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International Civil Aviation Organization

Fourth Meeting of Spectrum Review Working Group (SRWG/4)

Web-conference, 09 - 10 June 2020

Agenda Item 5: Next meeting and any other business

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

(Presented by the Secretariat)

SUMMARY

This paper presents the latest updates on the revision of the Handbook on Radio Frequency Spectrum Requirement for Civil Aviation (DOC9718), Volume II, *Frequency assignment planning criteria for aeronautical radio communication and navigation systems*. It is reproduced from IP10 of CNS SG/23 with latest updates.

1. INTRODUCTION

1.1 **The Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (DOC 9718), Volume II, Frequency assignment planning criteria for aeronautical radio communication and navigation systems**, was published in 2013 as the first edition.

1.2 There are 2 chapters and 3 appendices in the present Handbook, 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.

1.3 In the Navigation Systems Panel (NSP), work has been progressed on the development of frequency assignment planning criteria for NAV systems (ILS, VOR, DME and GBAS/VDB). This work is now mature and is expected to be approved by the NSP in November 2020.

1.4 The updated frequency assignment planning criteria presented in this paper (**IP/02 - Appendix**) replace the criteria currently in use in the APAC Region. **IP/02- Appendix** is embedded at the end of this paper.

2. DISCUSSION

2.1 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. The overall achievements of these revisions 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 are presented in this **IP/02 - Appendix**.

2.1.1 IP/02 - Appendix includes also the current material on frequency assignment planning for VHF Air-Ground communication systems as well as, in Appendices B and C, the current regional frequency allotment plans/tables. Appendix D on the ITU-R Recommendation P.528-4 on Aeronautical Propagation Curves is in preparation.

Agenda Item 5

09-10/06/20

2.2 The main revisions to Chapter 1 as in **IP-02 - Appendix** include:

- An updated description of the ITU propagation curves as in ITU-R Recommendation P.528-4;
- The introduction of a generic model for calculating geographical separation distances between desired and undesired facilities;
- The use of the ITU-R aeronautical propagation curves in compatibility calculations.

2.2.1 The main goal of these revisions is to improve the material on using the ITU-R propagation curves for aeronautical mobile and radionavigation services as contained in ITU-R Recommendation P.528-4. This Recommendation was updated by ITU-R Study Group 3 in June 2019. This material has been used for updating the ICAO program **Frequency Finder** to include the module for frequency assignment planning for NAV systems.

2.2.2 Paragraph 1.1 has been modified to describe the limitations in using the frequency assignment planning criteria as contained in the Handbook, in particular with respect to compatibility assessment between aeronautical and non-aeronautical systems.

2.2.3 Paragraph 1.3.3 has been largely re-written with the view to describe the increased propagation loss in the region closer to the radio line-of-sight of the radio path. This is caused by interference between the direct ray and a ray reflected from the surface of the Earth as well as the effect of the ground where diffraction starts to manifest itself and differs from the previous method using the free space propagation formulas.

2.2.4 The new paragraph 1.4 describes the generic model for the calculation of the minimum geographical separation distance between desired and undesired facilities. This model is assuming the protection of the minimum required field strength of the desired signal at the aircraft antenna. The minimum required field strength (desired signal) is specified in Annex 10. Protection of the desired signal is obtained by ensuring that the transmission loss between the undesired facility and the aircraft at the edge of the DOC of the desired facility is large enough to attenuate the undesired signal to below the maximum allowed level. This level in turn is determined by the established D/U ratio.

2.2.5 The new section 1.5 describes how to use the ITU-R propagation curves in compatibility calculations.

2.3 Chapter 2 contains the current, not modified, material in the Handbook on frequency assignment planning for aeronautical VHF air-ground communication systems. Work on incorporating in the Chapter material on the compatibility assessment between these communication systems and GBAS/VDB is in progress in the NSP.

2.4 The Chapter 3 presents material for the frequency assignment planning of ILS Localizer and Glide Path for incorporation in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (DOC 9718), Volume II. It also contains material to assess compatibility between Localizer and VOR systems. This material is being used for updating the ICAO program **Frequency Finder** to include the module for ILS Localizer and Glide Path frequency assignment planning.

2.4.1 Frequency assignment planning material for assessing compatibility with adjacent frequency VOR systems has been introduced. The same protection requirements for Localizer/Localizer compatibility has been applied to VOR/ILS compatibility. This is based on the protection requirements for ILS as in RTCA DO-195.

Agenda Item 5

09-10/06/20

2.5 The Chapter 4 includes material for the frequency assignment planning of the VOR systems for incorporation in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (DOC 9718), Volume II. It also contains material to assess compatibility between Localizer and VOR systems. The material in this paper is being used for updating the ICAO program **Frequency Finder** to include the module for VOR frequency assignment planning.

2.5.1 Frequency assignment planning material for assessing compatibility with adjacent frequency ILS/Localizer systems has been introduced. The same protection requirements for VOR/VOR compatibility has been applied to VOR/ILS compatibility. This is based on the protection requirements for VOR as is RTCA DO-196.

2.6 The Chapter 5 includes material for the frequency assignment planning of the DME systems for incorporation in Chapter 5 of the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (DOC 9718), Volume II.

2.6.1 The frequency assignment planning criteria for the DME in the Appendix D is based on the material as in Annex 10, Volume I, Attachment C, paragraph 7 as well as relevant DME planning principles that were developed in the EUR/NAT Region and incorporated in the EUR frequency manual (EUR DOC. 11).

2.7 The Chapter 6 includes material for the frequency assignment planning of the GBAS/VDB (VHF Data Broadcast) systems for incorporation in Chapter 6 of the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (DOC 9718), Volume II.

2.7.1 The material in the Chapter 6 is based on the frequency assignment planning criteria as currently contained in Annex 10, Appendix D, section 7.2 and subsequently updated by the NSP. The protection requirements for the VDB (Signal-in-Space) were brought in line with recent decisions taken by the NSP/Spectrum Working Group.

2.7.2 The frequency assignment planning criteria for GBAS/VDB as contained in Annex 10, Volume I, Attachment D, section 7.2 are brought in line with the generic compatibility assessment method as described in the revised Chapter 1 of the Handbook, Volume II.

2.8 **IP/02 - Appendix** introduces in Appendix A various conversions and formulas that are frequently used in frequency assignment planning

2.9 The material in the Appendix to this paper (**IP/02- Appendix** as embedded below) has been considered to be mature for approval by the NSP in November 2020 and has been incorporated in **Frequency Finder** for compatibility assessment of frequency assignments to NAV systems (ILS, VOR, DME and GBAS/VDB) .

2.9.1 Together with the approval of this material, consequential amendments will be reviewed.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

- a) to note the material in IP/02 – Appendix
- b) to discuss any relevant matter as appropriate.

Note: Any comment that may be required to address the special needs for the APAC region in frequency assignment planning for NAV systems is welcome. Such comments can be presented to the Secretariat.

SRWG/4 – IP/02
Agenda Item 5
09-10/06/20

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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

First Edition — 2013

This version of the Handbook includes amendments that were agreed by the Spectrum Working Group of the Navigation Systems Panel. It is subject to a further review by the NSP and the FSMP later in 2020.

The material in this Handbook has been incorporated in the ICAO program Frequency Finder.

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retrieval system or transmitted in any form or by any means, without prior
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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 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.

Future revisions will include material on frequency assignment planning for aeronautical HF air-ground communication systems (voice and data) and for radio navigation systems (NDB, ILS, VOR, GBAS, DME and MLS).

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.

TABLE OF CONTENTS

	<i>Page</i>
Glossary	(ix)
Chapter 1. General methodology for compatibility analysis	1-1
1.1 Introduction.....	1-1
1.2 Compatibility model	1-1
1.3 Propagation modelling.....	1-7
Chapter 2. Aeronautical VHF air-ground radio communication systems operating in the band 117.975 — 137 MHz	2-1
2.1 Introduction.....	2-1
2.2 Interference model	2-2
2.3 Frequency assignment planning criteria	2-11
2.4 Allotment of the frequency band 117.975 – 137 MHz.....	2-15
2.5 Frequency separation and channelling.....	2-17
2.6 Services and designated operational coverage (DOC)	2-18
2.7 Calculation of separation distances (methodology).....	2-23
2.8 Separation distances (air-ground communication services and ground-based broadcasting services)	2-32
2.9 Separation distances for VDL (VDL Mode 2 and VDL Mode 4).....	2-35
2.10 Guidance on the implementation and use of backup frequencies	2-36
Appendix A. Aeronautical propagation curves for 125 MHz, 300 MHz, 1 200 MHz and 5 100 MHz	App A-1
Appendix B. Regional frequency allotment plans	App B-1
Appendix C. Regional frequency allotment tables	App C-1

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
dB.	Decibel
dB_i.	Decibels relative to an isotropic radiator
dB_m.	Decibels relative to 1 milliWatt
dB_W.	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
GBAS.	Ground-based augmentation system
ILS.	Instrument landing system
ITU.	International Telecommunication Union
MSL.	Mean sea level
RF.	Radio frequency
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 (flight level 500)).

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*”.

MOD NSP/SWG:

[1.1.3 The material in this Handbook 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 the Handbook, 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 this Handbook, 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](#)

1.2 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:

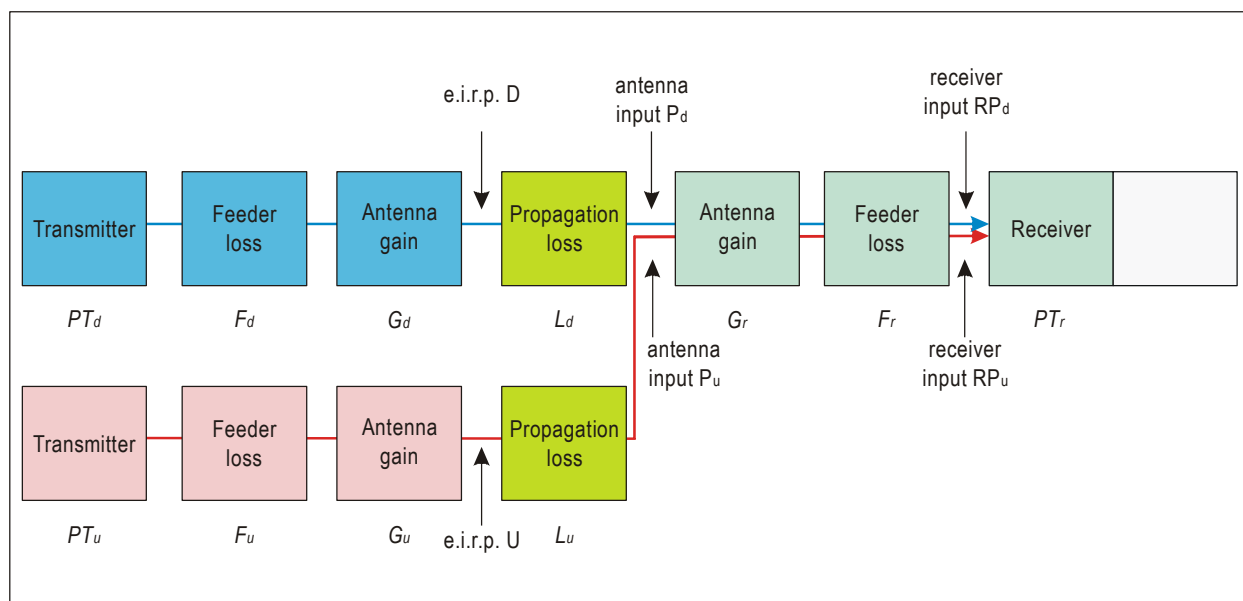


Figure 1-1. Schematic diagram of the complete scenario to be analysed

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 :	propagation loss for the desired signal (dB)
L_u :	propagation 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.

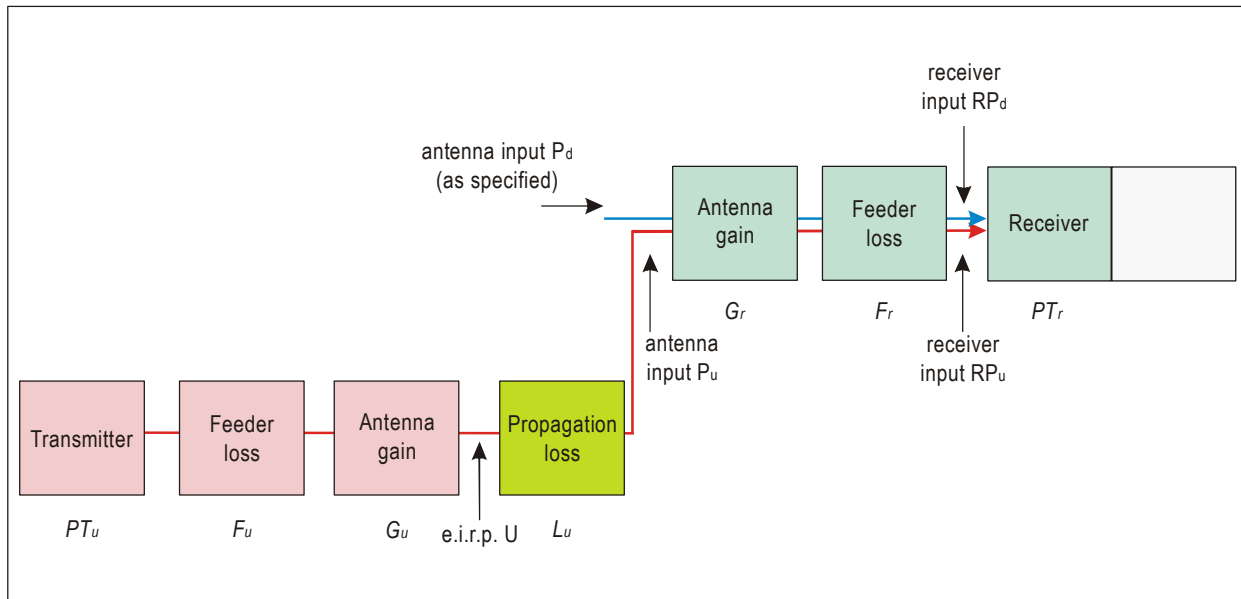


Figure 1-2. Schematic diagram of the minimum signal scenario

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 receiver noise power 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.

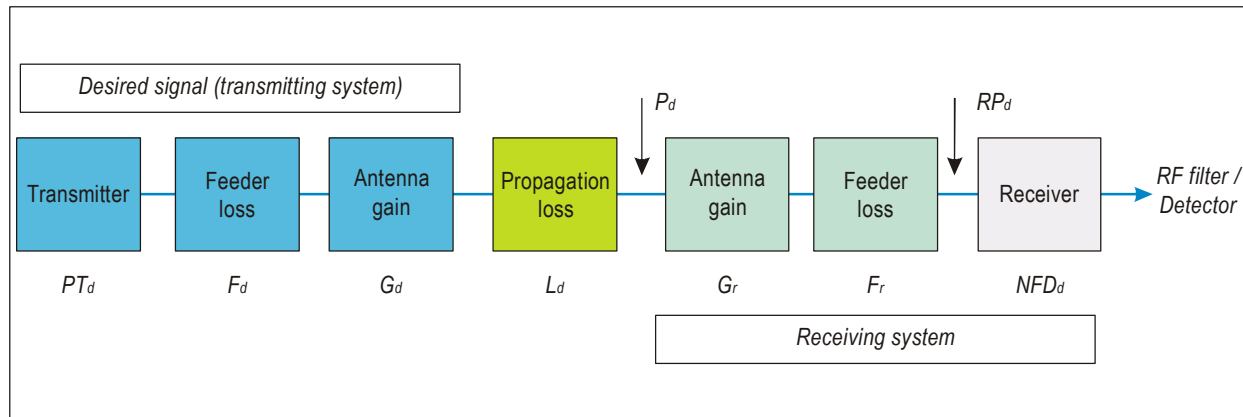


Figure 1-3. Schematic diagram of the desired signal path to the receiving antenna

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):

$$P_d = P_{T_d} - F_d + G_d - L_d \quad (1)$$

where:

- P_{T_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 : propagation loss for the desired signal (dB)
- P_d : power of the desired signal at the antenna of the receiver (dBm)

The propagation loss L_d is calculated in accordance with the appropriate propagation model as developed by the ITU. See 1.3 on propagation modelling and using the 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 $\mu\text{V/m}$) 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 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 as specified by ICAO; for the conversion from $\mu\text{V/m}$ to dBm, see 2.3.2).

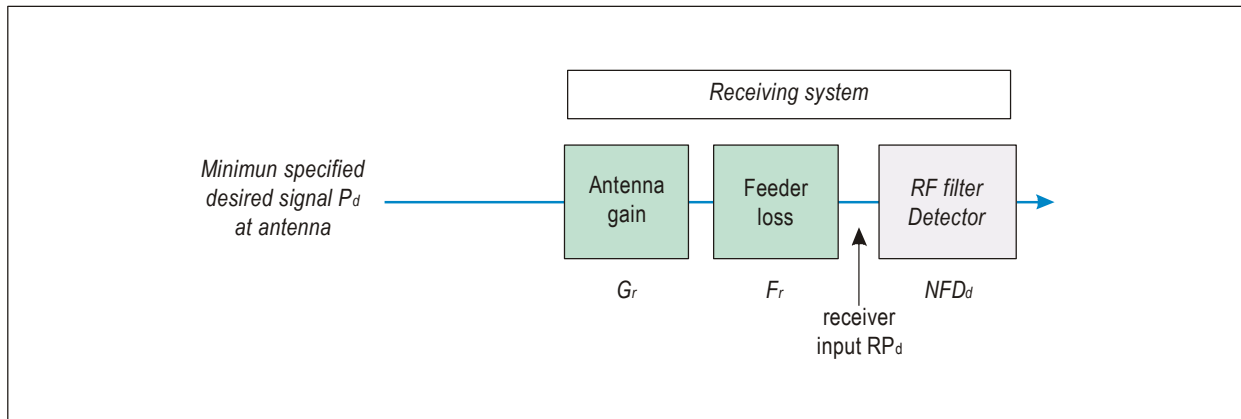


Figure 1-4. Desired signal path when minimum field strength is specified

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.

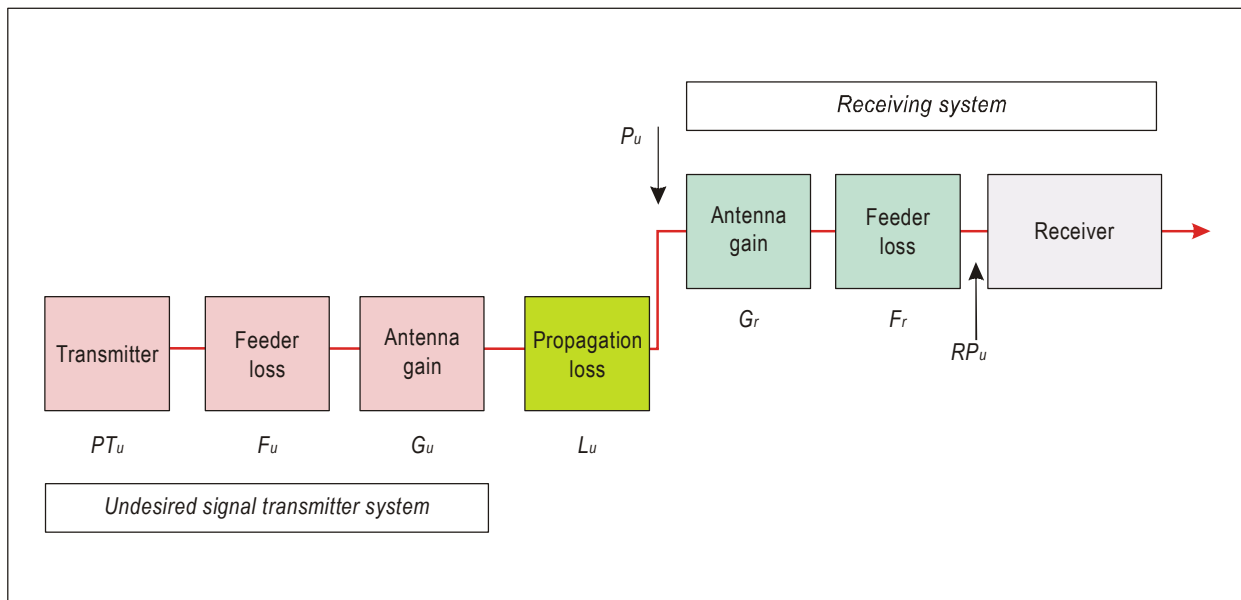


Figure 1-5. Schematic diagram of the undesired signal path

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: propagation 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 propagation 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):

$$P_d - P_u = \frac{D}{U} \quad (4)$$

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 P_u 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 planning criteria for aeronautical systems and the protection of those systems from 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 [and their applicability, including the advantages and disadvantages, are described in 1.3.5.](#)

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 propagation loss can be calculated using formula (6):

$$L_{bf} = 20 \log \frac{4\pi d}{\lambda} \quad (6)$$

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

$$L_{bf} = 37.8 + 20 \log f + 20 \log d \quad (8)$$

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 propagation. 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 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.

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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.

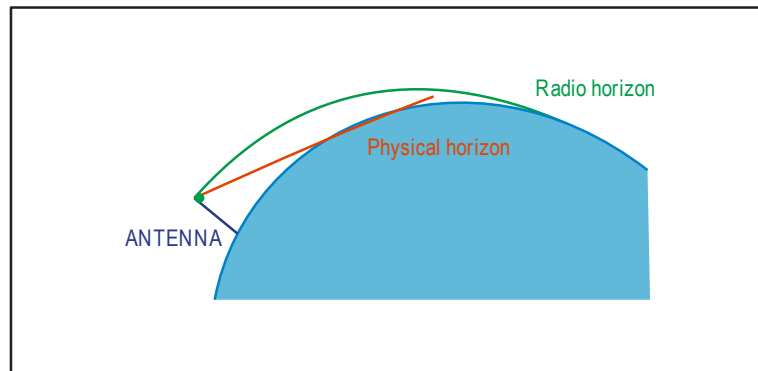


Figure 1-6. Radio horizon versus physical horizon

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.

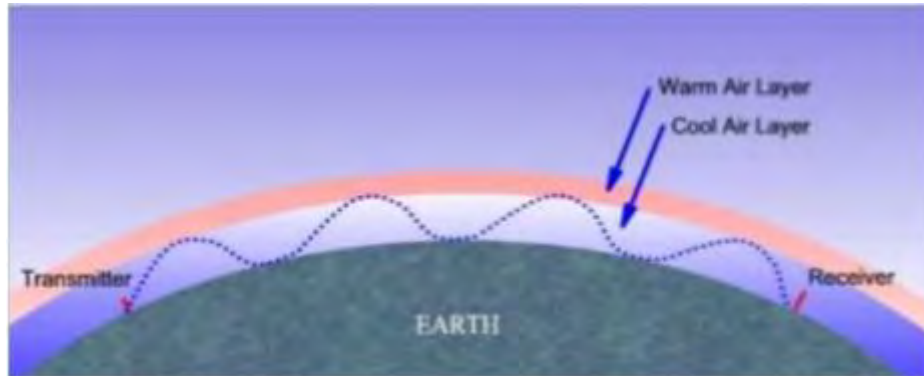


Figure 1-7. Propagation through ducting

!3.2.2.2 **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.

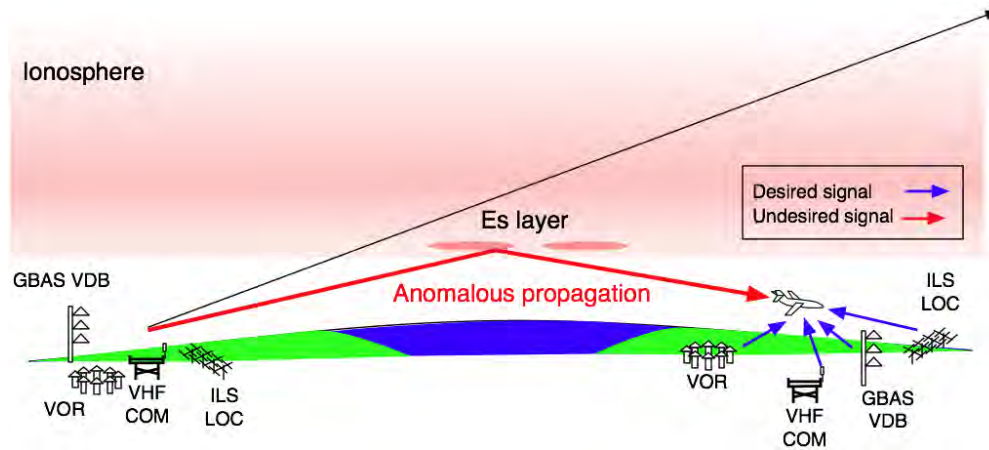


Figure 1-7A¹ – Propagation of VHF radio waves by the sporadic E-layer (Es layer).

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.

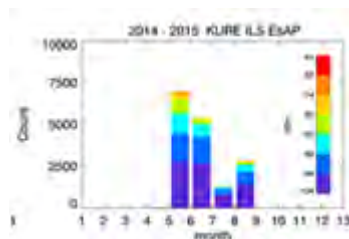


Figure 7B¹- Sporadic E-layer propagation Seasonal variations observed in Japan

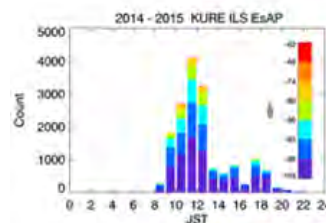


Figure 7C¹- Sporadic E-layer propagation Daily variations observed in Japan

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 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>

1.3.2.5 The distance to the radio horizon (4/3 Earth radius) can be calculated using equation (9):

$$d_{RH} = 1.23(\sqrt{h_{TX}}) \quad (9)$$

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:

$$d_{RH} = 1.23(\sqrt{h_{TX}} + \sqrt{h_{RX}}) \quad (10)$$

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)

h_{RX} : the height of the receiver above the Earth's surface (feet)

1.3.3 Aeronautical propagation curves

The material in this paragraph replaces section 1.3.3 in the current edition of the Handbook, Volume II.

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 MHz² 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 percentage³ 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 A. 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-l/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

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 propagation loss will be less than the plotted value for only 5% of the time

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 propagation losses for 5%, 50% and 95%-time availability. Within the radio horizon, 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 based on the curves for 5% of the time for assessing the level of the interfering signal.

1.3.3.5 An example of the ITU-R propagation curve 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. This curve is valid for 50% 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 and export the curves in .csv format. A short description on the use of this program is in Appendix A. This program was developed by the U.S. based Institute for Telecommunication Services (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.

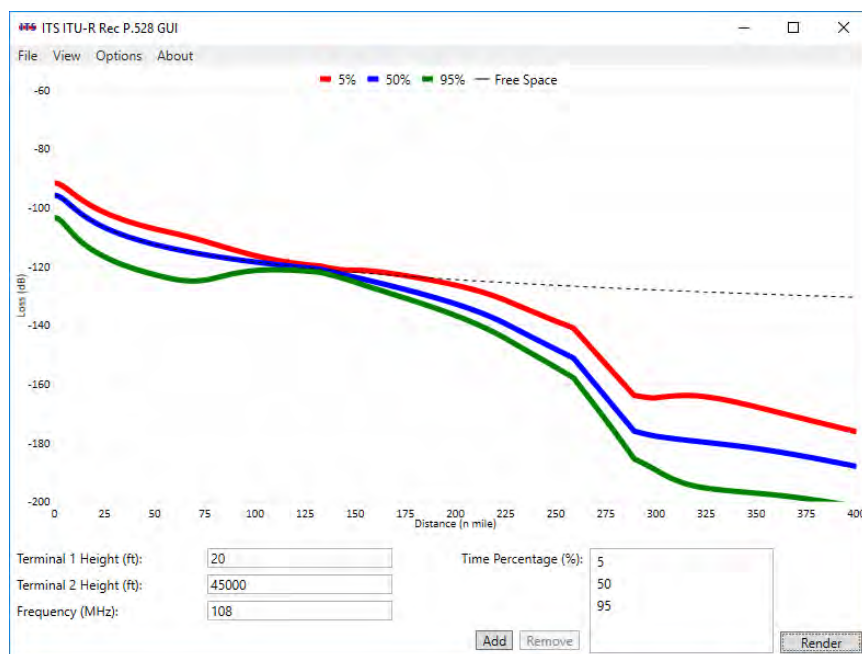


Figure 1.8 – ITU_R aeronautical propagation curve for a VOR 20 ft / 45000 ft/5% – 50% – 95 %

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 propagation loss at short distances may be appropriate. Figure 1.8.A presents the propagation losses at a short distance between the terminals for different altitudes of the aircraft (Terminal 2).

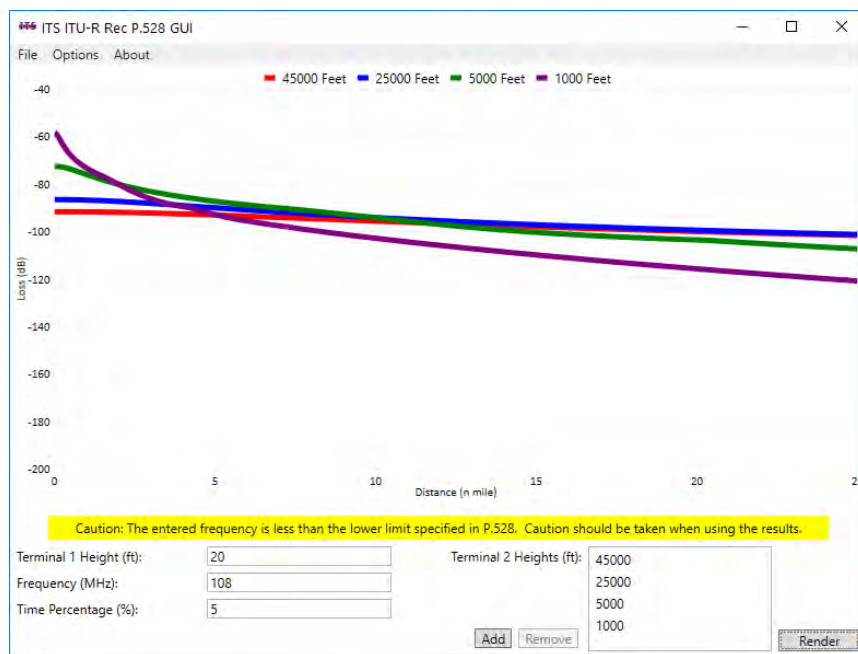


Figure 1.8.A Propagation loss for different altitudes at a short distance between Terminals 1 and 2.

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 propagation loss with the higher frequency.

As an example, at 108 MHz / 50 % of the time, a propagation loss of 150 dB is achieved at a distance of 256 NM, while the same propagation 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.

For the frequency range 960 – 1215 MHz (DME) these values are (50% of the time):
 Propagation loss is 140 dB for 960 MHz at 130 NM and for 1215 MHz at 103NM
 Propagation loss at 130 NM is for 960 MHz at 140 dB and for 1215 MHz at 142 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.

1.3.3.9.6 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.

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 propagation 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. (equivalent isotropically radiated power) 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 propagation 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 propagation 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 propagation 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 propagation loss at low angles and over a short distance (e.g. on the surface of an airport).

Insert new paragraph 1.4 and 1.5

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

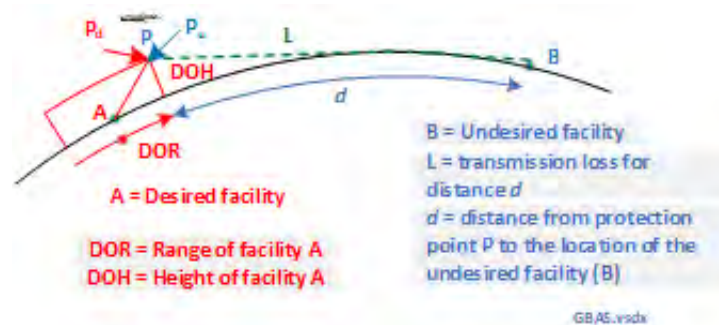


Figure 1-9 – Generic model for establishing minimum separation distance

1.4.2.1 The principle in this model is that, through frequency assignment planning, the maximum signal level from an undesired facility (P_u in Figure 1-9) does not cause harmful interference to the minimum signal (P_d 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 (P_u) from the undesired facility at the protection point is [D/U] dB below the minimum signal level of the desired facility (P_d) 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:

$$P_d = E - 20 \log f - 107.2 \quad (1.4-1)$$

where:

P_d is the isotropically received power at the antenna output (dB(W))

E is the minimum (desired) field strength (dB(μ V/m)) as specified in Annex 10

f is the frequency (MHz)

Note: $E = 20 \log FS$ where FS is the field strength in μ V/m

- b) Determine the maximum power P_u of the undesired signal (facility B in Figure 1-9) at the location of the aircraft. This can be calculated with the formula:

$$P_u = P_d - D/U \quad (1.4-2)$$

where:

P_u is the maximum allowed level of the undesired (interfering) signal (dBW)

P_d 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:

$$P_u = T_x - L \quad (1.4-3)$$

where P_u is the maximum allowed level of the unwanted signal (dBW)

T_x 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:

$$L = T_x - P_d + D/U \quad (1.4-4)$$

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 of the desired station. When the DOC 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 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. 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

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.

1.5.2 Through the ITU an additional set (in addition to those in the Recommendation P.528-4) of propagation curves has been provided. A sub-set of these curves are presented in Figure 1-10 (for the frequency 108 MHz; VOR), figure 1-11a/b (108 MHz and 328 MHz; Localizer and Glide Path) and Figure 1-12 (for the frequency 960 MHz; DME/TACAN) below. Tabulated transmission loss values for a larger set of propagation curves can be calculated with the program P.528 GUI that can be downloaded from <https://github.com/NTIA/p528-gui/releases>.

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 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.

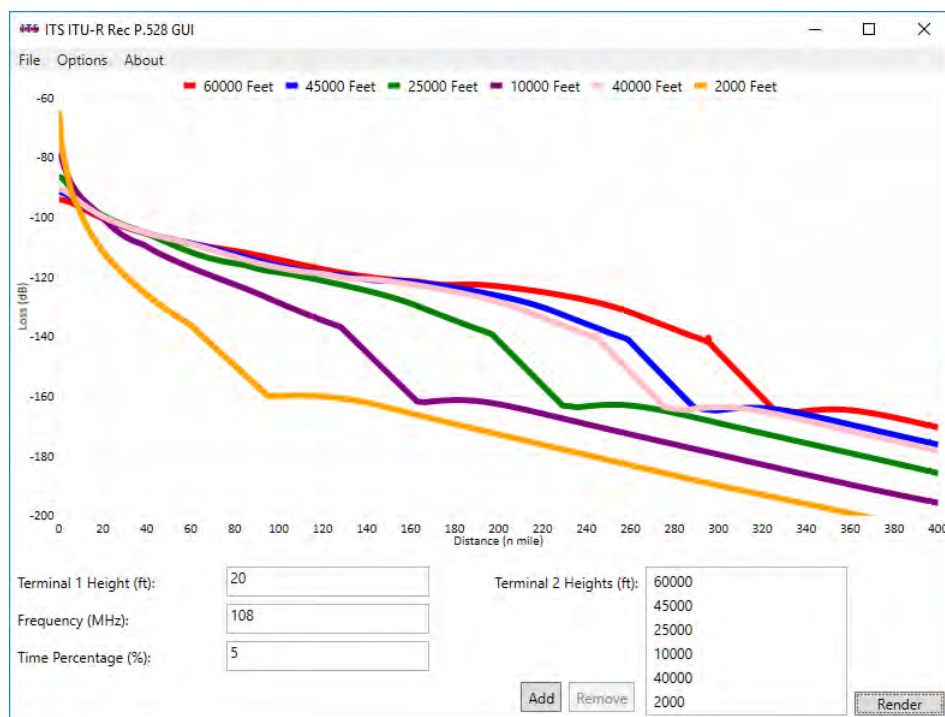


Figure 1-10 – ITU Propagation curves for the frequency 108 MHz (5% availability).

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 5% of the time, an antenna height of the (undesired) localizer transmitter of 6 ft and a height of the 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.

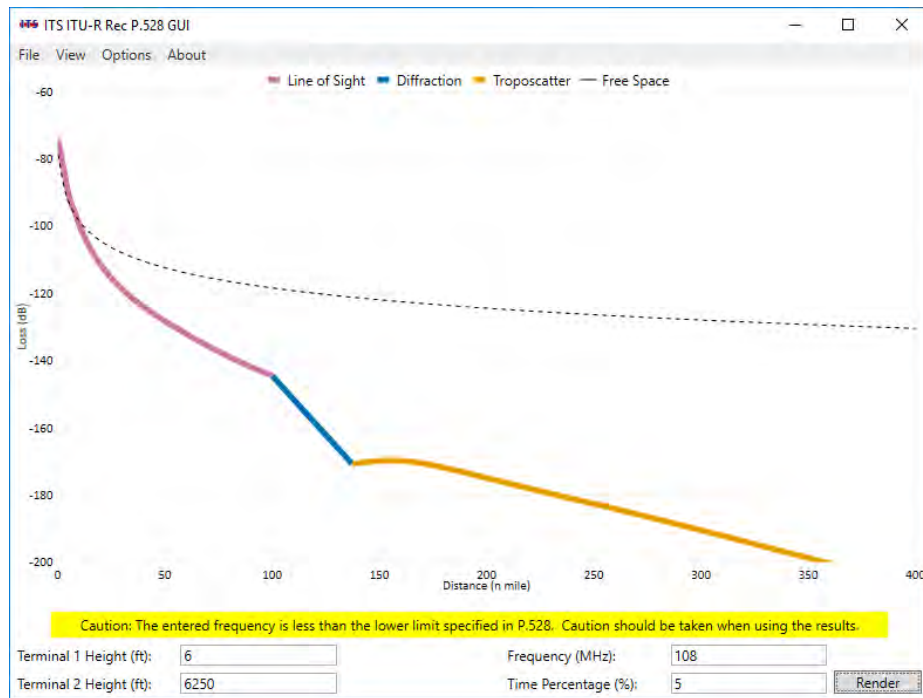


Figure 1-11a – ITU Propagation curves for the frequency 108 MHz at 6250 ft and 5 % of time.

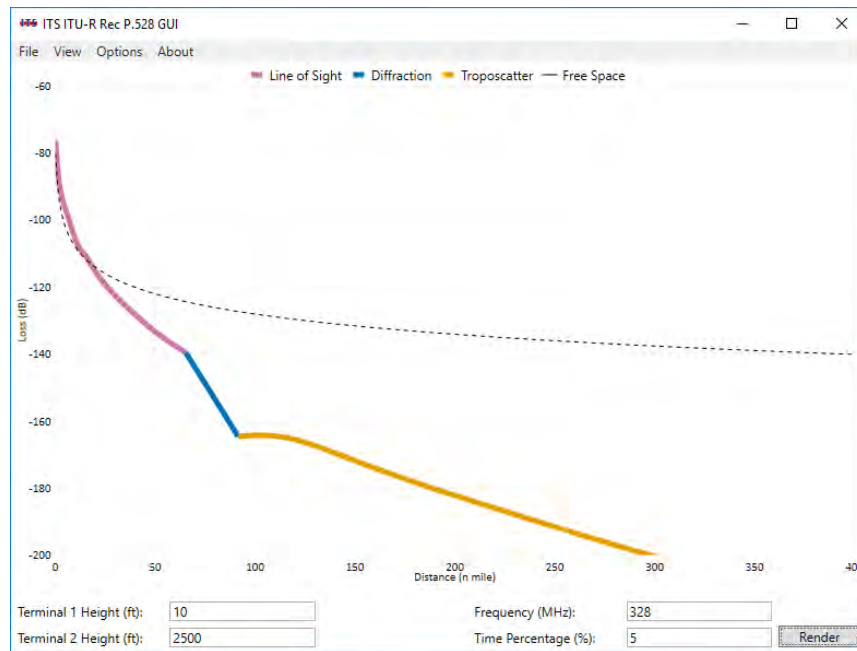


Figure 1-11b – ITU Propagation curves for the frequency 328 MHz at 2500 ft and 5 % of time.

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 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.

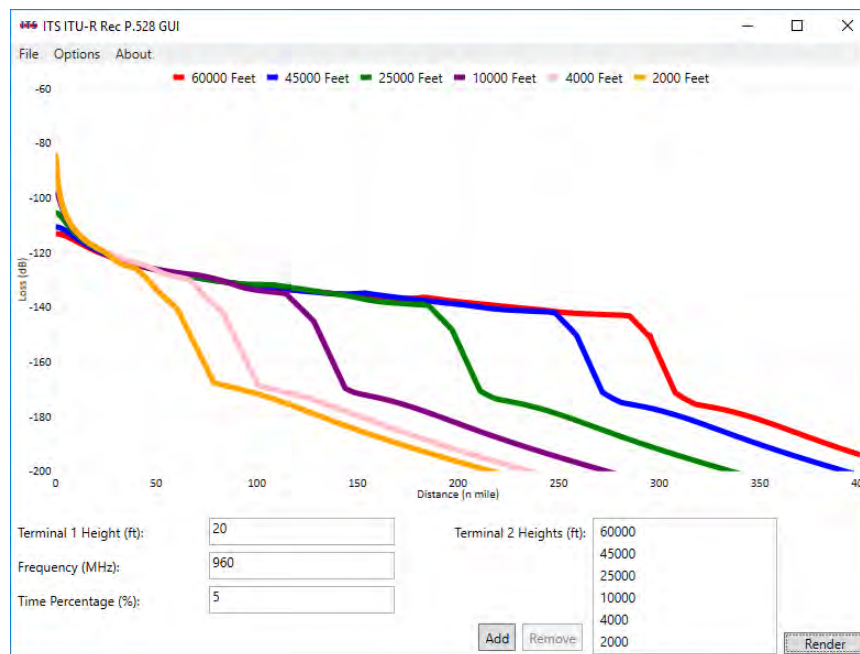


Figure 1-12 – ITU Propagation curves for the frequency 960 MHz.

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 ($\mu\text{V}/\text{m}$)) of the desired facility. For a Localizer **$E = 32\text{dB } \mu\text{V}/\text{m}$**
- ii. Determine the minimum desired power P_d at the aircraft receiver (assuming a loss less isotropic aircraft antenna) with formula (1.4-1):
 $P_d = E - 20\log f - 107.2$ ($P_d = \text{dBW}$; $f = 110 \text{ MHz}$). For a Localizer **$P_d = -116 \text{ dBW}$**
- iii. Determine the maximum undesired power P_u with formula (1.4-2):
 $P_u = P_d - D/U$ ($P_u = \text{dBW}$, D/U is the required desired/undesired signal ratio (dB). For a co-frequency Localizer $D/U = 36 \text{ dB}$; $P_u = -116 - 36 = -152 \text{ dBW}$
- iv. Determine the transmission loss L (dB) that is required to achieve the maximum P_u at the aircraft receiver with formula (1.4-4).
 $L = T_x - P_d + D/U$ ($L = \text{transmission loss (dB)}$; T_x is the e.i.r.p. of the undesired facility).
For an undesired Localizer with a T_x e.i.r.p. of 17 dBW , $L = 17 - (-116) + 36 = 169 \text{ dB}$
- 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 1.9 with $h_1 = 6250 \text{ ft}$ and h_2 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 $126 + 25 = 151 \text{ NM}$ 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 When applying these curves, it should be considered that these provide for a worst-case scenario. More sophisticated propagation models, which may provide for increased transmission losses, may be agreed for use by States or in Regions.

1.5.6 Site elevation.

1.5.6.1 The site elevation⁴ 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

⁴ The site elevation is the height of the site of the ground station referenced to Mean Sea Level (MSL).

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 desired facility is referenced 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

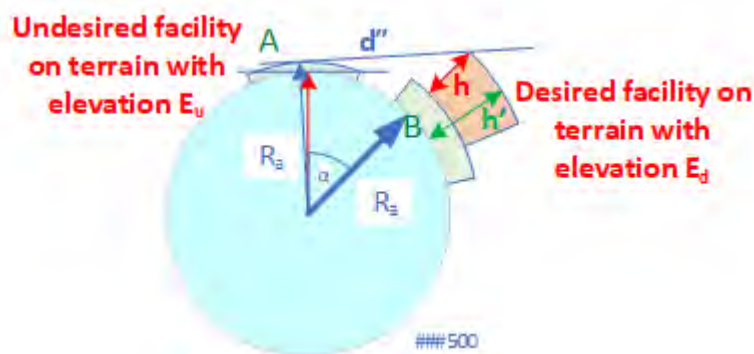


Figure 1.13 Effect of site elevation

The distance d'' to the radio horizon can be calculated with

$$d'' = \sqrt{(R_e + E_d + h)^2 - (R_e + E_u)^2} \quad (4)$$

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 A on the ITU-R propagation curves contains more background information.

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 propagation 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
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 *Editorial note: include paragraph on horizontal vs vertical polarization; ITU-R Rec. P.528 is only for horizontal polarization.*

1.5.9 The application of this generic methodology on frequency assignment planning is further described in:

- Chapter 3 for ILS systems
- Chapter 4 for VOR systems
- Chapter 5 for DME/TACAN systems
- Chapter 6 for GBAS/VDB systems

Chapter 2

AERONAUTICAL VHF AIR-GROUND RADIO COMMUNICATION SYSTEMS OPERATING IN THE BAND 117.975 – 137 MHz

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.

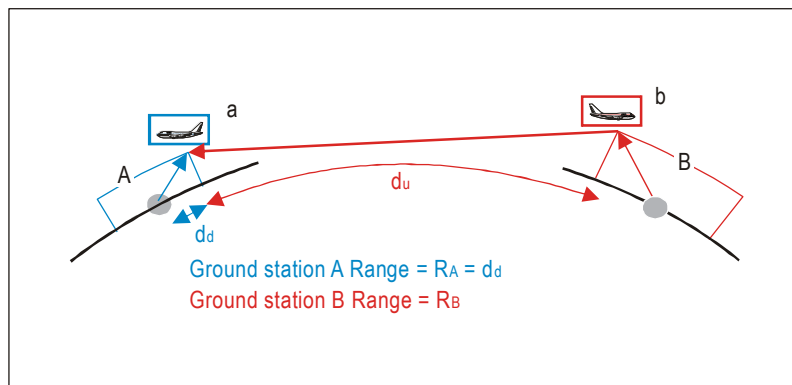


Figure 2-1. Model for establishing separation distances

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 $P_d - P_u = \frac{D}{U}$

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.

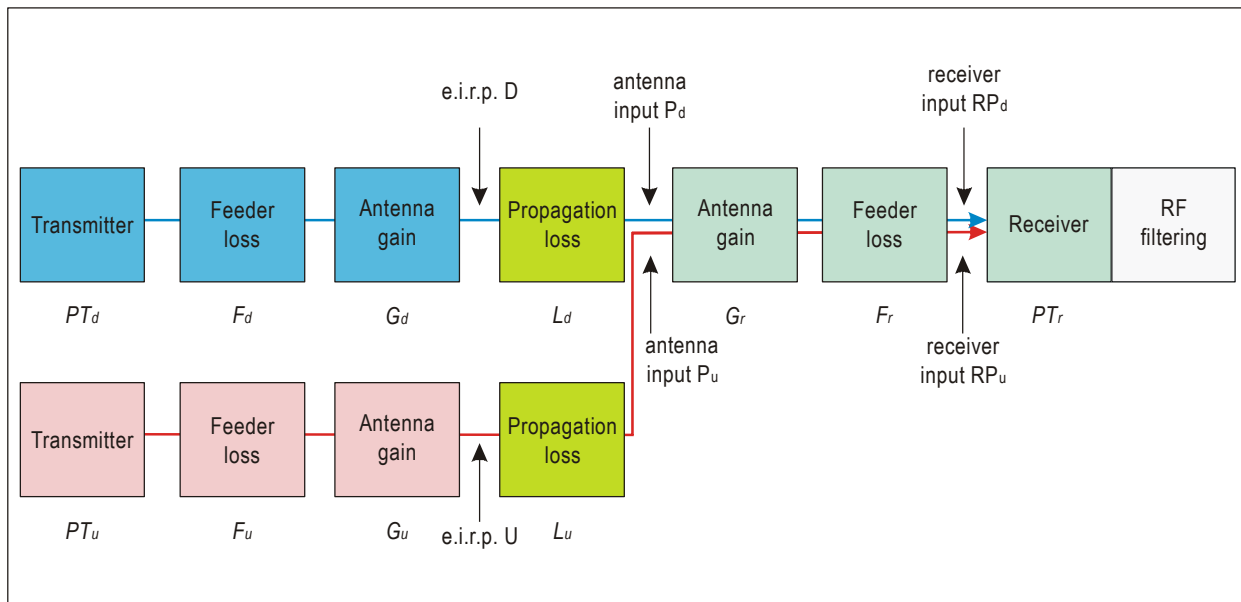


Figure 2-2. Desired signal and undesired signal path to desired (victim) receiver

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:

$$\begin{aligned} \frac{D}{U} &= (L'_u + ACR) - L_d \\ \frac{D}{U} = L_u - L_d &= (L'_u + ACR) - L_d = (20 \log d'_u + ACR) - 20 \log d_d \\ \frac{D}{U} - ACR &= 20 \log d'_u - 20 \log d_d = 20 \log \frac{d'_u}{d_d}; \\ \frac{d'_u}{d_d} &= 10^{(D/U - ACR)/20} \end{aligned}$$

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 $\mu\text{V}/\text{m}$ 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 $\mu\text{V}/\text{m}$) 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.

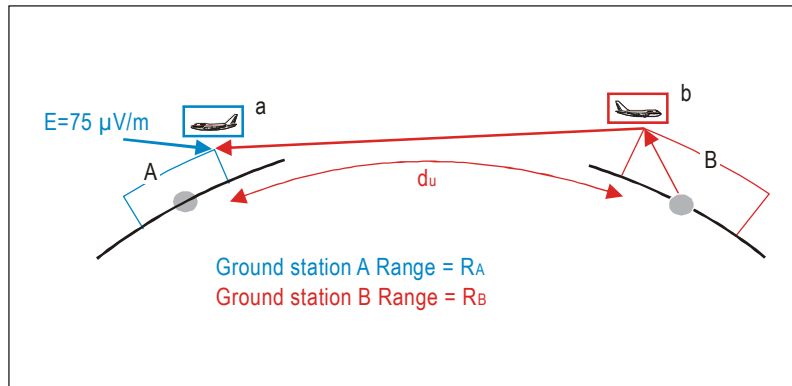


Figure 2-3. Model for establishing separation distances when minimum field strength is specified

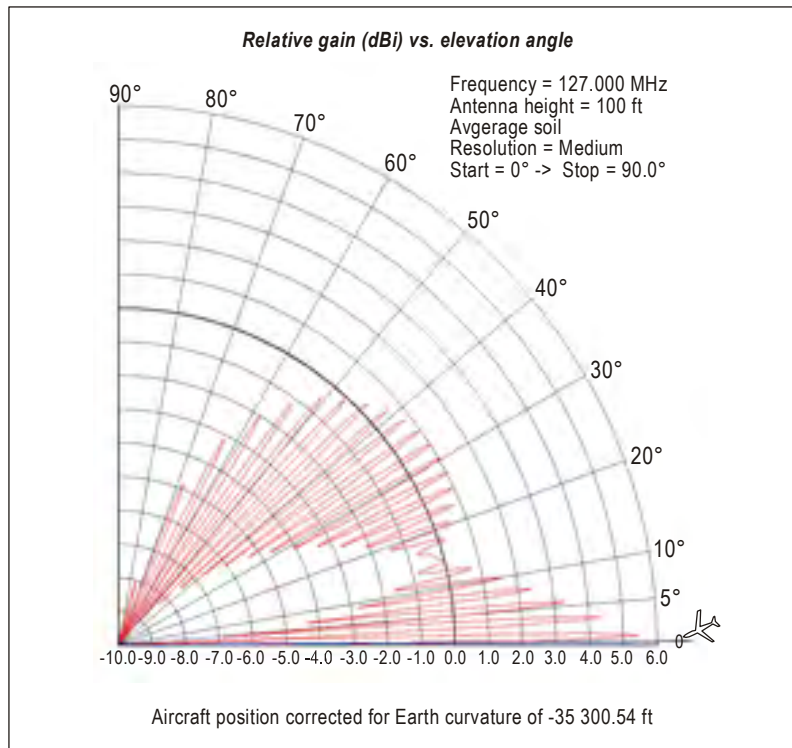


Figure 2-4. Vertical polar diagram of antenna 30 m above ground level

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 $\mu\text{V/m}$. The D/U ratio ($P_d - P_u$ (dBm)) is 20 (14) dB. The analysis below describes this method which is illustrated in the schematic diagram in Figure 2-5.

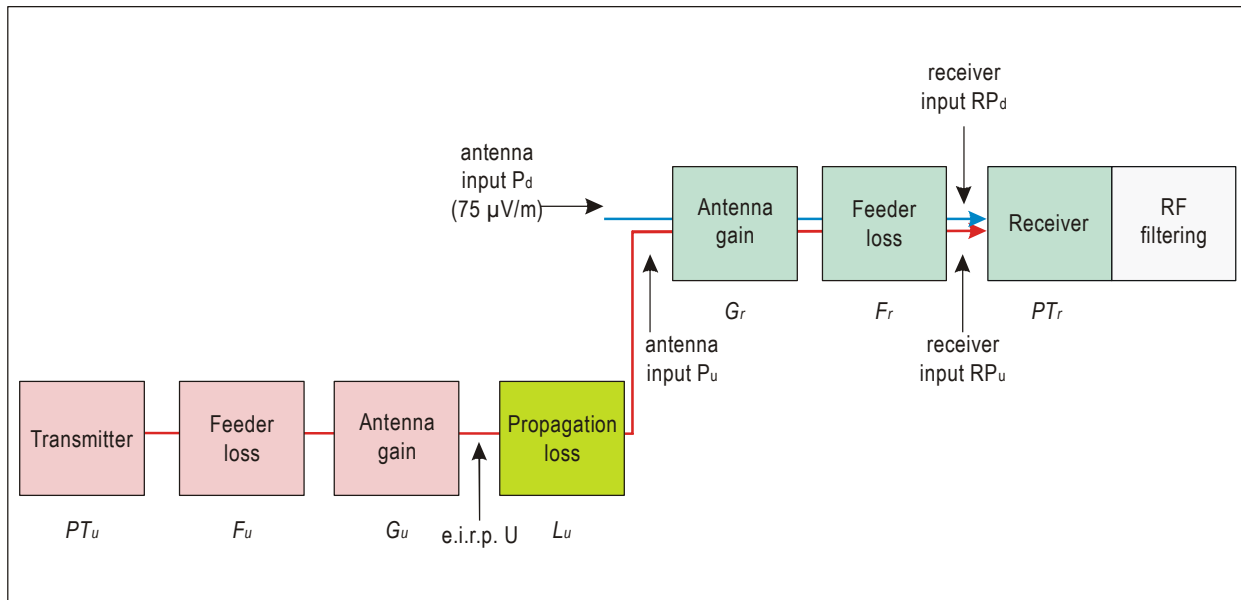


Figure 2-5. Minimum desired signal at antenna and undesired signal path to desired (victim) receiver antenna

2.2.4.7 The (desired) signal level (P_d) at the antenna is $75 \mu\text{V/m}$ (-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.

$$P_d = 75 \mu\text{V/m} = -82 \text{ dBm} \text{ (at the receiver antenna)}$$

$$P_u = P_{T_u} - F_u + G_u - L_u \text{ (at the receiver antenna; } P_{T_u} \text{ is for most transmitters typical 25 W)}$$

For $P_{T_u} = 25 \text{ W}$ (44 dBm), $F_u = 3 \text{ dB}$ and $G_u = 0 \text{ dB}$,

$$P_u = 44 - 3 + 0 - L_u = (41 - L_u) \text{ dBm}$$

$$\frac{D}{U} = 20 \text{ dB} = P_d - P_u = -82 \text{ dBm} - 41 \text{ dBm} + L_u = -123 \text{ dBm} + L_u$$

$$L_u = 143 \text{ dB}$$

2.2.4.8 In this scenario ($D/U = 20 \text{ dB}$), 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 ($f = 127 \text{ MHz}$) a (free-space) distance of $1\,428 \text{ NM}$ is required. This distance is far greater than double the distance to the radio horizon for aircraft at an altitude of $45\,000 \text{ ft}$ ($2 \times 261 \text{ NM}$), 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:

$$\frac{D}{U} = 14 \text{ dB} = P_d - P_u = -82 \text{ dBm} - 41 \text{ dBm} + L_u = -123 \text{ dBm} + L_u$$

$$L_u = 137 \text{ dB}$$

Formula (8) in Chapter 1, 1.3.2 calculates that for a free-space transmission loss of 137 dB ($f = 127 \text{ MHz}$) 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:

$$P_d = 75 \mu\text{V/m} = -82 \text{ dBm} \text{ (at the receiver antenna)}$$

$$P_u = PT_u - F_u + G_u - (L'_u + ACR) \text{ (at the receiver antenna)}$$

Where the total transmission loss for the undesired signal $L_u = L'_u + ACR$

(ACR is +60 dB for the first adjacent channel)

For $PT_u = 25 \text{ W}$ (44 dBm), $F_u = 3 \text{ dB}$ and $G_u = 0 \text{ dB}$,

$$P_u = 44 - 3 + 0 - L'_u - ACR = 41 - L'_u - ACR \text{ (dBm)}$$

$$\frac{D}{U} = 20 \text{ dB} = P_d - P_u = -82 \text{ dBm} - 41 \text{ dBm} + L'_u + ACR = -123 + L'_u + ACR \text{ (dB)}$$

$$L'_u = 123 + \frac{D}{U} - ACR \text{ (for the values of } P_d \text{ and } P_u \text{ above)}$$

If ACR = 60 dB (first adjacent channel rejection), $L_u = 63 + \frac{D}{U}$

$$L'_u = 37.8 + 20 \log f + 20 \log d_u = 83 \text{ (dB)}$$

For $f = 127 \text{ MHz}$ and $D/U = 20 \text{ DB}$, $L'_u = 1.4 \text{ NM}$

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.

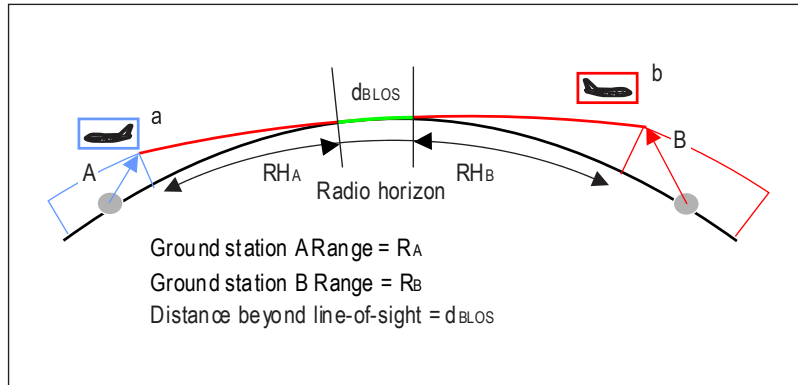


Figure 2-6. Propagation path greater than radio line-of-sight

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:

$$d_{RH} = 1.23(\sqrt{h})$$

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)

<i>Parameter</i>	<i>DSB-AM</i>	<i>DSB-AM</i>	<i>VDL-M2</i>	<i>VDL-M2</i>	<i>VDL-M3</i>	<i>VDL-M3</i>	<i>VDL-M4</i>	<i>VDL-M4</i>
TRANSMITTER	<i>Airborne</i>	<i>Ground</i>	<i>Airborne</i>	<i>Ground</i>	<i>Airborne</i>	<i>Ground</i>	<i>Airborne</i>	<i>Ground</i>
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	75 µV/m (-82 dBm) Part II, Annex 10, Volume III	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:

P_r : 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

$$[dB(\mu V/m) = 20 \log(\mu V/m)]$$

$10 \log P_r$ 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.

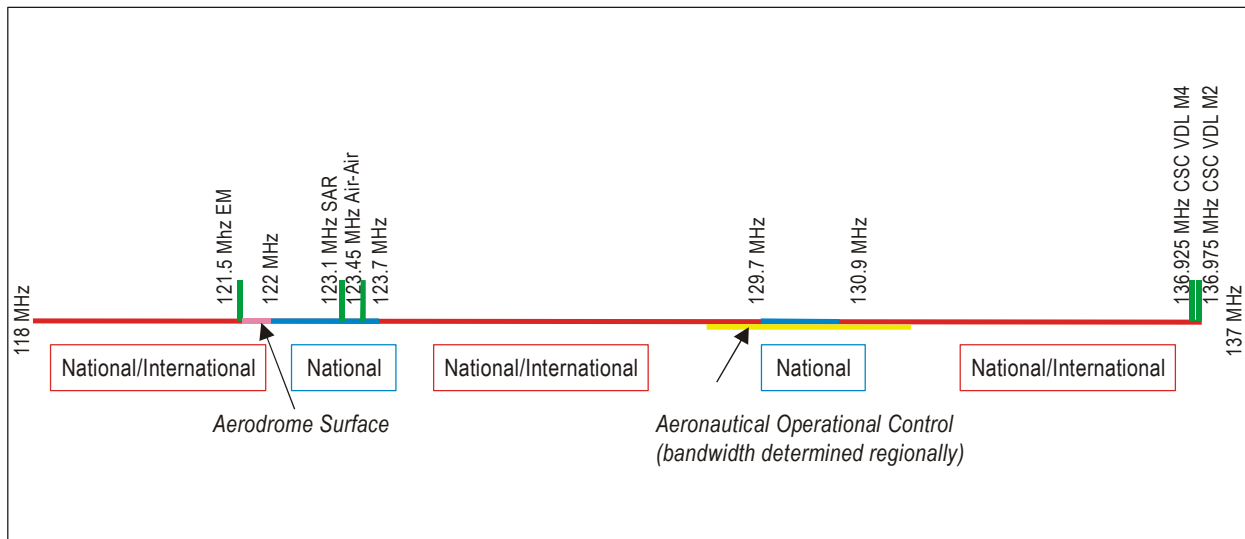


Figure 2-7. Special frequencies and allotments (Annex 10)

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

<i>Frequency (MHz)</i>	<i>Usage</i>	<i>Comments</i>	<i>Annex 10, Volume V</i>
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

<i>Frequency (MHz)</i>	<i>Frequency separation (kHz)</i>	<i>Channel</i>
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

<i>Frequency (MHz)</i>	<i>Frequency separation (kHz)</i>	<i>Channel</i>
118.0417	8.33	118.040
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	47
.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.

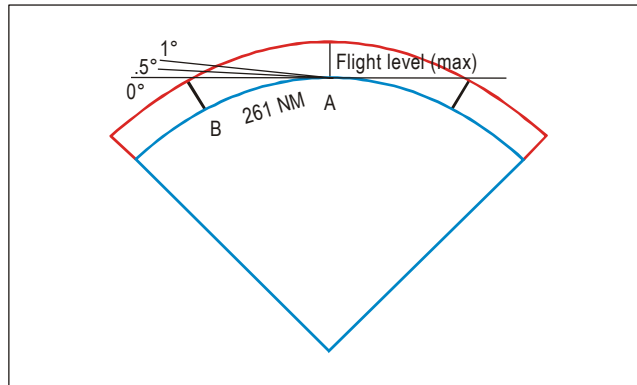


Figure 2-8. Range as function of angle above horizon

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:

$$R_A + RH_A + RH_B + R_B.$$

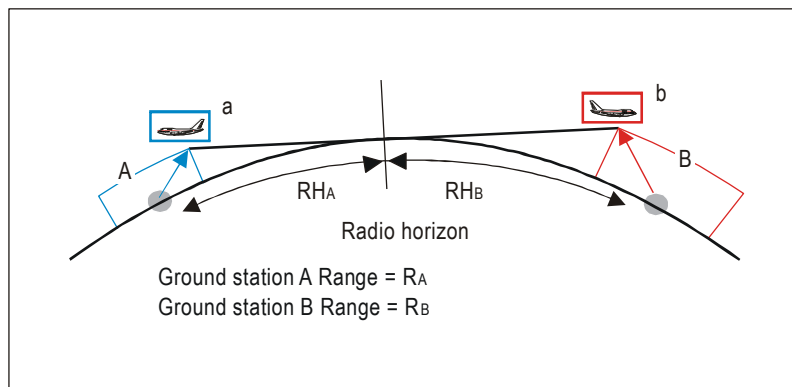


Figure 2-9. Separation based on radio line-of-sight

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** ($5 \cdot R_A$), 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** ($5 \cdot R_B$), 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:

$$(Max) [5 \cdot R_A \text{ or } 5 \cdot R_B]$$

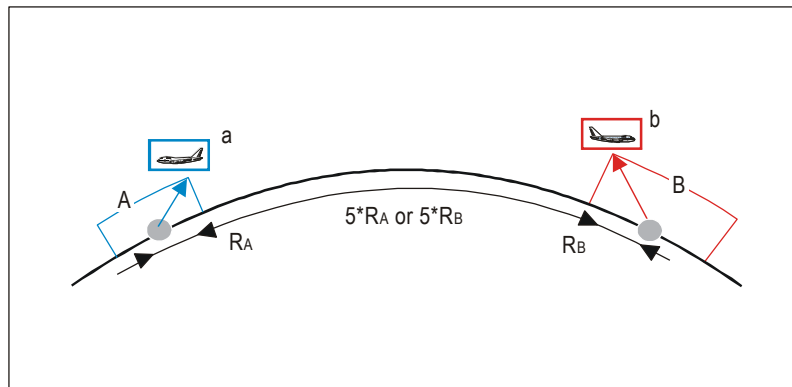


Figure 2-10: Separation distance based on the 5:1 distance ratio

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 $(Max) [5 \cdot R_A \text{ or } 5 \cdot R_B]$ 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 $5 \mu\text{V/m}$ (-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.

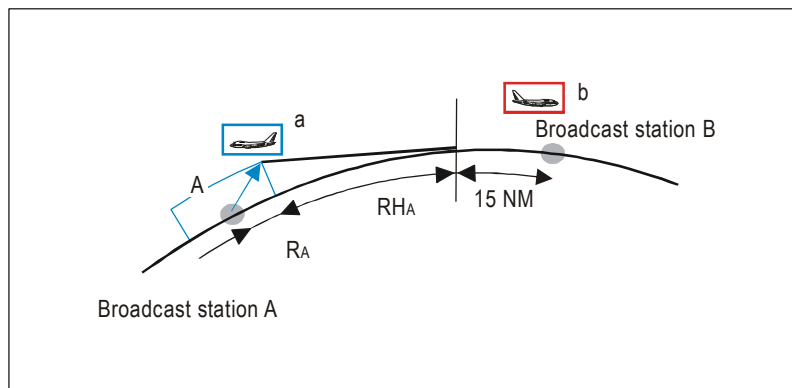


Figure 2-11. Interference mechanism between broadcast services

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:

$$\text{(Max) } RH_A + R_A + 15 \text{ or } RH_B + R_B + 15$$

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.

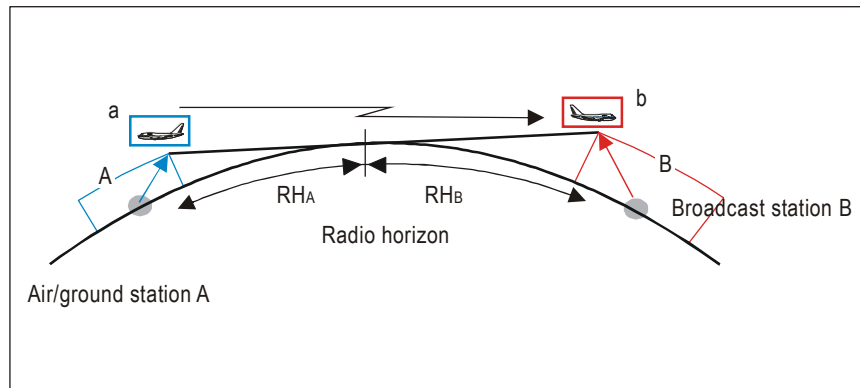


Figure 2-12. Interference mechanism between broadcast services and air-ground services

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):

$$R_A + RH_A + 15 \text{ NM}$$

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.

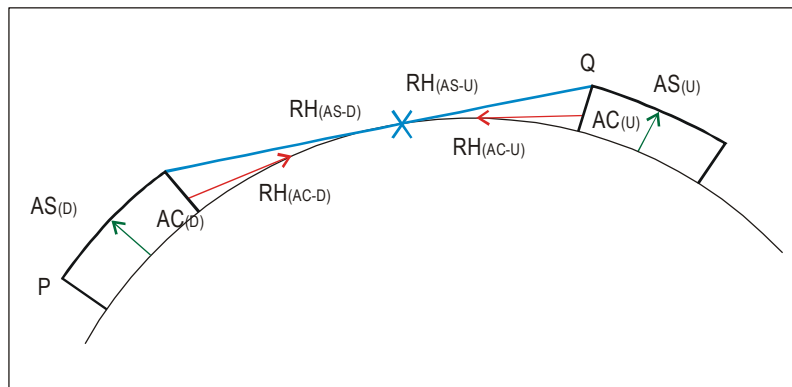


Figure 2-13. Geometry for calculating separation distances for AS communication services

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 $L_d = 20 \log d_d = 13.9 \text{ dB}$ ($d_d = 5 \text{ NM}$)

and $L_u = 20 \log d_u + A = 13.9 \text{ dB}$ (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 $2 \times 12.3 \text{ NM}$. **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 $\mu\text{V/m}$ 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

<i>Symbol</i>	<i>Service range (NM)</i>	<i>Service height</i>	<i>Radio horizon</i>
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)

		<i>Interference source</i>		
		<i>DSB-AM</i>	<i>VDL 2</i>	<i>VDL 4</i>
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

		<i>Interference source</i>		
		<i>DSB-AM</i>	<i>VDL 2</i>	<i>VDL 4</i>
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.

DOC 9718, Handbook on radio frequency spectrum requirement for Civil Aviation
Volume II, Frequency assignment planning criteria for aeronautical radio communication and
navigation systems.

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 center 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)

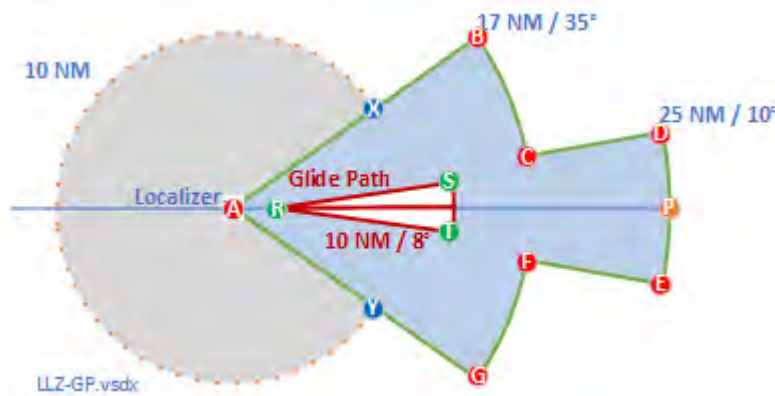


Figure 3-1 – Designated Operational Coverage of the ILS Localizer and Glide Path.

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.

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 $\mu\text{V/m}$ (or 32 dB($\mu\text{V/m}$) or -116 dBW) throughout the DOC. For a Glide Path the minimum field strength is 400 $\mu\text{V/m}$ (or 52 dB($\mu\text{V/m}$) 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.

3.3 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.

Editorial note: A separate proposal that is being developed modifies the current provisions in Annex 10, Volume V, paragraphs 4.2.2.1 and 4.2.2.2.

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.

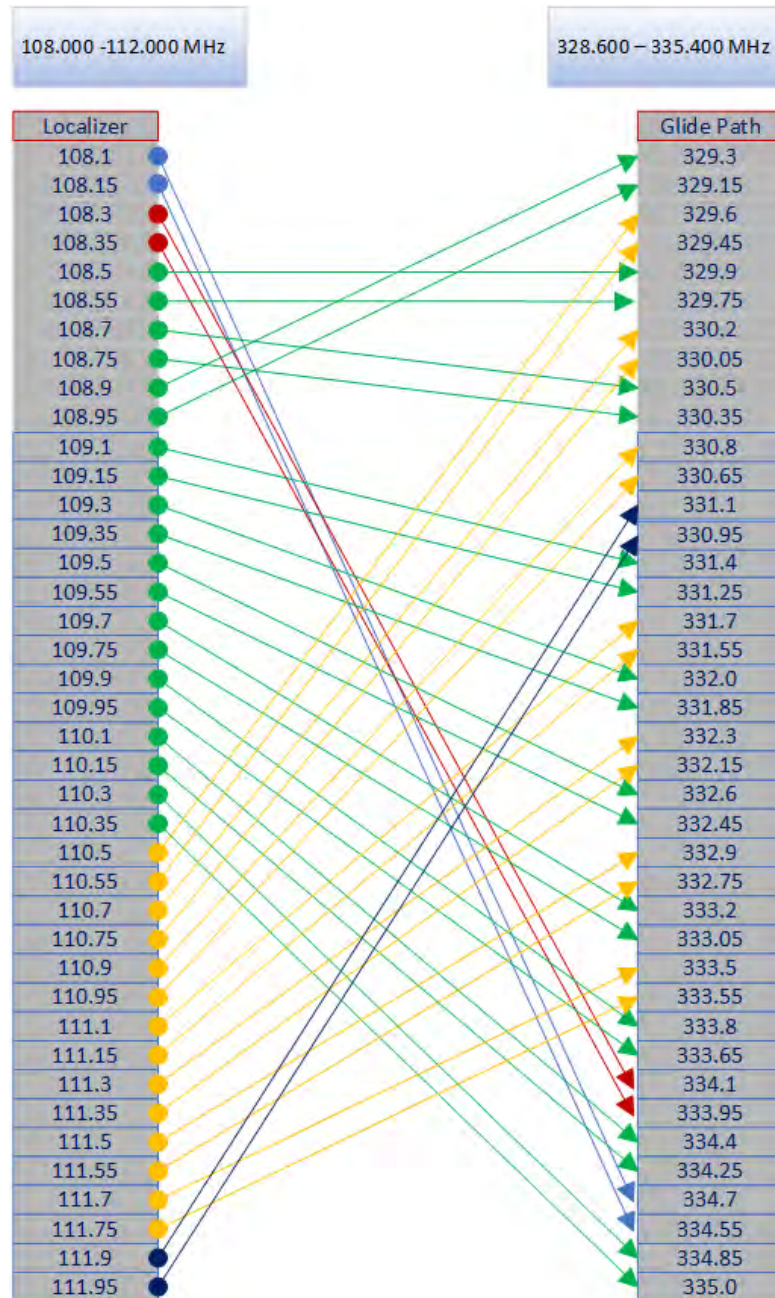


Figure 3-2 Localizer/Glide Path frequency pairing (re. Annex 10, Volume I, paragraph 3.1.6.1)

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.

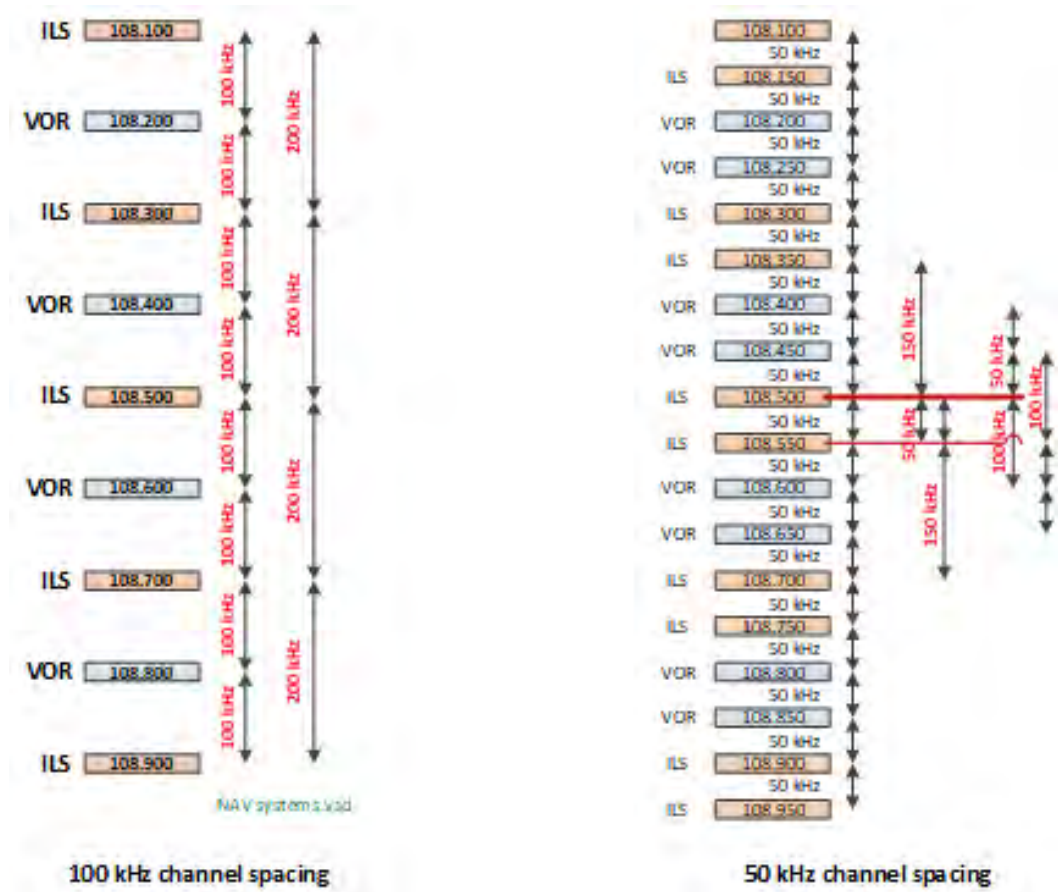


Figure 3.3 – ILS/VOR frequency allotment in the band 108 – 112 MHz.

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 200 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 GBASD/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 when the disturbance from the interference does not exceed one tenth of the full deflection (150 microampere) of the ILS indicator. 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:

Δf (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,

Δf (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:

Δf (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:

1	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:

Δf (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: $40 \mu\text{V/m}$ (or $32 \text{ dB}(\mu\text{V/m}) = -116 \text{ dBW}$)
- 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 $40 \mu\text{V/m}$ ($32 \text{ dB}(\mu\text{V/m})$) 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 P_u at the edge of the DOC of the desired Localizer is
 - $-116 - 36 = -152 \text{ dBW}$. (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
 $L = 30 - (-116) + 36 = 182 \text{ dB}$ (Chapter 1, formula 1.4-4)
- d) The ITU-R propagation curve for the antenna heights $h_1 = 6250 \text{ ft}$ and h_2 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

¹ The radiated power in the front course sector of a Localizer typically varies between 27 – 30 dBW.

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 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	182	246	0	Co-frequency undesired Localizer; 36 dB
32	108	-116	20	-136	30	166	131	0	Co-frequency undesired Localizer; 20 dB
32	108	-116	-7	-109	30	139	81	50	Undesired adj. Localizer; 100 kHz receiver
32	108	-116	-34	-82	30	112	21	50	Undesired adj. Localizer; 50 kHz receiver
32	108	-116	-50	-66	30	96	9	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 an 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.

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 channeling 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 200 kHz, no compatibility assessment is necessary

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)	ΔF (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

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	-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 3.6.7 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 $20\log 400 = 52$ 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 $400 \mu\text{V/m}$ (52 dB($\mu\text{V/m}$) 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).

$$P_d = E - 20 \log f - 106.2 = 52 - 20 \log 333 - 107.2 = 52 - 50 - 107.2 = -105 \text{ dBW}$$

(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
 $P_u = -105 - 36 = -141 \text{ dBW}$. (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
 $L = 20 - (-105) + 36 = 161 \text{ dB}$ (Chapter 1, formula 1.4-4) (L= 145 dB for D/U = 20 dB)
- d) The ITU-R propagation curve for the antenna heights $h_1 = 2500 \text{ ft}$ and h_2 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 ($\Delta f = 150 \text{ kHz}$) channel, the D/U is -20 dB for a 150 kHz GP receiver. The minimum required transmission loss is $20 - (-106) - 20 = 106 \text{ dB}$. $\rightarrow D = 11 \text{ NM}$

3.7.3.2 For the first adjacent ($\Delta f = 150 \text{ kHz}$) channel, the D/U is 0 dB for a 300 kHz GP receiver. The minimum required transmission loss is $20 - (-106) + 0 = 126 \text{ dB}$. $\rightarrow D = 36 \text{ NM}$

3.9.3.3 For the second adjacent ($\Delta f = 300 \text{ kHz}$) channel, the D/U is -40dB for a 150 kHz GP receiver. The minimum required transmission loss is $20 - (-106) - 40 = 86 \text{ dB}$. $\rightarrow D = 1 \text{ NM}$

3.9.3.4 For the second adjacent ($\Delta f = 300 \text{ kHz}$) channel, the D/U is -20 dB for a 300 kHz GP receiver.
The minimum required transmission loss is $20 - (-106) - 20 = 106 \text{ dB}$. $\rightarrow D = 11 \text{ NM}$

3.9.3.4 For the third adjacent ($\Delta f = 450 \text{ kHz}$) channel, the D/U is -40 dB for a 300 kHz GP receiver. The minimum required transmission loss is $20 - (-106) - 40 = 86 \text{ dB}$. $\rightarrow D = 1 \text{ NM}$

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:

Facility:					
Localizer (e.i.r.p = 30 dBW)	Δf :	100 kHz receiver	D/U	50 kHz receiver	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
	0 kHz	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 channeling 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)	ΔF (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.

**Doc. 9718, Handbook on radio frequency spectrum requirement for Civil Aviation
Volume II, Frequency assignment planning criteria for aeronautical radio communication and
navigation systems.**

Chapter 4 VHF Omnidirectional Range (VOR)

Editorial 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/m² 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/m²
- P_a = 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/m²) 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 center 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.

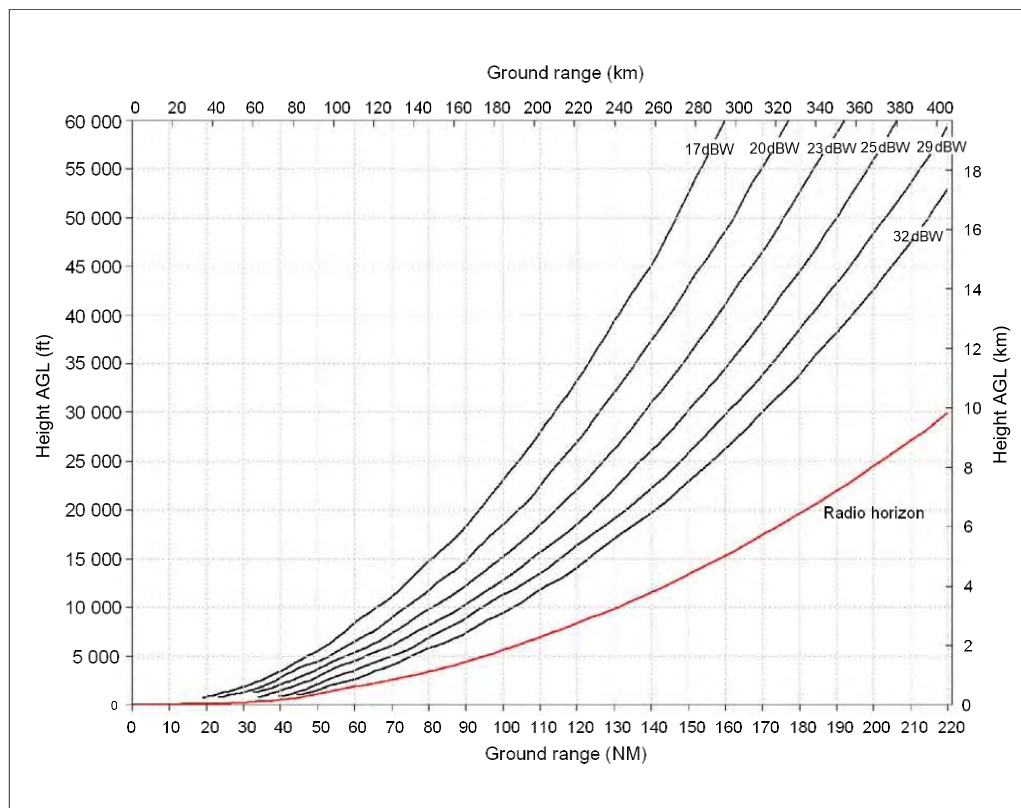


Figure 4 – 1; Necessary EIRP to achieve a field strength of 90 microvolts per metre (–107 dBW/m²) as a function of height above and distance from the VOR/DVOR

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 Channeling.

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 spacing 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 signaling channel for VDL Mode 4 (Annex 10, Volume V, paragraph 4.1.3.3.2).

4.3.2 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	108.200 – 111.975	Ending in even tenths of a mega Hertz (“100” kHz channels)

Order	Band (MHz)	Frequency
		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	108.200 – 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 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 Figure 3.2.

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.

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.

ΔF (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.

ΔF (kHz)	D/U (dB)
0	20
50	-34
100	-46
≥ 150	-50

Table 4.4 Minimum D/U ratios for 50 kHz receivers

Editorial Note: The undesired signal can be a VOR or a Localizer signal. Paragraph 3.6.4 in Annex 10, Volume I, Attachment C may not be required.

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:

Δf (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.

4.6 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:

<i>Subcarrier</i>	<i>Level</i>
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.

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.

4.8.2 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 $\mu\text{V/m}$ or 39 dB($\mu\text{V/m}$) 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.

4.8.5 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

4.8.5.1 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, $L = T_x - P_d + D/U$.

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 $L = Tx - Pd + D/U = 26 - (-110) + 20 = 156 \text{ dB}$

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**

4.8.5.2 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 $L = 20 - (-110) + 20 = 150 \text{ dB}$

The VOR antenna height is 20 ft; the ITU-R propagation table for 10ft/45.000 ft (5% of the time) show this transmission loss is obtained at a distance of **272 NM**.

The minimum station-to-station separation distance is **272+100 = 372 NM**

4.8.5.3 The minimum geographical (station to station) separation distance between VOR1 and VOR 2 is the largest as was obtained in 4.8.5.1 and 4.8.5.2 and is 361 NM.

4.8.5.4 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).

4.8.5.5 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. **Should this be corrected for a Localizer at 6 ft above ground?**

ΔF (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks Desired VOR at 45000 ft
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	
0	20	147	268	150	271	160	284	50/100 kHz receiver
50	-7	120	134	123	174	133	231	100 kHz receiver

ΔF (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks Desired VOR at 45000 ft
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	
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”.

ΔF (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks Desired VOR at 25000 ft
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	
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”.

ΔF (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks Desired VOR at 10000 ft
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	
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”.

ΔF (kHz)	D/U (dB)	Tx = 17 dBW		Tx = 20 dBW		Tx=30 dBW		Remarks Desired VOR at 5000 ft
		L (dB)	D (NM)	L (dB)	D (NM)	L (dB)	D (NM)	
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".

4.8.6 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.

4.8.6.1 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.

4.8.6.2 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)

4.8.6.3 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.

VOR - Height (ft)	Distance between the <i>edge</i> of the DOC of the desired VOR (50 kHz receiver) and the <i>location</i> of the undesired GBAS/VDB (e.i.r.p for VDB = 17 dBW)				
	Co-frequency D/U = 26 dB L = 153 dB	1 st adj freq. (+/-25 kHz) D/U = 0 dB L = 126 dB	2 nd adj freq. (+/- 50 kHz) D/U = - 34 dB L = 92 dB	3 rd adj freq. (+/-75 kHz) D/U = -46 dB L = 87 dB	4 th 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 \leq 5 NM may be considered as operational insignificant

4.9. Sectorized coverage

4.9.1 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:

4.9.2 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.

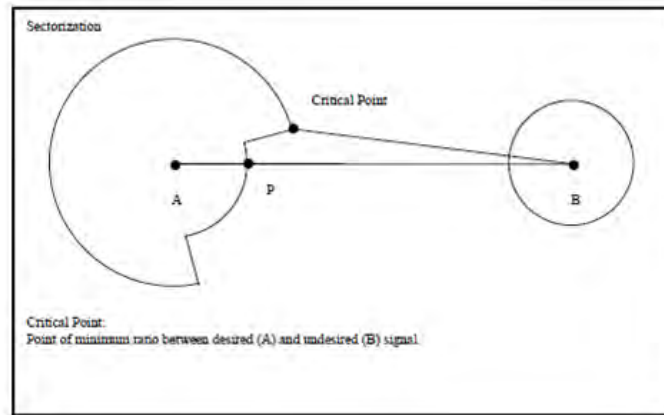


Figure 4 – 2 Geometry for determining the test points

Doc. 9718 Handbook on radio frequency spectrum requirements for Civil Aviation
Volume 2, Frequency assignment planning criteria for aeronautical radio
communication and navigation systems

Chapter 5 – Frequency assignment planning for DME / TACAN

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.

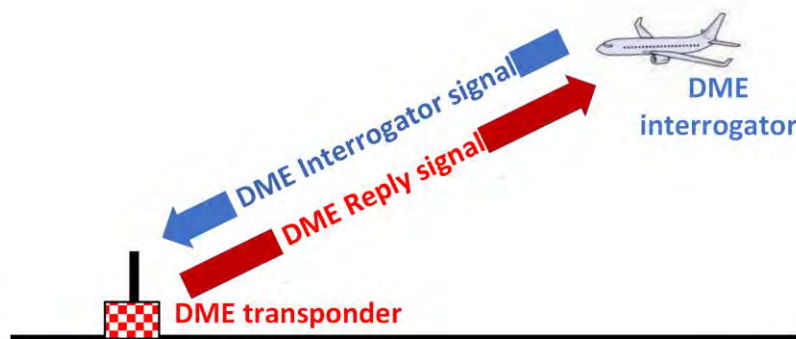


Figure 5.1 DME interrogations and replies

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 propagation 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 minus 89 dBW/ m² at the mid-band frequency.

5.2.4.2 Nominal values of the necessary EIRP to achieve a power density of minus 89 dBW/m² 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 density may be achieved with a lower EIRP.

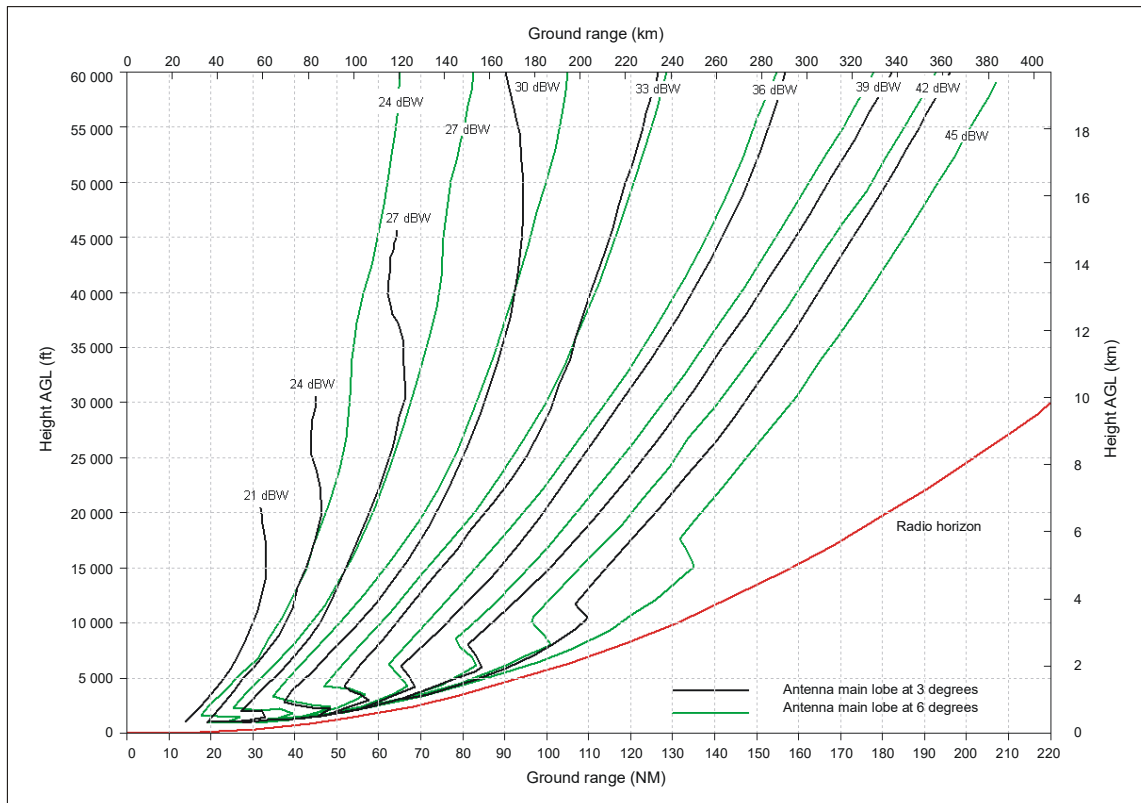


Figure 5-2 Necessary EIRP to achieve a power density of -89 dBW/m² as a function of height above and distance from the DME

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 / Channeling.

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 channeling 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 channeling 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 channeling 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.

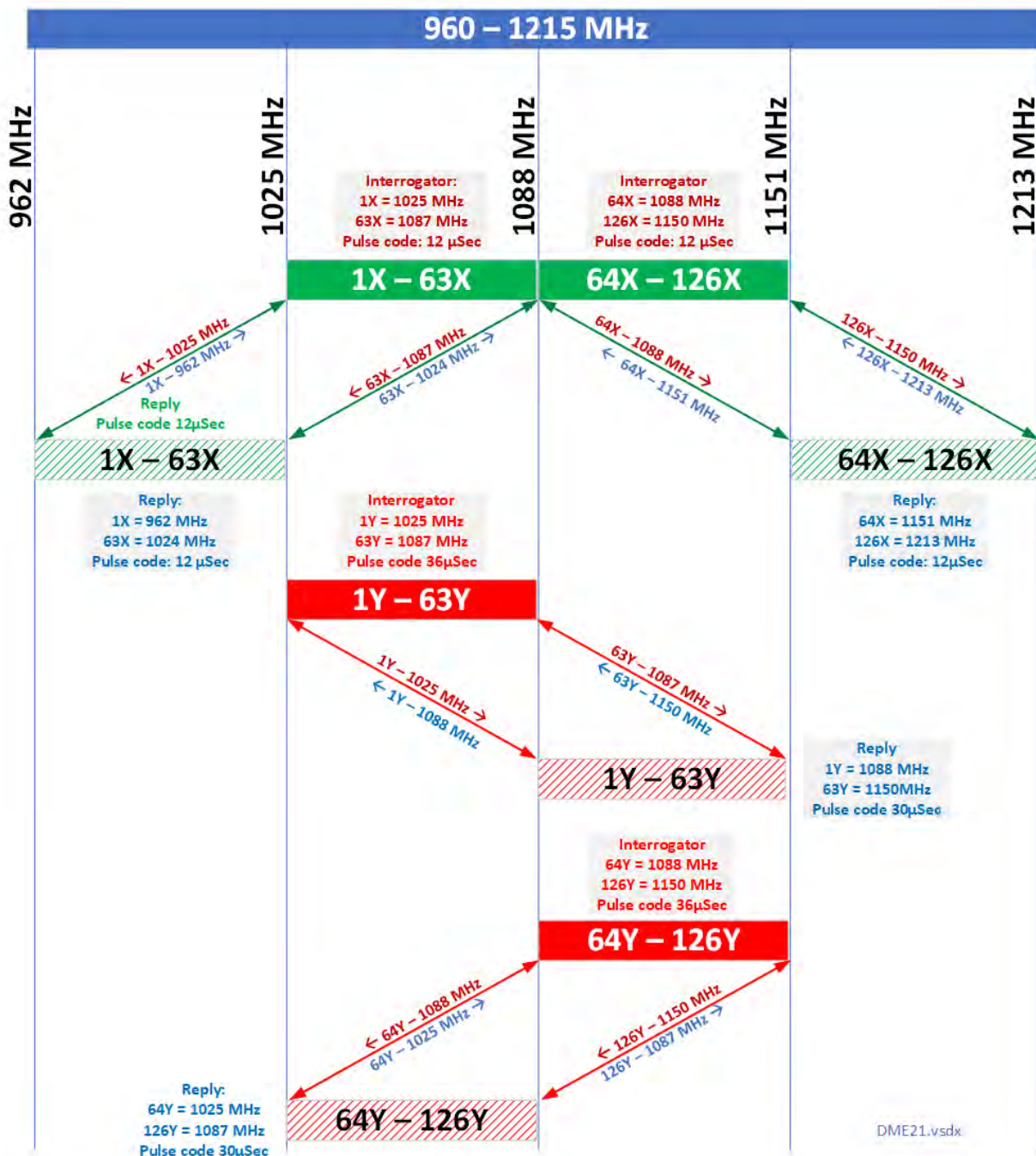


Figure 5.3 DME channeling arrangement

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. ⁶

⁶ 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.

5.3.4 Pairing of DME channels with ILS/VOR

5.3.4.1 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.

5.3.4 Frequencies used by the SSR system.

5.3.4.1 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.

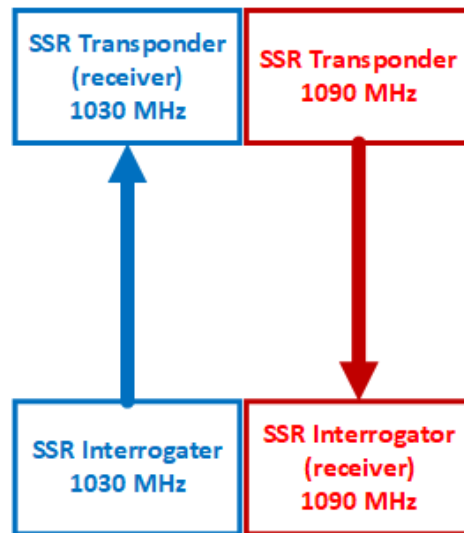


Figure 5.4 – SSR frequency utilization

5.3.4.2 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

5.3.4.2.1 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.

5.3.5 Universal Access Transceiver (UAT)

5.3.5.1 The reply frequency of channel 17X (978 MHz) is also used for the operation of the Universal Access Transceiver. Standards and recommended practices for the UAT are in Annex 10, Volume III, Chapter 12.

5.3.5.2 Frequency assignment planning criteria to ensure compatibility between DME and UAT are in Part II of the *Manual on the Universal Access Transceiver (UAT)* in ICAO Doc. 9861.

Editorial Note: it needs to be checked what planning criteria are in Doc.9861 and if these criteria should be incorporated in this Handbook.

5.4 Protection requirements

5.4.1 Desired to undesired (D/U) signal ratios at the airborne receiver for X and Y channels

5.4.1.1 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.

5.4.1.2 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.

5.4.1.3 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).

5.4.1.4 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 -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.

5.4.1.5 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.

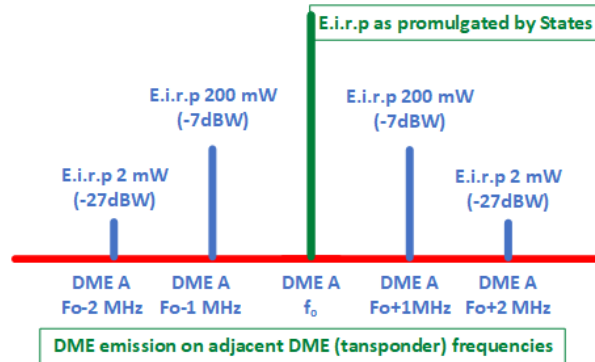


Figure 5.5 Out-of-band radiation of DME transponders
Re. Annex 10, Volume 1, Chapter 3 paragraph 3.5.4.1.3

5.4.1.6 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.

5.5 Geographical separation distances

5.5.1 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.

5.5.2 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.

5.5.3 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)

5.5.3.1 The e.i.r.p of the DME station (P_u) 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)

5.5.3.1.1 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).

5.5.3.2 For the calculation of geographical separation distances between DME facilities operating on adjacent channels, the e.i.r.p of the undesired facility (P_u) 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.

5.5.3.3 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.

5.6 Calculation examples.

5.6.1. With formula (1.4-4) $L = P_u - P_d + D/U$ 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.

5.6.2 Co-channel geographical separation distances.

5.6.2.1 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

$$\rightarrow L = 27 - (-111) + 8 = 146 \text{ dB.}$$

ITU-R propagation curve for 1080 MHz, $h_1 = 20$ ft and $h_2 = 10.000$ 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).

5.6.2.2. 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

$$\rightarrow L = 37 - (-111) + 8 = 156 \text{ dB.}$$

ITU-R propagation curve for 1080 MHz, $h_1 = 20$ ft and $h_2 = 25.000$ 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 135 NM.

5.6.2.3 En-route DME (2) or TACAN

- E.i.r.p is 40 dBW
- DOC is 200/450

The minimum required transmission loss L as per formula 1.4.-4 is

$$\rightarrow L = 40 - (-111) + 8 = 159 \text{ dB.}$$

ITU-R propagation curve for 1080 MHz, $h_1 = 20$ ft and $h_2 = 45.000$ 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 137 NM.

5.6.3 Adjacent channel separation

5.6.3.1 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 P_u has a signal level of -7dBW.

P_d (at aircraft antenna) = -111 dBW

$\rightarrow L = P_u - P_d + D/U$; $D/U = 8 \text{ dB}$ $\rightarrow L = P_u - P_d + 8 = -7 - (-111) + 8 \text{ dB} = -112 \text{ dB}$ $\rightarrow D = 10 \text{ NM}$ using the ITU-R 5% curve for $h_1 = 20$ ft and $h_2 = 10\,000$ ft. D is measured from the edge of the desired facility to the location of the undesired (first adjacent channel) DME ground station.

5.6.3.2 2nd adjacent channel (2 MHz)

For the second adjacent channel $P_u = -27 \text{ dBW}$

$\rightarrow L = P_u - P_d + D/U$; $D/U = 8 \text{ dB}$ ($P_u + 19$) $\rightarrow L = -27 - (-111) + 8 = -92 \text{ dB}$. $D = 0.5 \text{ NM}$ 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.

5.7 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 Figure 5.6. 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.

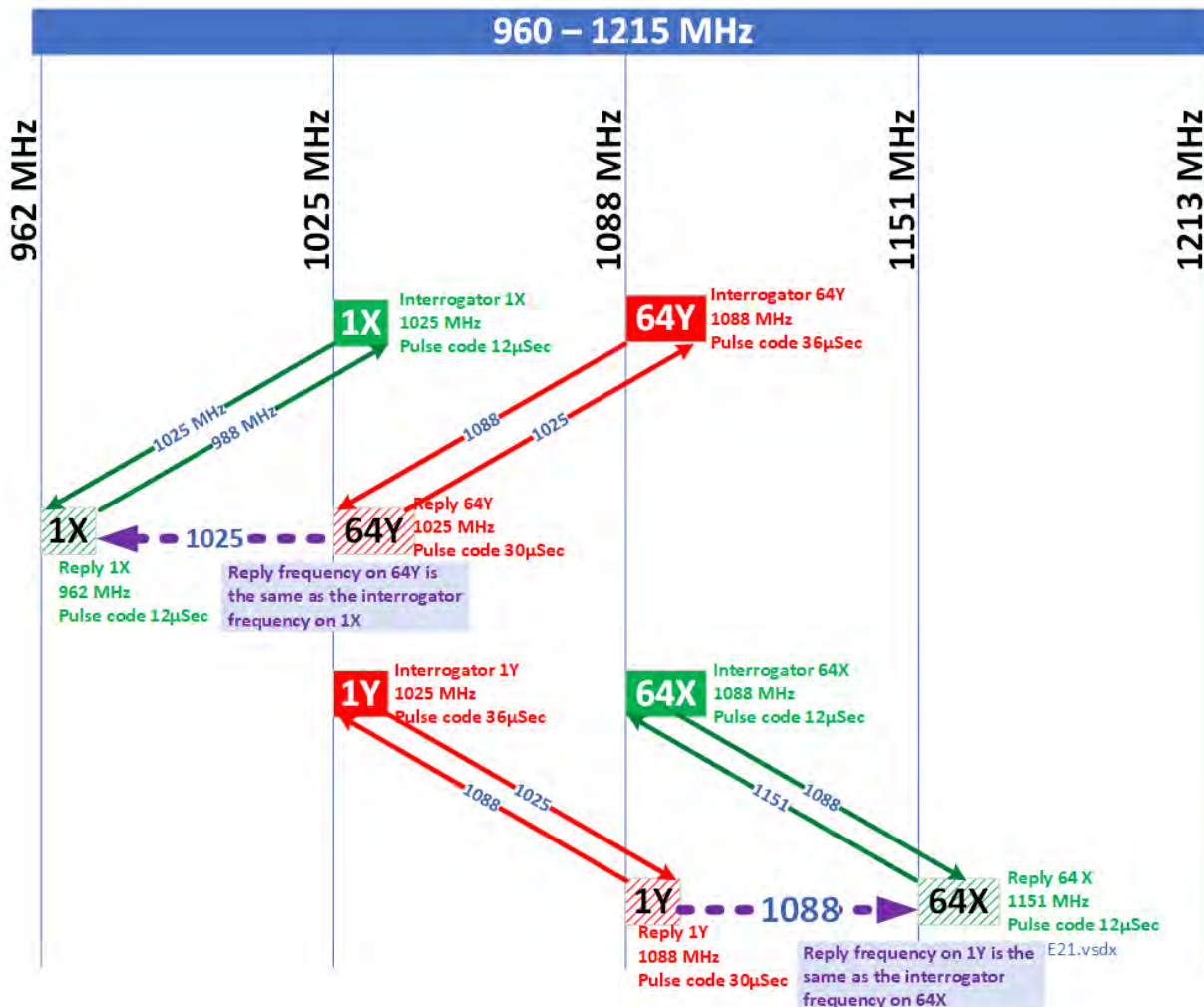


Figure 5.6 – Interference scenario between two DME transponders separated by 63 MHz

5.8 Sectorized DOC of the DME

Similar to VOR (as described in Chapter 4 or this manual), the DME DOC may 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.

5.9 Use of directional antenna

5.9.1 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.

5.9.2 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.

5.9.3 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.

Re. 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	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						Initial approach µs	Final approach µs		
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number						
*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	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME channel number	VHF frequency MHz		
Initial approach µs	Final approach 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	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME channel number	VHF frequency MHz		
		Initial approach µs	Final approach 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	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						Initial approach µs	Final approach µs		
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	DME/P mode					
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	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME channel number	VHF frequency MHz		
Initial approach µs	Final approach 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
**63X	–	–	–	1 087	12	–	–	1 024	12
**63Y	–	–	–	1 087	36	–	–	1 150	30

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME channel number	VHF frequency MHz		
		Initial approach µs	Final approach µs						
**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
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

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number			Initial approach µs	Final approach µs		
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
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

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
Channel pairing				Frequency MHz	Pulse codes			Frequency MHz	Pulse codes µs
					DME/N µs	DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Initial approach µs		Final approach µs			
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
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

Source: Annex 10, Volume 1, Table A				DME parameters						
				Interrogation				Reply		
Channel pairing				Pulse codes				Frequency MHz		Pulse codes µs
				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	
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	
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	

Source: Annex 10, Volume 1, Table A				DME parameters					
				Interrogation				Reply	
Channel pairing				Frequency MHz	DME/N µs	Pulse codes		Frequency MHz	Pulse codes µs
						DME channel number	VHF frequency MHz		
		Initial approach µs	Final approach µs						
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.

② 108.0 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.

5.10 Geographical separation criteria for DME, including DME X, Y, W and Z channels

Source: Annex 10, Volume I, Attachment C paragraphs 7.1.7, 7.1.8, 7.1.9 and 7.1.10

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.

5.10.1 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.

5.10.2 *Desired to undesired (D/U) signal ratios at the airborne receiver*

5.10.2.1 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.

5.10.2.2 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

5.10.3 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.

5.10.4 Special considerations for DME/P associated with ILS

5.10.4.1 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.

5.10.4.2 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/m². 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.

Doc. 9718, Handbook on radio frequency spectrum requirements for Civil Aviation
Volume II, Frequency assignment planning criteria for aeronautical radio communication and
navigation systems.

Revised 3 March 2020 in the light of comments from Felix Butsch and Stefan Muller

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

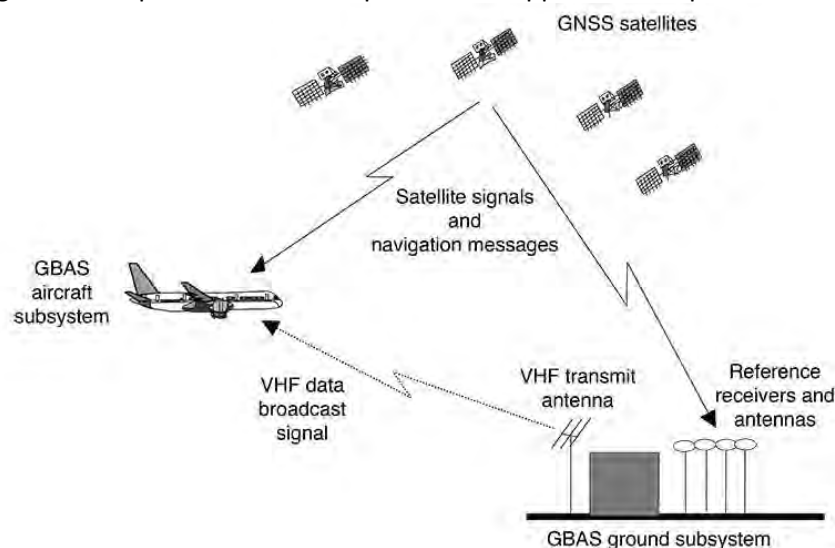


Figure 6-1 Principles of the operation of GBAS

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.

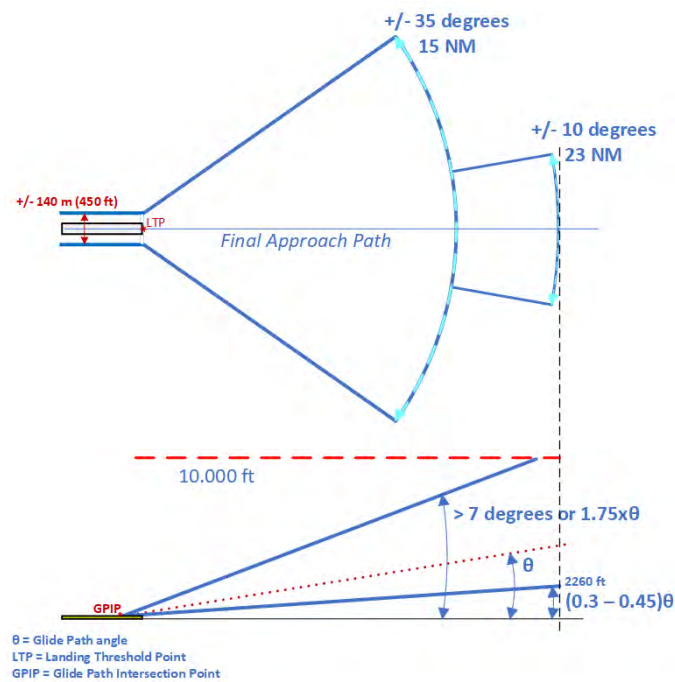


Figure 6-2 Minimum required DOC of GBAS

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.

6.2.3 Replace with VDB location 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 with [3] NM from the location of the VDB transmitter, 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.

Note: For GBASVDB frequency assignments above 116.400 MHz it is necessary to consider compatibility with frequency assignments for VHF communication systems operating in the frequency band 117.975 – 137 MHz. Relevant compatibility criteria are under development.

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 $\mu\text{V/m}$ (-99dBW/m²) 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/m²).

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.

6.3.5 FM immunity

6.3.5.1 Once a candidate frequency is identified for which the GBAS separation criteria are satisfied, compatibility with FM transmissions must be determined. Material on the compatibility between FM broadcast and GBAs and VDB interference immunity is in Annex 10, Volume I, Appendix B paragraph 3.6.8.2.2.8 and Annex 10, Volume I, Attachment D paragraph 7.2.1.2 and ITU-R Recommendation M.1841-1.

6.3.5.2 The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Annex 10, Volume I, Attachment D, paragraph 7.2.1.2.

6.3.6 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.

6.3.6.1 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

6.3.6.2 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

6.3.6.2.1 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.

Editorial 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.

6.4 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 as per State letter AN 7/62.1.3-19/20 from 2 April 2019.

6.4.1 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

6.4.2 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 $15 + \text{Min}(6, 6 \times \text{Frequency Offset (in kHz)} / 1000)$ with a maximum frequency offset of 1000 kHz.

6.4.2.1 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

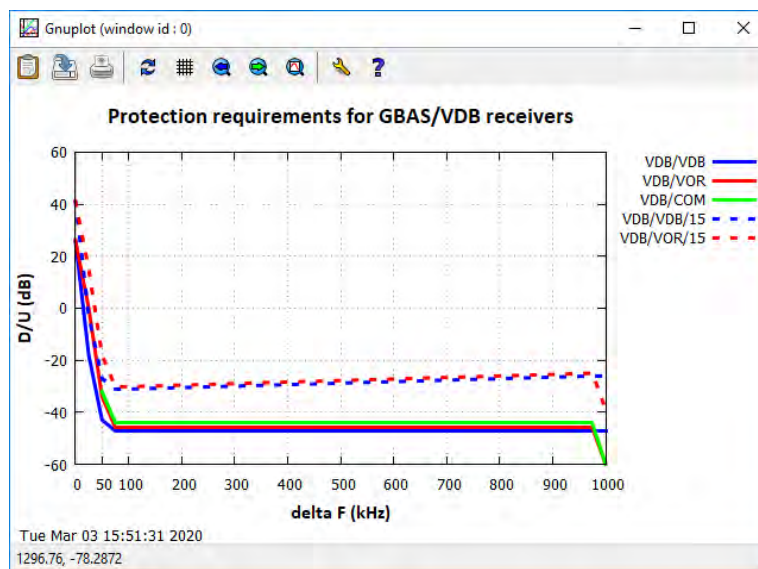


Figure 6.3 – Protection requirements for GBAS VDB systems (Re. Table 6-2 and Table 6-3)

6.4.2.2 The blue curves in Figure 6-3 present the D/U ratios between desired and undesired VDB signals. The solid line is 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).

6.4.2.3 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 is 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).

6.4.2.4 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 is 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).

6.4.3 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.

6.4.4 VDB versus VDL Mode 4 signals
(to be added from NSP VDL Mode 4 studies)

6.4.5 VDB versus VHF COM signals in the frequency band above 117.975 MHz.
(to be added from NSP studies)

6.5 ***This paragraph is moved to 6.2.3; renumbering of the following paragraph is necessary***

6.6 Propagation model

6.6.1 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

Editorial Note: *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.*

6.7 Geographical separation distances between co- and adjacent-frequency facilities

6.7.1 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.

6.7.2 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.

6.7.3 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:

$$L = Tx - Pd + D/U$$

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

6.8 Calculation of minimum separation distances

6.8.1 Calculation of the minimum separation distance between a desired VDB and an undesired VDB GBAS/VDB vs GBAS/VDB.

6.8.1.1 Example: Desired VDB versus undesired VDB; co-frequency,

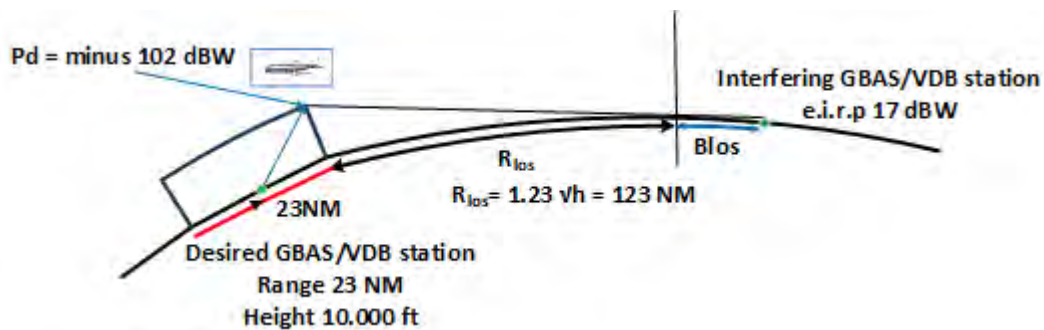


Figure 6.3 Interference scenario for co-frequency GBAS stations

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

6.8.1.2 The required transmission loss between the undesired GBAS/VDB station and the edge of coverage of the desired GBAS/VDB station $L = Tx - Pd + D/U = 17 \text{ (dBW)} + 102 \text{ (dBW)} + 41 \text{ (dB)} = 160 \text{ dB}$

6.8.1.3 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 $213 + 23 = 236 \text{ NM}$.

Editorial note: At this distance, propagation is by troposcatter

6.8.1.4 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.

6.8.1.4.1 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
$\Delta f = 0$ (Co- frequency)	41	160	213 NM	236 NM
$\Delta f = 25$ kHz	-3	116	81 NM	104 NM
$\Delta f = 50$ kHz	-27	92	9 NM	32 NM
$\Delta f = 75$ kHz – 975 kHz	-30 to -25	89 to 94	6 to 11 NM	29 to 33 NM
$\Delta f \geq 1000$ kHz	-25	94	11 NM	33 NM

Table 6-5 – Minimum separation distances between desired and undesired GBAS stations

6.8.2 Calculation of the minimum separation distance between a desired VDB and an undesired VOR or localizer facility (VOR or Localizer is the interferer).

6.8.2.1 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:

$P_d = -102$ dBW (re. Paragraph 6.4.1.1)

D/U is as in Table 6-2

$T_x = 17$ 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

$$L = T_x - P_d + D/U$$

The implementation of this calculation scheme is illustrated in the following examples (sections 6.8.2.2 to 6.8.2.4) for typical combinations of e.i.r.p values for desired and undesired stations:

6.8.2.2 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 ($\Delta f = 0$)	160	160	146
15 ($\Delta f = 25$)	134	118	36
-18 ($\Delta f = 50$)	101	21	14
-30 ($\Delta f = 75$)	89	6	6
-25 ($\Delta f = 975$)	94	11	8
-39 ($\Delta f \geq 1000$)	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

6.8.2.3 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 ($\Delta f = 0$)	170	243	171
15 ($\Delta f = 25$)	144	138	121
-18 ($\Delta f = 50$)	111	43	25
-30 ($\Delta f = 75$)	99	18	12
-25 ($\Delta f = 975$)	104	26	17
-39 ($\Delta f \geq 1000$)	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

6.8.2.4 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 ($\Delta f = 0$)	173	260	209
15 ($\Delta f = 25$)	147	143	129
-18 ($\Delta f = 50$)	114	51	29
-30 ($\Delta f = 75$)	103	24	16
-25 ($\Delta f = 975$)	107	31	20
-39 ($\Delta f \geq 1000$)	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.

6.9 Frequency assignment planning methodology for GBAS/VDB

6.9.1 For the frequency assignment planning and coordination of frequency assignments, the following methodology can be 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 or 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.

To be updated in the light of further discussions

Further work on the same-airport compatibility is necessary and expected to progress at the next meeting of the JWG.s

Appendix A

Conversion sheet and formulas

Field strength

Convert $\mu\text{V}/\text{m} \rightarrow \text{dB}(\mu\text{V}/\text{m})$: $\mathbf{dB(\mu V/m) = 20 \log(\mu V/m)}$ (1A)

Example: field strength is $90 \mu\text{V}/\text{m} \rightarrow 20 \log 90 \text{ dB}(\mu\text{V}/\text{m}) = 39 \text{ dB}(\mu\text{V}/\text{m})$

Convert $\text{dB}(\mu\text{V}/\text{m})$ to $\mu\text{V}/\text{m}$: $\mathbf{\mu V/m = 10^{(dB(\mu V/m)/20)}}$ (1B)

Example: field strength is $32 \text{ dB}(\mu\text{V}/\text{m}) \rightarrow 10^{(32/20)} = 39.8 \mu\text{V}/\text{m}$

Power Flux Density (PFD)

Convert $\text{dB}(\mu\text{V}/\text{m}) \rightarrow \text{dB}(\text{W}/\text{m}^2)$ $\mathbf{dB(W/m^2) = dB(\mu V/m) - 145.8}$ (2A)

Example: field strength is $39 \text{ dB}(\mu\text{V}/\text{m}) \rightarrow$ the power flux density $= 39 - 145.8 = -106.8 \text{ dB}(\text{W}/\text{m}^2)$

Convert $\text{dB}(\text{W}/\text{m}^2) \rightarrow \text{dB}(\mu\text{V}/\text{m})$ $\mathbf{dB(\mu V/m) = dB(W/m^2) + 145.8}$ (2B)

Example: PFD $= -107 \text{ dB}(\text{W}/\text{m}^2) \rightarrow$ field strength is $-107 + 145.8 = 38.8 \text{ dB}(\mu\text{V}/\text{m})$

The power flux density PFD, *assuming free space propagation*, is calculated with:

$$\mathbf{PFD = \frac{P_T}{4\pi D^2}} \quad (3A)$$

$$\mathbf{10 * \log PFD = 10 \log P_T - 10 \log 4\pi - 20 \log D \text{ (dBW/m}^2\text{)}} \quad (3B)$$

$10 \log P_T$ is the radiated power in dBW; D is the distance in meters.

Formula 3B can be re-written for D in km and $10 \log P_T = \text{eirp}$ of the transmitter (dBW):

$$\mathbf{PFD \text{ (dBW/m}^2\text{)} = \text{eirp} - 10 \log 4\pi - 20 \log 1000 D_{km}}$$

or $\mathbf{PFD \text{ (dBW/m}^2\text{)} = \text{eirp} - 71 - 20 \log D_{km}}$ (3C)

Formula 3C can be re-written for D in NM:

$$\mathbf{PFD \text{ (dBW/m}^2\text{)} = \text{eirp} - 10 \log 4\pi - 20 \log 1.852 D_{km}}$$

or $\mathbf{PFD \Phi \text{ (dBW/m}^2\text{)} = \text{eirp} - 76.3 - 20 \log D_{NM}}$ (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:

$$D = 10^{\frac{eirp-PFD\Phi-71}{20}} \text{ km or } D = 10^{\frac{eirp-PFD\Phi-76.31}{20}} \text{ NM} \quad (3D)$$

Effective area $Ae(f)$ of a lossless isotropic antenna:

$$Ae(f) = 10 \log_{10} \frac{(c/f)^2}{4\pi} \quad (3E)$$

f is the frequency in Hertz and c is speed of light (300×10^6) m/s

Power

Convert W to dB(W) $dB(W) = 10 \log W$; $dBm = 10 \log W + 30 = dBW + 30$ (4A)

Convert dB(W) \rightarrow W $W = 10^{(dB(W)/10)}$; $W = 10^{((dBm-30)/10)}$ (4B)

Received power

$$P_d = E - 20 \log f - 107.2 \quad (5)$$

where:

P_d = isotropically received power at the antenna output (dB(W))

E is the field strength (dB(μ V/m))

f is the frequency (MHz)

Example: $E = 90 \mu\text{V/m} \rightarrow 39 \text{ dB}(\mu\text{V/m})$; $f = 112 \text{ MHz} \rightarrow 20 \log f = 41$; $P_d = 39 - 41 - 107.2 = 109.2 \text{ dB(W)}$

Frequency vs. wave length

Convert frequency to wavelength: $\lambda = c/f$ where: (6A)

λ = wavelength (meter)

$c = 3 \times 10^8$ (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 wave length have the same units of measurement

or Free space transmission loss: $L_{bf} = 32.4 + 20 \log f_{MHz} + 20 \log d_{km} \text{ (dB)}$ (7A)

or Free space transmission loss: $L_{bf} = 37.8 + 20 \log f_{MHz} + 20 \log d_{NM} \text{ (dB)}$ (7B)

Distance to the radio horizon (4/3 Earth radius) using NM and feet or km and meter

$$d_{RH} = 1.23(\sqrt{h_{TX}}) \quad (8)$$

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)

$$d_{RH} = 4.12(\sqrt{h_{TX}}) \quad (8A)$$

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)

$$d_{RH} = 1.23(\sqrt{h_{TX}} + \sqrt{h_{RX}}) \quad (8B)$$

d_{RH} : the radio horizon separation distance between the transmitter and receiver (NM)

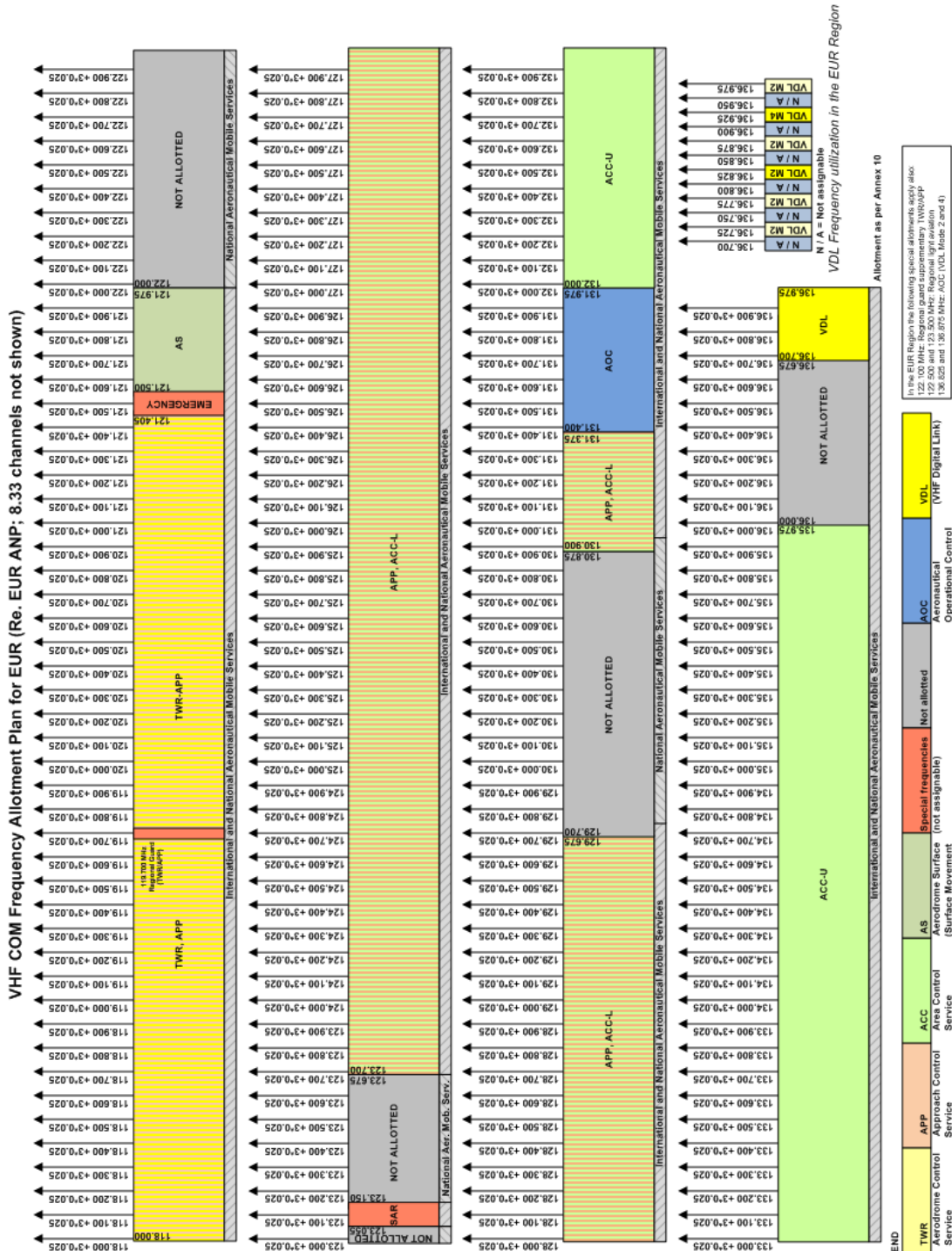
h_{TX} : the height of the transmitter above the Earth's surface (feet)

h_{RX} : the height of the receiver above the Earth's surface (feet)

Convert into fractional degrees and from fractional degrees

Convert 1 degree lat into 60 NM

Convert 1 degree of longitude into $60(\cos A)$ where A is the latitude where longitude is measured



Appendix D

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 GUI for this ITU-R Recommendation

— END —