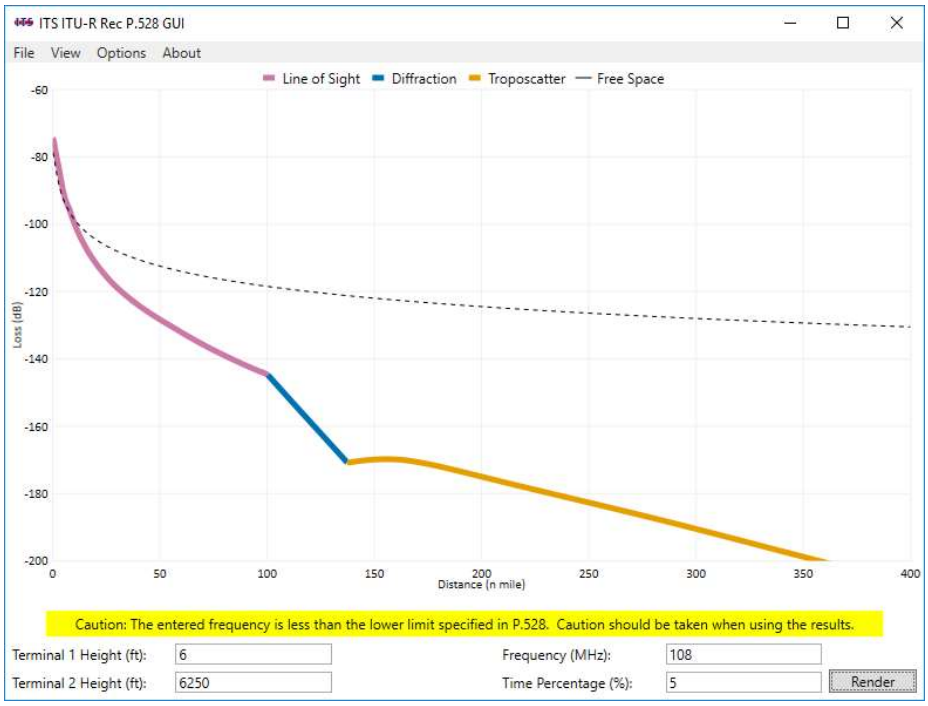

Figure 1-11a – ITU Propagation curves for the frequency 108 MHz at 6250 ft and 5 % of time.

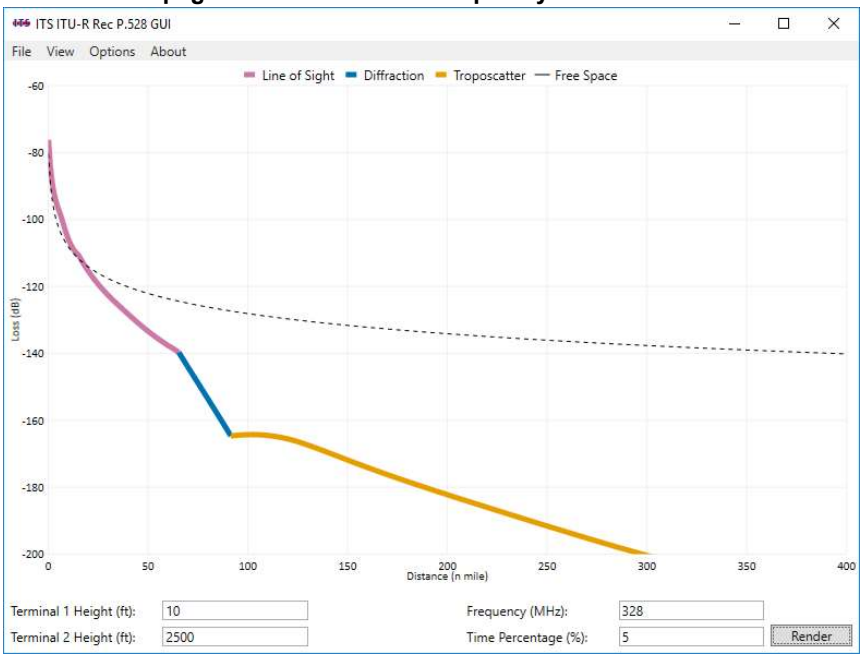

Figure 1-11b – ITU Propagation curves for the frequency 328 MHz at 2500 ft and 5 % of time.

1.5.2.3 The curves in Figure 1.12 can be used to assess the transmission loss for DME/TACAN systems operating at 960 MHz. These curves apply to the undesired (potentially interfering) signal, 5% of the time, an antenna height of the (undesired) transmitter of 20 ft and a height of the aircraft receiver of between 2000 ft and 60000 ft. Additional curves can be generated with the program P528GUI as described in paragraph 1.3.3.

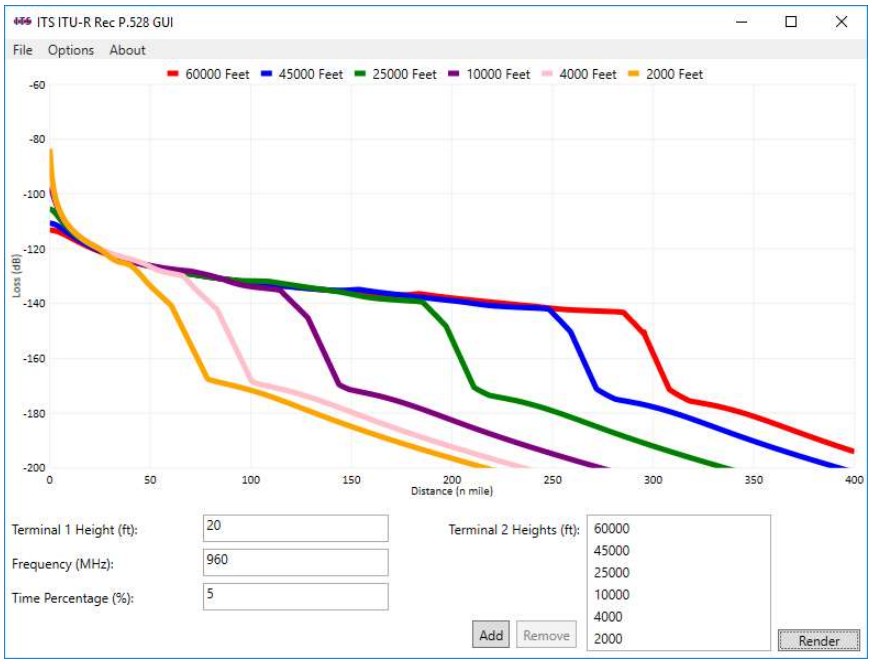

Figure 1-12 – ITU Propagation curves for the frequency 960 MHz.

1.5.3 Use of the ITU propagation curves.

1.5.3.1 The propagation curves are used to establish the minimum required geographical separation distance between a desired radionavigation facility and an undesired (potentially interfering) facility operating on the same or on adjacent frequencies.

1.5.3.2 The calculations to establish the minimum separation distance include the following steps:

i. Determine the minimum field strength **E** (dB (µV/m)) of the desired facility. For a Localizer **E = 32dB µV/m**

ii. Determine the minimum desired power Pd at the aircraft receiver (assuming a loss less isotropic aircraft antenna) with formula (1.4-1):
Pd = E - 20log f - 107.2 (Pd = dBW; f = 110 MHz). For a Localizer **Pd = -116 dBW**

iii. Determine the maximum undesired power Pu with formula (1.4-2):
Pu = Pd – D/U (Pu = dBW, D/U is the required desired/undesired signal ratio (dB). For a co-frequency Localizer D/U = 36 dB; Pu = -116 – 36 = --152 dBW

iv. Determine the transmission loss L (dB) that is required to achieve the maximum Pu at the aircraft receiver with formula (1.4-4).
L = Tx – Pd + D/U (L = transmission loss (dB; Tx is the e.i.r.p. of the undesired facility).
For an undesired Localizer with a Tx e.i.r.p of 17 dBW, L = 17 – (-116) +36 = 169 dB

v. Look up in the table for the relevant propagation curve the distance at which the required transmission loss is achieved. For the example, use the curve in Figure 1.9with h1 = 6250 ft and h2 is 10 ft. The minimum separation distance is 126 NM. This is the distance from the edge of coverage of the desired Localizer to the location of the undesired Localizer. The minimum separation distance between the location of the desired and the undesired Localizer facilities for a DOR of 25 NM is then 126 + 25 = 151 NM in cases where the direction of the Localizer is not known.

Note.— This exercise needs to be repeated for the case where the undesired Localizer in the example above becomes the desired Localizer and the desired Localizer becomes the undesired Localizer. The minimum required separation distance is the larger of the two values

1.5.5 Applying these curves may be considered as a worst-case scenario. More sophisticated propagation models, such as with the IF-77 model / program, may be used for a more detailed compatibility analysis.

1.5.6 Site elevation.

1.5.6.1 The site elevation[5] of the radio navigation facility is a factor that may need to be considered in cases where the elevation of the site of the desired and of the undesired facility is different. The main effect of the site elevation is the increase of the distance to the radio horizon, or, when the ITU-R aeronautical propagation curves are used, to use a propagation curve corresponding to the site elevation of the undesired facility and/or the elevation of the upper boundary of the DOC for the desired facility.
Note.— If the upper level of the DOC of the desire facility is reference to MSL (e.g. as Flight Level, the actual site elevation of the desired facility must be ignored.

1.5.6.2 The ITU-R aeronautical propagation curves in Recommendation ITU-R P.528.4 are based on a spherical Earth where the site of the undesired facility is at MSL and the maximum height of the DOC of the desired facility is referenced to MSL.

1.5.6.3 In the ICAO COM lists for radio navigation systems, the site elevation is not included and therefore is normally not taken into consideration in (international) frequency assignment planning and coordination. In these cases, the compatibility calculations assume that all facilities operate at a height referenced to MSL.

1.5.6.4 The geometry to calculate the effect of the site elevation is shown in Figure 1.13

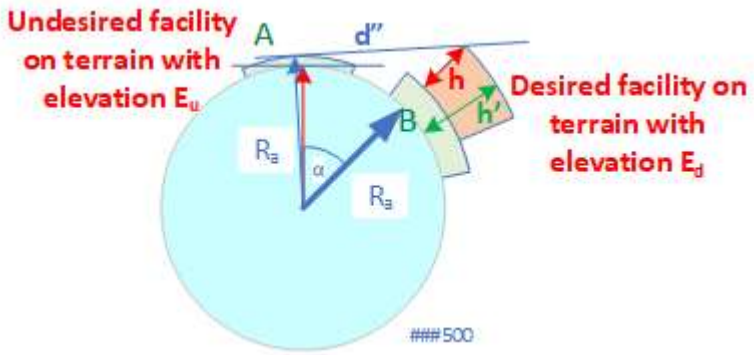

Figure 1.13 Effect of site elevation

The distance **d"** to the radio horizon can be calculated with

$$d" = \sqrt{(R_a + E_d + h)^2 - (R_a + E_u)^2} \qquad (4)$$

This formula gives $d" \approx 1.23\sqrt{E_D - E_u + h}$ (5) (where *d"* is in NM; E_d, E_u and *h* are in ft.)

Note.— If the upper boundary of the DOC of the desired facility is referenced to MSL, E_d is zero.

1.5.6.5 In cases where the site elevation between navigation facilities differ with 1000 ft or more, the separation distance, in order to protect the facility with the higher elevation, must be increased as follows:

for a VOR with an operational height of 45 000 ft: add 3 NM per 1000ft site elevation difference
for a VOR with an operational height of 10 000 ft: add 4 NM per 1000ft site elevation difference
for a VOR with an operational height of 5000 ft: add 7 NM per 1000ft site elevation difference

Alternatively, when using the actual ITU-R propagation curves, the selection of the curve should be increased with the height difference between the navigation facilities. Appendix D on the ITU-R propagation curves contains more background information.

[5] The site elevation is the height of the site of the ground station referenced to Mean Sea Level (MSL).

1.5.6.6 The effect of the height of the antenna above ground.

The actual height of the antenna above the local terrain affects the propagation curves to the extent that with a higher antenna, the transmission losses are less.
The following typical antenna height are normally used in the compatibility assessment of frequency assignments.

Localizer:	6ft
Glide Path	10 ft
VOR	20 ft (counterpoise: diameter 52 ft., 12 ft. above ground; antenna 4ft above counter poise
GBAS	45 ft
DME	20 ft

1.5.6.6.1 When States are deploying facilities with different antenna heights, ICAO should be informed accordingly to adjust interference calculations, as required.

1.5.7 Transmitter power degradation.

1.5.7.1 Typically, in aeronautical frequency assignment planning the effect of power degradation of the desired transmitter that may occur before the system is shut down (3dB) is not taken into consideration. This is because frequency assignment planning is based on the minimum field strength of the desired signal that has been specified for the relevant facility in Annex 10. This minimum field strength should also be maintained during periods of power degradation before the system is shut down. States should secure these minimum values when implementing NAV or COM facilities.

1.5.7.2 When frequency planning within a Region or State is based on a methodology that uses the radiated power of the desired transmitter, the addition of a 3-dB factor to the D/U ratios used in the compatibility assessment may be necessary.

1.5.8 The application of this generic methodology of frequency assignment planning is further described in:

- Chapter 2 for GBAS/VDB systems vs VHF-COM systems
- Chapter 3 for ILS systems
- Chapter 4 for VOR systems
- Chapter 5 for DME/TACAN systems
- Chapter 6 for GBAS/VDB systems

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Chapter 2

AERONAUTICAL VHF AIR-GROUND RADIO COMMUNICATION SYSTEMS OPERATING IN THE BAND 117.975 – 137 MHz

Editorial Note.— No change to Sections 2.1 – 2.10.

2.1 INTRODUCTION

2.1.1 The frequency band 108 – 137 MHz is allocated by the International Telecommunication Union (ITU) to the Aeronautical Mobile (Route) Service (AM(R)S) and used for air-ground voice and for air-ground and air-air data link communications. The use of this band is regulated by the ITU through the ITU Radio Regulations and relevant ITU-R Recommendations and Reports. Details on these Regulations can be found in Volume I of this Handbook. Specific provisions pertaining to the aeronautical use of this band is in the relevant ICAO Standards and Recommended Practices (SARPs) in Annex 10, Volumes III and V. This chapter contains technical and operational material on the assignment and use of frequencies in the band 117.975 – 137 MHz. Material on the use of the band 108 – 117.975 MHz by the AM(R)S (GBAS/VDB and VDL Mode 4) is in Chapter 3 of this Handbook (in preparation) on VHF/UHF navigation systems (ILS, VOR, GBAS/VDB, VDL Mode 4, DME).

Note.— The use of the allocation to the AM(R)S in the band 108 – 117.975 MHz by the AM(R)S is subject to the conditions as contained in ITU Resolution 413 (WRC-12).

2.1.2 ICAO documents relevant to frequency assignment planning in the band 117.975-137 MHz:

a) Annex 10, Volume III (*Communication Systems*),

i) Part I (Digital Data Communication Systems) — Chapter 6 — *VHF Air-Ground Digital Link (VDL);*

ii) Part II (Voice Communication Systems) — Chapter 2 — *Aeronautical Mobile Service;*

b) Annex 10, Volume V, Chapter 4 — *Utilization of frequencies above 30 MHz*;

c) ICAO Regional Air Navigation Plans and relevant ICAO regional air navigation agreements.

2.2 INTERFERENCE MODEL

2.2.1 General

2.2.1.1 Aeronautical communication systems can be subject to interference caused by transmissions from other (nearby) aircraft and from ground stations. These interfering transmissions can be generated on the desired (operational) frequency (co-frequency interference) or on frequencies adjacent to the desired frequency (adjacent frequency interference).The general methodology (as described in Chapter 1) which is used to establish separation distances between co-frequency and adjacent frequency assignments for air-ground communication systems is illustrated in Figures 2-1 and 2-2.

2.2.1.2 The protection of communications from harmful interference requires that, in general, when receiving a signal from a desired radio frequency (RF) source, the receiver will not simultaneously receive a signal from another (undesired) RF source that can cause harmful interference to the proper reception and processing of the desired signal. To achieve this, the frequency assignment planning process has to ensure that the undesired RF source is separated in distance (if both sources operate on the same frequency) from the (desired) receiver or, when operating on adjacent frequencies, is sufficiently separated in frequency and distance. There needs to be sufficient distance separation (or frequency/distance separation) to bring the undesired signal level to a value below which the interference, if any, is no longer harmful and the total receiving system performance requirements are met.

2.2.2 Interference model for aeronautical frequency assignment planning

2.2.2.1 The model used for establishing (co-frequency) separation distances in aeronautical frequency assignment planning for systems used in the band 117.975 – 137 MHz for VHF air-ground communications, is based on the general methodology in Chapter 1 and illustrated in Figures 2-1 and 2-2. This model assesses interference at the antenna input (signals-in-space). Specifications for aeronautical systems as established by ICAO also refer to signals-in-space.

2.2.2.2 RF emissions that are co-frequency (or adjacent frequency) to the actual operating frequency of ground station **A** and aircraft station **a** in Figure 2-1 (e.g. emissions from aircraft station **b** or ground station **B**) may interfere with communications within the DOC of the desired station or service (area **A** in Figure 2-1). Frequency assignment planning for both ground stations **A** and **B** in Figure 2-1 needs to secure that no harmful interference is caused between any stations operating within the DOC of ground station **A** and of ground station **B**. This is achieved by securing sufficient geographical separation between the ground stations.

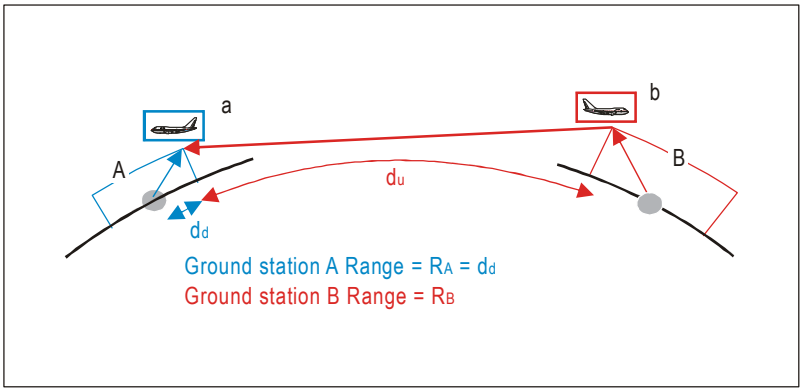

Figure 2-1. Model for establishing separation distances

2.2.2.3 For air-ground communications, the protection of the desired aircraft receiver (which is communicating with a ground station) from harmful interference caused by transmissions from another aircraft (operating on the same or an adjacent frequency) is normally the most constraining factor in securing that these frequencies are free from harmful interference. This model is illustrated in Figure 2-1; the schematic diagram of this model is in Figure 2-2.

2.2.2.4 In Figure 2-1, aircraft station **a**, which is receiving signals from the (desired) ground station **A**, can be interfered by transmissions from aircraft station **b** (or any other undesired RF source). The separation distance between aircraft station **a** and aircraft station **b** needs to secure that the level of (undesired) signals received by aircraft station **a** from aircraft station **b** are sufficiently below the level of the signals received by aircraft station **a** from ground station **A** to

prevent harmful interference. The signal ratio necessary to protect the desired signal from harmful interference from the undesired signal is the protection ratio (D/U).

*Note.— If ground station **B** (or both ground stations **A** and **B**) is an aeronautical broadcast station (e.g. meteorological information for aircraft in flight (VOLMET)), a different geometry from that shown in Figure 2-1 applies. This is further described in 2.7.2.4 and 2.7.2.5.*

2.2.2.5 The signal level of the desired and the undesired signal at the aircraft antenna can be calculated with the method as illustrated in Figure 2-2.

The level of the desired and of the undesired signal at the (desired) antenna input can be calculated using formulae (14) and (15) and as shown in Chapter 1, 1.2.3 (formula (1)) and 1.2.4 (formula (3)).

The level of the desired signal at the antenna input is:

$$P_d = PT_d - F_d + G_d - L_d \quad (14)$$

The level of the undesired signal at the antenna input is:

$$P_u = PT_u - F_u + G_u - L_u \quad (15)$$

Formula (4) in Chapter 1, 1.2.5 shows that $\mathrm{P_d} - \mathrm{P_u} = \frac{\mathrm{D}}{\mathrm{U}}$

Note.— For both the desired signal and the undesired signal, the antenna gain and the feeder losses of the receiving station are the same when the frequency of both signals is the same (co-frequency) or when both transmitters operate on the (first) adjacent frequency (25 kHz). The ratio of the desired to the undesired signal at the antenna is therefore the same as at the receiver input.

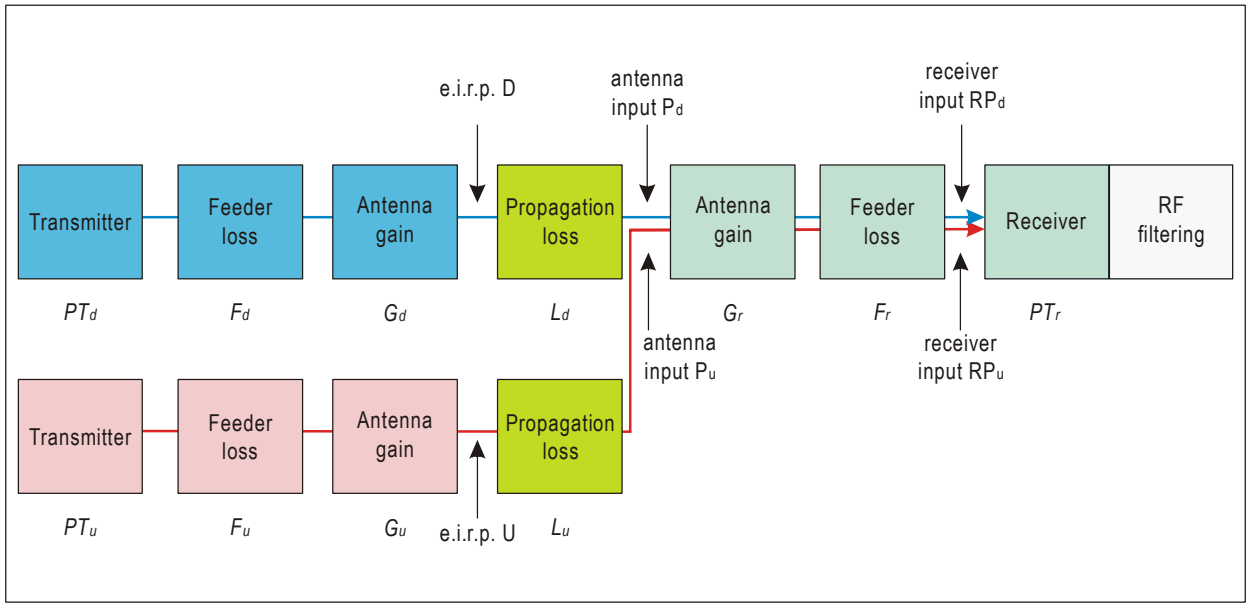

Figure 2-2. Desired signal and undesired signal path to desired (victim) receiver

In formula (14), L_d is the free-space propagation loss for the designated operational range (DOR) of the desired facility (**A** in Figure 2-1) and can be calculated as shown in Chapter 1, 1.3.2 (formula (8)):

$$L_d = 37.8 + 20\log f + 20\log d_{DOR}$$

In formula (15), L_u is the free-space propagation loss for the separation distance between the undesired RF source (aircraft station **b** in Figure 2-1) and the desired receiver (aircraft station **a** in Figure 2-1) and can be calculated as follows:

$$L_u = 37.8 + 20\log f + 20\log d_{SEPDIST}$$

$$\frac{D}{U} = P_d - P_u = e.i.r.p\ D - L_d - (e.i.r.p\ U - L_u) = e.i.r.p.D - e.i.r.p\ U - 20\log d_{DOR} + 20\log d_{SEPDIST}$$

From this formula, the minimum free-space separation distance between the desired receiver and the undesired transmitter ($d_{SEPDIST}$) can be calculated.

2.2.3 Separation distance ratio method

2.2.3.1 If the e.i.r.p. of both the desired transmitter (**A** in Figure 2-1) and the undesired RF source (**b** in Figure 2-1) are the same, the (required) D/U can be expressed as the ratio between $d_{SEPDIST}$ and d_{DOR} in the formula above.

For the desired signal at the receiver antenna: $P_d = e.i.r.p - L_d$

For the undesired signal at the receiver antenna: $P_u = e.i.r.p - L_u$

Note.— Equal e.i.r.p. for ground and aircraft transmitters is normally assumed in frequency assignment planning for aeronautical air-ground communication systems. The e.i.r.p includes the transmitter output power and the effect of cable losses and antenna gain. Tables 2-1 and 2-2 in 2.3.2 provide typical values normally used in compatibility analyses.

The D/U signal ratio equals $P_d - P_u$ (formula (4) in Chapter 1); P_d and P_u are expressed in dBm.

$$\frac{D}{U} = e.i.r.p - L_d + G_r - F_r - (e.i.r.p - L_u + G_r - F_r) = L_u - L_d$$

L_d and L_u are respectively the propagation losses along the radio path from the desired transmitter and from the undesired transmitter to the receiver and are based on free-space propagation conditions. L_d (dB) is calculated based on the DOR of the desired facility. The free-space propagation model is documented in Chapter 1, 1.3.2. If the separation between the desired receiver and the undesired transmitter is larger than the radio horizon of each station, the effect of the propagation beyond the radio horizon needs to be considered. The effect of beyond-the-radio horizon propagation is described in Chapter 1, 1.3.3, and Chapter 2, 2.2.5. The free-space propagation loss is calculated using formula (8) in Chapter 1, 1.3.2 as follows:

$$L_d = 37.8 + 20\log f + 20\log d_d$$

and

$$L_u = 37.8 + 20\log f + 20\log d_u$$

which brings

$$\frac{D}{U} = L_u - L_d = 37.8 + 20\log f + 20\log d_u - (37.8 + 20\log f + 20\log d_d) = 20\log d_u - 20\log d_d = 20\log\frac{d_u}{d_d} \quad (16)$$

Formula (16) demonstrates that the D/U signal ratio can be expressed as the ratio between the distance from the receiver

to the undesired transmitter and the distance to the desired transmitter under free-space propagation conditions.

For aeronautical VHF air-ground voice communication systems, ICAO SARPs specify that the D/U protection ratio for air-ground voice communication systems is 20 dB (signals-in-space). In areas with frequency congestion, a D/U protection ratio of 14 dB may be used.

Substituting in formula (16) D/U = 20 gives a separation distance ratio (d_u/d_d) of 10. If (in free-space) the distance from the receiver to the undesired transmitter is **10 times** larger than the distance to the desired transmitter (when both the desired and the undesired transmitter radiate with the same e.i.r.p.), the signal ratio of the desired signal to the undesired signal is 20 dB.

Substituting in formula (16) D/U = 14, gives a separation distance ratio (d_u/d_d) of 5. If (in free-space) the distance from the receiver to the undesired transmitter is **5 times** larger than the distance to the desired transmitter (when both the desired and the undesired transmitter radiate with the same e.i.r.p.), the signal ratio of the desired signal to the undesired signal is 14 dB.

Note.— Free-space propagation conditions only apply when the transmitter and the receiver are within radio line-of-sight of each other (within the radio horizon).The separation distance ratio (d_u/d_d) assumes equal e.i.r.p. of both the desired and the undesired transmitter station. See 2.3.1 for the application of the D/U ratio of 20 dB or of 14 dB.

2.2.3.2 The interference model described in 2.2.2 and the distance ratio method in 2.2.3 calculate (directly or indirectly) the desired signal level at the receiver antenna (or the receiver input). In these models, when the distance between the desired transmitter and receiver is decreased, the actual signal strength at the receiver increases and, while meeting the required D/U criteria, the distance from the undesired (interfering) transmitter to the receiver may be decreased.

Note.— The minimum signal level method, described in 2.2.4, is based on the protection of the minimum field strength throughout the DOC of the desired service. The frequency assignment planning constraints in this case are more restrictive.

2.2.3.3 Adjacent channel separation distance ratios can also be calculated using the separation distance ratio method. When calculation of the adjacent channel separation, formula 16 calculates:

$$\frac{D}{U} = L_u - L_d$$

For adjacent channel calculations, taking into account the ACR, this formula can be rewritten into:

$$\frac{D}{U} = (L'_u + ACR) - L_d$$

$$\boldsymbol{\frac{D}{U} = L_u - L_d = (L'_u + \mathrm{ACR}) - L_d = (20 \log d'_u + \mathrm{ACR}) - 20 \log d_d}$$

$$\boldsymbol{\frac{D}{U} - \mathrm{ACR} = 20 \log d'_u - 20 \log d_d = 20 \log \frac{d'_u}{d_d}};$$

$$\frac{d'_u}{d_d} = 10^{(\frac{D}{U} - \mathrm{ACR})/20}$$

Note.— d'_u is the distance from the undesired transmitter to the receiver.

The D/U ratio to be used (normally 20 dB) depends on the regionally agreed frequency assignment planning criteria.

2.2.3.4 The minimum geographical separation distance between facilities operating on the first adjacent channel (either 25 kHz or 8.33 kHz) is normally less than 3 NM. This has led to the conclusion that adjacent channels interference, which in most cases is transient in nature, should not be considered in frequency assignment planning for VHF air-ground voice communication (VHF COM) systems.

2.2.3.5 In a mixed environment where both 8.33 kHz and 25 kHz channels are being used, adjacent channel criteria apply (see 2.7.4). The method in 2.2.4 is recommended for determining adjacent channel separation.

2.2.3.6 The distance ratio method cannot be used for determining geographical separation distances for area services (e.g. ACC, FIR) or for cases where the transmitter is located well outside the centre of (or even outside) a circular service area.

2.2.4 Minimum signal level method

2.2.4.1 Annex 10, Volume III, specifies minimum field strength levels (signal-in-space) for the air-ground communication systems that can operate in the frequency band 112 – 137 MHz. Protection of aeronautical VHF air-ground communication systems is typically based on the principle that the minimum desired signal is not subject to harmful interference when the interfering (undesired) signal is 20 dB or more (or 14 dB, as required) below the specified minimum field strength (of the desired signal), in accordance with the provisions in Annex 10. As specified in Annex 10, Volume III, Part II, 2.2.1.2, the minimum field strength for VHF COM systems should be 75 μV/m throughout the DOC and as specified in Annex 10, Volume V, 4.1.4.1 and 4.1.4.2; the D/U ratio is either 20 dB or, where applicable, 14 dB.

Note.— These field strength levels, together with other relevant data such as typical values for ground and airborne transmitter power, are reproduced in Tables 2-1 and 2-2 (see 2.3.2).

2.2.4.2 When protecting only the minimum specified field strength level (which, from the frequency assignment protection point of view is the safest method), the method used for establishing co-frequency separation distances does not take into account the radiated energy of the desired transmitter but requires that the minimum specified RF signal throughout the DOC area is protected. Generally, this method provides for better protection compared to the distance ratio method described in 2.2.3.

2.2.4.3 The minimum signal level method is described in Chapter 1, 1.2.2.1.2, Figure 1-2 and is illustrated in Figures 2-3 and 2-5. In this method, protection of the desired signal from harmful interference requires that a signal from an undesired source (e.g. aircraft station **b** in Figure 2-3) at the desired receiver is sufficiently below the minimum signal level (75 μV/m) of the desired signal (and NOT the actual (desired) signal level as calculated in 2.2.2 and 2.2.3).

2.2.4.4 This model also applies to calculating separation distances when the desired receiver and the undesired transmitter are operating on adjacent frequencies. Due to the effect of RF selectivity of the desired receiver, the minimum separation distance in this case is less than when they are operating on the same frequency. The undesired (interfering) station can be an aircraft station or a ground station.

2.2.4.5 *Effect of the vertical polar diagram of VHF COM antennas*

2.2.4.5.1 The minimum signal level method assumes that the VHF COM facility radiates, in all directions, just enough power to achieve at the edge of the coverage area the minimum signal level as specified in Annex 10. In the system design for VHF COM systems, it should be secured that for the ground station the conditions of Annex 10 (which specify the minimum field strength) are met. Since the alternative (or simplified) model does not take into account the actual e.i.r.p. of the desired ground station (transmitter), no separation distance ratio criterion, as described in 2.2.2.4, can be developed.

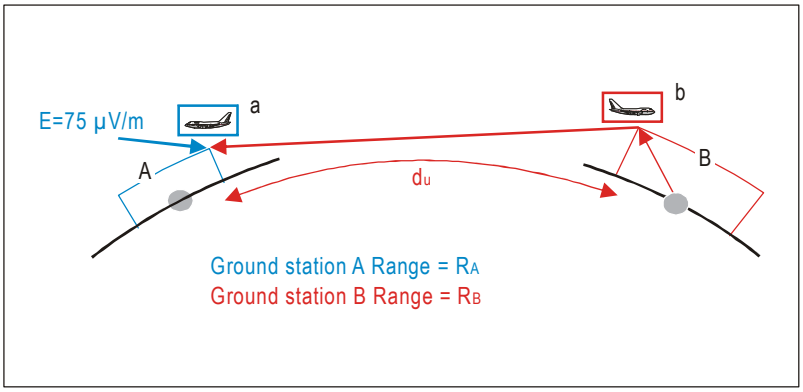

Figure 2-3. Model for establishing separation distances when minimum field strength is specified

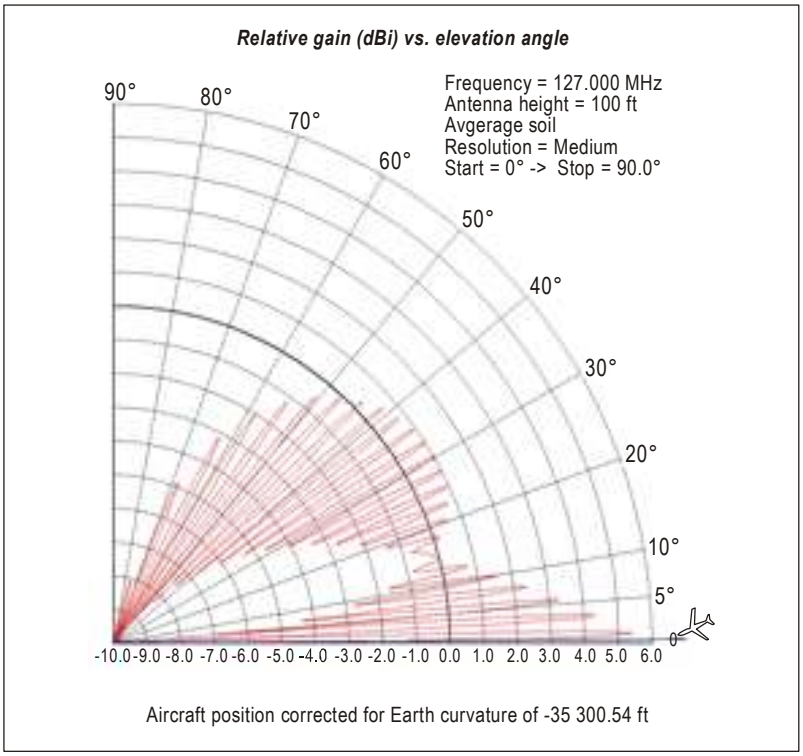

Figure 2-4. Vertical polar diagram of antenna 30 m above ground level

2.2.4.5.2 The minimum signal level method is recommended for use in particular when compatibility with dissimilar systems (e.g. VHF COM voice and VDL) has to be established.

2.2.4.6 The minimum signal level method requires that the signal level of the undesired (interfering) signal be calculated at the antenna of the receiver. The desired signal level is 75 µV/m. The D/U ratio (P_d – Pu (dBm)) is 20 (14) dB. The analysis below describes this method which is illustrated in the schematic diagram in Figure 2-5.

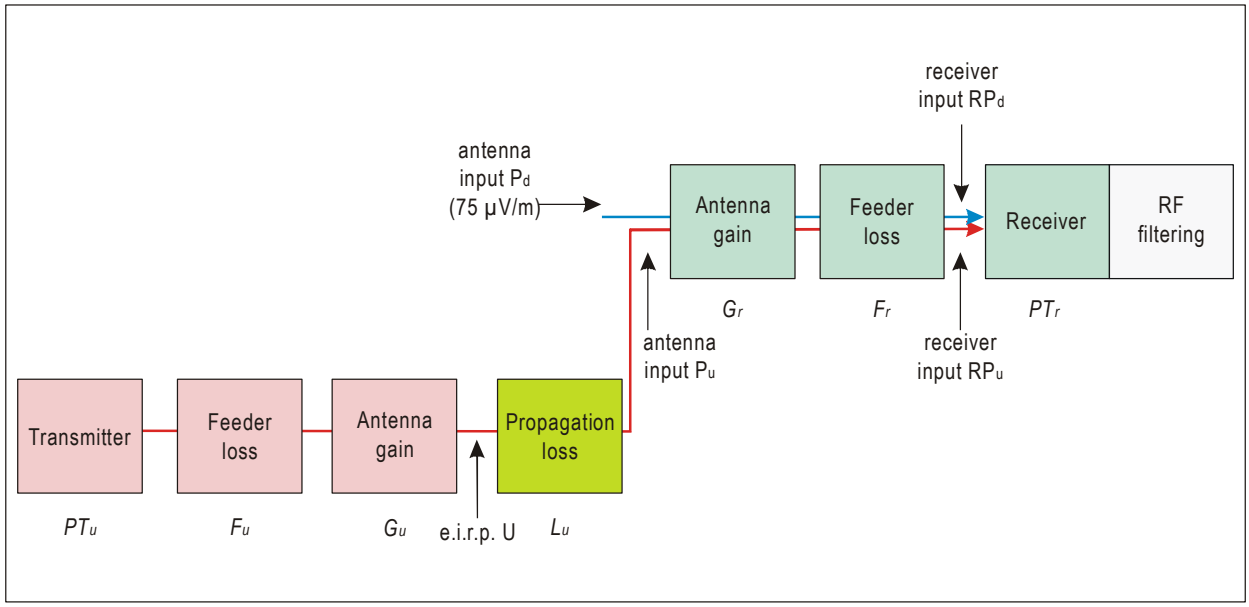

Figure 2-5. Minimum desired signal at antenna and undesired signal path to desired (victim) receiver antenna

2.2.4.7 The (desired) signal level *(P_d)* at the antenna is 75 µV/m (–82 dBm). The level of the undesired signal *(P_u)* (aircraft station **b** in Figure 2-3) is calculated using formula (15) in 2.2.2.5.

$P_d = 75\ \mu V/m = -82\ dBm$ (at the receiver antenna)

$P_u = PT_u - F_u + G_u - L_u$ (at the receiver antenna; P_{Tu} is for most transmitters typical 25 W)

For P_{Tu} = 25 W (44 dBm), F_u = 3dB and G_u = 0 dB,

$$P_u = 44 - 3 + 0 - L_u = (41 - L_u) dBm$$

$$\frac{D}{U} = 20\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L_u = -123\ dBm + L_u$$

$$L_u = 143\ dB$$

2.2.4.8 In this scenario (D/U = 20 dB), and assuming a typical transmitter power for the undesired aircraft transmitter of 25 W, the minimum separation distance between the desired receiver and the undesired (aircraft) transmitter needs to secure that the transmission losses over the radio path are 143 dB.

Formula (8) in Chapter 1, 1.3.2, calculates that for a free-space transmission loss of 143 dB (f = 127 MHz) a (free-space) distance of 1 428 NM is required. This distance is far greater than double the distance to the radio horizon for aircraft at an altitude of 45 000 ft (2*261 NM), as required by Annex 10. The effect of the radio horizon is described in 2.2.5. Calculations for establishing the minimum separation distance between facilities are in 2.7.

2.2.4.9 If the protection ratio is 14 dB (see 2.3.1), the required free-space transmission loss is calculated as follows:

$$\frac{D}{U} = 14\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L_u = -123\ dBm + L_u$$

$$\boldsymbol{L_u = 137\ dB}$$

Formula (8) in Chapter 1, 1.3.2 calculates that for a free-space transmission loss of 137 dB (f = 127 MHz) a (free-space) separation distance of 718 NM is required. This distance is greater than double the distance to the radio horizon for aircraft at a maximum altitude of 45 000 ft. The effect of the radio horizon is described in 2.2.5. Calculations for establishing the minimum separation distance between facilities are in 2.7.

Note.— When applying the minimum signal level method as described in this section, the application of a D/U of 14 dB or 20 dB has no (or a limited) effect on the minimum separation distance with a co-frequency interfering station since, in both cases, the free-space separation distance that is required to secure protection of the desired signal from harmful interference is more than the sum of the distances to the radio horizon of the respective facilities.

2.2.4.10 As described in 2.2.4.7, the minimum signal level method can also be used to calculate the adjacent channel separation distance as follows:

$P_d = 75\ \mu\text{V/m} = -82\ dBm$ (at the receiver antenna)

$P_u = PT_u - F_u + G_u - (L'_u + ACR)$ (at the receiver antenna)

Where the total transmission loss for the undesired signal $L_u = L'_u + ACR$

(ACR is +60 dB for the first adjacent channel)

For PT_u = 25 W (44 dBm), F_u = 3 dB and G_u = 0 dB,

$$P_u = 44 - 3 + 0 - L'_u - \text{ACR} = 41 - L'_u - \text{ACR}\ (dBm)$$

$$\frac{D}{U} = 20\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L'_u + \text{ACR} = -123 + L'_u + \text{ACR}\ (\text{dB})$$

$$L'_u = 123 + \frac{D}{U} - ACR \quad \text{(for the values of } P_d \text{ and } P_u \text{ above)}$$

If ACR = 60 dB (first adjacent channel rejection), $L_u = 63 + \frac{D}{U}$

$$L'_u = 37.8 + 20\log f + 20\log d_u = 83\ (dB)$$

For f = 127 MHz and D/U = 20 DB, L'_u = 1.4 NM

2.2.4.11 In a mixed environment where both 8.33 kHz and 25 kHz channels are being used, different adjacent channel criteria apply (see 2.7.4).

2.2.5 The effect of the radio horizon

2.2.5.1 The effect of the radio horizon on the (radio) path loss is shown in Figure 2-6.

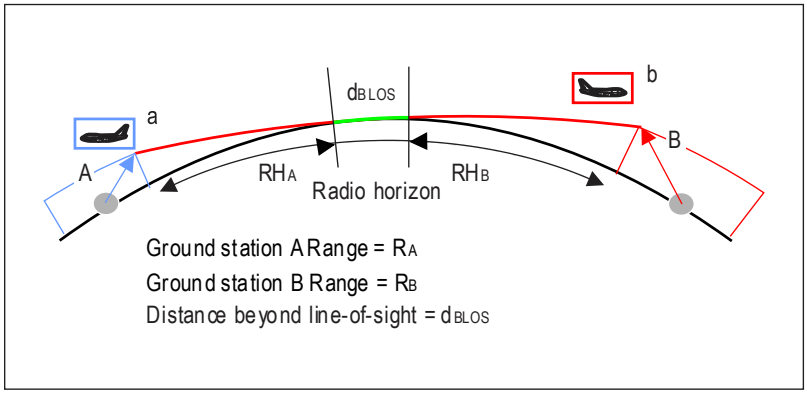

Figure 2-6. Propagation path greater than radio line-of-sight

2.2.5.2 In cases where minimum required free-space separation distance between the receiver and the undesired (interfering) transmitter, as calculated with the methods in 2.2.3 or 2.2.4, is greater than the sum of the distance to the radio horizon of the respective facilities, the calculation of the total minimum separation distance needs to include the conditions applicable to the "over the horizon" propagation. The radio signals over the horizon are attenuated at a much faster rate per nautical mile compared to free-space propagation. This is shown in the ITU propagation curves in Appendix A. For VHF frequencies, the attenuation beyond the radio horizon is 0.5 dB/NM (see Chapter 1, 1.3.3.1).

2.2.5.3 In the example given in Figure 2-6, the total free-space loss (propagation loss) between aircraft stations a and b is equal to the sum of the free-space attenuation of the path (RH_A + RH_B) to which the attenuation d_{BLOS} needs to be added.

Using formula (11) in Chapter 1, the total path loss between aircraft stations a and b as shown in Figure 2-3 can be calculated as follows:

$$L_{bf} = 37.8 + 20\log(RH_A + RH_B) + 20\log(f) + 0.5(d_{BLOS})$$

In this formula RH_A, RH_B and d_{BLOS} are expressed in NM; f is expressed in MHz. RH_A and RH_B can be calculated using formula (9) in Chapter 1.

2.2.6 Protection based on line-of-sight separation

2.2.6.1 When the minimum required separation between the DOC of facilities operating on the same frequency is larger than the sum of the distance to the radio horizon of each facility (to obtain the required D/U ratio (20 dB or 14 dB)) at the edge of coverage (maximum range and maximum height), the frequency assignment planning criteria for co-frequency assignment planning, as contained in Annex 10, Volume V, 4.1.4, require that the DOC areas for each facility be separated by no less than the sum of the distances to the radio horizon of each facility.

2.2.6.2 This implies that when the separation distance is indeed determined by the sum of the distance to the radio horizon of the respective facilities, the required D/U protection ratio is not met in a small area at the closest points between the two DOC areas. It is, however, recognized that it is highly unlikely that two aircraft will be at the closest point at the edge of each DOC area at the same time. The size of the small area depends on the dimensions of the DOC of the two facilities.

2.2.6.3 In some specific cases, however, as described in 2.7, the effect of propagation beyond the radio horizon has to be considered when establishing geographical separation distances.

Note.— The calculation of minimum separation distances for various air-ground communication services is described in 2.7 and 2.8.

2.3 FREQUENCY ASSIGNMENT PLANNING CRITERIA

Note.— This section describes the frequency assignment planning criteria for VHF air-ground voice communication systems. Frequency assignment planning criteria for the VHF air-ground data link (VDL Mode 2 and VDL Mode 4) are in 2.9.

2.3.1 General planning criteria

2.3.1.1 Provisions concerning the deployment of VHF frequencies and the avoidance of harmful interference are contained in Annex 10, Volume V, Chapter 4, 4.1.4.

2.3.1.2 For co-frequency assignments, the minimum geographical separation between facilities shall be such that the DOC of each facility is separated by a distance not less than:

a) that required to provide a D/U ratio of 20 dB; or

b) the sum of the distance to the radio horizon of the DOC area of each facility.

Alternatively, in areas where the frequency congestion is severe, a protection ratio of 14 dB can be used on the basis of a regional air navigation agreement.

Note 1.— Facilities using a common frequency do not require frequency protection between each other (e.g. extended range facilities).

Note 2.— The distance to the radio horizon is calculated as shown in Chapter 1, 1.3.2, with the formula:

$$d_{RH} = 1.23\left(\sqrt{h}\right)$$

where:

d_{RH}*:* *the distance of the station to the radio horizon (NM)*

h*:* *the height of the transmitter or receiver above the Earth's surface (feet)*

2.3.1.2.1 The application of the minimum separation distance based on the sum of the radio horizon distance of each facility assumes that it is highly unlikely that two aircraft will simultaneously be at the closest points between the two facilities and at the maximum altitude of the frequency protected service volume of each facility.

2.3.1.2.2 Details on the calculation of separation distances are in 2.7. Paragraph 2.8 contains separation distances for the uniform DOC for aeronautical services as identified in 2.6.

2.3.1.2.3 The separation distance is calculated for aircraft operating at the maximum range and maximum height of the DOC.

2.3.1.2.4 In cases where broadcast services (VOLMET) are involved, the minimum geographical separation distance required to obtain a protection ratio D/U of 20 dB is established relative to the ground broadcast transmitter.

2.3.1.3 For adjacent frequency assignments, the minimum geographical separation between facilities shall be such that each facility is separated by a distance sufficient to ensure operations free from harmful interference.

Note 1.— The edge of the DOC is at the maximum range and maximum height.

Note 2.— For facilities operating with 25 kHz or 8.33 kHz channel spacing, no geographical separation is required (see 2.7.4).

Note 3.— Protection is based on an ACR of 60 dB with the first assignable 25 kHz or 8.33 kHz channel.

Note 4.— In a mixed environment, where both 25 kHz and 8.33 kHz channel spacings are deployed, the adjacent channel separation as shown in Table 2-6 is to be applied when making frequency assignments.

2.3.2 Typical signal parameters

2.3.2.1 Tables 2-1 and 2-2 contain typical values for ground and airborne transmitter power that can be used in a detailed compatibility assessment.

Table 2-1. Typical values for various parameters for VHF communication systems (transmitter)

Parameter	*DSB-AM*	*DSB-AM*	*VDL-M2*	*VDL-M2*	*VDL-M3*	*VDL-M3*	*VDL-M4*	*VDL-M4*
TRANSMITTER	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*
Output power transmitter (typical ground station output power is 25 W or 50 W (44 dBm or 47 dBm)	44 dBm (25 W)	50 dBm (100 W)	42 dBm (16 W)	44 dBm (25 W)	44 dBm (25 W)	44 dBm (25 W)	42 dBm (15 W)	45 dBm (32 W)
Feeder loss (assumed)	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB
Antenna gain (assumed)	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB
e.i.r.p.	41 dBm (12.5 W)	49 dBm (80 W)	39 dBm (8 W)	43 dBm (20 W)	41 dBm (12.5 W)	43 dBm (20 W)	40 dBm (10 W)	44 dBm (25 W)
Adjacent frequency emissions (transmitter) for VDL specified in Annex 10, Volume III, Part I, 6.3.4.								
1st adjacent frequency (16 kHz bandwidth)	Not specified in Annex 10		–18 dBm	–18 dBm	–18 dBm	–18 dBm	–18 dBm	–18 dBm
2nd adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–28 dBm	–28 dBm	–28 dBm	–28 dBm	–28 dBm	–28 dBm
4th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–38 dBm	–38 dBm	–38 dBm	–38 dBm	–38 dBm	–38 dBm
8th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–43 dBm	–43 dBm	–43 dBm	–43 dBm	–43 dBm	–43 dBm
16th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–48 dBm	–48 dBm	–48 dBm	–48 dBm	–48 dBm	–48 dBm
32nd adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–53.dBm	–53.dBm	–53.dBm	–53.dBm	–53.dBm	–53.dBm

Table 2-2 Typical values for various parameters for VHF communication systems (receiver)

Parameter	DSB-AM	DSB-AM	VDL-M2	VDL-M2	VDL-M3	VDL-M3	VDL-M4	VDL-M4
RECEIVER	Airborne	Ground	Airborne	Ground	Airborne	Ground	Airborne	Ground
Minimum signal at receiver antenna Annex 10, Volume III	75 µV/m (–82 dBm) Part II, 2.2.1.2	20 µV/m (–93 dBm) Part II, 2.3.1.2	75 µV/m (–82 dBm) Part I, 6.2.2.	20 µV/m (–93 dBm) Part I, 6.3.2	75 µV/m (–82 dBm) Part I, 6.2.2.	20 µV/m (–93 dBm) Part I, 6.3.2	75 µV/m (–82 dBm) Part I, 6.9.5.1.1.2	35 µV/m (–88 dBm) Part I, 6.9.5.1.1.1
Feeder loss	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB
Antenna gain	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB
Minimum signal at receiver input	–85 dBm	–94 dBm	–85 dBm	–94 dBm	–85 dBm	–94 dBm	–85 dBm	–89 dBm
Out-of-band immunity performance of receiver as per Annex 10, Volume III, Part I, 6.3.5.3 (VDL) and Volume III, Part II, 2.3.2.8 (DSB-AM).								
1st adjacent channel	–	–	–40 dB	–40 dB	–40 dB	–40 dB	–40 dB	–40 dB
4th adjacent channel	–50 dB	–50 dB	–60 dB	–60 dB	–60 dB	–60 dB	–60 dB	–60 dB

2.3.2.2 Conversion from input power (dBm) to field strength (µV/m and vice versa) was calculated using the following formula (17):

$$P_r = E - 20\log f - 167.2 \quad (17)$$

where:

Pr: is isotropically received power (dB(W))

E: is the electric field strength (dB(µV/m)

F: is the frequency (GHz) (ITU-R Recommendation P.525-2 refers)

This formula can be rewritten into:

$$10\,log\,P_r = 20\,log\,E - 20\,log\,f - 77.2 \quad (18)$$

where:

P_r: is the signal at receiver antenna (in space) in mW

E: is the field strength at the antenna in µV/m

F: is the frequency f in MHz

[dB(µV/m) = 20log(µV/m)]

$10\log P_r$ is expressed in dBm (power relative to 1 milliWatt).

Note.— The typical transmitter power of ground stations can vary from 10 – 100 W.

2.4 ALLOTMENT OF THE FREQUENCY BAND 117.975 — 137 MHz

2.4.1 SPECIAL FREQUENCIES

2.4.1.1 Annex 10, Volume V, Chapter 4, 4.1.1 and Table 4-1 contain a general allotment of the frequency band 117.975 – 137 MHz. The main subdivisions of this band are the frequency bands allocated to both international and national services and frequency bands solely allocated to national services. Specific allotments to services are to be determined regionally. Appendices B and C contain these regionally agreed allotment plans. In practice, not much consideration is given to the allotments for national/international use (see Figure 2-7).

Note.— Frequency assignments for international use are those that are required as per regional Air Navigation Plan. These frequencies are identified by "ICAO" in the frequency assignment plan. Other frequencies are for national use and are identified as "NAT" in the frequency assignment plan.

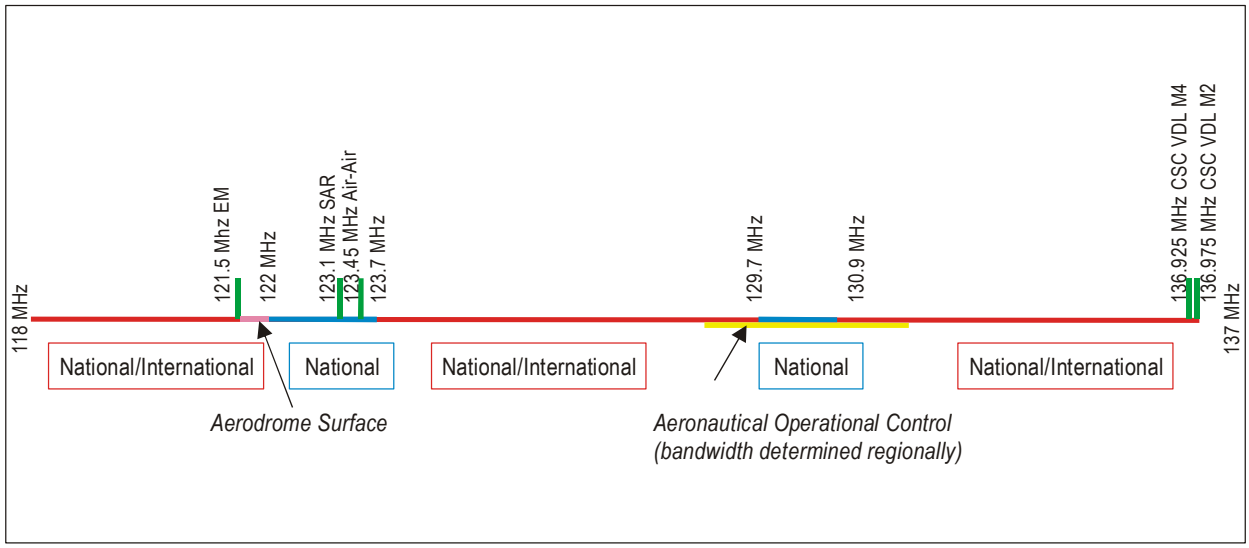

Figure 2-7. Special frequencies and allotments (Annex 10)

2.4.1.2 Annex 10, Volume V, includes provisions for the use of specific frequencies which are shown in Figure 2-7 and Table 2-3 as follows:

Table 2-3. Frequency allotment and special frequencies

Frequency (MHz)	*Usage*	*Comments*	*Annex 10, Volume V*
121.500	Aeronautical emergency frequency	Guard band* 121.450 – 121.550 MHz	4.1.3.1
121.550 – 122.917	Aerodrome surface communications		–
123.100	Auxiliary frequency (SAR)	Guard band* 123.050 – 123.150 MHz	4.1.3.4
123.450	Air-to-air communications	Outside range of VHF stations	4.1.3.2
128.825 – 132.025	Aeronautical operational control	Range to be determined regionally**	4.1.6.1.2 Recommendation
136.925	Common signalling channel	Reserved for VDL Mode 4	4.1.3.3.2
136.975	Common signalling channel	Reserved for VDL Mode 2	4.1.3.3.1
136.500 – 136.975	Only for frequency assignments with 25 kHz channel spacing		4.1.6.1, Note 1

* The frequencies 121.450 MHz, 121.550 MHz, 123.050 MHz and 123.150 MHz are assignable frequencies.

** Regional allotment plans have determined the actual band for aeronautical operational control communications.

2.4.1.3 Regional allotment plans provide for the use of the frequency band 136 – 137 MHz by VDL (VDL Mode 2 and VDL Mode 4).

2.4.2 Regional allotment plans

2.4.2.1 In addition to the general allotment plan in Annex 10, all regions have developed more detailed allotment plans through which operational services are allotted to certain frequency bands and are included in relevant ICAO Air Navigation Plans (ANP). The prime goal of these allotment plans is to accommodate new frequency assignments in the sub-bands allotted to a particular service. Appendix B and the supplement (published separately) to this Handbook contain a detailed overview of these allotment plans. The supplement can be downloaded at: http://www.icao.int/safety/fsmp/documents/doc9718.

2.4.2.2 Frequency assignments should preferably be made in accordance with the provisions of the regional allotment table. However, if a particular requirement for a frequency assignment cannot be made from within the sub-band that is allotted to the relevant service, other sub-bands can be considered to satisfy the requirement. The regional frequency allotment plans also include provisions for sub-bands for aeronautical operational control (AOC) communications.

2.4.2.3 Regional allotment plans provide the use of the frequency band 136 – 137 MHz by VDL (VDL Mode 2 and VDL Mode 4). In Europe, the frequency band 136.700 – 137.000 MHz is reserved for VDL (see Appendices B and C).

2.5 FREQUENCY SEPARATION AND CHANNELLING

2.5.1 Frequency separation between VHF COM channels

2.5.1.1 Annex 10 stipulates that the minimum separation between assignable frequencies in the aeronautical mobile (R) service shall be 8.33 kHz (see Annex 10, Volume V, 4.1.2.2). This provision recognizes that in regions or areas where 25 KHz channel spacing provides an adequate number of frequency assignments to meet national and international requirements, for equipment designed for 25 kHz channel spacing, will continue to be used and continue to be protected. The introduction of 8.33 kHz channel spacing in regions or areas requires a regional air navigation agreement for the mandatory carriage of equipment designed for 8.33 kHz channel spacing.

2.5.1.2 Currently, 8.33 kHz frequency separation has only been introduced in the EUR region. All other regions have agreed to base frequency assignment planning on 25 kHz frequency separation. This implies that radio equipment designed for 50 kHz or 100 kHz frequency separation, which may be still in operational use, may not always be protected from harmful interference that can be caused by stations operating on adjacent 25 kHz or 8.33 kHz frequencies.

2.5.2 Protection of 25 kHz frequency assignments from 8.33 kHz assignments

In regions that continue operating communication equipment designed for a frequency separation of 25 kHz, frequency assignments are protected from harmful interference from the use of frequencies operating on multiples of 8.33 kHz, both within the same region as well as in adjacent regions (see Annex 10, Volume V, 4.1.2.3, Note and 4.1.6.1, Note 2).

2.5.3 Channelling

Normally, in aviation (e.g. in radiotelephony), the frequency in use is identified by the actual frequency. When using 8.33 kHz frequencies, the frequency identification for 8.33 kHz frequencies is replaced with a channel identification using a number (similar to the identification of a frequency) which is mapped to the actual frequency in use. The channel/frequency identification to be used for identifying frequencies with a channel spacing of 8.33 kHz is as shown in Table 2-4.

Table 2-4. Channelling/frequency pairing for frequencies with 25 kHz and 8.33 kHz separation

Frequency (MHz)	*Frequency separation (kHz)*	*Channel*
118.0000	25	118.000
118.0000	8.33	118.005
118.0083	8.33	118.010
118.0167	8.33	118.015
118.0250	25	118.025
118.0250	8.33	118.030
118.0333	8.33	118.035
118.0417	8.33	118.040

Frequency (MHz)	*Frequency separation (kHz)*	*Channel*
118.0500	25	118.050
118.0500	8.33	118.055
118.0583	8.33	118.060
118.0667	8.33	118.065
118.0750	25	118.075
118.0750	8.33	118.080
118.0833	8.33	118.085
118.0917	8.33	118.090
118.1000	25	118.100
etc.		

2.6 SERVICES AND DESIGNATED OPERATIONAL COVERAGE (DOC)

2.6.1 Services

Frequency assignments are made to implement specific aeronautical services, as follows:

Aerodrome

AS	Aerodrome surface communications
AFIS	Aerodrome flight information service
TWR	Aerodrome control tower

Approach

APP	Approach control service
ATIS	Automatic terminal information service
PAR	Precision approach radar

En route

ACC	Area control centre
FIS	Flight information service

Other functions

A/A	Air-to-air
A/G	Air-to-ground
AOC	Aeronautical operational control
BC	(ground) broadcast communications
EM	Emergency
GP	VHF En-Route General Purpose
RGA	Regional Guard
SAR	Search and rescue
VOLMET	Meteorological information for aircraft in flight

2.6.2 Coordination of special frequencies

No coordination of frequency assignment planning is necessary for the emergency frequency 121.500 MHz and the SAR frequency 123.100 MHz as these services are available globally at each station where this service is required. The provisions in Annex 10 include a guard band for these frequencies to prevent adjacent channel interference. Also, no specific frequency assignment planning is required for the air-to-air communication channel 123.450 MHz as this channel is to be used only in remote and oceanic areas when the aircraft is out of the coverage of VHF ground stations.

2.6.3 Table of uniform values for designated operational coverage (DOC)

2.6.3.1 Frequencies for aeronautical radio communication services are (normally) implemented to satisfy the operational need for specific services. These services, and their uniform DOC areas, are as in Table 2-5.

Table 2-5. Table of uniform designated operational coverage (DOC)

Service	*Designated operational coverage (DOC)*		*Comments*	*Mode*
	Range (NM)	*Height (ft)*		
Aerodrome				
TWR	25	4 000	Height above ground	A/G
TWR/L	16	3 000	Height above ground; only in EUR	
PAR	25	4 000	Height above ground	A/G
AFIS	25 EUR: 15	4 000 EUR: 3 000	Height above ground	A/G
AS	Limits of aerodrome	Surface		A/G
Approach				
APP–L	50 EUR: 25	12 000 10 000		A/G
APP–I	75 EUR: 40	25 000 EUR: 15 000		A/G
APP–U	150 EUR: 50	45 000 EUR: 25 000		A/G
En-Route				
ACC–L	Area	25 000	Within specified area; maximum recommended range is 155 NM	A/G

Service	*Designated operational coverage (DOC)*		*Comments*	*Mode*
	Range (NM)	*Height (ft)*		
ACC-LL	EUR: Area	15 000	Within specified area; maximum recommended range is 120 NM	
ACC-I	Area	25 000 EUR: 35 000	Within specified area; maximum recommended range is 130 NM Within specified area; maximum recommended range is 185 NM	A/G
ACC–U	Area	45 000	Within specified area; maximum recommended range is 200 NM	A/G
FIS-L	Area	25 000	Within specified area; maximum recommended range is 155 NM	A/G
FIS or FIS-U	Area	45 000 EUR: 23 000	Within specified area; maximum recommended range is 200 NM Within specified area; maximum recommended range is 120 NM	A/G
VOLMET	200	45 000	Maximum recommended range is 200 NM	BC
Other functions				
ATIS	200 EUR: 60	45 000 EUR: 20 000		BC
A/A	200	45 000	Maximum recommended range is 200 NM	A/G
A/G	200	45 000	Maximum recommended range is 200 NM	A/G
AOC	100	250	Not protected; maximum recommended range is 100 NM	A/G
EM	N/A	N/A	No frequency coordination required	A/G
SAR	N/A	N/A	No frequency coordination required	A/G
GP	200	45 000	Maximum recommended range is 200 NM	A/G

Note 1.— Different DOC areas may be specified by States.

Note 2.— DOC for AOC-only provided to enable compatibility assessment when frequencies for AOC are shared with ATC services; different DOC may be specified.

Note 3.— For area services, no frequency protection is provided outside the specified area.

Note 4.— Unless specified by States, the DOC for A/A and A/G is assumed at 45 000 ft/200 NM.

Note 5.— Mode: A/G: air-ground communications; BC: (ground) broadcast communications.

2.6.3.2 Additional functionality concerning the use of these services in the column “comments” may be added to the services as follows:

CD: Clearance delivery

CTA: Control area

DF: Direction finding

ER: Extended range

PAR: Precision approach radar

RCAG: Remote controlled air-ground communication

SR: Surveillance radar

These additions do not alter the basic service or the DOC for which the frequency is required and should be included as a remark to the frequency assignment in the COM list in the global table of frequency assignments. Certain services may not require protection because they are not in operation to provide safety-of-life service (e.g. for gliders, hot air balloons). However, when these services are shared with ATC services, a compatibility analysis is required (see also 2.7.2.5.3).

2.6.3.3 Non-standard DOC (range and height) may be implemented as and when required. Reduced DOC, where operationally acceptable, may alleviate frequency congestion.

2.6.3.4 The use of common frequencies, preferably region-wide, to satisfy requirements for specific non-protected applications such as light aviation, gliding and hot air balloon activities is recommended, as such use increases the efficiency in frequency assignment planning.

2.6.3.5 Frequencies for aeronautical operational control are not protected through frequency planning. These frequencies are normally assigned on the basis of the traffic load that is expected (e.g. within the same area, smaller airlines can share the same frequency for operational control purposes).

2.6.4 Coverage at very low angles from the ground transmitter

2.6.4.1 Due to the vertical polar diagram of the antenna of the ground station, at very low angles the radiation of the transmitted energy is too low to provide coverage over a large area. Also, the distance to the aircraft decreases if the angle of the radio path with the horizontal plane through the ground antenna increases. As an example, for an aircraft operating at 45 000 ft, the distance to the ground transmitter decreases as shown in Table 2-6 (4/3 Earth radius).

Table 2-6. Distance as function of angle above horizon

Angle (degree)	*Distance (NM) Height: 45 000 ft*	*Distance (NM) 25 000 ft*	*Distance (NM) 4 000 ft*
0 (radio horizon)	261	195	78
.1	252	186	70
.2	245	178	63
.3	237	171	57
.4	230	164	52
.5	223	158	74
.6	217	152	43
.7	210	146	40
.8	204	140	37
.9	198	135	34
1	192	130	32

The geometry used in these calculations is shown in Figure 2-8.

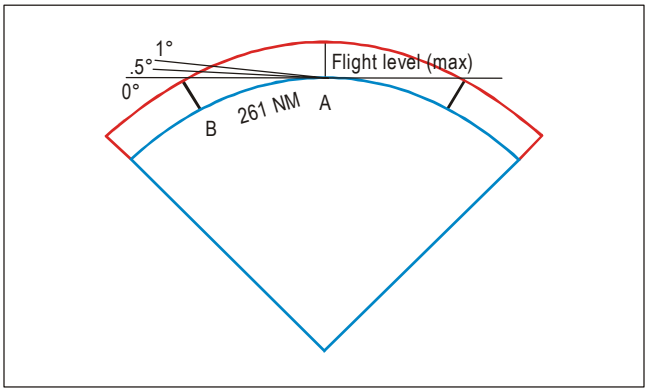

Figure 2-8. Range as function of angle above horizon

2.6.4.2 On the basis of the principles in 2.6.4.1, for certain services no actual maximum DOR has been specified; and the maximum operational range within which frequency protection is provided can be about 80% of the distance to the radio horizon. For some of these services, a maximum operational range has been incorporated in Table 2-5.

2.6.4.3 It is recognized that States may require different values for the DOC from the uniform values in Table 2-5 for certain services.

Note.— Application is to be decided on a regional level.

2.6.5 Interference from FM broadcasting stations

The risk of interference from FM broadcasting stations operating in the band 87 – 108 MHz is generally not considered for frequency assignments in the band 117.975 – 137 MHz.

2.6.6 Co-location of facilities

ICAO frequency assignment planning does not include protection against interference that may be caused if facilities are co-located (e.g. interference due to intermodulation products). During the installation of COM systems, the COM service provider needs to take measures to prevent such cases of interference (e.g. by using cavity filters).

2.6.7 Coordination of frequency assignments

Frequency coordination must take place with all States that may be affected by a proposal for a new frequency assignment or where the characteristics of an existing assignment are modified. Normally, such coordination is effected through the ICAO Regional Offices which have a central and coordinating role in frequency assignment planning.

2.7 CALCULATION OF SEPARATION DISTANCES (METHODOLOGY)

Note.— The material in this section can be used in cases where frequency assignment planning needs to consider systems with only 25 kHz or 8.33 kHz frequency separation to secure co- and adjacent frequency compatibility. Paragraph 2.7.4 contains material that can be used when there is a need to establish separation distances to secure compatibility between systems operating with 25 kHz and 8.33 kHz characteristics.

2.7.1 Frequency and/or distance separation

2.7.1.1 Protection of frequency assignments from harmful interference is achieved through frequency and/or distance separation. Normally, the determining factor in frequency assignment planning is the risk of interference between two aircraft operating within different DOC areas at the closest point. As normally the ground station is located well within the DOC area, the ground station is protected when the aircraft (receiver) is protected from harmful interference.

2.7.1.2 The separation distances provided in this section are the minimum distances that need to be maintained between the ground stations that provide the relevant service. The separation distances have been established using the method and provisions in 2.2 and 2.3 and comply with the frequency assignment planning criteria as specified in Annex 10, Volume V. Practical values for the separation of co-frequency facilities are in 2.8.

2.7.2 Co-frequency separation distances

2.7.2.1 *Air-ground communication services*

Protection of co-frequency assignments for air-ground communication services (involving aircraft transmissions) is obtained by securing that the D/U ratio is in accordance with the regionally agreed value. The D/U ratio can be either 14 dB or 20 dB (see 2.3).

2.7.2.2 *Circular service areas*

When the separation distance is based on D/U = 20 dB or radio line-of-sight distance:

As described in 2.3 and as per the requirements of Annex 10 the minimum *required* separation distance from the edge of the DOC (of the desired) ground station to another (undesired) aircraft, operating on the same frequency (and outside the desired DOC), should be no less than the sum of the distance to the radio horizon from each aircraft station. As shown in Figure 2-9, the minimum distance between the DOC of the service areas is equal to:

$$RH_A + RH_B$$

The distance to the radio horizon can be calculated using formulae (9) or (10) in Chapter 1, 1.3.2. In these formulae, the factor h_{TX} and or h_{RX} is the designated operational height of the respective DOC areas.

As shown in Figure 2-9, when the ground stations (with circular coverage and the ground stations located approximately at the centre of this coverage area) have a DOR of R_A and R_B respectively and RH_A and RH_B is the distance from the respective aircraft to the radio horizon, the minimum separation distance between the ground stations is:

$$R_A + RH_A + RH_B + R_B.$$

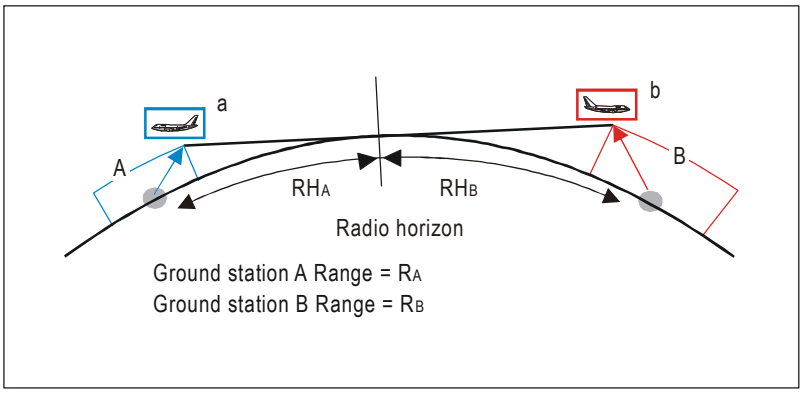

Figure 2-9. Separation based on radio line-of-sight

When the separation distance is based on D/U = 14 dB (1:5 separation distance ratio) or radio line-of-sight:

As described in 2.2.2 and as per the requirements of Annex 10 the minimum *required* geographical separation distance between the edges of the DOC areas can be calculated with the separation distance ratio method as follows (this method has been implemented in Europe and North America):

To meet the 14 dB protection requirement, the distance between the (desired) aircraft receiver and the (interfering) aircraft transmitter needs to be at least 5 times the distance between the (desired) aircraft receiver and the desired ground station in case all transmitters use the same e.i.r.p. (see 2.2.3).

In Figure 2-10, the DOR for ground station **A** is R_A and for ground station **B** is R_B. Aircraft stations **a** and **b** operate at the closest point and at the edge of the respective DOC areas. If the (minimum) separation distance from aircraft station **a** to aircraft station **b** is at least 5 times the distance from aircraft station **a** to ground station **A** ($5*R_A$), then aircraft station **a** is protected (14 dB) from interference from aircraft station **b**. Vice versa, if the distance from aircraft station **b** to aircraft station **a** is at least 5 times the distance from aircraft station **b** to ground station **B** ($5*R_B$), then aircraft station **b** is protected from interference from aircraft station **a**. The minimum required separation distance between the two DOC areas **A** and **B** is the largest of:

$$(Max)\ [5*R_A \text{ or } 5*R_B]$$

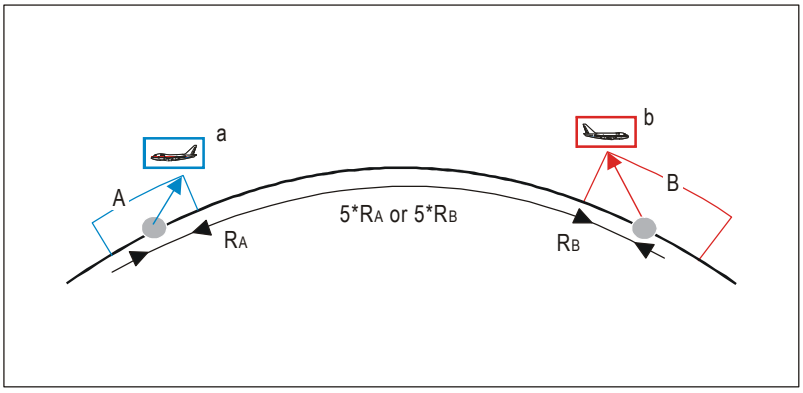

Figure 2-10: Separation distance based on the 5:1 distance ratio

The minimum separation between the ground stations (with circular coverage for **A** and **B** and the ground stations located in the approximate centre of the DOC) is the larger value of:

$$(Max)\ [\ (R_A + 5R_A + R_B) \text{ or } (\ R_A + 5R_B + R_B)]$$

In cases where the value (Max) [$5*R_A$ or $5*R_B$] is larger than the sum of the distances to the radio horizon of each facility **($RH_A + RH_B$) as described** in 1.3.3.1 and 2.2.5, the radio line-of-sight criterion should be used. The minimum total *required* separation distance between closest points at the edges of the respective coverage areas is therefore:

$$(Min)\ \{[RH_A+RH_B] \text{ or } (Max)\ [5R_A \text{ or } 5R_B]\}$$

Note 1.— In both the above cases, the edge of the DOC area is the point where the aircraft can operate at maximum DOR and height. Application of the 5:1 distance ratio assumes that the e.i.r.p. of both the desired station and the undesired/interfering station are the same. Where the e.i.r.p. of the transmitters is different, adjustments to the 5:1 distance ratio are necessary (see 1.3.4).

Note 2.— The application of the 5:1 distance ratio in frequency assignment planning is not recommended for area services or for services with circular DOC when the ground station is located well outside the centre of the circular service, since in these cases the worst case where the 5:1 distance ratio needs to be met is not always the closest point between the DOC areas being considered. In addition, it should be recognized that the benefits for efficient frequency assignment planning using the 5:1 distance ratio are marginal. Only in areas where frequency congestion is becoming desperate, the use of the 5:1 distance ratio for frequency assignment planning should be considered.

*Note 3.— In both the above cases, once protection of the aircraft receiver **a** is secured, the ground station is protected from harmful interference (from aircraft station **b,** since the ground station is well beyond the radio horizon of aircraft station **b**.*

2.7.2.3 *Area services — co-frequency separation distances*

2.7.2.3.1 The minimum separation distance between the DOC of two area services is equal to the sum of the radio line-of-sight for each area service at the limit of the DOC (coverage). This method provides frequency protection throughout the DOC of the area service and establishes for each of the area services a buffer zone equal to the distance to the radio horizon for an aircraft at maximum altitude of the relevant DOC. The minimum separation to protect the two area services from harmful interference is established at the closest point between the service areas.

2.7.2.3.2 In many cases, for large DOC areas of area services, a single ground station cannot provide coverage throughout the service area. In these cases, where required, additional coverage is provided through installing extended range stations (forward relay). These stations can operate on the same frequency (using the offset carrier system as specified in Annex 10, Volume III) or on a discrete frequency. Full VHF coverage may not be provided in all cases, in particular for lower flight levels.

2.7.2.3.3 When the same frequency used by an area service is also used by a broadcasting service (which is a circular service), the minimum separation is the larger value of the following:

a) To protect the aircraft receiver at the edge of the area coverage, the minimum distance to the ground broadcast transmitter should be at least the distance to the radio horizon + 15 NM from the limit of the DOC of the area service.

b) The minimum distance from the aircraft broadcast receiver to the airborne transmitter at the edge of the area service should be at least the sum of the distance to the radio horizon (radio line-of-sight) for each aircraft. The minimum distance from the edge of the DOC of the area service to the broadcast transmitter should be at least the sum of the distance to the radio horizon for each aircraft plus the range of the broadcast station.

2.7.2.3.4 The methodology for establishing the minimum separation distances is also applied in 2.7.3 and 2.7.4. However, in order to secure protection of area services throughout the DOC, separation distances for area services are measured from the limit of the DOC rather than from the ground station(s) providing the area service.

2.7.2.3.5 As pointed out in Note 2 to 2.7.2.2, the use of the 5:1 distance ratio for co-frequency assignment planning for area services is not recommended.

2.7.2.4 *Broadcast services (ATIS and VOLMET)*

2.7.2.4.1 Broadcast services such as ATIS and VOLMET are characterized by ground-to-air transmissions only and do not involve airborne transmissions. Consequently, only interference from the (undesired) ground broadcast station needs to be considered; due to the continuing nature of the broadcast transmissions, protection of the (desired) signal down to the muting level of the receiver is necessary.

2.7.2.4.2 A VOLMET (ATIS) broadcast station normally has a maximum DOR of 200 NM and a maximum designated operational height of 45 000 ft (see 2.6.3 and Table 2-5). For an (undesired) VOLMET transmitter with an e.i.r.p. of 100 W, the field strength at the (desired) aircraft, when the VOLMET station is 15 NM beyond the radio horizon of the (desired) aircraft, will be approximately at the receiver muting level of 5 µV/m (–105.6 dBm).

2.7.2.4.3 The DOC for these broadcast stations is normally the maximum that can be achieved (200 NM at flight level 450). The interference mechanism is shown in Figure 2-11.

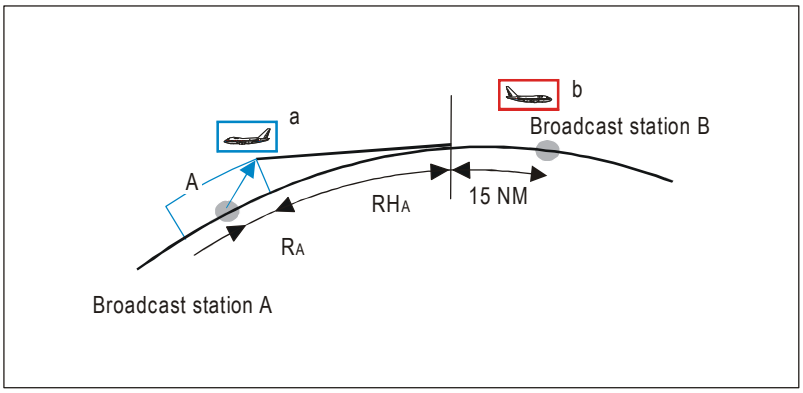

Figure 2-11. Interference mechanism between broadcast services

The minimum separation distance between two (ground) broadcast stations is:

$$R_A + RH_A + 15 \text{ (NM)}$$

To secure compatibility when ground station **B** is the wanted broadcast station and aircraft station **b** is the desired receiving aircraft station, the minimum separation distance between the (ground) broadcast stations A and B is:

$$R_B + RH_B + 15 \text{ (NM)}$$

To secure compatibility between the two broadcast stations, the minimum separation distance to be maintained between the ground broadcast stations A and B respectively is the larger value of:

$$(Max)\ RH_A + R_A + 15 \text{ or } RH_B + R_B + 15$$

where:

R_A: is the DOR for ground broadcasting station **A**

R_B: is the DOR for ground broadcasting station **B**

RH_A: is the distance to the radio horizon of aircraft station **a**

RH_B: is the distance to the radio horizon of aircraft station **b**

(Distances in NM)

The minimum separation distances between the edge of the DOC of each facility is 15 NM.

2.7.2.5 *Broadcast and air-ground services*

2.7.2.5.1 To protect an aircraft station receiving broadcasts from a ground station from another station providing air-ground communications, the mechanism as shown in Figure 2-12 applies.

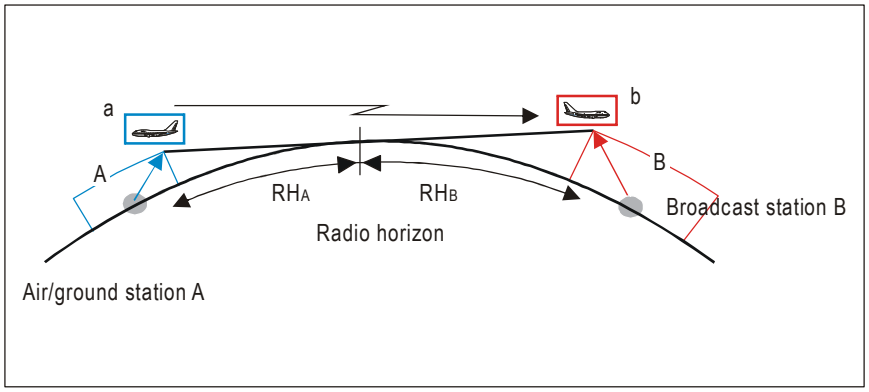

Figure 2-12. Interference mechanism between broadcast services and air/ground services

2.7.2.5.2 In order to protect aircraft station **b**, which is receiving (only) broadcast information from ground broadcast station **B** (e.g. VOLMET or ATIS), from interference that can be caused by transmissions from aircraft station **a**, the same methodology as described in 2.7.2.2 applies (separation distances are calculated if both the undesired and the desired stations provide air-ground communication services).

2.7.2.5.3 To protect aircraft station **a** from interference that can be caused by (ground) broadcast station **B**, the minimum separation between the two ground stations needs to be (see 2.7.2.4):

$$R_A + RH_A + 15\ NM$$

However, the distance to protect aircraft station **b** from interference from transmissions from aircraft station **a** is always greater than the distance to protect aircraft station **a** from interference that can be caused by broadcasting station **B**. Geographical separation between the facilities should be based on the method as described in 2.7.2.1.

2.7.2.6 *Aerodrome surface (AS) communications*

2.7.2.6.1 Aerodrome surface communications provide an essential safety service. If the separation distance is not sufficient, clearances or other instructions that are intended to be used solely on a nearby ("undesired") aerodrome can be understood as a valid instruction on the desired aerodrome. For AS communications, the actual difference in height (above MSL) at a nearby airport or the effect of anomalous propagation may need to be considered. A height difference of 100 m at the nearby aerodrome would result in the radio horizon (of the nearby aerodrome) being increased to about 25 NM. The resulting (D/U) would be 15.5 dB.

2.7.2.6.2 Along the same principles, as for aircraft in flight, as described in 2.7.2.2, the minimum separation distance can be calculated with the formula $RH_A + RH_B$ as illustrated in Figure 2-13.

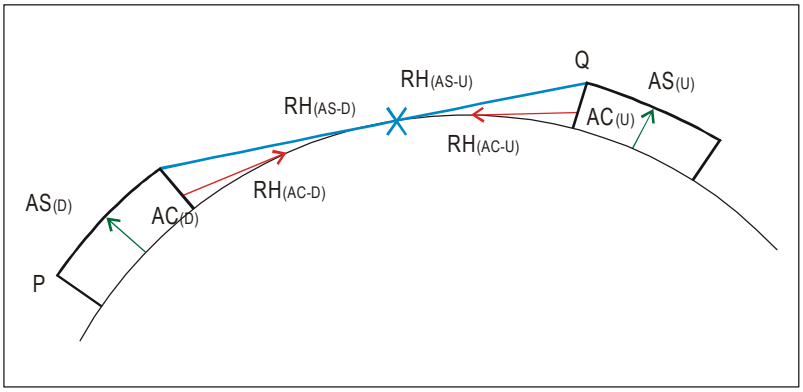

Figure 2-13. Geometry for calculating separation distances for AS communication services

In Figure 2-13, the parameters are:

$AS_{(D)}$ and $AS_{(U)}$: DOC for aerodrome surface communications (5 NM/100 ft)

$AC_{(D)}$: Desired aircraft (antenna height 30 ft)

$AC_{(U)}$: Undesired aircraft (antenna height 30 ft)

$AS_{(D)}$: Desired AS ground [base] station (antenna height 100 ft)

$AS_{(U)}$: Undesired AS ground [base] station (antenna height 100 ft)

$RH_{(AS-D)}$ and $RH_{(AS-U)}$: Distance to the radio horizon from the edge of coverage (12.3 NM)

$RH_{(AC-D)}$ and $RH_{(AC-U)}$: Distance to the radio horizon from the aircraft at maximum range (6.7 NM for 30 ft)

Using formulae (1) and (3) in Chapter 1, the required transmission loss can be calculated as:

$$\frac{D}{U} = L_u - L_d$$

In this formula $L_d = 20 \log d_d = 13.9\ dB$ (d_d = 5 NM)

and $L_u = 20 \log d_u + A = 13.9\ dB$ (d_u is the distance to the radio horizon between the two ground stations which is for stations at a height of 100 ft (30 m) above the terrain 2 x 12.3 NM. **A** is the required transmission loss beyond the radio horizon):

$$\frac{D}{U} = L_u - L_d = 20 \log (RH_{(AS-d)} + RH_{AS-u}) + A - 13.9 = 20$$

For $RH_{(AS-d)} + RH_{AS-u}$ = 24.6, the factor **A** (transmission loss beyond the radio horizon) equals 6 dB. This corresponds to a distance of 12 NM. As a result, the total minimum separation between the edges of the DOC of the two ground stations should be 36.3 NM (37 NM). Since the antenna height above the terrain of the ground station (100 ft) is higher than that of the aircraft station, this separation distance will protect the communications with an aircraft (on the surface of an airport) as well as vehicles using AS frequencies.

Note.— When using the two-ray propagation model (see Chapter 1, 1.3.4), the minimum separation distance between the two ground stations would be slightly more than 25 NM.

2.7.2.6.3 In frequency assignment planning, the DOC for AS services is circular with a DOC of 5 NM (100 ft). The minimum separation distance between the DOC of two (co-frequency) AS services is equal to the sum of the distance to the radio horizon of each station. This would provide for a co-frequency separation distance of 35 NM between the ground stations.

2.7.2.6.4 If so desired, on the basis of regional agreements, the separation distances to be applied can be amended. In addition, consideration could be given to increase the minimum separation distance to a value that would reduce the undesired signal to below a squelch level of 5 μV/m at the airborne and ground receiver antennas. However, when considering that more realistic propagation models for ground-ground propagation as in Chapter 1, 1.3.2 will result in better protection, the separation distance of 35 NM between AS ground stations may provide sufficient protection.

2.7.2.6.5 Adjacent channel protection for AS services needs to be provided by securing that the DOC of the undesired (interfering) station is separated by at least 10 NM from the DOC of the desired station.

2.7.2.7 *Unprotected services*

2.7.2.7.1 Certain services are not protected from interference and in many cases no coverage has been determined for these services. An example is the use of frequencies for aeronautical operational control or for special uses, such as for gliders and hot air balloons.

2.7.2.7.2 Assignment of frequencies to stations is, in these cases, normally determined on the basis of the traffic loading that can be expected by the users of these “unprotected” frequencies. As long as these frequencies are in operation exclusively for unprotected use, these assignments should not be subject to interference calculations.

2.7.2.7.3 When these frequencies are shared with protected services, consideration needs to be given to whether the use of the unprotected frequencies may cause interference to frequencies (co- and adjacent frequency) which do require protection from harmful interference and an assessment of potential interference should be undertaken. This may result in a situation that while the protected service is to be protected from interference from the unprotected service, the unprotected service is in turn also protected from interference from the protected service. In these cases, establishing a DOC for the unprotected service is necessary.

2.7.2.7.4 In the interest of efficient frequency assignment planning, it is important to realize that when frequency assignments to unprotected services are being made, these should preferably be concentrated in one (or more) sub-bands solely reserved for unprotected services. Where feasible, such sub-bands should be established.

2.7.3 Adjacent frequency separation

2.7.3.1 *Air-ground communication facilities using the same channel bandwidth (either 25 kHz or 8.33 kHz)*

2.7.3.1.1 For stations operating with the same frequency characteristics, no adjacent frequency assignment planning constraints apply. However, when one or both facilities are operating with 8.33 kHz frequency separation and at least one of these facilities operates on offset carrier frequencies as per Annex 10, Volume III/V the separation distances are to be determined using co-frequency assignment planning separation criteria.

2.7.3.1.2 The criteria in 2.7.3.1.1 are based on the consideration that air-to-air, air-to-ground and ground-to-air adjacent frequency interference is not harmful. The area within which such interference may occur is limited to a small area and is transient in nature.

2.7.3.1.3 For stations operating on the first adjacent frequency with the same characteristics (25 kHz or 8.33 kHz), a separation distance of 10 NM is to be maintained between the **ground transmitter** and the **ground receiver**. This is considered to be not a frequency assignment planning constraint but rather an implementation issue for States to consider when implementing or modifying frequency assignments. A practical measure may be to avoid assigning a first adjacent frequency to the same location. When a State is planning to implement a (ground) station closer than 10 NM to the border of a neighbouring State, bilateral coordination or coordination through the relevant ICAO Regional Office may be required to avoid potential interference from one ground transmitter into another ground receiver.

2.7.4 Co-frequency and adjacent frequency assignment planning in a mixed environment where both 25 kHz and 8.33 kHz frequency separation is being deployed

2.7.4.1 *Both facilities operate on the same (carrier) frequency*

2.7.4.1.1 Co-frequency geographical separation distances should be used when one facility is operating on the same frequency and with a channel bandwidth of 8.33 kHz as that of the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channel 119.000 and 119.005 operate on the same frequency 119.000 MHz).

2.7.4.2 *Both facilities operate on a (carrier) frequency with a frequency separation of 8.33 kHz*

2.7.4.2.1 Co-frequency geographical separation distances should also be used when one facility is operating on a frequency separated by 8.33 kHz from the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channels 119.010 and 118.990 using the frequency 119.0083 MHz and 118.9917 MHz respectively are to be considered as co-frequency to the (25 kHz) frequency/channel 119.000 MHz).

2.7.4.3 *Both facilities operate on a (carrier) frequency with a frequency separation of 16.67 kHz*

2.7.4.3.1 A geographical separation of 10 NM between the edges of the coverage of both stations must be maintained when one facility is operating on a frequency separated by 16.67 kHz from the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channel 119.015 is operating on the (carrier) frequency 119.0167 MHz and 119.000 is operating on the (carrier) frequency 119.000 MHz).

2.7.4.4 *Both facilities provide an aeronautical broadcast service (e.g. ATIS, VOLMET) and operate on a (carrier) frequency with a frequency separation of 16.67 kHz.*

2.7.4.4.1 When both facilities operate with a frequency separation of 16.67 kHz and both facilities provide an aeronautical broadcast service, the minimum requirement is that the ground station of each facility is located at least 10 NM outside the DOC of the other facility.

Note 1.— The frequency assignment planning criteria in this section apply when the ground station is located inside the DOC.

Note 2.— It is generally recommended to avoid the use of adjacent channels at the same airport (or radio station).

Note 3.— See Section 2.9 for separation distances for VDL Mode 2 and VDL Mode 4.

2.8 SEPARATION DISTANCES (AIR-GROUND COMMUNICATION SERVICES AND GROUND-BASED BROADCASTING SERVICES)

2.8.1 Calculation of distances to the radio horizon

2.8.1.1 By applying the methodology as described in 2.7.2, separation distances between the edges of the DOC areas are calculated using the distance to the radio horizon (R_{LOS}), as indicated in Table 2-7.

2.8.1.2 The minimum separation distance between the closest point of the DOC area of each service are summarized in Table 2-8 and are in accordance with the methods described in 2.7.2. Separation distances involving air-ground communication services are calculated as shown in 2.7.2.1.1 and are limited to the sum of the radio horizon of each facility. When using non-uniform values for the DOC of the services in Table 2-5, the minimum geographical separation distance between the edges of the DOC areas can be calculated as shown in 2.7.2.2 (separation distance based on radio line-of-sight distance).

2.8.1.3 The minimum separation distance between broadcast services (VOLMET, ATIS) assumes a DOC for these services of 260 NM/45 000 ft (see also 2.7.2.4).

Table 2-7. Distance to radio horizon with aircraft at maximum altitude

Symbol	*Service range (NM)*	*Service height*	*Radio horizon*
TWR	25 NM	4 000 ft	78 NM
AFIS	25 NM	4 000 ft	78 NM
AS	Limits of aerodrome	Surface	N/A
APP-U	150 NM	45 000 ft	260 NM
APP-I	75 NM	25 000 ft	195 NM
APP-L	50 NM	12 000 ft	134 NM
ACC-U	Specified area	45 000 ft	260 NM
ACC-L	Specified area	25 000 ft	195 NM
FIS-U	Specified area	45 000 ft	260 NM
FIS-L	Specified area	25 000 ft	195 NM
VOLMET	260 NM	45 000 ft	260 NM
ATIS	260 NM	45 000 ft	260 NM

2.8.2 Table of separation distances

2.8.2.1 *Separation distances between the edges of the designated coverage areas (see Table 2-8).*

Table 2-8. Minimum geographical co-frequency separation distances between the edges of the DOC

		VICTIM											
	Service	*TWR 25/4000*	*AFIS 25/4000*	*AS Surface*	*APP-U 150/450*	*APP-I 75/250*	*APP-L 50/120*	*ACC-U Area/450*	*ACC-L Area/250*	*FIS-U Area/450*	*FIS-L Area/250*	*VOLMET 260/450*	*ATIS 200/450*
INTERFERENCE	TWR	156	156		338	273	212	338	273	338	273	338	338
	AFIS	156	156		338	273	212	338	273	338	273	338	338
	AS (Note 2)			25									
	APP-U	338	338		520	455	394	520	455	520	455	520	520
	APP-I	273	273		455	390	329	325	390	455	390	455	455
	APP-L	212	212		394	329	268	394	329	394	329	394	394
	ACC-U (Note 1)	338	338		520	455	394	520	455	520	455	520	520
	ACC-L (Note 1)	273	273		455	390	329	455	390	455	390	455	455
	FIS-U (Note 1)	338	338		520	455	394	520	455	520	455	520	520
	FIS-L (Note 1)	273	273		455	390	329	455	390	455	390	455	455
	VOLMET	338	338		520	455	394	520	455	520	455	15	15
	ATIS	338	338		520	455	394	520	455	520	455	15	15

Note 1.— All distances are in NM.

Note 2.— Frequencies for aerodrome surface communications should be selected from the band 121.550 – 121.990 MHz. This band is reserved exclusively for AS communications. No separation distances with other services are provided. Should it be necessary to share frequencies for AS with air-ground communication services, the minimum geographical separation distance can be calculated as shown in 2.7.2.6 and assuming a DOC for AS communications of 5 NM/100 ft.

2.8.2.2 In the EUR Region, the table of separation distances has been developed, taking into account:

a) different values for the uniform DOC (see 2.6.3.1 and Table 2-5); and

b) application of the separation distance ratio method (5:1) using the D/U protection ratio of 14 dB.

For information purposes, this table is reproduced below:

EUR table of separation distances

Service	*AFIS/TWR 16/3000*	*TWR 25/4000*	*APP-U 50/250*	*APP-I 40/150*	*APP-L 25/100*	*ACC-U Area/450*	*ACC-I Area/350*	*ACC-L Area/250*	*ACC/LL Area/150*	*VOLMET 271/450*	*ATIS 60/02050*
AFIS/TWR	*80*	*125*	*250*	*200*	*125*	328	297	261	218	328	241
TWR	*125*	*125*	*250*	*200*	*125*	339	308	272	229	339	252
APP-U	*250*	*250*	*250*	*250*	*250*	455	424	388	345	455	*300*
APP-I	*200*	*200*	*250*	*200*	*200*	412	381	345	302	412	*300*
APP-L	*125*	*125*	*250*	*200*	*125*	384	353	317	274	384	297
ACC-U (Note 1)	328	339	455	412	384	522	491	455	412	522	*300*
ACC-I (Note 1)	297	308	424	381	353	491	460	424	381	491	*300*
ACC-L (Note 1)	261	272	388	345	317	455	424	388	345	455	*300*
ACC-LL	218	229	345	302	274	412	381	345	302	412	*300*
VOLMET	328	339	455	412	384	522	491	455	412	10	211
ATIS	241	252	*300*	*300*	297	*300*	*300*	*300*	*300*	211	124

Note 1.— Separation distances in NM.

Note 2.— All distances in red/italics have been calculated using the 5:1 distance ratio. Other separation distances are limited to the radio horizon.

Note 3.— Separation distances between VOLMET and ATIS were calculated assuming an antenna height of the VOLMET/ATIS transmitter of 65 ft (20 m).

2.9 Separation distances for VDL (VDL Mode 2 and VDL Mode 4)

2.9.1 VDL operating co-frequency with other VDL or VHF COM voice systems

2.9.1.1 The same planning criteria as that used between VHF voice systems (20 dB protection ratio) should be used. The separation criteria are calculated as described in 2.7.2. The DOC for VDL Mode 2 and VDL Mode 4 facilities needs to be separated from the DOC of a co-frequency VHF COM voice (DSB-AM) system by at least the sum of the distance to the radio horizon of each service.

Note.— This applies also to frequency assignments between VDL facilities not operating in the same network.

2.9.2 VDL operating on adjacent frequencies with other VDL or VHF COM voice systems

2.9.2.1 The first frequency adjacent (25 kHz) to either a DSB-AM frequency or a VDL frequency should not be used in the same airspace.

2.9.2.2 The second frequency adjacent (25 kHz) to a DSB-AM frequency should not be used in the same airspace for VDL Mode 4 (see Table 2-9).

Table 2-9. 25 kHz guard band (channels) between DSB-AM, VDL mode 2 and VDL mode 4 (air-air)

		Interference source		
		DSB-AM	*VDL 2*	*VDL 4*
Victim	DSB-AM		1	2
	VDL 2	1	1	1
	VDL 4	2	1	1

Note.— The numbers in Table 2-9 are guard bands (channels). The next frequency that can be used without a frequency planning constraint is 1 channel higher (e.g. a desired DSB-AM station that is interfered by a VDL Mode 2 aircraft station requires one 25 kHz guard band). The next frequency, 50 kHz away, can be used in the same DOC without any frequency assignment planning constraint.

2.9.3 Operation of VDL on the surface of an airport

2.9.3.1 Attention is drawn to the possibility of interference between DSB-AM and VDL Mode 2/4 when these systems are used on the surface of an airport. The following adjacent channel constraints have been developed under the assumption that the minimum separation between an aircraft on the surface of an airport and the ground station (transmitter/receiver) is at least 210 m. This is considered a realistic scenario at most airports. However, aircraft on the surface of an airport can be separated at closer ranges. Protection has been considered at the minimum required field strength and calculations have been made assuming free-space propagation. Measurements at a number of representative airports showed that, in many cases, the minimum field strength is about 10 – 12 dB higher than the minimum required.

2.9.3.2 On the basis of an analysis performed by the ICAO Aeronautical Communications Panel, the following

frequency assignment planning constraints have been developed for VDL Mode 2 and VDL Mode 4, when operating aircraft on the surface of an airport (see Table 2-10).

Table 2-10. 25 kHz guard band (channels) between DSB-AM and VDL (Modes 2 and 4) on the surface of an airport

		Interference source		
		DSB-AM	*VDL 2*	*VDL 4*
Victim	DSB-AM	–	4	4
	VDL 2	4	1	1
	VDL 4	4	1	1

2.9.3.3 Interference can occur if the frequency separation between a VDL frequency assignment (guard band) is four channels (25 kHz) or less. In this case, interference between aircraft stations can be prevented through securing that the minimum field strength of these systems is at least 70 dBm at the antenna. Any interference that may be caused in ground-based receiving stations (i.e. not aircraft stations) can be mitigated through using cavity filters that block the reception of unwanted signals from transmissions from aircraft operating on the surface of an airport.

Note.— Detailed information is available in the documents VDL Assignment Planning Criteria (117.975 – 137 MHz) *and* VDL Mode 4 and VOR Compatibility (112 – 117.975 MHz) *which can be downloaded from the website: http://www.icao.int/safety/acp/repository.*

2.10 GUIDANCE ON THE IMPLEMENTATION AND USE OF BACKUP FREQUENCIES

2.10.1 Assessment for the need for backup frequencies

2.10.1.1 Backup frequencies may be operationally required to provide an alternative air-ground communication channel in cases where an operational radio frequency is not available. Examples include: intentional interference; unintentional interference (e.g. badly designed FM broadcasting stations); stuck microphone; and phony air traffic controllers.

2.10.1.2 Implementation of backup frequencies should be limited only to the following ATC services:

AS: Aerodrome surface communications

TWR: Tower services

APP-L, APP-I and APP-U: Approach services

ACC-L, ACC-U: Area control services

VOLMET: Meteorological information

FIS-L, FIS-U: Flight information services

Other air-ground communication services such as ATIS, AFIS, generic unspecified air-to-air (A/A) services, generic

unspecified air-to-ground (A/G) services, generic unspecified general purpose (GP) services and aeronautical operational control services (AOC) do not require backup communication channels.

2.10.1.3 Backup frequencies should not be provided when communication channels are lost due to malfunctioning of the ground infrastructure. Adequate backup facilities in cases of malfunctioning ground infrastructure (or parts there-of) should be in place. Examples are: equipment failure; power loss; and loss of ground communication links to remote transmitter/receiver sites.

2.10.1.4 The assessment of the required number of backup frequencies should be kept to the minimum needed. Where possible, it should be based on experience (e.g. number of days per year that a communication channel is not available).

2.10.1.5 Where operationally feasible, arrangements should be in place to share backup frequencies either between different services (at the same ATC centre) or between different facilities (e.g. different aerodromes or different ACC/FIS from different ATC centres).

2.10.1.6 In the COM list in the global table of frequency assignments, backup frequencies are as such identified.

2.10.2 Backup frequency for short distance communications

2.10.2.1 Short distance communications that may require backup frequencies include AS, TWR and APP services.

2.10.2.2 Backup frequencies should only be implemented at aerodromes with a clear operational requirement.

2.10.2.3 The number of backup frequencies for the combined services described in 2.10.2.1 should not exceed two (with a maximum of one backup frequency for TWR and one backup frequency for APP services).

Note.— A single backup frequency can in principle be used to provide for a backup communications channel for both a TWR and an APP service or for a TWR and an AS service.

2.10.2.4 Adjacent ATS units are encouraged to make suitable arrangements to share backup frequencies where possible, operationally feasible and spectrally efficient.

2.10.3 Backup frequencies for long distance communications

2.10.3.1 A study or safety case should be presented to justify the number of backup frequencies required for ACC and FIS services.

2.10.3.2 Adjacent ATS units are encouraged to make suitable arrangements to share backup frequencies where possible, operationally feasible and spectrally efficient.

Editorial Note.— Insert a new Section 2.11 addressing compatibility between GBAS/VDB operating in the band 108 – 117.975 MHz and VHF COM systems operating in the band 117.975 – 137 MHz:

2.11 Compatibility with GBAS/VDB

2.11.1 Protection requirements.

The protection criteria necessary to protect VHF-COM systems from interference from GBAS/VDB transmissions are as in table 2.12.

Δf (kHz)	**D/U (dB)**
50	-26
5.833	-39
75	-41
100	-42
1000	-44
1500	-51
1800	-55
>1800	n/a

Table 2-12 – Protection ratio for VHF COM receivers; interferer is GBAS/VDB

Notes:
1 **Δf** = difference between the (desired) VHF COM frequency and the (undesired) GBAS/VDB frequency
2 **D/U** includes an equipment variation margin of plus 6 dB
3 These D/U ratios do NOT include the effect for the cross-polar isolation between the VHF-COM signals (vertically polarized) and the GBAS/VDB signals (horizontally polarized)

2.11.2 Separation distances.

The minimum signal level Pd for VHF COM systems is 75μV/m or -82 dBm or -112 dBW.

When assuming that the e.i.r.p of a typical GBAS/VDB station is 17 dBW (50 W), the minimum separation distance between a VDB facility and a VHF-COM receiver can be calculated with the following method.

2.11.2.1 Calculation of the minimum transmission loss using formula 1.4-4 in Chapter 1:

L = Tx – Pd +D/U

Tx (VDB) is 17 dBW; antenna height (VDB)is 45 ft
Pd = -112 dBW
ITU-R propagation curve for 5% of the time
D/U as per table 2.12:

Δf (kHz)	D/U (dB)	L (dB)	D (NM)
50	-26	103	28.5
58.33	-39	90	6
75	-41	88	4.8
100	-42	87	4.4
1000	-44	85	3.6
1500	-51	78	1.6
1800	-55	74	1
>1800	n/a	n/a	no restriction

Table 2-13 Example calculation of minimum separation distances[1]

2.11.2.2 For frequency assignment planning purposes, it is recommended to maintain a minimum separation of 50 kHz between an assigned VHF COM frequency and a GBAS/VDB frequency.

2.11.2.3 Alternatively, with the view to avoid the need for compatibility calculations between VHF COM and GBAS/VDB facilities, the frequency 117.950 MHz should not be used.

2.11.2.4 States are advised to secure that, in case a frequency assignment for a GBAS/VDB facility is made within the range of 117.000 – 117.900 [119.9650] MHz, no harmful interference is caused by GBAS/VDB transmission to the reception of VHF-COM signals operating on frequencies greater than 117.975 MHz. In practice, interference that may be predicted with the method described in this section may be less, taking into account the actual characteristics of the GBAS/VDB facility.

2.11.2.5 Figure 2-16 presents the relevant propagation curves that were used in the analysis as well as the interception of these curves at several frequency separation between the desired VHF-COM frequency and the undesired GBAS/VDB frequency.

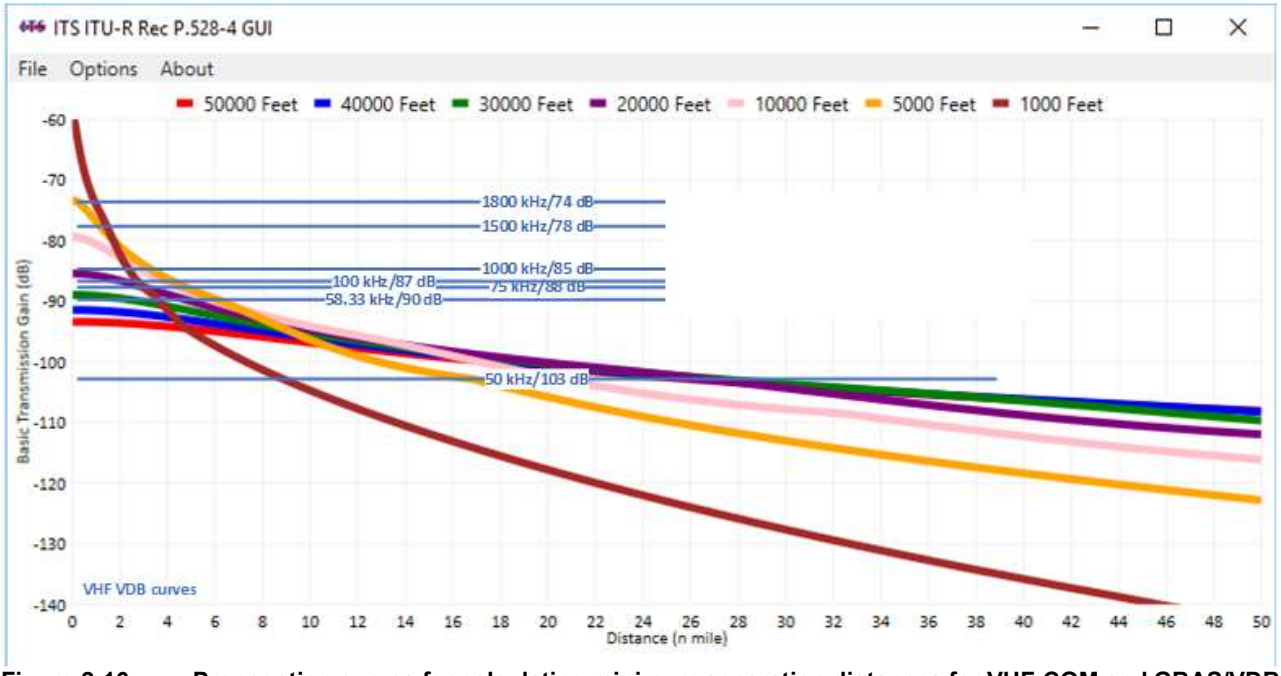

Figure 2-16 Propagation curves for calculating minimum separation distances for VHF-COM and GBAS/VDB

[1] Source: SESAR Report 15.03.229 (01 December 2012), paragraph 6.4.2.1 Tables 11 and 12.

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Editorial Note.— Insert new Chapters 3, 4, 5 and 6 as follows:

Chapter 3 Instrument Landing System (ILS)

3.1. Introduction

3.1.1 The ILS is designed to provide an aircraft on final approach with horizontal and vertical guidance relative to the runway.

3.1.2 The ILS ground equipment consists of:

- a Localizer providing horizontal guidance (azimuth relative to the extended runway centre line)
- a Glide Path providing vertical guidance

3.1.3 Information on the distance of the aircraft relative to the runway threshold is provided by either VHF marker beacons or DME.

3.2. Designated Operational Coverage (DOC)

3.2.1 The Designated Operational Coverage of the ILS Localizer and the ILS Glide Path is shown in Figure 3-1. The DOC outside the sector of plus or minus 35 degrees is optional.
Reference: Annex 10, Vol. I, 3.1.3.3 (Localizer) and 3.1.5.3 (Glide Path)

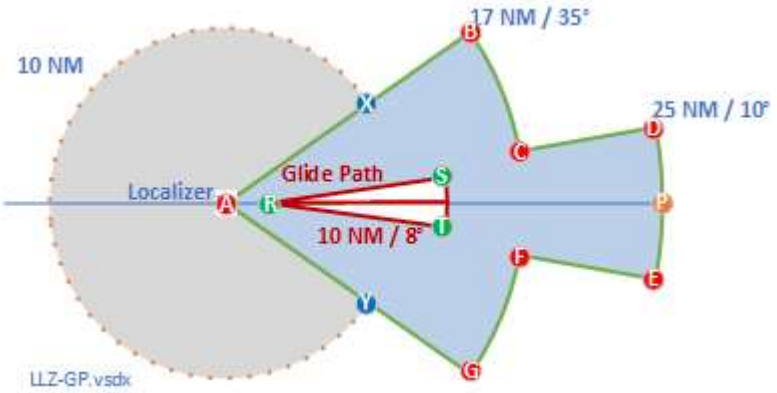

Figure 3-1 – Designated Operational Coverage of the ILS Localizer and Glide Path.

3.2.2 For frequency assignment planning purposes, protection of the desired ILS signal is provided throughout the DOC of the Localizer as per polygon ABCDEFGA in Figure 3-1 and for the Glide Path as per polygon RST. The maximum protection height of the localizer DOC is 6250 ft and for the Glide Path 2500 ft. This height is relative to the elevation of the Localizer transmitter.

Note.— With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.

3.2.2.1 The DOC can be extended (optional) with a range of 10 NM outside the clearance sector (segment XY in Figure 3-1) of the Localizer as promulgated by States.

3.2.3 States may modify the coverage to meet specific operational requirements. Unless a (modified) DOC has been provided, the standard DOC as in paragraph 3.2.1 is used in the frequency assignment planning process.

3.2.4 When the ILS is associated with a DME, the DOC of the DME is typically the same as for the Localizer. However, States may require the associated DME to provide coverage in a larger area.
Note.— in practice, many frequency assignments for a DME, associated with an ILS, have a DOC of 10.000 ft/100 NM. Frequency assignment planning criteria for DME are in Chapter 5

3.2.4.2 The minimum field strength for a Localizer is 40 µV/m (or 32 dB(µV/m) or -116 dBW) throughout the DOC. For a Glide Path the minimum field strength is 400 µV/m (or 52 dB(µV/m) or minus 106 dBW).

3.2.5 When the main direction of radiation of the ILS system is not known, for frequency assignment planning purposes, the coverage is assumed to be omnidirectional. The localizer coverage is originated from the location of the Localizer; the Glide Path coverage is originated from the location of the Glide Path.

3.2.6 In so far as the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility

3.2.7 ILS serving both ends of the same runway.

3.2.7.1 To alleviate frequency congestion problems at locations where two separate ILS facilities serve opposite ends of the same runway or different runways at the same airport, the assignment of identical ILS localizer and glide path paired frequencies should be permitted provided that:

a) the operational circumstances permit;

b) each localizer is assigned a different identification signal; and

c) arrangements are made whereby the localizer and glide path not in operational use cannot radiate.

Note.— The Standards in Annex 10, Volume I, 3.1.2.7.2 and 3.1.3.9, specify the equipment arrangements to be made.

3.3 Frequencies

3.3.1 Frequency band and channel spacing.

3.3.1.1 **Frequency band** – The Localizer is operating in the frequency band 108 – 112 MHz as in paragraph 3.3.1.4.3 below. This band is also used for VOR and GBAS/VDB systems. Localizers cannot be assigned a frequency allotted for a VOR and vice versa. The Glide Path is operating in the frequency band 328.6 – 335.4 MHz. The RF signals for the Localizer and the Glide Path are horizontally polarized.

3.3.1.2 **Channel spacing 100 kHz** – The channel spacing for the Localizer is 100 kHz and for the Glide Path 300 kHz. The Localizer operates on odd 100 kHz channels in the VHF band (e.g. 108.100 MHz, 108.300 MHz etc.).

3.3.1.3 **Channel spacing 50 kHz** – The use of 50 kHz channels for the Localizer (and 150 kHz for the Glide Path) is permitted as stipulated in Annex 10, Volume V, paragraph 4.2.2.1. Such use shall not cause harmful interference to ILS receivers not capable of tuning to these (50/150 kHz) channels and is subject to the condition that the operational service to international operators using airborne equipment designed for 100 kHz channel spacing (150 kHz for the Glide Path) is not derogated.

3.3.1.3.1 The use of 50 kHz channels for the Localizer and 150 kHz channels for the Glide Path *for general use* is permitted on the basis of a regional agreement as provided for in Annex 10, Volume V, paragraph 4.2.2.2. Such an agreement typically requires all aircraft operating within a Region to be equipped with receivers designed for 50 kHz (Localizer) and 150 kHz (Glide Path) channel spacing.

3.3.1.4 For regional frequency assignment planning, frequencies for ILS facilities shall be selected in the following order:

a) 100 kHz Localizer frequencies (and the associated 300 kHz Glide Path frequencies)
b) 50 kHz Localizer frequencies (and the associated 150 kHz Glide Path frequencies)

Re. Annex 10, Volume V, paragraph 4.2.2.

- 3.3.1.4.3 Frequencies for ILS facilities are to be selected from Table 3.1 The Localizer and Glide Path frequencies are paired as shown in Table 3.1 and Figure 3-2.
- *Re. Annex 10, Volume I, paragraph 3.1.6.1.*

LLZ / GP (MHz)	
108.100 / 334.700	110.100 / 334.400
108.150 / 334.550	110.150 / 334.250
108.300 / 334.100	110.300 / 335.000
108.350/ 333.950	110.350 / 334.850
108.500 / 329.900	110.500 / 329.600
108.550 / 329.750	110.550 / 329.450
108.700 / 330.500	110.700 / 330.200
108.750 / 330.350	110.750 / 330.050
108.900 / 329.300	110.900 / 330.800
108.950 / 329.150	110.950 / 330.650
109.100/ 331.400	111.100 / 331.700
109.150 / 331.250	111.150 / 331.550
109.300 / 332.000	111.300 / 332.300
109.350 / 331.850	111.350 / 332.150
109.500 / 332.600	111.500 / 332.900
109.550 / 332.450	111.550 / 332.750
109.700 / 333.200	111.700 / 333.500
109.750 / 333.050	111.750 / 333.350
109.900 / 333.800	111.900 / 331.100
109.950 / 333.650	111.950 / 330.950

- **Table 3.1 – Localizer/Glide Path frequency pairing**

3.3.1.5 The DOC for the Localizer is much larger than that for the Glide Path (See Figure 3-1). When a localizer frequency has been assigned, the associated Glide Path frequency is automatically protected from harmful interference from other *co-channel* ILS facilities. (See also the calculation examples in paragraph 3.9). However, when non-co-channel Localizer frequency has been assigned, a separate adjacent channel compatibility assessment is necessary for the Glide Path frequency with regard to other nearby ILS facilities operating on adjacent Glide Path frequencies.

3.3.1.5.1 Example:
The Localizer frequency 108.900 MHz is paired with the Glide Path frequency 329.300 MHz. The first adjacent Glide Path frequency 329.600 MHz (300 kHz channel spacing for the Glide Path) is paired with the Localizer frequency 110.500 MHz. While the Localizer frequencies are protected from each other, as they are separated by 1.6 MHz, the Glide Path frequency protection criteria prohibits the use of the frequency 329.600 MHz by an (undesired) Glide Path transmitter that is located not only inside but also within a buffer zone of 36 NM (for Glide Path receivers designed for 300 kHz channel spacing) beyond the DOC of the (desired) Glide Path facility operating on 329.300 MHz.

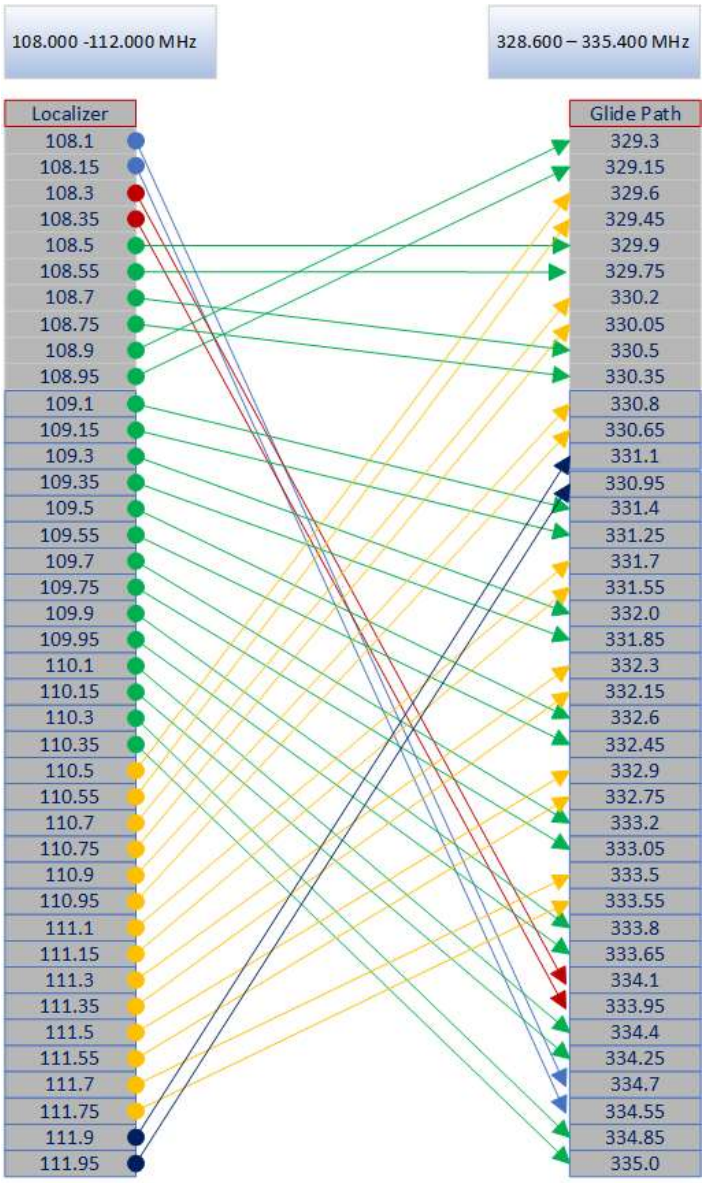

Figure 3-2 Localizer/Glide Path frequency pairing (re. Annex 10, Volume I, paragraph 3.1.6.1)

3.3.1.6 When the ILS is associated with a DME, the DME channels must be selected as per Annex 10, Volume I, paragraph 3.5.3.3.3 and Table A which includes the frequency pairing between the Localizer and the DME facilities. Further guidance on DME frequency assignment planning, including the ILS/DME channel pairing, is in Chapter 5 of this Handbook.

3.3.2 Interleaving of frequency assignments for Localizer and VOR facilities.

3.3.2.1 Localizer and VOR frequencies in the frequency band 108 – 112 MHz are interleaved as shown in Figure 3-3. Localizer facilities operate on odd tenths of a MHz (or odd tenths plus a twentieth of a MHz) and VOR facilities operate on even tenths of a MHz (or even tenths plus a twentieth of a MHz). Localizer and VOR systems are not allowed to operate on the same frequency.

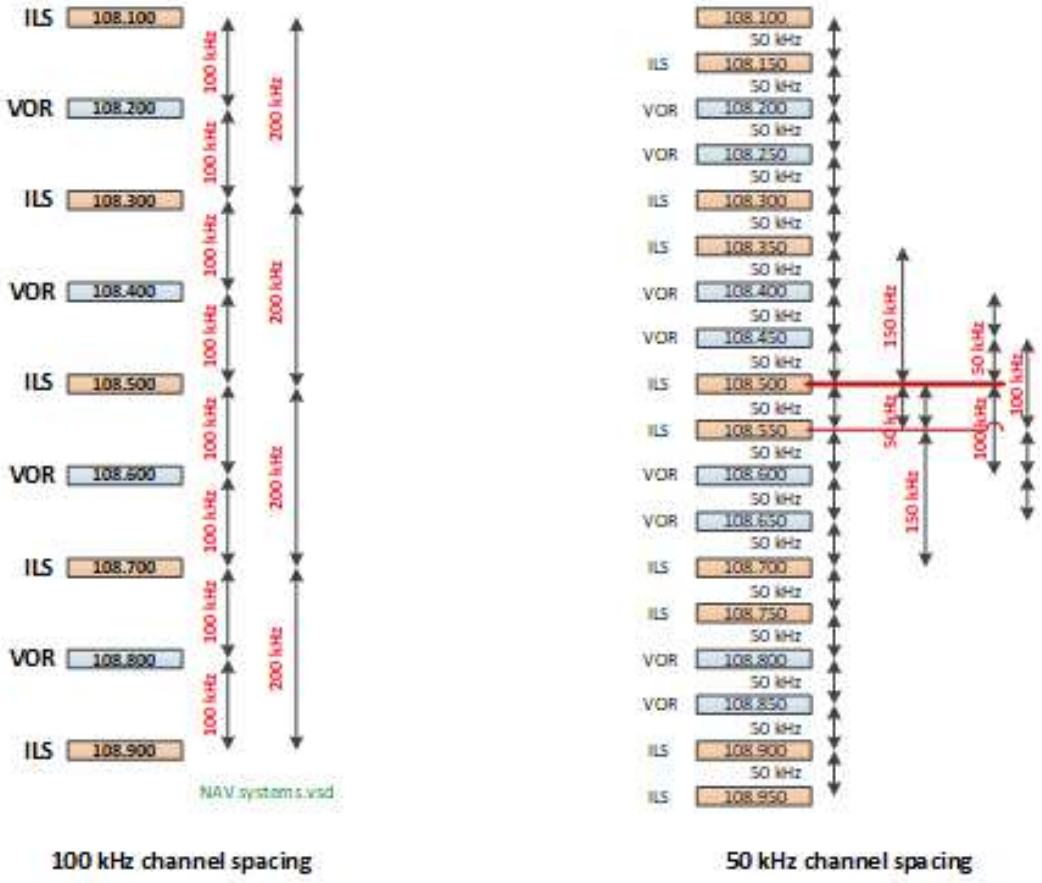

Figure 3.3 – ILS/VOR frequency allotment in the band 108 – 112 MHz.

3.3.2.2 In Regions where frequency assignment planning for ILS/VOR is solely based on 100 kHz channel spacing, the assignable Localizer frequencies are separated by 200 kHz. No compatibility assessment is required for adjacent Localizer frequency assignments separated by 100 kHz or more. However, compatibility with an adjacent 100 kHz VOR frequency assignment needs to be secured as is described in paragraph 3.8. In these Regions, the D/U ratios as in paragraph 3.4.3.1.2 (Table 3-3) are to be applied. In addition, a compatibility assessment is necessary for adjacent Glide Path frequencies as described in paragraph 3.3.1.5. The D/U ratio as in paragraph 3.4.3.2.2 (Table 3-5) are to be applied. For compatibility with GBAS/VDB the D/U ratios as in paragraph 3.5 (Table 3-6) are to be applied as described in paragraph 3.10.

Note.— The D/U ratios in paragraph 3.5 to assess interference from GBAS/VDB into an ILS receiver are based on ILS receivers designed for 50 kHz channel spacing and may not fully protect ILS receivers designed for 100 kHz channel spacing from harmful interference.

3.3.2.3 In areas or Regions where frequency assignment planning for ILS/VOR is solely based on 50 kHz channel spacing, compatibility with adjacent localizer frequency assignments at 50 kHz or 150 kHz separation needs to be established. In addition, a compatibility assessment of adjacent VOR frequency assignments that can be separated with 50 kHz, 100 kHz or 150 kHz from the (desired) Localizer frequency assignment is required as described in section

3.7 below. For these compatibility assessments the protection criteria as in paragraph 3.4.3.1.1 (Table 3-2) should be used. Glide Path compatibility (for adjacent channel compatibility) should be based on the protection requirements in paragraph 3.4.3.2.1 (Table 3-4). The D/U ratio as in paragraph 3.4.3.2.2 (Table 3-5) are to be applied. For compatibility with GBAS/VDB the D/U ratios as in paragraph 3.5 (Table 3-6) are to be applied as described in paragraph 3.10.

3.3.2.4 Regions or areas where both 50 kHz and 100 kHz frequency assignments are in use.

3.3.2.4.1 In these Regions, Localizer receivers designed for 100 kHz channel spacing and for 50 kHz channel spacing are in use. Both receivers need to be protected from harmful interference. For 100 kHz receivers, the protection requirements of paragraph 3.4.3.1.2 (Table 3-3) apply. For 300 kHz Glide Path receivers the protection criteria in paragraph 3.4.3.2.2 (Table 3-5) apply. For 50 kHz receivers the protection requirements of paragraph 3.4.3.1.1 (Table 3-2) apply and, similar for 150 kHz Glide Path receivers, the protection requirements in paragraph 3.4.3.2.1 (Table 3-4).

3.3.2.4.2 In practice, in cases where it is not determined if a frequency assignment on a 100 kHz assignment is intended to be used with 50 kHz receiver, the following method may be used:

- For frequency assignments on 100 kHz frequencies, ILS receivers designed for 100 kHz/300kHz may be assumed
- For frequency assignments on 50 kHz frequencies, ILS receivers designed for 50 kHz/150kHz may be assumed

This method may lead to overprotection of 50 kHz receivers that are operating on 100 kHz frequencies.

3.4 Protection requirements for a desired Localizer and an undesired Localizer or VOR facility and a desired Glide path and an undesired Glide Path facility.

3.4.1 The minimum required separation distances between the desired ILS system and potentially interfering ILS systems are based on the assumption that protection against interference is afforded to the desired signal from the undesired signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of the ILS.

3.4.2 The applicable co-frequency protection ratio depends on the frequency offset between the carriers of the desired and the undesired Localizer or Glide Path signals. For frequency offsets of less than 152 Hz, the applicable co-frequency protection ratio is 36 dB, whereas for greater frequency offsets the co-frequency protection ratio is 20 dB (for the Localizer as well as the Glide Path). These protection ratios ensure that the aircraft instrumentation is not affected. In practice, the use of a 20 dB protection ratio has been proved to be sufficient.

Note 1: The frequency offset between carriers depends on their frequency stability, which should be also considered in choosing the applicable protection ratio.
Note 2: The generic method provides for the required protection for the desired and undesired signal in space (at the aircraft antenna). No compensation is provided for specific non-omnidirectional aircraft antennas nor for differences in the on-board transmission loss for the different frequencies.

3.4.3 When calculating the minimum required separation distances, the receiver protection criteria as in 3.4.3.1 (Localizer) and 3.4.3.2 (Glide Path) are applied.

3.4.3.1 Localizer systems

3.4.3.1.1 Localizer receivers designed for 50 kHz channel spacing

- a) when the desired signal exceeds an undesired co-channel signal by 20 dB or more except as provided for in 3.4.2 above where a D/U ratio of 36 dB may be required;
- b) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;
- c) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;
- d) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB
- or, in summary:

Localizer	
∆f (kHz)	D/U (dB)
0	20 (36)
50	-34
100	-46
≥ 150	-50

Table 3-2 Minimum D/U ratio for 50 kHz Localizer receivers

Note.— These D/U ratios are also applied to desired Localizer and undesired VOR signals.

3.4.3.1.2 Localizer receivers designed for 100 kHz channel spacing

a) when the desired signal exceeds an undesired co-channel signal by 20 dB or more except as provided for in 3.4.2 above where a D/U ratio of 36 dB may be required;
b) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;
c) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;
d) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB

or, in summary,

∆f (kHz)	D/U (dB)
0	20 (36)
50	-7
100	-46
≥150	-50

- **Table 3-3 Minimum D/U ratio for 100 kHz Localizer receivers**

Note.— These D/U ratios are also applied to desired Localizer and undesired VOR signals.

3.4.3.2 Glide Path systems

3.4.3.2.1 Glide Path receivers designed for 150 kHz channel spacing

- a) when a desired signal exceeds an undesired co-channel signal by 20 dB or more except as provided for in 3.4.2. above where a D/U ratio of 36 dB may be required;
- b) when an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;
- c) when an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Note.— When a Localizer frequency has been assigned, the associated Glide Path frequency is automatically protected against interference from other co-frequency Glide Path facilities. No compatibility assessment is necessary for the co-frequency Glide Path. However, a compatibility check for adjacent frequency Glide Path facilities is necessary.

or, in summary:

∆f (kHz)	D/U (dB)
0	20 (36)
150	-20
≥ 300	-40

- **Table 3-4 Minimum D/U ratio for 150 kHz Glide Path receivers**

3.4.3.2.2 Glide Path receivers designed for 300 kHz channel spacing

- a) when a desired signal exceeds an undesired co-channel signal by 20 dB or more except as provided for in 3.4.2. above where a D/U ratio may be 36 dB is required;
- b) when an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

- c) when an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;
- d) when an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

or, in summary:

∆f (kHz)	D/U (dB)
0	20 (36)
150	0
300	-20
≥ 450	-40

Table 3-5 Minimum D/U ratio for 300 kHz Glide Path receivers

3.4.3.2.3 The protection of the Localizer is based on Localizer receivers designed for 100 kHz channel spacing and Glide Path receivers designed for 300 kHz channel spacing. Minimum geographical separation distances between the Localizer and Glide Path facilities are based on the receiver characteristics in paragraph 3.4.3.1.2 and 3.4.3.2.2

3.4.3.2.5 In Regions where both 100 kHz and 50 kHz Localizer channels are being used (300 kHz and 150 kHz channels for the Glide Path), the protection of the Localizer is based on receivers designed for 100 kHz channel spacing. In these Regions, the minimum geographical separation distances between the Localizer facilities and Glide Path facilities operating on 100 kHz (Localizer)/300 kHz (Glide Path) channels are based on the receiver characteristics in paragraph 3.4.3.1.2 and 3.4.3.2.2. However, for frequency assignments on 50 kHz (Localizer)/150 kHz (Glide Path) channels, the protection requirements are as in 3.4.3.1.1 and 3.4.3.2.1

3.4.3.2.6 In Regions where 50 kHz channel spacing for the Localizer is (exclusively) used the protection of the Localizer is based on receivers designed for 50 kHz channel spacing (and for the Glide Path for 150 kHz channels). The minimum geographical separation distances between the Localizer and Glide Path facilities in these Regions are based on the receiver characteristics in paragraph 3.4.3.1.1 and 3.4.3.2.1.

3.4.3.2.7 In the above cases, when the frequency offset is greater than 150 kHz for the Localizer and 450 kHz for the Glide path, practical experience has shown that freedom of using such frequencies can be applied.

3.5 Protection criteria for a desired Localizer and an undesired GBAS/VDB

Note.— Criteria to protect a desired GBAS/VDB facility from interference that can be caused by a Localizer are in Chapter 6.

3.5.1 GBAS can operate on any of the frequencies 25 kHz channels between 108.100 – 117.975 MHz and operate co-frequency or adjacent frequency to a Localizer frequency assignment. The protection of ILS Localizer facilities operating on the same frequency as an undesired GBAS/VDB facility is 26 dB.

3.5.2 The (assumed) minimum D/U ratios to protect Localizer receivers designed for 50 kHz channel spacing from interference that can be caused by GBAS/VDB signals are as in Table 3-6:

∆f (frequency offset)	D/U
0 co-frequency	26 dB
+/- 25 kHz	0 dB
+/- 50 kHz	-34 dB
+/- 75 kHz	-46 dB
+/- 100 kHz	-65 dB

Table 3-6 Assumed D/U ratios to protect the Localizer from GBAS/VDB

Note 1: for areas/regions with frequency congestion, a more precise determination of separation may be required using the appropriate criteria.

Note 2: The geographical separation between a GBAS and an ILS/Localizer facility must consider the performance of Localizer receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing Localizer receivers were not specifically designed to reject VDB transmissions, desired-to-undesired (D/U) signal ratios for co-channel and

adjacent channel rejection of the VDB were determined empirically for VOR receivers designed for 50 kHz channel spacing.
Note 3: No protection criteria for compatibility assessment between GBAS/VDB and Localizer receivers designed for 100 kHz channel spacing have been developed yet.

3.5.3 When the frequency separation between the Localizer and the GBAS/VDB facility is 100 kHz or greater no compatibility assessment is required. (See also paragraph 3.10)

3.6. Compatibility of ILS Localizer with FM broadcasting stations.

3.6.1 A compatibility assessment for potential interference that can be caused by FM broadcasting stations operating in the frequency band 87 – 108 MHz is necessary before a Localizer frequency can be put into operational use.

3.6.2 The FM immunity performance requirements for Localizer receivers are contained in Annex 10, Volume I, paragraph 3.1.4. Additional information on the process to assess compatibility with FM broadcast stations is in Recommendation ITU-R SM.1009.

3.7 Geographical separation distances between Localizer facilities
Note.— In this section, the separation distances are established between the edge of coverage of the desired Localizer and the location of the undesired Localizer facility

3.7.1 For the calculation of minimum separation distances with a (desired) Localizer facility and an (undesired) Localizer facility the generic model as described in Chapter 1, paragraph 1.4 has been applied.

3.7.2 Geographical separation criteria are established on the basis of a regional agreement. Regions and States may apply different compatibility criteria that differ from those described in this Handbook taking into account more detailed specifications of the desired and the undesired facilities.

3.7.3. The generic model as described in Chapter 1, paragraph 1.4, establishes the minimum separation distance between the edge of coverage of a desired Localizer and the location of an undesired Localizer. This model protects the minimum required field strength of the desired Localizer at the aircraft antenna. The undesired facility should be separated with a distance that, taking into account the e.i.r.p of the undesired Localizer the minimum desired Localizer signal is protected from harmful interference. The undesired facility as described in this section can be a co- or adjacent frequency Localizer.

3.7.4 To establish minimum geographical separation distances between a (desired) Localizer and an undesired Localizer, the following parameters are used:

a) Minimum field strength of the desired Localizer: 40 µV/m (or 32 dB(µV/m) = - 116 dBW)
b) D/U ratio;
    a. for co-frequency compatibility with another Localizer the D/U ratio is 36 dB or 20 dB
    b. for adjacent frequency compatibility the D/U ratio is as per paragraph 3.4.3.1
c) E.i.r.p of the undesired facility (dBW).
d) Designated operational range of the desired facility.
e) ITU-R aeronautical propagation curve for 5% of the time.

3.7.4.1 Example of calculating co-frequency Localizer vs Localizer separation distance.

3.7.4.1.1 The minimum field strength E of a Localizer is 40 µV/m (32 dB(µV/m) at the edge of the DOC (Designated Operational Range = 25 NM and Designated Operational Height = 6250 ft). The assumed e.i.r.p of the undesired Localizer is typically in the order of 27 – 30 dBW (in the front course sector which is the worst case). Outside the front course sector, the e.i.r.p is normally in the order of 17 dBW. The D/U ratio is 36 dB or 20 dB as in paragraph 3.4.2.

Example:

a) The minimum received desired power at the aircraft, assuming an isotropic antenna, is minus 116 dBW. (Chapter 1, formula 1.4.-1)
b) The maximum undesired power Pu at the edge of the DOC of the desired Localizer is

- -116 – 36 = -152 dBW. (Chapter 1, formula (1.4-2)

c) The e.i.r.p of the undesired Localizer is 30 dBW[1], the required transmission loss between the location of the undesired Localizer and the edge of DOC of the desired Localizer L = 30 - (- 116) + 36 = 182 dB (Chapter 1, formula 1.4-4)

d) The ITU-R propagation curve for the antenna heights h1 = 6250 ft and h2 is 10 ft for 5% of the time shows that this transmission loss is achieved at a distance of 267 NM.

- For a D/U of 20 dB the minimum required transmission loss is 166 dB which corresponds with a separation distance of 136 NM

The variables in this method are:

i. In the formula 1.4-4 the D/U ratio is as presented in 3.4.3.1 and applies when the when the undesired facility either a Localizer or a VOR.
ii. The e.i.r.p of the undesired facility.
iii. The designated operational range of the desired Localizer (typically 25 NM).

3.7.5 With the methodology as in 3.5.4 the following minimum geographical separation distances D between the edge of the coverage of the desired Localizer and the location of the undesired Localizer as in Table 3-7 were established. The (undesired) Localizer transmitter height is 6ft. The desired Localizer receiver is at 6250 ft. The ITU propagation curves in ITU-R Recommendation P.528-4 used is for 5% of the time.

E dB (µV/m)	f (MHz)	Pd (dBW)	D/U (dB)	Pu (dBW)	Tx (dBW)	L (dB)	D (NM)	ΔF (kHz)	Remarks
32	108	-116	36	-152	30 17	182 169	**246** **135**	0	Co-frequency undesired Localizer; 36 dB
32	108	-116	20	-136	30 17	166 153	**131** **112**	0	Co-frequency undesired Localizer; 20 dB
32	108	-116	-7	-109	30 17	139 126	**81** **44**	50	Undesired adj. Localizer; 100 kHz receiver
32	108	-116	-34	-82	30 17	112 99	**21** **10**	50	Undesired adj. Localizer; 50 kHz receiver
32	108	-116	-50	-66	30 17	96 83	**9** **1**	150	Undesired adj. Localizer; 50 and 100 kHz receiver

Table 3-7 – Minimum geographical separation distances between the edge of coverage of a desired localizer and the location of an undesired localizer facility.

Note.— For the protection of a (desired) localizer from interference from and (undesired) VOR see paragraph 3.8 and from interference from un undesired GBAS/VDB see paragraph 3.10.
Note.— These separation distances are calculated assuming that the interfering localizer facility radiates with an e.i.r.p of 30 dBW (1000W) which may be typical for a 20 element Localizer. Other Localizer facilities typically radiate with 27 dBW (500 W). These values are limited to the front course sector of the Localizer.
Note.— L = Tx – Pd +D/U
Note.— To calculate the separation distance between the location of the desired and the undesired Localizer facilities, add the designated operational range of the desired Localizer to "D" in Table 3-5.

3.7.6 No compatibility assessment is necessary when the frequency separation between the desired and the undesired Localizer is 200 kHz or more.

3.7.7 Once compatibility between a desired Localizer and an undesired Localizer or VOR facility has been assessed, a second compatibility assessment is necessary to secure that no interference is caused to the "undesired" facilities by the desired Localizer.

[1] The radiated power in the front course sector of a Localizer typically varies between 27 – 30 dBW.

3.8 Geographical separation distances between (desired) Localizer and (undesired) adjacent frequency VOR facilities.

3.8.1 The criteria for the geographical separation of ILS/Localizer and VOR facilities are based on the following assumptions:

a) The Localizer protection ratios for interference from VOR facilities are as in paragraph 3.4.3.1 and 3.4.3.2 (Localizer receivers designed for 100 kHz and for 50 kHz channel spacing)
   - *Note.— This assumes that the protection of (desired) Localizer signals from VOR signals is the same as for the Localizer signals*

b) The e.i.r.p of the VOR varies from 17 dBW to 30 dBW.
c) The designated operational coverage of the (desired) Localizer.

3.8.2 With the view to establish geographical separation distance between an ILS facility and adjacent frequency VOR facilities, it is assumed that the susceptibility of the ILS receiver to interference from VOR signals is the same as for interference caused by for ILS signals and the protection criteria in 3.4.3.1 apply equally to undesired VOR signals.
Note.— This applies vice versa for the VOR receiver susceptibility of undesired Localizer signals. This assumption needs to be confirmed.

3.8.3 In accordance with the channelling plans for the Localizer and VOR facilities, the Localizer and the VOR will not operate on the same frequency. Only an assessment of Localizer and VOR facilities operating on adjacent frequencies is necessary.

3.8.4 In areas where frequency assignment for Localizer facilities is based on 100 kHz channel spacing, the nearest assignable VOR frequency is separated with 100 kHz. However, when a frequency assignment on a 50 kHz channel is made, compatibility needs also be assessed taking into account the receiver characteristic as in paragraph 3.4.3.1.1.

3.8.5 When the frequency separation between the Localizer and the VOR is equal or more than [100] [200] kHz, no compatibility assessment is necessary. However, careful attention should be paid when a VOR is located close to the Localizer centre line.

3.8.5.1 Protection of the ILS system from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.

3.8.6 With the methodology as in 3.7.3 the minimum geographical separation distances “D” between the edge of the DOC (at 6250 ft.) of the desired ILS Localizer and the location of an undesired VOR facility (operating on frequencies adjacent to the desired Localizer) as in Table 3-8 were established, using the ITU-R propagation curves in Recommendation ITU-R P.528-4 for 5% of the time. The antenna of the (undesired) VOR is at 20 ft above local terrain.

E dB (µV/m)	f (MHz)	Pd (dBW)	D/U (dB)	Pu (dBW)	Tx (dBW)	L (dB)	D (NM)	∆F (kHz)	Remarks
32	108	-116	-7	-109	17	126	72	50	Undesired VOR; 17 dBW; 100 kHz receiver;
32	108	-116	-34	-82	17	99	15	50	Undesired VOR; 17 dBW; 50 kHz receiver
32	108	-116	-46	-70	17	87	5	100	Undesired VOR; 17 dBW; 50/100 kHz receiver
32	108	-116	-50	-66	17	83	3	150	Undesired VOR; 17 dBW; 50/100 kHz receiver
32	108	-116	-7	-109	20	129	80	50	Undesired VOR; 20 dBW; 100 kHz receiver;
32	108	-116	-34	-82	20	102	19	50	Undesired VOR; 20 dBW; 50 kHz receiver
32	108	-116	-46	-70	20	90	7	100	Undesired VOR; 20 dBW; 50/100 kHz receiver
32	108	-116	-50	-66	20	86	4	150	Undesired VOR; 20 dBW; 50/100 kHz receiver
32	108	-116	-7	-109	30	139	107	50	Undesired VOR; 30 dBW; 100 kHz receiver;
32	108	-116	-34	-82	30	112	36	50	Undesired VOR; 30 dBW; 50 kHz receiver
32	108	-116	-46	-70	30	100	16	100	Undesired VOR; 30 dBW; 50/100 kHz receiver
32	108	-116	-50	-66	30	96	13	150	Undesired VOR; 30 dBW; 50/100 kHz receiver

Table 3-8 – Minimum separation distances between the edge of coverage of a desired Localizer and the location of an undesired VOR facility.

Note.— L = Tx – Pd +D/U

3.8.7 Protection of the ILS receivers from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the actual VOR and ILS field densities, and the characteristics of the airborne installation.

Note.— Material relevant to the protection of VOR from ILS signals is presented Chapter 4 addressing VOR geographical separation criteria.

Editorial Note.— The provision in 3.8.7 does not give guidance on how it should be applied in frequency assignment planning.

3.9 Geographical separation distances between co- and adjacent frequency Glide Path facilities

Note.— The minimum separation distances calculated are from the edge of the coverage from the desired Glide Path and the location of the undesired Glide Path facilities.

3.9.1 To establish minimum geographical separation distances between a (desired) Glide Path and an undesired Glide Path the following parameters are required:

a) Minimum field strength of the desired Glide Path: 400 µV/m (or 20log400 = 52 dB(µV/m))
b) D/U ratio;
    a. for co-frequency compatibility with another Glide Path the D/U ratio is 36 dB or 20 dB
    b. for adjacent frequency compatibility the D/U ratio is as per paragraph 3.4.3.2
c) E.i.r.p of the undesired facility (dBW); a typical value for the e.i.r.p. for a Glide Path is 20 dBW (100 W)
d) The Designated Operational Range of the desired Glide Path.
e) ITU-R aeronautical propagation curve for 5% of the time.

3.9.2 Co-frequency Glide Path vs Glide Path separation distance (calculation example).

3.9.2.1 The minimum field strength E of a Glide Path is 400 μV/m (52 dB(μV/m) at the edge of the DOC (Designated Operational Range = 10 NM and Designated Operational Height = 2500 ft). The assumed e.i.r.p of the undesired Glide Path is 20 dBW. The D/U ratio is 36 dB (or 20 dB).
Pd = E -20logf-106.2 = 52 – 20log333-107.2 = 52 – 50 – 107.2 = -105 dBW
(f=333 MHz)

a) The minimum received desired power at the aircraft, assuming an isotropic antenna, is -105 dBW. (Chapter 1, formula 1.4.-1)
b) The maximum undesired power at the edge of the DOC of the desired Glide Path
   Pu = -105 – 36 = - 141 dBW. (Chapter 1, formula (1.4-2)
c) The e.i.r.p of the undesired Glide Path is 20 dBW, the required transmission loss between the location of the undesired Glide Path and the edge of DOC of the desired Glide Path
   L = 20 - (- 105) + 36 = 161 dB (Chapter 1, formula 1.4-4) (L= 145 dB for D/U = 20 dB)
d) The ITU-R propagation curve for the antenna heights h1 = 2500 ft and h2 is 10 ft for 5% of the time shows that this transmission loss is achieved at a distance of 88 NM
   For a D/U of 20 dB, the minimum separation distance is 71 NM

3.9.2.2 The minimum separation distance between co-frequency Glide Path facilities as in the example in paragraph 3.7.2.1 (87 NM) is less than required for Localizer facilities calculated in paragraph 3.9.2.6.1**. It is therefore sufficient to undertake only a compatibility assessment for the Localizer in the case of co-frequency operation of a desired ILS and an undesired ILS.**

3.9.3 Adjacent frequency Glide Path vs Glide Path separation distance (5% of the time).

3.9.3.1 For the first adjacent (Δf = 150 kHz) channel, the D/U is -20 dB for a 150 kHz GP receiver.
The minimum required transmission loss is 20 – (-106) - 20 = 106dB. → D = 11 NM

3.9.3.2 For the first adjacent (Δf = 150 kHz) channel, the D/U is 0 dB for a 300 kHz GP receiver.
The minimum required transmission loss is 20 – (-106) + 0 = 126dB. → D = 36 NM

3.9.3.3 For the second adjacent (Δf = 300 kHz) channel, the D/U is -40dB for a 150 kHz GP receiver.
The minimum required transmission loss is 20 – (-106) - 40 = 86dB. → D = 1 NM

3.9.3.4 For the second adjacent (Δf = 300 kHz) channel, the D/U is -20 dB for a 300 kHz GP receiver.
The minimum required transmission loss is 20 – (-106) - 20 = 106dB. → D = 11 NM

3.9.3.4 For the third adjacent (Δf = 450 kHz) channel, the D/U is -40 dB for a 300 kHz GP receiver.
The minimum required transmission loss is 20 – (-106) - 40 = 86dB. → D = 1 NM

Note.— The minimum separation distances in paragraph 3.9 are calculated from the edge of the DOC of the desired Glide Path to the location of the undesired Glide Path.

Summary of separation distances between ILS facilities (measured from the edge of coverage of the desired ILS facility) ITU propagation curve for 5% of the time is in Table 3.9:

Undesired Facility:					
Localizer (e.i.r.p = 30 dBW)	Δf:	Distance for 100 kHz receiver (desired facility)	D/U	Distance for 50 kHz receiver (desired facility)	D/U
	0 kHz	268 NM	36 dB	268 NM	36 dB
	0 kHz	135 NM	20 dB	135 NM	20 dB
	50 kHz	94 NM	-7 dB	36 NM	-34 dB
	100 kHz	n/a	n/a	n/a	n/a
	150 kHz	9 NM	-50 dB	9 NM	-50 dB
Glide Path (e.i.r.p. = 20 dBW)	Δf:	300 kHz receiver	D/U	150 kHz receiver	D/U
	0 kHz	88 NM	36 dB	74 NM	36 dB
	0kHz	71 NM	20 dB	58 NM	20 dB
	150 kHz	36 NM	-0 dB	11 NM	-20 dB
	300 kHz	11 NM	-20 dB	1 NM	-40 dB
	450 kHz	1	-40	- - -	- - -

Table 3-9 Separation distances between the edge of coverage of a desired ILS and the location of an undesired ILS facilities

3.10 Separation distance between the (desired) Localizer and the location of an (undesired) GBAS/VDB

3.10.1 The criteria for the geographical separation of Localizer and GBAS/VDB facilities are based on the following assumptions:

a) The Localizer protection ratios for interference from GBAS/VDB facilities are as in paragraph 3.5.2. (Only for Localizer receivers designed for 50 kHz channel spacing).
b) The e.i.r.p of the GBAS/VDB is typically 17 dBW; the height of the VDB antenna is 45 ft above local terrain.
c) The Designated Operational Coverage for the Localizer is as in paragraph 3.2.1.
d) The use of the ITU-R aeronautical propagation curves for 5% of the time

3.10.2 With the view to establish geographical separation distances between an ILS/Localizer facility and GBAS/VDB facilities it is assumed that the susceptibility of the ILS/Localizer receiver to interference from GBAS/VDB signals is the same as for VOR receivers.

3.10.2.1 In accordance with the channelling plans for the Localizer and the GBAS/VDB facilities, GBAS may operate co-frequency with a Localizer or on adjacent frequencies. The channel separation for GBAS/VDB is 25 kHz.

3.10.3 For the protection of the Localizer signals from interference that can be caused by GBAS/VDB signals with a frequency separation 100 kHz or more no compatibility assessment is required.

3.10.4 Following the methodology as in paragraph 3.7.3 the minimum geographical separation distances “D” between the edge of the coverage (DOC) of the desired ILS/Localizer and the location of the undesired GBAS/VDB facility as in Table 3-10 were established.

E dB (µV/m)	f (MHz)	Pd (dBW)	D/U (dB)	Pu (dBW)	Tx (dBW)	L (dB)	D (NM)	∆F (kHz)	Remarks
32	108	-116	26	-142	17	159	187	0	
32	108	-116	0	-116	17	133	108	25	
32	108	-116	-34	-82	17	99	20	50	
32	108	-116	-46	-70	17	87	5	75	
32	108	-116	-65	-51	17	68	0	100	Planning freedom

Table 3-10 Geographical separation distances between a desired Localizer and an undesired GBAS/VDB.

D is calculated with the ITU aeronautical propagation curve for 108 MHz, 6250 ft and 5% of the time. The distance is measured from the edge of the coverage of the desired Localizer and the location of the undesired GBAS/VDB facility.

Chapter 4 VHF Omnidirectional Range (VOR)

Note.— The material in this chapter is based on the assumption that only ILS Localizer or VOR receivers are in use that are specifically designed for either 100 kHz or 50 kHz channel spacing.

4.1. Introduction

4.1.1 The VOR is a radio navigation aid used for determining, at the aircraft, the bearing of the aircraft relative to the magnetic North measured from the location of the VOR.

4.1.2 The VOR is often used in conjunction with a co-located DME to provide the aircraft with its distance relative to the VOR/DME.

4.2. Coverage

4.2.1 The designated operational coverage (DOC) of the VOR is determined through the operational requirement as promulgated by States. In many cases the DOC is circular and can be as large as 200 NM, normally up to flight level 450. Sectorized coverage (in the horizontal plane), which improves efficiency in frequency assignment planning, is also used and is further described in paragraph 4.9. Vertical coverage may be extended up to flight level 600 to meet specific operational requirements. Protection from harmful interference is only provided *within* the DOC.

4.2.2 Guidance relating to VOR/DVOR equivalent isotropically radiated power (EIRP) and coverage.

4.2.2.1 The field strength specified at in Annex 10, Volume I, chapter 3, 3.3.4.2, is based on the following consideration:

Airborne receiver sensitivity	-117 dBW	
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+7	dB
	---------- +	
Power required at antenna	-110 dBW	

** Transmission line loss includes mismatch losses and antenna polar pattern variations relative to an isotropic antenna*

The power required of minus 110 dBW is obtained at 118 MHz with a power density of minus 107 dBW/m^2 which is equivalent to 90 microvolts per meter, i.e. plus 39 dB referenced to 1 microvolt per meter.

Note.— The power density for the case of an isotropic antenna may be computed in the following manner:

$$P_d = P_a - 10\log_{10}\frac{\lambda^2}{4\pi}$$

Where:

P_d = power density in dBW/m^2
Pa = power of receiving point in dBW
λ = wavelength in meters

4.2.2.2 The necessary EIRP to achieve a field strength of 90 microvolts per meter (minus 107 dBW/m^2) is given in Figure 4-1. The field strength is directly proportional to the antenna elevation pattern. The actual radiation patterns of the antennas depend on a number of factors such as height of the antenna phase centre above ground level (AGL), surface roughness, terrain form and conductivity of ground and counterpoise. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, a conservative value has been provided. Whenever more precise system data are available, a more precise estimation of range is permissible.

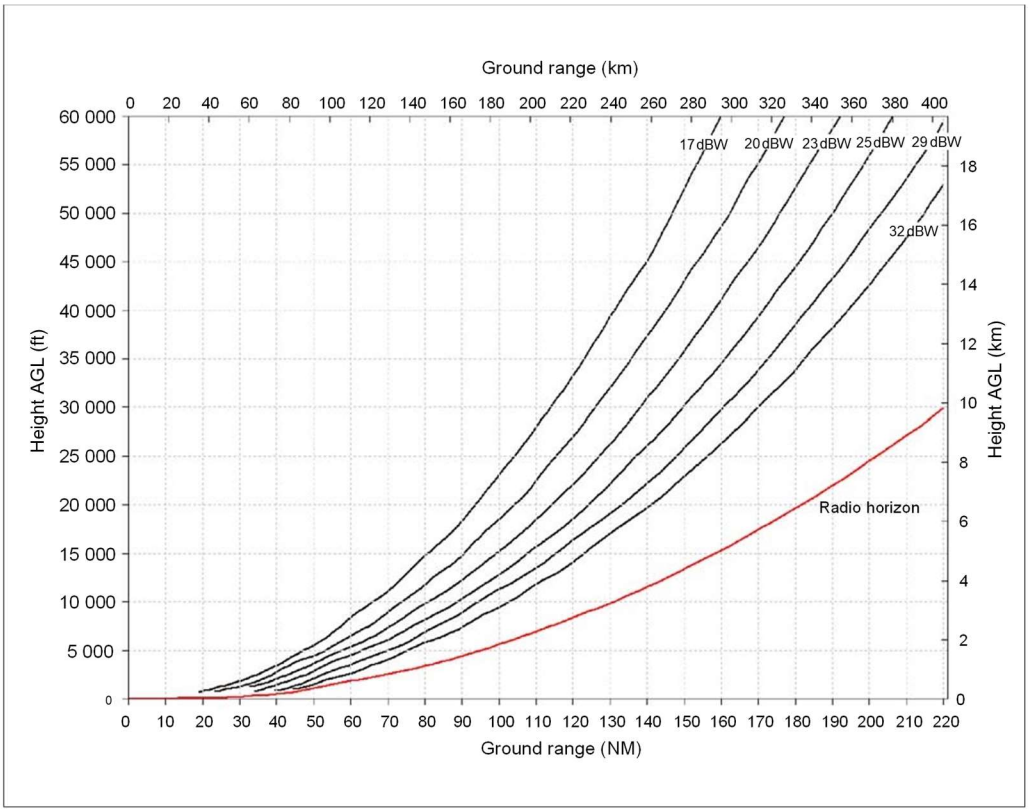

Figure 4 – 1; Necessary EIRP to achieve a field strength of 90 microvolts per metre (−107 dBW/m^2) as a function of height above and distance from the VOR/DVOR

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.
Note 2.— The guidance provided assumes that the VOR/DVOR counterpoise height above ground level (AGL) that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.
Note 3.— The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. As an example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.

4.2.3 Typical e.i.r.p values for VOR are as in Table 4.1

Range (NM)	e.i.r.p. (dBW)
<50	17
50 – 100	20
100 – 150	23
>150	27 - 30

Table 4.1 – typical e.i.r.p values for VOR

4.3. Frequencies.

4.3.1 Channelling.

4.3.1.1 VOR is operating in the frequency band 108 – 117.975 MHz. The channel spacing is 100 kHz. The use of 50 kHz channel sparing is permitted as described in paragraph 4.3.1.2 and 4.3.1.3.

4.3.1.2 The use of 50 kHz VOR channels is permitted as stipulated in Annex 10, Volume V, paragraph 4.2.3.3. Such use shall not cause harmful interference to VOR receivers not capable of tuning to these channels and the operational service to international operators using airborne 100 kHz equipment is not derogated. In addition, the performance of [ILS or] VOR equipment (receivers) not capable of operating on these frequencies will be protected from harmful interference and a general requirement for the carriage of [ILS or] VOR airborne equipment capable of operation on these frequencies will not be imposed

4.3.1.3 The use of 50 kHz VOR channels for general use is permitted for general use on the basis of a regional air navigation agreement as provided for in of Annex 10, Volume V, paragraph 4.2.3.2. Such use requires all aircraft to be equipped with VOR receivers capable of tuning on 50 kHz VOR channels.
Note.— The frequency 113.250 is reserved as common signalling channel for VDL Mode 4 (Annex 10, Volume V, paragraph 4.1.3.3.2).

4.3.2 Order of the selection for VOR channels

4.3.2.1 Frequency assignments for VOR facilities should be made in the following order (Re. Annex 10, Volume V, paragraph 4.2.3):

Order	Band (MHz)	Frequency
1	111.975 – 117.975	Ending in odd tenths of a mega Hertz (“100” kHz channels) e.g. 112.100 MHZ, 112.300 MHz, 112.500 MHz
2	111.975 – 117.975	Ending in even tenths of a mega Hertz (“100” kHz channels) e.g. 112.200 MHZ, 112.400 MHz, 112.600 MHz
3	108.000 – 111.975	Ending in even tenths of a mega Hertz (“100” kHz channels) e.g. 108.200 MHZ, 108.400 MHz, 108.600 MHz
4	111.975 – 117.975	Ending in odd tenths of a mega Hertz plus 50 kHz (“50” kHz channels) e.g. 112.150 MHZ, 112.350 MHz, 112.550 MHz
5	111.975 – 117.975	Ending in even tenths of a mega Hertz plus 50 kHz (“50” kHz channels) e.g. 112.050 MHZ, 112.250 MHz, 112.450 MHz
6	108.000 – 111.975	Ending in even tenths of a mega Hertz plus 50 kHz (“50” kHz channels) e.g. 108.250 MHZ, 108.450 MHz, 108.650 MHz

Table 4.2 – Preferred order when making frequency assignments.

4.3.3 VOR associated with DME

4.3.3.1 VOR facilities are often associated with DME facilities. The associated DME channels shall be selected in accordance with Annex 10, Volume I, paragraph 3.5.3.3.4 and Table A. This material is reproduced in Chapter 5.

4.3.3.1 A separate compatibility assessment for the DME facilities associated with a VOR facility is required in all cases. Chapter 5 of this Handbook contains guidance material on the compatibility of DME frequency assignments with other DME/TACAN assignments in the ICAO frequency assignment plan.

4.3.4 VOR systems operating in the band 108 – 112 MHz.

4.3.4.1 In the band 108 – 112 MHz VOR operates only on channels ending in even tenths of a MHz (e.g. 108.200 MHz, 108.400 MHz, 108.600 MHz etc.) or, for 50 kHz channels ending in even tenths of a MHz plus 50 kHz (e.g. 108.250 MHz, 108.450 MHz, 108.650 MHz etc.). The VOR channels are interleaved with Localizer channels as described in Chapter 3, paragraph 3.3.2 and Figure3.2.

4.3.4.2 Localizer and VOR facilities cannot operate on the same frequency. Adjacent channel compatibility with an (undesired) Localizer is assessed in the same way as adjacent channel interference from a VOR is assessed and takes into account the e.i.r.p of the Localizer.
Note.— Material for assessing compatibility between a (desired) Localizer and an (undesired) VOR is in Chapter 3, section 3.6.

4.3.5 Compatibility of VOR with FM broadcast stations operating in the frequency band 87 – 108 MHz.

4.3.5.1 A compatibility assessment for potential interference that can be caused by FM broadcasting stations operating in the frequency band 87 – 108 MHz is necessary.

The FM immunity performance requirements for VOR receivers are contained in Annex 10, Volume I, paragraph 3.3.8. Additional information on the process to assess compatibility with FM broadcast stations is in Recommendation ITU-R SM.1009.

4.3.5.2 With reference to Annex 10, Volume I, Chapter 3, 3.3.8, the VOR receiver immunity performance defined therein must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Additional information can be found in Recommendation ITU-R SM.1140 on *Test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108 – 118 MHz*. *Note.— Receiver test procedures are also given in the VOR receiver MOPS (RTCA DO-196, and EUROCAE ED-22B).*

4.3.5.3 Commonly agreed formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Annex 10, Volume I, chapter 3, paragraph 3.3.8. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R SM.1009-1, on "*Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108-137 MHz*".

4.4. Protection criteria for a desired VOR and an undesired VOR or Localizer signal

4.4.1 The protection of VOR facilities operating on the same frequency is based on a desired to undesired (D/U) signal ratio of 20 dB. This corresponds to a bearing error of less than 1 degree due to unwanted signals

4.4.2 When the undesired frequency is off-set from the desired frequency, the minimum D/U ratio is for receivers designed for 100 kHz channel spacing as in 4.4.2.1 and is for receivers designed for 50 kHz channel spacing as in 4.4.2.2 below. Protection of (the desired) VOR receivers is based on the receiver characteristics in paragraph 4.4.2.1 (100 kHz receivers) and 4.4.2.2 (50 kHz receivers).

4.4.2.1 Receivers designed for 100 kHz channel spacing:

a) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;
b) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;
c) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

∆F (kHz)	D/U (dB)
0	**20**
50	**-7**
100	**-46**
≥ 150	**-50**

Table 4.3 Minimum D/U ratios for 100 kHz receivers

4.4.2.2 Receivers designed for 50 kHz channel spacing:

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;
b) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;
c) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

∆F (kHz)	D/U (dB)
0	**20**
50	**-34**

100	**-46**
≥ 150	**-50**

Table 4.4 Minimum D/U ratios for 50 kHz receivers

Note.— The undesired signal can be a VOR or a Localizer signal.

4.5 Protection criteria for a desired VOR and an undesired GBAS/VDB

4.5.1 GBAS can operate on any of the frequencies (25 kHz channels) between 108.100 – 117.975 MHz. The protection of VOR facilities operating on the same frequency as an undesired GBAS/VDB facility is 26 dB.

4.5.2 When the undesired frequency is off-set from the desired frequency, the (assumed) minimum D/U ratios to protect VOR receivers designed 50 kHz channel spacing from interference that can be caused by GBAS/VDB signals are as in Table 4-5:

∆f (frequency offset)	**D/U**
0 – co-frequency	**26 dB**
+/- 25 kHz	**0 dB**
+/- 50 kHz	**-34 dB**
+/- 75 kHz	**-46 dB**
+/- 100 kHz	**-65 dB**

Table 4-5 Assumed D/U ratios to protect VOR from GBAS/VDB
(source: Annex 10, Vol. I, Att. D (table D-2);

Note.— For areas/regions with frequency congestion, a more precise determination of separation may be required using the appropriate criteria
Note.— The geographical separation between a VOR and a GBAS/VDB facility needs to consider the performance of VOR receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing VOR receivers were not specifically designed to reject VDB transmissions, desired-to-undesired (D/U) signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically. Table 4-5 summarizes the assumed signal ratios based upon empirical performance of numerous VOR receivers designed for 50 kHz channel spacing;
Note.— No protection criteria for VOR receivers designed for 100 kHz channel spacing, with GBAS/VDB have been developed yet.

4.5.3 When the frequency separation between the VDB station and a VOR station is 100 kHz or greater no compatibility assessment is required.

4.5.3.1 It is recognized that, in the case of adjacent channel operation, there is a small region in the vicinity of a VOR facility, in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible and, in any case, it is probable that the aircraft would change its usage from one facility to the other.

4.6 Areas where both 100 kHz and 50 kHz VOR receivers are in use.

4.6.1 In certain regions a mixed use of 50 kHz and 100 kHz VOR receivers may be in use. In these cases, a compatibility assessment for frequency assignments made on 100 kHz channels needs to comply with the minimum D/U ratios as per Table 4.3. A compatibility assessment for frequency assignments made on 50 kHz channels needs to comply with the D/U ratios as per Table 4.4.

4.7 Consideration of VOR harmonics of the 9960 Hz sub-carrier.

4.7.1 With regard to the emission of harmonics of the VOR sub-carrier 9960 Hz, frequency assignment planning is based on the assumption that the VOR facilities comply with the provisions in Annex 10, Volume I, Chapter 3, paragraphs 3.3.2.2 and 3.3.5.7 and Volume V, Chapter 4, paragraph 4.2.4 as reproduced below:

4.7.1.1 The (general) deployment of 50 kHz VOR channel spacing requires compliance with the provisions of Annex 10:

- Volume I, Chapter 3, 3.3.2.2 The frequency tolerance of the radio frequency carrier of all new installations implemented after 23 May 1974 in areas where 50 kHz channel spacing is in use shall be plus or minus 0.002 per cent.
- Volume I, Chapter 3, 3.3.5.7 Where 50 kHz VOR channel spacing is implemented, the sideband level of the harmonics of the 9 960 Hz component in the radiated signal shall not exceed the following levels referred to the level of the 9 960 Hz sideband:

Subcarrier	*Level*
9 960 Hz	0 dB reference
2nd harmonic	–30 dB
3rd harmonic	–50 dB
4th harmonic and above	–60 dB

- Volume V, Chapter 4, 4.2.4 To protect the operation of airborne equipment during the initial stages of deploying VORs utilizing 50 kHz channel spacing in an area where the existing facilities may not fully conform with the Standards in Annex 10, Volume I, Chapter 3, all existing VORs within interference range of a facility utilizing 50 kHz channel spacing shall be modified to comply with the provisions of Annex 10, Volume I, 3.3.5.7.

4.7.1.2 States that operate VOR facilities that do not comply with these provisions are requested to inform ICAO accordingly. In this case the frequency coordination will take this into account.

4.8. Geographical separation distance. (between VOR and VOR as well as between VOR and GBAS/VDB

4.8.1 For the calculation of minimum separation distances with a (desired) VOR facility and an (undesired) Localizer, VOR or GBAS/VDB facility the generic model as described in Chapter 1, paragraph 1.4 has been established.

4.8.1.1 Adjacent channel protection of the VOR system is effectively obtained without geographical separation of the facilities. However, protection of the Localizer needs to be afforded as provided for in Chapter 3. Paragraph 3.8 *Geographical separation distances between the (desired) localizer* and the (*undesired)* VOR

4.8.2 Geographical separation criteria are established on the basis of a regional agreement. Regions and States may apply different compatibility criteria that differ from those described in this Handbook taking into account more detailed specifications of the desired and the undesired facilities.

4.8.3. The generic model establishes the minimum separation distance between a desired and an undesired facility on the basis of the protection of the minimum required VOR signal of the (desired) VOR. The undesired facility should be separated with a distance that, taking into account the e.i.r.p of the undesired facility protects the minimum desired signal as per paragraph 4.4 and 4.5. The undesired facility can be a co-frequency VOR or GBAS facility or an adjacent Localizer, VOR or GBAS facility.

4.8.4 To establish minimum geographical separation distances between a (desired) VOR and an undesired Localizer, VOR or GBAS facility, the following parameters are required:

f) Minimum field strength of the desired VOR: 90 µV/m or 39 dB(µV/m) or minus 110 dBW for 118 MHz (re. Annex 10, Volume I, 3.3.4.2)
g) D/U ratio;
    a. for co-frequency compatibility with another Localizer or VOR the D/U ratio is 20 dB
    b. for co-frequency compatibility with GBAS the D/U ratio is 26 dB
    c. for adjacent frequency compatibility the D/U ratio is as per paragraph 4.4.2 and 4.5.2
h) E.i.r.p of the undesired facility (dBW)

4.8.4.1 The generic method establishes the minimum geographical separation distance between the edge of the DOC of the desired VOR (maximum range and maximum height) and the location of the undesired facility. This distance provides for the transmission loss (attenuation) of the undesired signal to a level that meets the D/U requirement for the desired signal. This distance is obtained with using the relevant (frequency) ITU propagation curve applicable for the maximum height of the DOC of the desired facility and the site elevation of the undesired facility. When such elevation is

not provided, the height of the antenna of the undesired facility above ground is used. This height is typically between 10 – 30 ft.

4.8.4.2 When the minimum distance from the edge of coverage from the desired VOR to the undesired facility has been established, the station-to-station separation distance can be obtained by adding the DOR to the minimum distance from the edge of coverage to the undesired facility.

4.8.4.3 These steps need to be undertaken in the reverse direction whereby the desired VOR becomes the undesired facility and the undesired facility becomes the desired facility. The maximum distance between the two processes determine the minimum separation between the two facilities.

4.9 Calculation example for VOR vs VOR.

VOR (1) DOC = 25/100 (25 NM, 10.000ft). 100 W (e.i.r.p = 20 dBW)
VOR (2) DOC = 100/450 (100 NM, 45.000 ft. 400W (e.i.r.p = 26 dBW)

Both VOR (1) and VOR (2) operate on the same frequency; D/U = 20 dB

4.9.1 Compatibility of VOR (1) with VOR (2).

Calculate the minimum required transmission loss L from the location of VOR (2) to the edge of the DOC of VOR (1). With formula (1.4-4) in Chapter 1, L=Tx – Pd +D/U.
In this formula:
Tx = the e.i.r.p of the undesired facility (dBW) → **26 dBW**
Pd = the minimum required field strength of the desired facility → **minus110 dBW**
D/U = **20 dB**

This results in L=Tx – Pd +D/U **= 26 - (-110) + 20 = 156 dB**

The VOR antenna height is 20 ft; the ITU-R propagation table for (20ft/10.000 ft) (5% of the time) show this transmission loss is obtained at a distance of **156 NM.**
The minimum station-to-station separation distance is **156 + 25 = 181 NM**

4.9.2 Compatibility of VOR (2) with VOR (1).

Calculate the minimum required transmission loss L from the location of VOR (2) to the edge of the DOC of VOR (1). When using formula (1.4-4) in Chapter 1, L=Tx – Pd +D/U.
In this formula:
Tx = the eirp of the undesired facility (dBW) → **20 dBW**
Pd = the minimum required field strength of the desired facility → **minus110 dBW**
D/U = **20 dB**

This results in **L = 20 – (- 110) + 20 = 150 dB**

The VOR antenna height is 20 ft; the ITU-R propagation table for 10ft/45.000 ft (5% of the time) shows this transmission loss is obtained at a distance of **272 NM.**
The minimum station-to-station separation distance is **272+100 = 372 NM**

4.9.3 The minimum geographical (station to station) separation distance between VOR1 and VOR 2 is the largest as was obtained in 4.9.1 and 4.9.2 and is 372 NM.

4.9.4 For the assessment of the compatibility of a desired VOR with an undesired facility operating on adjacent channels insert in the equations above the relevant D/U ratio as per Table 4.3 (100 kHz receivers) or Table 4.4 (50 kHz receivers).

4.9.5 Tables 4-5A – 4-5D present the co- and adjacent frequency separation distance between the **edge** of the DOC of the (desired) VOR and the **location** of the (undesired) VOR or ILS-Localizer facility. The calculation results are based on:

- Pd = -110 dBW
- D/U ratios are as per Tables 4-3 and 4-4.
- Tx = e.i.r.p of undesired facility (calculations are for Tx = 17 dBW, 20 dBW and 30 dBW)
- L is calculated with formula (1.4-4) in Chapter 1, L=Tx – Pd +D/U.
- D is established with the ITU-R propagation curve for 108 MHz and 5% of the time. Antenna height of the desired aircraft receiver is as indicated in the column Remarks and the antenna height of the undesired facility is 20 ft above ground.
-

∆F (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	Desired VOR at 45000 ft
0	20	147	268	150	271	160	284	50/100 kHz receiver
50	-7	120	134	123	174	133	231	100 kHz receiver
50	-34	93	5	96	11	106	43	50 kHz receiver
100	-46	81	<0.5	84	<0.5	94	7	50/100 kHz receiver
150	-50	77	<0.5	80	<0.5	90	<0.5	50/100 kHz receiver

Table 4-5A – Minimum separation distances between desired and undesired VOR.

*Note.— The separation distances D are between the **edge of coverage** for a desired VOR at 45000 ft and the **location** of an undesired VOR (or Localizer) facility. The e.i.r.p of the undesired VOR (or Localizer) is as specified in column "Tx".*

∆F (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	Desired VOR at 25000 ft
0	20	147	208	150	212	160	225	50/100 kHz receiver
50	-7	120	115	123	131	133	175	100 kHz receiver
50	-34	93	9	96	13	106	42	50 kHz receiver
100	-46	81	<0.5	84	<0.5	94	10	50/100 kHz receiver
150	-50	77	<0.5	80	<0.5	90	5	50/100 kHz receiver

Table 4-5B – Minimum separation distances between desired and undesired VOR.

*Note.— The separation distances are between the **edge of coverage** for a desired VOR at 25000 ft and the **location** of an undesired VOR (or Localizer) facility. The e.i.r.p of the undesired VOR (or Localizer) is as specified in column "Tx".*

∆F (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	Desired VOR at 10000 ft
0	20	147	143	150	147	160	161	50/100 kHz receiver
50	-7	120	71	123	82	133	115	100 kHz receiver
50	-34	93	10	96	14	106	29	50 kHz receiver
100	-46	81	1	84	3	94	11	50/100 kHz receiver
150	-50	77	<0.5	80	1	90	7	50/100 kHz receiver

Table 4-5C – Minimum separation distances between desired and undesired VOR.

*Note.— The separation distances are between the **edge of coverage** for a desired VOR at 10000 ft and the **location** of an undesired VOR (or Localizer) facility. The e.i.r.p of the undesired VOR (or Localizer) is as specified in column "Tx".*

∆F (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	Desired VOR at 5000 ft
0	20	147	108	150	113	160	127	50/100 kHz receiver
50	-7	120	49	123	57	133	83	100 kHz receiver
50	-34	93	9	96	11	106	24	50 kHz receiver
100	-46	81	2	84	3	94	10	50/100 kHz receiver
150	-50	77	1	80	2	90	7	50/100 kHz receiver

Table 4-5D – Minimum separation distances between desired and undesired VOR.

*Note.— The separation distances are between the **edge of coverage** for a desired VOR at 5000 ft and the **location** of an undesired VOR (or Localizer) facility. The e.i.r.p of the undesired VOR (or Localizer) is as specified in column "Tx".*

4.10 Calculation example for a desired VOR vs an undesired GBAS/VDB facility

Note.— Calculation of separation distances between a desired GBAS/VDB and an undesired VOR are in Chapter 6.

4.10.1 To protect the VOR from interference from GBAS/VDB signals, it is necessary to ensure that the minimum signal level of the VOR (Pd is minus 110 dBW) is protected from harmful interference. The co-frequency protection ratio (D/U) for the VOR is 26 dB (re. Table 4-5). The undesired GBAS/VDB signal at the VOR aircraft antenna must be below minus 135 dBW.

4.10.2 The transmission loss between the (undesired) GBAS/VDB and the edge of coverage of the (desired) VOR facility can be calculated with the formula

L = D/U +Tx – Pd

where:
L is the transmission loss (as per ITU-R aeronautical curve)
D/U is the required D/U ratio as in Table 4-5.
Tx is the e.i.r.p of the GBAS station (dBW)
Pd is the minimum VOR signal level (- 110 dBW)

4.10.3 Example:
VOR: Designated operational coverage is 200/450 (200 NM up to 45000 ft)
VDB: e.i.r.p is 17 dBW
D/U = 26 dB (co-frequency)
f = 112 MHz
ITU-R propagation curve (aircraft receiver antenna height of 45000 ft and VDB antenna height of 45 ft.

Required transmission loss is L = D/U +Tx – Pd = 26 + 17 – (-110) = 153 dB.
With the ITU-R propagation curve for a VOR receiver at 45.000 ft and VDB antenna height of 45 ft; for 5% of the time, the separation distance is 284 NM. This separation distance is measured from the edge of coverage of the desired VOR to the location of the undesired VDB station. The station-to-station separation is 284 + 200 = 484 NM (5% of the time).

Table 4-7 presents the co- and adjacent frequency separation distance between the **edge** of the DOC of the (desired) VOR and the **location** of the (undesired) GBAS/VDB station. D/U ratios are as per Table 4-5. The (undesired) GBAS/VDB antenna is at 45 ft above local terrain. The ITU-R P.528-4 propagation curves for 5% of the time were used.

	Distance between the *edge* of the DOC of the desired VOR (50 kHz receiver) and the *location* of the undesired GBAS/VDB (e.i.r.p for VDB = 17 dBW)				
VOR - Height (ft)	**Co-frequency D/U = 26 dB L = 153 dB**	**1st adj freq. (+/-25 kHz) D/U = 0 dB L = 126 dB**	**2nd adj freq. (+/- 50 kHz) D/U = - 34 dB L = 92 dB**	**3rd adj freq. (+/-75 kHz) D/U = -46 dB L = 87 dB**	**4th adj freq. (+/- 100 kHz) D/U = -65 dB L = 61 dB**
5 000	127 NM	80 NM	9 NM	5 NM	Frequency assignment planning freedom
10 000	161 NM	111 NM	8 NM	5 NM	
15 000	186 NM	135 NM	8 NM	4 NM	
20 000	206 NM	155 NM	8 NM	3 NM	
25 000	225 NM	172 NM	8 NM	2 NM	
30 000	242 NM	189 NM	7 NM	Frequency assignment planning freedom	
35 000	237 NM	203 NM	6 NM		
40 000	271 NM	217 NM	5 NM		
45 000	284 NM	228 NM	3 NM		
50 000	297 NM	242 NM	Planning freedom		
60 000	320 NM	264 NM			

Table 4-7 – Minimum separation distances to protect VOR from interference from GBAS/VDB

Note 1: The separation distances are established with the ITU-R P.528-4 propagation curves for 5% of the time. With minimum separation distances less than 0.5 NM frequency assignment planning freedom is assumed.
Note 2: Separation distances ≤ 5 NM may be considered as operational insignificant

4.11 Sectorized coverage

4.11.1 Application of the calculation methods described above may produce incorrect results if sectorization (key-holing) is used. Figure 4 – 2 can be used to explain the problem:

4.11.2 Consider A to be the desired VOR facility and B the undesired one. The "Critical Point" is most exposed to interference from facility B because it is the point of the DOC of facility A which is nearest to transmitter B.

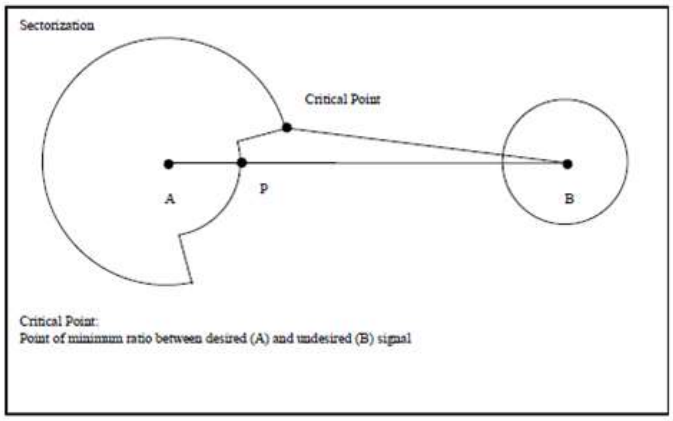

Figure 4 – 2 Geometry for determining the test points

Chapter 5 – Distance Measuring Equipment

Note.— Currently only the use of DME X and Y channels is described in this chapter.

5.1 Introduction.

5.1.1 The DME provides for continuous and accurate information to the aircraft of the slant range distance from an aircraft based DME interrogator to the ground based DME transponder. When in operation, the (aircraft based) interrogator interrogates the (ground based) transponder which in turn responds with replies. The time difference between the transmission of the interrogation and the (aircraft) received reply from the DME transponder provides means for an accurate measurement of the distance (slant range) from the aircraft to the transponder.

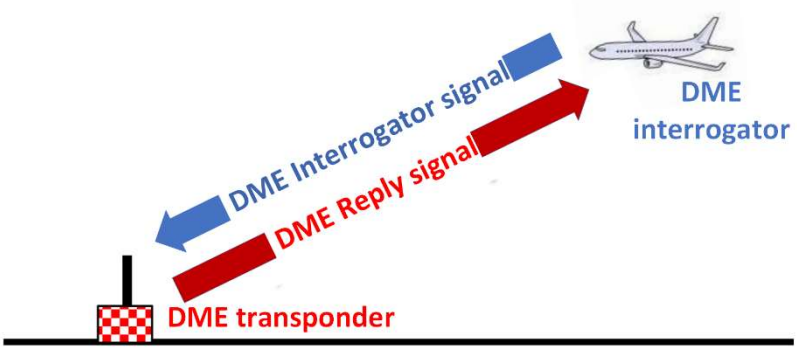

Figure 5.1 DME interrogations and replies

5.1.2 The DME is in many cases associated with an ILS or a VOR. Increased use is being made of stand-alone DME facilities to support area navigation (RNAV).

5.2 Designated Operational Coverage

5.2.1 The Designated Operational Coverage (DOC) of the DME is normally as promulgated by States. When the DME is associated with an ILS or a VOR the DOC of the DME is normally not less than the DOC of the ILS or VOR.

5.2.2 Typical DME coverage is for:

- When associated with an ILS: 25 NM / 10.000 ft. *(e.i.r.p = 27 dBW)*
- Landing DME: 25 NM / 10000 ft. *(e.i.r.p = 27 dBW)*
- Terminal DME: 100 NM / 25000 ft. *(e.i.r.p = 30 dBW)*
- En-Route DME: 200 NM / 45000 ft. *(e.i.r.p = 37 dBW)*

Note.— The e.i.r.p above is typical. States may provide more exact information to take into account in frequency assignment planning. See also paragraph 5.3.3.1 below.

5.2.2.1 States may require different combinations of range / height in accordance with the operational requirements.

5.2.3 Whether a particular installation can provide the required Designated Operational Coverage can be determined by using Figure 5.2. The transmission loss in this figure is based on the IF-77 propagation model.

5.2.3.1 Whenever a DME that provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antenna main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent isotropically radiated power (EIRP). Conversely, practical experience has shown, that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a

lower EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure 5.2 are recommended.

5.2.4 EIRP of DME/N facilities

5.2.4.1 The power density figure prescribed in Chapter 3, 3.5.4.1.5.2 is based on the following example:

Airborne receiver sensitivity	–120 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+9 dB
Power required at antenna	–111 dBW

Minus 111 dBW at the antenna corresponds to a power flux density of minus 89 dBW/ m^2 at the mid-band frequency.

5.2.4.2 Nominal values of the necessary EIRP to achieve a power flux density of minus 89 dBW/m^2 are given in Figure 5.2. For coverage under difficult terrain and siting conditions it may be necessary to make appropriate increases in the EIRP. Conversely, under favourable siting conditions, the stated power flux density may be achieved with a lower EIRP.

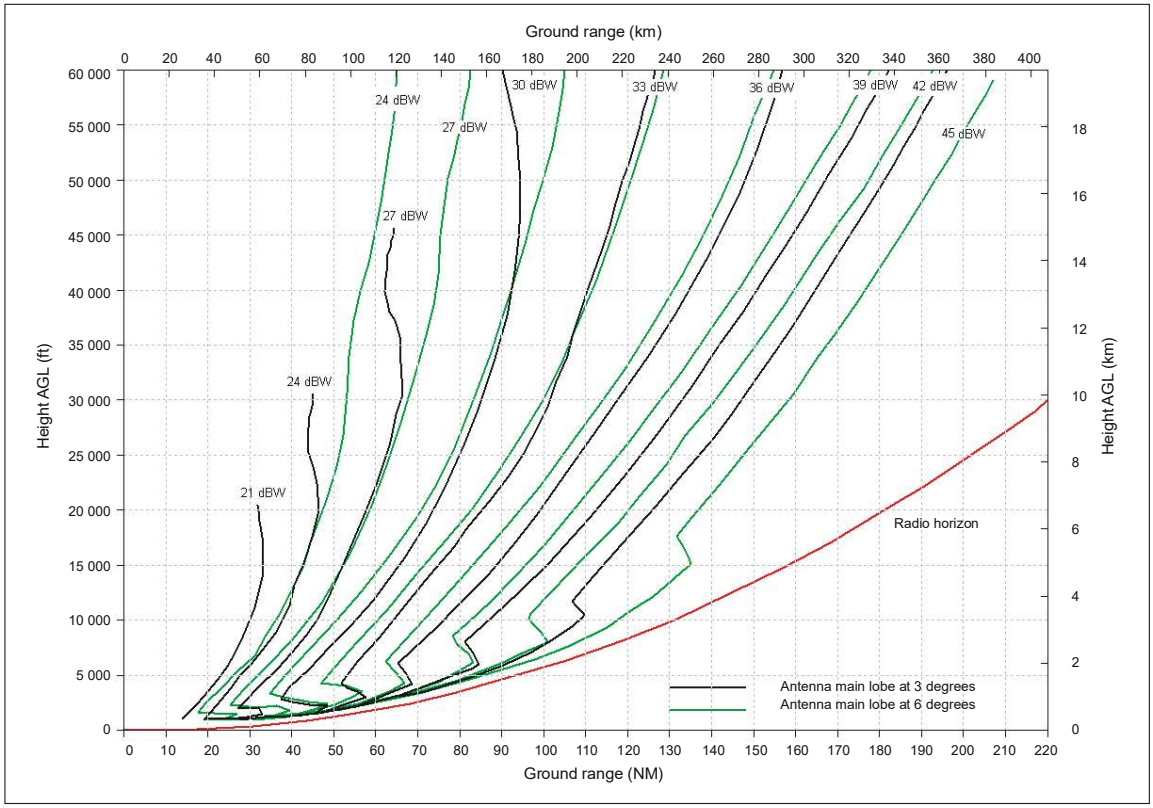

Figure 5-2 Necessary EIRP to achieve a power density of –89 dBW/m^2 as a function of height above and distance from the DME

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.

Note 2.— The radio horizon in Figure 5.2 is for a DME antenna located 5 m (17 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— If the antenna is located significantly higher than the assumed reference antenna, the radio horizon and power density will increase.

Note 4. – An antenna main lobe of 6 degrees is typical for a TACAN; an antenna lobe of 3 degrees is typical for a DME.

5.3 Frequencies / Channelling.

5.3.1 The DME operates on paired interrogation and reply frequencies (each combination of these frequencies is a "channel") in the frequency band 960 – 1215 MHz. A number of these channels are in turn paired with ILS or VOR VHF frequencies. The DME channelling arrangement is shown in Figure 5.3 below and Table 5.4 at the end of this chapter. The frequency band 960 – 1215 MHz is also used for TACAN. TACAN operates with the same channelling scheme as the DME and can be paired with a VOR (VOR/TAC). From the frequency assignment planning point of view TACAN is equivalent to DME.

5.3.2 The sub-band 1164 – 1215 MHz is shared with the Radionavigation Satellite Service with the condition that the Radionavigation Satellite Service shall not claim protection from the Aeronautical Radionavigation Service (e.g. DME). For more details on the use of this band see Volume I of this Handbook.

5.3.3 In the DME channelling arrangement, the (aircraft) DME interrogator sends an interrogation on a frequency in the band 1025 – 1150 MHz. The (ground) transponder sends a reply:

- For X-channels in the bands 962 – 1024 MHZ and 1151 – 1213 MHz.
- For Y-channel in the band 1025 – 1150 MHz

Note that the frequencies between 1025 MHz and 1151 MHz in Figure 5.3 are used as interrogator frequency of the X and Y channels *as well as* the reply frequency for the Y channels.

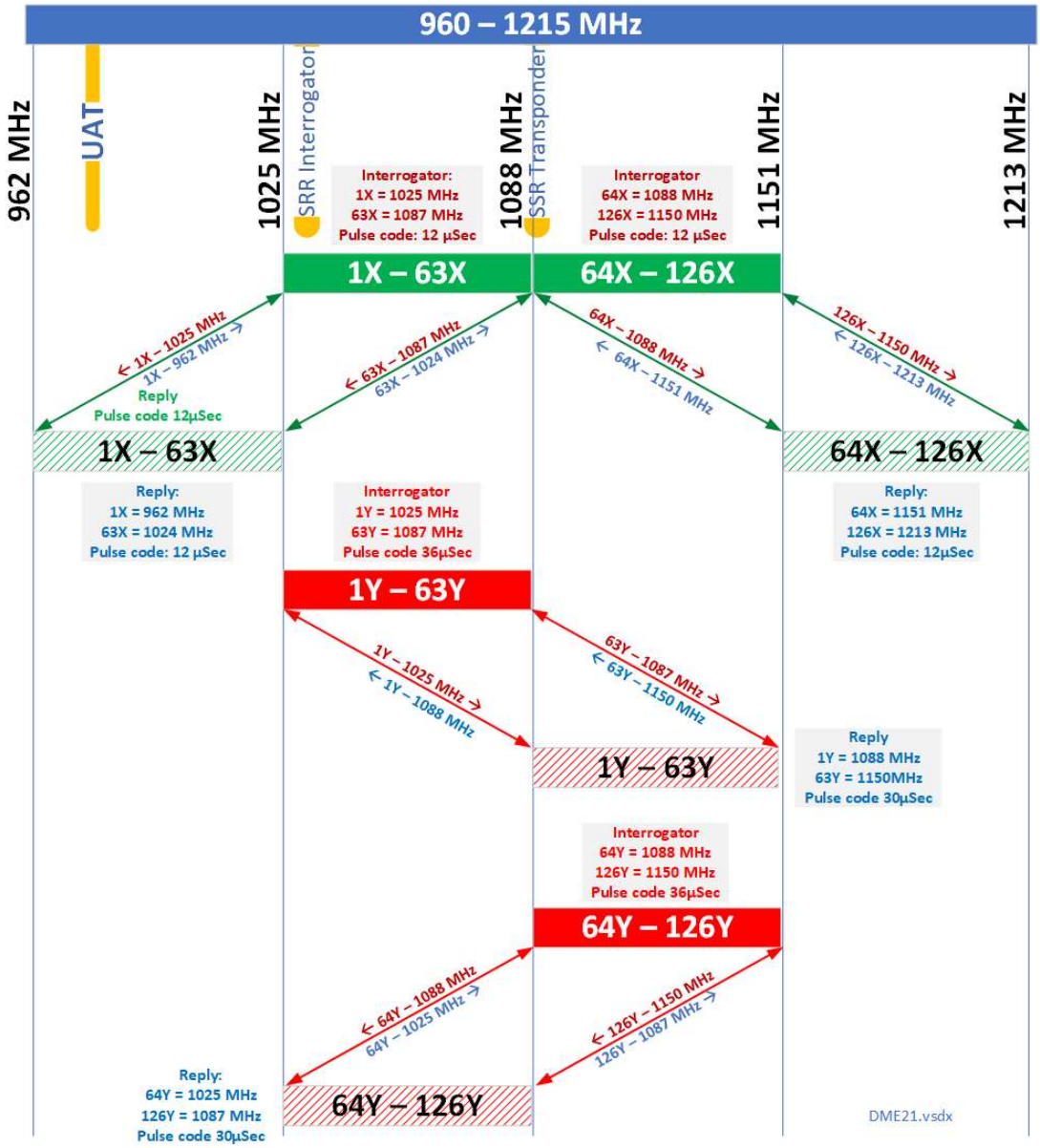

Figure 5.3 DME channeling arrangement

5.3.3.1 The spacing between DME channels is 1 MHz. DME X and Y channels with the same channel number use the same interrogator frequency but with different pulse coding for the X and Y channel. The reply frequency for the X and Y channel is different as well as the pulse coding. The Y channels reuse the reply frequencies within the interrogation frequency block (1025 – 1150 MHz).

5.3.3.2 The aircraft interrogator can send interrogation pulses on channel 1 X or on channel 1 Y Re. Figure 5.3 and Table 5.4. The interrogation that is transmitted on channel 1 X and 1Y is on the same frequency (1025 MHz. The DME interrogation pulses have a different pulse code/spacing on channel 1X (12µSec) and on channel Y (36µSec) channel. When the ground transponder operating on channel 1X receives the interrogation pulses with a pulse spacing of 12 µSec, it responds on the frequency 962 MHz with a reply signal with a pulse spacing of 12 µSec. Any aircraft transmission on the frequency 1025 MHz with a pulse spacing that is different from 12 µSec is discarded by this transponder.

5.3.3.2.1 If the aircraft transmission on channel 1Y on the frequency 1025 MHz with a pulse spacing of 36 µSec is received by transponder 1Y, this transponder replies with a signal on the frequency 1088 MHz with a pulse spacing of 30 µSec. Any signal that is received by transponder 1Y on the frequency 1025 MHz but with a different pulse spacing is discarded by transponder 1Y (e.g. from an interrogator operating on channel 1X (1025 MHz but with a pulse spacing of 12 µSec).

5.3.3.2.2 In summary, DME channels 1X and 1Y can operate in the same or overlapping DME. Since the transponder sends reply signals on different frequencies (and with different pulse coding / spacing) they do not interfere with each other. [1]

5.4 Pairing of DME channels with ILS/VOR

5.4.1 DME channels are paired with ILS or VOR as in table 5.1 and Table 5.4

DME channel	Paired with	Navaid	
18X – 56X (even numbers)	108.100 – 111.900 MHz	ILS Localizer; 100 kHz	
18Y – 56Y (even numbers	108.150 – 111.950 MHz	ILS Localizer; 50 kHz	
19X – 55X (odd numbers)	108.200 – 111-800 MHZ	VOR; 100 kHz	
19Y – 55Y (odd numbers)	108.250 – 111.850 MHz	VOR; 50 kHz	
57X – 59X	112.000 – 112.200 MHz	VOR; 100 kHz	
57Y – 59Y	112.050 – 112.250 MHz	VOR; 50 kHz	
70X – 126X	112.300 – 117.900 MHz	VOR; 100 kHz	
70Y – 126Y	112.350 – 117.950 MHz	VOR; 50 kHz	See note

Table 5.1 – DME channel pairing with ILS or VOR frequencies

Note.— The channels 70Y – 79Y cannot be used when protection to the SSR system is required.

5.5 Frequencies used by the SSR system.

5.5.1 In the frequency band 960 – 1215 MHz also the Secondary Surveillance Radar (SSR) system is operational. The SSR operates on:

- 1030 MHz – Interrogator (ground-to-air)
- 1090 MHz – Transponder (air-to-ground).

These frequencies are also used for the Airborne Collision Avoidance (ACAS) system. The frequency 1090 MHz is also used with SSR Mode S extended squitter signals to support ADS-B functionality and Multilateration (MLAT) systems (re. Annex 10, Volume IV) as in Figure 5.4.

[1] The channel assignment process explicitly considers only the assignment of beacon reply frequencies. Air-to-ground frequency protection is provided by appropriate specifications imposed on the ground equipment in terms of off-code and off-frequency signal rejection. These specifications require that ground transponders be equipped with both:
(1) A Ferris Discriminator which will inhibit the generation of replies for all signals 900 kHz and more removed from the desired channel nominal frequency; and
(2) A decoder which will inhibit the generation of replies for all signals less than 75 dB above the minimum receiver sensitivity level with the received pulse pair ±2 J micro seconds removed from the nominal channel code spacing.

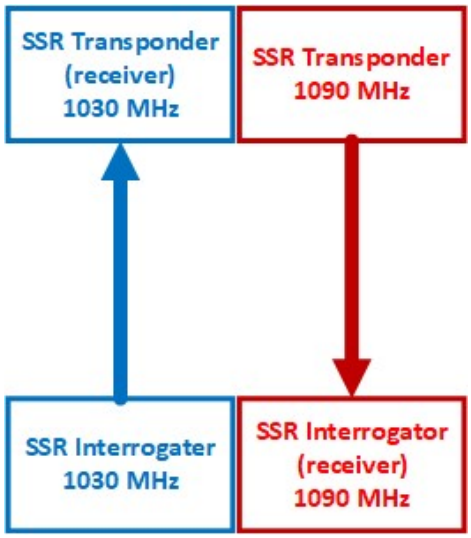

Figure 5.4 – SSR frequency utilization

5.5.2 In order to protect the secondary surveillance system from interference that can be caused by emissions from DME transmitters (and vice versa to protect the DME signals from interference that can be caused by transmissions from these surveillance systems) the use of DME channels on and around the frequencies 1030 MHz and 1090 MHz is restricted. This affects the DME channels:

a) 01X – 16X; DME interrogations on the frequencies 1025 – 1040 MHz
b) 01Y – 16Y; DME interrogations on the frequencies 1025 – 1040 MHz and DME replies on the frequencies 1088 – 1103 MHz
c) 60X – 63X; DME interrogations on the frequencies 1084 – 1087 MHz and DME replies on the frequencies 1021 – 1024 MHz
d) 60Y – 63Y; DME interrogations on the frequencies 1084 – 1087 MHz
e) 64X – 69X; DME interrogations on the frequencies 1088 – 1093 MHz
f) 64Y – 69Y; DME interrogations on the frequencies 1088 – 1093 MHz and DME replies on the frequencies 1025 – 1030 MHz
g) 70Y – 79Y; DME interrogations on the frequencies 1094 – 1103 MHz and DME replies on the frequencies 1031 – 1040 MHz
h) 124Y – 126Y; DME replies on the frequencies 1084 – 1087 MHz

5.5.3 It is recommended that the DME channels 01X – 16X, 01Y-16Y, 60X – 69X, 60Y – 69Y, 70Y – 79Y and 124Y – 126Y are not used for international aircraft operations (see also Table 5.4 at the end of this chapter). Channel 17X is only used for emergency applications.

5.6 Universal Access Transceiver (UAT)

5.6 Use of the frequency 978 MHz by the Universal Access transceiver (UAT)

5.6.1 Use of the frequency 978 MHz by both the UAT and DME (channel 17X) is not recommended. In areas where UAT is being implemented, the use of DME channel 17X should be terminated or blocked.

5.6.2 Other than siting restrictions as in 5.6.3, the use of the frequency 978 MHz for UAT does not place restrictions on using DME channel 16X (977 MHZ) or lower and DME channel 18X (979 MHz) or higher.

5.6.3 Siting restrictions for the UAT use on with regard to DME/TACAN usage of frequencies adjacent to 978 MHz are in the Manual on the Universal Access Transceiver (Doc. 9861).

5.7 Protection requirements

5.7.1 Desired to undesired (D/U) signal ratios at the airborne receiver for X and Y channels

5.7.1.1 In making an assignment, each DME facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made. This “reverse” check is necessary if the DME facilities being considered radiate with different e.i.r.p or have a different DOC.

Frequency assignment planning for DME is aimed at protecting the DME signal at the aircraft receiver.

5.7.1.2 As described in paragraphs 5.3.3.1 and 5.3.3.2, for each DME X and Y channel a unique reply frequency has been established. For DME frequency assignment planning purposes, channel 17X (reply frequency 978 MHz), 18X (reply frequency 979 MHz), 19X (reply frequency 980 MHz) etc. are adjacent channels. Similarly, channels 17Y (reply frequency 1104 MHz), 18Y (reply frequency 1105 MHz), 19 Y (reply frequency 1106 MHz) etc. are adjacent channels. The adjacent X channels use the same pulse code. The adjacent Y channels use the same pulse code, but different from the X channels. Channel 1X (reply frequency 978 MHz) and channel 1Y (reply frequency 1104 MHz) are not adjacent channels. Note that channel 126 Y (reply frequency 1087) is an adjacent channel to channel 1 Y (reply frequency 1088 MHz), channel 63X (reply frequency 1024 MHz) is adjacent to channel 64Y (reply frequency 1025 MHz) and channel 63Y (reply frequency 1150 MHz) is adjacent to channel 64X (1088 MHz).

However, for DME facilities operating on Y channels, the reply frequency may be the same as the interrogator frequency of another DME X facility. This requires special attention as is described in paragraph 5.7 below.

5.7.1.3 To each X or Y DME channel corresponds a specific reply frequency within the band 960-1215 MHz. X and Y DME channels do not have reply frequencies in common. Hence, for the protection of the desired transponder replies from other co-channel transponder replies, it is sufficient to consider only DME facilities with the same channel designation (including the pulse code).

5.7.1.4 Protection of the first adjacent channel is based upon the assumption that the DME first adjacent frequency rejection is 50 dB. In this case, a distinction is to be made between undesired DME facilities with an e.i.r.p that is > 43 dBW (20 kW) and DME facilities with an e.i.r.p that is < 43 dBW.

When the e.i.r.p of the undesired facility is greater than 43 dBW, the adjacent frequency D/U ratio is minus 42 dB

When the e.i.r.p of the undesired facility is less than 43 dBW, consideration needs to be given to the out-of-band radiation of the DME transponder on the first adjacent channel. As is shown in Figure 5.5, the spectrum in a band of 0.5 MHz and centered at 0.8 MHz above (or below) the nominal frequency (of the undesired facility) is 200 mW (-7 dBW). This is co-frequency interference to the desired facility and requires a D/U ratio of 8 dB.

5.7.1.5 Protection of the second adjacent channel is based upon the assumption that the DME second adjacent frequency rejection is 70 dB. In this case, a distinction is to be made between undesired DME facilities with an e.i.r.p that is > 63 dBW (2000 kW) and DME facilities with an e.i.r.p that is < 63 dBW.
When the e.i.r.p of the undesired facility is greater than 63 dBW, the D/U ratio is -72 dB

When the e.i.r.p of the undesired facility is less than 63 dBW, consideration needs to be given to the out-of-band radiation of the DME transponder on the second adjacent channel. As is shown in Figure 5.5, the spectrum in a band of 0.5 MHz and centered at 2 MHz above (or below) the nominal frequency (of the undesired facility) is 2 mW (-27 dBW). This is co-frequency interference to the desired facility and requires a D/U ratio of 8 dB.

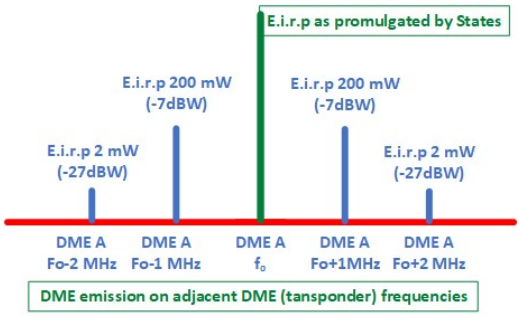

Figure 5.5 Out-of-band radiation of DME transponders
Re. Annex 10, Volume 1, Chapter 3 paragraph 3.5.4.1.3

5.7.1.6 The protection requirements as specified in this paragraph are implemented in the ICAO Regions. Only DME X and Y channels are being implemented and protection of adjacent channel interference is based on the out-of-band radiation of DME transponders. A full set of D/U signal ratios at the airborne receiver is, for information, reproduced at the end of this Chapter in paragraph 5.10. Note that these signal ratios include protection requirements for DME W and Z channels which are currently not implemented.

5.8 Geographical separation distances

5.8.1 The signal ratios necessary to assure interference-free operation of the DME facilities are provided in paragraph 5.4. Geographical separation distances are established with the generic methodology as described in Chapter 1, paragraph 1.4 and 1.5.

5.8.2 The generic model establishes the minimum separation distance between a desired and an undesired DME facility based on the protection of the minimum signal of the (desired) DME (-111dBW) at the aircraft antenna. The undesired facility should be separated with a distance that, taking into account the e.i.r.p. of the undesired facility protects the minimum desired signal as per paragraph 5.4 above. The protection is provided through the path loss of the undesired signal using the aeronautical propagation curves as in ITU-R Recommendation P.528-4 for 5% of the time.

Note.— A brief description of the ITU-R propagation curves in in Chapter 1, paragraph 1.3.3 and the use of these curves in aeronautical frequency assignment planning is in Chapter 1, section 1.4 and 1.5.

5.8.3 In summary, in order to establish the minimum geographical separation distances between a (desired) DME and the location of an undesired DME, the following parameters are used:

- The minimum required signal level at the aircraft antenna = **-111dBW**
- The e.i.r.p of the undesired DME (see 5.5.3.1 and 5.5.3.2)
- Protection point at the edge of the DOC of the desired DME (see 5.5.3.3.)
- The required co-channel D/U ratio (8 dB)

5.8.3.1 The e.i.r.p of the DME station (Pu) is normally provided by the State responsible for the DME station. In case no such information is provided, the following typical e.i.r.p values, based on standard transmitter output power, feeder losses and antenna gain, are assumed for ICAO frequency assignment planning purposes:

Landing/Terminal DME: 27 dBW (500 W), (29 dBW for directional DME)
En-route DME: 37 dBW (5 kW)
TACAN: 40 dBW. (10 kW)

5.8.3.1.1 To improve spectrum economy, it is highly recommended that technical measures be taken to not exceed the e.i.r.p of a landing DME above 29 dBW (800 W).

5.8.3.2 For the calculation of geographical separation distances between DME facilities operating on adjacent channels, the e.i.r.p of the undesired facility (Pu) or:

- - 7 dBW for the first adjacent channel
- -27 dBW for the second adjacent channel

Note.— These signals are co-frequency with the desired DME reply frequency.

5.8.3.3 The maximum height of the DOC of the desired facility determines the ITU-R propagation curve to be used when assessing the minimum geographical separation distance between the location of the undesired facility and the edge of coverage of the desired facility. This distance needs to provide for the minimum transmission loss as can be calculated with formula 1.4-4.

5.9 Calculation examples.

5.9.1. With formula (1.4-4) $L = Pu - Pd + D/U$ the required transmission loss between the location of the undesired facility and the edge of coverage of the desired facility that protects the desired signal from harmful interference can be calculated.

5.9.2 Co-channel geographical separation distances.

5.9.2.1 Landing/Terminal DME:

- E.i.r.p of the undesired DME is 27 dBW
- DOC of the desired DME is 25/100
- D/U is 8 dB

The minimum required transmission loss L as per formula 1.4.-4 is

→ L = 27 -(-111) + 8 = 146 dB.

ITU-R propagation curve for 1080 MHz, h1 = 20 ft and h2 = 10.000 ft for 5% of the time shows that the required transmission loss of 146 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 129 NM. The minimum separation between the *location* of the desired and the undesired DME is 129 + 25 = 154 NM (where 25 NM is the designated operational range of the desired DME).

5.9.2.2. En-route DME (1)

- E.i.r.p is 37 dBW
- DOC is 100/250

The minimum required transmission loss Las per formula 1.4.-4 is

→ L = 37- (-111) + 8 = 156 dB.

ITU-R propagation curve for 1080 MHz, h1 = 20 ft and h2 = 25.000 ft and 5% of the time shows that the required transmission loss of 156 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 201 NM.

5.9.2.3 En-route DME (2) or TACAN

- E.i.r.p is 40 dBW
- DOC is 200/450

The minimum required transmission loss Las per formula 1.4.-4 is

→ L = 40-(-111) + 8 = 159 dB.

ITU-R propagation curve for 1080 MHz, h1 = 20 ft and h2 = 45.000 ft and 5% of the time shows that the required transmission loss of 159 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 263 NM.

5.9.3 Adjacent channel separation

5.9.3.1 1st adjacent channel (1MHz).

When considering the co-channel interference that can be caused by the out-of-band emissions for a DME, the D/U ratio is 8dB. On the first adjacent channel the undesired signal Pu has a signal level of - 7dBW.

Pd (at aircraft antenna) = -111 dBW

→ L = Pu -Pd +D/U; D/U = 8 dB → L = Pu-Pd +8 =-7 –(-111)+8 dB =-112dB → D= 10 NM using the ITU-R 5% curve for h1 = 20 ft and h2 =10 000 ft. D is measured from the edge of the desired facility to the location of the undesired (first adjacent channel) DME ground station.

5.9.3.2 2nd adjacent channel (2 MHz)

For the second adjacent channel Pu = -27 dBW

→ L = Pu -Pd +D/U; D/U = 8dB- (Pu+19) → L = -27 – (-111) +8 =-92 dB. D= 0.5 NM using free space transmission loss. D is measured from the edge of the desired facility to the location of the undesired (first adjacent channel) DME ground station.

Note.— Because of the short minimum separation distances, the transmission loss is calculated using the free space formula. At these short distances, using the ITU-R curve is not recommended because the interference scenario should consider the protection of the DME signal when the aircraft is operating at low altitudes.

5.10 Separation requirement for DME reply frequencies which are separated by 63 MHz

A potential interference situation may occur between DME X and DME Y channels since interference between two DME (ground) transponders which are 63 MHz apart may occur. (e.g. the transmissions (replies) from a transponder operating on channel 64 Y (1025 MHz) could interfere with the reception of the transmission from an (aircraft) interrogator operating on channel 1X (1025 MHz) resulting in desensitization of the transponder operating on channel 1X. See Figure5.6. In this case, the (desired) DME operating on channel 1X may become overloaded with the replies from DME transponder 64Y (which replies to the aircraft on the same frequency where DME transponder 1X is receiving. The transponders should be separated with a distance which is at least the distance of the radio horizon between the two facilities.

In general, a minimum separation distance of 15 NM between these (ground) facilities would be required.

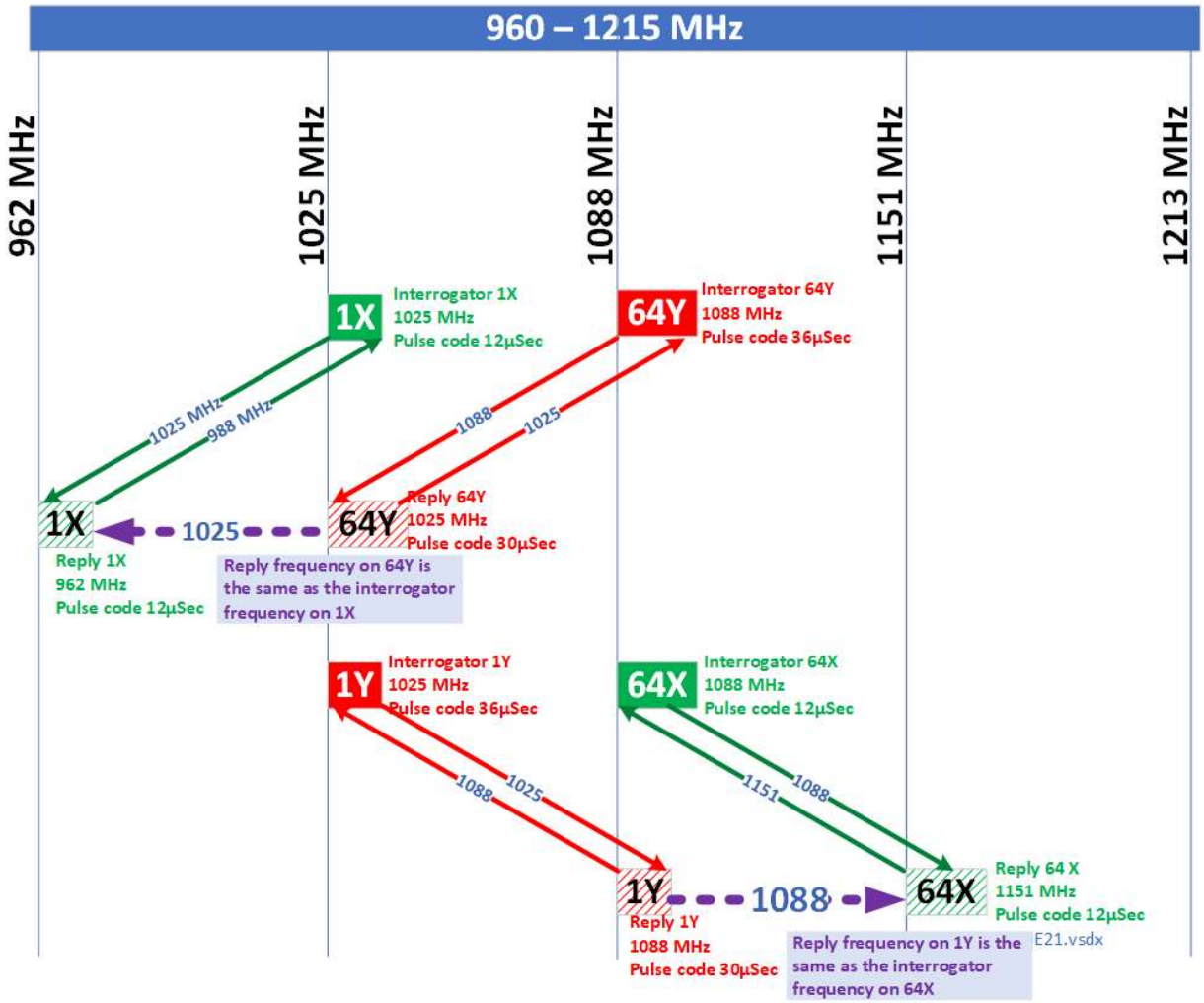

Figure 5.6 – Interference scenario between two DME transponders separated by 63 MHz

5.11 Sectorized DOC of the DME

Similar to VOR (as described in Chapter 4 or this manual), the DME DOC many be sectorized (instead of circular). In this case, compatibility of the DME with other DME assignments needs to be assured at the critical point which is the closest point of the DOC of the desired DME (with sectorized DOC) and any potential interfering DME transponder.

5.12 Use of directional antenna

5.12.1 When omnidirectional DOC is not required, the use of a DME with directional antenna is encouraged, subject to the proviso that the operational requirements for the service to be provided by this facility are met. In Particular, they are useful for the replacement of ILS marker beacons. The directional DME could provide a means to mitigate frequency congestion.

5.12.2 The compatibility of DMEs with directional antennas can be examined basically along the same lines as those developed for omnidirectional DME. However, because of the variable antenna gain of a DME with directional antenna, the value of the quantity K (EIRP of the desired minus the EIRP of the undesired facility) in the above formulas depends in general on the position of the airborne receiver. It is noted in particular that because of the orientation of a

DME with directional antenna, the minimum D/U value is not necessarily attained along the direct line connecting desired and undesired facilities, as opposed to the case of compatibility between omnidirectional DME.

5.12.3 In the presence of at least one DME with directional antenna, the following method should be applied. At first an appropriate number of points is selected along the edge of the DOC of the desired DME, regardless of the type of its antenna. Subsequently at all such points the required D/U criteria are checked. Compatibility is ensured if at all such points the required D/U criteria are met.

5.13 Table with the pairing of ILS/VOR/MLS with DME channels

Source: *Annex 10, Volume 1, Chapter 3 paragraph 3.5.4.1.3*

Table 5.4 Pairing of ILS/VOR/MLS/DME channels

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
*1X	–	–	–	1 025	12	–	–	962	12
**1Y	–	–	–	1 025	36	–	–	1 088	30
*2X	–	–	–	1 026	12	–	–	963	12
**2Y	–	–	–	1 026	36	–	–	1 089	30
*3X	–	–	–	1 027	12	–	–	964	12
**3Y	–	–	–	1 027	36	–	–	1 090	30
*4X	–	–	–	1 028	12	–	–	965	12
**4Y	–	–	–	1 028	36	–	–	1 091	30
*5X	–	–	–	1 029	12	–	–	966	12
**5Y	–	–	–	1 029	36	–	–	1 092	30
*6X	–	–	–	1 030	12	–	–	967	12
**6Y	–	–	–	1 030	36	–	–	1 093	30
*7X	–	–	–	1 031	12	–	–	968	12
**7Y	–	–	–	1 031	36	–	–	1 094	30
*8X	–	–	–	1 032	12	–	–	969	12
**8Y	–	–	–	1 032	36	–	–	1 095	30
*9X	–	–	–	1 033	12	–	–	970	12
**9Y	–	–	–	1 033	36	–	–	1 096	30
*10X	–	–	–	1 034	12	–	–	971	12
**10Y	–	–	–	1 034	36	–	–	1 097	30
*11X	–	–	–	1 035	12	–	–	972	12
**11Y	–	–	–	1 035	36	–	–	1 098	30
*12X	–	–	–	1 036	12	–	–	973	12
**12Y	–	–	–	1 036	36	–	–	1 099	30
*13X	–	–	–	1 037	12	–	–	974	12
**13Y	–	–	–	1 037	36	–	–	1 100	30
*14X	–	–	–	1 038	12	–	–	975	12
**14Y	–	–	–	1 038	36	–	–	1 101	30
*15X	–	–	–	1 039	12	–	–	976	12
**15Y	–	–	–	1 039	36	–	–	1 102	30
*16X	–	–	–	1 040	12	–	–	977	12
**16Y	–	–	–	1 040	36	–	–	1 103	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
17X	108.00	–	–	1 041	12	–	–	978	12
17Y	108.05	5 043.0	540	1 041	36	36	42	1 104	30
17Z	–	5 043.3	541	1 041	–	21	27	1 104	15
18X	108.10	5 031.0	500	1 042	12	12	18	979	12
18W	–	5 031.3	501	1 042	–	24	30	979	24
18Y	108.15	5 043.6	542	1 042	36	36	42	1 105	30
18Z	–	5 043.9	543	1 042	–	21	27	1 105	15
19X	108.20	–	–	1 043	12	–	–	980	12
19Y	108.25	5 044.2	544	1 043	36	36	42	1 106	30
19Z	–	5 044.5	545	1 043	–	21	27	1 106	15
20X	108.30	5 031.6	502	1 044	12	12	18	981	12
20W	–	5 031.9	503	1 044	–	24	30	981	24
20Y	108.35	5 044.8	546	1 044	36	36	42	1 107	30
20Z	–	5 045.1	547	1 044	–	21	27	1 107	15
21X	108.40	–	–	1 045	12	–	–	982	12
21Y	108.45	5 045.4	548	1 045	36	36	42	1 108	30
21Z	–	5 045.7	549	1 045	–	21	27	1 108	15
22X	108.50	5 032.2	504	1 046	12	12	18	983	12
22W	–	5 032.5	505	1 046	–	24	30	983	24
22Y	108.55	5 046.0	550	1 046	36	36	42	1 109	30
22Z	–	5 046.3	551	1 046	–	21	27	1 109	15
23X	108.60	–	–	1 047	12	–	–	984	12
23Y	108.65	5 046.6	552	1 047	36	36	42	1 110	30
23Z	–	5 046.9	553	1 047	–	21	27	1 110	15
24X	108.70	5 032.8	506	1 048	12	12	18	985	12
24W	–	5 033.1	507	1 048	–	24	30	985	24
24Y	108.75	5 047.2	554	1 048	36	36	42	1 111	30
24Z	–	5 047.5	555	1 048	–	21	27	1 111	15
25X	108.80	–	–	1 049	12	–	–	986	12
25Y	108.85	5 047.8	556	1 049	36	36	42	1 112	30
25Z	–	5 048.1	557	1 049	–	21	27	1 112	15
26X	108.90	5 033.4	508	1 050	12	12	18	987	12
26W	–	5 033.7	509	1 050	–	24	30	987	24
26Y	108.95	5 048.4	558	1 050	36	36	42	1 113	30
26Z	–	5 048.7	559	1 050	–	21	27	1 113	15
27X	109.00	–	–	1 051	12	–	–	988	12
27Y	109.05	5 049.0	560	1 051	36	36	42	1 114	30
27Z	–	5 049.3	561	1 051	–	21	27	1 114	15

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
28X	109.10	5 034.0	510	1 052	12	12	18	989	12
28W	–	5 034.3	511	1 052	–	24	30	989	24
28Y	109.15	5 049.6	562	1 052	36	36	42	1 115	30
28Z	–	5 049.9	563	1 052	–	21	27	1 115	15
29X	109.20	–	–	1 053	12	–	–	990	12
29Y	109.25	5 050.2	564	1 053	36	36	42	1 116	30
29Z	–	5 050.5	565	1 053	–	21	27	1 116	15
30X	109.30	5 034.6	512	1 054	12	12	18	991	12
30W	–	5 034.9	513	1 054	–	24	30	991	24
30Y	109.35	5 050.8	566	1 054	36	36	42	1 117	30
30Z	–	5 051.1	567	1 054	–	21	27	1 117	15
31X	109.40	–	–	1 055	12	–	–	992	12
31Y	109.45	5 051.4	568	1 055	36	36	42	1 118	30
31Z	–	5 051.7	569	1 055	–	21	27	1 118	15
32X	109.50	5 035.2	514	1 056	12	12	18	993	12
32W	–	5 035.5	515	1 056	–	24	30	993	24
32Y	109.55	5 052.0	570	1 056	36	36	42	1 119	30
32Z	–	5 052.3	571	1 056	–	21	27	1 119	15
33X	109.60	–	–	1 057	12	–	–	994	12
33Y	109.65	5 052.6	572	1 057	36	36	42	1 120	30
33Z	–	5 052.9	573	1 057	–	21	27	1 120	15
34X	109.70	5 035.8	516	1 058	12	12	18	995	12
34W	–	5 036.1	517	1 058	–	24	30	995	24
34Y	109.75	5 053.2	574	1 058	36	36	42	1 121	30
34Z	–	5 053.5	575	1 058	–	21	27	1 121	15
35X	109.80	–	–	1 059	12	–	–	996	12
35Y	109.85	5 053.8	576	1 059	36	36	42	1 122	30
35Z	–	5 054.1	577	1 059	–	21	27	1 122	15
36X	109.90	5 036.4	518	1 060	12	12	18	997	12
36W	–	5 036.7	519	1 060	–	24	30	997	24
36Y	109.95	5 054.4	578	1 060	36	36	42	1 123	30
36Z	–	5 054.7	579	1 060	–	21	27	1 123	15
37X	110.00	–	–	1 061	12	–	–	998	12
37Y	110.05	5 055.0	580	1 061	36	36	42	1 124	30
37Z	–	5 055.3	581	1 061	–	21	27	1 124	15
38X	110.10	5 037.0	520	1 062	12	12	18	999	12
38W	–	5 037.3	521	1 062	–	24	30	999	24
38Y	110.15	5 055.6	582	1 062	36	36	42	1 125	30
38Z	–	5 055.9	583	1 062	–	21	27	1 125	15

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
39X	110.20	–	–	1 063	12	–	–	1 000	12
39Y	110.25	5 056.2	584	1 063	36	36	42	1 126	30
39Z	–	5 056.5	585	1 063	–	21	27	1 126	15
40X	110.30	5 037.6	522	1 064	12	12	18	1 001	12
40W	–	5 037.9	523	1 064	–	24	30	1 001	24
40Y	110.35	5 056.8	586	1 064	36	36	42	1 127	30
40Z	–	5 057.1	587	1 064	–	21	27	1 127	15
41X	110.40	–	–	1 065	12	–	–	1 002	12
41Y	110.45	5 057.4	588	1 065	36	36	42	1 128	30
41Z	–	5 057.7	589	1 065	–	21	27	1 128	15
42X	110.50	5 038.2	524	1 066	12	12	18	1 003	12
42W	–	5 038.5	525	1 066	–	24	30	1 003	24
42Y	110.55	5 058.0	590	1 066	36	36	42	1 129	30
42Z	–	5 058.3	591	1 066	–	21	27	1 129	15
43X	110.60	–	–	1 067	12	–	–	1 004	12
43Y	110.65	5 058.6	592	1 067	36	36	42	1 130	30
43Z	–	5 058.9	593	1 067	–	21	27	1 130	15
44X	110.70	5 038.8	526	1 068	12	12	18	1 005	12
44W	–	5 039.1	527	1 068	–	24	30	1 005	24
44Y	110.75	5 059.2	594	1 068	36	36	42	1 131	30
44Z	–	5 059.5	595	1 068	–	21	27	1 131	15
45X	110.80	–	–	1 069	12	–	–	1 006	12
45Y	110.85	5 059.8	596	1 069	36	36	42	1 132	30
45Z	–	5 060.1	597	1 069	–	21	27	1 132	15
46X	110.90	5 039.4	528	1 070	12	12	18	1 007	12
46W	–	5 039.7	529	1 070	–	24	30	1 007	24
46Y	110.95	5 060.4	598	1 070	36	36	42	1 133	30
46Z	–	5 060.7	599	1 070	–	21	27	1 133	15
47X	111.00	–	–	1 071	12	–	–	1 008	12
47Y	111.05	5 061.0	600	1 071	36	36	42	1 134	30
47Z	–	5 061.3	601	1 071	–	21	27	1 134	15
48X	111.10	5 040.0	530	1 072	12	12	18	1 009	12
48W	–	5 040.3	531	1 072	–	24	30	1 009	24
48Y	111.15	5 061.6	602	1 072	36	36	42	1 135	30
48Z	–	5 061.9	603	1 072	–	21	27	1 135	15
49X	111.20	–	–	1 073	12	–	–	1 010	12
49Y	111.25	5 062.2	604	1 073	36	36	42	1 136	30
49Z	–	5 062.5	605	1 073	–	21	27	1 136	15

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
50X	111.30	5 040.6	532	1 074	12	12	18	1 011	12
50W	–	5 040.9	533	1 074	–	24	30	1 011	24
50Y	111.35	5 062.8	606	1 074	36	36	42	1 137	30
50Z	–	5 063.1	607	1 074	–	21	27	1 137	15
51X	111.40	–	–	1 075	12	–	–	1 012	12
51Y	111.45	5 063.4	608	1 075	36	36	42	1 138	30
51Z	–	5 063.7	609	1 075	–	21	27	1 138	15
52X	111.50	5 041.2	534	1 076	12	12	18	1 013	12
52W	–	5 041.5	535	1 076	–	24	30	1 013	24
52Y	111.55	5 064.0	610	1 076	36	36	42	1 139	30
52Z	–	5 064.3	611	1 076	–	21	27	1 139	15
53X	111.60	–	–	1 077	12	–	–	1 014	12
53Y	111.65	5 064.6	612	1 077	36	36	42	1 140	30
53Z	–	5 064.9	613	1 077	–	21	27	1 140	15
54X	111.70	5 041.8	536	1 078	12	12	18	1 015	12
54W	–	5 042.1	537	1 078	–	24	30	1 015	24
54Y	111.75	5 065.2	614	1 078	36	36	42	1 141	30
54Z	–	5 065.5	615	1 078	–	21	27	1 141	15
55X	111.80	–	–	1 079	12	–	–	1 016	12
55Y	111.85	5 065.8	616	1 079	36	36	42	1 142	30
55Z	–	5 066.1	617	1 079	–	21	27	1 142	15
56X	111.90	5 042.4	538	1 080	12	12	18	1 017	12
56W	–	5 042.7	539	1 080	–	24	30	1 017	24
56Y	111.95	5 066.4	618	1 080	36	36	42	1 143	30
56Z	–	5 066.7	619	1 080	–	21	27	1 143	15
57X	112.00	–	–	1 081	12	–	–	1 018	12
57Y	112.05	–	–	1 081	36	–	–	1 144	30
58X	112.10	–	–	1 082	12	–	–	1 019	12
58Y	112.15	–	–	1 082	36	–	–	1 145	30
59X	112.20	–	–	1 083	12	–	–	1 020	12
59Y	112.25	–	–	1 083	36	–	–	1 146	30
**60X	–	–	–	1 084	12	–	–	1 021	12
**60Y	–	–	–	1 084	36	–	–	1 147	30
**61X	–	–	–	1 085	12	–	–	1 022	12
**61Y	–	–	–	1 085	36	–	–	1 148	30
**62X	–	–	–	1 086	12	–	–	1 023	12
**62Y	–	–	–	1 086	36	–	–	1 149	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
**63X	–	–	–	1 087	12	–	–	1 024	12
**63Y	–	–	–	1 087	36	–	–	1 150	30
**64X	–	–	–	1 088	12	–	–	1 151	12
**64Y	–	–	–	1 088	36	–	–	1 025	30
**65X	–	–	–	1 089	12	–	–	1 152	12
**65Y	–	–	–	1 089	36	–	–	1 026	30
**66X	–	–	–	1 090	12	–	–	1 153	12
**66Y	–	–	–	1 090	36	–	–	1 027	30
**67X	–	–	–	1 091	12	–	–	1 154	12
**67Y	–	–	–	1 091	36	–	–	1 028	30
**68X	–	–	–	1 092	12	–	–	1 155	12
**68Y	–	–	–	1 092	36	–	–	1 029	30
**69X	–	–	–	1 093	12	–	–	1 156	12
**69Y	–	–	–	1 093	36	–	–	1 030	30
70X	112.30	–	–	1 094	12	–	–	1 157	12
**70Y	112.35	–	–	1 094	36	–	–	1 031	30
71X	112.40	–	–	1 095	12	–	–	1 158	12
**71Y	112.45	–	–	1 095	36	–	–	1 032	30
72X	112.50	–	–	1 096	12	–	–	1 159	12
**72Y	112.55	–	–	1 096	36	–	–	1 033	30
73X	112.60	–	–	1 097	12	–	–	1 160	12
**73Y	112.65	–	–	1 097	36	–	–	1 034	30
74X	112.70	–	–	1 098	12	–	–	1 161	12
**74Y	112.75	–	–	1 098	36	–	–	1 035	30
75X	112.80	–	–	1 099	12	–	–	1 162	12
**75Y	112.85	–	–	1 099	36	–	–	1 036	30
76X	112.90	–	–	1 100	12	–	–	1 163	12
**76Y	112.95	–	–	1 100	36	–	–	1 037	30
77X	113.00	–	–	1 101	12	–	–	1 164	12
**77Y	113.05	–	–	1 101	36	–	–	1 038	30
78X	113.10	–	–	1 102	12	–	–	1 165	12
**78Y	113.15	–	–	1 102	36	–	–	1 039	30
79X	113.20	–	–	1 103	12	–	–	1 166	12
**79Y	113.25	–	–	1 103	36	–	–	1 040	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
80X	113.30	–	–	1 104	12	–	–	1 167	12
80Y	113.35	5 067.0	620	1 104	36	36	42	1 041	30
80Z	–	5 067.3	621	1 104	–	21	27	1 041	15
81X	113.40	–	–	1 105	12	–	–	1 168	12
81Y	113.45	5 067.6	622	1 105	36	36	42	1 042	30
81Z	–	5 067.9	623	1 105	–	21	27	1 042	15
82X	113.50	–	–	1 106	12	–	–	1 169	12
82Y	113.55	5 068.2	624	1 106	36	36	42	1 043	30
82Z	–	5 068.5	625	1 106	–	21	27	1 043	15
83X	113.60	–	–	1 107	12	–	–	1 170	12
83Y	113.65	5 068.8	626	1 107	36	36	42	1 044	30
83Z	–	5 069.1	627	1 107	–	21	27	1 044	15
84X	113.70	–	–	1 108	12	–	–	1 171	12
84Y	113.75	5 069.4	628	1 108	36	36	42	1 045	30
84Z	–	5 069.7	629	1 108	–	21	27	1 045	15
85X	113.80	–	–	1 109	12	–	–	1 172	12
85Y	113.85	5 070.0	630	1 109	36	36	42	1 046	30
85Z	–	5 070.3	631	1 109	–	21	27	1 046	15
86X	113.90	–	–	1 110	12	–	–	1 173	12
86Y	113.95	5 070.6	632	1 110	36	36	42	1 047	30
86Z	–	5 070.9	633	1 110	–	21	27	1 047	15
87X	114.00	–	–	1 111	12	–	–	1 174	12
87Y	114.05	5 071.2	634	1 111	36	36	42	1 048	30
87Z	–	5 071.5	635	1 111	–	21	27	1 048	15
88X	114.10	–	–	1 112	12	–	–	1 175	12
88Y	114.15	5 071.8	636	1 112	36	36	42	1 049	30
88Z	–	5 072.1	637	1 112	–	21	27	1 049	15
89X	114.20	–	–	1 113	12	–	–	1 176	12
89Y	114.25	5 072.4	638	1 113	36	36	42	1 050	30
89Z	–	5 072.7	639	1 113	–	21	27	1 050	15
90X	114.30	–	–	1 114	12	–	–	1 177	12
90Y	114.35	5 073.0	640	1 114	36	36	42	1 051	30
90Z	–	5 073.3	641	1 114	–	21	27	1 051	15
91X	114.40	–	–	1 115	12	–	–	1 178	12
91Y	114.45	5 073.6	642	1 115	36	36	42	1 052	30
91Z	–	5 073.9	643	1 115	–	21	27	1 052	15
92X	114.50	–	–	1 116	12	–	–	1 179	12
92Y	114.55	5 074.2	644	1 116	36	36	42	1 053	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
92Z	–	5 074.5	645	1 116	–	21	27	1 053	15
93X	114.60	–	–	1 117	12	–	–	1 180	12
93Y	114.65	5 074.8	646	1 117	36	36	42	1 054	30
93Z	–	5 075.1	647	1 117	–	21	27	1 054	15
94X	114.70	–	–	1 118	12	–	–	1 181	12
94Y	114.75	5 075.4	648	1 118	36	36	42	1 055	30
94Z	–	5 075.7	649	1 118	–	21	27	1 055	15
95X	114.80	–	–	1 119	12	–	–	1 182	12
95Y	114.85	5 076.0	650	1 119	36	36	42	1 056	30
95Z	–	5 076.3	651	1 119	–	21	27	1 056	15
96X	114.90	–	–	1 120	12	–	–	1 183	12
96Y	114.95	5 076.6	652	1 120	36	36	42	1 057	30
96Z	–	5 076.9	653	1 120	–	21	27	1 057	15
97X	115.00	–	–	1 121	12	–	–	1 184	12
97Y	115.05	5 077.2	654	1 121	36	36	42	1 058	30
97Z	–	5 077.5	655	1 121	–	21	27	1 058	15
98X	115.10	–	–	1 122	12	–	–	1 185	12
98Y	115.15	5 077.8	656	1 122	36	36	42	1 059	30
98Z	–	5 078.1	657	1 122	–	21	27	1 059	15
99X	115.20	–	–	1 123	12	–	–	1 186	12
99Y	115.25	5 078.4	658	1 123	36	36	42	1 060	30
99Z	–	5 078.7	659	1 123	–	21	27	1 060	15
100X	115.30	–	–	1 124	12	–	–	1 187	12
100Y	115.35	5 079.0	660	1 124	36	36	42	1 061	30
100Z	–	5 079.3	661	1 124	–	21	27	1 061	15
101X	115.40	–	–	1 125	12	–	–	1 188	12
101Y	115.45	5 079.6	662	1 125	36	36	42	1 062	30
101Z	–	5 079.9	663	1 125	–	21	27	1 062	15
102X	115.50	–	–	1 126	12	–	–	1 189	12
102Y	115.55	5 080.2	664	1 126	36	36	42	1 063	30
102Z	–	5 080.5	665	1 126	–	21	27	1 063	15
103X	115.60	–	–	1 127	12	–	–	1 190	12
103Y	115.65	5 080.8	666	1 127	36	36	42	1 064	30
103Z	–	5 081.1	667	1 127	–	21	27	1 064	15
104X	115.70	–	–	1 128	12	–	–	1 191	12
104Y	115.75	5 081.4	668	1 128	36	36	42	1 065	30
104Z	–	5 081.7	669	1 128	–	21	27	1 065	15

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
105X	115.80	–	–	1 129	12	–	–	1 192	12
105Y	115.85	5 082.0	670	1 129	36	36	42	1 066	30
105Z	–	5 082.3	671	1 129	–	21	27	1 066	15
106X	115.90	–	–	1 130	12	–	–	1 193	12
106Y	115.95	5 082.6	672	1 130	36	36	42	1 067	30
106Z	–	5 082.9	673	1 130	–	21	27	1 067	15
107X	116.00	–	–	1 131	12	–	–	1 194	12
107Y	116.05	5 083.2	674	1 131	36	36	42	1 068	30
107Z	–	5 083.5	675	1 131	–	21	27	1 068	15
108X	116.10	–	–	1 132	12	–	–	1 195	12
108Y	116.15	5 083.8	676	1 132	36	36	42	1 069	30
108Z	–	5 084.1	677	1 132	–	21	27	1 069	15
109X	116.20	–	–	1 133	12	–	–	1 196	12
109Y	116.25	5 084.4	678	1 133	36	36	42	1 070	30
109Z	–	5 084.7	679	1 133	–	21	27	1 070	15
110X	116.30	–	–	1 134	12	–	–	1 197	12
110Y	116.35	5 085.0	680	1 134	36	36	42	1 071	30
110Z	–	5 085.3	681	1 134	–	21	27	1 071	15
111X	116.40	–	–	1 135	12	–	–	1 198	12
111Y	116.45	5 085.6	682	1 135	36	36	42	1 072	30
111Z	–	5 085.9	683	1 135	–	21	27	1 072	15
112X	116.50	–	–	1 136	12	–	–	1 199	12
112Y	116.55	5 086.2	684	1 136	36	36	42	1 073	30
112Z	–	5 086.5	685	1 136	–	21	27	1 073	15
113X	116.60	–	–	1 137	12	–	–	1 200	12
113Y	116.65	5 086.8	686	1 137	36	36	42	1 074	30
113Z	–	5 087.1	687	1 137	–	21	27	1 074	15
114X	116.70	–	–	1 138	12	–	–	1 201	12
114Y	116.75	5 087.4	688	1 138	36	36	42	1 075	30
114Z	–	5 087.7	689	1 138	–	21	27	1 075	15
115X	116.80	–	–	1 139	12	–	–	1 202	12
115Y	116.85	5 088.0	690	1 139	36	36	42	1 076	30
115Z	–	5 088.3	691	1 139	–	21	27	1 076	15
116X	116.90	–	–	1 140	12	–	–	1 203	12
116Y	116.95	5 088.6	692	1 140	36	36	42	1 077	30
116Z	–	5 088.9	693	1 140	–	21	27	1 077	15
117X	117.00	–	–	1 141	12	–	–	1 204	12
117Y	117.05	5 089.2	694	1 141	36	36	42	1 078	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
					Pulse codes				
Channel pairing						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
117Z	–	5 089.5	695	1 141	–	21	27	1 078	15
118X	117.10	–	–	1 142	12	–	–	1 205	12
118Y	117.15	5 089.8	696	1 142	36	36	42	1 079	30
118Z	–	5 090.1	697	1 142	–	21	27	1 079	15
119X	117.20	–	–	1 143	12	–	–	1 206	12
119Y	117.25	5 090.4	698	1 143	36	36	42	1 080	30
119Z	–	5 090.7	699	1 143	–	21	27	1 080	15
120X	117.30	–	–	1 144	12	–	–	1 207	12
120Y	117.35	–	–	1 144	36	–	–	1 081	30
121X	117.40	–	–	1 145	12	–	–	1 208	12
121Y	117.45	–	–	1 145	36	–	–	1 082	30
122X	117.50	–	–	1 146	12	–	–	1 209	12
122Y	117.55	–	–	1 146	36	–	–	1 083	30
123X	117.60	–	–	1 147	12	–	–	1 210	12
123Y	117.65	–	–	1 147	36	–	–	1 084	30
124X	117.70	–	–	1 148	12	–	–	1 211	12
**124Y	117.75	–	–	1 148	36	–	–	1 085	30
125X	117.80	–	–	1 149	12	–	–	1 212	12
**125Y	117.85	–	–	1 149	36	–	–	1 086	30
126X	117.90	–	–	1 150	12	–	–	1 213	12
**126Y	117.95	–	–	1 150	36	–	–	1 087	30

* These channels are reserved exclusively for national allotments.

** These channels may be used for national allotment on a secondary basis.

The primary reason for reserving these channels is to provide protection for the secondary surveillance radar (SSR) system.

 108.0 MHz is not scheduled for assignment to ILS service. The associated DME operating channel No. 17X may be assigned for emergency use. The reply frequency of channel No. 17X (i.e. 978 MHz) is also utilized for the operation of the universal access transceiver (UAT). Standards and Recommended Practices for UAT are found in Annex 10, Volume III, Part I, Chapter 12.

5.14 Geographical separation criteria for DME, including DME X, Y, W and Z channels

Note.— This paragraph includes protection criteria for DME W and Z channels. These are, currently, not used. The material in this paragraph is provided for information.

5.14.1 In order to allow consideration of actual antenna designs, equipment characteristics, and service volumes, the signal ratios needed to assure interference-free operation of the various facilities operating on DME channels are provided below. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.

5.14.2 *Desired to undesired (D/U) signal ratios at the airborne receiver*

5.14.2.1 Table 5.5 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

5.14.2.2 Accordingly, DME channel assignments depend upon the following:

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments:* This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

e) *For second adjacent frequency, same or different code assignments:* The second adjacent frequency combinations generally need not be frequency protected. However, special attention should be given to Note 4 of Table 5.5, especially if the undesired facility is a DME/P transponder.

Table 5.5 Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	–42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	–42
Different pulse code	$-(P_u + 7)$	–75
Second adjacent frequency:		
Same pulse code	$-(P_u + 19)$	–75
Different pulse code	$-(P_u + 27)$	–75

Note 1.— The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to decoder rejection of 6 microseconds.

Note 2.— The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with Annex 10, Volume I, Chapter 3, paragraphs 3.5.5.3.4.2 and 3.5.5.3.4.3 of Chapter 3 and providing a decoder rejection conforming to Annex 10, Volume I, Chapter 3, paragraph 3.5.5.3.5.

Note 3.— P_u is the peak effective radiated power of the undesired signal in dBW.

Note 4.— The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.

Note 5.— In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B

5.14.3 Special considerations for DME Y and Z channel assignments

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

5.14.4 *Special considerations for DME/P associated with ILS*

5.14.4.1 For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

5.14.4.2 When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the transponder antenna is at least minus 93 dBW/m^2. This sensitivity level is based on the values contained in Chapter 3, 3.5.4.2.3.1 and it is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

Chapter 6 Ground Based Augmentation System (GBAS)

6.1 Introduction

6.1.1 GBAS is an element of the Global Navigation Satellite (GNSS) system and defined in Annex 10, Volume I, section 3.7.3.5. Guidance material for GBAS is in Annex 10, Volume I, Attachment D. GBAS provides precision approach with vertical guidance to the aircraft.

6.1.2 GBAS includes a ground (broadcast) transmitter (VHF Data Broadcast or VDB) and an associated aircraft receiver. The GBAS ground transmitter can support all aircraft, within the coverage, with approach data, GNSS corrections and GNSS integrity information for GNSS satellites within view. GBAS systems also include multiple reference receivers. These receivers process GNSS satellite signals. The GBAS system generates the data messages to augment the GNSS signals. The data messages are transmitted by the VDB transmitter.
Note.— A GBAS/VDB system may include multiple transmitters to provide adequate coverage.

6.1.3 GBAS can provide:

- Approach service to provide guidance to the aircraft within the approach service volume
- Positioning service to provide horizontal position to support RNAV operations

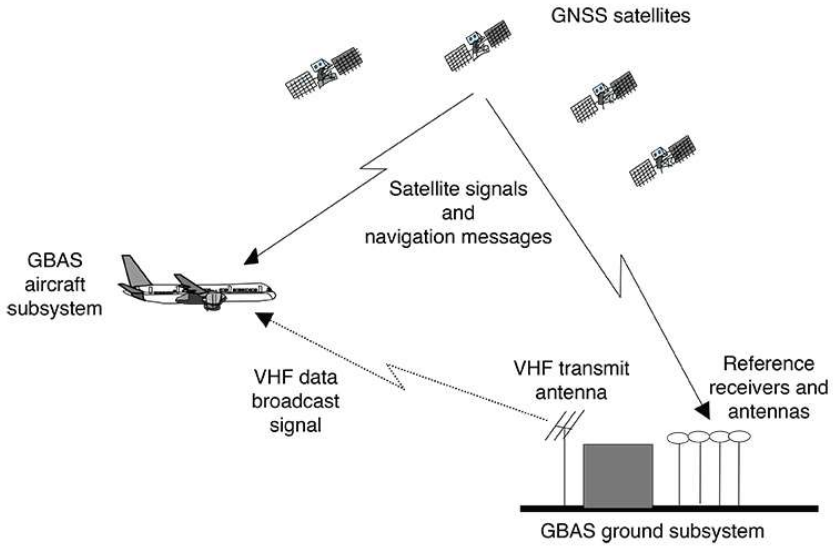

Figure 6-1 Principles of the operation of GBAS

6.1.4 A more detailed description of the GBAS system is contained in Annex 10, Volume I, Attachment D paragraph D-7.

6.2 Designated Operational Coverage (DOC).

6.2.1 The DOC of the GBAS/VDB to provide the approach service is as shown in Figure 6-2

6.2.1.1 The vertical coverage extends up to 10.000 ft above the runway threshold.

6.2.1.2 Figure 6-2 presents the minimum approach DOC (Re. Annex 10, Volume I, Chapter 3, paragraph 3.7.3.5.3). States may, as required, specify an extended DOC based upon to operational requirements. It is recommended to use an omnidirectional coverage that extends to 23 NM from the runway threshold and up to a level of 10.000 ft above runway threshold. States may specify different (larger) DOC areas.

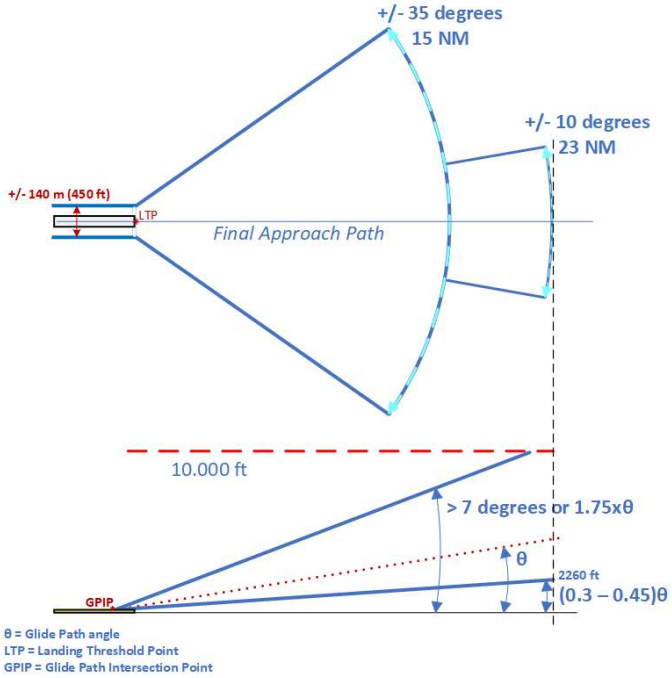

Figure 6-2 Minimum required DOC of GBAS

6.2.1.2.1 The vertical coverage is limited by a plane that extends from the glide path interception point with an angle of 0.3 times the Glide Path angle. For a Glide Path with 3 degrees, this angle is 0.9 degrees. At 20 NM, this plane is 2260 ft above the Earth. The upper limit of coverage is 10000 ft that follows the Earth curvature.

6.2.1.3 When GBAS supports multiple approaches, use of a single omnidirectional VDB may be considered, if geographically feasible. In this case, frequency coordination should include all GBAS coverage areas.
Note.— The success rate for GBAS frequency assignments could be improved by using for each runway-end the minimum required DOC.

6.2.2 The DOC for the GBAS/VDB when providing the GBAS positioning service is the area as promulgated by States. More information on establishing the DOC is in Annex 10, Volume I, Attachment D, paragraph 7.3

6.2.3 Typically, the DOC for GBAS/VDB facilities is referenced to the location and the elevation of the threshold of the runway. However, in cases where such information is not available, the coverage may be referenced to the location of the VDB transmitter. In this case, considering the off-set of the VDB transmitter from the runway threshold, for frequency assignment planning purposes, the DOC of the GBAS should be extended wit [3] NM from the location of the VDB transmitter or the aerodrome reference point (ARP), in which case a circular coverage [may] need to be considered / assumed

6.2.4 GBAS/VDB positioning service e.i.r.p

6.2.4.1 The e.i.r.p for the GBAS/VDB when providing the approach service is typically 17 dBW (50 W) to provide service down to about 2000 ft at the lower edge of the DOC.

6.2.4.2 The e.i.r.p for the GBAS/VDB when providing the positioning service is in Table 6-1.

Range (NM)	e.i.r.p (dBW)	e.i.r.p (W)
50	14	25
100	20	100
150	23	200
200	26	400

Table 6 – 1 Typical e.i.r.p for GBAS/VDB positioning service
(source: Annex 10, Vol. I, Att. D (table D-3); figures slightly modified)

6.2.4.3 The link budget used for establishing these e.i.r.p values is in Annex 10, Volume I, Attachment D Table D-3. Only the horizontally polarized signals are considered.

6.3 GBAS/VDB RF Frequencies and characteristics

6.3.1 GBAS operates in the frequency band 108 – 117.975 MHz. The lowest assignable frequency is 108.025 MHz and the highest assignable frequency is 117.950 MHz.

6.3.2 The channel spacing is 25 kHz.

6.3.3 For use in civil aviation, the GBAS signal is horizontally polarized. This reduces significantly the minimum separation distances between vertically polarized signals such as are used in VHF COM systems, VDL Mode 2 and VDL Mode 4. In this chapter consideration is given to the use of only horizontally polarized GBAS signals.

6.3.3.1 In areas where only horizontal polarization is operation, the consideration of cross-polar isolation between a purely horizontal polarized GBAS system and a vertical polarized system, like VHF-COM will provide significantly reduced separation requirements. The temporary value for cross polarization isolation between horizontal and vertical polarization is [assumed to be] 10 dB *(Re. Annex 10, Attachment D, 7.2.4)*.

6.3.4 For frequency assignment planning purposes, it is assumed the field strength of the desired corresponds to the minimum field strength, as defined in Annex10, Volume I, throughout the designated operational coverage. The minimum field strength is 215 μV/m (-99dBW/m^2) which is equivalent to a power level at the aircraft antenna output of -102 dBW with an ideal isotropic antenna (for the horizontal component of the GBAS/VDB signal). The maximum field strength is (SIS_{max}) 0.879 V/m (-27 dBW/m^2 or -29 dBW).

The minimum field strength is based on the following considerations:
Required receiver sensitivity: - 117 dBW
Maximum aircraft implementation loss: 15 dB
----------+
Power from isotropic aircraft antenna - 102 dBW
(Re. Annex 10, Volume I, Chapter 3, 3.7.3.5.4.4 and Attachment D, table D-3)

Note.— Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the actual aircraft implementation loss for the horizontal component is 19 dB the receiver sensitivity must exceed the minimum requirement and achieve –121 dBW to satisfy the nominal link budget.

6.4. FM immunity

6.4.1. Once a candidate frequency is identified for which the GBAS and VOR separation criteria are satisfied, compatibility with FM transmissions must be determined. This is to be accomplished using the methodology applied when determining FM compatibility with VOR. If FM broadcast violates this criterion, an alternative candidate frequency has to be considered.

6.4.2 The desensitization is not applied for FM carriers above 107.7 MHz and VDB channels at 108.050 MHz

because the off-channel component of such high-level emissions from FM stations above 107.7 MHz will interfere with GBAS VDB operations on 108.025 and 108.050 MHz, hence those assignments will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate interference in the VDB receiver.

6.4.3 The FM intermodulation immunity requirements are not applied to a VDB channel operating below 108.1 MHz, hence assignments below 108.1 MHz will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate intermodulation products in the VDB receiver.

6.5 GBAS Data Selector and Time Slot Planning Criteria

GBAS slot assignments and GBAS 5-digit channel numbers require coordination when the same GBAS frequency is used at different airports within the respective DOC's.

6.5.1 RPDS and RSDS assignments are to be controlled to avoid duplicate use of channel numbers within the protection region for the data broadcast frequency. Therefore, the GBAS service provider has to ensure that an RPDS and RSDS are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. Assignments of RPDS and RSDS are to be managed along with assignments of frequency and time slots for the VHF data broadcast

6.5.2 Time slot co-ordination among GBAS VDB systems operating on the same frequency will not be used initially, i.e. all 8 time slots (A – H) are assigned to a station together with the VDB frequency. Since Annex 10 provides in Table D-3. Typical GBAS/GBAS frequency assignment criteria the following note:

Note.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 200 m from areas where the desired signal is at minimum field strength.
Reuse of a frequency is possible if the limitations in the note are observed.
Editorial Note.— This paragraph is copied from the EUR DOC 11 and may need further clarifications

6.5.3 Reference path data selectors (RPDS) and reference station data selectors (RSDS) must not be duplicated within the protection region of a given frequency. As long as time slot co-ordination is not used to share frequencies, as indicated above, RPDS and RSDS (0 to 48) compatibility is automatically established via frequency co-ordination, i.e. all 49 data selectors are available together with the assigned VDB frequency.
Note.— More information on the use and coordination of the RPDS and RSDS is in Annex 10, Volume I, Appendix B, section 3.6.5.7. Further guidance on this is necessary.

6.5.4. **GBAS Reference Path Identifier** Between GBAS installations within radio range of a particular GBAS ground subsystem the reference path identifier is assigned to be unique. The requirement is found in Annex 10, Volume I, Appendix B, paragraph 3.6.4.5.1

6.5.5 **GBAS identifier.** GBAS identifier the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Annex 10. Volume I, Appendix B, paragraph 3.6.3.4.1

6.5.6 **Slot assignments.** The relative assignment of slots to a GBAS ground subsystem can impact performance in instances where messages in multiple slots need to be received by the airborne subsystem prior to processing. This will occur when using linked messages and/or for a GAST D ground subsystem where correction data is contained in both the Type 1 and Type 11 messages. In these cases slot assignments for all MT 1 and 11 should be adjacent to avoid unnecessary latency and complexity of design. Non-adjacent assignments may, depending on the design of the ground subsystem, result in a lack of time for the ground subsystem to process fault detections, render some slot combinations unusable and thus result in lower efficiency of spectrum use.

6.6 Protection requirements

Source: Annex 10, Volume I, Appendix B, paragraph 3.6.8.2.2.3, 3.6.8.2.2.5 and 3.6.8.2.2.6.

6.6.1 Protection requirements for GBAS/VDB receivers

6.6.1.1 The GBAS/VDB receiver shall be capable to achieve a message failure rate of not more than one failed message per 1000 data messages. The D/U ratios in Table 6.2 will meet this requirement.

Frequency offset	VDB/VDB	VDB/VOR	VDB/ILS	VDB/VHF-COM
Co-frequency	26 dB	26 dB	26 dB	n/a
+/- 25 kHz	-18 dB	0 dB	0 dB	n/a
+/- 50 kHz	-43 dB	-34 dB	-34 dB	-32 dB
+/- 58.33 kHz	n/a	n/a	n/a	-37 dB
+/- 66.66 kHz	n/a	n/a	n/a	-41 dB
+/- 75 kHz – +/- 975 kHz	-46 dB	-46 dB	-46 dB	-44 dB
+/- 83.33 kHz	n/a	n/a	n/a	-47 dB
+/- 91.66 kHz	n/a	n/a	n/a	-49 dB
+/- 100 kHz	-46 dB	-46 dB	-46 dB	
≥ 1000 kHz	-46 dB	-60 dB	-60 dB	

Table 6.2 – Co- and adjacent channel protection requirements for GBAS/VDB receivers

6.6.2 Airborne Contribution Factor

6.6.2.1 With the view to protect the desired VDB signals in space, an airborne contribution factor has been added. This airborne contribution factor compensates for antenna gain variations in the horizontal plane (between the direction of the desired versus the undesired transmitter) and on-board transmission line loss variation (between the frequency of the desired and the undesired signal. The airborne contribution factor can be calculated with 15 + Min (6, 6 x Frequency Offset (in kHz) /1000) with a maximum frequency offset of 1000 kHz.

6.6.2.2 Table 6-3 contains the protection ratios that are to be observed in frequency assignment planning to protect a desired GBAS/VDB from interference that can be caused by an undesired GBAS/VDB, VOR or ILS or VHF COM facility.

Frequency offset	VDB/VDB	VDB/VOR	VDB/ILS	VDB/VHF-COM
Co-frequency	41 dB	41 dB	41 dB	n/a
25 kHz	-3 dB	15 dB	15 dB	n/a
50 kHz	-27 dB	-18 dB	-18 dB	
+/- 58.33 kHz	n/a	n/a	n/a	
+/- 66.66 kHz	n/a	n/a	n/a	
75 kHz	-30 dB	-30 dB	-30 dB	
+/- 83.33 kHz	n/a	n/a	n/a	
+/- 91.66 kHz	n/a	n/a	n/a	
+/- 100 kHz				
975 kHz	-25 dB	-25 dB	--25 dB	
≥ 1000 kHz	-25 dB	-39 dB	-39 dB	

Table 6-3 – Co- and adjacent channel protection requirements for GBAS/VDB; signal-in-space

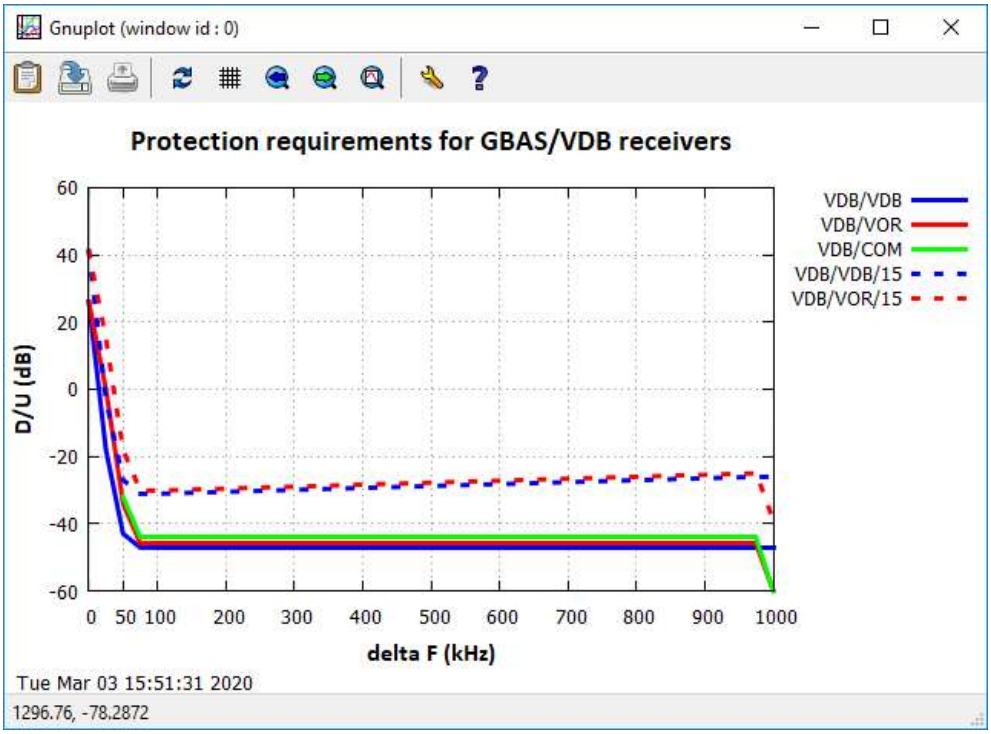

Figure 6.3 – Protection requirements for GBAS VDB systems (Re. Table 6-2 and Table 6-3)

6.6.2.2.1 The blue curves in Figure 6-3 present the D/U ratios between desired and undesired VDB signals. The solid line if of the D/U ratio at the receiver input; the dotted line is for the D/U ratio at the aircraft antenna (Signal-in-Space).

6.6.2.2.2 The red curves in Figure 6-3 present the D/U ratios between the desired VDB signal and the undesired VOR or ILS-Localizer signals. The solid line if of the D/U ratio at the receiver input; the dotted line is for the D/U ratio at the aircraft antenna (Signal-in-Space).

6.6.2.2.3 The green curve in Figure 6-3 present the D/U ratios between the desired VDB signal and the undesired VHF-COM signal. The solid line if of the D/U ratio at the receiver input; the dotted line is for the D/U ratio at the aircraft antenna (Signal-in-Space).

6.6.3 Compatibility criteria to protect ILS-Localizer and VOR signals from interference that can be caused by GBAS/VDB signals are in Chapter 3 and 4 respectively.

6.6.4 Interference from VDL Mode 4 signals. (to be added as and when implemented)

6.6.5 Interference from VHF-COM signals

6.6.5.1 On-board compatibility – No frequency assignment planning constraints have been identified to secure the compatibility between the on-board transmission of VHF-COM signals and the reception of GBAS/VDB signals on the same aircraft.

6.6.5.2 Air-to-air interference can be expected as in Table 6-4

ΔF (kHz)	D/U	10dBW[1]		14 dBW[1]		17dBW[1]		20 dBW[1]	
		L (dB)	D(NM)	L (dB)	D(NM)	L (dB)	D(NM)	L (dB)	D(NM)
50	-34 dB	78	< 1	82	1.5	85	3	88	4.5
58.3	-37 dB	75	< 1	79	< 1	82	1	85	3
66.6	-40 dB	72	< 1	76	< 1	79	<1	82	1.5
75	-39 dB	73	< 1	77	< 1	80	< 1	83	2
83.3	-42 dB	70	< 1	76	< 1	77	< 1	80	1
91.5	-42 dB	70	< 1	76	< 1	77	< 1	80	1
100	-42 dB	70	< 1	76	< 1	77	< 1	80	1
125	-46 dB	66	< 1	70	< 1	79	< 1	76	< 1

Table 6-4 Minimum separation distances between aircraft

The minimum required transmission loss is calculated with the formula = Tx – Pd +D/U

- Tx is the e.i.r.p. of the undesired aircraft transmitter
- Pd is the level of the minimum GBAS/VDB signal at the (desired) aircraft and is -102 dBW
- D/U is as per Table 6-4

6.6.5.2.1 The minimum separation distances as in Table 6-4 were calculated assuming isotropic antennas on board the desired and the undesired aircraft. Taking into account that the effect of the actual antenna diagram of the VHF-COM and the GBAS/VDB antenna as well as the transient effect of air-to-air interference, at a frequency separation greater than 100 kHz no air-to-air interference is expected

Note.— An aircraft e.i.r.p. of 20 dBW (100 W) is not normally used. For aircraft e.i.r.p. of 17dBW (50 W) or less, a minimum frequency separation between the aircraft VHF-COM and the GBAS/VDB receiver of 50 [58.3] kHz may be recommended.

6.6.5.3 Ground-to-Air interference. At short distances, as shown in Table 6-4, interference from a VHF-Ground facility can be expected when the e.i.r.p of the ground station is between 14 dBW (25W) to 20 dBW (100W). Maintaining a minimum frequency separation of 100 kHz between the assigned GBAS/VDB and VHF-COM frequency would avoid such interference. One option is to ensure in the frequency assignment planning process that a guard band of 100 kHz is introduced which would exclude the frequencies between 117.900 – 117.975 MHz to be used for GBAS/VDB.

Note.— This condition seems to be extremely conservative. Taking into account the actual antenna diagram and the geography of short distances to the (interfering) VHF COM station, is may be sufficient to only exclude the frequency 117.950 MHz from being assigned to a GBAS/VDB station.

6.7 Propagation model

6.7.1 The propagation model that can be used to assess compatibility between GBAS/VDB stations and with ILS/VOR stations is as described in Chapter 1 of this Handbook in paragraph 1.3.3. Details on this propagation model can also be found in ITU-R Recommendation P.528-4[2]

6.8 Geographical separation distances between co- and adjacent-frequency facilities

6.8.1 For the calculation of the minimum geographical separation distance between a (desired) GBAS/VDB facility and an undesired GBAS/VDB (or Localizer, VOR or VDL M-4) facility the generic model as described in Chapter 1, paragraph 1.4 is applied.

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[1] E.i.r.p. of the (undesired) aircraft transmitter

[2] ITU R P.528 is expected to be updated in the near future implementing a lower frequency band edge (below 125 MHz) and horizontal polarization case. Throughout the Handbook, it will become necessary to update all references to ITU R P.528 and to apply the relevant curves, taking into account the polarization of the relevant aeronautical radio communication and navigation facilities.

6.8.2 The generic model establishes the minimum separation distance between a desired and an undesired facility on the basis of the minimum required GBAS/VDB signal of the (desired) GBAS/VDB facility. The undesired facility should be separated with a distance that, taking into account the e.i.r.p of the undesired facility, protects the minimum desired VDB signal as per paragraph 6.3.4 above.

6.8.3 For the calculation of the minimum separation distance, the required transmission loss, taking into account the minimum required field (signal) strength at the aircraft antenna of the desired facility, the D/U ratios as per Table 6-2 as well as the e.i.r.p of the undesired facility are used. The minimum separation distance between the desired and the undesired facility is established using the relevant ITU-R propagation curves as per ITU-R Recommendation 528-4 The required transmission loss between the location of the undesired transmitter and the edge of coverage of the desired facility is calculated with formula 1.4.4 in Chapter 1:

$$L = Tx - P_d + D/U$$

Where: L is the required transmission loss
Tx is the e.i.r.p of the undesired facility (as specified by States; typical 17 dBW)
Pd is the minimum required field strength as per Annex 10. For a VDB facility this is -102 dBW
D/U is the D/U ratio (SIS) as per Table 6.2

6.9 Calculation of minimum separation distances

6.9.1 Calculation of the minimum separation distance between a desired VDB and an undesired VDB.

6.9.1.1 Example: Desired VDB versus undesired VDB; co-frequency,

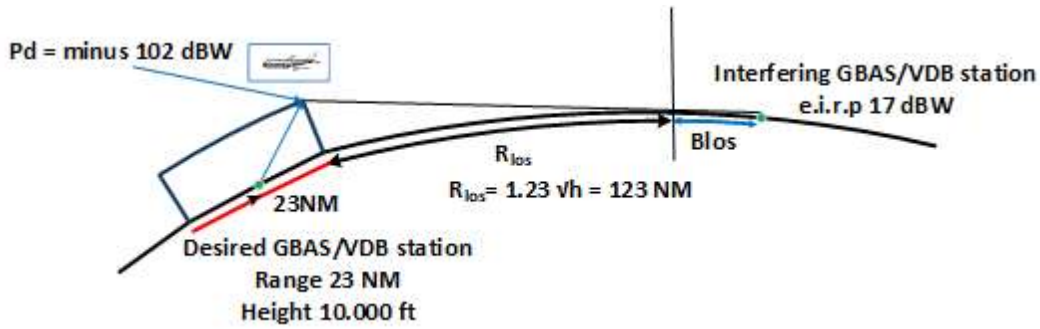

Figure 6.3 Interference scenario for co-frequency GBAS stations

The parameters used in the calculations are:

Tx = 17 dBW (re. Paragraph 6.5.1)
Pd = -102 dBW (re. Paragraph 6.3.4)
D/U = 41 dB (SIS; re. paragraph 6.4.2 and Table 6-2)
ITU-R aeronautical propagation curve for 112 MHz, h1 = 45 ft, h2 = 10.000 ft;5% of the time

6.9.1.2 The required transmission loss between the undesired GBAS/VDB station and the edge of coverage of the desired GBAS/VDB station L = Tx -Pd + D/U = 17 (dBW) + 102 (dBW) +41 (dB) = 160 dB

6.9.1.3 With the ITU-R aeronautical propagation curve for 112 MHz and 5% of the time, the height of the (undesired) VDB 45 ft and the height of the (desired) aircraft receiver at 10000 ft. The minimum required transmission loss of 160 dB is obtained with a separation distance of 213 NM. This is the minimum separation distance between an undesired VDB transmitter and an aircraft at the edge of coverage of the (desired) VDB facility. The station-to-station separation distance is 213 + 23 = 236 NM.
Note.— At this distance, propagation is by troposcatter

6.9.1.4 With the method as described above, Table 6-5 with GBAS vs GBAS separation distances was developed for the desired GBAS facility providing the approach service.

6.9.1.4.1 These separation criteria do not allow for the use of a second VDB frequency within the DOC of the desired VDB even for a frequency separation greater than 1 MHz. For the use of a second VDB frequency a more detailed analysis is necessary.
Note.— Guidelines for the detailed analysis are being developed.

Frequency offset	D/U (dB)	L (dB)	Distance from DOC of desired station to undesired station	Distance between GBAS stations
∆f = 0 (Co- frequency)	41	160	213 NM	236 NM
∆f = 25 kHz	-3	116	81 NM	104 NM
∆f = 50 kHz	-27	92	9 NM	32 NM
∆f = 75 kHz – 975 kHz	-30 to -25	89 to 94	6 to 11 NM	29 to 33 NM
∆f ≥ 1000 kHz	-25	94	11 NM	33 NM

Table 6-5 – Minimum separation distances between desired and undesired GBAS stations

6.9.2 Calculation of the minimum separation distance between a desired VDB and an undesired VOR or localizer facility (VOR or Localizer is the interferer).

6.9.2.1 The calculation of the minimum separation distances between the edge of coverage (DOC) of a (desired) GBAS/VDB facility and the location of an (undesired) VOR in the Tables 6-6, 6-7 and 6-8 follows the same principles as described in 6.8.1.1.

The parameters used in the calculations below are:
Pd = -102 dBW (re. Paragraph 6.3.4)
D/U is as in Table 6-2
Tx = 17 dBW, 27 dBW and 30 dBW respectively (e.i.r.p of undesired VOR or Localizer)
Height of the antenna of the (undesired) VOR is 20 ft above local terrain
Height of the antenna of the (undesired) Localizer) is 6 ft above local terrain
Note.— For the purpose of specifying the curve to be used in a compatibility assessment, the local terrain is assumed at Mean Sea Level. Chapter 1 of this Handbook, Volume II, provides information to address differences in site elevation between desired and undesired facilities.
Frequency = 112 MHz
Height of the (desired) VDB aircraft is 10.000 ft.
ITU-R aeronautical propagation curves (Recommendation P.528-4) for 112 MHz, 5% of the time
$L = Tx - P_d + D/U$

The implementation of this calculation scheme is illustrated in the following examples (sections 6.7.2.2 to 6.7.2.4) for typical combinations of e.i.r.p values for desired and undesired stations:

6.9.2.2 Separation distances between a (desired) VDB and an (undesired) VOR. The e.i.r.p for the undesired VOR is 17 dBW.

D/U (dB)	L(dB); 5%	VOR (17 dBW) Distance (NM)	Localizer (17dBW) Distance (NM)
41 (∆f = 0)	160	160	146
15 (∆f = 25)	134	118	36
-18 (∆f = 50)	101	21	14
-30 (∆f = 75)	89	6	6
-25 (∆f = 975)	94	11	8
-39 (∆f ≥ 1000)	80	1	1

Table 6-6 – Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR / Localizer

6.9.2.3 Separation distances between a (desired) VDB and an (undesired) VOR or Localizer; The e.i.r.p for the undesired VOR or Localizer is 27 dBW.

D/U (dB)	L(dB); 5%	VOR (27 dBW) Distance (NM)	Localizer (27 dBW) Distance (NM)
41 (Δf = 0)	170	243	171
15 (Δf = 25)	144	138	121
-18 (Δf = 50)	111	43	25
-30 (Δf = 75)	99	18	12
-25 (Δf = 975)	104	26	17
-39 (Δf ≥ 1000)	90	7	6

Table 6-7 – Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR or Localizer

6.9.2.4 Separation distances between a (desired) VDB and an (undesired) VOR or Localizer; The e.i.r.p for the undesired VOR or Localizer is 30 dBW; Pd is -102dBW, propagation as per ITU propagation curves.

D/U (dB)	L(dB); 5%	VOR (30 dBW) Distance (NM)	Localizer (30 dBW) Distance (NM)
41 (Δf = 0)	173	260	209
15 (Δf = 25)	147	143	129
-18 (Δf = 50)	114	51	29
-30 (Δf = 75)	103	24	16
-25 (Δf = 975)	107	31	20
-39 (Δf ≥ 1000)	93	10	7

Table 6-8 – Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR or Localizer

Note.— The separation distances as in Tables 6-6, 6-7 and 6-8 are measured from the location of the undesired VOR or Localizer facility to the edge of the coverage of the desired GBAS/VDB facility. The protection height of the GBAS/VDB facility is 10.000 ft.

6.10 Frequency assignment planning methodology for GBAS/VDB

6.10.1 For the frequency assignment planning and coordination of frequency assignments, the following methodology can used.
Note.— Alternative methods may be developed on the basis of a regional agreement

Step 1 – For the frequency coordination for a GBAS facility, all frequencies that were for assigned to ILS-Localizer, VOR or VDB facilities that are within the DOC +10 NM of the (desired) GBAS/VDB facility *and* that are within the range of +/- 975 kHz of the assigned Localizer, VOR of VDB frequency should be excluded for consideration as a candidate frequency for the (desired) GBAS/VDB facility.

Step 2 – For the undesired stations (ILS, VOR, VDB) that are outside the DOC of the desired GBAS/VDB facility, the frequency assignment planning criteria as in Chapter 6, paragraph 6.8.1 (GBAS/VDB) and 6.8.2 (Localizer and VOR) apply. These are based on the protection requirements as in paragraph 6.4.2.1 to protect the Signal-in-Space. The undesired stations can operate throughout the band 108 – 117.975 MHz.

Step 3 – Check if the required D/U ratio is always met with respect to the relative separation distance between GBAS VDB receiver and ILS/LOC or VOR stations located in the vicinity. This may include a detailed analysis taking into account the

exact characteristics of the Localizer and VOR facilities, ground and flight measurements of actual signal strength (of the desired and the undesired signal). Further guidance is in the "GBAS/VDB siting and same-airport frequency compatibility guidance". It is the State's responsibility that this step is performed prior to putting a GBS/VDB facility into operation.

Appendix A

Editorial Note.— Replace all of Appendix A with this material

Conversion sheet and formulas

Field strength

Convert μV/m → dB(μV/m): $\boldsymbol{dB(\mu V/m) = 20\log(\mu V/m)}$ **(1A)**
Example: field strength is 90 μV/m → 20log 90 dB(μV/m) = 39 dB(μV/m)

Convert dB(μV/m) to μV/m: $\boldsymbol{\mu V/m = 10^{(dB(\mu V/m)/20)}}$ **(1B)**
Example: field strength is 32 dB(μV/m) → $\boldsymbol{10^{(32/20)}}$ = 39.8 μV/m

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Power Flux Density (PFD)

Convert dB(μV/m) → dB(W/m^2) $\boldsymbol{dB(W/m^2) = dB(\mu V/m) - 145.8}$ **(2A)**
Example: field strength is 39 dB(μV/m) → the power flux density = 39 – 145.8 = -106.8 dB(W/m^2)

Convert dB(W/m^2) → dB(μV/m) $\boldsymbol{dB(\mu V/m) = dB(W/m^2) + 145.8}$ **(2B)**
Example: PFD = -107 dB(W/m^2) → field strength is -107 + 145.8 = 38.8 dB(μV/m)

The power flux density PFD, ***assuming free space propagation***, is calculated with:

$$\boldsymbol{PFD = \frac{P_T}{4\pi D^2}} \quad \textbf{(3A)}$$

$$\boldsymbol{10 * \log PFD = 10\log P_T - 10\log 4\pi - 20\log D} \ \textbf{(dBW/m}^2\textbf{)} \quad \textbf{(3B)}$$

10logP_T is the radiated power in dBW; D is the distance in meters.

Formula 3B can be re-written for D in km and $10\log P_T = eirp$ of the transmitter (dBW):

$$\boldsymbol{PFD\ (dBW/m^2) = eirp - 10\log 4\pi - 20\log 1000 D_{km}}$$

or $$\boldsymbol{PFD\ (dBW/m^2) = eirp - 71 - 20\log D_{km}} \quad \textbf{(3C)}$$

Formula 3C can be re-written for D in NM:

$$\boldsymbol{PFD\ (dBW/m^2) = eirp - 10\log 4\pi - 20\log 1.852 D_{km}}$$

or $$\boldsymbol{PFD\ \Phi\ (dBW/m^2) = eirp - 76.3 - 20\log D_{NM}} \quad \textbf{(3D)}$$

When the PFD (dBW/m^2) and the e.i.r.p (dBW) are known, the distance D to achieve the PFD from the given e.i.r.p can be calculated with:

$$\boldsymbol{D = 10^{\frac{eirp - PFD\Phi - 71}{20}}}\ \textbf{km} \qquad \text{or } \boldsymbol{D = 10^{\frac{eirp - PFD\Phi - 76.31}{20}}}\ \textbf{NM} \quad \textbf{(3D)}$$

Effective area $Ae(f)$ of a lossless isotropic antenna:

$$Ae(f) = 10\log_{10}\frac{\left(c/f\right)^2}{4\pi} \quad \textbf{(3E)}$$

where f is the frequency in Hertz and c is speed of light ($300x10^6$) m/s

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Power

Convert W to dB(W) $dB(W) = 10\log W$; $dBm = 10\log W + 30 = dBW + 30$ **(4A)**

Convert dB(W) → W $W = 10^{(dB(W)/10)}$; $W = 10^{((dBm-30)/10)}$ **(4B)**

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Received power

Convert µV/m → dB(W) $P_d = E - 20logf - 107.2$ **(5)**

where:
P_d = isotropically received power at the antenna output (dB(W))
E is the field strength (dB(µV/m))
f is the frequency (MHz)
Example: E = 90 µV/m → 39 dB(µV/m); f=112 MHz →20logf = 41; P_d = 39 – 41 – 107.2 = 109.2 dB(W)

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Frequency vs. wavelength

Convert frequency to wavelength: $\lambda = c/f$ where: **(6A)**
λ = wavelength (meter)
c = $3*10^8$ (m/sec)
f = frequency (Hertz)

Convert wavelength to frequency: $f = c/\lambda$ **(6B)**

- - - -

Free space propagation

Free space transmission loss: $L_{bf} = 20\log\frac{4\pi d}{\lambda}$ **(7)**

L_{bf}: free-space basic transmission loss (dB)
d: distance
λ: wavelength

Note.— Distance and wavelength have the same units of measurement

or Free space transmission loss: $L_{bf} = 32.4 + 20\log f_{MHz} + 20\log d_{km}$ **(dB)** **(7A)**

or Free space transmission loss: $L_{bf} = 37.8 + 20\log f_{MHz} + 20\log d_{NM}$ **(dB)** **(7B)**

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Distance to the radio horizon (4/3 Earth radius) using NM and feet or km and meter

$$d_{RH} = 1.23\left(\sqrt{h_{TX}}\right) \quad \textbf{(8)}$$

d_{RH}: the distance of the station to the radio horizon (NM)
h_{TX}: the height of the transmitter (or receiver) above the Earth's surface (feet)

$$d_{RH} = 4.12\left(\sqrt{h_{TX}}\right) \quad \textbf{(8A)}$$

d_{RH} distance from the station to the radio horizon (km)
h_{TX} the height of the transmitter (or receiver) above the Earth's surface (meter)

$$d_{RH} = 1.23\left(\sqrt{h_{TX}} + \sqrt{h_{RX}}\right) \quad \textbf{(8B)}$$

d_{RH}: the radio horizon separation distance between the transmitter and receiver (NM)
h_{Tx}: the height of the transmitter above the Earth's surface (feet)
h_{Rx}: the height of the receiver above the Earth's surface (feet)

Angle conversion:
Degrees to fractional degrees: D°M'S'' = D + M/60 + S/3600 fractional degrees

Fractional degrees to degrees	P.ABCDE:	Degrees is Integer of P.ABCDE degrees = P degrees Minutes is integer of the fraction ABCDE*60 Seconds is fraction of ABCDE *60
Convert degrees to radians	(Dfr)*π/180; Dfr = fractional degrees	
Convert radians to degrees	Drad*180/π; Drad = degrees in radians	

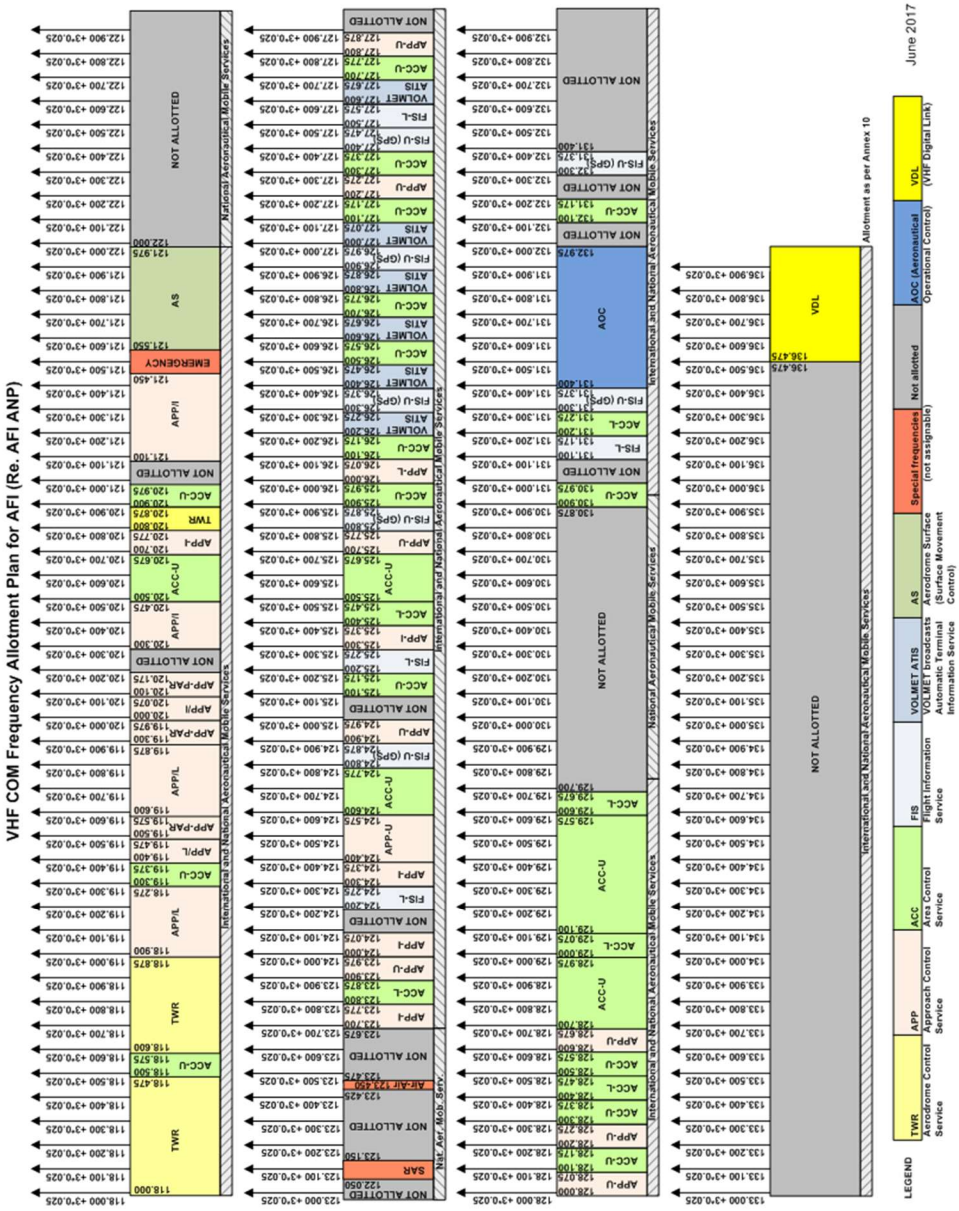
For spherical formulas see https://www.edwilliams.org/avform.htm

Earth radius: 6371 km or 3440 NM

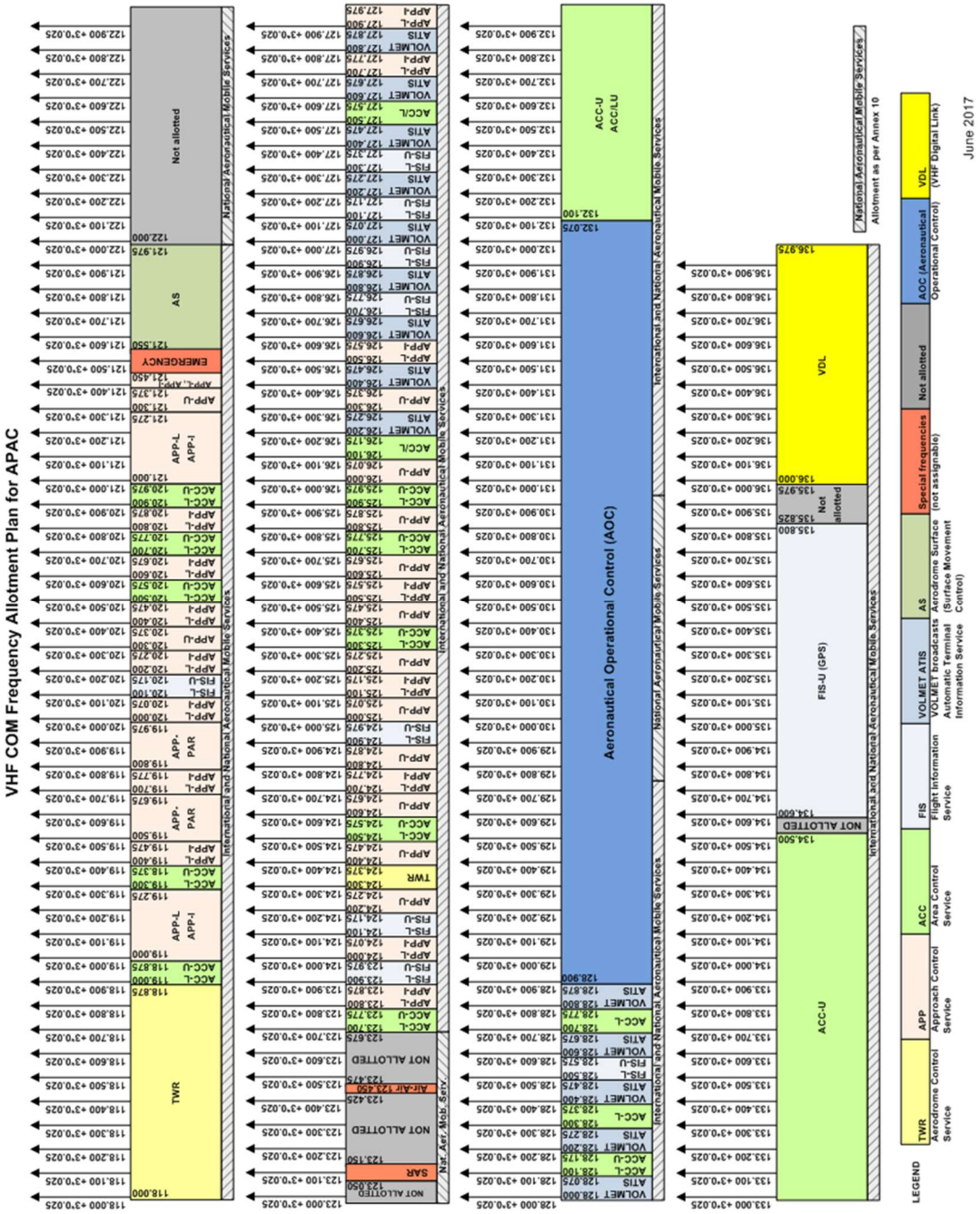
1NM = 1/60 degree or oneminute of a great circle at the Earth surface

Appendix B

Regional frequency allotment plans



Appendix B – Regional frequency allotment plans



Appendix B – Regional frequency allotment plans

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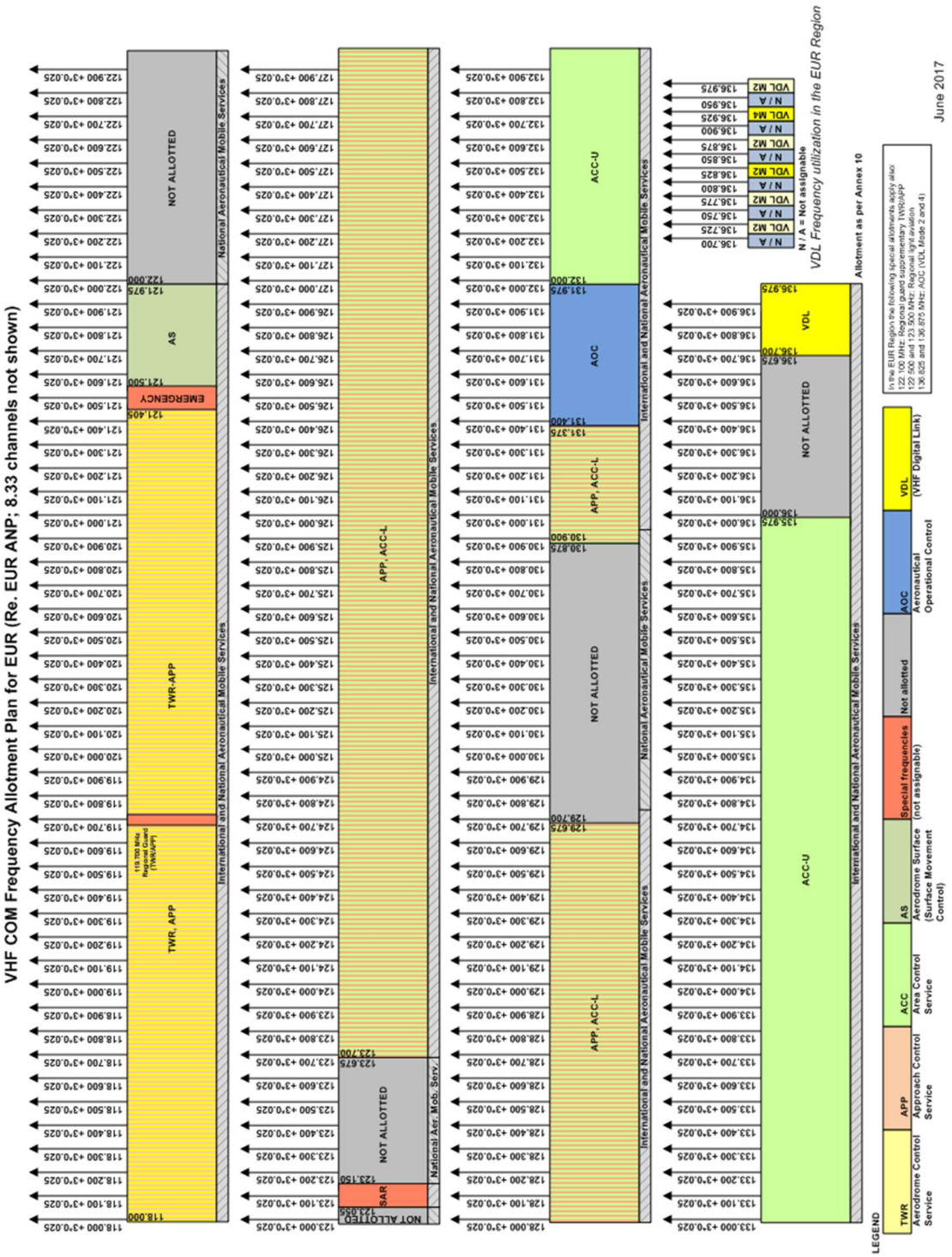

Appendix C

Regional frequency allotment tables

The regional frequency allotment tables referenced in this Handbook (Volume II) are contained in a supplement to the Handbook and can be downloaded from the Frequency Spectrum Management Panel website at:

http://www.icao.int/safety/fsmp/documents/doc9718.

Appendix D

Editorial Note.— New Appendix D – placeholder -.

ITU-R Recommendation P.528-4

To be added when the Recommendation P-528-4 has been modified into P-528-5
Add also material on the new GUI for this ITU-R Recommendation

— END —