International Civil Aviation Organization

Twenty Seventh Meeting of the Communications/ Navigation and Surveillance Sub-group (CNS SG/27) of APANPIRG

Bangkok, Thailand, 28 August – 01 September 2023

Agenda Item 5.3: Update on status of datalink applications and VHF capability sharing by States

SPACE-BASED VERY HIGH FREQUENCY (VHF) COMMUNICATION SERVICES

(Presented by Singapore)

SUMMARY

This paper is to update the meeting on the progress of the technical and regulatory studies of space-based VHF communications (voice and data) in the frequency band 117.975 – 137 MHz.

1. INTRODUCTION

1.1 Space-based VHF communication is a concept in which aircraft operating in remote regions and oceanic areas provide communications from the aircraft to air traffic control (ATC) via satellite. This concept is expected to support air traffic management and flight operations in oceanic and remote airspace and complement current use of satellite-based navigation and surveillance technologies in aviation.

1.2 While there are existing long-range communication systems such as HF and SATCOM available to facilitate communications between aircraft and ATC in remote and oceanic airspace, the performance of these systems is not adequate to safely support close aircraft-to-aircraft separation in a similar fashion as to what is being applied in dense airspace where terrestrial-based VHF communications infrastructure is predominant. This leads to constraints in airspace capacity and efficiency in oceanic and remote areas, where it is not possible nor practical to deploy terrestrial-based infrastructures.

1.3 With the space-based VHF communication concept, VHF stations are deployed in the sky, with a larger footprint than terrestrial ones.

2. DISCUSSION

2.1 Space-based VHF communications is envisaged to extend the coverage of the following aeronautical VHF communication services using satellite as a platform:

- Voice is the most critical VHF communication application in terms of safety and dependability.

- Datalink is commonly used for ACARS and VDL Mode 2 applications.

2.2 The following considerations were adopted in the design of the space-based VHF communication system:

- No change to aircraft avionics equipment.
- No change to terrestrial-based stations configuration located in flight information regions (FIRs) which do not need the space-based VHF service.
- No or minimal change to terrestrial-based stations configuration in FIRs with space-based VHF service.
- No or minimal change to operational aspects for pilots and controllers.

<u>International Telecommunication Union ("ITU")</u>

2.3 Space-based VHF frequency allocation is an Agenda Item 1.7 for the World Radiocommunication Conference 2023 ("WRC-23").

2.4 The frequency band 117.975-137 MHz is currently allocated to aeronautical mobile (R) service ("AM(R)S") for air-ground communications. To enable satellite-aircraft communications, amendments to the ITU Radio Regulations ("RR") are necessary to allocate the VHF frequency spectrum for aeronautical mobile-satellite (R) service ("AMS(R)S").

2.5 The ITU - Radio Sector ("ITU-R") has studied the architecture, parameters, and baseline link budgets of a reference AMS(R)S system based on signal propagation considerations adopted by ITU-R. Based on link budget computation, a constellation of low earth orbit (LEO) satellite was found to be feasible. The detailed report on the technical studies and assessments of the space-based VHF studies is attached below.

Attachment A: Technical studies - ITU-R M.[SPACE-VHF]	R19-WP5B-C-0731!N09!MSW-E.pdf

2.6 In preparation for WRC-23, regulatory changes to the RR were discussed during the Conference Preparatory Meeting (CPM) in Apr 2023 and methods to change the regulatory text for Agenda Item1.7 were proposed as follows:

- **Method A** - No change to RR, i.e. frequency allocation for AMS(R)S is not granted.
- **Method B1 and B2** are proposing new allocation in the entire 117.975-137 MHz.
- **Method B2** has a much more stringent protection criteria to be fulfilled by AMS(R)S.
- **Method B3** is proposing a frequency separation of 200 kHz, therefore limiting the new allocation to 117.975-136.8 MHz to accommodate space services in adjacent band.
- **Method B4** is proposing a frequency separation of 1 MHz, therefore limiting the new allocation to 117.975-136 MHz to accommodate space services in adjacent band.

2.7 For Method B3 and B4, the exclusion of the 200 kHz or 1 MHz directly below 137 MHz may affect the implementation of VDL Mode 2 applications which use the common signalling channel (CSC) at 136.975 MHz.

Future VHF Subgroup (“FVSG”)

2.8 In Oct 2020, the formation of Future VHF Subgroup (“FVSG”) was approved under the Data Communications Infrastructure Working Group of the Communications Panel (“CP-DCIWG”) to facilitate global/regional adoption and implementation of space-based VHF communications.

2.9 A new job card was created and approved by Air Navigation Commission (ANC) in Mar 2023 with defined timeline to review the ICAO provisions, such as Annex 10, and provide necessary technical inputs and materials to support and guide the implementation of new aeronautical satellite VHF communication technologies. The detailed job card is attached below.

Attachment B: Job card – Approved by ANC - Appendix B to AN-WP/9627	AN.2023.WP.9627.en.pdf

Frequency Spectrum Management Panel (“FSMP”)

2.10 In 2021, the ICAO Council approved the Draft ICAO Position for WRC-23 prepared by FSMP in support of the space-based VHF Agenda Item 1.7. Taking into consideration developments from the ITU-R and ICAO studies, the ICAO Position has been updated to continue the support of Agenda Item 1.7. The paper on the updated ICAO Position was tabled for discussion at ANC in May 2023 and is attached below for reference.

Attachment C: ICAO Position - WRC-23 Agenda Item 1.7	AN.2023.WP.9668.en.pdf

2.11 To address questions that States may have on space-based VHF, a Satellite VHF coordination group (CG-SV) was formed by FSMP to develop a comprehensive set of frequently asked questions for knowledge sharing and to address any queries by the aviation community.

2.12 The current set of questions and answers (Q&As) contains information on technical and operational topics such as doppler shift, latency, interoperability, satellite coverage, frequency coordination, co-existence with terrestrial system and preliminary concept on the communication handover. The list of Q&As is attached below.

Attachment D: Questions and Answers (Q&A) - AMS(R)S Concept	FSMP-WG15-IP05_Attachment_CG-SV_Q

Proof-of-Concept (PoC) Demonstration

2.13 Currently, there are at least two commercial companies working in parallel to launch prototype satellites with VHF payload for PoC demonstrations between 2023 and 2025. The companies are Skykraft, an Australian space services company and Startical, a joint venture of Enaire and Indra.

2.14 Both companies are planning to launch a constellation of satellites specifically designed for ATM to provide space-based VHF communications as well as ADS-B surveillance services with global coverage.

2.15 To conduct the PoC demonstration, there will be a need for respective ICAO regional office to assign appropriate VHF frequencies so that verification tests could take place.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained within this paper;

b) support the ICAO Position for WRC-23 Agenda Item 1.7;

c) support the actions needed in the Job Card;

d) support the frequency assignments for proof-of-concept demonstration when the need arises; and

e) discuss any relevant matter as appropriate.

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Radiocommunication Study Groups

Source: Document 5B/TEMP/298

Subject: WRC-23 agenda item 1.7
Resolution **428 (WRC-19)**

Annex 9 to
Document 5B/731-E
14 December 2022
English only

Annex 9 to Working Party 5B Chairman's Report

PRELIMINARY DRAFT NEW REPORT ITU-R M.[SPACE-VHF]

Space-based aeronautical VHF communications in the frequency band 117.975-137 MHz

(202X)

Scope

In preparation for WRC-23 Agenda Item 1.7 and pursuant to Resolution 428 (WRC-19), ITU-R was invited to define relevant technical characteristics and to study compatibility between possible AMS(R)S satellite systems within the band 117.975-137 MHz and existing primary services in-band and in adjacent bands, taking into account RR No. **5.200** and RR No. **5.111**. Such satellite systems would relay aeronautical VHF communications over oceanic and remote areas and complement terrestrial communication infrastructures without modification to aircraft equipment. This Report is the response from ITU-R to that invitation.

Glossary of abbreviations

AM(OR)S	Aeronautical mobile (off-route) service
AM(R)S	Aeronautical mobile (route) service
AMS(R)S	Aeronautical mobile satellite (route) service
ANSP	Air navigation service provider
ATC	Air traffic control
epfd	Effective power flux density
FIR	Flight information region
ICAO	International Civil Aviation Organization
IoT	Internet of things
LEO	Low earth orbit
MASPS	Minimum aviation system performance standards
MSS	Mobile satellite service
M2M	Machine to machine
pfd	Power flux density
RR:	Radio Regulations
SARPs:	Standards and Recommended Practices

SATCOM	Satellite communications
SOS	Space operation service
SRS	Space research service
VDES	VHF data exchange system
VDL	VHF data link
VHF	Very high frequency

Relevant ITU-R Recommendations and Reports

Recommendations

ITU-R M.1231 Interference criteria for space-to-Earth links operating in the mobile-satellite service with non-geostationary satellites in the 137-138 MHz band

ITU-R M.1232 Sharing criteria for space-to-Earth links operating in the mobile-satellite service with non-geostationary satellites in the 137-138 MHz band

ITU-R M.2092 Technical characteristics for a VHF data exchange system in the VHF maritime mobile band

ITU-R P.531 Ionospheric propagation data and prediction methods required for the design of satellite networks and systems

ITU-R SA.363 Space Operation Systems

ITU-R SA.609 Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites

ITU-R SA.1026 Aggregate interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit

ITU-R SA.1027 Sharing criteria for space-to-Earth data transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit

ITU-R SA.1743 Maximum allowable degradation to radiocommunication links of the space research and space operation services arising from interference from emissions and radiations from other radio sources

Reports

ITU-R SA.2426 Technical characteristics for telemetry, tracking and command in the space operation service below 1 GHz for non-GSO satellites with short duration missions

ITU-R SA.2488 Characteristics to be used for assessing interference to systems operating in the Earth exploration-satellite and meteorological-satellite services, and for conducting sharing studies

1 Description of space-based VHF communications concept

1.1 General concept

Space-based VHF communication is a concept in which aircraft operating in remote regions and oceanic areas provide communications from the aircraft to air traffic control (ATC) via satellite using VHF frequencies within the 117.975-137 MHz frequency range.

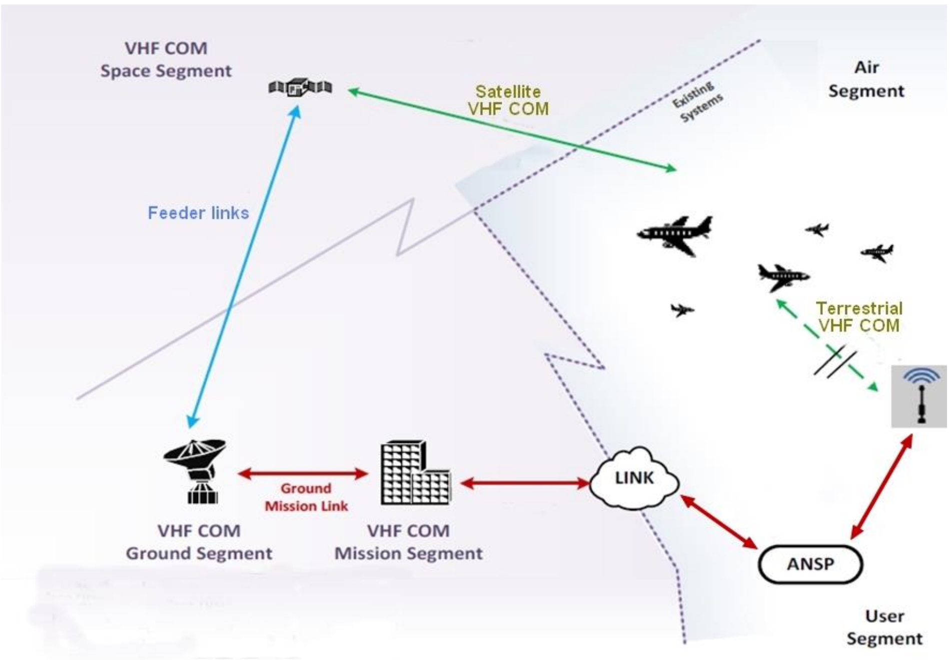
This concept, when implemented, is expected to enhance air traffic management and flight operations in oceanic and remote airspace and will complement current aviation use of satellite-based navigation and surveillance technologies.

While currently there are other long-range communication systems, such as HF and SATCOM, available to facilitate communications between aircraft and ATC in remote and oceanic airspace, the performance of these current systems is not adequate to safely support close aircraft-to-aircraft separation in a similar fashion as to what is being applied in dense airspace where terrestrial-based VHF communications infrastructure is predominant. Therefore, this leads to constraints in airspace capacity and efficiency in oceanic and remote areas, where it is not practical to deploy VHF terrestrial infrastructure.

Figure 1 is an illustration of the space-based VHF communication concept. The space segment is able to receive and transmit to standard VHF radios already installed onboard aircraft and is designed to behave as if it was just another VHF-tower located in the sky, with a larger footprint than terrestrial towers.

FIGURE 1

The space-based VHF communication concept



This report provides studies on the use of low-Earth orbiting satellites to relay air traffic control messages between the pilot and the controller. Operation of the space-based VHF systems within the frequency band 117.975-137 MHz, currently allocated to the aeronautical mobile (Route) service (AM(R)S), aims to utilize existing on-board VHF radios used for terrestrial-based VHF communications.

A new allocation to the aeronautical mobile satellite (Route) service (AMS(R)S) within this frequency band 117.975-137 MHz is being considered under the agenda item 1.7 of the WRC-23.

AMS(R)S links between aircraft and satellite (shown as “Satellite VHF COM” in Figure 1) will operate within the frequency band 117.975-137 MHz and are the subject of considerations contained in this Report. Feeder links of AMS(R)S systems between earth station and satellite are not implemented within the VHF frequency band and may be accommodated in the fixed-satellite service, therefore consideration of feeder links is out of the scope of this Report.

1.2 High-level objectives

The following objectives and characteristics are considered for the space-based VHF system under study:

– The applications provided are within AMS(R)S communications.
  - Voice is the most critical VHF communication application in terms of safety and dependability. It is studied within the sub-band 117.975-136 MHz.
  - VHF datalink (VDL) Mode 2 is studied within the sub-band 136-137 MHz, as channels currently assigned worldwide to this application are within this range.

– No change is made on:
  - aircraft avionic equipment.
  - terrestrial base stations specifications, and configuration of base stations located in flight information regions (FIRs) which do not make use of the space-based VHF service.

– No or minimal change would be made on:
  - operational aspects for pilots and controllers.
  - terrestrial base stations configuration in FIRs with space-based VHF service.

The service area covered by the space-based VHF system will depend on satellite constellation architecture and design. It can be limited to one or several FIRs, regional or global. The space-based VHF system is primarily intended to cover oceanic and remote areas where terrestrial service is not available, but it could also be used to backup terrestrial stations in case they are affected by a catastrophic event.

To achieve the above objectives, the following tasks were carried out:

– ITU-R carried out sharing and compatibility studies for the co-existence between potential new AMS(R)S systems operating in the frequency band 117.975-137 MHz (Earth-to-space and space-to-Earth), providing voice and data applications as mentioned above, and existing primary in-band and adjacent band services.

– Based on the outcome of the studies, technical and regulatory proposals are provided in the summary section towards a possible new AMS(R)S allocation within the frequency band 117.975-137 MHz.

– ICAO participation was beneficial in ITU-R sharing and compatibility studies to provide aeronautical operational requirements, between the new AMS(R)S systems and the existing aeronautical systems, and other relevant available operational characteristics.

2 Current use of the VHF frequency band 117.975-137 MHz

Below is the Radio Regulations (RR), (Edition of 2020) table of allocations and associated footnotes for the band 117.975-137 MHz. It shows that services allocated in this band on a primary basis are:

– Aeronautical mobile (R) service throughout the entire frequency band.

– Aeronautical mobile (OR) service (AM(OR)S) in the frequency bands 132-136 MHz and 136-137 MHz in certain countries listed respectively in RR Nos. **5.201** and **5.202**.

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

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

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

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

5.201 *Additional allocation:* in Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, the Russian Federation, Georgia, Hungary, Iran (Islamic Republic of), Iraq (Republic of), Japan, Kazakhstan, Mali, Mongolia, Mozambique, Uzbekistan, Papua New Guinea, Poland, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine, the frequency band 132-136 MHz is also allocated to the AM(OR)S on a primary basis. In assigning frequencies to stations of the AM(OR)S, the administration shall take account of the frequencies assigned to stations in the aeronautical mobile (R) service. (WRC-19)

5.202 *Additional allocation:* in Saudi Arabia, Armenia, Azerbaijan, Bahrain, Belarus, Bulgaria, the United Arab Emirates, the Russian Federation, Georgia, Iran (Islamic Republic of), Jordan, Mali, Oman, Uzbekistan, Poland, the Syrian Arab Republic, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine, the frequency band 136-137 MHz is also allocated to the AM(OR)S on a primary basis. In assigning frequencies to stations of the AM(OR)S, the administration shall take account of the frequencies assigned to stations in the aeronautical mobile (R) service. (WRC-19)

3 Current Use of the frequency bands adjacent to 117.975-137 MHz

3.1 Radiocommunication services operating in the 108-117.975 MHz frequency band based on the RR Table of Allocations

Below is the RR (Edition of 2020) table of allocations and associated footnotes for the frequency band 108-117.975 MHz. It shows that services allocated in this band on a primary basis are:

– Aeronautical radio navigation service

– Aeronautical mobile (R) service.

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

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

5.197A *Additional allocation:* the band 108-117.975 MHz is also allocated on a primary basis to the aeronautical mobile (R) service, limited to systems operating in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **413 (Rev.WRC-07)**[*]. The use of the band 108-112 MHz by the aeronautical mobile (R) service shall be limited to systems composed of ground-based transmitters and associated receivers that provide navigational information in support of air navigation functions in accordance with recognized international aeronautical standards. (WRC-07)

3.2 Radiocommunication services operating in the frequency band 137-143.6 MHz based on the Radio Regulations Table of Allocations

Below is the RR (Edition of 2020) table of allocations and associated footnotes for the frequency band 137-143.6 MHz. It shows that services allocated in this band on a primary basis are:

Primary services in the frequency band 137-138 MHz:

– AM(OR)S in certain countries under RR No. **5.206**

– Broadcasting service in Australia under RR No. **5.207**

– Fixed service in certain countries under RR No. **5.204** and No. **5.205**

– Meteorological satellite service (space-to-Earth)

– Mobile satellite service (space-to-Earth)

– Mobile service in certain countries under RR No. **5.204** and No. **5.205**

– Space operation service (space-to-Earth)

– Space research service (space-to-Earth).

Primary services in the frequency band 138-143.6 MHz:

– AM(OR)S in Region 1

– Broadcasting service in Australia under RR No. **5.207**

– Fixed service in Region 2, Region 3, and certain countries in Region 1 under RR No. **5.212** and No. **5.214**

– Land mobile service in certain countries in Region 1 under RR No. **5.211**

– Mobile service in Region 2, Region 3, and certain countries in Region 1 under RR No. **5.212**

– Maritime mobile service in certain countries in Region 1 under RR No. **5.211**

– Radio location service in Region 2 and in China under RR No. **5.213**.

Allocation to Services		
Region 1	**Region 2**	**Region 3**
137-137.025	SPACE OPERATION (space-to-Earth) 5.203C METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208A 5.208B 5.209 SPACE RESEARCH (space-to-Earth) Fixed Mobile except aeronautical mobile (R) 5.204 5.205 5.206 5.207 5.208	
137.025-137.175 MHz	SPACE OPERATION (space-to-Earth) 5.203C METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth) Fixed Mobile except aeronautical mobile (R) Mobile-satellite (space-to-Earth) 5.208A 5.208B 5.209 5.204 5.205 5.206 5.207 5.208	

137.175-137.825 MHz	SPACE OPERATION (space-to-Earth) 5.203C 5.209A METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208A 5.208B 5.209 SPACE RESEARCH (space-to-Earth) Fixed Mobile except aeronautical mobile (R) 5.204 5.205 5.206 5.207 5.208	
137.825-138 MHz	SPACE OPERATION (space-to-Earth) 5.203C METEOROLOGICAL-SATELLITE (space-to-Earth) SPACE RESEARCH (space-to-Earth) Fixed Mobile except aeronautical mobile (R) Mobile-satellite (space-to-Earth) 5.208A 5.208B 5.209 5.204 5.205 5.206 5.207 5.208	
138-143.6 MHz AERONAUTICAL MOBILE (OR) 5.210 5.211 5.212 5.214	**138-143.6** FIXED MOBILE RADIOLOCATION Space research (space-to-Earth)	**138-143.6** FIXED MOBILE Space research (space-to-Earth) 5.207 5.213

5.203C The use of the space operation service (space-to-Earth) with non-geostationary satellite short-duration mission systems in the frequency band 137-138 MHz is subject to Resolution **660 (WRC-19)**. Resolution **32 (WRC-19)** applies. These systems shall not cause harmful interference to, or claim protection from, the existing services to which the frequency band is allocated on a primary basis. (WRC-19)

5.204 *Different category of service:* in Afghanistan, Saudi Arabia, Bahrain, Bangladesh, Brunei Darussalam, China, Cuba, the United Arab Emirates, India, Indonesia, Iran (Islamic Republic of), Iraq, Kuwait, Montenegro, Oman, Pakistan, the Philippines, Qatar, Singapore, Thailand and Yemen, the frequency band 137-138 MHz is allocated to the fixed and mobile, except aeronautical mobile (R), services on a primary basis (see No. **5.33**). (WRC-19)

5.205 *Different category of service:* in Israel and Jordan, the allocation of the band 137-138 MHz to the fixed and mobile, except aeronautical mobile, services is on a primary basis (see No. **5.33**).

5.206 *Different category of service:* in Armenia, Azerbaijan, Belarus, Bulgaria, Egypt, the Russian Federation, Finland, France, Georgia, Greece, Kazakhstan, Lebanon, Moldova, Mongolia, Uzbekistan, Poland, Kyrgyzstan, the Syrian Arab Republic, Slovakia, the Czech Rep., Romania, Tajikistan, Turkmenistan and Ukraine, the allocation of the band 137-138 MHz to the aeronautical mobile (OR) service is on a primary basis (see No. **5.33**). (WRC-2000)

5.207 *Additional allocation:* in Australia, the band 137-144 MHz is also allocated to the broadcasting service on a primary basis until that service can be accommodated within regional broadcasting allocations.

5.208 The use of the band 137-138 MHz by the mobile-satellite service is subject to coordination under No. **9.11A**. (WRC-97)

5.208A In making assignments to space stations in the mobile-satellite service in the frequency bands 137-138 MHz, 387-390 MHz and 400.15-401 MHz and in the maritime mobile-satellite service (space-to-Earth) in the frequency bands 157.1875-157.3375 MHz and 161.7875-161.9375 MHz, administrations shall take all practicable steps to protect the radio astronomy service in the frequency bands 150.05-153 MHz, 322-328.6 MHz, 406.1-410 MHz and 608-614 MHz from harmful interference from unwanted emissions as shown in the most recent version of Recommendation ITU-R RA.769-2. (WRC-19)

5.208B* In the frequency bands:

137-138 MHz,
157.1875-157.3375 MHz,
161.7875-161.9375 MHz,
387-390 MHz,
400.15-401 MHz,
1 452-1 492 MHz,
1 525-1 610 MHz,
1 613.8-1 626.5 MHz,
2 655-2 690 MHz,
21.4-22 GHz,

Resolution **739 (Rev.WRC-19)** applies. (WRC-19)

5.209 The use of the bands 137-138 MHz, 148-150.05 MHz, 399.9-400.05 MHz, 400.15-401 MHz, 454-456 MHz and 459-460 MHz by the mobile-satellite service is limited to non-geostationary-satellite systems. (WRC-97)

5.209A The use of the frequency band 137.175-137.825 MHz by non-geostationary-satellite systems in the space operation service identified as short-duration mission in accordance with Appendix **4** is not subject to No. **9.11A**. (WRC-19)

5.210 *Additional allocation:* in Italy, the Czech Rep. and the United Kingdom, the bands 138-143.6 MHz and 143.65-144 MHz are also allocated to the space research service (space-to-Earth) on a secondary basis. (WRC-07)

5.211 *Additional allocation:* in Germany, Saudi Arabia, Austria, Bahrain, Belgium, Denmark, the United Arab Emirates, Spain, Finland, Greece, Guinea, Ireland, Israel, Kenya, Kuwait, Lebanon, Liechtenstein, Luxembourg, North Macedonia, Mali, Malta, Montenegro, Norway, the Netherlands, Qatar, Slovakia, the United Kingdom, Serbia, Slovenia, Somalia, Sweden, Switzerland, Tanzania, Tunisia and Turkey, the frequency band 138-144 MHz is also allocated to the maritime mobile and land mobile services on a primary basis. (WRC-19)

5.212 *Alternative allocation:* in Angola, Botswana, Cameroon, the Central African Rep., Congo (Rep. of the), Eswatini, Gabon, Gambia, Ghana, Guinea, Iraq, Jordan, Lesotho, Liberia, Libya, Malawi, Mozambique, Namibia, Niger, Oman, Uganda, Syrian Arab Republic, the Dem. Rep. of the Congo, Rwanda, Sierra Leone, South Africa, Chad, Togo, Zambia and Zimbabwe, the frequency band 138-144 MHz is allocated to the fixed and mobile services on a primary basis. (WRC-19)

5.213 *Additional allocation:* in China, the band 138-144 MHz is also allocated to the radiolocation service on a primary basis.

5.214 *Additional allocation:* in Eritrea, Ethiopia, Kenya, North Macedonia, Montenegro, Serbia, Somalia, Sudan, South Sudan and Tanzania, the frequency band 138-144 MHz is also allocated to the fixed service on a primary basis. (WRC-19)

4 Aircraft VHF transmitter and receiver characteristics

To address link budgets, this report considers the worldwide 25 kHz channelization of the VHF frequency band, the lowest assignable frequency being 118.000 MHz and the highest assignable frequency 136.975 MHz.

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* This provision was previously numbered as No. **5.347A**. It was renumbered to preserve the sequential order.

However, it can be noted that in order to address increasing demand for voice channels over particular regions, 8.33 kHz channel spacing has been implemented in these regions.

4.1 Aircraft VHF transmitter characteristics

The same antenna pattern is considered for aircraft VHF transmitters and receivers.

4.1.1 Aircraft VHF transmit power for voice application

In terms of transmitted power, the minimum aircraft transmit output powers for voice are 16 watts for 200 nautical miles maximum range, and 4 watts for 100 nautical miles maximum range. The first figure of 16 watts is retained in this report, as the range between aircraft and satellite will exceed 200 nautical miles as shown in next sections. The International Civil Aviation Organization (ICAO) has confirmed the relevance of this value.

4.1.2 Aircraft VHF transmit power for data application

In the same way, in terms of transmitted power, for data using VDL Mode 2, the RF output power, measured at the transmitter antenna port, on all frequencies for which the transmitter is designed, will be typically 15 watts for 200 nautical miles, and 4 watts for 100 nautical miles (EUROCAE ED-92C, section 2.2.1.3.2). The first figure of 15 watts is retained in this report for services using VDL Mode 2, as the range between aircraft and satellite will exceed 200 nautical miles as shown in next sections.

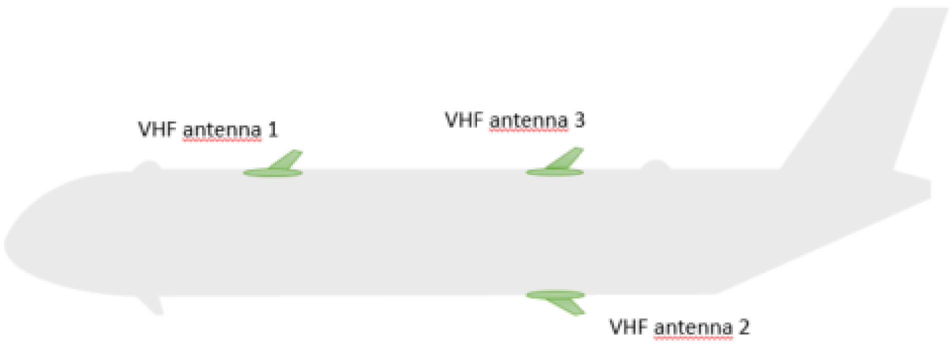
4.2 Aircraft VHF receiver characteristics

4.2.1 Aircraft VHF receiver antenna

Aircrafts are usually equipped with two or three VHF antennas, in which case at least one of them is located on top of the aircraft, and one on the bottom. In the case of three VHF antennas, their typical location installed on a generic aircraft is shown in Figure 2 below provided by ICAO.

FIGURE 2

Typical VHF antenna location on aircraft



The aircraft VHF receiving antenna pattern is obviously an essential element to consider in the studies. The performances of available products show that:

– Relatively low gains are achieved
– Radiation patterns are globally omni-directional, and more precisely
  - omnidirectional in azimuth
  - cosinusoidal in elevation, meaning a theoretical zero is achieved at aircraft zenith (90° elevation).

As a guide, ICAO provided the following general characteristics of the VHF antenna to be used as a baseline for ITU-R studies. ICAO has also confirmed the co-sinusoidal shape and consequential null at aircraft zenith, which has an important implication on the performance of the satellite VHF link: one can assume that the AMS(R)S downlink operation is expected to be 'off-zenith' between the aircraft and the satellite.

– Frequency band: 117.975-137 MHz
– Polarization: Vertical
– Radiation pattern: Omni directional
– Gain: −1 dBi.

4.2.2 Aircraft VHF receiver performance requirement

4.2.2.1 Voice application performance requirement

Regarding the aircraft VHF receiver sensitivity for voice application, ICAO Standards and Recommended Practices (SARPs) provide the following reference recommendation contained in Annex 10 Volume III (Communication System) Part II (Voice Communication Systems) of the Convention on International Civil Aviation:

PART II

Annex 10 – Aeronautical communications

2.3 System characteristics of the airborne installation

[…]

2.3.2 Receiving function

[…]

2.3.2.2 Sensitivity

2.3.2.2.1 Recommendation

After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 75 microvolts per metre (minus 109 dBW/m^2).

Note: For planning extended range VHF facilities, an airborne receiving function sensitivity of 30 microvolts per metre may be assumed.

A satellite system relaying aeronautical VHF communications over oceanic and remote areas can be considered as part of "extended range VHF facilities", hence the Note referring to a field strength of 30 microvolts per metre would be more relevant for the satellite case than the 75 microvolts per metre reference. Such a field strength corresponds to a sensitivity power flux density of −116.2 dB(W/m^2). Indeed the relation between electric field strength and power flux density is given by:

Power flux density (dB(W/m²)) = 10log(electric field strength(V/m)² / 120π)

ICAO recommends using the 30 microvolts per meter requirement, which becomes −90 dBm through an isotropic antenna @ 131 MHz. Indeed at 131 MHz, the aircraft VHF receiver effective aperture area ($A = G_r.\lambda^2/(4\pi)$) for an isotropic antenna (G_r = 0 dBi) is −3.8 dBm², hence with a power flux density of −116.2 dB(W/m²), corresponding received power is −120 dBW or −90 dBm at the aircraft antenna flange.

Feeder/cable losses on board aircraft should also be accounted for. It is proposed to consider 2 dB for voice applications in this study.

4.2.2.2 Aeronautical mobile satellite (route) service data application performance requirement

Regarding the aircraft VHF receiver sensitivity data using VDL Mode 2 modulation application, ICAO SARPs provide the following reference recommendation contained in Annex 10 Volume III (Communication System) Part I (Digital Data Communication Systems) of the Convention on International Civil Aviation:

PART I

Annex 10 – Aeronautical communications

6.3 System characteristics of the aircraft installation

[…]

6.3.5 Receiving function

[…]

6.3.5.2 ***Sensitivity*. The receiving function shall satisfy the specified error rate with a desired signal strength of not more than 20 microvolts per metre (minus 120 dBW/m²).**

Note.— The required signal strength at the edge of the service volume takes into account the requirements of the system and signal losses within the system, and considers environmental noise sources.

This sensitivity power flux density of −120 dB(W/m²) becomes −93.8 dBm through an isotropic antenna @ 131 MHz. Indeed at 131 MHz, the aircraft VHF receiver effective aperture area ($A = G_r.\lambda^2/(4\pi)$) for an isotropic antenna (G_r = 0 dBi) is −3.8 dBm², hence with a power flux density of −120 dB(W/m²), corresponding received power is −123.8 dBW or −93.8 dBm at the aircraft antenna flange. (Note: According to EUROCAE ED-92, Section 2.2.1.2.1 sensitivity "A signal level of minus 98 dBm at the input of the receiver from a VDL Mode 2 signal source will produce an error rate that meets the requirements specified in Section 2.2.1.2"),

Feeder/cable losses on board aircraft should also be accounted for. It is proposed to consider 3 dB in this study, as specified in section 3.8.1 ("transmitter power", page 241) of document RTCA DO-224C (Signal-in-Space minimum aviation system performance standards (MASPS) for Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques). The 1 dB difference with the 2 dB feeder loss figure considered for voice application is due to different typical locations on the aircraft for corresponding antenna.

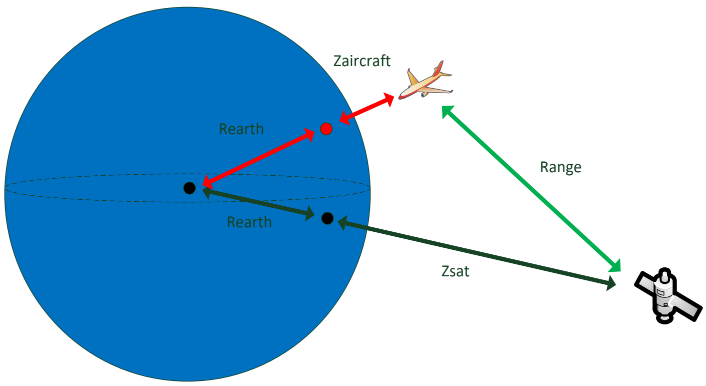
5 Operational environment for the transmission and reception of satellite VHF

5.1 Satellite-aircraft range

The effective path range is relative to the satellite altitude, and to the actual satellite and aircraft positions, which change continuously. Definition of the maximum range considered for satellite operation is helpful in the assessment of system performance and is an important assumption in the overall architecture design. Together with the targeted service area (FIR specific, regional, global) and the desired availability performance under given propagation conditions, this parameter directly impacts the number of satellites required in the satellite constellation.

FIGURE 3

Satellite-aircraft range



An assessment of satellite-to-aircraft link budget with a geostationary satellite (i.e. at around 36 000 km altitude) indicates that required power at satellite is out-of-reach. Indeed, Table 1 below provides an estimation of satellite power required in order to obtain the power-flux level of −116.2 dB(W/m²) for voice application specified in section 4.2.2 at 36 000 km distance, first with the typical assumption of a satellite transmitting gain of 3 dBi, second with the very optimistic assumption of a satellite transmitting gain of 20 dBi. Required satellite power is 155.5 kW and 3.1 kW respectively, which is either not achievable or not reasonable for a single 25 kHz carrier.

This leads to the conclusion that a geostationary AMS(R)S solution is not a workable architecture in order to address satellite VHF requirements. Hence only a non-geostationary case is considered in this report.

TABLE 1

Estimation of satellite RF power required for a geostationary satellite operating in the aeronautical mobile satellite (route) service

		Units	Satellite-to-aircraft link budget	
			GSO with average VHF antenna gain	GSO with very high VHF antenna gain
a.	Frequency	MHz	137	137
b.	Range	km	36 000	36 000
Satellite transmitter				
c.	RF power required for 0 dB link margin	W	155 531	3 103

d.	Satellite Tx antenna gain	dBi	3	20
e.	Feeder loss	dB	1.0	1.0
f.	Satellite e.i.r.p. (calculated from c, d and e)	dBW	53.9	53.9
Signal propagation				
g.	Free space loss (calculated from a and b)	dB	166.3	166.3
h.	Additional propagation losses (scintillation)	dB	5	5
i.	Polarization losses to receive V polar	dB	3	3
Receiver power flux at aircraft antenna input				
	Effective received power flux density (calculated from a, f, g, h, i)	dBW/m^2	-116.2	-116.2

The detailed definition of an AMS(R)S satellite constellation is out of the scope of this report. Several options are possible, and trade-offs are required on many elements such as the number of satellites in the constellation, their altitude, the desired coverage and number of simultaneously visible satellites (for redundancy), the presence or not of inter-satellite links, the number of VHF channels that can be addressed by each satellite, the desired quality of service, etc.

However, studies require certain assumptions to be made, and it is proposed to retain for this report a satellite altitude of 600 km, representative of typical low earth orbit (LEO) solutions. This altitude was for example considered in Recommendation ITU-R M.2092-0 related to the satellite component of a VHF data exchange system (VDES). Technical characteristics of the reference AMS(R)S system are detailed in Section 0. Of course, other orbital selections are also possible according to the overall system design consideration.

5.2 Propagation

Satellite transmissions in the VHF range are known to be significantly affected by scintillation events that occur within the ionospheric layer. The ionosphere causes a delay proportional to the electron-density along the wave path, where the wave path passes patches of more or less dense ionosphere, scintillation occurs.

Scintillation is generally more pronounced at high latitudes and within ±20° of the geomagnetic equator. For much of the locations in mid-latitudes, propagation loss and phase changes due to scintillation will be less pronounced than those at high latitudes or near the geomagnetic equator. Notably, there are also areas which are not affected by ionospheric propagation loss. At this stage according to Recommendation ITU-R P.531-14, it is recommended that Global Ionospheric Scintillation Model is used to predict the effects of scintillation on a given link geometry. Careful consideration of the temporal, spatial and geomagnetic environment must be used to assess the range of ionospheric behaviour, noting that scintillation events last from 30 minutes to hours and commence after local ionospheric sunset. For every longitudinal position, the highest intensity of scintillation (if any) is observed for a period of time after sunset at 1800 (local time) and up to 0:00 at the equinox period, and for years of maximal solar activity (see in Figure 4, extracted from Recommendation ITU-R P.531-14, a representation at 1.5 GHz).

If qualitative effects are pretty well known, their accurate prediction is still challenging for the design of telecom systems. Given the limit of the current model accuracy, it is not possible yet to precisely quantify ionospheric propagation losses in relation to a given link availability for all ranges of latitude and aircraft station elevation.

Further work is required in order to appropriately take ionospheric losses into account in the design of an aeronautical VHF satellite system. A reference availability target should be identified so as to define the relevant attenuation margin, but considering the extent of the phenomenon and its variability against time and location, it may be appropriate to consider some splitting by region, and possibly between day and night period (for instance 1800-0000, and 0000-1800).

The three following reference ionospheric losses is given for different regions:

– A low level of 1 dB attenuation losses for medium latitude regions.

– A medium level of 5 dB attenuation losses for high latitude regions.

– A high level of 10 dB attenuation losses for low latitude regions.

ICAO has indicated that the levels of VHF service availability to be required will depend on the types of operations and airspace. Once a satellite system is designed, its availability performance will be evaluated, and will represent an important input for air navigation service providers (ANSPs) interested in the service. They will define a set of operational measures required to reach a given safety objective. Depending on satellite system design trade-offs, it may be of interest not to dimension the satellite system to account for the worst-case propagation loss, which is transient and highly dependent to time, weather and location, and to compensate with appropriate measures (like appropriate flight planning) over the concerned regions when affected.

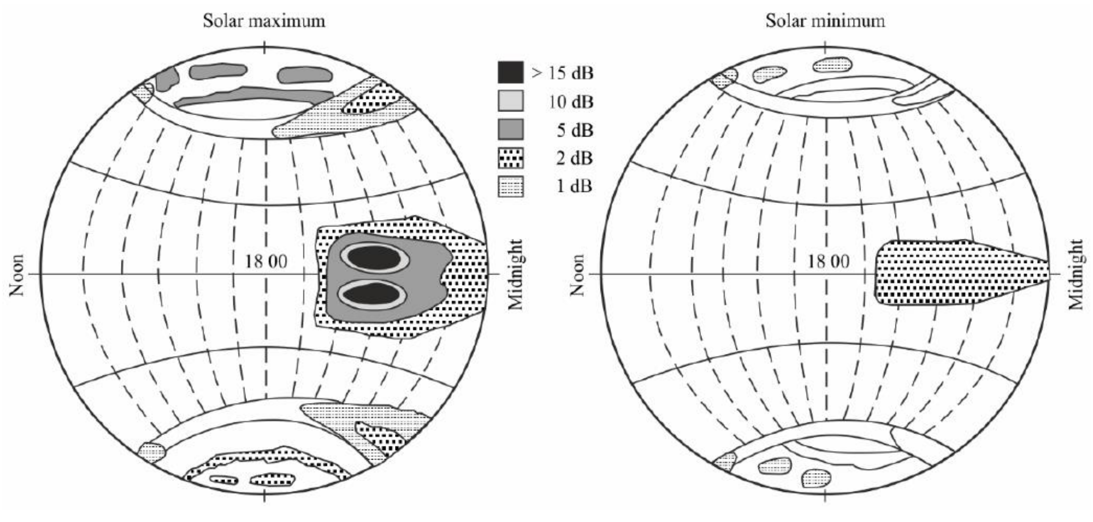
ICAO also noted that, depending on ANSPs' requirements and geographical constraints, both satellite and terrestrial systems may be used together to overcome the VHF scintillation trade-offs, to meet the service availability requirements. Moreover, the satellite system could also be designed with redundancies in place, an example would be to replicate the terrestrial VHF system setup to mount on different satellites.

Based on these considerations, it is proposed to retain in this report the assumptions corresponding to the low and medium levels of scintillation losses, i.e. 1 dB and 5 dB respectively, and to establish link budgets under both of these assumptions.

It is important to note that the phenomena leading to higher attenuation loss due to scintillation can be predicted. Consequently, it is possible for aviation competent authority to decide in advance to not operate in area and in the period of time where and when ionospheric propagation would preclude the use of satellite VHF link; it is similar situation that can be met for HF links.

FIGURE 4

Ionospheric propagation loss at 1.5 GHz during solar maximum and minimum years (from Recommendation ITU-R P.531-14)



5.3 Polarization

Emissions of standardised air-ground VHF communication systems are vertically polarized. Recommendation ITU-R P.531-14 identifies Faraday rotation as an effect on propagation for the proposed corresponding new satellite system. For systems that use linearly polarized antennas, potential phase rotation through the ionosphere depends on many factors such as location, time of year, time of day, solar cycle and geomagnetic conditions. It is therefore very difficult to predict the extent of associated polarization loss.

At satellite level, a setup with linear polarization, compatible with the vertical polarization used at aircraft would be preferable for link budget purposes. However, its design seems difficult to match in terms of alignment with aircraft antenna, taking into account the real-time link geometry between the transmitter and receiver, and Faraday rotation changing polarization angles. For this reason, circularly polarized receiving and transmitting antennas are assumed, mitigating by design against the Faraday effect, and leading to a polarization loss factor of 3 dB.

6 Technical characteristics of the proposed reference system operating in the aeronautical mobile (route) service

Satellite link budgets are proposed at the upper edge of the considered AMS(R)S allocation, i.e. 136 or 137 MHz frequency. This is considered a worst case, as link budgets at 118 MHz is more favourable by 1.3 dB in terms of free space losses.

6.1 Satellite transmission characteristics

The output of the link budget considered for satellite downlink determines the power required on-board the satellite. This power is another important driver of satellite system design, which cannot exceed a few hundred watts maximum to remain implementable.

Satellite antennas represent an essential element in any satellite system design. Their performance and pattern are main drivers in the overall system architecture, and in the compatibility of this system with its radio-frequency environment.

In our case of an AMS(R)S system within the band 117.975-137 MHz, an important consideration to take into account, outlined by ICAO, is that AMS(R)S operation is expected to be ‘off-zenith’ between the aircraft and the satellite, because of the co-sinusoidal shape of the aircraft VHF antenna pattern and consequential null at aircraft zenith (see Section 4.2.1). An antenna pattern defined within ITU-R Recommendation for a different purpose was considered relevant for the study and was taken into account. In that framework, the example of a satellite antenna described in Recommendation ITU-R M.2092-1 seems appropriate (see Sections 2.2 and 2.3 of Annexe 5, which detail technical characteristics of the satellite downlink/uplink for the VDES operating around 160 MHz), because the main lobe is pointed towards the horizon of the Earth (similar as Figure 5 below). The communications coverage area is mainly around this main lobe, corresponding to low elevation angles, and high elevation angle (> 70°) coverage is sacrificed, corresponding to null at zenith of the aircraft VHF antenna pattern. It is therefore proposed to retain for the present study this example from Recommendation ITU-R M. 2092-1 as reference satellite antenna pattern for our baseline satellite architecture.

Satellite gain example according to aircraft elevation angle (for a satellite at 600 km altitude) in shown in Table 2. This example is for a Yagi antenna but could be representative for a maximum antenna gain at 0 degrees angle for aircraft elevation, i.e. an Isoflux antenna with a maximum gain of 8 dBi at 66.1 Nadir offset degrees angle is feasible.

TABLE 2

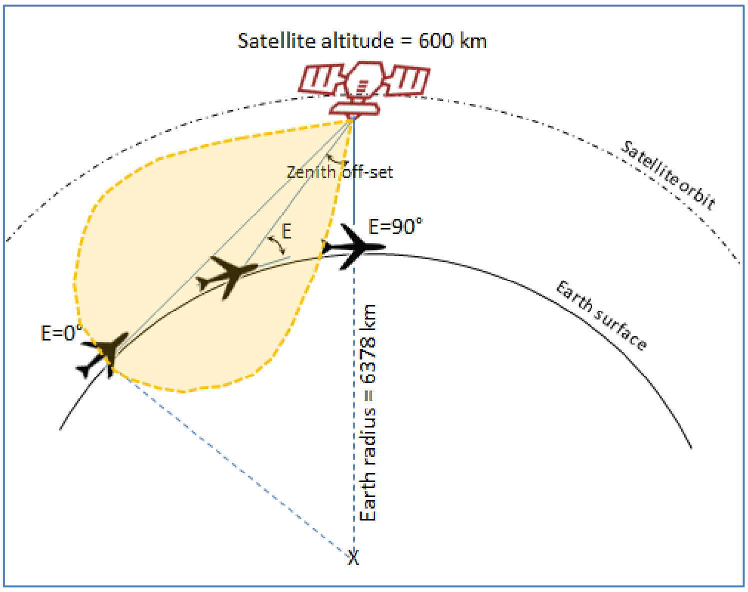
Antenna gain pattern example of a satellite operating in the aeronautical mobile satellite (route) service

Aircraft elevation angle (degrees)	Nadir offset angle (degrees)	Boresight offset angle (degrees)	Satellite-Aircraft range (km)	Satellite antenna Rx/Tx gain (dBi)
0	66.1	0	2831	8
10	64.2	1.9	1932	8
20	59.2	6.9	1392	8
30	52.3	13.8	1075	7.8
40	44.4	21.7	882	6.9
50	36	30.1	761	5.5
60	27.2	38.9	683	3.6
70	18.2	47.9	635	0.7
80	9.1	57	608	−2.2
90	0	66.1	600	−5.5

Figure 5 below provides an illustration of an antenna pattern example, showing its main lobe directed towards the low elevation angles and neglecting the satellite zenith region with high elevation angles.

FIGURE 5

Illustration of the proposed reference satellite antenna pattern



Additional dynamic sharing and compatibility studies may be also carried out for cases where static worst-case analyses don't lead to a firm conclusion. As a reference example, a constellation using polar orbits with 600 km altitude, inclination of 90 degrees, 34 satellites per plane and 10 planes with equal spacing to achieve global coverage could be considered, as presented on Figure 6 below. The number of planes and satellites is determined so as to ensure global coverage, taking into account the 20°-70°E operational elevation range considered later in section 6.3.

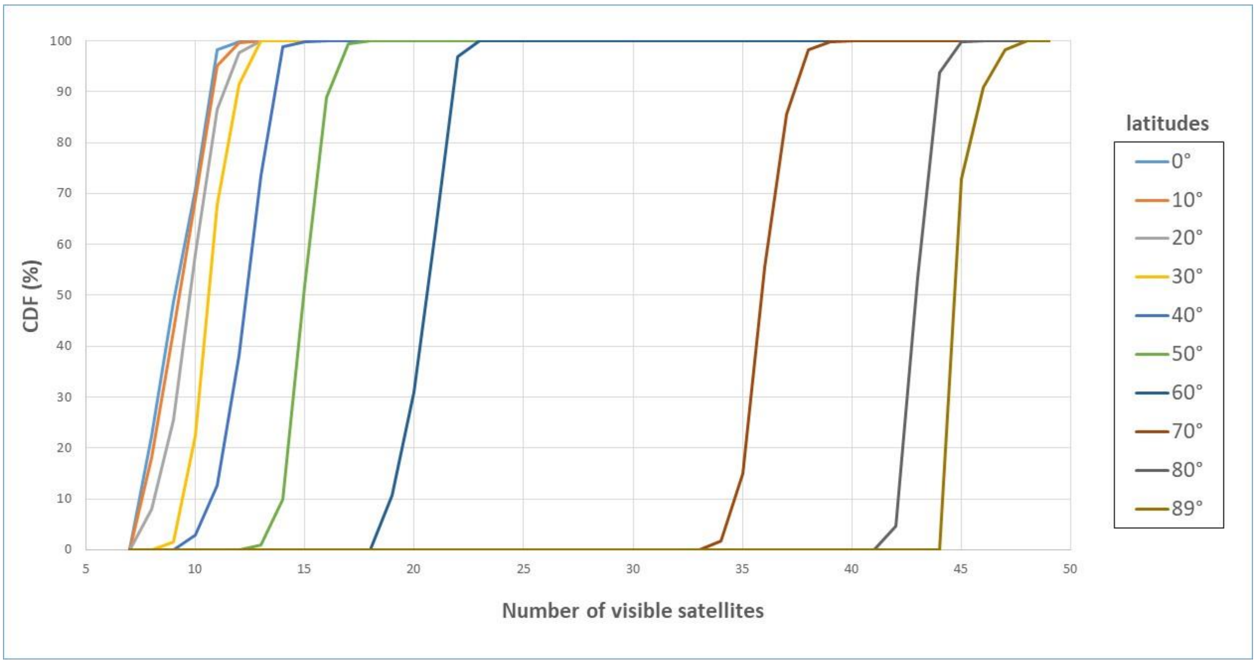
FIGURE 6

Illustration of a reference satellite constellation

With such a constellation, the number of satellites visible from a given point on the Earth will depend on the latitude of this point. Figure 7 below provides the associated statistic:

FIGURE 7

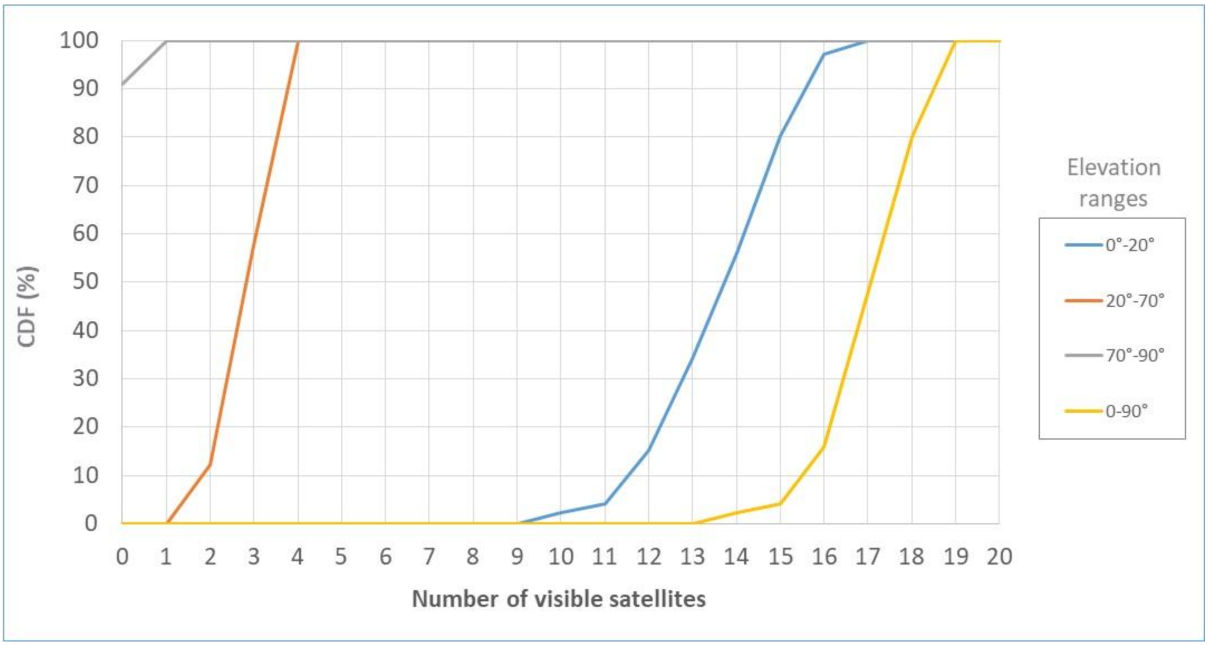
Statistic of the number of visible satellites function of latitude



Only few (possibly only one) of the visible satellites will be within the 20°-70°E operational elevation range considered in section 6.3. As an illustration, Figure 8 below provides the statistic of the elevation ranges for satellites visible from a given point at 55° latitude. The difference is made between satellites visible within the 20°-70° elevation range, those which are seen with an elevation below 20°, and those with an elevation greater than 70°.

FIGURE 8

Statistic of the number of visible satellites per elevation range at 55° latitude



It is important to note that not all satellites which are visible from a given point will be active on the same channel, this would generate intra-system self-interference. As a result of frequency planning exercises assigning frequencies to the satellite system over interested regions, the satellite system would therefore be operationally controlled so as to ensure that, for any point on the Earth, 2 satellites maximum are active on the same channel, irrespective of the elevation at which these satellites are seen. This operational mechanism is an important assumption with respect to co-frequency sharing. Different assumptions on the number of satellites operating on the same channel could be considered.

For adjacent band compatibility, studies consider some assumptions on attenuation level for unwanted emissions. It should depend on the spurious and out-of-band of emissions. The number of frequency carriers transmitted simultaneously by satellites and taken into account at the receiver of an adjacent band earth station needs further investigations.

6.2 Satellite Doppler and latency time

A LEO satellite will move at a speed of about 8 km/s and this will cause a Doppler of ±4 kHz maximum at VHF. The implementation a compensation mechanism on the satellite transmitter to mitigate Doppler effects at the aircraft receiver without making any modification on existing aircraft equipment is under study within ICAO, thus maintaining compliance with the existing aviation standards. In the uplink at satellite reception, this effect could be compensated.

Also, a LEO satellite at 600 km altitude will correspond to a latency time due to propagation comprised between 4 ms (at zenith) and 18.9 ms (at horizon). ICAO is of the view that no operational impact is expected, as the latency ranges expected from the AMS(R)S systems are compatible with existing aeronautical VHF systems.

6.3 Satellite-to-aircraft (i.e. downlink) link budget example for voice application

AMS(R)S from a LEO constellation using VHF aeronautical band 117.975-137 MHz is feasible for the Space to Earth link communications. Table 3 provides an example of satellite-to-aircraft link budget, taking into account all considerations discussed in previous paragraphs (mainly satellite altitude of 600 km, satellite antenna pattern and gain corresponding to different elevations, aircraft VHF antenna gain of −1 dBi except for high elevation angles, etc). In this table, the satellite power required at each aircraft elevation angle is calculated in order to close the link budget under the assumption of 5 dB scintillation losses, i.e. to obtain a 0 dB margin on the satellite to aircraft forward link, taking into account the 30 μV/m requirement expressed by ICAO, equivalent to −116.2 dB(W/m²) power-flux.

TABLE 3

Example satellite-to-aircraft (downlink) link budget
- satellite power required for different aircraft elevation angles

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	304.1	141.7	73.6	45.9	38.1	39.1	48.8	82.2	147.1	305.9
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	31.8	28.5	25.7	23.4	21.7	20.4	19.5	18.8	18.5	18.4
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2
	Recommended SAPRs power flux density	dBW/m^2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2
	Power flux margin	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Receiver											
	Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder Losses	dBi	2	2	2	2	2	2	2	2	2	2
	Rx Signal power	dBm	-93.4	-93.4	-93.4	-93.4	-93.4	-93.4	-93.4	-93.4	-96.4	-100.4

A significant level of satellite power is required per channel to meet the aircraft receiver sensitivity requirement and the different losses. Under the assumptions mentioned above, it can be noted that, as an example, a satellite power of 85 watts per 25 kHz channel is compatible with aircraft elevation angles between 20° and 70°. It is proposed to consider this power level as a reference, and to establish the link budget contained in Table 4 as an example of satellite-to-aircraft link budget taken into account for studies in this report with 5 dB scintillation losses.

TABLE 4

**Example satellite-to-aircraft (downlink) link budget
with 5 dB scintillation losses**

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	85	85	85	85	85	85	85	85	85	85
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-121.7	-118.4	-115.6	-113.5	-112.7	-112.8	-113.8	-116.1	-118.6	-121.8
	Recommended SAPRs power flux density	dBW/m^2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2
	Power flux margin	dB	-5.5	-2.2	0.6	2.7	3.5	3.4	2.4	0.1	-2.4	-5.6
	Receiver											
	Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder Losses	dBi	2	2	2	2	2	2	2	2	2	2
	Rx Signal power	dBm	-98.9	-95.6	-92.8	-90.7	-89.9	-90.0	-91.0	-93.2	-98.8	-105.9
	Power flux density at Earth's surface (taking only free space path loss into account)	dBW/m^2	-113.7	-110.4	-107.6	-105.5	-104.7	-104.8	-105.8	-108.1	-110.6	-113.8

Under the assumption of the lower level of 1 dB scintillation losses corresponding to medium latitude regions, corresponding satellite power can be reduced by around 4 dB from 85W to 35W, and associated link budget becomes as shown in Table 5 below.

TABLE 5

**Example satellite-to-aircraft (downlink) link budget
with 1 dB scintillation losses**

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	35	35	35	35	35	35	35	35	35	35
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1

Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
Effective received power flux density	dBW/m²	-121.6	-118.3	-115.4	-113.4	-112.6	-112.7	-113.6	-115.9	-118.4	-121.6
Recommended SAPRs power flux density	dBW/m²	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2	-116.2
Power flux margin	dB	-5.4	-2.1	0.8	2.8	3.6	3.5	2.6	0.3	-2.2	-5.4
Receiver											
Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
Feeder Losses	dBi	2	2	2	2	2	2	2	2	2	2
Rx Signal power	dBm	-98.8	-95.5	-92.6	-90.6	-89.7	-89.9	-90.8	-93.1	-98.6	-105.8
Power flux density at Earth's surface (taking only free space path loss into account)	dBW/m²	-117.6	-114.3	-111.4	-109.4	-108.6	-108.7	-109.6	-111.9	-114.4	-117.6

Noteworthy, satellite power can be reduced appropriately in areas that are not affected by scintillation losses.

6.4 Aircraft-to-satellite (i.e. uplink) link budget example for voice application

It is also interesting to consider an uplink link budget for the aircraft-to-satellite link, noting that this link does not introduce any new transmitting equipment. Aircraft VHF transmitter is assumed to have a power capability of 16 watts, as explained in Section 0.

Other assumptions regarding antenna patterns and losses (here 5 dB scintillation losses) are identical to the downlink link budget. A required satellite sensitivity level of −107 dBm is assumed taking into account state of the art technology, and there is some margin with that respect.

TABLE 6

**Aircraft-to-satellite (uplink) link budget example
with 5 dB scintillation losses**

RETURN (From Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	16	16	16	16	16	16	16	16	16	16
	Aircraft Tx gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder loss	dB	2	2	2	2	2	2	2	2	2	2
	Aircraft EIRP	dBW	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	6.0	2.0
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m²	-139.0	-135.7	-132.8	-130.6	-128.9	-127.6	-126.6	-126.0	-128.6	-132.5
	Receiver											
	Satellite Rx Antenna Gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder Losses	dBi	1	1	1	1	1	1	1	1	1	1
	Rx Signal power	dBm	-106.2	-102.9	-100.0	-98.0	-97.1	-97.3	-98.2	-100.5	-106.0	-113.2
	Rx sensitivity target	dBm	-107	-107	-107	-107	-107	-107	-107	-107	-107	-107
	Receiver link margin	dB	0.8	4.1	7.0	9.0	9.9	9.7	8.8	6.5	1.0	-6.2

For the uplink budget it shows also that the AMS(R)S is feasible in the Earth to Space link communications.

6.5 Satellite-to-aircraft (i.e. downlink) link budget example for data application

AMS(R)S from a LEO constellation using VHF aeronautical band 117.975-137 MHz is feasible for the Space to Earth link communications. Table 7 provides an example of satellite-to-aircraft link budget, taking into account all considerations discussed in previous paragraphs (mainly satellite altitude of 600 km, satellite antenna pattern and gain corresponding to different elevations, aircraft VHF antenna gain of −1 dBi except for high elevation angles, etc). In this table, the satellite power required at each aircraft elevation angle is calculated in order to close the link budget under the assumption of 5 dB scintillation losses, i.e. to obtain a 0 dB margin on the satellite to aircraft forward link, taking into account the 20 µV/m requirement expressed by ICAO, equivalent to −120 dB(W/m²) power-flux.

Note: a 0,2 dB have been assigned to the Power flux margin to fulfil the –98dBm sensitivity according to EUROCAE ED-92, section 2.2.1.2.1.

TABLE 7

Example satellite-to-aircraft (downlink) link budget (VHF data link mode 2 modulation) – satellite power required for different aircraft elevation angles assuming 5dB of scintillation loss-

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	132.7	61.8	32.1	20.1	16.6	17.1	21.3	35.9	64.2	133.5
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	28.2	24.9	22.1	19.8	18.1	16.8	15.9	15.2	14.9	14.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-119.8	-119.8	-119.8	-119.8	-119.8	-119.8	-119.8	-119.8	-119.8	-119.8
	Recommended SAPRs power flux density	dBW/m^2	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120
	Power flux margin	dB	0	0	0	0	0	0	0	0	0	0
	Receiver											
	Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder Losses	dBi	3	3	3	3	3	3	3	3	3	3
	Rx Signal power	dBm	-98.0	-98.0	-98.0	-98.0	-98.0	-98.0	-98.0	-98.0	-101.0	-105.0

A level of satellite power is required per channel in order to meet the aircraft receiver sensitivity requirement and the different losses. Under the assumptions mentioned above, it can be noted that, as an example, a satellite power of 36 watts per 25 kHz channel is compatible with aircraft elevation angles between 20° and 70°. Following this example, it could be considered this power level as a reference, and to establish the link budget contained in Table 8 as an example of satellite-to-aircraft link budget taken into account for studies in this report with 5 dB scintillation losses.

TABLE 8

Example satellite-to-aircraft (downlink) link budget (VHF data link mode 2 modulation) with 5 dB scintillation losses

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	36	36	36	36	36	36	36	36	36	36
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	22.6	22.6	22.6	22.4	21.5	20.1	18.2	15.3	12.4	9.1
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-125.5	-122.2	-119.3	-117.3	-116.4	-116.6	-117.5	-119.8	-122.3	-125.5
	Recommended SAPRs power flux density	dBW/m^2	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120
	Power flux margin	dB	-5.5	-2.2	0.7	2.7	3.6	3.4	2.5	0.2	-2.3	-5.5
	Receiver											
	Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder Losses	dBi	3	3	3	3	3	3	3	3	3	3
	Rx Signal power	dBm	-103.7	-100.3	-97.5	-95.4	-94.6	-94.7	-95.7	-98.0	-103.5	-110.7
	Power flux density at the earth surface	dBW/m^2	-117.5	-114.2	-111.3	-109.3	-108.4	-108.6	-109.5	-111.8	-114.3	-117.5

Under the assumption of the lower level of 1 dB scintillation losses corresponding to medium latitude regions, corresponding satellite power can be reduced, as an example, by around 2,5 dB from 36W to 20 W, and associated link budget becomes as shown in Table 9 below.

TABLE 9

Example satellite-to-aircraft (downlink) link budget (VHF data link mode 2 modulation) with 1 dB scintillation losses

FORWARD (To Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	20	20	20	20	20	20	20	20	20	20
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	20.0	20.0	20.0	19.8	18.9	17.5	15.6	12.7	9.8	6.5

	Signal Propagation										
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-124.0	-120.7	-117.9	-115.8	-115.0	-115.1	-116.1	-118.3	-120.9	-124.0
	Recommended SAPRs power flux density	dBW/m^2	-120	-120	-120	-120	-120	-120	-120	-120	-120	-120
	Power flux margin	dB	-4.0	-0.7	2.1	4.2	5.0	4.9	3.9	1.7	-0.9	-4.0
	Receiver										
	Aircraft Rx Antenna Gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder Losses	dBi	3	3	3	3	3	3	3	3	3	3
	Rx Signal power	dBm	-102.2	-98.9	-96.0	-94.0	-93.2	-93.3	-94.3	-96.5	-102.0	-109.2
	Power flux density at the earth surface	dBW/m^2	-120	-116.7	-113.9	-111.8	-111.0	111.1	-112.1	-114.3	-116.9	-120.0

Noteworthy, satellite power can be reduced appropriately in areas that are not affected by scintillation losses.

6.6 Aircraft-to-satellite (i.e. uplink) link budget example for data application

It is also interesting to consider an uplink link budget for the aircraft-to-satellite link, noting that this link does not introduce any new transmitting equipment. Aircraft VHF transmitter is assumed to have a power capability of 15 watts as explained in Section 0 and detailed in EUROCAE ED-92C, section 2.2.1.3.2. Typical signal parameters.

Other assumptions regarding antenna patterns and losses (here 5 dB scintillation losses) are identical to the downlink link budget. A required satellite sensitivity level of −107 dBm is assumed taking into account state of the art technology, and there is some margin with that respect.

TABLE 10

Aircraft-to-satellite (uplink) link budget example for data (VHF data link mode 2 modulation) with 5 dB scintillation losses

RETURN (From Aircraft)	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter										
	RF Power for 25 KHz channel	W	15	15	15	15	15	15	15	15	15	15
	Aircraft Tx gain	dBi	-1	-1	-1	-1	-1	-1	-1	-1	-4	-8
	Feeder loss	dB	3	3	3	3	3	3	3	3	3	3
	Aircraft EIRP	dBW	8	8	8	8	8	8	8	8	5	1
	Signal Propagation										
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	5	5	5	5	5	5	5	5	5	5
	Polarization losses	dB	3	3	3	3	3	3	3	3	3	3
	Effective received power flux density	dBW/m^2	-140.3	-137.0	-134.1	-131.9	-130.1	-128.9	-127.9	-127.3	-129.9	-133.8
	Receiver										
	Satellite Rx Antenna Gain	dBi	8	8	8	8	7	6	4	1	-2	-6
	Feeder Losses	dBi	1	1	1	1	1	1	1	1	1	1

Rx Signal power level	dBm	-107.5	-104.1	-101.3	-99.25	-98.43	-98.54	-99.51	-101.8	-107.3	-114.5
Rx sensitivity target	dBm	-107	-107	-107	-107	-107	-107	-107	-107	-107	-107
Receiver link margin	dB	-0.5	2.9	5.7	7.8	8.6	8.5	7.5	5.2	-0.3	-7.5

For the uplink budget it shows also that the AMS(R)S is feasible in the Earth-to-space link communications.

7 Technical parameters used in the sharing and compatibility studies related to emissions in the aeronautical mobile satellite (route) service (space-to-Earth)

7.1 Characteristics of spectral emissions of systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in the frequency band 117.975-136 MHz (voice applications)

7.1.1 Spectrum mask

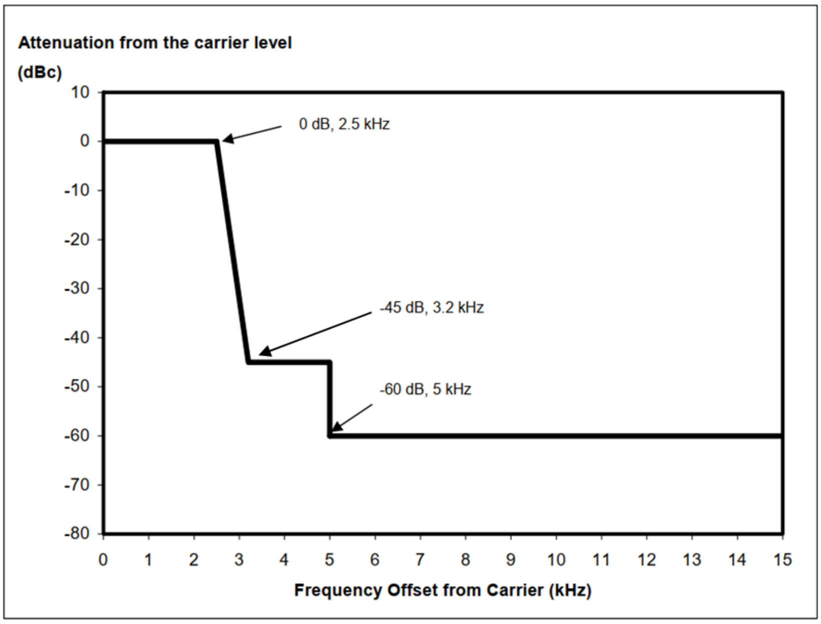
A necessary bandwidth of 5 kHz is considered for voice emission. This value is relevant worldwide, irrespective of the 25 kHz or 8.33 kHz channelization of the VHF band mentioned at the beginning of Section 4.

Document EUROCAE ED-23C provides the following emission mask for voice application (in the frame of 8.33 kHz channelization), showing a minimum attenuation of 60 dB for frequency offset greater than 5 kHz from the carrier centre frequency. This value corresponds to the spectral roll-off of the voice signal.

It can be noted that, according to Appendix 3 of the Radio Regulations, the minimum attenuation for AMS(R)S spurious emission is 60 dBc ("*43 + 10 log (P), or 60 dBc, whichever is less stringent*") in 4 kHz reference bandwidth. Therefore, for the spurious emission domain (i.e. for frequency offset greater than 200% = 10 kHz from the carrier centre frequency), Appendix 3 represents a regulatory requirement to follow this mask with its 60 dB roll-off.

FIGURE 9

Spectrum mask considered for voice emission



7.1.2 Number of voice carriers considered in sharing studies per 25 kHz channel

In order to extend the service area operated through one 25 kHz channel for voice application, a specific mechanism may be implemented, with several stations transmitting voice carriers within that same channel, but with an off-set of few kHz between them.

Such a mechanism may be used via satellite, and the assumption is therefore made in the following sections that two voice carriers are transmitted in the 25 kHz channel under consideration.

7.2 Characteristics of spectral emissions of systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in the frequency band 136-137 MHz

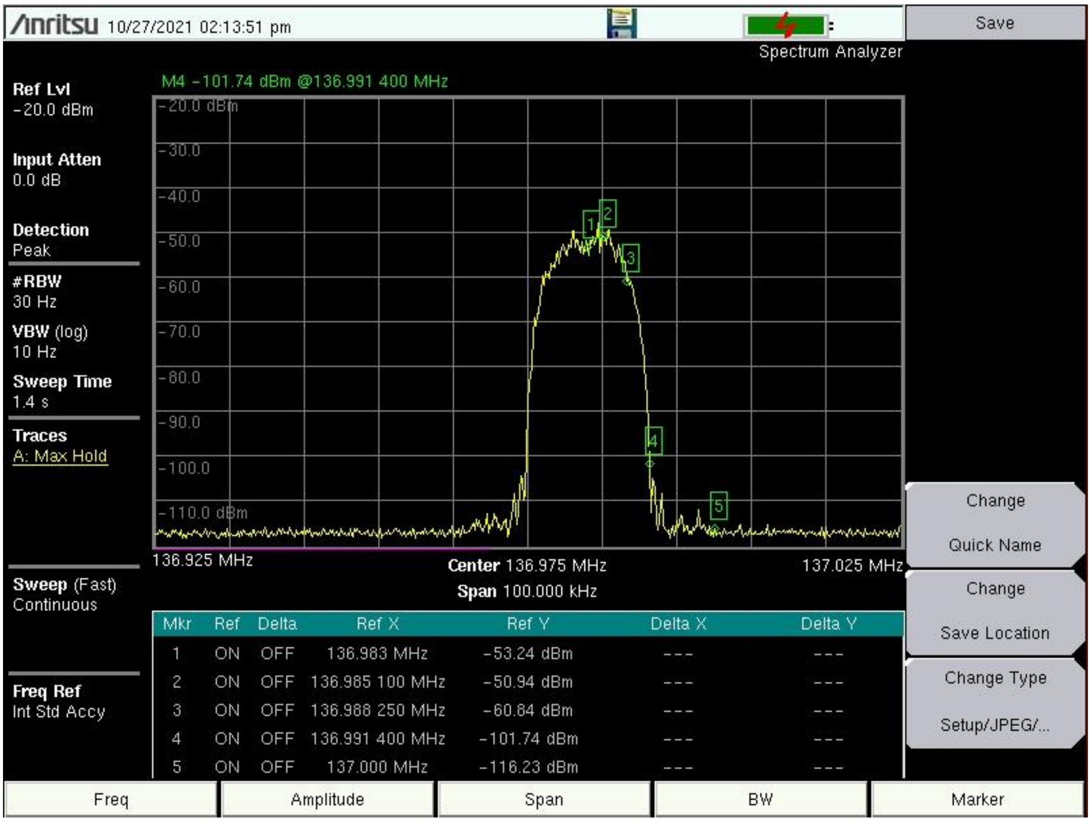
The necessary bandwidth for the VDL-2 signal (worst case) is assumed to be 14.0 kHz corresponding to a 14K0G1DE class type signal (DO-224 Signal-In-Space Minimum Aviation System Performance Standards (MASPS) For Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques. 3.2.1.2.4, and Recommendation ITU-R SM.1138).

7.2.1 Spectrum mask

The typical spectrum mask demonstrates that the spectral roll-off has an attenuation higher than 60 dB. Figure 10 below represents the case of the Common Signalling Channel (CSC) at 136.975 MHz, with a rejection of 60 dB at a frequency separation that can accommodate even a potential worst case of +/-4 kHz frequency Doppler shift pre-compensation (-/+ 8 kHz frequency shift at receiver).

FIGURE 10

Example of VHF data link mode 2 modulation spectral roll-off.
differential 8-phase shift keying modulation with 10,5 Ksymbols/s rate (Example of VHF Radio)



7.2.2 Minimum expected attenuation from emissions of systems operating in the aeronautical mobile satellite (route) service (satellite-to-aircraft) in the frequency band 136-137 MHz (VDL Mode 2 applications) above 137 MHz

Considering a typical spectrum emission of AMS(R)S emission for VDL Mode 2 (minimum 60 dB, see 7.2.1) it can be concluded that such attenuation of 60 dB of AMS(R)S emission (satellite-to-aircraft) operating in the frequency band 136-137 MHz (VDL Mode 2 applications) can be accounted for in following sharing and compatibility studies with respect to systems operating above 137 MHz.

7.2.3 Number of VHF data link Mode 2 carriers considered in sharing studies per 25 kHz channel

Taking in to account the AMS(R)S channelling spacing of 25 kHz and the necessary bandwidth of 14 kHz for the VDL Mode 2 application, only one carrier can be transmitted within the 25 kHz channel under consideration.

7.3 Protection criteria considered for adjacent band systems operating in the frequency band 137-138 MHz

Adjacent band compatibility studies are conducted between systems operating in the AMS(R)S within 117.975-137 MHz and other satellite systems operating on a primary basis in the space-to-Earth direction in the frequency band 137-138 MHz, namely under allocations to the mobile-satellite service (MSS), the space operation service (SOS), the space research service (SRS) and the meteorological satellite service (MetSat). The following sections provide details on the protection criteria considered for these services.

7.3.1 Protection criteria for the mobile satellite systems operating in the frequency band 137-137.025 MHz and 137.175-137.825 MHz

The frequency bands 137-137.025 MHz and 137.175-137.825 MHz are allocated to the mobile-satellite service (MSS) on a primary basis in the space-to-Earth direction.

Characteristics and protection criteria for MSS systems in the frequency band 137-138 MHz can be found in Recommendations ITU-R M.1231 and ITU-R M.1232 entitled respectively "*Interference* (M.1231) / *sharing* (M.1232) *criteria for space-to-Earth links operating in the mobile-satellite service with non-geostationary satellites in the 137-138 MHz band*". Two general types of modulation are considered for non-geostationary MSS systems, namely frequency division multiple access narrow-band modulation and spread spectrum wide-band modulation. However only narrow-band modulation systems have been implemented or are being deployed, for the provision of Internet of Things (IoT) and Machine-to-Machine ("M2M") applications.

Recommendation ITU-R M.1232 provides single-entry interference levels to be used as sharing criteria for the protection of MSS. These levels are based on an assessment of the maximum possible aggregate interference level derived from typical link budgets detailed in Recommendation ITU-M.1231, and on an apportionment of this aggregate interference between terrestrial and satellite sources and between long-term and short-term. For the protection of subscriber terminals of narrow-band modulation MSS systems from unwanted emissions of AMS(R)S space-to-Earth links operating below 137 MHz, the following criteria should be applied:

Protection criteria for earth stations the mobile satellite service to be applied to the unwanted emissions of systems operating in the aeronautical mobile satellite (route) service

	Long-term	Short-term
Maximum interference level	−159.9 dBW	−144.7 dBW
Associated percentage of time	20% of the time	0.0625% of the time
Reference bandwidth	19.2 kHz	19.2 kHz
Propagation loss	1 dB	5 dB
MSS receiver antenna gain	−0.5 dB	0 dB
Demodulator implementation loss	3 dB	3 dB

7.3.2 Protection criteria for systems operating in the space operations service (space-to-Earth) in the frequency band 137-138 MHz

The frequency band 137-138 MHz is allocated to the space operation service (SOS) on a primary basis in the space-to-Earth direction.

Characteristics and protection criteria for SOS systems in the frequency band 137-138 MHz can be found in Recommendation ITU-R SA.363-5 entitled "*Space operation systems*" and in Report ITU-R SA.2426 entitled "*Technical characteristics for telemetry, tracking and command in the space operation service below 1 GHz for non-GSO satellites with short duration missions*". According to recommends 6 of this Recommendation, the aggregate interference criteria for earth station receivers in the SOS for frequencies above 1 GHz is a maximum interference power in each frequency band 1 kHz wide of −184 dBW at the receiver input for more than 1% of the time each day. This value is increased by 20 dB per decreasing frequency decade, hence in our case at 137 MHz, a maximum interference power in each frequency band 1 kHz wide of −164 dBW at the receiver input for more than 1% of the time each day is to be considered. Recommendation ITU-R SA.1743, *recommends* 2.1 and 2.2, indicates that adjacent band interference from AMS(R)S belongs to "category 3", for which an apportionment of 1% of the total allowable degradation should be applied. There are two understandings provided in this report on adjacent-band apportionment of the total allowable degradation.

One understanding assumes uncorrelated interference events distributed over time and, considering that the SOS aggregate criteria in Recommendation ITU-R SA.363-5 is short-term, applies the 1% apportionment to AMS(R)S on a percentage of time basis. This results in the following sharing criteria for AMS(R)S:

> Protection of SOS : in each frequency band 1 kHz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −164 dBW at the SOS receiver input for more than 0.01% of the time each day;

Another understanding assumes constant interference and possible simultaneous arrival from different sources. Therefore the 1% apportionment to AMS(R)S is applied on a power level basis. This results in the following sharing criteria for AMS(R)S:

> Protection of SOS : in each frequency band 1 kHz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −184 dBW at the SOS receiver input for more than 1% of the time each day;

NOTE : subject to the result of pending discussions within ITU-R on Recommendation ITU-R SA.1743, this Report might be revised in the future.

According to Table 2 of Report ITU-R SA.2426, a typical value for the peak antenna gain of SOS earth stations at 137 MHz is 12 dBi (Yagi-Uda or parabolic type antenna, conforming to Recommendation ITU-R F.699-7 antenna pattern). Table 2 also indicates that SOS receiving earth stations polarisation is circular.

7.3.3 Protection criteria for systems operating in the Space research service (space-to-Earth) in the frequency band 137-138 MHz

The frequency band 137-138 MHz is allocated to the space research service (SRS) on a primary basis in the space-to-Earth direction.

Protection criteria for SRS systems in the frequency band 137-138 MHz can be found in Recommendation ITU-R SA.609-2 entitled "*Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites*". According to *recommends* 1.1 of this Recommendation, the protection criteria for earth station receivers in the SRS for frequencies in the 1-20 GHz frequency range is –216 dB(W/Hz). For frequencies below 1 GHz, the permissible interference may be increased at the rate of 20 dB per decreasing frequency decade. In our case around 137 MHz, a protection of –196 dB(W/Hz) is therefore to be considered. According to *recommends* 1.2 of this Recommendation, calculation of interference that may result from atmospheric and precipitation effects should be based on weather statistics for 0.001% of the time for manned missions and for 0.1% of the time for unmanned missions. Similarly, to SOS, Recommendation ITU-R SA.1743 applies and results in an apportionment of 1% of the total allowable degradation to be applied to AMS(R)S. There are two understandings provided in this report on adjacent-band apportionment of the total allowable degradation.

One understanding assumes uncorrelated interference events distributed over time and, considering that the SRS criteria in Recommendation ITU-R SA.609-2 is short-term, applies the 1% apportionment to AMS(R)S on a percentage of time basis. This results in the following sharing criteria for AMS(R)S:

> Protection of SRS: in each frequency band 1 Hz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −196 dBW at the SRS receiver input for more than 10^{-5} % of the time for manned missions and for more than 10^{-3} % of time for unmanned missions;

Another understanding assumes constant interference and possible simultaneous arrival from different sources. Therefore the 1% apportionment to AMS(R)S is applied on a power level basis. This results in the following sharing criteria for AMS(R)S:

> Protection of SRS : in each frequency band 1 Hz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −216 dBW at the SRS receiver input for more than 10^{-3} % of the time for manned missions and for more than 10^{-1} % of time for unmanned missions;

NOTE : subject to the result of pending discussions within ITU-R on Recommendation ITU-R SA.1743, this Report might be revised in the future.

7.3.4 Protection criteria for systems operating in the meteorological satellite service (space-to-Earth) in the frequency band 137-138 MHz

The frequency band 137-138 MHz is allocated to the meteorological satellite service (MetSat) on a primary basis in the space-to-Earth direction.

Aggregate protection criteria for MetSat systems in the frequency band 137-138 MHz are given in Recommendation ITU-R SA.1026-5 ("*Aggregate interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit*"). In addition, MetSat single-entry protection criteria are derived from MetSat aggregate criteria, using Recommendation ITU-R SA.1023-0 methodology for apportionment of aggregate interference criteria between space-to-Earth and Earth-to-space links, as well as multiple sources of interference. These can then be found in Recommendation ITU-R SA.1027-6 entitled "*Sharing criteria for space-to-Earth data transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit*".

Recommends 2 of Recommendation ITU-R SA.1027-6 indicates that the assumptions under which these single entry criteria are derived from Recommendation ITU-R SA.1026-5 should be periodically revisited in order to determine whether the typical interference environment and consequential sharing criteria should be revisited. The ITU expert group for the meteorological-satellite service was therefore consulted in the particular framework of the need for protection criteria in relation to an adjacent-band services, and provided the following values to consider specifically to this context:

Protection criteria for MetSat earth stations to be applied to the unwanted emissions from systems operating in the aeronautical mobile satellite (route) service

Frequency band (MHz)	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than p% of the time
137-138	−151 dBW per 150 kHz	−137 dBW per 150 kHz(1) p = 0.0013

According to Annex 1/Section 2 of Recommendation ITU-R SA.1027-6, MetSat earth stations use either low antenna gains of 2 dBi or higher antenna gains of 10 dBi. For the latter, the ITU expert group for the meteorological-satellite service indicated that the antenna pattern given in RR Appendix **8** could be considered.

7.3.5 Summary of protection criteria considered for MSS, MetSat, SOS and SRS (space-to-Earth) in the frequency band 137-138 MHz

As detailed in sections 7.3.2 and 7.3.3 above, there are two understandings on adjacent-band apportionment of the total allowable degradation to be used for the protection of SOS and SRS operating in the frequency band 137-138 MHz from adjacent band emissions below 137 MHz : One understanding distributes the arrival of the interference over time, whereas another understanding assumes simultaneous arrival of the interference.

Though they correspond to widely different applications, with different requirements in terms of quality of service, it is of interest to make a summary between the protection criteria associated to MSS, MetSat, SOS and SRS.

In order to compare power spectral density levels associated with the long term and short-term protection criteria of these services, these levels are translated into the same bandwidth of 1 kHz, as shown in the table below.

TABLE 11

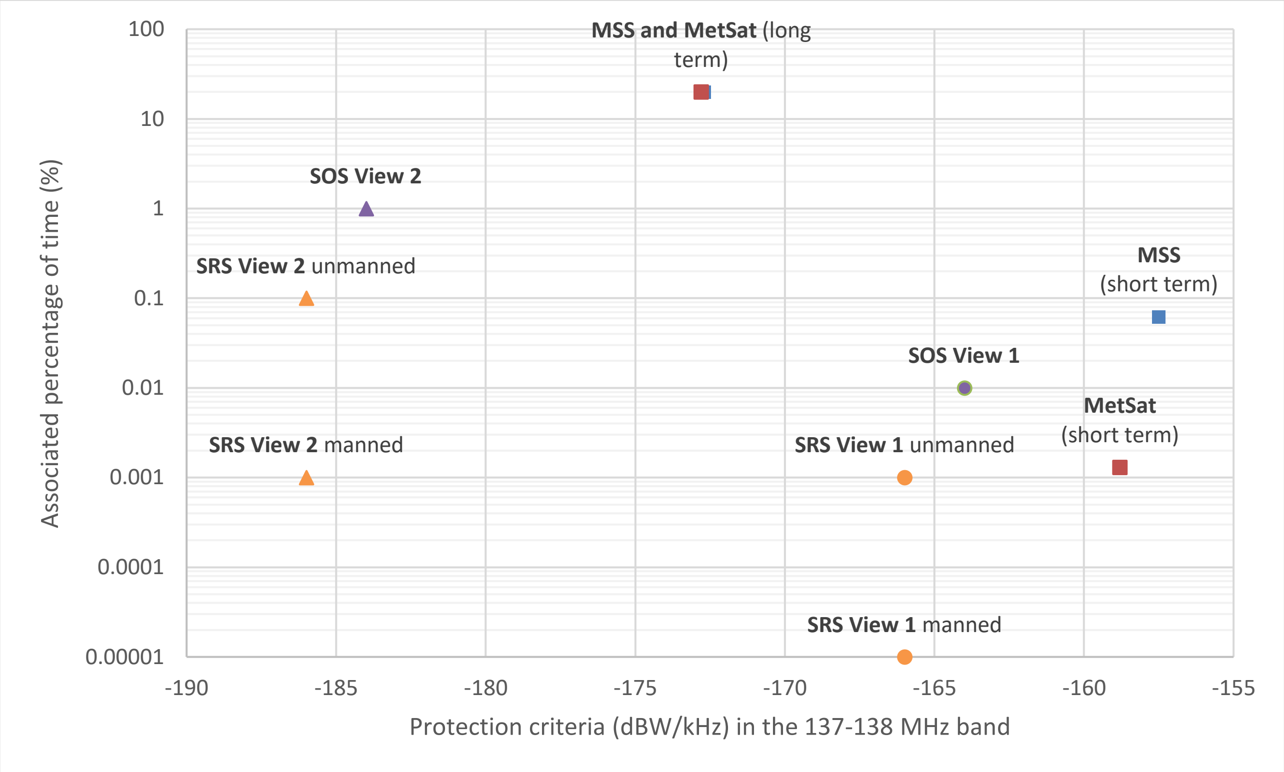
Comparison of the different understandings on apportionment of protection criteria for SRS and SOS

<table>
<tr><th colspan="2"></th><th>MSS</th><th>MetSat</th><th>SOS</th><th>SRS</th></tr>
<tr><td colspan="2">Reference bandwidth for protection criteria (kHz)</td><td>19.2</td><td>150</td><td>1</td><td>0.001</td></tr>
<tr><td rowspan="2">Long-term protection level at receiver input</td><td>in reference bandwidth (dBW)</td><td>−159.9</td><td>−151</td><td>N/A</td><td>N/A</td></tr>
<tr><td>in 1 kHz (dBW)</td><td>−172.7</td><td>−172.8</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="3">Short-term protection level at receiver input</td><td>in reference bandwidth (dBW)</td><td>−144.7</td><td>−137</td><td>−164</td><td>−196</td></tr>
<tr><td>in 1 kHz (dBW)</td><td>−157.5</td><td>−158.8</td><td>View 1: −164
View 2: −184</td><td>View 1: −166
View 2: −186</td></tr>
<tr><td>associated % of time (%)</td><td>0.0625</td><td>0.0013</td><td>View 1: 0.01
View 2: 1</td><td>View 1: 10^{-3};10^{-5}
View 2: 10^{-1};10^{-3}</td></tr>
</table>

These values and associated percentages of time are illustrated in the figure below.

FIGURE 11

Comparison of the different understandings on apportionment of protection criteria for SRS and SOS



8 Sharing and compatibility studies related to emissions of the aeronautical mobile-satellite (route) service in the frequency band 117.975-136 MHz for voice application

ICAO has recommended to take into account the fact that there are existing AM(R)S application(s) that are mainly operated in sub-bands (for example, typical terrestrial VHF voice links within the frequency band 117.975-136 MHz, typical terrestrial VDL Mode 2 within the sub-band 136-137 MHz), by dividing the analysis of the AMS(R)S allocation into two parts:

– Firstly to consider the frequency band 117.975-136 MHz for the new AMS(R)S allocation, noting that the 1 MHz guard band (136-137 MHz) will ease compatibility with non-ICAO services above 137 MHz. This range is considered in this section 8 for AMS(R)S voice application. According to ICAO SARPs, it is possible to also establish data links using DSB-AM modulation, with the same performance requirement as voice, hence identical RF parameters and link budgets. In terms of in-band and adjacent band sharing within 117.975-136 MHz, the conclusions are therefore identical for voice and DSB-AM data applications.

– Secondly, to consider the sub-band 136-137 MHz for the new AMS(R)S allocation, which sharing and compatibility analysis are provided in Chapter 9.

8.1 In-band sharing between systems operating in the aeronautical mobile satellite (route) and aeronautical mobile (route) services

ICAO has outlined that even though AM(R)S and AMS(R)S would represent two different ITU-R services within the frequency band 117.975-137 MHz, the same on-board cockpit avionics system (for VHF communications) would be used for ground and satellite communications. Indeed, AMS(R)S would not correspond to a new aeronautical service but would relay VHF communications operating under the AM(R)S over oceanic and remote areas, without modification to aircraft equipment. AMS(R)S would therefore not trigger new compatibility issue with aircraft system.

ICAO is of the position that if there is any potential interference between AM(R)S and AMS(R)S space stations, it would be resolved by the ICAO through conventional frequency planning exercise, assigning frequencies to the satellite system over interested regions, to ensure compatibility between ground and satellite facilities. Therefore, from an ICAO perspective there is no need to perform a comprehensive compatibility study within ITU-R between these two different services, that cover the same system on-board the aircraft. Both are technically similar services as the same on-board cockpit avionics system (for VHF communications) would be used for ground and satellite communications.

Terrestrial out of band and spurious limits exists to ensure that adjacent and near adjacent channels can coexist when a distant wanted channel is adjacent in the band to an unwanted channel and the unwanted transmitter is substantially nearer to the victim receiver than the wanted transmitter.

AMS(R)S signals will always be subject to a spreading loss in the range of 130-135 dB which exceeds the spreading loss of operation AM(R)S signals by at least 10-15 dB.

Therefore, terrestrial equipment standards intended to minimise the probability of adjacent and near adjacent channel interference are not needed for AMS(R)S equipment installed on a satellite as this form of interference will not occur as a result of an AMS(R)S signal.

The detailed ITU regulatory framework associated with AMS(R)S is outside the scope of this technical report. Article 9 coordination procedures may complement the ICAO framework in order to ensure full compatibility between AM(R)S and AMS(R)S systems.

A coordination process as defined in RR Article **9** could be considered for a new AMS(R)S allocation in all or part of the frequency band 117.975-137 MHz. An example of coordination threshold that could be used for coordination between AMS(R)S transmitting space stations and AM(R)S under RR No. **9.11A** is provided in Table 12:

TABLE 12

Coordination Threshold to protect AM(R)S in all of part of the frequency band 117.975-137 MHz

	Units	**Aircraft**
k = 1.38064852e-23 (J/K)	dBW/K/Hz	−228.60
Standard room temperature, T_0 = 290 K	dB-K	24.62
Rx noise figure, NF,	dB	6
Noise density, $N_0 = kT_0$ + NF	dB(W/Hz)	−197.98
Protection criteria, I/N	dB	−10
Max RFI power density at receiver input	dBW/Hz	−207.98
Max RFI power density at receiver input	dBW/4 kHz	−172
Feeder loss	dB	2
Receiver antenna gain	dBi	−1
dBW to dBW/m^2 (RR IV Rec. ITU-R P.525 section 2.3: 10 log(4π/λ^2))	dB	4.18
Polarization mismatch loss	dB	3
Max AMS(R)S power flux-density at antenna input	dB(W/(m^2 · 4 kHz))	−161.8

An important assumption in the application of the coordination threshold is that it is applied at the antenna input of an AM(R)S receiver onboard an aircraft operating at the edge of a terrestrial service volume, as defined by 250 nmi in range and at 40,000 feet above mean sea level.

[Editor's note : other ways to address the threshold for coordination are under consideration. In particular, characteristics in Table 12 are still under consideration.]

8.2 In-band sharing between systems operating in the aeronautical mobile satellite (route) and aeronautical mobile (off-route) services

As indicated in Section 0, the frequency bands 132-136 MHz and 136-137 MHz are allocated to the Aeronautical mobile (OR) service on a primary basis in 24 and 22 countries respectively, listed in RR Nos. **5.201** and **5.202**.

Currently, compatibility between AM(R)S and AM(OR)S is ensured through a kind of planning mechanism, with administrations taking account of AM(R)S assignments when assigning frequencies to AM(OR)S stations. The introduction of AMS(R)S in the frequency band is not expected to significantly impact this mechanism. Provided AM(OR)S assignments are known, they could be taken into account by ICAO when introducing AMS(R)S in its frequency planning exercise.

Although there are no available characteristics for AM(OR)S systems, they should be close to that of AM(R)S, since AM(OR)S is also intended for aeronautical communications, including those relating to flight coordination, but is operated in a different framework primarily outside national or international civil air routes.

AM(OR)S systems operate in channels within national assignments, which themselves are managed by ICAO, regional organizations and national regulators. Compatibility between AMS(R)S and AM(OR)S assignments should be resolved through their conventional frequency planning exercise. It is anticipated that, in the event that a new allocation is made to AMS(R)S in this frequency band, the corresponding responsible organization will develop a corresponding channel plan for use of AMS(R)S frequencies to ensure compatibility between the satellite and terrestrial uses of the frequency band. By protecting existing terrestrial assignments, this plan should protect any assignments to AM(OR)S.

The detailed ITU regulatory framework associated with AMS(R)S is outside the scope of this technical report. Article 9 coordination procedures may also provide a complementary mechanism to ensure full compatibility between AM(OR)S and AMS(R)S systems.

8.3 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service above 117.975 MHz and systems operating in the aeronautical radionavigation service below 117.975 MHz

Similarly, ICAO has outlined that there is also no need to perform a comprehensive compatibility study within ITU-R between the AMS(R)S and aeronautical radionavigation services. The same frequency planning and coordination works on-going within ICAO will be performed to ensure compatibility between AMS(R)S and aeronautical radionavigation services.

8.4 Adjacent band compatibility with non-ICAO services above 137 MHz

8.4.1 General consideration

It is to be noted that, although the possible primary new AMS(R)S allocation within the frequency band 117.975-137 MHz would be both in the Earth-to-space and space-to-Earth directions, related sharing and adjacent band compatibility studies should be conducted only with respect to AMS(R)S (space-to-Earth). Indeed, transmitting earth stations in the AMS(R)S (Earth-to-space) would correspond to the AM(R)S aircraft station already in place.

8.4.2 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) below 136 MHz and systems operating in the mobile satellite service (space-to-Earth) above 137 MHz

Characteristics and protection criteria for MSS systems in the range 137-138 MHz used in this compatibility study are given in section 0.

Table 13 below is an assessment of the maximum power level per 19.2 kHz above 137 MHz at the MSS receiver input resulting from AMS(R)S emissions in 117.975-136 MHz. It takes into account:

– The reference downlink AMS(R)S link budget in Table 4, with only 1 dB propagation loss on the path towards the MSS earth station (instead of 5 dB towards aircraft).

– The 5 kHz necessary bandwidth considered for voice emission in section 0.

– The minimum attenuation of 60 dB specified in section 0 for the level of spurious emissions above 137 MHz resulting from AMS(R)S satellite in-band emissions below 136 MHz.

– MSS long-term protection criteria from section 0, as it is more stringent than the short-term criteria in the frame of such a static analysis.

TABLE 13

Assessment of the maximum power levels in 19.2 kHz at mobile satellite service subscriber terminal receiver inputs of the spurious emission levels above 137 MHz resulting from systems operating in the aeronautical mobile satellite (route) service below 136 MHz

Long-term protection of MSS subscriber receiver	Frequency	MHz	136	136	136	136	136	136	136	136	136	136
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.8	138.0	135.7	134.0	132.7	131.8	131.2	130.8	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Polarization losses	dB	0	0	0	0	0	0	0	0	0	0
	Receiver											
	MSS Rx Antenna Gain	dBi	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Demodulator implementation loss	dB	3	3	3	3	3	3	3	3	3	3
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Rx signal power level in 19.2 kHz	dBW	-182.4	-179	-176.2	-174.1	-173.3	-173.4	-174.4	-176.7	-179.2	-182.4
	MSS long-term protection requirement	dBW	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9
	Margin	**dB**	**22.5**	**19.1**	**16.3**	**14.2**	**13.4**	**13.5**	**14.5**	**16.8**	**19.3**	**22.5**

The 13.4 dB minimum margin obtained through Table 13 is to be lowered:

– by 3 dB in order to account for two voice carriers being possibly transmitted simultaneously in the 25 kHz channel under consideration, as indicated in section 7.1.4, and received in the 19.2 kHz MSS receiver.

– by an additional 3 dB factor to account for two active satellites possibly visible from the MSS earth station (see section 0).

Even with these additional factors, the margin remains positive. This shows that, based on assumptions considered in studies, protection criteria for MSS above 137 MHz is met from AMS(R)S satellite emissions in 117.975-136 MHz.

8.4.3 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) below 136 MHz and systems operating in the space operations service (space-to-Earth) above 137 MHz

Static study

Characteristics and protection criteria for space operation systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 14 below is an assessment of the maximum power level per 1 kHz above 137 MHz at the SOS receiver input resulting from AMS(R)S single space station with single carrier emissions in 117.975-136 MHz. It takes into account:

– The worst case assumption of the SOS antenna pointing towards the AMS(R)S satellite.

– The reference downlink AMS(R)S link budget in Table 4, with only 1 dB propagation loss on the path towards the SOS earth station (instead of 5 dB towards aircraft).

– The 5 kHz necessary bandwidth considered for voice emission in section 0.

– The attenuation of 60 dB specified in section 0 for the level of spurious emissions above 137 MHz resulting from AMS(R)S satellite in-band emissions below 136 MHz.

TABLE 14

Assessment of the maximum power level per 1 kHz at space operation service receiver input of the spurious emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 117.975-136 MHz

AMS(R)S satellite downlink into SOS earth station receiver	Frequency	MHz	136	136	136	136	136	136	136	136	136	136
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.8	138.0	135.7	134.0	132.7	131.8	131.2	130.8	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Receiver											
	SOS Rx antenna gain	dBi	12	12	12	12	12	12	12	12	12	12

	Rx signal power level per 1 kHz	dBW	-113.8	-110.5	-107.7	-105.6	-104.8	-104.9	-105.9	-108.2	-110.7	-113.9
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Maximum power level per 1 kHz at SOS receiver input	dBW	-173.8	-170.5	-167.7	-165.6	-164.8	-164.9	-165.9	-168.2	-170.7	-173.9
	SOS protection criteria: max. interference power in 1 kHz	dBW	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164
	Margin	**dB**	**9.8**	**6.5**	**3.7**	**1.6**	**0.8**	**0.9**	**1.9**	**4.2**	**6.7**	**9.9**

There are two understandings provided in this report on adjacent-band apportionment of the protection criteria. One understanding assumes uncorrelated interference events distributed over time. Another understanding assumes constant interference and possible simultaneous arrival from different sources. The summaries of the results of the study under each understanding are described hereafter.

The minimum margin obtained through Table 14 is 0.8 dB under the first understanding, when the protection criteria for SOS is assumed to be −164 dBW for more than 0.01% of the time from section 0. This margin is to be lowered by a factor of 3 dB maximum to account for two active satellites possibly visible from the SOS earth station. As the resulting margin would become negative, it is interesting to consider dynamic studies, which results are more accurate as they take into account the antenna pattern of the SOS earth station, and the fact that his earth station tracks its own satellite.

Dynamic studies

Based on information provided by the ITU expert group responsible for the space operation service, the following parameters have been considered for the SOS system:

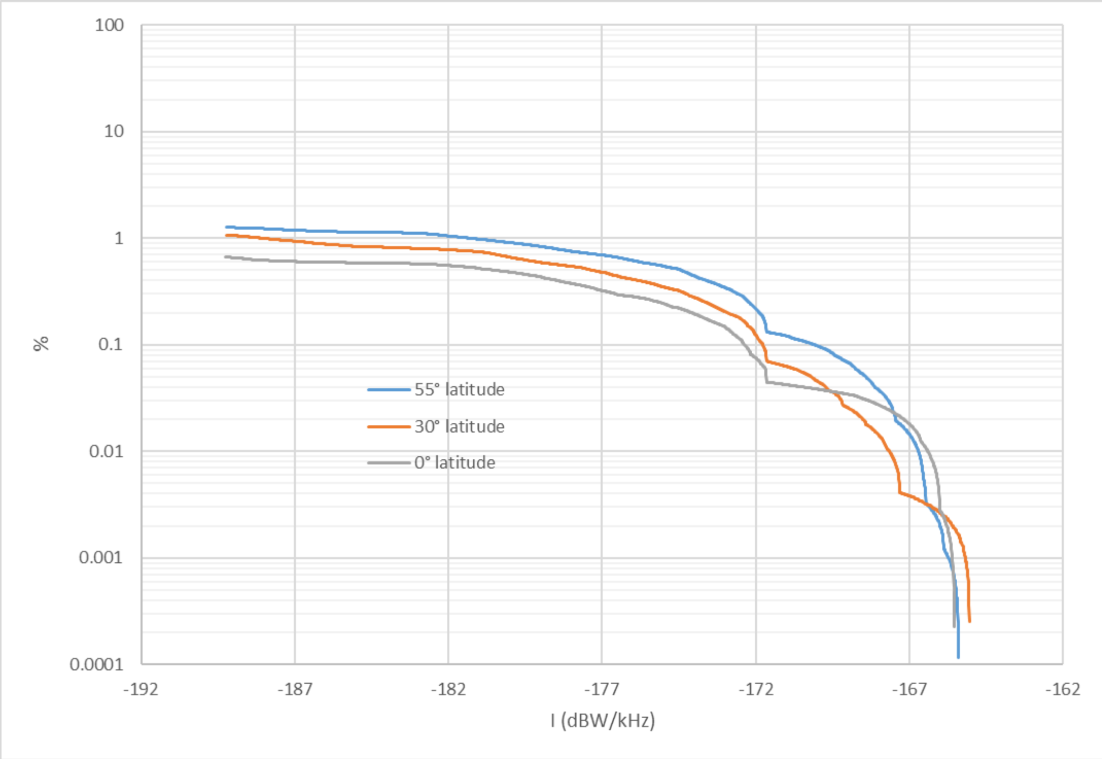
– 1 satellite at 835 km altitude in a sun-synchronous orbit with 98.85° inclination;

– 12 dBi receiving earth station with an antenna pattern compliant with Recommendation ITU-R F.699-8, located at 0°, 30° and 55° latitude. The earth station tracks the satellite with a minimum elevation angle of 5°.

With parameters for the complete AMS(R)S constellation taken from section 6.1, a simulation was run for 365 days with time-steps of 1 second. The power level received at the SOS receiving earth station was assessed, respectively with only one AMS(R)S satellite always active within the 20°-70° operational elevation range, and with possibly two AMS(R)S satellites always active in this range.

FIGURE 12

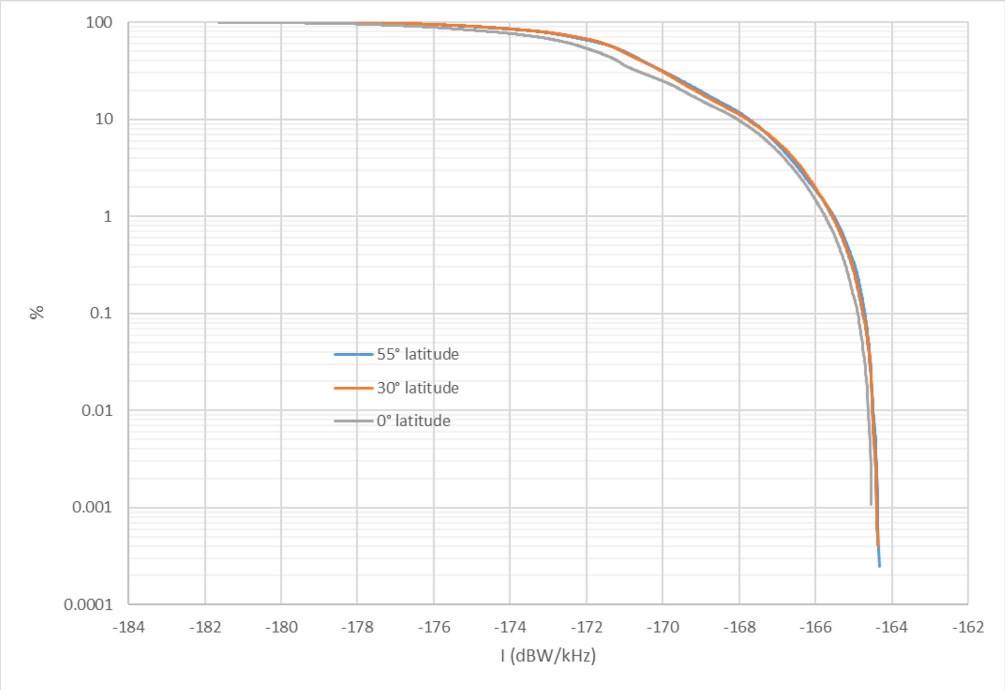
Dynamic study with only one satellite operating in the aeronautical mobile satellite (route) service always active within the 20°-70° operational elevation range. Assessment of the maximum power level per 1 kHz at receiver input operating in the space operations service for the spurious emissions above 137 MHz resulting from emissions of stations operating in the aeronautical mobile satellite (route) service in 117.975-136 MHz



This study with only one active satellite within the 20°-70° operational elevation range provides a maximum of –165.0 dBW/kHz for the spurious emission power level at the receiver input of systems operating in the space operation service. This compares very well with the level of –164.8 dBW/kHz which was determined in the table above on the basis of worst case assumptions.

FIGURE 13

Dynamic study with two AMS(R)S satellites maximum always active within the 20°-70° operational elevation range Assessment of the maximum aggregate power level per 1 kHz at SOS receiver input for the spurious emissions above 137 MHz resulting from AMS(R)S emissions in 117.975-136 MHz



This study with up to two active satellites within the 20°-70° operational elevation range provides a maximum of −164.3 dBW/kHz for the emission power level at SOS receiver input. Hence, even when considering the aggregate effect of two active satellites, the margin remains positive with respect to the protection criteria of −164 dBW/kHz.

This shows that, based on assumptions considered in studies, protection criteria for SOS above 137 MHz is met from AMS(R)S satellite emissions in 117.975-136 MHz.

Another understanding of the protection criteria is also considered as follows. The minimum margin obtained through Table 14 is −19.2 dB under this understanding, when the protection criteria for SOS is assumed to be −184 dBW for more than 1% of the time from section 0. This margin is to be lowered by a factor depending on the maximum number of satellites of the AMS(R)S constellation possibly visible from the SOS earth station.

This shows that, based on assumptions considered in studies, protection criteria for SOS above 137 MHz could not be met from AMS(R)S satellite emissions in 117.975-136 MHz, unless there is a limit, yet to be defined, to the level of AMS(R)S spurious emissions.

It is also possible to define maximum pfd limit at Earth surface as alternative to spurious emission limit. Considering protection criterion "in each frequency band 1 kHz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −184 dBW at the SOS receiver input for more than 1% of the time each day" and possible isotropic SOS antenna maximum interference would be −184 dBW. Based on ITU-R P.525 it is possible to conclude that pfd limit could be calculated as:

$$S = I_{max} + 20log_{10}f + 21.4$$

Which leads to maximum pfd value of −179.93 dB (W/(m^2*·kHz)) at Earth surface for the 1% of time. This limit could be used as maximum aggregate pfd value for all AMS(R)S systems combined. For higher SOS antenna gains this value would be lowered by relevant gain value.

8.4.4 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) below 136 MHz and systems operating in the space research service (space-to-Earth) above 137MHz

Characteristics and protection criteria for space research systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 15 below is an assessment of the maximum power level per Hz above 137 MHz at the SRS receiver input resulting from AMS(R)S single space station with single carrier emissions in 117.975-136 MHz. It takes into account:

– The worst case assumption of the SRS antenna pointing towards the AMS(R)S satellite.

– The value of 3.2 dBi for the peak antenna gain of SRS earth stations at 137 MHz, as recommended by the ITU-R expert group responsible for this service.

– The reference downlink AMS(R)S link budget in Table 4, with only 1 dB propagation loss on the path towards the SRS earth station (instead of 5 dB towards aircraft).

– The 5 kHz necessary bandwidth considered for voice emission in section 0.

– The attenuation of 60 dB specified in section 0 for the level of spurious emissions above 137 MHz resulting from AMS(R)S satellite in-band emissions below 136 MHz.

TABLE 15

Assessment of the maximum power level per Hz at space research service receiver input of the spurious emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 117.975-136 MHz

AMS(R)S satellite downlink into SRS earth station receiver	Frequency	MHz	136	136	136	136	136	136	136	136	136	136
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
	Signal Propagation											
	Free space path loss	dB	144.2	140.8	138.0	135.7	134.0	132.7	131.8	131.2	130.8	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Receiver											
	SRS Rx antenna gain	dBi	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	Rx signal power level per 1 Hz	dBW	-152.6	-149.3	-146.5	-144.4	-143.6	-143.7	-144.7	-147	-149.5	-152.7
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Maximum power level per 1 Hz at SRS receiver input	dBW	-212.6	-209.3	-206.5	-204.4	-203.6	-203.7	-204.7	-207	-209.5	-212.7
	SRS protection criteria: max. interference power in 1 Hz	dBW	-196	-196	-196	-196	-196	-196	-196	-196	-196	-196
	Margin	**dB**	**16.6**	**13.3**	**10.5**	**8.4**	**7.6**	**7.7**	**8.7**	**11.0**	**13.5**	**16.7**

There are two understandings provided in this report on adjacent-band apportionment of the protection criteria. One understanding assumes uncorrelated interference events distributed over time.

Another understanding assumes constant interference and possible simultaneous arrival from different sources. The summaries of the results of the study under each understanding are described hereafter.

The minimum margin obtained through Table 15 is 7.6 dB under the first understanding, when the protection criteria for SRS is assumed to be −196 dBW for more than 10^{-5} % of the time for manned missions and for more than 10^{-3} % of time for unmanned missions from section 0. This margin is to be lowered by a factor of 3 dB to account for two active satellites possibly visible from the SRS earth station (see section 6.1). Even with this additional factor, the margin remains positive.

This shows that, based on assumptions considered in studies, protection criteria for SRS above 137 MHz is met from AMS(R)S satellite emissions in 117.975-136 MHz.

Another understanding of the protection criteria is also considered as follows. The minimum margin obtained through Table 15 is −12.4 dB under this understanding, when the protection criteria for SRS is assumed to be −216 dBW for more than 10^{-3} % of the time for manned missions and for more than 10^{-1} % of time for unmanned missions from section 0. This margin is to be lowered by a factor depending on the maximum number of satellites of the AMS(R)S constellation possibly visible from the SRS earth station.

This shows that, based on assumptions considered in studies, protection criteria for SRS above 137 MHz could not be met from AMS(R)S satellite emissions in 117.975-136 MHz, unless there is a limit, yet to be defined, to the level of AMS(R)S spurious emissions.

It is also possible to define maximum pfd limit at Earth surface as alternative to spurious emission limit. Considering protection criterion "Protection of SRS: in each frequency band 1 Hz wide above 137 MHz, the power level of AMS(R)S unwanted emissions must not exceed −216 dBW at the SRS receiver input for more than 10^{-3} % of the time for manned missions and for more than 10^{-1} % of time for unmanned missions" and possible isotropic SRS antenna, this leads to maximum tolerable interference of −216 dBW. Based on ITU-R P.525 it is possible to conclude that pfd limit could be calculated as:

$$S = I_{max} + 20log_{10}f + 21.4$$

Which leads to maximum pfd value of −211.93 dB (W/(m^2·Hz)) at Earth surface for 10^{-3} % of the time. This limit could be used as maximum aggregate pfd value for all AMS(R)S systems combined. For higher SRS antenna gains this value would be lowered by relevant gain value.

8.4.5 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) below 136 MHz and systems operating in the meteorological satellite service (space-to-Earth) operating above 137 MHz

Static study

Characteristics and protection criteria for meteorological satellite systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 16 below is an assessment of the maximum power level per 150 kHz above 137 MHz at the MetSat receiver input resulting from AMS(R)S single space station with single carrier emissions in 117.975-136 MHz. It takes into account:

– The worst case assumption of the MetSat antenna pointing towards the AMS(R)S satellite.

– The value of 10 dBi for the peak antenna gain of MetSat earth stations at 137 MHz. This represents a worst case from the sharing point of view under this static analysis, the alternative being the lower 2 dBi antenna gain.

– The reference downlink AMS(R)S link budget in Table 4, with only 1 dB propagation loss on the path towards the MetSat earth station (instead of 5 dB towards aircraft).

– The minimum attenuation of 60 dB specified in section 0 for the level of spurious emissions above 137 MHz resulting from AMS(R)S satellite in-band emissions below 136 MHz.

– MetSat long-term protection criteria from section 0, as it is more stringent than the short-term criteria in the frame of such a static analysis.

– The worst case assumption that up to 6 channels of 25 kHz may be contained in the 150 kHz bandwidth of MetSat receiving earth station.

TABLE 16

Assessment of the maximum power level per 150 kHz at MetSat receiver input (with high antenna gain antenna) of the spurious emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 117.975-136 MHz

AMS(R)S satellite downlink into MetSat earth station receiver

Frequency	MHz	136	136	136	136	136	136	136	136	136	136
AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
Transmitter											
RF Power for 25 KHz channel	W	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
Satellite EIRP	dBW	26.3	26.3	26.3	26.1	25.2	23.8	21.9	19.0	16.1	12.8
Signal Propagation											
Free space path loss	dB	144.2	140.8	138.0	135.7	134.0	132.7	131.8	131.2	130.8	130.7
Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
Receiver											
MetSat Rx antenna gain	dBi	10	10	10	10	10	10	10	10	10	10
Rx signal power level per 150 kHz	dBW	-101.1	-97.76	-94.91	-92.87	-92.05	-92.16	-93.13	-95.39	-97.92	-101.1
Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
Maximum power level per 150 kHz at MetSat receiver input	dBW	-161.1	-157.8	-154.9	-152.9	-152	-152.2	-153.1	-155.4	-157.9	-161.1
MetSat protection criteria: max. interference power in 150 kHz	dBW	-151	-151	-151	-151	-151	-151	-151	-151	-151	-151
Margin	**dB**	**10.1**	**6.8**	**3.9**	**1.9**	**1.0**	**1.2**	**2.1**	**4.4**	**6.9**	**10.1**

The 1 dB minimum margin obtained through Table 16 is to be lowered:

– by 3 dB in order to account for two voice carriers being possibly transmitted simultaneously in the 25 kHz channel under consideration, as indicated in section 7.1.2.

– by a factor of 3 dB maximum to account for two active satellites possibly visible from the MetSat earth station.

As the resulting margin would become negative, it is interesting to consider dynamic studies, which results are more accurate as they take into account the antenna pattern of the MetSat earth station, and the fact that his earth station tracks its own satellite. Furthermore, dynamic studies enable the consideration of the percentages of time associated with protection criteria.

Dynamic studies

Based on information provided by the ITU expert group responsible for the meteorological-satellite service, the following parameters corresponding to the METEOR-3M system have been considered for the MetSat system:

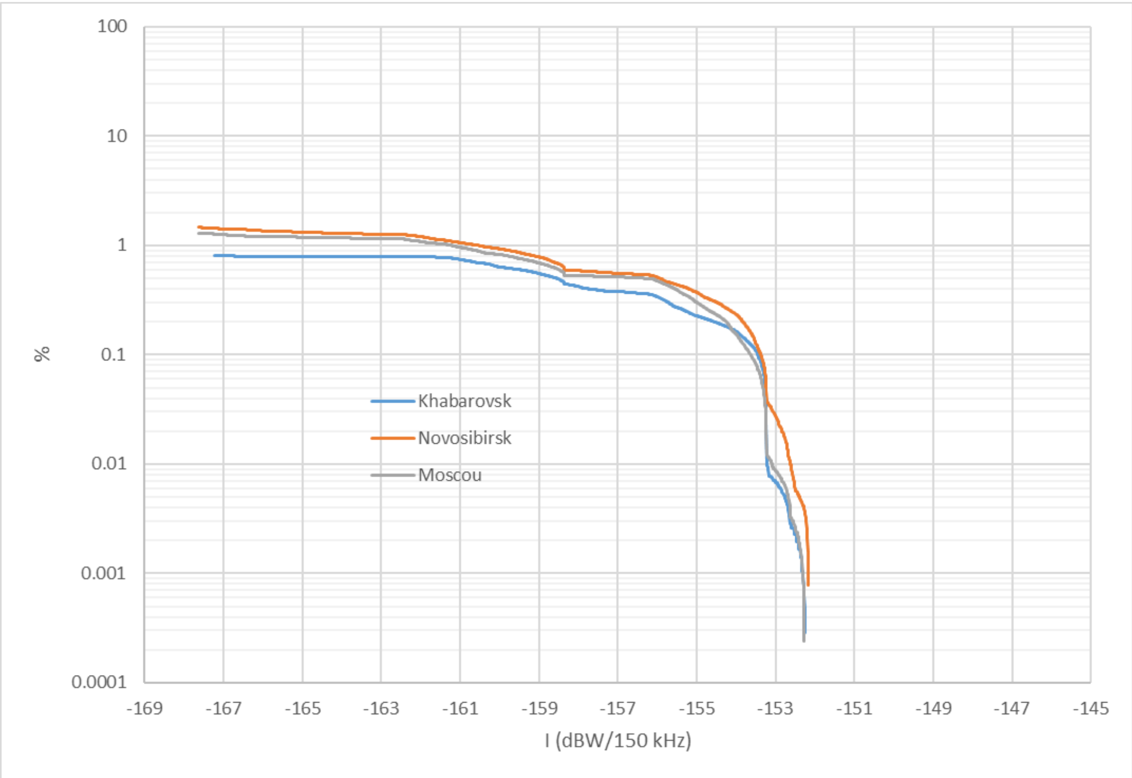
– 2 equidistant satellites at 835 km altitude with 98.85° inclination;

– 10 dBi receiving earth stations with an antenna pattern compliant with Appendix 8, located in Moscow, Novosibirsk and Khabarovsk. Earth stations track satellites with a minimum elevation angle of 25° as mentioned in Recommendation ITU-R SA.1027.

With parameters for the complete AMS(R)S constellation taken from section 0, a simulation was run for 365 days with time-steps of 1 second. The power level received at the MetSat receiving earth stations was assessed, respectively with only one AMS(R)S satellite always active within the 20°-70° operational elevation range, and with possibly two AMS(R)S satellites always active in this range.

FIGURE 14

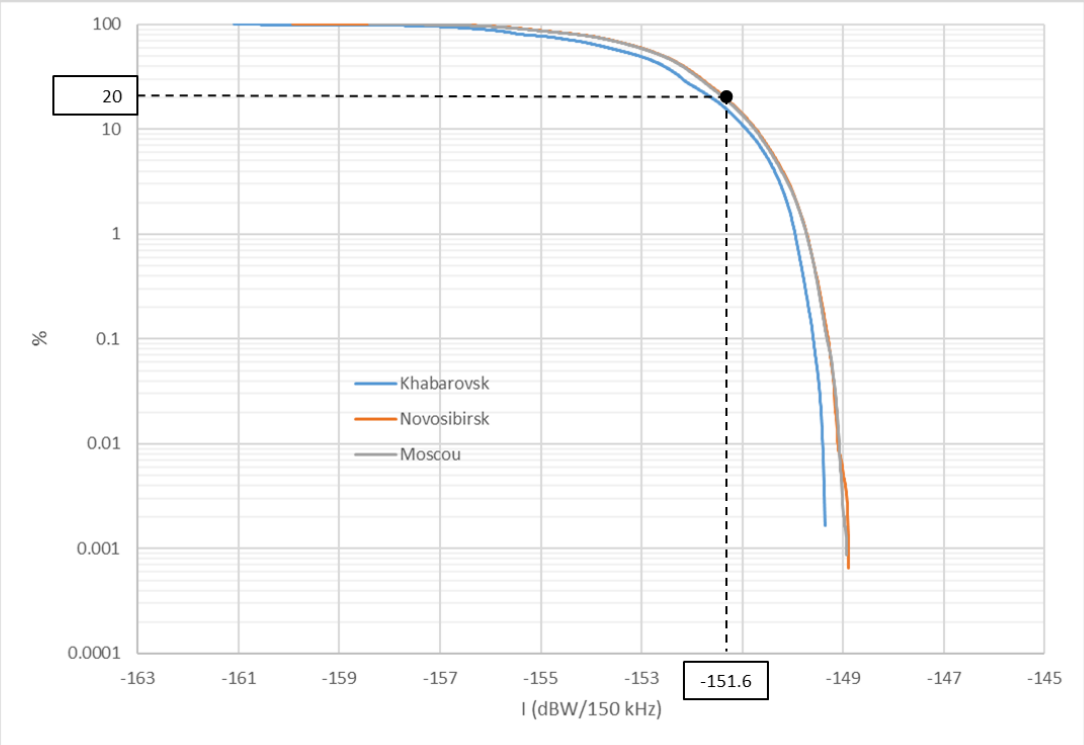
Dynamic study with only one AMS(R)S satellite always active within the 20°-70° operational elevation range Assessment of the maximum power level per 150 kHz at MetSat receiver input for the spurious emissions above 137 MHz resulting from AMS(R)S emissions in 117.975-136 MHz



This study with only one active satellite within the 20°-70° operational elevation range provides a maximum of −152.2 dB(W/150 kHz) for the spurious emission power level at MetSat receiver input. This compares very well with the level of −152 dB(W/150 kHz) which was determined in the table above on the basis of worst case assumptions. Here both the long-term criteria (−151 dB(W/150 kHz), 20% of time possible exceedance) and the short-term criteria (−137 dB(W/150 kHz), 0.0013% of time possible exceedance) are met.

FIGURE 15

Dynamic study with two AMS(R)S satellites maximum always active within the 20°-70° operational elevation range Assessment of the maximum aggregate power level per 150 kHz at MetSat receiver input for the spurious emissions above 137 MHz resulting from AMS(R)S emissions in 117.975-136 MHz



This study with up to two active satellites within the 20°-70° operational elevation range provides the following outcome:

– the maximum emission power level at MetSat receiver input is −148.9 dB(W/150 kHz). This value is to be compared with the short term criteria −137 dB(W/150 kHz).

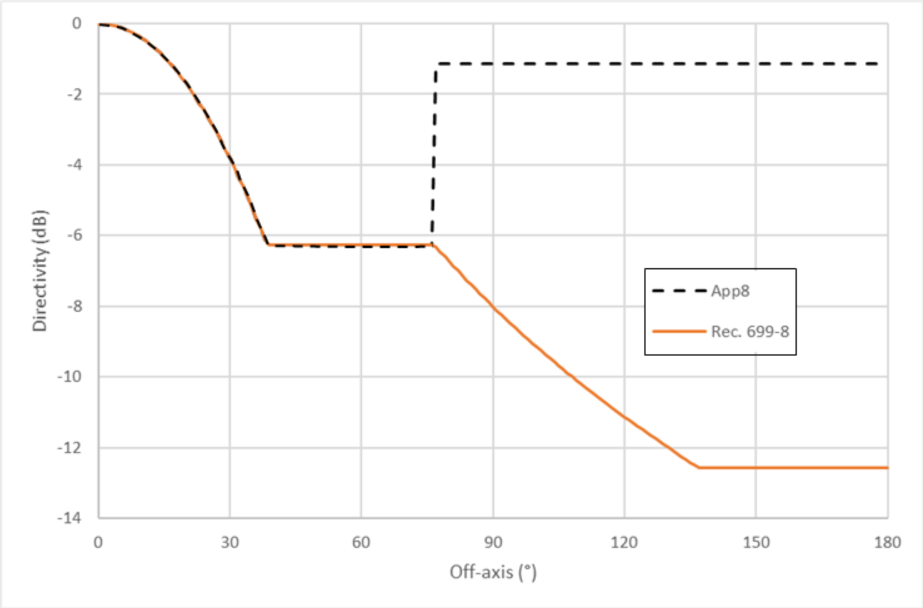
– the maximum emission power level at MetSat receiver input exceeded not more than 20% of time is −151.6 dB(W/150 kHz). This value is to be compared with the long term criteria −151 dB(W/150 kHz).

This shows that the meeting the long term criteria is the driving element. The apparent 0.6 dB margin is to be lowered by 3 dB in order to account for two voice carriers being possibly transmitted simultaneously in the 25 kHz channels under consideration, as indicated in section 0. This results in a negative margin of −2.6 dB.

It is therefore interesting to investigate the RR Appendix **8** antenna pattern associated with the 10 dBi MetSat earth station. Figure 16 below shows that, according to this pattern, the gain for off-axis angles greater than 70° rises at a level close to the maximum gain, which is not physically possible. This obviously has a relatively strong impact on the result of dynamic studies, and it is therefore interesting to reproduce these studies with the consideration of an alternative pattern. The pattern contained in Recommendation ITU-R F.699-8, considered under section 0 for the 12 dBi SOS earth station, provides a more realistic alternative, as shown in the comparison provided in Figure 16.

FIGURE 16

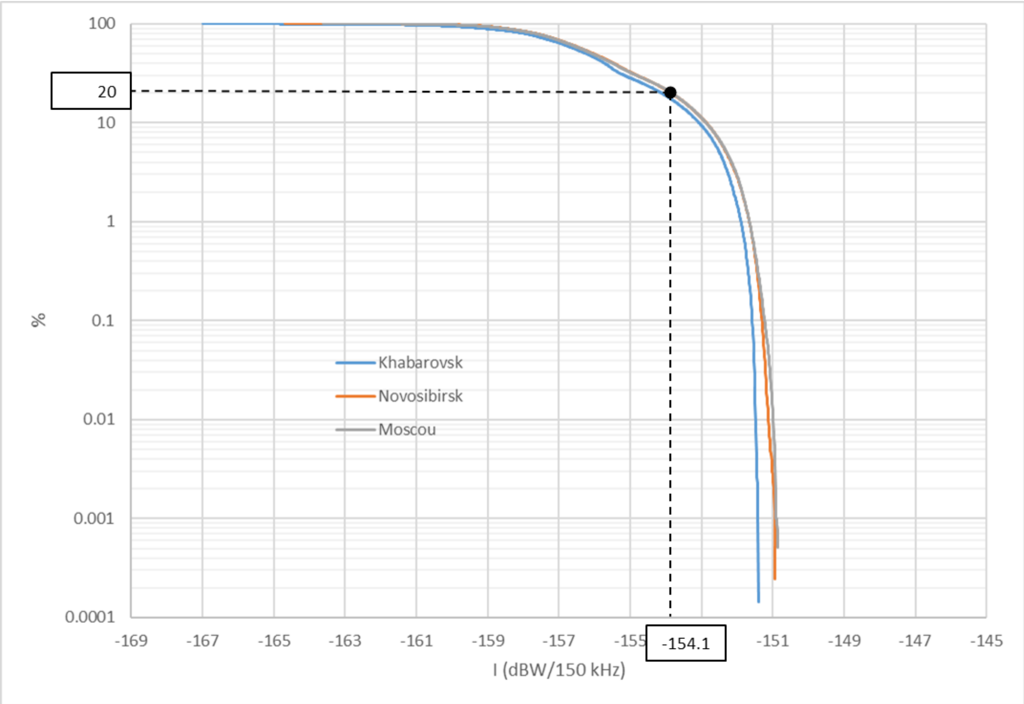
Comparison of the off-axis patterns for the 10 dBi MetSat earth station obtained with RR Appendix 8 and with Recommendation ITU-R F.699-8



With the consideration of the Recommendation ITU-R F.699-8 pattern for the 10 dBi MetSat earth station, dynamic studies with two AMS(R)S satellites maximum always active provide the following results.

FIGURE 17

Dynamic study with two AMS(R)S satellites maximum always active within the 20°-70° operational elevation range, with Recommendation ITU-R F.699-8 pattern for the MetSat earth station Assessment of the maximum aggregate power level per 150 kHz at MetSat receiver input for the spurious emissions above 137 MHz resulting from AMS(R)S emissions in 117.975-136 MHz



With the consideration of this more realistic antenna pattern, the maximum emission power level at MetSat receiver input exceeded not more than 20% of time is now −154.1 dB(W/150 kHz).

This value is to be lowered by 3 dB in order to account for two voice carriers being possibly transmitted simultaneously in the 25 kHz channels under consideration, as indicated in section 0, resulting in the level of −151.1 dB(W/150 kHz), to be compared with the long term criteria -151 dB(W/150 kHz).

The margin of 0.1 dB obtained through dynamic studies with the consideration of a realistic pattern for the 10 dBi earth station shows that, based on assumptions considered in studies, protection criteria for MetSat above 137 MHz is met from AMS(R)S satellite emissions in 117.975-136 MHz. It should be noted that such low margin highly depends on number of active satellites and requires proper emission control to ensure compatibility with MetSat.

Alternative approach study

It is also possible to define maximum pfd limit at Earth surface as alternative to spurious emission limit. Considering protection criteria "−151 dBW per 150 kHz and −137 dBW per 150 kHz" and possible isotropic MetSat antenna maximum interference would be −151 dBW and −137 dBW respectively. Based on ITU-R P.525 it is possible to conclude that pfd limit could be calculated as:

$$S = I_{max} + 20log_{10}f + 21.4$$

Which leads to maximum pfd values of -146.93 dB (W/(m^2·150kHz)) at Earth surface for 20% of the time and −132.93 dB (W/(m^2·150kHz)) at Earth surface for 0.0013% of the time. This limit could be used as maximum aggregate pfd value for all AMS(R)S systems combined. For higher MetSat antenna gains this value would be lowered by relevant gain value.

8.4.6 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) below 136 MHz and systems operating in the radioastronomy service in the frequency band 150.05-153 MHz

MSS (space-to-Earth) systems in the frequency bands 137-137.025 MHz and 137.175-137.825 MHz must comply with the effective power flux density (epfd) limits provided in Resolution **739 (Rev.WRC-19)** to protect the radio astronomy service in certain adjacent and nearby frequency bands.

More specifically, Table 2 of Resolution **739 (Rev.WRC-19)** contains an epfd limit of −238 dB(W/m²) in a reference bandwidth of 2.95 MHz for the protection of radio astronomy in the frequency band 150.05-153 MHz by MSS (space-to-Earth) in 137-138 MHz.

Regarding the Earth-to-space direction (the AMS(R)S allocation would be both in the Earth-to-space and space-to-Earth directions), since transmitting AMS(R)S earth stations correspond to the AM(R)S aircraft station already in place, which are not known to cause any difficulty to radio astronomy observations in 150.05-153 MHz, there is no need for specific limit on AMS(R)S Earth-to-space.

Regarding the AMS(R)S space-to-Earth direction, it is noted that:

– Certain space services in 137-138 MHz allocated in the space-to-Earth direction, which correspond to narrow band emissions, are not subject to the Resolution **739 (Rev.WRC-19)** epfd limit.

– The frequency separation between the possible AMS(R)S allocation within 117.975-137 MHz and the radio astronomy allocation in the frequency band 150.05-153 MHz would be 13.05 MHz or more.

– Studies conducted in the framework of the introduction of the SOS allocation in 137-138 MHz by WRC-19, which are reported in Report ITU-R SA.2427, resulted in the need for a guard band of at least 1.5 MHz for the protection of radio astronomy in 150.05-153 MHz, which was largely existing.

For these reasons, taking into account the fact that AMS(R)S emissions are also narrow band, it does not appear necessary to mandate that the epfd limit in Resolution **739 (Rev.WRC-19)** applies to the space-to-Earth AMS(R)S allocation.

8.5 Summary of sharing and compatibility studies related to applications of the aeronautical mobile (route) service in the frequency band 117.975-136 MHz for voice application

Main conclusion of static and dynamic studies conducted in section 8 on the basis of voice application is that an AMS(R)S system operating in the frequency band 117.975-136 MHz is compatible with primary services in this frequency band and in adjacent frequency bands under certain assumptions. In particular:

– Protection of in-band systems operating under AM(R)S and AM(OR)S, and of adjacent band systems below 117.975 MHz under ARNS would be resolved through conventional frequency planning exercise, involving the relevant aeronautical authorities including ICAO, and assigning frequencies to the satellite system over interested regions in a manner that ensures compatibility between ground and satellite facilities.

– Protection criteria for adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth) and Meteorological satellite service (space-to-Earth) is met with a 1 MHz guard band (136-137 MHz) and RR Appendix **3** limits for AMS(R)S spurious emissions falling above 137 MHz, under the assumptions considered in studies. Different assumptions on AMS(R)S systems may lead to different conclusions.

– Regarding protection of adjacent-band systems operating above 137 MHz in the Space operation service (space-to-Earth) and Space research service (space-to-Earth):

  • When AMS(R)S spurious emissions is considered as uncorrelated interference events distributed over time, protection is also met with a 1 MHz guard band (136-137 MHz) and RR Appendix **3** limits for AMS(R)S spurious emissions falling above 137 MHz, under the assumptions considered in studies relative to the maximum number of co-frequency satellites seen from any point on the Earth.

  • When AMS(R)S spurious emissions is considered as constant interference events possibly existing simultaneously with other sources of interference, protection criteria could not be met, unless there is a limit, yet to be defined, to the level of AMS(R)S spurious emissions.

9 Sharing and compatibility studies related to emissions of the aeronautical mobile-satellite (route) service operating in the frequency band 136-137 MHz for VDL mode 2 application

The sharing and compatibility context is already explained in section 8. However, one significant difference with respect to services to be protected above 137 MHz is that they are now in an immediately adjacent band, therefore the AMS(R)S unwanted emissions in the upper last channel (corresponding to the VDL mode 2 common signalling channel centred in 136.975 MHz) are in the out-of-band domain.

9.1 In-band sharing between systems operating in the aeronautical mobile satellite (route) and aeronautical mobile (route) services

Refer to section 8.1. Considerations developed in this section for AMS(R)S voice application in 117.975-136 MHz are also relevant for AMS(R)S VDL mode 2 application in 136-137 MHz.

9.2 In-band sharing between systems operating in the aeronautical mobile satellite (route) and aeronautical mobile (off-route) services

Refer to section 8.2. Considerations developed in this section for AMS(R)S voice application in 117.975-136 MHz are also relevant for AMS(R)S VDL mode 2 application in 136-137 MHz.

9.3 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service above 117.975 MHz and systems operating in the aeronautical radionavigation service below 117.975 MHz

Refer to section 8.3. Considerations developed in this section for AMS(R)S voice application in 117.975-136 MHz are also relevant for AMS(R)S VDL mode 2 application in 136-137 MHz.

9.4 Adjacent band compatibility with non-ICAO services above 137 MHz

9.4.1 General consideration

Refer to section 8.4.1 General considerations contained in that section for AMS(R)S voice application in 117.975-136 MHz are also relevant for AMS(R)S VDL Mode 2 application in 136-137 MHz.

9.4.2 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in the frequency band 136-137 MHz and systems operating in the mobile satellite service (space-to-Earth) above 137 MHz

Characteristics and protection criteria for MSS systems in the range 137-138 MHz used in this compatibility study are given in section 0.

Table 17 below provides an assessment of the received power at subscriber terminals in the mobile satellite service from unwanted emission levels above 137 MHz from systems operating in the aeronautical mobile satellite (route) service in the frequency band 136-137 MHz, taking into account:

– The AMS(R)S maximum downlink power of 36 W, with only 1 dB propagation loss on the path towards the MSS earth station (instead of 5 dB towards aircraft).

– The 14 kHz necessary bandwidth considered for VDL Mode 2 emission in section 7.2.

– AMS(R)S VDL Mode 2 signal attenuation above 137 MHz (see section 7.2.2) is 60 dB.

– MSS long-term protection criteria from section 0, as it is more stringent than the short-term criteria in the frame of such a static analysis.

TABLE 17

Assessment of the maximum power levels in 19.2 kHz at mobile satellite service subscriber terminal receiver inputs of the unwanted emission levels above 137 MHz resulting from systems operating in the aeronautical mobile satellite (route) service in the frequency band 136-137 MHz

Long-term protection of MSS subscriber receiver	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											

	RF Power for 25 KHz channel	W	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	22.6	22.6	22.6	22.4	21.5	20.1	18.2	15.3	12.4	9.1
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Polarization losses	dB	0	0	0	0	0	0	0	0	0	0
	Receiver											
	MSS Rx Antenna Gain	dBi	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Demodulator implementation loss	dB	3	3	3	3	3	3	3	3	3	3
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Rx signal power level in 19.2 kHz	dBW	-186.2	-182.8	-180	-177.9	-177.1	-177.2	-178.2	-180.5	-183	-186.2
	MSS long-term protection requirement	dBW	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9	-159.9
	Margin	**dB**	**26.3**	**22.9**	**20.1**	**18.0**	**17.2**	**17.3**	**18.3**	**20.6**	**23.1**	**26.3**

The 17.2 dB minimum margin obtained is to be lowered by a factor of 3 dB assuming the maximum simultaneous operation of 2 active AMS(R)S space stations using VDL Mode 2, as visible from the MSS earth station (see section 0).

This shows that, based on assumptions considered in studies, protection criteria fro MSS above 137 MHz is met from AMS(R)S satellite emissions in 136-137 MHz.

9.4.3 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in 136-137 MHz and systems operating in the space operations service (space-to-Earth) above 137 MHz

Characteristics and protection criteria for space operation systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 18 below provides an assessment of the maximum power level per 1 kHz above 137 MHz at the SOS receiver input resulting from AMS(R)S single space station with single carrier emissions in 136-137 MHz, taking into account:

– The worst case assumption of the SOS antenna pointing towards the AMS(R)S satellite.

– The AMS(R)S maximum downlink power of 36 W, with only 1 dB propagation loss on the path towards the SOS earth station (instead of 5 dB towards aircraft).

– The 14 kHz necessary bandwidth considered for VDL Mode 2 emission in section 7.2.

– AMS(R)S VDL Mode 2 signal attenuation above 137 MHz (see section 7.2.2) is 60 dB.

TABLE 18

Assessment of the maximum power level per 1 kHz at space operation service receiver input of the unwanted emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 136-137 MHz

AMS(R)S satellite downlink into SOS earth station receiver	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	22.6	22.6	22.6	22.4	21.5	20.1	18.2	15.3	12.4	9.1
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Receiver											
	SOS Rx antenna gain	dBi	12	12	12	12	12	12	12	12	12	12
	Rx signal power level per 1 kHz	dBW	-122.1	-118.8	-115.9	-113.9	-113.1	-113.2	-114.2	-116.4	-119	-122.1
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Maximum power level per 1 kHz at SOS receiver input	dBW	-182.1	-178.8	-175.9	-173.9	-173.1	-173.2	-174.2	-176.4	-179	-182.1
	SOS protection criteria: max. interference power in 1 kHz	dBW	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164
	Margin	**dB**	**18.1**	**14.8**	**11.9**	**9.9**	**9.1**	**9.2**	**10.2**	**12.4**	**15.0**	**18.1**

There are two understandings provided in this report on adjacent-band apportionment of the protection criteria. One understanding assumes uncorrelated interference events distributed over time. Another understanding assumes constant interference and possible simultaneous arrival from different sources. The summaries of the results of the study under each understanding are described hereafter.

The minimum margin obtained through Table 18 is 9.1 dB under the first understanding, when the protection criteria for SOS is assumed to be −164 dBW for more than 0.01% of the time from section 0. This margin is to be lowered by a factor of 3 dB assuming the maximum simultaneous operation of 2 active AMS(R)S space stations using VDL Mode 2, as visible from the SOS earth station (see section 0).

This shows that, based on assumptions considered in studies, protection criteria for SOS above 137 MHz is met from AMS(R)S satellite emissions in 136-137 MHz.

Another understanding of the protection criteria is also considered as follows. The minimum margin obtained through Table 18 is −10.9 dB under this understanding, when the protection criteria for SOS is assumed to be −184 dBW for more than 1% of the time from section 0. This margin is to be lowered by a factor depending on the maximum number of satellites of the AMS(R)S constellation possibly visible from the SOS earth station.

This shows that, based on assumptions considered in studies, protection criteria for SOS above 137 MHz could not be met from AMS(R)S satellite emissions in 136-137 MHz, unless there is a limit, yet to be defined, to the level of AMS(R)S unwanted emissions.

9.4.4 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in 136-137 MHz and systems operating in the space research service (space-to-Earth) above 137 MHz

Characteristics and protection criteria for space research systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 19 below provides an assessment of the maximum power level per Hz above 137 MHz at the SRS receiver input resulting from AMS(R)S single space station with single carrier emissions in 136-137 MHz, taking into account:

– The worst case assumption of the SRS antenna pointing towards the AMS(R)S satellite.

– The value of 3.2 dBi for the peak antenna gain of SRS earth stations at 137 MHz, as recommended by the ITU-R expert group responsible for this service.

– The AMS(R)S maximum downlink power of 36 W, with only 1 dB propagation loss on the path towards the SRS earth station (instead of 5 dB towards aircraft)

– The 14 kHz necessary bandwidth considered for VDL Mode 2 emission in section 7.2.

– AMS(R)S VDL Mode 2 signal attenuation above 137 MHz (see section 7.2.2) is 60 dB.

TABLE 19

Assessment of the maximum power level per Hz at space research service receiver input of the unwanted emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 136-137 MHz

AMS(R)S satellite downlink into SRS earth station receiver	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	22.6	22.6	22.6	22.4	21.5	20.1	18.2	15.3	12.4	9.1
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Receiver											
	SRS Rx antenna gain	dBi	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	Rx signal power level per 1 Hz	dBW	-160.9	-157.6	-154.7	-152.7	-151.9	-152	-153	-155.2	-157.8	-160.9
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Maximum power level per 1 Hz at SRS receiver input	dBW	-220.9	-217.6	-214.7	-212.7	-211.9	-212	-213	-215.2	-217.8	-220.9
	SRS protection criteria: max. interference power in 1 Hz	dBW	-196	-196	-196	-196	-196	-196	-196	-196	-196	-196
	Margin	**dB**	**24.9**	**21.6**	**18.7**	**16.7**	**15.9**	**16.0**	**17.0**	**19.2**	**21.8**	**24.9**

There are two understandings provided in this report on adjacent-band apportionment of the protection criteria. One understanding assumes uncorrelated interference events distributed over time. Another understanding assumes constant interference and possible simultaneous arrival from different sources. The summaries of the results of the study under each understanding are described hereafter.

The minimum margin obtained through Table 19 is 15.9 dB under the first understanding, when the protection criteria for SRS is assumed to be −196 dBW for more than 10^{-5} % of the time for manned missions and for more than 10^{-3} % of time for unmanned missions from section 0. This margin is to be lowered by a factor of 3 dB assuming the maximum simultaneous operation of 2 active AMS(R)S space stations using VDL Mode 2, as visible from the SRS earth station (see section 0).

This shows that, based on assumptions considered in studies, protection criteria for SRS above 137 MHz is met from AMS(R)S satellite emissions in 136-137 MHz.

Another understanding of the protection criteria is also considered as follows. The minimum margin obtained through Table 19 is −4.1 dB under the second understanding, when the protection criteria for SRS is assumed to be −216 dBW for more than 10^{-3} % of the time for manned missions and for more than 10^{-1} % of time for unmanned missions from section 0. This margin is to be lowered by a factor depending on the maximum number of satellites of the AMS(R)S constellation possibly visible from the SRS earth station.

This shows that, based on assumptions considered in studies, protection criteria for SRS above 137 MHz could not be met from AMS(R)S satellite emissions in 136-137 MHz, unless there is a limit, yet to be defined, to the level of AMS(R)S unwanted emissions.

9.4.5 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in 136-137 MHz and systems operating in the meteorological satellite service (space-to-Earth) operating above 137 MHz

Characteristics and protection criteria for meteorological satellite systems in the frequency band 137-138 MHz used in this compatibility study are given in section 0.

Table 20 below provides an assessment of the maximum power level per 150 kHz above 137 MHz at the MetSat receiver input resulting from AMS(R)S single space station with single carrier emissions in 136-137 MHz, taking into account:

– The worst case assumption of the MetSat antenna pointing towards the AMS(R)S satellite.
– The value of 10 dBi for the peak antenna gain of MetSat earth stations at 137 MHz. This represents a worst case from the sharing point of view under this static analysis, the alternative being the lower 2 dBi antenna gain.
– The AMS(R)S maximum downlink power of 36 W, with only 1 dB propagation loss on the path towards the MetSat earth station (instead of 5 dB towards aircraft).
– AMS(R)S VDL Mode 2 signal attenuation above 137 MHz (see section 7.2.2) is 60 dB.
– MetSat long-term protection criteria from section 0, as it is more stringent than the short-term criteria in the frame of such a static analysis.
– The worst case assumption is for six simultaneous AMS(R)S carriers (one 14 kHz carriers per 25 kHz channel) within the 150 kHz bandwidth of MetSat receiving earth station.

TABLE 20

Assessment of the maximum power level per 150 kHz at MetSat receiver input (with high antenna gain antenna) of the unwanted emissions above 137 MHz resulting from aeronautical mobile satellite (route) service satellite emissions in 136-137 MHz

AMS(R)S satellite downlink into MetSat earth station receiver	Frequency	MHz	137	137	137	137	137	137	137	137	137	137
	AMS(R)S satellite altitude	km	600	600	600	600	600	600	600	600	600	600
	Elevation	(degrees)	0	10	20	30	40	50	60	70	80	90
	Range	km	2831	1932	1392	1075	882.4	760.8	683.2	634.9	608.4	600
	Transmitter											
	RF Power for 25 KHz channel	W	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
	Sat Tx gain	dBi	8	8	8	7.8	6.9	5.5	3.6	0.7	-2.2	-5.5
	Feeder loss	dB	1	1	1	1	1	1	1	1	1	1
	Satellite EIRP	dBW	22.6	22.6	22.6	22.4	21.5	20.1	18.2	15.3	12.4	9.1
	Signal Propagation											
	Free space path loss	dB	144.2	140.9	138.1	135.8	134.1	132.8	131.9	131.2	130.9	130.7
	Additional. propagation loss	dB	1	1	1	1	1	1	1	1	1	1
	Receiver											
	MetSat Rx antenna gain	dBi	10	10	10	10	10	10	10	10	10	10
	Rx signal power level per 150 kHz	dBW	-104.9	-101.6	-98.71	-96.66	-95.84	-95.96	-96.92	-99.19	-101.7	-104.9
	Minimum attenuation above 137 MHz	dB	60	60	60	60	60	60	60	60	60	60
	Maximum power level per 150 kHz at MetSat receiver input	dBW	-164.9	-161.6	-158.7	-156.7	-155.8	-156	-156.9	-159.2	-161.7	-164.9
	MetSat protection criteria: max. interference power in 150 kHz	dBW	-151	-151	-151	-151	-151	-151	-151	-151	-151	-151
	Margin	**dB**	**13.9**	**10.6**	**7.7**	**5.7**	**4.8**	**5.0**	**5.9**	**8.2**	**10.7**	**13.9**

The 4.8 dB minimum margin obtained is to be lowered by a factor of 3 dB assuming the maximum simultaneous operation of 2 active AMS(R)S space stations using VDL Mode 2, as visible from the MetSat earth station (see section 6.1). Hence minimum margin taking all factors into account is 1.8 dB.

This shows that, based on assumptions considered in studies, protection criteria for MetSat above 137 MHz is met from AMS(R)S satellite emissions in 136-137 MHz. It should be noted that this result depends on number of active satellites and requires proper emission control to ensure compatibility with MetSat.

From the AMS(R)S characteristics considered for this analysis (satellite altitude, EIRP density level, 60 dB roll-off factor, 1.8 dB minimum remaining margin at 40° elevation when all factors are considered under worst case assumptions), it can be concluded that, based on assumptions considered in studies, the protection criteria for MetSat is met provided that the power-flux density (pfd) for the unwanted emissions above 137 MHz AMS(R)S systems operating in the frequency band 136-137 MHz does not exceed the following level, derived from the 40° elevation column:

$$\text{Maximum pfd} \quad = 21.5 - 10.\log(4\pi(882400)^2) - 60 + 1.8 \quad \text{dB(W/(m}^2 \text{ . 14 kHz))}$$

$$= -166.6 \quad \text{dB(W/(m}^2 \text{ . 14 kHz))]}$$

9.4.6 Adjacent band compatibility between systems operating in the aeronautical mobile satellite (route) service (space-to-Earth) in 136-137 MHz and systems operating in the radioastronomy service in the frequency band 150.05-153 MHz

Refer to section 0. Considerations developed in this section for AMS(R)S voice application in 117.975-136 MHz are also relevant for AMS(R)S VDL mode 2 application in 136-137 MHz.

9.5 Summary of adjacent band compatibility with non-ICAO services

Main conclusion of static studies conducted in section 9 on the basis of VDL Mode 2 application is that an AMS(R)S system operating in the frequency band 136-137 MHz is compatible with primary services in this frequency band and in adjacent frequency bands under certain assumptions. In particular:

– Protection of in-band systems operating under AM(R)S and AM(OR)S, and of adjacent band systems below 117.975 MHz under ARNS would be resolved through conventional frequency planning exercise, involving the relevant aeronautical authorities including ICAO, and assigning frequencies to the satellite system over interested regions in a manner that ensures compatibility between ground and satellite facilities.

– Protection criteria for adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth) and Meteorological satellite service (space-to-Earth) is met through a roll-off factor for AMS(R)S unwanted emissions, under the assumptions considered. Studies show that a maximum PFD level of −166.6 dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the frequency band 136-137 MHz is required to ensure this result.

– Regarding protection criteria of adjacent-band systems operating above 137 MHz in the Space operation service (space-to-Earth) and Space research service (space-to-Earth):

  • When AMS(R)S unwanted emissions is considered as uncorrelated interference events distributed over time, protection is also met with a maximum PFD level of -166.6 dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the frequency band 136-137 MHz, under the assumptions considered in studies relative to the maximum number of co-frequency satellites seen from any point on the Earth.

  • When AMS(R)S unwanted emissions is considered as constant interference events possibly existing simultaneously with other sources of interference, protection criteria is met with a maximum pfd level of [TBD] dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the frequency band 136-137 MHz.

10 Adjacent band compatibility studies related to the protection of receiving space stations of the aeronautical mobile-satellite (route) service (Earth-to-space) in the frequency band 117.975-137 MHz from unwanted emissions of transmitting space stations operating above 137 MHz

As indicated in Section 3.2, the frequency band 137-138 MHz is allocated on a primary basis to the Mobile satellite service (space-to-Earth), the Space operation service (space-to-Earth), the Space research service (space-to-Earth), and the Meteorological satellite service (space-to-Earth). Pursuant to Resolution **428 (WRC-19)**, it is necessary to ensure that a new AMS(R)S allocation in all or part of the frequency band 117.975-137 MHz will not adversely impact planned usage of systems operating in these adjacent band allocations. This sections therefore provides compatibility studies between receiving AMS(R)S satellites below 137 MHz and transmitting MSS/SOS/SRS/MetSat satellites in the frequency band 137-138 MHz.

10.1 Characteristics of space systems operating above 137 MHz

Compatibility studies between these transmitting MSS/SOS/SRS/MetSat space stations and receiving AMS(R)S space stations are performed on a static basis, by assessing the minimum worst-case C/I that would be experienced at AMS(R)S satellite receivers by spurious emissions from the above-mentioned services operating above 137 MHz.

Characteristics used for MSS/SOS/SRS/MetSat space stations are those recommended by the corresponding ITU-R expert group, in particular Table 2 of Recommendation ITU-R M.1231 for MSS, Table 2 of Report ITU-R SA.2426 for SOS, and Tables 1 and 4 of Report ITU-R SA.2488 for MetSat.

The maximum level of MSS/SOS/SRS/MetSat spurious emissions are derived from the section of Appendix 3 of the Radio Regulations related to space services, noting that this level applies for the spurious domain, i.e. at a separation of 250 % of the necessary bandwidth from the centre frequency. Hence, the attenuation (*43 + 10 log(P) or 60 dBc, whichever is the less stringent, calculated in a 4 kHz reference bandwith*) below the power supplied to the antenna transmission line is used to calculate maximum permitted spurious domain emission power levels, as indicated in Table 1 of Appendix 3. Assuming that MSS/SOS/SRS/MetSat emissions are at the edge of their allocation, the spurious domain corresponds to frequencies below 137- 2.NB (MHz), where NB is the MSS/SOS/SRS/MetSat necessary bandwith expressed in MHz.

The case of MSS/SOS/SRS/MetSat out-of-band emissions requires further studies, on the basis of precise characteristics for satellite systems architectures and emissions.

10.2 Worst-case assumptions for the adjacent-band compatibility study

The C/I at the AMS(R)S satellite receiver is evaluated considering the following worst-case assumptions:

– A minimum received wanted power at the AMS(R)S receiver of −100.5 dBm. This corresponds to the minimum received value (70° elevation) considering 5 dB scintillation (see Table 6 in Section 6.4), and is therefore a worst-case received value.

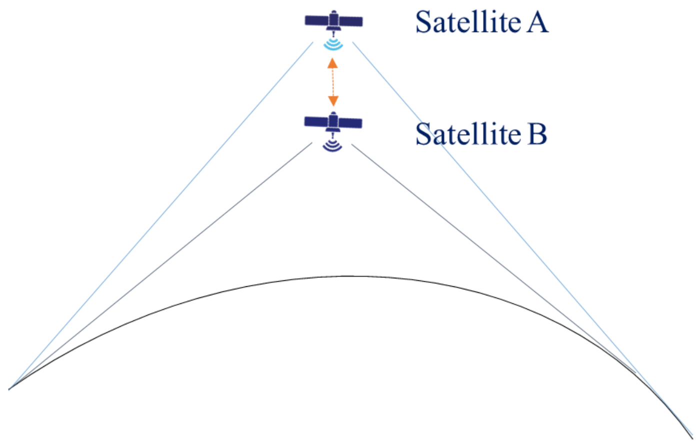
– Maximum MSS/SOS/SRS/MetSat spurious levels as defined per Appendix 3 of the Radio Regulations

– Up to three static scenarios, as described in the following sections.

10.2.1 Scenario 1 : "above / below"

In this scenario, Satellite B is passing at the nadir of Satellite A. In that case, Satellite A is located in the backlobes of Satellite B, and the distance between Satellite A and Satellite B is minimum.

In this scenario, when the AMS(R)S altitude is lower than the interfering satellite altitude, the AMS(R)S backlobes gain is assumed to be 0 dBi .

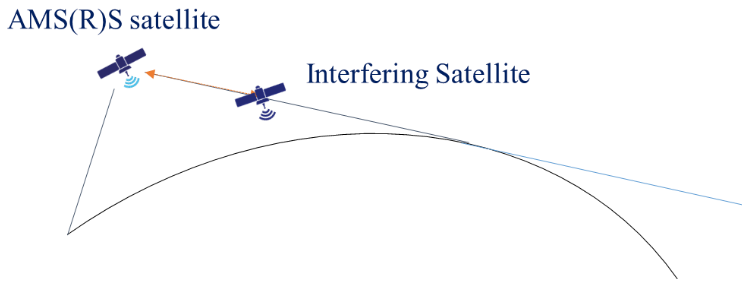


10.2.2 Scenario 2: "at the limit of the coverage of a system operating in the aeronautical mobile satellite (route) service "

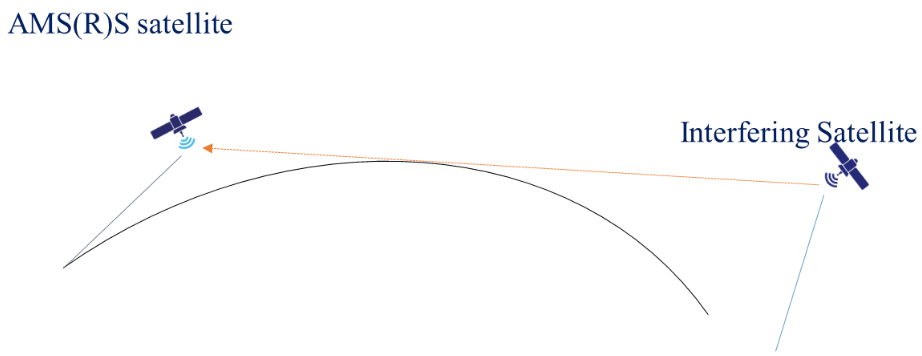
In this scenario, the interfering satellite is assumed to be located at the limit of the AMS(R)S coverage area (i.e. in the direction where the AMS(R)S is seen at 0° elevation as seen from the Earth). This scenario is of particular importance as the AMS(R)S satellite gain towards the horizon is important (8 dBi).

Two cases are considered:

– Case 1: the altitude of the AMS(R)S satellite is greater than the altitude of the interfering satellite. In such a case, the AMS(R)S satellite is located backwards the interfering satellite and is therefore in the backlobes of the interfering satellite antenna.



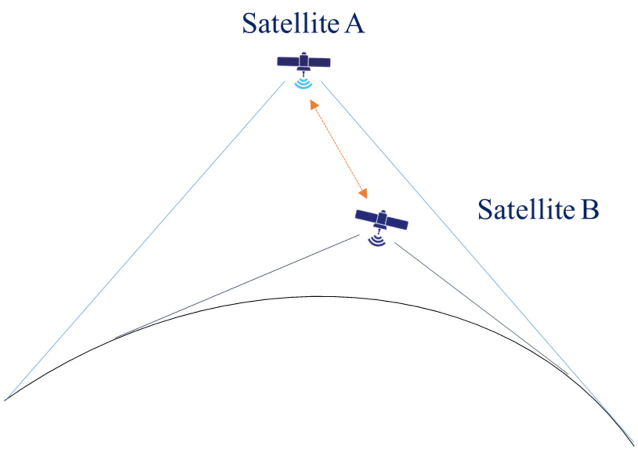
– Case 2: the altitude of the AMS(R)S satellite is lower than the altitude of the interfering satellite. In such a case, the 2 satellites are located opposite from the Earth, and each satellite is located in the sidelobes of the antenna of the other one.



10.2.3 Scenario 3: "in between"

This scenario is considered when the antenna of Satellite A is isoflux. Calculation is made for the particular Satellite A antenna off-nadir angle for which the combination (Free Space Loss – Gain) is minimum.

This particular configuration occurs for example in the case where the altitude of the AMS(R)S satellite is greater than the interfering satellite altitude, for the particular off-nadir angle of 44.4° at the AMS(R)S satellite antenna (40° elevation angle as seen from the Earth). In that case, AMS(R)S antenna gain is 6.9 dBi.



10.3 Assessment of the impact of spurious emissions from systems operating in the mobile satellite service, space operations service, space research service and MetSat satellites on satellite receivers operating in the aeronautical mobile satellite (route) service below 137 MHz

10.3.1 Adjacent band compatibility with satellite systems operating in the mobile satellite service

MSS satellite parameters used in the compatibility study are based on Recommendation ITU-R M.1231 and summarized in Table 21.

TABLE 219

Satellite parameters of systems operating in the mobile satellite service used in the compatibility study

MSS modulation type		DPSK	OQPSK
MSS satellite altitude	km	775	
MSS satellite antenna pattern		Assumed to be omni	
MSS satellite antenna gain	dBi	3.1 (worst-case assumption)	0.8
Transmit output power	dBW	13.1	7.1
Filter/cable line losses	dB	1	1.4
Reference bandwidth – BW	kHz	19.2	44.0
Appendix 3 calculations			
Attenuation requirement (Appendix 3)	dBc	56.1	50.1
MSS maximum spurious level	dBW/4kHz	-43.0	-43.0
	dBW/BW	-36.2	-32.6
	dBW/5kHz	-42.0	-42.0
Spurious attenuation	dB	49.3	39.1

The MSS satellite antenna gain is assumed to be omnidirectional. Hence, and given that MSS satellite altitude is higher than AMS(R)S satellite's one, scenario 1 and scenario 2 (case 2) are considered below.

The worst-case C/I experienced at the AMS(R)S receiver due to MSS spurious emissions is calculated in Table 22.

TABLE 12

Estimation of C/I received at a satellite receiver operating in the aeronautical mobile satellite (route) service due to spurious emissions from systems operating in the mobile satellite service

			Scenario 1	Scenario 2
Free space losses		dB	120.0	150.8
AMS(R)S satellite antenna gain in the direction of the MSS satellite		dBi	0	8
AMS(R)S feeder loss		dB	1	
Minimum C/I	DPSK	dB	30.5	53.3
	OQPSK		33.2	56.0

Calculations show that the minimum worst-case C/I experienced at the AMS(R)S receiver due to MSS spurious emission would be greater than 30 dB, for both MSS modulation types.

Considering the MSS emission bandwidth of 44 kHz (OQPSK modulation), the minimum worst-case C/I would be achieved below the 136.912 MHz spurious boundary (considering a MSS emission at the limit of the 137 MHz MSS allocation).

10.3.2 Adjacent band compatibility with satellite systems operating in the space operations service

SOS satellite parameters used in the compatibility study are based on Table 2 of Report ITU-R SA.2426 and summarized in Table 23.

SOS satellite altitudes are within the range 300 to 1000 km. In the following, calculations are made assuming 300, 500, 750 and 1000 km altitude for the SOS spacecraft.

TABLE 23

Satellite parameters of systems operating in the space operations service used in the compatibility study

SOS satellite altitude	km	300, 500, 750 and 1000 km
SOS satellite antenna pattern		Omni
SOS satellite antenna gain	dBi	3
Transmit output power	dBW	0
Reference bandwidth	kHz	25
Attenuation requirement (Appendix 3)	dBc	43
Appendix 3 calculations		
SOS maximum spurious level	dBW/4kHz	-43.0
	dBW/25kHz	-35.0
	dBW/5kHz	-42.0
Spurious attenuation	dB	35.0

Depending on the SOS satellite altitude, the following interference scenario are considered:

– Scenario 1, 2 (case 1) and 3 in the case of SOS satellite altitude of 300 and 500 km

– Scenario 1 and 2 (case 2) in the case of SOS satellite altitude of 750 and 1000 km.

The worst-case C/I experienced at the AMS(R)S receiver due to SOS spurious emissions is calculated in the Table 24.

TABLE 24

Estimation of C/I received at a satellite receiver operating in the aeronautical mobile satellite (route) service due to spurious emissions from systems operating in the space operations service

	SOS satellite altitude		Scenario 1	Scenario 2	Scenario 3
Free space losses	300 km	dB	124.7	133.8	127.8
	500 km		115.2	123.4	118.2
	750 km		118.7	150.8	
	1000 km		127.2	151.5	
AMS(R)S satellite antenna gain in the direction of the SOS satellite	300 km	dBi	-5.5	8	6.9
	500 km				
	750 km		0	8	
	1000 km				
AMS(R)S feeder loss		dB	1		
Minimum C/I	300 km	dB	39.7	35.3	30.5
	500 km		30.2	24.9	20.8
	750 km		28.2	52.3	
	1000 km		36.7	53.0	

Calculations show that in the cases listed above, the minimum worst-case C/I experienced at the AMS(R)S receiver due to SOS spurious emission is 20.8 dB. This minimum worst-case C/I would be achieved below the 136.95 MHz spurious boundary (considering a SOS emission at the limit of the 137 MHz SOS allocation).

Logically, the C/I value greatly depends on the SOS altitude: the closer the SOS satellite to the 600 km altitude, the lower the C/I at the AMS(R)S receiver. Especially, if the SOS satellite altitude is close to the AMRS(R)S 600 km orbit then the C/I at the AMS(R)S satellite receiver could be lower than the ones shown in Table 24. For such situations, the detailed calculation of C/I would need to be made, knowing precisely the exact orbit parameters of the satellites (inclination, apogee, perigee, mean anomaly, longitude of the right ascending node,…). And in such cases, experienced interference at the AMS(R)S satellite receiver – if any – is expected to be short in time and in probability.

10.3.3 Adjacent band compatibility with satellite systems operating in the space research service

SRS satellite parameters used in the compatibility study are based on information provided by corresponding ITU-R expert group and summarized in Table 25. As indicated in Recommendation ITU-R SA.354, the SRS transmission bandwidth is assumed to be narrowband and the SRS satellite is assumed to be omnidirectional. A SRS satellite antenna gain of 5 dBi is used, which is considered a maximum representative value in this frequency range. A value of SRS spurious emission levels of −43 dBW/4kHz is used in the following calculations. This level is considered as typical satellite maximum spurious emissions for this frequency range.

TABLE 25

Satellite parameters for systems operating in the space research service used in the compatibility study

SRS satellite altitude	km	826 / 846 km
SRS satellite antenna pattern		Omni
SRS satellite antenna gain	dBi	5
SRS maximum spurious level	dBW/5kHz	-42.0

Given that the SRS satellite altitude is higher than AMS(R)S satellite's one, scenario 1 and scenario 2 (case 2) are considered below.

The worst-case C/I experienced at the AMS(R)S receiver due to SRS spurious emissions is calculated in Table 26.

TABLE 26

Estimation of C/I received at a satellite receiver operating in the aeronautical mobile satellite (route) service due to spurious emissions from systems operating in the space research service

		Scenario 1	**Scenario 2**
Free space losses	dB	122.3 / 123.0	151.0 / 151.1
AMS(R)S satellite antenna gain in the direction of the SRS satellite	dBi	0	8
AMS(R)S feeder loss	dB	1	
Minimum C/I	dB	29.8 / 30.5	50.5 / 50.6

Calculations show that based on the assumptions detailed above, the minimum worst-case C/I experienced at the AMS(R)S receiver due to SRS spurious emission would be in the range of 30 dB.

10.3.4 Adjacent band compatibility with MetSat satellite systems

MetSat satellite parameters used in the compatibility study are based on Table 1 and 4 of Report ITU-R SA.2488 and summarized in Table 27.

TABLE 27

MetSat satellite parameters for use for compatibility study

[Additional explanations on "Function" acronyms is required]

Function		**APT**		**TIP**	**LRPT**
Satellite		**A and D**	**B**	**D**	**B**
Minimum centre frequency of the emission	MHz	137.5 (A) 137.1 (D)	137.5	137.35	137.1
MetSat satellite altitude	km	812 (A) 854 and 870 (D)	835	854 and 870	835
MetSat satellite gain at nadir	dBi	3.7	4	5.8	4
MetSat satellite gain at horizon	dBi	-0.25	~2	-6	~2

Transmit output power	dBW	4.9	4	–2.5	5
Reference bandwidth	kHz	38	56.8	46	144
Appendix 3 calculations					
Attenuation requirement	dBc	47.9	47	29.9	48
MetSat maximum spurious level	dBW/4kHz	-43	-43	-43	-43
	dBW/BW	-33.2	-31.5	-32.4	-27.4
	dBW/5kHz	-42	-42	-42	-42
Spurious attenuation	dB	38.1	35.5	29.9	32.4
Frequency under which spurious levels apply	MHz	137.424 (A) 137.024 (D)	137.3864	137.258	136.812

Given that MetSat satellites altitudes are higher than AMS(R)S satellite's one, scenario 1 and scenario 2 (case 2) are considered below.

The worst-case C/I experienced at the AMS(R)S receiver due to MetSat spurious emissions is calculated in Table 28.

TABLE 28

Estimation of C/I received at a satellite receiver operating in the aeronautical mobile satellite (route) service due to MetSat spurious emissions

[Additional explanations on "Function" acronyms is required]

	Function	Satellite	Units	Scenario 1	Scenario 2
Free space losses	APT	A	dB	121.7	151.0
		D		123.3 / 123.8	151.1
		B		122.6	151.0
	TIP	D		123.3 / 123.8	151.1
	LPRT	B		122.6	151.0
AMS(R)S satellite antenna gain in the direction of the MetSat satellite	APT	A	dBi	3.7	-0.25
		D			
		B		4	2
	TIP	D		5.8	-6
	LPRT	B		4	2
AMS(R)S feeder loss			dB	1	
Minimum C/I	APT	A	dB	30.5	55.7
		D		32.1 / 32.6	55.9
		B		31.4	55.8
	TIP	D		30.0 / 30.5	61.6 / 61.7
	LPRT	B		31.1	53.6

Calculations show that the minimum worst-case C/I experienced at the AMS(R)S receiver due to MetSat spurious emission would be of the order of 30 dB.

Considering the MetSat LRPT emission bandwidth of 144 kHz this minimum worst-case C/I would be achieved below the 136.812 MHz spurious boundary.

10.4 Conclusion of adjacent band compatibility studies on the protection of receiving space stations operating in the aeronautical mobile satellite (route) service from the unwanted emissions of systems operating in the mobile satellite service, space operations service, space research service and MetSat space stations operating above 137 MHz

Adjacent band compatibility studies detailed in previous sections show that, when considering MSS/SOS/SRS/MetSat spurious emissions, the expected minimum C/I experienced at AMS(R)S satellite receiver would be of the order of 30 Db under worst case assumptions. It can therefore be considered that AMS(R)S satellite reception is adequately protected from these spurious emissions. On the basis of the ranges considered for the necessary bandwidth of MSS/SOS/SRS/MetSat emissions, these minimum C/I values would be reached below about 136.8 MHz.

This paragraph may need to be revisited. For instance, on the basis of the absence of AMS(R)S protection criteria, conclusion should rather be that impact of systems above 137 MHz on AMS(R)S in negligible.

It can therefore be concluded that :

– The protection of AMS(R)S receiving space stations from the spurious emissions of adjacent-band satellite systems operating above 137 MHz in the Mobile satellite service (space-to-Earth), Space operation service (space-to-Earth), Space research service (space-to-Earth), and Meteorological satellite service (space-to-Earth) is ensured.

– This applies for the spurious domain of MSS/SOS/SRS/MetSat emissions, hence at a certain frequency separation below 137 MHz, depending on the maximum necessary bandwidth of MSS/SOS/SRS/MetSat emissions.

– Protection of AMS(R)S receiving space stations from the out-of-band of adjacent-band satellite systems operating above 137 MHz requires further studies, on the basis of precise characteristics for satellite systems architectures and emissions

11 Dynamic analysis on protection of receiving space stations operating in the aeronautical mobile satellite (route) service below 137 MHz from the unwanted emissions of systems operating in the mobile satellite service, space operations service, space research service and MetSat operating in the frequency band 137-138 MHz

11.1 Introduction

This chapter reports on a study simulating the interference from satellite networks and satellite constellation networks of the MSS, SOS, SRS, MetSat operating in the frequency band 137-138 MHz into the receiving space stations in the AMS(R)S in the frequency band 117.975-137 MHz.

In accordance with Resolution **428 (WRC-19)**, it is necessary to ensure that planned usage of systems operating above 137 MHz will not be adversely affected.

This chapter reports on the compatibility study to evaluate the potential interference received in space receiver of the AMR(R)S below 137 MHz due to emissions from systems operating in the MSS/SRS/MetSat/SOS services above 137 MHz.

11.2 Basis and assumptions for dynamic compatibility studies

AMS(R)S are intended to be provided in the frequency bands ranging from 117.975 MHz to 137 MHz, in particular:

1 Voice and Data Link services (DSB-AM modulation) are used in frequency range 117.975-136 MHz.

2 Data Link services over VDL Mode 2 application (D8PSK modulation) are used in frequency range 136-137 MHz.

The interference is computed for the worst case of interference level received in the first 25kHz below 137 MHz affecting only to the AMS(R)S operating over VDL Mode 2 application (D8PSK modulation).

As indicated in section 3.2, the space services allocated in the frequency band 137-138 MHz on a primary basis are (direction space-to-Earth):

– Meteorological-satellite service (space-to-Earth)
– Mobile-satellite service (space-to-Earth)
– Mobile service in certain countries under RR No. **5.204** and No. **5.205**
– Space operation service (space-to-Earth)
– Space research service (space-to-Earth).

The satellites systems considered in this study are those providing the above services operating in the frequency band 137-138 MHz and their characteristics have been extracted from the ITU Space Network Systems Online Data Base system.

Note should be taken that this scenario studied is a theoretical worst-case, as it assumes that all interfering systems considered would be in operation, which could not be the case as it would be interference between those systems. The assumption in this study is to assume that all those systems would be able to simultaneously operate, irrespective of the interference which would be created between themselves.

11.3 Typical characteristics of space systems operating in the aeronautical mobile satellite (route) service

The characteristics used for AMS(R)S space system in this dynamic study are those from section 6, and additional parameters assumed for conducting the dynamic study are the following:

1 Satellite keplerian orbit:

a) 600 km altitude. Semimajor axis = 6978.137 km

b) Circular orbit. Eccentricity = 0

c) Polar orbit. Inclination = 90 deg

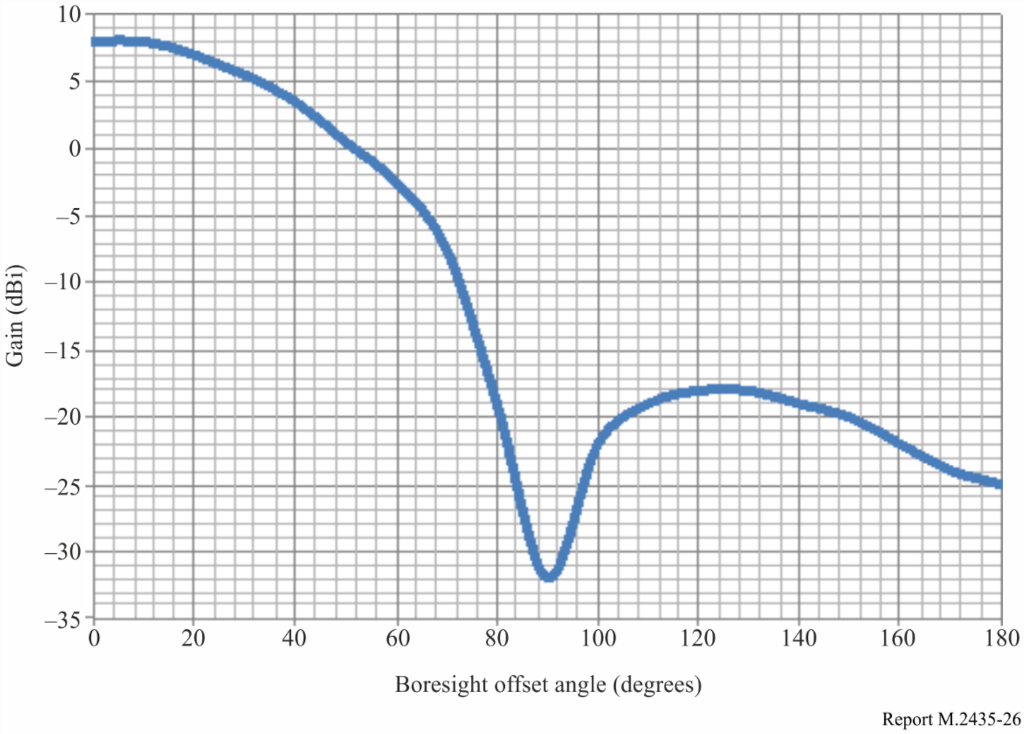
d) Right Ascension of Ascending Node, Argument of pericentre and anomaly randomly selected.

2 VHF antenna radiation diagram follows the profile provided in Table 2.

The above pattern is further extended as per Report ITU-R M.2435-0, Figure 26. The antenna is considered with the boresight at 66º tilt in the direction of satellite movement.

FIGURE 18

Extended aeronautical mobile satellite (route) antenna diagram



3 Space system receiver (as per Table 10):

a) Feeder Loss: 1 dB.

b) Rx sensitivity target: −107 dBm, i.e. −137 dBW.

c) Rx Signal power level: −101.8 dBm (i.e. −131,8 dBW), worst case reference for VDL Mode 2, with 5 dB scintillation losses corresponding to 70º useful elevation angle.

4 Expected noise level at receiver input (RTCA document DO-224D "Signal-In-Space Minimum Aviation System Performance Standards (MASPS) For Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques"):

a) Assuming an equivalent worst case for long range for VHF Digital radio (DO-224D, Table 3-98), the typical value for total system noise power density is −160.4 (dBm/Hz), assuming worst case for channelling receiver with a 25 kHz bandwidth reception, the total system noise power is −116.4 dBm (−146.4 dBW).

11.4 Satellite characteristics of space systems operating in the frequency band 137-138 MHz

1 The list of satellites with their parameters was extracted on 21 September 2022 from the ITU SNS database (Space International Frequency Information Circular Databases Online https://www.itu.int/online/sns/). This list extracts the filings from space networks with frequencies from 137 MHz to 138 MHz. The satellites/constellations identified in the frequency range 137-138 MHz are 4429 satellites.

2 The radiation diagram employed for the simulations is an isotropic antenna, specified as ND-SPACE, with Gain = 0dB, as declared on ITU filings. Some satellites have specific radiation diagrams declared, nevertheless, due to the similarity to an omnidirectional antenna, this has been maintained through all the networks, and maintaining the declared Gain, being the worst-case scenario.

3 All orbital characteristics of these satellite/constellations are extracted from their filings data. The rest of the required orbital elements are randomly assigned on the simulation.

a) Keplerian orbit.

b) Semimajor axis is computed using apogee and perigee provided in Annex 1 in km.

c) Eccentricity is computed using apogee and perigee provided in Annex 1 in km.

d) Inclination is provided in Annex 1 in degrees.

e) Right Ascension of Ascending Node provided in Annex 1 in degrees. If not present in the table for a satellite/constellation, it is randomly assigned on the simulation.

f) Argument of perigee is randomly assigned on the simulation.

g) Anomaly, randomly assigned for the first satellite of an orbital plane. The rest of satellites in the same orbital plane are equally spaced in anomaly. Each row in the tables of Annex 1 define one orbital plane.

4 The out of band spectrum roll-off attenuation assumed is calculated as described on ITU-R SM.1541-6, Annex 5, section 3, for OoB emissions, extrapolating to the range below 1GHz as the worst-case when no other recommendation is specified, according to the formula:

$$Attenuation = 40log_{10}\left(\frac{F}{50}+1\right)dB_{sd}$$

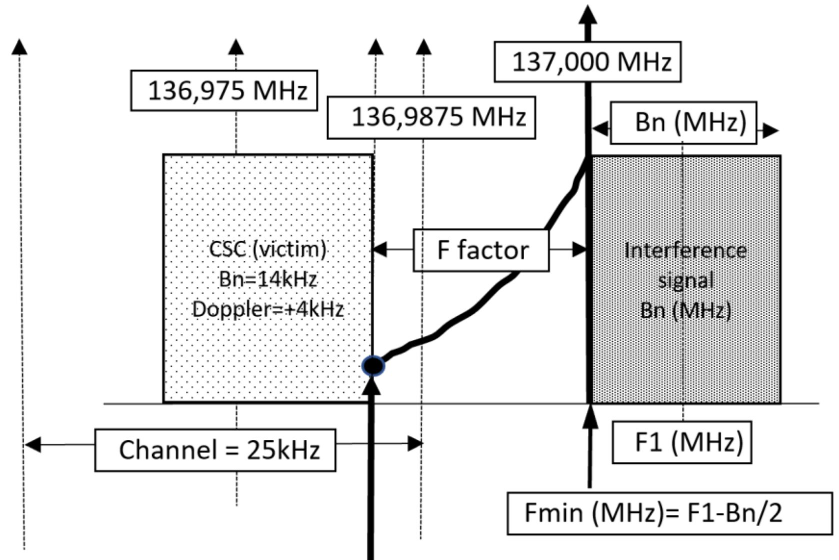
Where F is the frequency offset from the edge of the total assigned band, expressed as a percentage of necessary bandwidth:

$$F = 100 * \frac{136{,}986(MHz) - \text{Fmin(MHz)}}{Bn\ (MHz)}$$

The F frequency offset it is calculated at the higher border of the last assigned frequency channel, that is at 136,975 MHz, adding the Bn/2, where Bn is the VDLM2 necessary bandwidth as described in section 7.2. Additionally, a worst case of 4 kHz frequency shift for a Doppler effect has been taken into account, the final reference to use the F frequency offset and to calculate the Attenuation factor is 136,986 MHz. The following Figure shows this detail.

FIGURE 19

Attenuation and F offset applicability



$$Interference\ Attenuation = 40log_{10}\left(\frac{F}{50}+1\right) dB_{sd}$$

$$F = 100 * \frac{136{,}986\ (MHz) - \text{Fmin(MHz)}}{Bn\ (MHz)}$$

If the frequency offset from the edge (*F*) is higher than 200%, the emission is considered to be within the spurious region, applying an attenuation of 60 dBsd or 43+log10(*P*), whichever is less stringent, and where *P* has been considered as the maximum peak power as per every ITU filing. Reference: Appendix **3**, Table I, Radio Regulations 2020.

The bandwidth used for the calculation, has been obtained from the emission designator. In case there is more than one emission, the worst-case scenario has been selected: highest power spectral density, minimum bandwidth with maximum power.

5 The interference power has been computed with the maximum peak power on each of the filings for the current emission designator.

6 All notified satellite networks are taken into account for the analysis. In addition, all satellite networks that have been launched (at least one satellite) are included in the analysis too, regardless their ITU status (API, coordination or notification). The overall resulting number of satellites is 580, of which 156 have already been launched.

7 Of these 580 satellites, 222 satellites include frequency assignment and associated bandwidth of the emissions that would cause out-of-band emissions below 137 MHz. Similarly, 358 satellites would contribute to interference in the spurious domain. It should be noted that all theoretical frequency assignment of the interfering satellites is considered in the study, despite this scenario would be non-realistic (frequency assignment with minimum frequency starting at 137.000 MHz).

8 For constellations with spacecraft with different TX attenuated power, the selection of which spacecraft transmits with which attenuated power is assigned randomly.

9 The operational channel selected for the calculations, is the closest in frequency to 137 MHz, where the lowest attenuation is calculated, therefore highest OoB emissions will occur. It is assumed that the satellites are operating only on the mentioned channel, which gives the worst-case scenario.

10 On one case it has been considered that the constellation of 150 satellites is uniformly distributed among the 34 channels declared, having 4.4 satellites on each of the channels, distributed randomly. To select a worse case, we have considered that 5 satellites are operating within each band, calculating therefore the attenuation of the OoB signals as well as within the spurious domain. These channels are distributed in the frequency band 137-138 MHz, with 20.8kHz of bandwidth each, operating in the MSS service for IoT purposes. Only 5 satellites are falling within the OoB emissions, with 145 satellites in the spurious domain.

In the IoT literature, following standard ETSI EN300.220, section 7.2.3, the maximum duty cycle for IoT services is limited to 10% of the time. On this study it has been assumed that these satellites are transmitting 10% of the time in bursts.

11 In other case, being a large constellation and as well with IoT purposes and several channels, all these channels are within the spurious domain, therefore they have been grouped for the purpose of these calculations.

12 All satellites are assumed to be transmitting 100% of the time, except for those used for IoT which are assumed to be transmitting 10% of the time due to the nature of their service (see item 10 above).

11.5 Study methodology

The methodology for the analysis is here summarized:

1 The simulation computes different parameters over one day with steps of 10 seconds.

2 Over one day, the received power by all satellites is stored at steps of 10 seconds.

3 At each time step, the position of all satellites involved is computed.

4 For those satellites which are not operational 100% of the time, at each timestep, the satellite is considered to compute the total power received with the probability to be on based on the generation of a random number with a uniform distribution and checking if the result is over or below the percentage of its operational time.

5 Interfering satellites are setup with the orbit defined in assumptions with the orbital parameters provided their filings data. The antenna uses an isotropic radiation diagram with capabilities to radiate in any direction.

6 The power received by all satellites visible at each time step is added as interfering power.

7 For each power level, the number of steps with received power over the required power level is computed and divided by the total number of simulation time steps to get the percentage of time at which the power received by interfering satellites is over the required level.

8 AMS(R)S satellite is setup with the orbit defined in assumptions.

9 The scenarios evaluated are the following:

a) Scenario 1 considers both notified satellites plus operational (not yet notified) satellites (580 satellites).

b) Scenario 2 considers only operational satellites (156 satellites), some operational satellites are not yet notified but have been included in the study. When a constellation is not complete in operation, the number of satellites launched have been allocated in their announced orbit in a random position.

11.6 Outcome of the dynamic study

The number of spacecrafts per service and notification status with detail of spacecraft already launched between brackets is shown in the following table:

TABLE 29

Number of spacecraft per service and notification status

	N	C	A	All
SOS	210	150 (2)	0	360 (2)
SRS	1	0	0	1
MET	5 (3)	0	0	5 (3)
MSS	190 (151)	0	0	190 (151)
Other	24	0	0	24
All	430 (154)	150 (2)	0	580 (156)

Note: Number in brackets are the number of spacecrafts currently in operation.

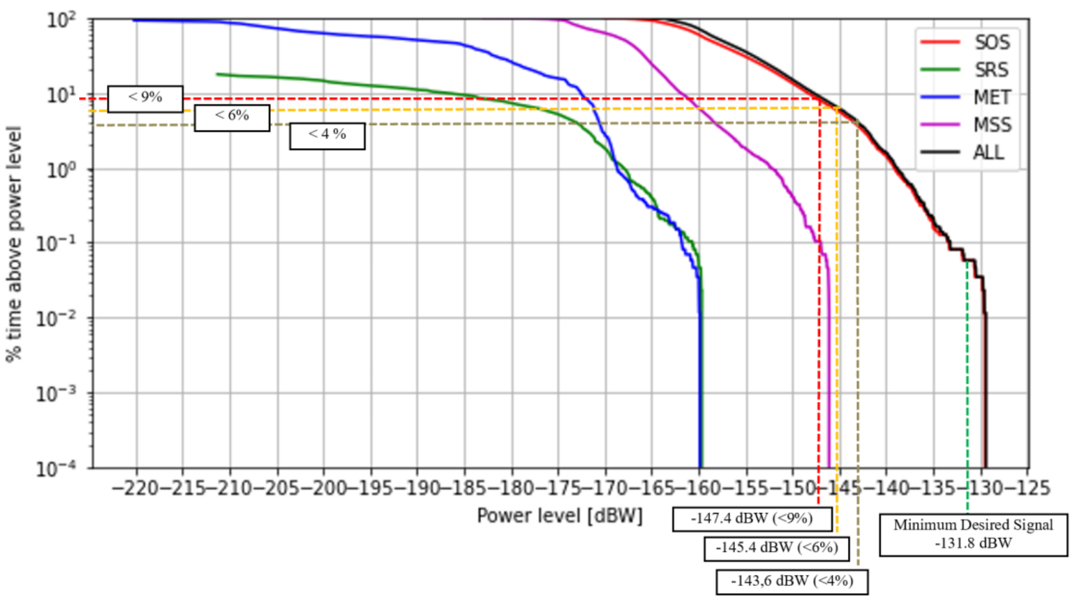
The total number of interfering spacecrafts from all reported spacecraft/constellations is 580 of which 156 are currently in operation.

11.6.1 Scenario 1: Spacecrafts in operational and notified status – power level received

The following Figure 20 shows the probability to receive a power level over a certain level considering all constellation networks in operational of notified status.

FIGURE 20

Probability to receive an interference power level (operational and notified constellation networks)

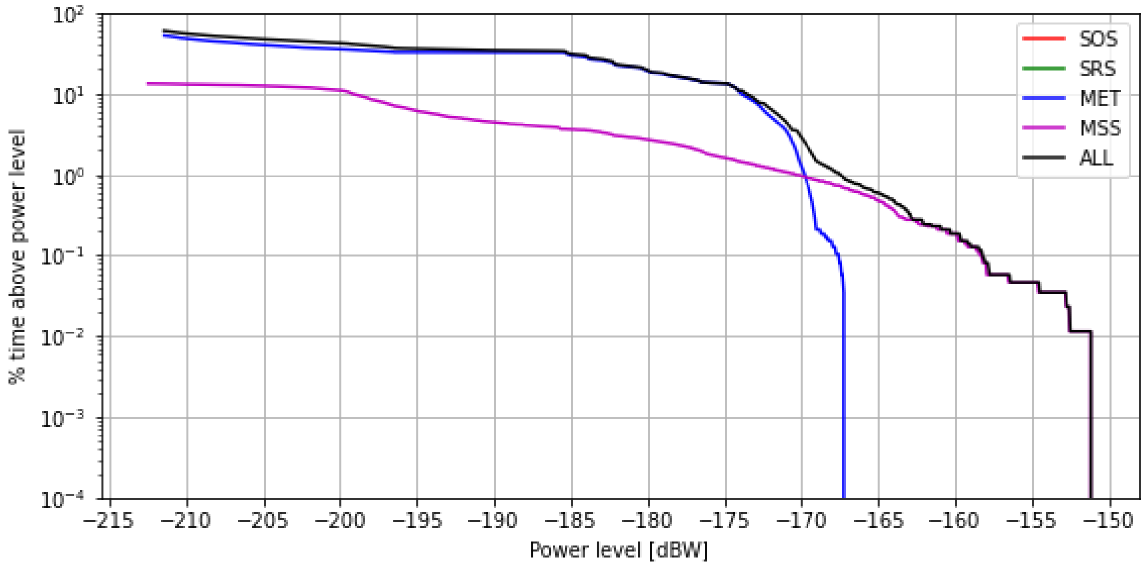


11.6.2 Scenario 2: Spacecrafts in operational status – power level received

The following Figure 21 shows the probability to receive a power level over a certain level considering all spacecraft and constellation networks in operational status.

FIGURE 21

Probability to receive an interference power level (operational constellation networks)



The following table shows the probability to receive a power level above interference threshold for different thresholds.

TABLE 30

Percentage of time with interference level over a threshold

Threshold	Scenario 1: Operational and notified [%] of time over threshold	Scenario 2: Operational [%] of time over threshold
−143.6dBW	< 3%	< 10^{-4}%
−145.4dBW	< 6%	< 10^{-4}%
−147.4 dBW	< 9%	< 10^{-4}%

In order to examine the impact of the above interference probability into a AMS(R)S data link and considering the Document RTCA DO-224D, an uncorrected Bit Error Ratio (BER) of 10^{-3} equivalent to ICAO SARPs corrected BER of 10^{-4} for Mode 2 data operations, could operate with a value of Eb/No = 13 dB assuming 0,8 dB compensation.

Table 31 provides the aggregated interference level (I) that will allow achieving an Es/(No+Io) equal to the desired Es/No (to fulfil the BER reference value). Using this interference (I) values, it is possible to obtain in Figures 22 and 23 the interference level thresholds (power and time). This calculation has been made for minimum, maximum and average desired signal, extracted from Table 10, and for Scenario 1 and Scenario 2.

TABLE 31

Interference Threshold for uplink

Parameter	Source Data	PDNR Received Level Minimum	 Average	 Maximum	Unit
C/I	Computed	14,6	14,4	14,3	dB
C	According to Table 10	-101,8	-100,1	-98,4	dBm
Ts	ITU-R SA.2426-0. Table 3	1000,0	1000,0	1000,0	K
No	10 log (*k*Ts)	-168,6	-168,6	-168,6	dBm
C/No	C-No	66,8	68,5	70,2	dB
BW	Channel Bandwidth	25,0	25,0	25,0	kHz
C/Io	C/I+10log (BW)	58,6	58,4	58,3	dB/Hz
C/(No+Io)	$-10\log\left(10^{-\frac{(\frac{C}{Io})}{10}} + 10^{-\frac{(\frac{C}{No})}{10}}\right)$	58,0	58,0	58,0	dB/Hz
Es/(No+Io) - Computed up to obtain Margin 0.8	$\left(\frac{C}{No+Io}\right) - 10 * \log(10500)$	17,8	17,8	17,8	dB
Eb/No (10^{-3} uncorrected BER)	DO-224D. (3.6.1-Note)	13,0	13,0	13,0	dB
Es/Eb	DO-224D. Table 3-97	4,8	4,8	4,8	dB
Theory Es/No for Spec Block Error Rate (dB)	DO-224D. Table 3-98	17,8	17,8	17,8	dB
Margin= Es/(No+Io)-Es/No.	DO-224D. (3.7.4 - Note)	**0,8**	**0,8**	**0,8**	dB
Interference In 25 kHz Channel	Target Value M=0.8 - I (C-C/I)	**-117,4**	**-115,4**	**-113,6**	dBm
Interference In 25 kHz Channel	Target Value M=0.8 - I (C-C/I)	**-147,4**	**-145,4**	**-143,6**	dBW
% I from 137-138MHz Sat > Threshold - Scenario 1	Figure 22	**9**	**6**	**3**	% time
% I from 137-138MHz Sat > Threshold - Scenario 2	Figure 23	**< 10^{-4}**	**< 10^{-4}**	**< 10^{-4}**	% time

The above figures have been calculated for the 100% of time with the AMS(R)S space system in receiving mode but the real operation is that when the AMS(R)S space system is in transmission mode the AMS(R)S space system is not receiving and therefore, the potential interferences are not affecting. Assuming a 50% ratio transmission/reception the above [%] figures could be reduced to the half.

No further margins are considered regarding improved AMS(R)S receiver antenna design which could be further improved to reduce the lateral beam lobes and reduce the potential undesired interferences.

Among other factors contributing to margins are:

– That the satellites transmitting the maximum declared power and not the coordinated power, but some SOS space stations could be operating under Resolution **660 (WRC-19)** with power flux-density at any point on the Earth's surface limited to -140 dB(W/(m^2 · 4 kHz)).

– Even being the interfered satellite in reception status, it should be considered the probability to receive an interference just in the moment when a desired signal is arriving to the Space System receiver. Being these two processes random and independent phenomena, the interference could be reduced even by a considerable factor in terms of % in time of real interference.

– Another margin and an important operational factor is that the communications protocol used by the VDLM2 data services contains message recovery mechanisms that will reduce drastically the effect of any potential interferences.

Should be taken into account all the improvement factors detailed in the previous paragraphs, it could be extrapolated that an improvement factor of 10 is perfectly feasible and therefore it could be concluded that the interference levels obtained would not exceed 1% of the time when C/I > 14 dB or an aggregate interference level < −146.6 dBW.

These above figures are based on theoretical simulation statistic results which required further interpretation of their practical impact of each interfering ephemeris. The interfering time slots are really very short term which mean that each interfering episode would have not practical impact and would not risk the quality of the uplink in the space system of AMS(R)S.

These results allow concluding that currently operating satellite networks would not cause any harmful interference to an operating AMS(R)S network (Scenario 2). In the hypothetical case that more than 200 satellites were operating in the frequency band137-138 MHz with interfering radiation in the frequency band below 137 MHz (Scenario 1), even though the service availability margin would be limited, they would not cause any risk of harmful interference to the AMS(R) service.

11.7 Conclusions of dynamic analysis on protection of aeronautical mobile satellite reception below 137 MHz from mobile satellite service, space operations service, space research service and MetSat satellite unwanted emissions in the frequency band 137-138 MHz.

This section may need to be revisited and possibly completed with the set of assumptions used, including the arguments for AMS(R)S protection.

This study reports on the results obtained via a simulation of interference from satellite networks and satellite constellation networks of the MSS, SOS, SRS, MetSat operating in the frequency band 137-138 MHz. This study is consistent with technical characteristic defined in this Report and adding data extracted from the ITU SNS database (Space International Frequency Information Circular Databases Online). to allow represent overall interference scenarios. The simulations have been undertaken using the published parameters of the interfering satellite networks including their maximum transmitting power.

The Out of Band transmitting power considered follows the pattern defined by ITU-R SM.1541-6 for OoB emissions. When the interfering transmitting power falls in the spurious domain, Appendix **3**, Table I, Radio Regulations 2020 was taken into account. The interference power radiated below 137 MHz from all satellites has been calculated as an aggregated interference, considering 580 aggregated interfering sources originated by current and future operating satellites of which 156 aggregated interfering sources generated by the current satellites in operation.

The result of the study allows concluding that the interference created by adjacent band satellite services into space receivers of AMS(R)S would not create any relevant degradation of the AMS(R)S because the percentages of time when interference assumable threshold would be exceeded are very short-term, even without taking into consideration any other improvement (factor like dual or multiple operation of several AMS(R)S space receivers providing redundancies). Consequently, the impact on the AMS(R)S due to the time slots when interference thresholds are exceeded, is negligible. Therefore, the operation of AMS(R)S in the 117.975-137 MHz would not require any new constrains on existing VHF systems operating the in the frequency band 137-138 MHz.

12 Summary

In the framework of the consideration of a possible new allocation to the AMS(R)S within the aeronautical frequency band 117.975-137 MHz, this report defines the relevant technical characteristics of a reference satellite system that would relay VHF voice communications operating today under the Aeronautical Mobile (Route) Service (AM(R)S), and complement terrestrial communications infrastructures for the coverage of oceanic and remote areas.

This report also reviews existing primary services in-band and in adjacent bands, and studies compatibility between systems operated under these services and the reference AMS(R)S system.

Main results are as follows:

- Protection of in-band systems operating under AM(R)S and AM(OR)S, and of adjacent band systems below 117.975 MHz under ARNS would be resolved through conventional frequency planning exercise, involving the relevant aeronautical authorities, and assigning frequencies to the satellite system over interested regions in a manner that ensures compatibility between ground and satellite facilities. Depending on the decision of the Conference on the matter, further action may be necessary to address necessary coordination aspects.
- For an AMS(R)S system operating in the frequency band 117.975-136 MHz
  - Protection criteria for adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth) and Meteorological satellite service (space-to-Earth) is met with a 1 MHz guard band (136-137 MHz) and RR Appendix 3 limits for AMS(R)S spurious emissions falling above 137 MHz, under the assumptions considered in studies. Different assumptions on AMS(R)S systems may lead to different conclusions.
  - Regarding protection criteria of adjacent-band systems operating above 137 MHz in the Space operation service (space-to-Earth) and Space research service (space-to-Earth), two possibilities below are considered at this stage:
    - When AMS(R)S spurious emissions is considered as uncorrelated interference events distributed over time, protection is also met with a 1 MHz guard band (136-137 MHz) and RR Appendix 3 limits for AMS(R)S spurious emissions falling above 137 MHz, under the assumptions considered in studies relative to the maximum number of co-frequency satellites seen from any point on the Earth.
    - When AMS(R)S spurious emissions is considered as constant interference events possibly existing simultaneously with other sources of interference, protection criteria could not be met, unless there is a limit, [TBD] dB below the level of Appendix 3, to the level of AMS(R)S spurious emissions.
- For an AMS(R)S system operating in the frequency band 136-137 MHz
  - Protection criteria for adjacent-band systems operating above 137 MHz in the Mobile satellite service (space-to-Earth) and Meteorological satellite service (space-to-Earth) is met through a roll-off factor for AMS(R)S unwanted emissions, under the assumptions considered. Studies show that a maximum PFD level of -166.6 dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the frequency band 136-137 MHz is required to ensure this result. Different assumptions on AMS(R)S systems may lead to different conclusions.
  - Regarding protection criteria of adjacent-band systems operating above 137 MHz in the Space operation service (space-to-Earth) and Space research service (space-to-Earth), two possibilities below are considered at this stage:
    - When AMS(R)S unwanted emissions is considered as uncorrelated interference events distributed over time, protection is also met with a

maximum pfd level of -166.6 dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the band 136-137 MHz, under the assumptions considered in studies relative to the maximum number of co-frequency satellites seen from any point on the Earth.

- ○ When AMS(R)S unwanted emissions is considered as constant interference events possibly existing simultaneously with other sources of interference, protection criteria is met with a maximum pfd level of [TBD] dB(W/(m² . 14 kHz)) for the unwanted emissions above 137 MHz of AMS(R)S systems operating in the frequency band 136-137 MHz.

Additional work may be required on the confirmation of AMS(R)S operational concepts and related assumptions in compatibility studies. In particular on the following points:

– Assumption that the AMS(R)S system would be operationally controlled to ensure that, for any point on the Earth, no more than 2 satellites are visible and operating on the same channel within 20°-70° elevation angle.

– Potential aggregate impact of AMS(R)S system operating in the band 117.975-136 MHz and of AMS(R)S system operating in the band 136-137 MHz.

In addition, considerations could be added on an alternative approach, which would define a maximum pfd value from the aggregated unwanted emissions above 137 MHz of all AMS(R)S systems combined. First analysis under this approach provides the following values for the protection of low gain receiving earth stations in the different services, to be lowered by relevant gain value for higher antenna gains:

– maximum pfd value of -179.93 dB (W/(m2·kHz)) at Earth surface for 1% of time in the case of SOS protection, under the understanding of constant interference.

– maximum pfd value of -211.93 dB (W/(m2·Hz)) at Earth surface for 10-3 % of the time in the case of SRS protection, under the understanding of constant interference.

– maximum pfd values for out of band [and spurious] emissions of −146.93 dB (W/(m^2·150kHz)) at Earth surface for 20% of the time and -132.93 dB (W/(m^2·150kHz)) at Earth surface for 0.0013% of the time in the case of MetSat protection.

{Editor's Note: it as to be noted that under this alternative approach further consideration would be needed in order to take into account the aggregation of all unwanted emission of all service}

– Regarding protection of AMS(R)S space stations receivers operating below 137 MHz from the unwanted emissions of transmitted space stations of satellite systems operating above 137 MHz in the MSS; SOS, SRS and MetSat:

  - A static study conducted on spurious emissions
  - A dynamic study conducted on out-of-band emissions
  - Both studies conclude that the operation of the AMS(R)S would not require any new constraints on services allocated above 137 MHz

[Editor's note: These studies were considered for the first time at the November 2022 meeting of WP5B and deserve further considerations.]

International Civil Aviation Organization

WORKING PAPER

AN-WP/9627
14/03/2023

AIR NAVIGATION COMMISSION

REVIEW OF THE REPORTS OF THE FIFTH AND SIXTH MEETINGS OF THE DATA COMMUNICATIONS INFRASTRUCTURE WORKING GROUP OF THE COMMUNICATIONS PANEL (CP-DCIWG/5 and /6)

(Item No. 22117)

(Presented by the Chairperson of the ANC Working Group of the Whole for Strategic Review and Planning)

SUMMARY

The ANC Working Group of the Whole for Strategic Review and Planning hereby presents its review of the reports of the CP-DCIWG/5 and /6 Meetings.

Action by the Air Navigation Commission is in paragraph 3.

WORK PROGRAMME ELEMENTS

As per CP-DCIWG work programme

COORDINATION

Related Panel Secretaries

REFERENCES

*CP-DCIWG/5 report
*CP-DCIWG/6 report
CP-DCIWG/5 and /6 Presentation to SRP

This working paper relates to the strategic objectives for safety and air navigation capacity and efficiency.

*Principal references

1. INTRODUCTION

1.1 The Air Navigation Commission referred the reports of fifth and sixth meetings of the Data Communications Infrastructure Working Group of the Communications Panel (CP-DCIWG/5 and /6) to its working group of the Whole for Strategic Review and Planning (WG/SRP) for review.

1.2 The WG/SRP reviewed a draft report on 2 February 2023.The SRP meeting was facilitated by a previous review of the CP-DCIWG/5 and /6 Reports by Commission Group 3 (CG-3). The WR/SRP expressed appreciation for the valuable advance review conducted by CG-3.

2. DISCUSSION

2.1 The Secretary of the panel provided an overview of the working structure of specific working group and the outcomes of the fifth and sixth meetings. In terms of working structure, this specific working group continues to have a strong collaboration with industry groups (AEEC, RTCA, EUROCAE) and project meetings are held regularly with these external groups in which detailed work programmes are jointly discussed to ensure alignment of deliverables.

2.2 The main outcomes of the meetings CP-DCIWG/5 and /6 were the proposal for amendment of Annex 10 — *Aeronautical Telecommunications*, Volume III — *Communication Systems* related to SATCOM, Aeronautical Telecommunications Network using the Internet Protocol Suite (ATN/IPS) and L-band Digital Aeronautical Communications System (LDACS). The CP-DCIWG also delivered an update to the *Technical Specifications for ATN using ISO/OSI Standards and Protocols* (Doc 9880). The CP-DCIWG reviewed and updated its work programme and proposed a new job card related to space-based VHF.

2.3 The WG/SRP considered the key questions elevated by CG-3 during its previous review of the report. The WG/SRP noted with interest the discussions related to the coordination with the Trust Framework Study Group (TFSG) and particularly the work on the Certificate Policy.

2.4 The Secretariat provided further explanation on the coordination with TFSG (new Trust Framework Panel (TFP)) and presented a development tracker of Doc 10095. The IPS Security Subgroup of the CP-DCIWG had been working in close coordination with TFSG and will continue with the formation of TFP. A joint working group is expected to be established between the CP-DCIWG and TFP to continue the work. The *Manual of the Public Key Infrastructure (PKI) Policy for Aeronautical Communications* (Doc 10095) will make reference to the Certificate Policy developed by TFP and include the restrictions/refinements to apply it to the ATN/IPS context.

2.5 With respect to the development of the LDACS provisions, the Secretariat provided an update of the status of the coordination after CP-DCIWG/6. Following the concerns expressed by the Surveillance Panel (SP), a joint session between members of SP and members of DCIWG was held on 25 October 2022. The SP insisted on the need of a test campaign to ensure that the Surveillance systems won't be interfered before submitting the proposal for amendment for preliminary review and a joint working group was formed to develop a testing campaign for LDACS compatibility with Surveillance systems.

2.6 The LDACS has also compatibility issues with Distance Measurement equipment (DME). LDAC systems transmit in the same frequency band as DME receivers. Some DME systems have no filters to protect them against interference. To mitigate this, LDAC is designed to work with pulse transmissions on a limited duty cycle and a very strict spectral masks. Validation work was already done within Single European Sky ATM Research (SESAR), China and other States (organizations to ensure LDACS and DME compatibility).

2.7 The WG/SRP reviewed current work programme of the CP-DCIWG and agreed with the changes proposed to the existing Job Cards. The WG/SRP reiterated the concern expressed by CG3 related to the lack of progress of Job Card CP-001 (Global Data Link Implementation Strategy), since this job card was prioritized as high. With respect to the Job Cards related to LDACS (CP-(DCIWG.010) the WG/SRP noted that the applicability date may need to move depending on the outcome of the current work on this subject. A detail status of the current work programme is presented in Appendix A.

2.8 The WG/SRP reviewed the proposed new job card related to space-based VHF. The Secretariat informed that this work will enable improvements for remote/oceanic airspace and is in support of the Council´s adopted ICAO positions for the ITU Work Radiocommunications Conference 2023 agenda Item 1.7. The Secretariat also informed that several letters from regions have been received showing support for this work. The WG/SRP agreed with the approval of this work and also the changes proposed by the POA process and CG3 were agreed. An updated version of the Job Card is presented in appendix B.

2.9 The WG/SRP suggested proceeding with the prioritization exercise of the new job card and presenting the results of the prioritization as part of the SRP report (Appendix C).

2.10 The WG/SRP thanked the Panel Secretary for the informative briefing.

3. ACTION BY THE AIR NAVIGATION COMMISSION

3.1 The Air Navigation Commission is invited to:

a) note the CP-DCIWG/5 and /6 reports and the report of the ANC WG/SRP thereon, as contained in this paper;

b) approve the proposed changes to Job Cards, as presented in Appendix A;

c) approve the proposed new Job Card as presented in Appendix B; and

d) agree with prioritization of the Job Cards as detailed in Appendix C.

CP-DCIWG Existing job cards

CP.001.01	Global Data Link Implementation Strategy
Source	The Second Meeting of the Communications Panel (CP/2)
Problem Statement	The existing aeronautical communications systems cannot support the operational concepts which underpin the global air navigation plan (GANP) and the supporting ASBU concept in the Block 1 and 2 timeframe. States, Regions and industry have proposed divergent solutions; this has and will continue to impact progress towards a harmonized framework that ensures global technical interoperability and seamless operations. A global data link implementation strategy to foster harmonization is needed.
Specific Details	Aeronautical data link today is supported by various technologies which have been implemented in different parts of the world. These technologies have different levels of capability and performance, to meet different needs. The future air traffic management (ATM) system envisioned by the GANP will require high-quality data link communications for all stages of a flight and new technologies will be available to support the necessary performance enhancements. However, experience has shown that the implementation of new technologies can be protracted process due to: a) uncertainty regarding operational benefits and their dependence on a “critical mass” of users; b) divergent approaches taken with data link operations and technology; c) the lack of a clear context showing the mix of technologies that can support various services/applications and under what conditions. d) the difficulties of retrofitting ground and aircraft systems. To provide guidance to stakeholders in making necessary and timely investments in data link technology, a performance-based implementation strategy is proposed that will include the following: a) multi-dimensional coverage including aircraft and ground equipage, services/applications and different operational environments; b) forthcoming technologies and their availability to meet operational needs; c) transitional steps with consideration for interoperability among ground-based, space-based and airborne systems d) a cost-effectiveness analysis (CEA) in support of deployment e) a strategy to support coordinated implementation. f) review and update as needed.
GANP/GASP Link	
Expected Benefits	Certainty in planning for stakeholders, leading to the earliest possible implementation of harmonized data link technology and procedures.
Reference Documents	Doc 9750, Global Air Navigation Plan Yellow Report of the second meeting of the Communications Panel (CP/2)
Primary Expert Group:	Communications Panel (CP)
For Information purposes (to be completed by the Secretariat)	
Proposed Metric	

Interdependencies								
Initial Impact Assessment	Impact on States							
	Impact on Industry							
Secretariat Project Team	Secretariat Project Coordinator							
	Secretariat Project Team Members							
	Regional Office Focal Points							

	WPE No.	Document Affected or Actions Needed	Description of Amendment proposal or Action	Supporting Expert Group	Status	Expected dates:		
						Delivery	Effective	Applicability
✓	9767	Actions	Global Data Link Implementation Strategy (initial version)	RPASP FSMP IMP ATMRPP	On-schedule	Q4 2018	-	Nov 2018
For Information purposes (to be completed by the Secretariat)								
GLOBAL IMPLEMENTATION ACTIONS								

Status:	**Priority:**	**Initial Issue Date:**	**Date Approved by ANC:**	**Session / Meeting:**
Approved	High	11 May 2017	11 May 2017	205-4
RATIONALE				
No change. Under review (ACTION ITEM CP-DCIWG/6-16: DCIWG members to provide comments to the secretary on the proposal for job card CP001.01 by 28 Feb 2023)				

CP-DCIWG.006.04	Provisions on the exchange of information using the aeronautical telecommunication network over the internet protocol suite	
Source	First Meeting of the Communications Panel (however this is derived from Job Card ACP001)	
Problem Statement	Although ATN/IPS technical specifications for the key components have been produced. Implementation guidance, IPS mobility across multiple media, naming and addressing, IPS Security, QOS, system management and overall transitional aspects are required for the provision of a telecommunications network meeting the requirements for ATM communications in the Block 2 and 3 timeframe and beyond.	
Specific Details	An IP-based network for ATM is a key enabler for developments such as SWIM, FF/ICE, TBO and RPASs and many others. However there are complex issues that need to be addressed to ensure network security and mobility across various media. Some of these include stringent performance requirements (especially for A/G); higher availability requirements, accommodation of the ICAO 24-bit aircraft address, a robust network architecture and interfaces, naming conventions unique to aviation which must be globally consistent and unique addressing to provide protection from random intrusions. This will include validation of the provisions developed to support the above.	
GANP/GASP Link	- COMI B1/1 Ground/Ground Communication using the Aeronautical Telecommunication Network/Internet Protocol Suite (ATN/IPS) - COMI-B2/1 Air/Ground Aeronautical Telecommunication Network/Internet Protocol Suite (ATN/IPS) - COMI-B3/4 Links meeting requirements for safety critical communication	
Expected Benefits	A secure high capacity network which will act as an enabler for air-ground datalink and other operational improvements such as, SWIM, FF/ICE, TBO, RPAS, etc.	
Reference Documents	CP/1 Report	
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)	
For Information purposes (to be completed by the Secretariat)		
Proposed Metric		
Interdependencies		
Initial Impact Assessment	Impact on States	
	Impact on Industry	
Secretariat Project Team	Secretariat Project Coordinator	

		Secretariat Project Team Members						
		Regional Office Focal Points						
	WPE No.	**Document Affected or Actions Needed**	**Description of Amendment proposal or Action**	**Supporting Expert Group**	**Status**	**Expected dates:**		
						Delivery	**Effective**	**Applicability**
✓	548	Annex 10 - Vol III	Part I: Amendment with updates on Addressing and Naming conventions and their Management and security		~~Re-scheduled~~Delivered	~~Q2 2022~~ Q4 2022	Jul 2024	Nov 2024
✓	1012 6	Annex 10 - Vol III	Part II: Amendments to bring document up to date with current practices and technology (VOIP)		~~Re-scheduled~~Delivered	Q4 2022 ~~Q2 2022~~	Jul 2024	Nov 2024
✓	1012 7	Annex 10 - Vol II	Amendments to bring document up to date with current practices and technology		~~Re-scheduled~~Delivered	~~Q2 2022~~ Q4 2022	Jul 2024	Nov 2024
✓	453	Manual on ATN using IPS Standards and Protocols (Doc 9896)	Third Update - provide required security, mobility, performance, addressing and naming conventions and provisions on their management		Re-scheduled	Q3 2023	Nov 2024	Nov 2024
			For Information purposes (to be completed by the Secretariat)					
			GLOBAL IMPLEMENTATION ACTIONS					

Status:	**Priority:**	**Initial Issue Date:**	**Date Approved by ANC:**	**Session / Meeting:**
Approved	Medium	17 June 2015	28 October 2021	218-5

RATIONALE

Delivery of SARPs

CP-DCIWG.007.05	SARPS and guidance on Air Navigation (Cyber) Resilience	
Source	First Meeting of the Communications Panel	
Problem Statement	With the increasing reliance on automated systems and networked communications, protection from malicious, intentional and unintentional interference is needed to ensure the safety and integrity of the global ATM system. The Aeronautical Telecommunications Network using the Internet Protocol Suite (ATN/IPS) and the ATN/OSI is expected to carry the majority of telecommunication traffic for the global ATM system including legacy ATN and other applications, while FANS-1/A will continue to be used. Hence there is a need for solutions to protect the ATN/IPS, ATN/OSI, FANS-1/A and other ATS and AOC applications from unlawful interference.	
Specific Details	SARPS and guidance will be needed across a whole range of areas, especially those related to Information Management (IM) and Communications. In addition to this, the automated systems used to support operational improvements such as FF/ICE, CDM, TBO and RPAs will require protection against external intrusion. Protection for Navigation and Surveillance systems will be covered by separate job cards prepared by the Navigation and Surveillance Panels respectively.	
GANP/GASP Link	- COMI B1/1 Ground/Ground Communication using the Aeronautical Telecommunication Network/Internet Protocol Suite (ATN/IPS) - COMI-B2/1- Air/Ground Aeronautical Telecommunication Network/Internet Protocol Suite (ATN/IPS) - COMI-B3/4 Links meeting requirements for safety critical communication	
Expected Benefits	Protection from intrusion for automated systems, including IM and communications technology.	
Reference Documents	CP/1 Report	
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)	
For Information purposes (to be completed by the Secretariat)		
Proposed Metric		
Interdependencies		
Initial Impact Assessment	Impact on States	
	Impact on Industry	
Secretariat Project Team	Secretariat Project Coordinator	
	Secretariat Project Team Members	
	Regional Office Focal Points	

	WPE No.	Document Affected or Actions Needed	Description of Amendment proposal or Action	Supporting Expert Group	Status	Expected dates:		
						Delivery	Effective	Applicability

ü	433	Annex 10 - Vol III	Amendments related to air navigation cyber-resilience	ATMOPSP CP-OPDLWG	~~Re-scheduled~~Delivered	Q4 2022 ~~Q2 2022~~	Jul 2024	Nov 2024
✓	~~432~~	~~Annex 10 - Vol II~~	~~Amendments related to air navigation cyber-resilience~~	~~ATMOPSP CP-OPDLWG~~	~~Re-scheduled~~	~~Q2 2022~~	~~Jul 2024~~	~~Nov 2024~~
✓	1012 8	Manual of Security Services for Aeronautical Communications (Doc 10090)	Manual of Security Services for Aeronautical Communications	AVSECP ~~TFSG~~TFP	Re-scheduled	Q3 2023	Nov 2024	Nov 2024
✓	1012 9	Manual of the Public Key Infrastructure (PKI) Policy for Aeronautical Communications (Doc 10095)	Manual of the Public Key Infrastructure (PKI) Policy for Aeronautical Communications	AVSECP ~~TFSG~~TFP	Re-scheduled	Q3 2023	Nov 2024	Nov 2024
✓	1013 0	Manual of the Aeronautical Telecommunication Network (ATN) Secure Dialogue Service (Doc 10094)	Manual of the Aeronautical Telecommunication Network (ATN) Secure Dialogue Service		Re-scheduled	~~Q3 2023~~ Q3 2025	Nov 2026 ~~Nov 2024~~	Nov2026 ~~Nov 2024~~
✓	1017 2	Manual on ATN using IPS Standards and Protocols (Doc 9896)	Amendments on cyber-resilience of aeronautical communications		Re-scheduled	Q3 2023	Nov 2024	Nov 2024
✓	1017 3	Manual of ~~the~~ Security Risk Assessment for Aeronautical Communications (Doc 10145)	Manual of ~~the~~ Security Risk Assessment for Aeronautical Communications ~~systems,~~ First Edition	AVSECP	Re-scheduled	Q3 2023	Nov 2024	Nov 2024
For Information purposes (to be completed by the Secretariat)								
GLOBAL IMPLEMENTATION ACTIONS								

Status:	**Priority:**	**Initial Issue Date:**	**Date Approved by ANC:**	**Session / Meeting:**
Approved	High	17 June 2015	28 October 2021	218-5
RATIONALE				
SARPS Delivered, (WPE 432 cancelled since eventually no need to amend Annex 10 Vol II)..Extension of dated for Manual 10094				

CP-DCIWG.009.03	Satellite Communication Systems in support of ASBU Blocks 1 and 2	
Source	CP-DCIWG (held during meeting of CP/2)	
Problem Statement	ATM Operations in the ASBU Block 1 and 2 timeframe will require capacity, performance and ease of use, that cannot be met by the satellite systems in use today. Implementation of the new systems must be possible while maintaining continuity with existing legacy ground-based and airborne equipment.	
Specific Details	Update of the ICAO provisions on satellite systems supporting AMS(R)S, including the following tasks • Update of the SATCOM SARPS to include more stringent performance requirements. • Application of PBCS principles and development of means to validate and verify the capability of the new systems. • Update of ICAO Document 9925 - Manual for Aeronautical Mobile Satellite (Route) Service, to provide guidance on the new systems (Inmarsat and Iridium) ~~eg; INMARSAT, SwiftBroadband, Iridium CERTUS)~~ including a Concept of Operations showing their use • Coordination as required on the equivalent activities undertaken by EUROCAE and RTCA. • Development of a transition plan through various candidate systems/services, ~~ie: IRIS Pre-Cursor service, IRIDIUM NEXT system that~~ ensuring~~es~~ seamless operations.	
GANP/GASP Link	- SATCOM CLASS B Voice and Data	
Expected Benefits	Improved satellite communications offering greater ease of use for end-users and support for the operational concepts of ASBU Block 1 and 2. These systems can also be used in the domestic environment (as opposed to remote/oceanic only) which can expand the range of services available and can complement existing terrestrial communications. Similarly the Block 1 and 2 capabilities can also be made available in oceanic/remote airspace.	
Reference Documents	GANP and ASBU documents (current editions) Document 9925 - Manual for Aeronautical Mobile Satellite (Route) Service Annex 10, Volume III – Aeronautical Communications, Part 1, Chapter 4 PBCS Manual – Document 9869	
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)	
For Information purposes (to be completed by the Secretariat)		
Proposed Metric	The number of States, ANSPs, operators, or manufacturers that use the new satellite systems for voice and data communications;	
Interdependencies		
Initial Impact Assessment	Impact on States	- Possible amendment to national regulations, for the use of the new satellite systems - Amendment to the procedures to incorporate the use of SAT voice and data using the new satellite systems
	Impact on Industry	Possible changes to the communication systems, air navigation services providers, communication services providers, satellite services providers to support the new satellite systems
	Secretariat Project	Secretary of the CP-DCIWG

Secretariat Project Team	Coordinator	
	Secretariat Project Team Members	Secretaries of CP-OPDLWG, ATMOPSP, and FSMP
	Regional Office Focal Points	RO/ATM, RO/CNS and/or as assigned by Regional Directors

	WPE No.	**Document Affected or Actions Needed**	**Description of Amendment proposal or Action**	**Supporting Expert Group**	**Status**	**Expected dates:**		
						Delivery	**Effective**	**Applicability**
✓	9762	Annex 10 - Vol III	Update of the SATCOM SARPS to include more stringent performance requirements.		~~Re-scheduled~~Delivered	Q2 2022	Jul 2024	Nov 2024
✓	9763	Manual on AMS(R)S (Doc 9925)	Application of PBCS principles and development of means to validate and verify the capability of the new systems	ATMOPSP CP-OPDLWG	Re-scheduled	~~Q1~~ Q4 2023	Nov 2024	Nov 2024
✓	9765	Manual on AMS(R)S (Doc 9925)	Update to provide guidance on the new systems (Inmarsat ~~NMARSAT Precursor~~ and Iridium ~~Next~~)	ATMOPSP	Re-scheduled	~~Q1~~ Q4 2023	Nov 2024	Nov 2024
✓	9766	Manual on AMS(R)S (Doc 9925)	Development of a transition plan through various candidate systems/services, (Inmarsat and Iridium) ~~ie: IRIS Pre-Cursor service, IRIDIUM NEXT system~~		Re-scheduled	~~Q1~~ Q4 2023	Nov 2024	Nov 2024
For Information purposes (to be completed by the Secretariat)								
GLOBAL IMPLEMENTATION ACTIONS								

Status:	**Priority:**	**Initial Issue Date:**	**Date Approved by ANC:**	**Session / Meeting:**
Approved	Medium	11 May 2017	28 October 2021	218-5
RATIONALE				
SARPS Delivered. Extension of dates to complete Guidance Material				

CP-DCIWG.010.02	Future L-Band Terrestrial Data Link System	
Source	CP-DCIWG	
Problem Statement	ATM operations emanating from the ~~implementaiton~~implementation of ASBU Blocks 2 and 3 will require capacity and performance that cannot be met by the terrestrial data link systems in use today. H~~h~~ence new data link systems are required. The development of new ATM operational procedures and ~~increasig~~increasing demands for operational and business continuity require greater robustness, resilience and secrity in communications systems. ITU Policy to ~~ahcieve~~achieve spectrum ~~efficency~~efficiency dictates that future ~~aeronatical~~aeronautical communication ~~sustems~~systems are more spectreally efficent than today's communications systems.	
Specific Details	Selection and standardisation of the future terrestrial data link system will consider the following items: - Identiifcation of compatibility requirements, interference mitigation nad subsequent frequency assignment planning for the use of the (protected) aeronautical L-Band spectrum. - Integation with the overall aeronautical communications architecture. - Development of SARPS and guidance (subject to input and support from Regional programmes, industry timelines, revised operational requirements and the development of new applications). - Development of a deployment concept and a migration strategy maintaining continuity with existing legacy ground-based and airborne equipment for data link and voice communications. - Aplication of PBCS principles and the determination of capability. - Additional capabilities such as alternative positionaing, navigation and timing (APNT) supporting a reversionary capability for RNP applications in cases of GNSS unavailability.	
GANP/GASP Link	- L-Band Digital Aeronautical Communication System (LDACS)	
Expected Benefits	Improved capacity, performance and spectrum efficiency to enable ATM operations in the Block 2 timeframe and beyond.	
Reference Documents		
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)	
For Information purposes (to be completed by the Secretariat)		
Proposed Metric		
Interdependencies		
Initial Impact Assessment	Impact on States	
	Impact on Industry	
	Secretariat Project	

Secretariat Project Team	Coordinator	
	Secretariat Project Team Members	
	Regional Office Focal Points	

	WPE No.	**Document Affected or Actions Needed**	**Description of Amendment proposal or Action**	**Supporting Expert Group**	**Status**	**Expected dates:**		
						Delivery	**Effective**	**Applicability**
✓	~~9774~~	~~New ICAO Document (Doc ####)~~	~~Interface Document – defining performance boundaries of technology~~		~~Re-scheduled~~	~~Q4 2019~~	~~Nov 2021~~	~~Nov 2021~~
✓	9775	Annex 10 - Vol V	Identification of requirements for frequency assignment and interference mitigation	FSMP,NSP, SP	Re~~On~~-schedule	~~Q4 2020~~ Q4 2023	July 2026 ~~Jul 2022~~	Nov 2026~~Nov 2022~~
✓	9772	Annex 10 - Vol III	Development of proposed amendment for future L-Band terrestrial data link system	NSP, SP	~~Re-scheduled~~Delivered	Q4 2022 ~~Q4 2024~~	Jul 2024 ~~Jul 2026~~	Nov 2024 ~~Nov 2026~~
✓	9771	PBCS Manual (Doc 9869)	Application of PBCS principles and the determination of capability	CP-OPDLWG	~~On~~Re-schedule	Q3 2025 ~~Q4 2024~~	~~Nov 2026~~	Nov 2026
✓	9773	New ICAO Document (LDACS Manual Doc 10172~~####~~)	Development of Guidance Material (initial material to focus on spectrum issues, with subsequent updates leading to publication in 2026)		~~On~~Re -schedule	Q4 2024	~~Nov 2026~~	~~Nov 2026~~ Nov 2024
For Information purposes (to be completed by the Secretariat)								
GLOBAL IMPLEMENTATION ACTIONS								

Status:	**Priority:**	**Initial Issue Date:**	**Date Approved by ANC:**	**Session / Meeting:**
Approved	Medium	11 May 2017	13 June 2019	211-12

RATIONALE

SARPS Delivered (pending coordination with SP). Update of work related to the guidance material

CP-DCIWG Proposed new job card
(track changes)

Title	~~Development and standardization of emerging aeronautical~~ Aeronautical Satellite communication technologies and systems operating in VHF frequency band	Reference	[CP-DCIWG.011.01] ~~[Panel.xxx.yy]~~
Source	DCIWG/05		
Problem Statement	The limitations of line of sight communications have placed constraints on the use of the VHF frequency spectrum and more specifically VHF voice/datalink. A number of States along with industry are currently investigating the potential for applying space-based VHF in oceanic or remote areas. In this context, there are no technical studies nor provisions for the space-based VHF to support the ICAO position to ITU-R WRC-23, Agenda Item 1.7. ~~The limitations of line of sight communications have placed constraints on the use of the VHF frequency spectrum and more specifically VHF voice/datalink~~. ~~These have had a direct impact on both efficiency and safety.~~ ~~On efficiency:~~ ~~Until now satellite and/or HF communications have served as appropriate media to support aeronautical communications in oceanic and remote airspace. A consequence of this has been that en-route aircraft separations in this airspace are much greater than in the domestic en-route environment. This limits both the capacity and (schedule) flexibility of routes in this airspace. These are both key KPAs in Doc 9883, Manual on Global Performance of the Air Navigation System. Furthermore, an introduction of emerging VHF communication technologies, including space-based VHF, can complement recent implementation of space-based ATS surveillance capability to further enhance capacity and safely reduced aircraft separation in the area without conventional terrestrial VHF infrastructure, thus supporting smoother transition between remote/oceanic and continental/domestic airspaces.~~ ~~On Safety:~~ ~~VHF communication systems are installed in all types of aircrafts. However, due to line of sight constraints, conventional terrestrial VHF communication systems cannot be used in many airspace areas. Using space-based VHF will open the potential for the use of the VHF communication system to maintain safety without relying on other technologies or new aircraft equipment.~~ ~~• Aeronautical spectrum faces increasing competition and demands for co-existence from other non-aviation sectors, notably mobile telecommunications (e.g. 5G). Hence technologies should be sought out which offer more efficient use of spectrum, while allowing aviation to maintain or improve upon existing services.~~		

	~~• To gain industry support and regional/global adoption, the implementation of new air-ground communications technologies must involve minimal or no change to existing avionics equipment and configurations, including cabling, power, antennae, etc.~~ ~~Emerging VHF technologies are being designed considering the above limitations and the need to ensure interoperability with existing CNS infrastructure.~~
Specific Details	Spectrum availability is governed on a world-wide basis by the ITU Radio Regulations, as amended every four years by ITU World Radiocommunication Conferences (WRC). One WRC Agenda Item currently being studied in preparation for the upcoming WRC (WRC-23, November 2023) is the provision of aeronautical VHF services by low-earth-orbit satellite (also known as space-based VHF). In support of ICAO position to WRC-23, technical studies for space-based VHF should be completed and validated. This includes the necessary studies on interference analysis and spectrum compatibility. Depending on the outcome of the technical studies' validation and WRC-23 resolution, in support of space-based VHF, detailed provisions, including the Doppler shift and scintillation effects, will be required in Annex 10, Volumes III and V. ~~Existing aeronautical air-ground communications have the potential to benefit from recent and emerging advances in satellite and general communications technologies, as industry and research institutions have begun to study ways to improve and enhance air-ground communications.~~ ~~Adoption of new air-ground communications technologies are however, limited by two key operational and technical constraints, namely: spectrum availability and aircraft equipage.~~ ~~To deal with the first of these, ICAO provisions to support aeronautical communication technologies operating in VHF frequency band must be in line with ICAO Positions for ITU World Radiocommunication Conference (WRC). The first such technology being considered is space-based VHF, which is an agenda item being considered by the WRC-2023. This work will therefore be conducted in close coordination with the Frequency Spectrum Management Panel (FSMP).~~ ~~In support of WRC2023, by Q4 2022, technical studies and concept of operations for space based VHF should be completed in coordination with ICAO FSMP. This include the necessary studies on interference analysis and spectrum compatibility and overall concept of operations.~~ ~~The decision by airspace users to equip with a new technology will depend on there being minimum impact on avionics. Hence Proposals for Amendment (PfA) and Change Proposals (CPs) to ICAO provisions, such as Annex 10, to support recent and emerging communication technologies in the aeronautical VHF frequency band, will be developed with this objective.~~

	~~Any necessary ICAO guidance and implementation support material will also be developed to support the implementation of the adopted VHF technologies.~~ ~~.~~
GANP/GASP Link	~~Change Requests (CRs) to GANP will be submitted to formulate or modify existing threads for VHF technologies that includes enhancement of existing VHF technology. This may include use of VHF technology with Satellite communication technology to relay VHF communication over satellite (space-based aeronautical VHF)~~
Expected Benefits	The implementation of new air-ground communications technologies will involve minimal or no change to existing avionics equipment and configurations, including cabling, power, antennae, etc, and this be a good gain for the industry and the regions for global adoption and implementation. VHF communications, using the existing VHF radios and other avionics aboard the aircraft can be leveraged in the remote/oceanic airspace, especially when in synergy with satellite-based ADS-B, this will make a seamless transition between space-based VHF and conventional VHF possible ~~Expected benefits of these new VHF aeronautical communication technologies include improvements in communication capability and performance in oceanic and remote airspace.~~ ~~These technologies~~T~~t~~he Space-based VHF may ~~also~~ increase communication performance and available bandwidth (or channel capacity) required for aircraft, airlines and ATM operations. The~~se~~ ~~future~~ space-based VHF ~~technologies~~ will ~~be designed to~~ complement existing ~~terrestrial~~ conventional VHF ~~voice/datalink services~~ and ~~should~~ will be fully interoperable with existing VHF infrastructures and avionics.
References	Annex 10 — Aeronautical Telecommunications, Volume III — Communication Systems Annex 10 — Aeronautical Telecommunications, Volume V — Aeronautical Radio Frequency Spectrum Utilization DOC 9776 - Manual on VHF Digital Link (VDL) Mode 2 State letter E3/5-21/37 - ICAO position for ITU WRC-23~~ITU-R Working Party 5B Input Documents on WRC-23 Agenda Item 1.7~~
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)
For Information purposes (to be completed by the Secretariat)	
Proposed Metric Note: there could be three sources: 1- Initial 2- Panel ideas	The number of States, ~~ANSPs, operators, or manufacturers~~ that use the ~~new~~ space-based aeronautical VHF for Air Ground communications;

Secretariat IAA section		
Interdependencies	Results of ITU-R Working Party 5B Studies on WRC-23 Agenda Item 1.7	
Initial Impact Assessment Note: This is only an initial impact assessment on resources (financial, personnel, etc.). Detailed Impact Assessment is done when SARPs are developed.	**Impact on States**	Possible amendment to national regulations, and/or directives to allow the use of the new aeronautical VHF communication technologies
	Impact to Industry	The design of new VHF technologies must be fully compatible with existing aircraft VHF avionics and current installations. Possible changes to the communication systems software for ~~,~~ air navigation services providers, communication services providers, satellite services providers to support the new aeronautical VHF services Minor changes to the operations manual/procedures for ANSPs and aircraft operators to support the new aeronautical VHF communication system
Project Team	**Secretariat Project Lead**	Secretary of the CP-DCIWG
	Secretariat Project Team Members	Secretaries of CP-OPDLWG, ATMOPSP, FLTOPSP and FSMP
	Regional Office Focal Points	~~RO/ATM, RO/CNS~~ A~~a~~s assigned by Regional Directors

WPE No.	Document Affected or Actions Needed	Description of Amendment proposal or Action	Supporting Expert Group	Status	Expected dates: Delivery	Effective	Applicability
	Technical Study	Validate the technical studies developed by States for the space-based VHF	FSMP		Q3 2023		
	Annex 10 - Vol III	Depending on the outcome of the Feasibility/technical studies and Agenda item 1.7 of WRC-23 Review and, as necessary, update SARPs to support medium-term ~~future VHF technologies~~space-based VFH communication systems	ATMOPSP, FLTOPSP, CP-OPDLWG SASP	~~Not approved~~	Q2 2024	~~Q4~~ July 2026~~5~~	Q4 2026

	Annex 10 - Vol V	Depending on the outcome of the Feasibility/technical studies and Agenda item 1.7 of WRC-23 Review and, as necessary, update SARPs to support medium-term ~~future VHF technologies~~space-based VHF communication systems	FSMP	~~Not approved~~	Q2 2024	July ~~Q4~~ 2026~~5~~	Q4 2026
	Manual on Space based VHF communication systems (Doc xxx)	Provide guidance on the space-based VHF communication systems ~~new Space VHF system~~ that assist future ICAO activities in support of the implementation	ATMOPSP, FLTOPSP, CP-OPDLWG SASP	~~Not approved~~	Q2 2024	~~Q4 2025~~	~~Q4 2026~~
	Actions	Identify and develop any consequential amendments to any other ICAO Documents	FSMP, ATMOPSP, FLTOPSP, CP-OPDLWG SASP	~~Not approved~~	Q4 2024	~~Q4~~ July 2026~~5~~	Q4 2026
For Information purposes (to be completed by the Secretariat)							
Global Implementation Actions							
	e.g. Global Symposia, webinar						
	e.g Workshop etc.						
Status:	**Priority:**	**Initial Issue Date:**	**Date Approved:**			**Session / Meeting:**	
	~~• proposal from peer review~~		**ANC:**				

(clean version)

Title	Aeronautical Satellite communication technologies and systems operating in VHF frequency band	Reference	[CP-DCIWG.011.01]
Source	DCIWG/05		
Problem Statement	The limitations of line of sight communications have placed constraints on the use of the VHF frequency spectrum and more specifically VHF voice/datalink. A number of States along with industry are currently investigating the potential for applying space-based VHF in oceanic or remote areas. In this context, there are no technical studies nor provisions for the space-based VHF to support the ICAO position to ITU-R WRC-23, Agenda Item 1.7..		
Specific Details	Spectrum availability is governed on a world-wide basis by the ITU Radio Regulations, as amended every four years by ITU World Radiocommunication Conferences (WRC). One WRC Agenda Item currently being studied in preparation for the upcoming WRC (WRC-23, November 2023) is the provision of aeronautical VHF services by low-earth-orbit satellite (also known as space-based VHF). In support of ICAO position to WRC-23, technical studies for space-based VHF should be completed and validated. This includes the necessary studies on interference analysis and spectrum compatibility. Depending on the outcome of the technical studies' validation and WRC-23 resolution, in support of space-based VHF, detailed provisions, including the Doppler shift and scintillation effects, will be required in Annex 10, Volumes III and V.		
GANP/GASP Link			
Expected Benefits	The implementation of new air-ground communications technologies will involve minimal or no change to existing avionics equipment and configurations, including cabling, power, antennae, etc, and this be a good gain for the industry and the regions for global adoption and implementation. VHF communications, using the existing VHF radios and other avionics aboard the aircraft can be leveraged in the remote/oceanic airspace, especially when in synergy with satellite-based ADS-B, this will make a seamless transition between space-based VHF and conventional VHF possible		

	The Space-based VHF may increase communication performance and available bandwidth (or channel capacity) required for aircraft, airlines and ATM operations. The space-based VHF will complement existing conventional VHF and will be fully interoperable with existing VHF infrastructures and avionics.	
References	Annex 10 — Aeronautical Telecommunications, Volume III — Communication Systems Annex 10 — Aeronautical Telecommunications, Volume V — Aeronautical Radio Frequency Spectrum Utilization DOC 9776 - Manual on VHF Digital Link (VDL) Mode 2 State letter E3/5-21/37 - ICAO position for ITU WRC-23	
Primary Expert Group:	CP - Data Communication Infrastructure Specific Working Group (CP-DCIWG)	
For Information purposes (to be completed by the Secretariat)		
Proposed Metric Note: there could be three sources: 1- Initial 2- Panel ideas Secretariat IAA section	The number of States, that use the space-based aeronautical VHF for Air Ground communications;	
Interdependencies	Results of ITU-R Working Party 5B Studies on WRC-23 Agenda Item 1.7	
Initial Impact Assessment Note: This is only an initial impact assessment on resources (financial, personnel, etc.). Detailed Impact Assessment is done when SARPs are developed.	**Impact on States**	Possible amendment to national regulations, and/or directives to allow the use of the new aeronautical VHF communication technologies
	Impact to Industry	The design of new VHF technologies must be fully compatible with existing aircraft VHF avionics and current installations. Possible changes to the communication systems software for air navigation services providers, communication services providers, satellite services providers to support the new aeronautical VHF services Minor changes to the operations manual/procedures for ANSPs and aircraft operators to support the new aeronautical VHF communication system
	Secretariat Project Lead	Secretary of the CP-DCIWG

Project Team	**Secretariat Project Team Members**	Secretaries of CP-OPDLWG, ATMOPSP, FLTOPSP and FSMP					
	Regional Office Focal Points	As assigned by Regional Directors					
WPE No.	**Document Affected or Actions Needed**	**Description of Amendment proposal or Action**	**Supporting Expert Group**	**Status**	**Expected dates**		
					Delivery	**Effective**	**Applicability**
	Technical Study	Validate the technical studies developed by States for the space-based VHF	FSMP		Q3 2023		
	Annex 10 - Vol III	Depending on the outcome of the Feasibility/technical studies and Agenda item 1.7 of WRC-23 Review and, as necessary, update SARPs to support medium-term space-based VFH communication systems	ATMOPSP, FLTOPSP, CP-OPDLWG SASP		Q2 2024	July 2026	Q4 2026
	Annex 10 - Vol V	Depending on the outcome of the Feasibility/technical studies and Agenda item 1.7 of WRC-23 Review and, as necessary, update SARPs to support medium-term space-based VHF communication systems	FSMP		Q2 2024	July 2026	Q4 2026
	Manual on Space based VHF communication systems (Doc xxx)	Provide guidance on the space-based VHF communication systems that assist future ICAO activities in support of the implementation	ATMOPSP, FLTOPSP, CP-OPDLWG SASP		Q2 2024		
	Actions	Identify and develop any consequential amendments to any other ICAO Documents	FSMP, ATMOPSP, FLTOPSP, CP-OPDLWG		Q4 2024	July 2026	Q4 2026

			SASP				
For Information purposes (to be completed by the Secretariat)							
Global Implementation Actions							
	e.g. Global Symposia, webinar						
	e.g Workshop etc.						
Status:	**Priority:**	**Initial Issue Date:**	**Date Approved:**			**Session / Meeting:**	
			ANC:				

OUTCOMES OF THE PRIORITIZATION EXERCISE

Subsequent to the SRP meeting a prioritization exercise of proposed new job card emanating from CP-DCIWG/6 has been conducted.

The outcomes of the prioritization and the proposal of priority is presented below (the complete result of the calculations can be found in the following link):

Reference	Title	Score	Priority
CP-DCIWG.011.01	Aeronautical satellite communication technologies and systems operating in VHF frequency band	3,16	M

The updated priority list of Job cards of the CP-DCIWG obtained after inclusion of the new job card and is presented in the table below.

Reference	Title	Score	Priority
CP-DCIWG.007.04	SARPS and guidance on Air Navigation (Cyber) Resilience	4,38	H
CP.001.01	Global Data Link Implementation Strategy	4,15	H
CP-DCIWG.006.03	Provisions on the exchange of information using the aeronautical telecommunication network over the internet protocol suite	3,62	M
CP-DCIWG.010.02	Future L-Band Terrestrial Data Link System	3,45	M
CP-DCIWG.009.02	Satellite Communication Systems in support of ASBU Blocks 1 and 2	3,34	M
CP-DCIWG.011.01	Aeronautical satellite communication technologies and systems operating in VHF frequency band	3,16	M

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International Civil Aviation Organization

AN-WP/9668
27/4/23

WORKING PAPER

AIR NAVIGATION COMMISSION

REVIEW OF UPDATES TO THE ICAO POSITION FOR ITU WRC-23 ARISING FROM THE FREQUENCY SPECTRUM MANAGEMENT PANEL (FSMP) AND APPROVAL OF DRAFT REPORT TO COUNCIL

(Item No. 22309)

(Presented by the Director of the Air Navigation Bureau)

SUMMARY

This paper presents a proposal to the Air Navigation Commission for updates to the ICAO Position for the International Telecommunication Union (ITU) World Radiocommunication Conference (2023) (WRC-23). The proposal takes into consideration developments resulting from studies conducted by ICAO, ITU and regional telecommunication organizations following the approval of the ICAO Position by Council in 2021 (C-DEC 223/6 refers).

Action by the Air Navigation Commission is in paragraph 2.

WORK PROGRAMME ELEMENTS

1213, 1221, 1128

COORDINATION

AOI, ATM, OPS, RPAS

REFERENCES

*C-WP/15199
*C-DEC 223/6
AN-WP/9495
AN-WP/9438
AN Min. 217-2
AN Min. 215-7
State letter E 3/5-21/37

Doc 10184, *Assembly Resolutions in Force (as of 7 October 2022)*
Doc 9718, *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I — *ICAO spectrum strategy, policy statements and related information*

This working paper relates to the Strategic Objectives for Safety and Air Navigation Capacity and Efficiency.

∗ Principal references

1. INTRODUCTION

1.1 This paper contains the draft report to Council on proposed updates to the ICAO Position for the International Telecommunication Union (ITU) World Radiocommunication Conference (2023) (WRC-23).

1.2 When the ICAO Position was established, studies were still ongoing in the Frequency Spectrum Management Panel (FSMP), ITU and regional telecommunication organizations.

1.3 Studies by the FSMP were completed in February 2023 during the sixteenth meeting of the FSMP Working Group (FSMG-WG/16) and have resulted in proposed amendments to the ICAO Position as presented in the appendix to the draft report to Council.

2. ACTION BY THE AIR NAVIGATION COMMISSION

2.1 The Air Navigation Commission is invited to review and approve the attached draft report to Council.

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International Civil Aviation Organization

WORKING PAPER

C-WP/15486
ANC Report
xx/xx/23

COUNCIL — 229TH SESSION

Subject No. 14.3.9: Communications

PROPOSED UPDATES TO THE ICAO POSITION FOR THE INTERNATIONAL TELECOMMUNICATION UNION (ITU) WORLD RADIOCOMMUNICATION CONFERENCE 2023 (WRC-23)

(Presented by the President of the Air Navigation Commission)

EXECUTIVE SUMMARY

This paper presents a proposal of the Air Navigation Commission (ANC) for updates to the ICAO Position for the International Telecommunication Union (ITU) World Radiocommunication Conference (2023) (WRC-23). The proposal takes into consideration developments resulting from studies conducted by ICAO, ITU and regional telecommunication organizations following the approval of the ICAO Position by Council in 2021 (C-DEC 223/6).

Action: The Council is invited to:

a) approve the updated ICAO Position for the ITU WRC-23 as contained in the appendix;
b) request the Secretary General to submit to ICAO Member States, relevant international organizations and to the ITU WRC-23, in an appropriate format, the ICAO Position, including the updates contained in the appendix, together with additional relevant material as required;
c) urge States to apply the ICAO Position to the maximum extent possible in the formation of their positions for WRC-23; and
d) urge States to include aviation experts in the development of their State's position and as part of the State's delegation to WRC-23.

Strategic Objective:	This working paper relates to the Safety and Air Navigation Capacity and Efficiency Strategic Objectives.
Financial implications:	No additional resources required as the activity presented can be accommodated within existing budget resource allocations.
References:	C-WP/15199 C-DEC 223/6 AN-WP/9668 AN Min. 223-x Doc 10184, *Assembly Resolutions in Force (as of 7 October 2022)* Doc 9718, *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I — *ICAO spectrum strategy, policy statements and related information* State letter E 3/5-21/37

1. INTRODUCTION

1.1 On 14 June 2021, the Council (C-DEC 223/6) approved the ICAO Position on issues of critical concern to aviation which are on the agenda of the International Telecommunication Union (ITU) World Radiocommunication Conference (2023) (WRC-23), to be held in Dubai, United Arab Emirates from 20 November to 15 December 2023. The approved Position was transmitted to States and international organizations under cover of State letter E 3/5-21/37, dated 18 August 2021.

1.2 When approving the ICAO Position, the Council requested the Secretary General to submit it to the ITU WRC-23, together with any additional supporting material from ICAO studies. The present proposal contains such additional material as developed by the Commission with the support of the Frequency Spectrum Management Panel (FSMP), and was reviewed by the Commission on x May 2023 (AN Min. 223-x). The additional material complements and updates the original Position and reflects the latest results of studies completed by ICAO and ITU.

1.3 No changes to the statement of approved ICAO policies contained in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I – *ICAO spectrum strategy, policy statements and related information* (Doc 9718) are envisaged at this time. Following ITU WRC-23, any consequential changes to the policies that may be required due to modifications of the ITU Radio Regulations will be presented to Council for approval.

2. NATURE AND SCOPE OF THE PROPOSED UPDATES

2.1 The proposed amendments, as shown in the appendix, are based on the results of studies conducted within the FSMP and the information received from the ITU. They refine and complement the approved ICAO Position in light of developments that have occurred since its approval by Council in 2021.

2.2 The amendments address in particular the following:

a) with regard to sub-orbital vehicles, the studies within the ITU Radiocommunication Sector (ITU-R) have concluded that additional spectrum to accommodate this class of vehicles will not be required. However, it is likely that access to aeronautical safety spectrum will be required during portions of the flight, for example, while traversing through traditional airspace. The studies focussed in large part on the definition of the sub-orbital vehicle itself, and how or whether to define a new class of station on-board the sub-orbital vehicles. The outcome was that the existing radioregulatory definitions of classes of operation would be sufficient, whereas the vehicles operate as typical terrestrial stations during portions of their flight while operating more akin to stations onboard a satellite during other portions of the flight. Hence minimal changes to the ITU Radio Regulations are expected to be required (WRC-23 Agenda Item 1.6 refers).

b) when the initial ICAO Position was developed for the agenda item on satellite based VHF, the focus was on voice communications for air traffic control (ATC) only. In order to also accommodate the potential operation of VHF Digital Link Mode 2 (VDL-2) over satellite, providing digital communications for ATC and airlines operational control (AOC), the ICAO Position has been amended to indicate "*safety and regularity of flight*". Studies within ICAO and ITU-R have mainly concentrated on two aspects: 1) the technical compatibility of a new aeronautical mobile satellite

(R) service (AMS(R)S) allocation with the incumbent services operating both in-band and in adjacent bands; and 2) the current aeronautical frequency assignment planning and management by ICAO and States performed within the band, which relies on the detailed provisions contained in Annex 10 — *Aeronautical* Telecommunications, Volume V — *Aeronautical Radio Frequency Spectrum Utilization* and ICAO Doc 9718, Volume II, while portions of the band are also shared with other, non-"*safety and regularity of flight*" users, which may not closely follow the ICAO assignment planning procedures. Hence, it is likely that any solution to accommodate a new AMS(R)S allocation in the band will also need to rely on ITU satellite coordination provisions in the frequency assignment planning and management process. While the ICAO and ITU-R studies have progressed well, they have not been finalized. For instance, different views have been raised whether a guard band would be required to protect against the non-aviation satellite services operating in the band above 137 MHz. The ICAO Position has been amended accordingly to account for these different views within aviation, as care should be taken that the Position should not be structured such that any remaining issues would result in objection to any AMS(R)S allocation at all (WRC-23, Agenda Item 1.7 refers).

c) a significant amount of spectrum is required to accommodate the C2 Link for beyond line of sight operation of remotely piloted aircraft (RPA). The ITU World Radiocommunication Conference in 2015 (WRC-15) agreed to new allocations in the fixed satellite service (FSS) Ku and Ka frequency bands, identifying over 2.2 GHz of spectrum against an ITU Resolution. However, as the FSS is not a safety service, the conditions by which the FSS is coordinated are incompatible with the stringent frequency management conditions applied to protected spectrum allocations traditionally used for *safety-of-life* applications, in accordance with **Article 4.10** of the ITU Radio Regulations. Without explicitly placing the burden of responsibility on the radio regulatory authorities of States, Resolution 155 introduces an application with *safety-of-life* implications into the FSS, while making an indirect reference; ("…*consistent with **Article 4.10***…"). This approach requires a significant part of the burden to ensure operation without harmful interference, such as real time interference monitoring and predicting/correcting interference, to be addressed in the Standards and Recommended Practices (SARPs) and thus assigns it to the Remotely Piloted Aircraft Systems (RPAS) operators and aeronautical regulatory authorities. The recent RPAS SARPs, included in the new Annex 10, Volume VI — *Communication Systems and Procedures Relating to Remotely Piloted Aircraft Systems C2 Link*, adopted and effective since 12 July 2021 and applicable on 26 November 2026, contain appropriate provisions leveraging this approach. This novel methodology to facilitate the use of non-safety spectrum for the C2 Link has generated multiple views within the FSMP membership, on whether and how **Article 4.10** could best be accommodated in the new Resolution, given its non-applicability to the management of the non-safety FSS systems. Due the above, when developing the initial Position, a delicate compromise wording was reached, pointing to "… *the role of the responsible States*". In the absence of a clear solution to this controversial subject, a reference to Article 40 of the ITU Constitution has been added to the overall Position, paragraph 3.4 – referencing the need for absolute priority to "*safety of life*". A minor clarification has been made to the Position , to indicate more precisely the need to ensure there is no negative impact as a result of future satellite coordination (WRC-23, Agenda Item 1.8 refers).

d) ITU-R regulatory studies on wide-band digital high frequency (HF) communications have concluded that a very minimal amendment to Appendix 27 to the ITU Radio Regulations will be needed, to both protect current users of aeronautical HF and allow for the aggregation of narrow band channels using more modern radiocommunication technology into wideband links (WRC-23, Agenda Item 1.9 refers).

e) during the deliberations to finalize the ICAO Position, it was highlighted that non-safety aeronautical applications should not receive the same attention in the Position as safety applications. An amendment was made accordingly, while still indicating support (WRC-23, Agenda Item 1.10 refers)

f) an item not previously identified as having potential negative impact on aeronautical services, addressing space weather sensors, was added. The Position supports continued studies and appropriate recognition of space weather sensors given their role in global aviation, while providing the caveat that any resulting changes to the ITU Radio Regulations should not impact current or planned aeronautical systems or applications (WRC-23, Agenda Item 9.1 topic a) refers).

g) a Position was added to oppose an agenda item being proposed for the next World Radiocommunication Conerence in 2027 (WRC-27), for a potential new spectrum allocation to the mobile service in the frequency band 1300-1350 MHz which is used by aeronautical long-range L-band radars. Previous studies at the ITU have already demonstrated that co-frequency sharing between the incumbent radar systems and those potential new mobile services is not possible (WRC-23, Agenda Item 10 refers).

h) in addition, numerous adjustments were made to focus background descriptions and Positions towards the outcome of agreed studies as appropriate (WRC-23, Agenda Items, 1.1, 1.2, 1.3, 1.4, 1.11, 1.13, 1.15, 1.17, 4, 8 and 9.2 refer).

Padhraic Kelleher

APPENDIX

PROPOSED AMENDMENT TO THE ICAO POSITION FOR THE INTERNATIONAL TELECOMMUNICATION UNION (ITU) WORLD RADIOCOMMUNICATION CONFERENCE 2023 (WRC-23)

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

a)	~~Text to be deleted is shown with a line through it~~.	text to be deleted
b)	New text to be inserted is highlighted with grey shading.	new text to be inserted
c)	~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

EXECUTIVE SUMMARY

1. MAIN POINTS ADDRESSED BY THE ICAO POSITION FOR THE ITU WRC-23

1.1 The radio spectrum is a scarce natural resource with finite capacity for which demand is constantly increasing. Aeronautical radio services are recognized internationally to be prime users of radio frequencies, without which aircraft operation would not be capable of meeting the global demand for safe, efficient and cost-effective transport. The ICAO Position aims at protecting aeronautical spectrum for all radiocommunication and radionavigation systems used for ground facilities and on board aircraft.

1.2 The process of international competition between expanding radio services, which takes place in the ITU, obliges all existing spectrum users, aeronautical and non-aeronautical alike, to continually defend and justify the retention of frequency bands or the addition of new bands to those already allocated to their service. Civil aviation requirements continue to grow, requiring more navigation and communication facilities, thus creating ever-increasing pressure to an already stretched resource, similarly to other, non-aviation users, with whom aviation shares the frequency spectrum resource. Accordingly, civil aviation must develop and present its agreed policies and its quantified and qualified statements of requirement for radio frequency spectrum so as to ensure continuing availability and access to the frequency spectrum resource and, ultimately, the ongoing viability of air navigation services throughout the world.

1.3 Items for which aviation is seeking an action for WRC-23 include the following:

a) regulatory provisions to facilitate radiocommunications for sub-orbital vehicles (Agenda Item 1.6);

b) a new aeronautical mobile-satellite (R) service (AMS(R)S) allocation for aeronautical very high frequency (VHF) communications in the frequency band 117 975-137 MHz, while preventing any undue constraints on existing aeronautical VHF systems operating in the band (Agenda Item 1.7);

c) appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution 155 to accommodate the use of fixed-satellite service (FSS) networks by RPAS C2 Links (Agenda Item 1.8);

d) review of Appendix 27 of the ITU Radio Regulations and consideration of appropriate regulatory actions to accommodate digital technologies for aviation safety-of-life applications in existing aeronautical high frequency (HF) bands (Agenda Item 1.9);

e) studies on spectrum needs and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications (Agenda Item 1.10); and

f) consideration of any difficulties or inconsistencies encountered in the application of the ITU Radio Regulations (Agenda Item 9.2).

1.4 Other issues that will be addressed at WRC-23 for which aviation needs to ensure there is no undue impact to aeronautical systems or services include the following:

a) possible measures to address protection of stations in the aeronautical and maritime mobile services in the frequency band 4 800-4 990 MHz, located in international airspace and waters, from other stations located within national territories (Agenda Item 1.1);

b) identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis (Agenda Item 1.2);

c) primary service allocation of the frequency band 3 600-3 800 MHz to the mobile service within ITU Region 1 (Agenda Item 1.3);

d) use of high-altitude platform stations as IMT base stations in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level (Agenda Item 1.4);

e) possible regulatory actions to support the modernization of the Global Maritime Distress and Safety System (GMDSS) and the implementation of e-navigation (Agenda Item 1.11);

f) possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service (Agenda Item 1.13);

g) harmonization of the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the FSS (Agenda Item 1.15);

h) technical, operational and regulatory measures to facilitate the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-geostationary FSS earth stations in motion, while ensuring due protection of existing services in those frequency bands (Agenda Item 1.16);

i) appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate (Agenda Item 1.17);

j) review of Resolutions and Recommendations of previous WRCs with a view to their possible revision, replacement or abrogation (Agenda Item 4); ~~and~~

k) consideration and appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes if no longer required (Agenda Item 8);

l) review of studies relating to technical and operational characteristics of space weather sensors, with a view to describing appropriate recognition and protection in the ITU Radio Regulations without placing additional constraints on incumbent services (Agenda Item 9.1, topic a));

~~k)~~m) review of the amateur service and the amateur-satellite service allocations in the frequency band 1 240--1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite (space-to-Earth) service operating in the same band (Agenda Item 9.1, topic b))~~.~~; and

n) recommendations for inclusion in the agenda for the next world radiocommunication conference, and items for the preliminary agenda of future conferences (Agenda Item 10).

1.5 Major threats to aviation, should ICAO's spectrum goals not be met in a satisfactory manner, include the possibility of harmful interference to essential aeronautical radionavigation and radiocommunication systems. The consequences of this could be manifold and have a direct and severe impact on the safety as well as the efficiency of flight operations. To satisfy the future frequency spectrum needs of aviation, long-term planning and engagement is required. In order to provide a proactive response to the increasing pressure of other frequency spectrum dependent industries, active participation by the aviation regulatory authorities and industry is required in the national and international fora leading to and including WRC-23.

2. ACTIVE SUPPORT OF THE ICAO POSITION

2.1 Support for the ICAO Position within States, when developing their proposals and delegation briefs in preparation to the WRC-23, is required to ensure that decisions taken by the conference are in favour of the aeronautical requirements (Assembly Resolution A41-7~~A38-6~~: Support of the ICAO policy on radio frequency spectrum matters refers). Therefore, it is necessary that States:

a) in preparing their proposals to the ITU WRC-23, include, to the maximum extent possible, the material contained in the Appendix;

b) undertake to provide for aviation authorities to fully participate in the development of States' positions to ensure support for the ICAO Position at the WRC-23;

c) include representatives of their civil aviation administrations and experts from aviation in their national delegations to the extent possible, when participating in the ITU-R and regional preparatory activities for WRC-23; and

d) ensure, to the extent possible, that their delegations to the WRC-23 include representatives of their civil aviation administrations.

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ICAO POSITION FOR THE INTERNATIONAL TELECOMMUNICATION UNION (ITU) WORLD RADIOCOMMUNICATION CONFERENCE 2023 (WRC-23)

SUMMARY

This paper reviews the agenda for the International Telecommunication Union (ITU) World Radiocommunication Conference 2023 (WRC-23), discusses points of aeronautical interest and provides the ICAO Position for these agenda items.

The goal of the ICAO Position is to ensure aeronautical access to appropriately protected spectrum for radiocommunication and radionavigation systems that support current and future safety-of-flight applications. In particular, it describes the safety considerations necessary to ensure adequate protection against harmful interference.

Support of the ICAO Position by ITU Member States is required to ensure that the position is supported at the WRC-23 and that aviation requirements are met.

Attachment:
Agenda for ITU WRC-23

1. INTRODUCTION

1.1 The ICAO Position on issues of interest to international civil aviation to be addressed at the 2023 ITU World Radiocommunication Conference (WRC-23) is presented below. The agenda of this Conference is contained in the attachment. The ICAO Position is to be considered in conjunction with sections 7-II and 8 of the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I — *ICAO spectrum strategy, policy statements and related information* (Doc 9718, Second Edition, 2018). Doc 9718 is available on http://www.icao.int/safety/fsmp (see webpage: Documents). It should be noted that the Handbook contains a long-term policy based on a snapshot in time and, as such, it may lag behind the ICAO WRC Position. As a result, when there is conflict between the Handbook and a current ICAO WRC Position, the Position should be seen as being the guiding document.

1.2 ICAO supports the working principle within the ITU, as established during studies for WRC-07, that ICAO will ensure the compatibility of ICAO standard systems with existing or planned aeronautical systems operating in accordance with international aeronautical Standards. Compatibility of ICAO standard systems with non-ICAO standard aeronautical systems (or non-aeronautical systems) will be addressed in the ITU.

2. ICAO AND THE INTERNATIONAL REGULATORY FRAMEWORK

2.1 ICAO is the specialized agency of the United Nations providing for the international regulatory framework for civil aviation. The *Convention on International Civil Aviation* is an international treaty providing required provisions for the safety of flights over the territories of the 193 ICAO Member States and over the high seas. It includes measures to facilitate air navigation, including international Standards and Recommended Practices commonly referred to as SARPs.

2.2 The ICAO Standards constitute the rule of law through the ICAO Convention and form a regulatory framework for aviation, covering personnel licensing, technical requirements for aircraft operations, airworthiness requirements, aerodromes and systems used for the provision of communications, navigation and surveillance, as well as other technical and operational requirements.

3. SPECTRUM REQUIREMENTS FOR INTERNATIONAL CIVIL AVIATION

3.1 Air transport plays a major role in driving sustainable economic and social development worldwide. Since the mid-1970s and until the end of 2019, air traffic growth has consistently defied economic recessionary cycles, expanding two-fold once every 15 years. It is estimated that in 2019 air transport directly and indirectly supported the employment of 87.7 million people, contributing U.S.$ 3.5 trillion to the global gross domestic product (GDP), and carried over 4.5 billion passengers and over 52 million tonnes of cargo.

3.2 While the COVID-19 outbreak ~~has~~did significantly ~~impacted~~impact the global air transport industry, the industry continues to play a critical role in supporting humanity's fight against the global pandemic. The industry contributions ~~include~~have included delivering medical equipment and medicines, supporting traveller repatriations and medical evacuations, and maintaining crucial global supply chains through increased air cargo operations.

3.3 The safety of air operations is dependent on the availability of reliable communication and navigation services. Current and future communication, navigation, and surveillance/air traffic management (CNS/ATM) systems are highly dependent upon the availability of sufficient, suitably protected radio spectrum that can support the high integrity and availability requirements associated with aeronautical safety systems. Spectrum requirements for current and future aeronautical CNS systems are specified in the ICAO Spectrum Strategy[1], as addressed by the Twelfth Air Navigation Conference, and as approved by the ICAO Council.

3.4 In support of the safety aspects related to the use of radio frequency spectrum by aviation:~~,~~

a) **Article 40** of the ITU Constitution states, "*international telecommunication services must give absolute priority to all telecommunications concerning safety of life at sea, on land, in the air or in outer space, as well as to epidemiological telecommunications of exceptional urgency of the World Health Organization*"; and

b) **Article 4.10** of the Radio Regulations states, "*ITU Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies.*"

In particular, compatibility of aeronautical safety services with co-band or adjacent band aeronautical non-safety services or non-aeronautical services must be considered with extreme care in order to preserve the integrity of the aeronautical safety services.

3.5 The continuous increase in air traffic movements as well as the additional requirement for accommodating new and emerging applications such as unmanned aircraft systems (UAS[2]) and commercial sub-orbital vehicle flights are placing an increased demand on both the aviation regulatory and air traffic management mechanisms. As a result, the airspace is becoming more complex and the demand for frequency assignments (and consequential spectrum allocations) is increasing. While some of this demand can be met through improved spectral efficiency of existing radio systems in frequency bands currently allocated to aeronautical services, it is inevitable that these frequency bands may need to be increased or additional aviation spectrum allocations may need to be agreed upon to meet this demand.

3.6 In addition, it is noted that there is a general trend toward the development of new terrestrial mobile communications networks with higher radiated power base stations, in particular IMT base stations using active antennas. A review of unwanted emission levels of these stations should be considered to ensure continued compatibility with other systems and services, particularly aviation safety systems.

3.7 The ICAO Position for the ITU WRC-23 was initially developed in 2020 with the assistance of the Frequency Spectrum Management Panel (FSMP) and was reviewed by the Air Navigation Commission at the seventh meeting of its 215th Session on 27 October 2020. Following the review by the Commission, it was submitted to ICAO Contracting States and relevant international organizations for comment. After a further review of the ICAO Position in light of the comments received by the Commission on 29 April 2021, the ICAO Position was reviewed and approved by the ICAO Council on 14 June 2021.

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[1] The ICAO spectrum strategy is included in the ICAO *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, Volume I — *ICAO spectrum strategy, policy statements and related information* (Doc 9718).

[2] For the purposes of this document, UAS is referred to in ICAO as remotely piloted aircraft systems (RPAS).

Taking into account the results of studies within the ITU, the ICAO Position was updated and approved by the ICAO Council on [TBD June 2023]. This document contains that updated ICAO WRC-23 Position.

3.8 States and international organizations are requested to make use of the ICAO Position, to the maximum extent possible, in their preparatory activities for the WRC-23 at the national level, in the activities of the regional telecommunication organizations[3] and in the relevant meetings of the ITU.

4. AERONAUTICAL ASPECTS ON THE AGENDA FOR WRC-23

Note 1.— The statement of the ICAO Position on an agenda item is given in a text box at the end of the section addressing the agenda item, after the introductory background material.

*Note 2.— WRC-23 Agenda Items **1.6, 1.7, 1.8, 1.9**~~**, 1.10**~~ and **9.2** address issues where aviation is seeking action by the WRC.*

*Note 3.— WRC-23 Agenda Items **1.1, 1.2, 1.3, 1.4, 1.10, 1.11, 1.13, 1.15, 1.16, 1.17, 4, 8,** and **9.1 topics a** and **b,** and **10** could potentially affect aviation use of spectrum and hence aviation should participate in studies to ensure there is no undue impact. As a result, they are included in this position.*

*Note 4.— No impact on aeronautical services has been identified from WRC-23 Agenda Items **1.5**, **1.12**, **1.14**, **1.18, 1.19**, **2**, **3**, **5**, **6**, **7**, **9.1 topic** ~~**a, 9.1 topic**~~ **c, 9.1 topic d** and **9.3** which are therefore not addressed in this position.*

Note 5.— When in this document reference is made to "No. X.YYY", it means "No. X.YYY of the ITU Radio Regulations".

[3] African Telecommunication Union (ATU), Asia-Pacific Telecommunity (APT), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL), Arab Spectrum Management Group (ASMG) and the Regional Commonwealth in the Field of Communications (RCC).

WRC-23 Agenda Item 1.1

Agenda Item Title:

to consider, based on the results of the ITU-R studies, possible measures to address, in the frequency band 4 800-4 990 MHz, protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories, and to review the pfd criteria in No. 5.441B in accordance with Resolution 223 (Rev.WRC-19).

Discussion:

This agenda item seeks to study the technical and regulatory provisions necessary to ensure the protection of aeronautical and maritime mobile services, located either in or above international waters, from other stations located within national territories and operating in the frequency band 4 800-4 990 MHz. Additionally, the agenda item calls for the review of the pfd criteria contained in No.**5.441B**.

The frequency bands 4 800-4 825 MHz and 4 835-4 950 MHz are allocated to the aeronautical mobile service worldwide in accordance with the Table of Frequency Allocations and No. **5.442**. In addition, in parts of Region 2 and Australia as well as adjacent international airspace the frequency bands 4 400-4 940 and 4 825-4 835 MHz are used for aeronautical mobile telemetry for flight testing in accordance with the provisions of No.**5.440A**, **5.442** and Resolution **416 (WRC-07)**. According to Resolution **416 (WRC-07)** the aeronautical mobile telemetry emissions are limited to transmission from aircraft stations only.

Flight testing is key to maintaining and enhancing the safety of aircraft operation. Analysis of data gathered during flight testing is used to evaluate the aerodynamic flight characteristics of the vehicle and the performance of the systems onboard that vehicle in order to validate the design and its safety. The flight test phase allows any identified design issues to be addressed and resolved, as well as verifying and documenting the vehicle's performance for government certification and customer acceptance. It is key to ensure the integrity of the flight test data. Any interference to the transmission or reception of flight test data, if spotted, may invalidate the test data gathered during that flight and hence require a repetition of that flight test or if not spotted cause nugatory work to be carried out to address an issue that does not exist.

However, assignments to certain types of aeronautical systems, for example radio links between aircraft, are not registered in the MIFR. The absence of such recording together with No. **8.1**, which states that *rights and obligations of administrations in respect of frequency assignments shall be derived from the recording of those assignments in the MIFR*, could lead to questions being raised as to why the protection of the aeronautical mobile service is required. Unfortunately, although the Radio Regulations require assignments to be registered in order to be internationally recognized (No. **11.2** & **11.8**), provision No. **11.14** precludes the notification and registration of frequency assignments to aeronautical mobile stations that do not have associated aeronautical land stations. This apparent discrepancy should be resolved in a manner that ensures recognition and protection of aviation systems when they are operated in international airspace.

2.2 Though this agenda item is limited to the frequency band 4 800-4 990 MHz, its considerations might have influence on a general regulatory mechanism of protection of the aeronautical mobile service in international airspace. It is essential to ensure that the proposed methods to satisfy this agenda item would not have a negative impact on the use of aviation systems in other frequency bands.

ICAO Position:

To support any measures based on the results of studies taken to ~~enhance~~ensure the protection of flight testing in international airspace~~ that are consistent~~, especially those stations operated in accordance with ~~the results of agreed studies~~RR No. **5.440A**. To oppose any proposed measure that is not in line with the results of ~~agreed~~ studies and reduces the level of protection ~~afforded to~~of flight test operations in international airspace and above international waters, especially those operated in accordance with RR No. **5.440A**. To ensure that the proposed methods to satisfy this agenda item do not have a negative impact on the use of aviation systems in other frequency bands.

WRC-23 Agenda Item 1.2

Agenda Item Title:

to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 245 (WRC-19);

Discussion:

The agenda item, based on the called for studies, seeks additional IMT identification, and possible new allocations to the mobile service identified for IMT on a primary basis in the frequency bands:

- 3 300-3 400 MHz (Region 1 & 2);
- 3 600-3 800 MHz (Region 2);
- 6 425-7 025 MHz (Region 1);
- 7 025-7 125 MHz (globally);
- 10.0-10.5 GHz (Region 2).

In parts of Region 2, as well as adjacent international airspace, the frequency band 5 925-6 700 MHz is used for aeronautical mobile telemetry for flight testing in accordance with the provisions of Resolution **416 (WRC-07)**.

Flight testing is key to maintaining and enhancing the safety of aircraft. Analysis of data gathered during flight testing is used to evaluate the aerodynamic flight characteristics of the vehicle and the performance of the systems onboard that vehicle in order to validate the design and its safety. The flight test phase allows any identified design issues to be addressed, as well as verifying and documenting the vehicles performance for government certification and customer acceptance.

It is key to ensure the integrity of the flight data. Any interference to the transmission or reception of flight test data, if spotted, may invalidate the test data gathered during that flight and hence require a repetition of that flight, or if not spotted, cause ~~nugatory~~unnecessary work to be carried out to address an issue that does not exist.

~~Also,~~Parts of the frequency bands 3 600-3 800 MHz and 6 425-7 025 MHz are allocated to the fixed satellite service (FSS)~~, and parts of these bands are used for the provision of aeronautical services including the use of geo-stationary orbit (GSO) FSS very small aperture (VSAT) systems for the transmission of critical aeronautical and meteorological information. Parts of these frequency bands are also~~ are used by FSS feeder links (downlinks and uplinks) of GSO mobile satellite service (MSS) networks to support the transmission of AMS(R)S communications in the 1.6/1.5 GHz bands, which is used to support ATC and aircraft operations by many ANSPs and airlines. GSO satellites have visibility over a very wide area (about one third of the Earth surface), so any interference to MSS feeder uplinks operated in the band 6 425-6 575 MHz could endanger aircraft operations over a similar-sized area.

Some GSO very small aperture terminals (VSAT) may operate in the FSS in some countries of Region 1 and Region 2 in the frequency bands 3 600-3 700 MHz and 6 425-6 525 MHz for the provision of aeronautical services.

ITU-R studies identified under Resolution **245 (WRC-19)** will need to be completed to determine the potential for sharing of IMT with the FSS. In advance of results of these studies, ITU-R Report S.2368 contains sharing studies between IMT-Advanced systems and GSO FSS in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15[4].

The report summarises the required separation distances presented in the individual technical studies to protect GSO FSS earth stations. The separation distances vary depending on the study and range from ~~10 km to around 100s~~approximately ten to well over a hundred km for protection of the FSS interference criteria.

Studies have been conducted by the ITU-R to assess the aggregate interference from IMT systems to FSS satellites in the band 6425-7075 MHz. The studies show a range of results, in some cases showing interference below the FSS protection criterion, and in other cases showing interference above the criterion. The differences are mainly related to the scenarios used and to different assumptions on the number of IMT base station operating and their characteristics.

Recently ICAO has received several studies regarding the interference potential to radio altimeters from new mobile service systems planned to operate in frequency bands adjacent/nearby to that used by those altimeters. The radio altimeter is a mandated critical aircraft safety system operating in the 4 200-4 400 MHz frequency band and used to determine the aircraft's height above terrain, enabling several safety related flight operations and navigation functions on all commercial aircraft and a wide range of other civil aircraft types. Such functions and systems include terrain awareness, aircraft collision avoidance, wind shear detection, flight controls, and functions to automatically land an aircraft. Harmful interference to the function of the radio altimeter during any phase of flight would pose a serious safety risk. It is important to note, however, that the issues raised by the radio altimeter studies are not with the regulatory allocation and identification to the mobile service (i.e., it is not pertinent to WRC-23 Agenda Item 1.2 discussions), rather to how new systems are being authorized for deployment within that service. Work continues to assess any possible measures that might be needed, both near-term and in the future, to ensure compatible operation of radio altimeters and these new mobile service systems.

[4] Report ITU-R S.2368-0: Sharing studies between International Mobile Telecommunication-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15 (https://www.itu.int/pub/R-REP-S.2368)

ICAO Position:

To ensure that any IMT identification in the Region 2 in the frequency bands 3 600-3 800 MHz would include technical conditions to protect FSS in order to continue the use of these bands by the FSS for the provision of aeronautical services. In case of any IMT identification in the frequency band 6 425-6 575 MHz in Region 1, regulatory provisions would be required for protecting FSS uplinks in order to continue the use of these bands by GSO FSS networks used for the provision of aeronautical services. In case of any IMT identification in the frequency band 6 425-6 700 MHz in Region 1, to ensure that the flight test operations in accordance with Resolution **416** (WRC-07) would not be affected in Region 2. ~~To oppose any proposal in the frequency band 6 425-7 025 MHz in Region 1 that would reduce the level of protection below an acceptable level and hence compromise flight test operations.~~ ~~To oppose any proposal in the frequency bands 3 600-3 800 MHz and 6 425-7 025 MHz that could lead to harmful interference or could constrain the use of these bands by the FSS for the provision of aeronautical services or GSO MSS feeder links.~~

WRC-23 Agenda Item 1.3

Agenda Item Title:

To consider primary allocation of the band 3 600-3 800 MHz to mobile service within Region 1 and take appropriate regulatory actions, in accordance with Resolution 246 (WRC-19);

Discussion:

The agenda item, based on the called for studies, seeks to upgrade the secondary allocation to the mobile service identified for IMT in the frequency band 3 600-3 800 MHz in Region 1.

Systems operating under the allocation to the fixed satellite service (FSS) in the frequency range 3 400-4 200 MHz provide ground infrastructure for the transmission of critical aeronautical and meteorological information. These systems are also used for feeder links to support systems providing an aeronautical mobile satellite (route) service. ITU-R Reports M.2109 ~~&~~ and S.2199 contain sharing studies between systems operating under an allocation to the FSS and international mobile telecommunication (IMT) systems and broadband wireless access systems respectively in the frequency range 3 400-4 200 MHz. Studies show a potential for interference from IMT and broadband wireless access stations into Earth station in the FSS at distances of up to several hundred kilometres. Such large separation distances would impose substantial constraints on both mobile and satellite deployments. The studies also show that interference can occur when IMT systems are operated in frequency bands adjacent to those used by the FSS.

In addition, WRC-12 adopted Resolution **154** (revised at WRC-15) to support existing and future operation of Earth stations in the FSS within the frequency band 3 400-4 200 MHz, as an aid to safe operation of aircraft and reliable distribution of meteorological information in some countries, mainly in Africa, of Region 1

Recently ICAO has received several studies regarding the interference potential to radio altimeters from new mobile service systems planned to operate in frequency bands adjacent/nearby to that used by those altimeters. The radio altimeter is a mandated critical aircraft safety system operating in the 4 200-4 400 MHz frequency band and used to determine the aircraft's height above terrain, enabling several safety related flight operations and navigation functions on all commercial aircraft and a wide range of other civil aircraft types. Such functions and systems include terrain awareness, aircraft collision avoidance, wind shear detection, flight controls, and functions to automatically land an aircraft. Harmful interference to the function of the radio altimeter during any phase of flight would pose a serious safety risk.

It is important to note, however, that the issues raised by the radio altimeter studies are not with the regulatory allocation and identification to the mobile service (i.e., it is not pertinent to WRC-23 Agenda Item 1.3 discussions), rather to how new systems are being authorized for deployment within that service. Work continues to assess any possible measures that might be needed, both near-term and in the future, to ensure compatible operation of radio altimeters and these new mobile service systems.

ICAO Position:

To ~~oppose any changes to existing regulatory provisions of the ITU Radio Regulations for the~~ ensure that any mobile allocation in Region 1 in the frequency bands 3 600-3 800 MHz ~~that adversely affect the~~ would include technical conditions to protect FSS in order to continue the use of these bands by the FSS for the provision of aeronautical ~~use of systems operating in the FSS in Region 1~~services, including GSO MSS feeder links for the purpose of supporting aeronautical services.

WRC-23 Agenda Item 1.4

Agenda Item Title:

to consider, in accordance with Resolution 247 (WRC-19), the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level.

Discussion:

At WRC-2000, the frequency bands 1 885-1 980 MHz, 2 010-2 025 MHz and 2 110-2 170 MHz in Regions 1 and 3, and the frequency bands 1 885-1 980 MHz and 2 110-2 160 MHz in Region 2 were identified in RR No. **5.388A** for possible use by high-altitude platform stations as international mobile telecommunications (IMT) base stations (HIBS) within the mobile service allocation. Resolution **221 (Rev.WRC-07)** referred to in RR No. **5.388A** stipulates technical conditions for HIBS necessary for the protection of ground-based IMT stations in neighboring countries and other services based on the sharing and compatibility studies with IMT-2000.

In view of increasing demand to provide mobile broadband services to underserved areas and noting the increase in the number of frequency bands within which ground based IMT is deployed, there is a need to review the existing regulations for HIBS with a view to providing flexibility for the operators to deploy HIBS in all frequency bands below 2.7 GHz that are identified for IMT. This review should include the fact that HIBS are expected to be used as a part of terrestrial IMT networks and may use the same frequency bands as ground-based IMT base stations. As a result, this agenda item considers appropriate technical conditions and regulatory actions for HIBS in certain frequency bands below 2.7 GHz that are already identified for IMT, i.e.:

- 694-960 MHz;
- 1 710-1 885 MHz (1 710-1 815 MHz to be used for uplink only in Region 3);
- 2 500-2 690 MHz (2 500-2 535 MHz to be used for uplink only in Region 3, except 2 655-2 690 MHz in Region 3).

In accordance with *resolves* 2 of Resolution 247 (WRC-19), the sharing and compatibility studies under this agenda item should ensure the protection of services having allocations in the same and adjacent frequency bands.

One of the frequency bands considered for HIBS is 694-960 MHz, which is adjacent to the band 960-1 164 MHz allocated to AM(R)S and ARNS and heavily used by aeronautical systems, e.g. ADS-B, DME, LDACS, SSR etc.

Another frequency band being considered is 2 500-2 690 MHz which is close to the frequency band 2 700-2 900 MHz used for the provision of primary approach radars. Regarding that latter band, in order to enable the deployment of ground based IMT below 2 690 MHz the existing radars had to be modified to increase the receiver front end filter rejection in order to cope with the power in the IMT fundamental signal. The design of those modifications was based on a specific set of assumptions about the deployment of IMT base stations, the antenna characteristics including height and directivity, and the use of a specific terrestrial propagation model (Recommendation ITU-R P.452). Placing the IMT base station on a high-altitude platform changes the assumptions used in determining the modifications required to the radar receiver front ends to accommodate ground based IMT. It is essential to ensure that by placing the base station on a high altitude platform the maximum level of signal received by the radar both in-band and out of band from IMT does not exceed those predicted during the studies on ground based IMT and on which the radar modifications were designed.

ICAO Position:

To ensure that any identification of frequency bands for high-altitude platform stations as IMT-base stations (HIBs) ~~sharing and compatibility studies performed under Resolution **247 (WRC-19)** address~~should include provisions for the protection of aeronautical systems operating in the frequency bands 960-1 164 MHz and 2 700-2 900 MHz.

~~In particular, to~~To oppose the use of HIBS within the frequency band 2 500-2 690 MHz or parts thereof ~~where~~if agreed studies have not demonstrated ~~that~~ the ~~signal levels from the HIBS will be below the predicted levels from the ground based IMT studies.~~protection of aeronautical systems.

WRC-23 Agenda Item 1.6

Agenda Item Title:

to consider, in accordance with Resolution 772 (WRC-19), regulatory provisions to facilitate radiocommunications for sub-orbital vehicles.

Discussion:

Sub-orbital vehicles have been developed to reach altitudes and velocities that are much higher than conventional aircraft. Re-usable sub-orbital vehicles that launch like traditional rockets have become routine. ~~However~~Furthermore, with the advances in technology, re-useable sub-orbital vehicles that take off and land on a traditional runway are close to becoming a reality with companies testing such vehicles. These vehicles are intended to perform various missions, such as deploying satellites, conducting scientific research, or carrying passengers and cargo, and then returning to the Earth's surface. As one example, such vehicles could lead to hypersonic travel from Europe to Australia in 90 minutes, down from the current 24 hours.

The ~~introduction~~integration of sub-orbital vehicles into airspace managed by Member States will create ~~numerous~~various challenges for spectrum usage and frequency management. ~~They must safely~~A sub-orbital vehicle could share airspace with conventional aircraft during certain portions of its flight~~.~~, or be separated procedurally to maintain aviation safety. Therefore, there is a need~~ to track sub-orbital vehicles ~~, in some cases, for ~~the entire duration of the flight and for those vehicles~~that vehicle to communicate with other airspace users and air traffic control, as decided by the Member States. These sub-orbital vehicles may use a number of different terrestrial and space services, some standardized by ICAO, in various ranges of frequency bands.

With respect to spectrum for systems and applications related to aviation safety, ICAO standardized systems are necessary for harmonization and interoperability with the air traffic management system. However, sub-orbital vehicles are intended to achieve altitudes and velocities that are much higher than conventional aircraft and hence do not always perform as an aircraft. Also, the way that on-board ICAO~~ s~~Standard terrestrial or satellite systems operate may not necessarily be consistent with the definitions in the RR. Therefore, in the current Radio Regulations~~. Therefore~~, there is not a clear regulatory understanding as to how stations on board sub-orbital vehicles should be addressed and hence no clear understanding as to the radio service(s) under which they should operate.

Studies have shown that in principle from a technical perspective, some of the current ICAO standardized systems should have the capability, although potentially not the capacity, to provide suitable radio links for sub-orbital vehicles to operate safely. ~~Additional regulatory and technical analysis is~~RR modifications such as a WRC Resolution. may be required at WRC-23 to address the ~~questions and concerns raised in~~outcome of the studies ~~called for by~~under Resolution **772 (WRC-19)**. Any such changes to the Radio Regulations shall not create constraints on aeronautical operations.

ICAO Position:

To support the regulatory provision for terrestrial stations and earth stations required onboard a suborbital vehicle to safely integrate it into air traffic service airspace, as decided by the responsible Member State(s), to maintain the services under which these stations are classified.

Any such changes to the Radio Regulations shall not create constraints on aeronautical operations.

~~To support ITU-R studies and the definition of relevant technical characteristics as called for by Resolution **772 (WRC-19)** to ensure aviation needs are satisfied.~~

~~To support, if identified as required by the studies called for in Resolution **772 (WRC-19)**, modifications to the Radio Regulations that help enable the integration of sub-orbital vehicles into the airspace structure.~~

~~To support, if studies show the need for access to additional spectrum, the establishment of a WRC agenda item at a future competent conference.~~

WRC-23 Agenda Item 1.7

Agenda Item Title:

to consider a new aeronautical mobile-satellite (R) service (AMS(R)S) allocation in accordance with Resolution 428 (WRC-19) for both the Earth-to-space and space-to-Earth directions of aeronautical VHF communications in all or part of the frequency band 117.975-137 MHz, while preventing any undue constraints on existing VHF systems operating in the AM(R)S, the ARNS, and in adjacent frequency bands.

Discussion:

The use of low-Earth orbiting satellites for VHF aeronautical safety and regularity of flight messages between the pilot and controller have a potential to augment, but not replace, coverage of existing terrestrial VHF communications facilities. Several proposals currently being studied would provide complementary service to oceanic and remote regions that already exists for global navigation satellite systems and satellite based surveillance systems. These implementations would all use existing on-board aircraft VHF radios without any needed modification.

Such an AMS(R)S system will provide significant operational benefits to many different regions globally, but may not be viable in all areas given the extensive usage of existing AM(R)S systems in some Administrations. Therefore, in addition to any applied ITU coordination procedures, complementary coordination procedures in the ICAO will need to be established to ensure that all relevant entities are consulted before any frequency is used and not constrain the current or future AM(R)S systems in the same band.

~~In the past the level of aircraft traffic and separation in oceanic and remote areas has been limited due to either the geographical impracticality and/or prohibitive costs of providing and maintaining suitable terrestrial communication, navigation and surveillance (CNS) systems. However, with the existing availability of global navigation satellite systems and the implementation at WRC-15 of a satellite based surveillance broadcast systems in the frequency band 1 087.7-1 092.3 MHz, there has been progress in the areas of navigation and surveillance. However, in certain regions of the world there remains insufficient communications capability to complement these satellite navigation and surveillance functions.~~

~~One proposal currently being studied uses low-Earth orbiting satellites to relay regional air traffic control messages between the pilot and controller. Were the system to be operated in the frequency band 117.975-137 MHz, currently allocated to the aeronautical mobile (Route) service (AM(R)S), then it would be possible to avoid carrying out a prohibitively expensive aircraft retrofit programme as the system would utilize existing on-board radios.~~

~~Availability of VHF satellite communications in oceanic and remote areas, as noted above where terrestrial infrastructure is non-existent or impractical, would also enhance the efficiency and capacity of aircraft operations as well as supporting communications to RPAS (Remotely Piloted Aircraft Systems) flight operations. The primary intention of the VHF satellite concept is to provide bi-directional communications from ATC to aircraft, and aircraft to ATC. The satellite concept is not designed or intended to be a replacement for existing VHF terrestrial infrastructure due to limitations with the satellite payload.~~

~~Aeronautical VHF channel assignments are planned in accordance with the principles contained in ICAO Annex 10 to the Convention on International Civil Aviation Volume V and detailed in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation Volume II. These criteria have been designed to ensure that communications are free from harmful interference. Co-ordination is then undertaken prior to deployment, in line with ITU procedures, between the relevant aeronautical authorities including ICAO to ensure there are no objections to the proposed assignment with a master list of approved assignments normally being published regularly by the relevant ICAO regional office. The satellite VHF relay concept would be subject to the same scrutiny with planning criteria needing to be developed within ICAO to ensure that both the terrestrial and satellite aeronautical VHF frequencies are free from harmful interference and co-ordination procedures are established to ensure that all relevant entities are consulted before any frequency is used. Particular consideration should be given to the high current utilisation and future development of the terrestrial VHF band for voice and data communications in certain areas and the reduced channel bandwidth that is utilized in Europe.~~

~~The satellite system allocation to AMS(R)S shall operate in accordance with international standards, practices and procedures in accordance with the Convention on International Civil Aviation and not adversely impact or limit the operation of existing AM(R)S terrestrial VHF systems in the frequency band 117.975-137 MHz, nor require any changes to aircraft equipage or existing installations which do not participate in the provision of the link or service area provided by the satellite link.~~

ICAO Position:

~~To support ITU-R studies and the definition of relevant technical characteristics as called for by Resolution **428 (WRC-19)**.~~

To support a global primary allocation to the aeronautical mobile-satellite (route) service for both the Earth-to-space and space-to-Earth directions in all or part of the frequency band 117.975-137 MHz ~~and that the use of the allocation be limited to the relaying of aeronautical VHF air traffic management communications.~~subject to the following conditions:

- The use of any new AMS(R)S allocation be limited to aeronautical VHF communications for safety and regularity of flight.
- Ensure the protection of existing primary terrestrial aeronautical systems in the 117.975-137 MHz band, and not constrain the planned usage of those systems.

~~To support that those~~ The systems shall be implemented and operated and planned in accordance with international Standards and Recommended Practices and procedures established in accordance with the Convention on International Civil Aviation.

~~To ensure that any change to the regulatory provisions and spectrum allocation resulting from this agenda item do not adversely impact the operation of existing VHF systems in the band 117.975-137 MHz operating in the AM(R)S, including regional usage of terrestrial VHF, nor require any changes to aircraft equipage or to existing installations.~~

WRC-23 Agenda Item 1.8

Agenda Item Title:

to consider, on the basis of ITU-R studies in accordance with Resolution 171 (WRC-19), appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution 155 (Rev.WRC-19) and No. 5.484B to accommodate the use of fixed-satellite service (FSS) networks by control and non-payload communications of unmanned aircraft systems.

Discussion:

Resolution **155 (Rev.WRC-19)** was initially developed at WRC-15 and modified by WRC-19, with the aim of enabling the use of geostationary-satellite networks operating in the fixed satellite service (FSS) to be used for the provision of unmanned aircraft control and non-payload communication (CNPC) in the following frequency bands:

- For downlink (space-to-Earth):
  - 10.95-11.2 GHz,
  - 11.45-11.7 GHz,
  - 11.7-12.2 GHz in Region 2,
  - 12.2-12.5 GHz in Region 3,
  - 12.5-12.75 GHz in Regions 1 and 3,
  - 19.7-20.2 GHz,
- For uplink (Earth-to-space):
  - 14-14.47 GHz,
  - 29.5-30.0 GHz.

Resolution **155 (Rev.WRC-19)**, in its resolves, contains the conditions under which an unmanned aircraft can use a satellite network operating in the FSS for CNPC. However, it was recognised when the Resolution was originally developed that:

- ICAO had yet to complete the development of the relevant international aeronautical Standards and Recommended Practices (SARPs),
- additional work would be required to assess the feasibility of using the satellite networks under the conditions contained in Resolution **155**,
- there may be inconsistencies between some of the **resolves**,
- Resolution **155 (Rev.WRC-19)** was originally developed during WRC 15, and modifications may be required once the further study work and relevant ICAO SARPs material had been completed to ensure that the provisions of the Resolution meet the ICAO requirements.

Therefore, the Resolution as developed by WRC-15, contained a clause requiring WRC-23 “to consider the results of the above studies referred to in this Resolution with a view to reviewing and, if necessary, revising this Resolution, and take necessary actions, as appropriate". It also precluded operational use of the FSS by UAS CNPC before the review by WRC-23.

At WRC-19 Resolution **155** was revised and WRC-23 Agenda Item 1.8 adopted that through Resolution **171 (WRC-19)** *resolved to invite the ITU Radiocommunication Sector* to:

- continue and complete in time for WRC-23 relevant studies of the technical, operational and regulatory aspects, based on the frequency bands mentioned in *resolves* 1 of Resolution **155 (Rev.WRC-19)**, in relation to the implementation of Resolution **155 (Rev.WRC-19)**, taking into account the progress obtained by ICAO in the completion of SARPs on use of the FSS for the UAS CNPC links,
- review No. **5.484B** and Resolution **155 (Rev.WRC-19)** taking into account the results of the above studies.

Additionally, Resolution **171 (WRC-19)** *invites the 2023 World Radiocommunication Conference* to revise, if necessary, No. **5.484B** and Resolution **155 (Rev.WRC-19)** and take other necessary actions, as appropriate, on the basis of the studies conducted under Resolution **155 (Rev.WRC-19)** and **171 (WRC-19).** Work on the ITU-R studies is continuing, and the final outcome of the work has not yet been reached in order to allow WRC-23 to make decisions.

In this context, ICAO is invited to develop aeronautical Standards and Recommended Practices (SARPs) identifying how UAS CNPC operate under the existing FSS primary allocation, based on the Resolution **155 (Rev.WRC-19**). As a basis for developing these SARPs, since CNPC is a safety-of-life aeronautical system, ICAO is expecting that the decision of WRC-23 results in a Resolution that:

- clearly provides primary status;~~ to the various elements of the UAS CNPC link, including both the UAES and the UACS Earth station, taking into account the definitions contained within the radio regulations,~~

- removes the apparent inconsistencies;~~y, in common frequency bands, between a) Resolutions **156, 169,** and any future Resolution that require that Earth stations in motion shall not be used or relied upon for safety-of-life applications and b) Resolution **155** that addresses the use of Earth stations in motion on board UA for safety-of-life applications,~~

- acknowledges that in accordance with the Annexes ~~of~~ to the Convention of the International Civil Aviation Organization (ICAO)~~ on international civil aviation it is the States that are responsible for~~, ensuring the safety-of-life aspects of the use of UAS CNPC~~,~~ is the role of the responsible States;

- provides ~~operators, air traffic service providers and regulatory authorities~~ sufficient information ~~about the level of interference within the area of the UAS operation, including outside of the territory where they provide air traffic services,~~ to support and/or validate ~~supporting documentation for~~ safety cases~~,~~;

- ensures that ~~safety cases or supporting documentation do not need~~the UAS CNPC operator is notified prior to ~~be revisited~~any change in the service provision performance being implemented as a result of the satellite coordination process;

- ensures that any change as a result of ~~future satellite co-ordination agreements~~a satellite coordination process does not adversely affect the initial service level agreement.

Within the ITU during the last study period work has made substantive progress ~~but it has not been formally completed for the following two documents that addressed various resolves within Resolution **155**:~~

- ~~ITU-R M.[UAS CNPC_CHAR] - Characteristics of unmanned aircraft system control and non-payload Earth stations for use with space stations operating in the Fixed Satellite Service,~~

on document ITU-R M.[UA_PFD] - Review of power flux-density limits in accordance with resolves 16 of Resolution **155 (WRC-15)**~~.~~, which addresses the various resolves within Resolution **155**, however this work has not been formally completed. It has to be noted that ~~these documents~~this document will contain critical information that will be used for assessing the feasibility of UAS CNPC for different operational conditions, by ICAO, under Resolution **155**.

Within ICAO work has progressed on the development of Standards and Recommended Practices (SARPs) material. The first package of SARPs, dealing with the identification of frequency bands (including those listed in Resolves 1 of Resolution **155 (Rev.WRC-19)** and C2 Link procedures, has been adopted and became effective on 12 July 2021, following a review of comments received from States. The second package of SARPs, endorsed in November~~scheduled to be completed by~~ 2022 and now being further developed, ~~will~~ addresses the technical solutions for the FSS systems and the other relevant resolves of ~~the~~ Resolution **155**. ICAO will be responsible for the safety-of-life aspects of UAS CNPC under the existing RF environment given by the Resolution **155**.~~It should be noted that this work is still under development within ICAO.~~

The Director of the Radiocommunication Bureau will decide if the conditions included in the *instructs the Director of the Radiocommunication Bureau* 4 of Resolution **155 (Rev. WRC-19)** have been met. If they have, satellite network filings submitted by administrations with a new class of station can then be considered for processing.

It should be noted that work under Agenda Item 1.16 (Resolution **173 (WRC-19))** and Agenda Item 1.17 (Resolution **773 (WRC-19))** may have impacts on the use of the FSS by UAS CNPC during the WRC-23 cycle. The implications of any proposed amendment under these Agenda Items to the Radio Regulations need to be assessed and action taken, if necessary, to ensure that the radio regulatory provisions established during WRC-23 do not adversely impact the use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by unmanned aircraft for CNPC.

ICAO Position:

~~To support ITU-R studies, as called for by Resolutions **155 (Rev.WRC-19) and 171 (WRC-19)**~~.

To support the modification of No. **5.484B** and Resolution **155 (Rev.WRC-19)**.

ICAO is expecting that the decision of WRC-23 will result in a Resolution that:

- clearly provides primary status;
- removes any apparent inconsistencies;
- acknowledges that in accordance with the Annexes ~~of~~ to the Convention of the International Civil Aviation Organization (ICAO), ensuring the safety-of-life

aspects of the use of UAS CNPC is the role of the responsible States;

- provides sufficient information to support and/or validate safety cases; and
- ensures that ~~safety cases do not need~~the UAS CNPC operator is notified prior to ~~be revisited~~any change in the service provision performance being implemented as a result of ~~future~~the satellite ~~co-ordination agreements.~~coordination process.
- ensures that any change as a result of a satellite coordination process does not adversely affect the initial service level agreement.

WRC-23 Agenda Item 1.9

Agenda Item Title:

to review Appendix 27 of the Radio Regulations and consider appropriate regulatory actions and updates based on ITU-R studies, in order to accommodate digital technologies for commercial aviation safety-of-life applications in existing HF bands allocated to the aeronautical mobile (route) service and ensure coexistence of current HF systems alongside modernized HF systems, in accordance with Resolution 429 (WRC-19).

Discussion:

HF is the only terrestrial service with means of providing ubiquitous global communication coverage for aircraft, and is still the long-range system required by many aviation regulators for the provision of safety and regularity of flight communications in oceanic, polar and remote areas. Access to the various frequency bands in the range 2 850-22 000 kHz assigned to the aeronautical mobile (route) service (AM(R)S) is therefore essential. Since the last substantive review of Appendix **27** at the 1979 World Administrative Radio Conference, use of HF by aviation has continued to evolve and grow, especially with the introduction of HF datalink in the 1990s; now used by many airlines.

To date, operational capacity has been limited by the number of 3 kHz channels~~ and channel bandwidths (maximum of 3 kHz)~~ available in the HF band. However, the development of advanced digital techniques, including new waveforms, allows the aggregation of ~~both~~independent 3 kHz channels (either contiguous ~~and~~or non-contiguous~~ channels.~~) into wideband links. This opens the possibly for simultaneous transmission of voice and data, thus improving capacity, connectivity, and quality of HF communication systems. Aviation would like to take advantage of these developments to provide aircraft with additional capabilities and to improve the reliability, availability and continuity of communications especially when used in conjunction with existing L-band aviation SATCOM systems.

In order to take advantage of the various benefits that a modern wideband HF communication system could offer, Appendix **27** of the Radio Regulations needs to be modified to allow the introduction of new digital wideband systems in accordance with Resolution **429 (WRC-19)**. For the purpose of this agenda item, the term “wideband” in HF communications may refer to a combination of multiple 3 kHz channels to provide improved data rates. With the availability of advanced digital technologies and the demonstrated capabilities of aeronautical wideband HF, including contiguous or non-contiguous channel aggregation, faster data rates and digital voice communications are possible.

Studies have identified minor changes to Appendix 27 that would both protect current users of aeronautical HF, and allow for the aggregation of narrow band channels into wideband links to support growing aviation need.

ICAO Position:

~~To support ITU-R studies as called for by Resolution **429 (WRC-19)**~~. To support~~, based on agreed studies, the necessary~~ modification of Appendix 27 to the Radio Regulations <u>for explicitly recognizing digital</u>~~ that will enable the introduction of~~ HF wideband aeronautical communication systems <u>in a manner fully compatible with existing aeronautical HF assignments, and without modifying the Appendix 27 allotment plan</u>. Those systems shall be operated in accordance with international Standards and Recommended Practices and procedures established in accordance with the Convention on International Civil Aviation.

WRC-23 Agenda Item 1.10

Agenda Item Title:

to conduct studies on spectrum needs, coexistence with radiocommunication services and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications, in accordance with Resolution 430 (WRC-19).

Discussion:

As technology has developed and miniaturization has advanced, it has become possible to use aircraft as platforms for payload applications such as fire and border surveillance, air quality and environment monitoring, video surveillance, terrain mapping, and imagery such as film-making. As a result, the number of aircraft equipped with sensors and the demand for associated communication links to offload large amounts of data has also grown and is expected to continue to grow. Those communication links, whilst not associated with aeronautical safety, can be mission critical in providing data or sensor control for the application that they are supporting.

At the same time, there is no clear identification of the frequency bands in which non-safety aeronautical mobile applications can operate, due in-part to the limitations often placed on existing mobile allocations that either preclude or place technical/operational restrictions that are not compatible with aeronautical use. This has stifled further development due to a lack of confidence within the industry of long-term spectrum access and stability.

In consequence, there is a need for adaptation of the current regulatory framework in order to clearly identify spectrum that could only be used for aeronautical payload communication, giving the industry the stability it needs to allow it to develop innovative applications that can deliver tangible benefits. However, it is important that there is a clear distinction between such systems and those used to provide safety and regularity of flight communications, including UAS command and control functions.

The objective of this agenda item is to assess spectrum requirements for new non-safety aeronautical mobile service applications and seek:

- possible new primary allocations to the aeronautical mobile service in frequency band 15.4-15.7 GHz for such non-safety aeronautical applications, and
- possible revision ~~or deletion~~ of the “except aeronautical mobile” in the frequency band 22-22.21 GHz, already allocated on a primary basis to the mobile, except aeronautical mobile, service.

ICAO Position:

~~To support ITU-R studies as called for by Resolution **430 (WRC-19)**~~. ~~To support, b~~Based upon the agreed results of studies, not to oppose new allocations to the aeronautical mobile service ~~only~~ for use by non-safety aeronautical mobile applications on a primary basis in the frequency bands 15.4-15.7 GHz and 22-22.21 GHz. To ensure that any such modification does not adversely affect the status or provision of aeronautical safety services.

WRC-23 Agenda Item 1.11

Agenda Item Title:

to consider possible regulatory actions to support the modernization of the Global Maritime Distress and Safety System (GMDSS) and the implementation of e-navigation, in accordance with Resolution 361 (Rev.WRC-19).

Discussion:

Aircraft, of which helicopters are a subset, are an integral part of the global maritime distress and safety system, providing a rapid search capability that can affect a rescue or direct surface vessels to the scene of the incident. As such, they are fitted with appropriate global maritime distress and safety system (GMDSS) radio equipment to facilitate such activities. It is therefore essential to ensure that any change to the regulatory provisions and spectrum allocations resulting from this agenda item do not adversely impact on the capability of search and rescue aircraft to effectively communicate with vessels during disaster relief operations.

In addition, ICAO requires, inter alia, that satellite systems supporting aeronautical satellite safety communications (aeronautical mobile-satellite (route) service), must comply with priority requirements contained in ICAO Standards and Recommended Practices (SARPs). Therefore, if a system which already carries such communications were to be approved by the International Maritime Organization and identified to carry GMDSS, any resultant changes to the Radio Regulations should not adversely impact that, or other, system's SARPs compliance

ICAO Position:

To ensure that any change to the regulatory provisions and spectrum allocations resulting from this agenda item do not adversely impact on the capability of search and rescue aircraft, including helicopters, to effectively communicate with vessels during disaster-relief operations. With respect to Resolution **361** (**Rev. WRC-19**), resolves 3, to~~To~~ ensure that any regulatory provisions in response to this agenda item do not adversely affect the compliance of aeronautical mobile-satellite (route) service systems in the frequency band 1 610–1 626.5 MHz with international standards and recommended practices and procedures established in accordance with the Convention on International Civil Aviation.

WRC-23 Agenda Item 1.13

Agenda Item Title:

to consider a possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service, in accordance with Resolution 661 (WRC-19).

Discussion:

Under this agenda item, the following studies are to be conducted:

a) to investigate and identify all relevant scenarios between data relay satellites, non-geostationary satellites and manned flights in the space research service operating in the frequency band 14.8-15.35 GHz, to investigate and identify all relevant scenarios that need to be considered in compatibility and sharing studies, taking into account the latest relevant ITU Radiocommunication Sector (ITU-R) Recommendations,

b) to conduct and complete in time for WRC-23 sharing and compatibility studies in order to determine the feasibility of upgrading the SRS allocation to primary status in the frequency band 14.8-15.35 GHz, with a view to ensuring protection of the primary services,

c) to determine the technical and regulatory conditions according to the results of the studies necessary to ensure b) above.

Currently, the frequency band 14.8-15.35 GHz is allocated to the generic mobile and fixed services on a primary basis. According to Recommendations ITU-R M. 2089 mentioned in *noting a)* of Resolution **661** (**WRC-19**), systems operating in the aeronautical mobile service in the frequency range 14.5-15.35 GHz are used by airborne data links to support remote sensing applications on board either manned or unmanned aircraft. In addition, in some States systems operating under the fixed service allocation are used to support air traffic operations. Neither of these applications use ICAO standardized systems.

ICAO Position:

~~To support studies called for by Resolution **661** (WRC 19) ensuring that they take account of systems operating in the aeronautical mobile service.~~ To ensure that any radio regulatory action taken as a result of agreed studies does not adversely affect the provision of aeronautical services.

WRC-23 Agenda Item 1.15

Agenda Item Title:

to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally, in accordance with Resolution 172 (WRC-19).

Discussion:

This agenda item seeks to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on board an aircraft or vessel communicating with geostationary space stations in the fixed satellite service operating in accordance with the provisions of Appendix **30B** (No **5.441**). It resolves that such earth stations shall not be used or relied upon for safety-of-life applications nor result in changes or restrictions to existing Plan allotments and List assignments made under Appendix **30B**.

Resolution **172 (WRC-19)** calls for studies to:

- Identify the technical and operational characteristics and user requirements of earth stations on aircraft and vessels that communicate or plan to communicate with geostationary (GSO) space stations in the FSS in the frequency band 12.75-13.25 GHz (Earth-to-space) under the envelope of Appendix **30B** Article 6 recorded in the List or the Master International Frequency Register (MIFR) with favourable finding only,
- address the sharing and compatibility issues between earth stations on aircraft and vessels communicating with GSO space stations in the fixed satellite service with current and planned stations of existing services as well as services in adjacent frequency bands,
- to study the responsibility of the entities involved in the operation of the earth stations on aircraft and vessels,
- to develop the criteria to ensure that earth stations on aircraft and vessels, as a new FSS application in this frequency band, shall not claim more protection nor cause more interference than filed earth stations in Appendix **30B**.

Once consensus has been reached on those studies the Resolution calls on the ITU-R to develop technical conditions and regulatory provisions for the harmonised operation of earth stations on aircraft and vessels communicating with GSO space stations in the FSS operating in the frequency band 12.75-13.25 GHz (Earth-to-space). Those technical conditions and regulatory provisions shall ensure the protection of and not impose undue constraints on, the existing services in that frequency band. Additionally, they shall not adversely affect the criteria contained in Annex 4 to Appendix **30B** including the cumulative effect of multiple earth stations on aircraft and vessels nor limit access of other administrations to their national resources in Appendix **30B**.

WRC-23 should then consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period whilst ensuring that any action taken does not result in any additional status than that of the GSO satellite networks with which these stations are communicating.

The introduction of earth station in motion operations into a frequency band that is subject to Appendix **30B** restrictions could provide a welcome additional capacity for non-safety passenger/payload communication. Additionally, given the restriction that such use shall not be or relied upon for safety-of-life communication this agenda item should not adversely affect the provision of aeronautical safety service~~ nor set a precedent for their provision~~. However, how this agenda item develops needs to be monitored to ensure that modifications are not introduced that change that expectation.~~ For example, nothing should be introduced that implies that aeronautical safety communications can occur on a Secondary basis.~~

See also agenda item 1.16.

ICAO Position:

To ensure that any radio regulatory action, taken as a result of this agenda item, ~~neither~~does not adversely ~~affects~~affect the provision of aeronautical safety-of-life services~~ nor sets an unwanted precedent~~.

WRC-23 Agenda Item 1.16

Agenda Item Title:

to study and develop technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-geostationary fixed-satellite service earth stations in motion, while ensuring due protection of existing services in those frequency bands, in accordance with Resolution 173 (WRC 19).

Discussion:

This agenda item seeks to extend the concept of earth stations in motion (ESIMs) communicating with geostationary space stations, to operation of ESIMs with non-geostationary space stations in the fixed satellite service (FSS) to the 17.7-18.6 GHz, 18.8-19.3 GHz, 19.7-20.2 GHz (space-to-Earth), 27.5-29.1 GHz and 29.5-30 GHz frequency bands.

Resolution **173 (WRC-19)** calls for studies to:

- identify the technical and operational characteristics and user requirements of the different types of ESIMs that plan to operate within non-geostationary (non-GSO) satellite systems operating in the FSS in the frequency bands or parts thereof identified,
- address the sharing and compatibility between ESIMs communicating with non-GSO FSS systems and current & planned stations of primary services allocated in the frequency bands identified as well as in the adjacent frequency bands.

The Resolution also calls on the ITU-R to develop technical conditions and regulatory provisions for the operation of aeronautical and maritime ESIMs communicating with non-GSO space stations operating in the FSS in the frequency bands identified. Those technical conditions and regulatory provisions shall ensure the protection of and not impose additional constraints on the existing services in the frequency bands identified.

ITU-R should also consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period.

It should be noted that the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz are identified within Resolution **155 (Rev. WRC-19)** for the provision of unmanned aircraft systems (UAS) control and non-payload communication (CNPC). However, both Resolution **156 (WRC-15)** that regulates the use of these frequency bands for ESIMs communicating to GSO satellites and Resolution **173 (WRC-19)** that seeks to facilitate the use of ESIMs communicating to non-GSO satellites in these frequency bands preclude the use of the relevant ESIMs from being used or relied upon for safety-of-life applications. The implications of any proposed amendment under agenda item 1.16 to the Radio Regulations need to be assessed and action taken if they:

- could adversely affect the provision of UAS CNPC under Resolution **155 (Rev.WRC-19)**,
- do not make a clear regulatory distinction between satellite networks or satellite network resources providing UAS CNPC and those providing non-safety ESIMs applications such that it does not set a precedent that could adversely affect the provision of aeronautical safety-of-life services.~~,~~
- ~~set a precedent, such as giving the impression that safety communications can occur on a Secondary basis, that could adversely affect the provision of aeronautical safety-of-life services.~~

See also ~~a~~Agenda ~~i~~Items 1.8, 1.15 and 1.17.

ICAO Position:

To ensure that any radio regulatory action taken as a result of this agenda item:

- do not adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19)**;
- make a clear regulatory distinction between satellite networks or satellite network resources providing UAS CNPC and those providing non-safety ESIMs applications~~;~~ such that it does
- ~~do~~ not set a precedent that could adversely affect the provision of aeronautical safety-of-life services.

WRC-23 Agenda Item 1.17

Agenda Item Title:

to determine and carry out, on the basis of ITU R studies in accordance with Resolution 773 (WRC 19), the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate.

Discussion:

Inter-satellite links have traditionally been used to relay communication between space stations, normally situated on non-geostationary satellites, and an earth station where direct communication is impeded for some reason such as being beyond visual line of sight. With the planned expansion in the use of low earth orbit satellites the demand for inter-satellite links and associated spectrum is also increasing. This agenda item seeks to develop the technical conditions and regulatory provisions, including potential new allocations to the inter-satellite service, by which the different types of space station can operate inter-satellite links in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz.

Resolution **773 (WRC-19)** calls for studies to:

- identify the technical and operational characteristics, including spectrum requirements, for transmissions between space stations in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz,
- address the sharing and compatibility between satellite-to-satellite links intending to operate between space stations in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz and current and planned stations of the FSS and other existing services allocated in same frequency bands and adjacent frequency bands,

Based on those studies the Resolution calls on the ITU-R to develop, for different types of space stations, the technical conditions and regulatory provisions for satellite-to-satellite operations, including potential new inter-satellite service allocations, in the frequency bands identified.

WRC-23 should then consider the relevant regulatory action necessary based on the work, as detailed above, undertaken during this study period whilst ensuring the protection of the fixed and mobile services allocated on a primary basis within the identified frequency bands.

It should be noted that the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz are identified within Resolution **155 (Rev. WRC-19)** for the provision of unmanned aircraft systems (UAS) control and non-payload communication (CNPC). It is therefore important that the implications of any proposed amendment under agenda item 1.17 to the Radio Regulations are assessed and action taken if they could adversely affect the provision of UAS CNPC under Resolution **155 (Rev. WRC-19)**~~,~~.

See also ~~a~~Agenda ~~i~~Items 1.8 and 1.16.

ICAO Position:

To ensure that, given the overlap in frequency bands, any radio regulatory action taken as a result of this agenda item does not adversely affect the protection of the GSO stations in the frequency bands listed in ~~the provision of UAS CNPC under~~ Resolution **155 (Rev. WRC-19)**~~,~~.

WRC-23 Agenda Item 4

Agenda Item Title:

in accordance with Resolution 95 (Rev.WRC-19), to review the Resolutions and Recommendations of previous conferences with a view to their possible revision, replacement or abrogation.

ICAO Position:

Resolutions:

Resolution No.	*Title*	*Action recommended*
18 *(Rev. WRC-15)*	Relating to the procedure for identifying and announcing the position of ships and aircraft of States not parties to an armed conflict.	No change
20 *(Rev. WRC-03)*	Technical cooperation with developing countries in the field of aeronautical telecommunications.	No change
26 *(Rev. WRC-19)*	Footnotes to the Table of Frequency Allocations in Article **5** of the Radio Regulations.	No change
27 *(Rev. WRC-19)*	Use of incorporation by reference in the Radio Regulations.	No change
63 *(Rev. WRC-12)*	Protection of radiocommunication services against interference caused by radiation from industrial, scientific and medical (ISM) equipment.	No change
76 *(Rev. WRC-15)*	Protection of geostationary fixed-satellite service and geostationary broadcasting-satellite service networks from the maximum aggregate equivalent power flux-density produced by multiple non-geostationary fixed-satellite service systems in frequency bands where equivalent power flux-density limits have been adopted.	No change
95 *(Rev. WRC19)*	General review of the resolutions and recommendations of world administrative radio conferences and world radiocommunication conferences.	No change
114 *(Rev. WRC-15)*	Studies on compatibility between new systems of the aeronautical radionavigation service and the fixed-satellite service (Earth-to-space) (limited to feeder links of the non-geostationary mobile-satellite systems in the mobile-satellite service) in the frequency band 5 091-5 150 MHz.	No change

Resolution No.	***Title***	***Action recommended***
140 *(Rev. WRC-15)*	Measures and studies associated with the equivalent power flux-density (epfd) limits in the band 19.7-20.2 GHz.	No change
154 *(WRC-15)*	Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1.	No change
155 *(Rev. WRC-19)*	Regulatory provisions related to earth stations on board unmanned aircraft which operate with geostationary-satellite networks in the fixed-satellite service in certain frequency bands not subject to a plan of Appendices 30, 30A and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces.	Subject to WRC-23 Agenda Item 1.8.
156 *(WRC-15)*	Use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service	Modify if necessary to ensure clear ~~delineation~~distinction between ESIMs providing non-safety applications and unmanned aircraft control and non payload communication covered in Resolution **155 (Rev. WRC-19)**.
160 *(WRC-15)*	Facilitating access to broadband applications delivered by high-altitude platform stations.	Suppress based on the results of studies carried out under WRC-19 Agenda Item 1.14.
165 *(WRC-19)*	Use of the frequency band 21.4-22 GHz by high-altitude platform stations in the fixed service in Region 2	No change
166 *(WRC-19)*	Use of the frequency band 24.25-27.5 GHz by high-altitude platform stations in the fixed service in Region 2	No change

Resolution No.	*Title*	*Action recommended*
167 *(WRC-19)*	Use of the frequency band 31-31.3 GHz by high-altitude platform stations in the fixed service	No change
168*(WRC-19)*	Use of the frequency band 38-39.5 GHz by high-altitude platform stations in the fixed service	No change
~~**169** *(WRC-19)*~~	~~Use of the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service~~	~~Modify if necessary to ensure that the provisions for ESIMs do not limit the use of unmanned aircraft control and non payload communication covered in Resolution **155** ***(Rev. WRC-19)***.~~
171 *(WRC-19)*	Review and possible revision of Resolution **155 (Rev.WRC-19)** and No. **5.484B** in the frequency bands to which they apply	Subject to WRC-23 Agenda Item 1.8.
172 *(WRC-19)*	Operation of earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service in the frequency band 12.75-13.25 GHz (Earth-to-space)	Subject to WRC-23 Agenda Item 1.15.
173 *(WRC-19)*	Use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by earth stations in motion communicating with non-geostationary space stations in the fixed-satellite service	Subject to WRC-23 Agenda Item1.16.
176 *(WRC-19)*	Use of the frequency bands 37.5-39.5 GHz (space-to-Earth), 40.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) by aeronautical and maritime earth stations in motion communicating with geostationary space stations in the fixed-satellite service	Modify or suppress as necessary based on the results of studies carried out (preliminary WRC-27 Agenda Item 2.2).
205 *(Rev. WRC-19)*	Protection of the systems operating in the mobile satellite service in the band 406-406.1 MHz.	No change

Resolution No.	***Title***	***Action recommended***
207 *(Rev. WRC-15)*	Measures to address unauthorized use of and interference to frequencies in the bands allocated to the maritime mobile service and to the aeronautical mobile (R) service.	No change
217 *(WRC-97)*	Implementation of wind profiler radars.	No change
222 *(Rev. WRC-12)*	Use of the frequency bands 1 525-1 559 MHz and 1 626.5-1 660.5 MHz by the mobile-satellite service, and procedures to ensure long-term spectrum access for the aeronautical mobile-satellite (R) service.	No change
223 *(Rev WRC-19)*	Additional frequency bands identified for International Mobile Telecommunications	Modify, retain, or suppress, *invites the ITU Radiocommunications Sector* 1 to Resolution **223**, as appropriate, reflecting the need for continued studies, based on the results of the studies called for by that provision.
225 *(Rev. WRC-12)*	Use of additional frequency bands for the satellite component of IMT.	No change
229 *(Rev. WRC-19)*	Use of the frequency bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks	No change
240 *(WRC-19)*	Spectrum harmonization for railway radiocommunication systems between train and trackside within the existing mobile-service allocations.	Monitor studies and ensure protection of aeronautical systems.
245 *(WRC-19)*	Studies on frequency-related matters for the terrestrial component of International Mobile Telecommunications identification in the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz	Subject to WRC-23 Agenda Item 1.2.
246 *(WRC-19)*	Studies to consider possible allocation of the frequency band 3 600-3 800 MHz to the mobile, except aeronautical mobile, service on a primary basis within Region 1	Subject to WRC-23 Agenda Item 1.3.

Resolution No.	***Title***	***Action recommended***
247 *(WRC-19)*	Facilitating mobile connectivity in certain frequency bands below 2.7 GHz using high-altitude platform stations as International Mobile Telecommunications base stations	Subject to WRC-23 Agenda Item 1.4.
249 *(WRC-19)*	Study of technical and operational issues and regulatory provisions for space-to-space transmissions in the Earth-to-space direction in the frequency bands [1 610-1 645.5 and 1 646.5-1 660.5 MHz] and the space-to-Earth direction in the frequency bands [1 525-1 544 MHz], [1 545-1 559 MHz], [1 613.8-1 626.5 MHz] and [2 483.5-2 500 MHz] among non-geostationary and geostationary satellites operating in the mobile-satellite service	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.8)
250 *(WRC-19)*	Studies on possible allocations to the land mobile service (excluding International Mobile Telecommunications) in the frequency band 1 300-1 350 MHz for use by administrations for the future development of terrestrial mobile-service applications	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.9)
251 *(WRC-19)*	Removal of the limitation regarding aeronautical mobile in the frequency range 694-960 MHz for the use of International Mobile Telecommunications user equipment by non-safety applications	Modify or suppress as necessary based on the results of studies carried out for WRC-27 (preliminary WRC-27 Agenda Item 2.12)
339 *(Rev. WRC-07)*	Coordination of NAVTEX services.	No change
354 *(WRC-07)*	Distress and safety radiotelephony procedures for 2 182 kHz.	No change
356 *(WRC-07)*	ITU maritime service information registration.	No change
361 *(Rev. WRC-19)*	Consideration of regulatory provisions for modernization of the global maritime distress and safety system and related to the implementation of e-navigation.	Subject to WRC-23 Agenda Item 1.11.
405 *(Geneva 1979)*	Relating to the use of frequencies of the aeronautical mobile (R) service.	Subject to WRC-23 ~~a~~Agenda ~~i~~Item 1.9.
413 *(Rev. WRC-12)*	Use of the band 108-117.975 MHz by aeronautical service.	No change
417 *(Rev. WRC-12)*	Use of the frequency band 960-1 164 MHz by the aeronautical mobile (R) service.	No change
418 (*Rev. WRC-15*)	Use of the band 5 091-5 250 MHz by the aeronautical mobile service for telemetry applications.	No change

Resolution No.	*Title*	*Action recommended*
422 *(WRC-12)*	Development of methodology to calculate aeronautical mobile-satellite (R) service spectrum requirements within the frequency bands 1 545-1 555 MHz (space-to-Earth) and 1 646.5-1 656.5 MHz (Earth-to-space).	Suppress as a result of the approval of Recommendation ITU-R M.2091.
424 *(WRC-15)*	Use of wireless avionics intra-communications in the frequency band 4 200-4 400 MHz.	No change
425 *(Rev. WRC-19)*	Use of the frequency band 1 087.7-1 092.3 MHz by the aeronautical mobile-satellite (R) service (Earth-to-space) to facilitate global flight tracking for civil aviation.	No change
428 *(WRC-19)*	Studies on a possible new allocation to the aeronautical mobile-satellite (R) service within the frequency band 117.975-137 MHz in order to support aeronautical VHF communications in the Earth-to-space and space-to-Earth directions	Subject to WRC-23 Agenda Item 1.7.
429 *(WRC-19)*	Consideration of regulatory provisions for updating Appendix 27 of the Radio Regulations in support of aeronautical HF modernization	Subject to WRC-23 Agenda Item 1.9.
430 *(WRC-19)*	Studies on frequency-related matters, including possible additional allocations, for the possible introduction of new non-safety aeronautical mobile applications	Subject to WRC-23 Agenda Item 1.10.
608 *(Rev. WRC-19)*	Use of the frequency band 1 215-1 300 MHz by systems of the radionavigation satellite service.	No change
609 *(Rev. WRC-07)*	Protection of aeronautical radionavigation systems from the equivalent power flux-density produced by radionavigation satellite service networks and systems in the 1 164-1 215 MHz band.	No change
610 *(Rev. WRC-19)*	Coordination and bilateral resolution of technical compatibility issues for radionavigation satellite networks and systems in the band 1 164-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz.	No change
612 (*Rev. WRC-12*)	Use of the radiolocation service between 3 and 50 MHz to support oceanographic radar operations.	No change
660 (*WRC-19*)	Use of the frequency band 137-138 MHz by non-geostationary satellites with short-duration missions in the space operation service.	No change
661 *(WRC-19)*	Examination of a possible upgrade to primary status of the secondary allocation to the space research service in the frequency band 14.8-15.35 GHz	Subject to WRC-23 Agenda Item 1.13.
705 *(Rev. WRC-15)*	Mutual protection of radio services operating in the band 70-130 kHz.	No change
729 *(Rev. WRC-07)*	Use of frequency adaptive systems in the MF and HF bands.	No change

Resolution No.	*Title*	*Action recommended*
748 (*Rev. WRC-19*)	Compatibility between the aeronautical mobile (R) service and the fixed satellite service (Earth-to-space) in the band 5 091-5 150 MHz.	No change
762 *(WRC-15)*	Application of power flux density criteria to assess the potential for harmful interference under 11.32A for fixed-satellite and broadcasting-satellite service networks in the 6 GHz and 10/11/12/14 GHz bands not subject to a plan.	No change
772 *(WRC-19)*	Consideration of regulatory provisions to facilitate the introduction of sub-orbital vehicles.	Subject to WRC-23 ~~a~~Agenda ~~i~~Item 1.6.
773 *(WRC-19)*	Study of technical and operational issues and regulatory provisions for satellite-to-satellite links in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8 20.2 GHz and 27.5-30 GHz	Subject to WRC-23 ~~a~~Agenda ~~i~~Item 1.17.
774 *(WRC-19)*	Studies on technical and operational measures to be applied in the frequency band 1 240-1 300 MHz to ensure the protection of the radionavigation-satellite service (space-to-Earth)	Subject to WRC-23 ~~a~~Agenda ~~i~~Item 9.1 topic b.

2.3

Recommendations:

Recommendation No.	**Title**	***Action recommended***
7 *(Rev. WRC-97)*	Adoption of standard forms for ship station and ship earth station licences and aircraft station and aircraft earth station licences.	No change
9	Relating to the measures to be taken to prevent the operation of broadcasting stations on board ships or aircraft outside national territories.	No change
71	Relating to the standardization of the technical and operational characteristics of radio equipment.	No change
75 *(Rev. WRC-15)*	Study on the boundary between the out-of-band and spurious domains of primary radars using magnetrons.	No change
401	Relating to the efficient use of aeronautical mobile (R) worldwide frequencies.	No change
608 *(Rev. WRC-07)*	Guidelines for consultation meetings established in Resolution **609 (WRC-07)**.	No change

WRC-23 Agenda Item 8

Agenda Item Title:

to consider and take appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes, if no longer required, taking into account Resolution 26 (Rev.WRC-19).

Discussion:

Allocations to the aeronautical services are generally made for all ITU regions and normally on an exclusive basis. These principles reflect the global process of standardization within ICAO for the promotion of safety and to support the global interoperability of radiocommunication and radionavigation equipment used in civil aircraft. In some instances, however, footnotes to the ITU Table of Frequency Allocations allocate spectrum in one or more countries to other radio services in addition or alternatively to the aeronautical service to which the same spectrum is allocated in the body of the table.

The use of country footnote allocations to non-aeronautical services in aeronautical bands is generally not recommended by ICAO, on safety grounds, as such use may result in harmful interference to safety services. Furthermore, this practice generally leads to an inefficient use of available spectrum to aeronautical services, particularly when the radio systems sharing the band have differing technical characteristics. It also may result in undesirable (sub-) regional variations with respect to the technical conditions under which the aeronautical allocations can be used. This can have a serious impact on the safety of aviation.

The following footnotes in aeronautical bands should be carefully reviewed by administrations in order to preserve the safety and efficiency of aeronautical services for the reasons as discussed below:

a) In the frequency bands used for the ICAO instrument landing system (ILS), (marker beacons 74.8-75.2 MHz; localizer 108-112 MHz and glide path 328.6-335.4 MHz) and the VHF omnidirectional radio range system (VOR); 108-117.975 MHz, Nos. **5.181**, **5.197** and **5.259** allow for the introduction of the mobile service on a secondary basis and subject to agreement obtained under No. **9.21** of the Radio Regulations when these bands are no longer required for the aeronautical radionavigation service. The use of both ILS and VOR is expected to continue. In addition, WRC-03, as amended by WRC-07, has introduced No. **5.197A** stipulating that the band 108-117.975 MHz is also allocated on a primary basis to the aeronautical mobile (R) service (AM(R)S), limited to systems operating in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **413 (Rev. WRC-12)**. The use of the band 108-112 MHz by the AM(R)S shall be limited to systems composed of ground-based transmitters and associated receivers that provide navigational information in support of air navigation functions in accordance with recognized international aeronautical standards. ICAO encourages administrations listed in Nos. **5.181**, **5.197** and **5.259** to review their use and if no longer required, to remove their country's name from these footnotes.

b) Nos. **5.201** and **5.202** allocate the frequency bands 132-136 MHz and 136-137 MHz in some States to the aeronautical mobile (off-route) service (AM(OR)S). Since these frequency bands are heavily utilized for ICAO-standard VHF voice and data communications, ICAO encourages those concerned administrations to review their use and if no longer required, to remove their country's name from these footnotes.

c) In the frequency band 1 215-1 300 MHz, which is used by civil aviation for the provision of radionavigation services through No. **5.331**. Footnote No. **5.330** allocates the band in a number of countries to the fixed and mobile service. Given the receiver sensitivity of aeronautical uses of the frequency band, ICAO does not support the continued inclusion of an additional service through country footnotes. ICAO would therefore encourage administrations to review their use and if no longer required, to remove their country's name from No. **5.330**.

d) in the frequency band 1 525-1 530 MHz, which is used by civil aviation for the provision of satellite services No. **5.352A** specifies that stations in the mobile-satellite service, except stations in the maritime mobile-satellite service, shall not cause harmful interference to, or claim protection from, stations of the fixed service in a number of countries that were notified prior to 1 April 1998. As of August 2020, the ITU Master International Frequency Register shows out of 20 administrations listed in this footnote, only 4 Administrations have fixed stations notified prior to 1 April 1998. ICAO would therefore encourage Administrations listed in the footnote to review their use of fixed service assignments in 1 525-1 530 MHz, and if no longer required, to remove their country's name from No. **5.352A**.

e) In the frequency bands 1 540-1 559 MHz, 1 610.6-1 613.8 MHz and 1 613.8-1 626.5 MHz, within which some portions are assigned to or used by the aeronautical mobile-satellite (R) service, No. **5.355** also allocates the band on a secondary basis to the fixed service in a number of countries. Given that portions of these bands are utilized by a safety-of-life service, ICAO does not support the continued use of No **5.355** country footnote. ICAO encourages those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.355**.

f) In the frequency bands 1 550-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz which are assigned to mobile-satellite services, including in some portions assignment to or use by the aeronautical mobile-satellite (R) service, No. **5.359** also allocates the bands to the fixed service on a primary basis in a number of countries. Given that portions of these bands are utilized by a safety-of-life service, ICAO does not support the continued use of No. **5.359** country footnote. ICAO would therefore encourage those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.359**.

g) In the frequency band 4 200-4 400 MHz, which is reserved for use by airborne radio altimeters and wireless avionics intra-communications (WAIC), No. **5.439** allows the operation of the fixed service on a secondary basis in some countries. Radio altimeters are a critical element in aircraft automatic landing systems and serve as a sensor in ground proximity warning systems. WAIC provides aircraft safety communications between points on an airframe. Interference from the fixed service has the potential to affect the safety of both of these systems. ICAO would therefore encourage those concerned administrations to review their use and if no longer required, to remove their country's name from No. **5.439**.

ICAO Position:

To encourage administrations listed in the footnotes to review Nos. **5.181, 5.197** and **5.259**, as access to the frequency bands 74.8-75.2, 108-112 and 328.6-335.4 MHz by the mobile service is difficult and could create the potential for harmful interference to important radionavigation systems used by aircraft at final approach and landing as well as systems operating in the aeronautical mobile service in the frequency band 108-112 MHz.

To encourage administrations listed in the footnotes to review Nos. **5.201 and 5.202**, as use by the AM(OR)S of the frequency bands 132-136 MHz and 136-137 MHz in some States may cause harmful interference to current and future aeronautical safety communications.

To encourage administrations listed in the footnote to review No. **5.330** as access to the frequency band 1 215-1 300 MHz by the fixed and mobile services could potentially cause harmful interference to services used to support aircraft operations.

To encourage administrations listed the footnote to review No. **5.352A** as access to the frequency bands 1 525-1 530 MHz by the fixed services could potentially constrain aeronautical use of this frequency band.

To encourage administrations listed in the footnote to review No. **5.355** as access to the frequency bands 1 540-1 559, 1 610.6-1 613.8 and 1 613.8-1 626.5 MHz by the fixed services could potentially constrain aeronautical use of these frequency bands.

To encourage administrations listed in the footnote to review No. **5.359** as access to the frequency bands 1 550-1 559 MHz, 1 610-1 645.5 MHz and 1 646.5-1 660 MHz by the fixed services could potentially jeopardize aeronautical use of those frequency bands.

To encourage administrations listed in the footnote to review No. **5.439** to ensure the protection of the safety critical operation of radio altimeters and WAIC systems in the frequency band 4 200-4 400 MHz.

ICAO would encourage administrations to take appropriate actions under this agenda item to remove their country's name from these footnotes if no longer required.

Note 1.— Administrations indicated in the footnotes mentioned in the ICAO Position above which are urged to remove their country names from these footnotes are as follows:

No. ***5.181*** *Egypt, Israel and Syrian Arab Republic No.*

No. ***5.197*** *Syrian Arab Republic*

No. ***5.201*** *Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, the Russian Federation, Georgia, Hungary, Iran (Islamic Republic of), Iraq (Republic of), Japan, Kazakhstan, Mali, Mongolia, Mozambique, Uzbekistan, Papua New Guinea, Poland, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine*

No. ***5.202*** *Saudi Arabia, Armenia, Azerbaijan, Bahrain, Belarus, Bulgaria, the United Arab Emirates, the Russian Federation, Georgia, Iran (Islamic Republic of), Jordan, Mali, Oman, Uzbekistan, Poland, the Syrian Arab Republic, Kyrgyzstan, Romania, Senegal, Tajikistan, Turkmenistan and Ukraine*

No. ***5.259*** *Egypt and Syrian Arab Republic*

No. ***5.330*** *Angola, Bahrain, Bangladesh, Cameroon, Chad, China, Djibouti, Egypt, Eritrea, Ethiopia, Guyana, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Kuwait, Nepal, Oman, Pakistan, the Philippines, Qatar, Saudi Arabia, Somalia, Sudan, South Sudan, the Syrian Arab Republic, Togo, the United Arab Emirates and Yemen*

No. ***5.355*** *Bahrain, Bangladesh, Congo (Rep of the), Djibouti, Egypt, Eritrea, Iraq, Israel, Kuwait, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Chad, Togo and Yemen*

No. ***5.352A*** *Algeria, Saudi Arabia, Egypt, Guinea, India, Israel, Italy, Jordan, Kuwait, Mali, Morocco, Mauritania, Nigeria, Oman, Pakistan, the Philippines, Qatar, Syrian Arab Republic, Viet Nam and Yemen*

No. ***5.359*** *Germany, Saudi Arabia, Armenia, Azerbaijan, Belarus, Cameroon, the Russian Federation, Georgia, Guinea, Guinea-Bissau, Jordan, Kazakhstan, Kuwait, Lithuania, Mauritania, Uganda, Uzbekistan, Pakistan, Poland, the Syrian Arab Republic, Kyrgyzstan, the Dem. People's Rep. of Korea, Romania, Tajikistan, Tunisia, Turkmenistan and Ukraine*

No. ***5.439*** *Iran (Islamic Republic of)*

WRC-23 Agenda Item 9.1

Agenda Item Title:

To consider and approve the report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Convention:

On the activities of the Radiocommunication Sector since WRC-19.

Note.— *The subdivision of Agenda Item* ***9.1*** *into topics, such as a), b), etc. was made at the first session of the Conference Preparatory Meeting for WRC-23 (CPM23-1) and is summarized in the BR Administrative Circular CA/251, 19th December 2019. In addition, a topic d) was added which was not part of Resolution* ***811 (WRC-19)*** *(the WRC-23 agenda), however was agreed by WRC-19 (see WRC-19 document 573 §§ 35.2 to 35.4).*

Topic 9.1, a:

In accordance with Resolution 657 (Rev.WRC-19), review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services;

Space weather observations from ground-based networks of space weather sensor systems are becoming more and more important for the detection of solar activity that can harmfully affect the operation of international civil aviation. Solar events, such as large solar flares and coronal mass ejections (CMEs), produce magnetic storms that can present serious aviation safety risks. These events can cause major disruptions to the communications, navigation, and surveillance (CNS) systems critical to the operation of aircraft electronic systems and the aeronautical systems necessary to the safe operation of the airspace.

Data from Space Weather Sensors are provided to space weather forecast and warning centers around the world for many applications. Space weather advisories for international air navigation are provided to aircraft operators for planning mitigations to any potential risks. These forecasts and warnings also allow operators of aeronautical systems the opportunity to put in place mitigations to protect their systems and services. The Sun is the primary source of space weather of interest for spectrum management of civil aviation CNS systems. In addition, there are experimental research activities and other users of space weather sensor data that are not used by aviation.

Currently, space weather sensor systems are deployed in some countries and operate over a very large frequency range of approximately 10 kHz–10 GHz based on existing ITU-R Reports. While space weather sensors systems may operate in a variety of frequency bands, these may not be the same between different countries as there is not a harmonized approach to the use of space weather sensors worldwide.

Within the ITU, some space weather sensors have been reported to operate in frequency bands that are critical to aircraft aeronautical communications, navigation, and surveillance. There are also active systems that operate in frequency bands used by aviation safety services on a non-interference basis. Some systems may not be used by ICAO to serve the purpose of space weather observation for flight planning and forecasting purposes.

ICAO Position:

To support continuation of ITU-R studies and support appropriate recognition in the Radio Regulations of space weather sensors, provided that space weather systems do not impact current or planned aeronautical systems or applications.

Topic 9.1, ~~(b)~~:

Review of the amateur service and the amateur-satellite service allocations in the frequency band 1 240-1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite (space-to-Earth) service operating in the same band in accordance with Resolution 774 (WRC-19).

The amateur service has a secondary allocation in the frequency band 1 240-1 300 MHz (known as the "23 cm band" by the amateur community) and is currently used for amateur voice, data and image transmission. The frequency band is also allocated on a primary basis to the following services:

- Table Allocation
  - Earth exploration-satellite (active)
  - Radiolocation
  - Radionavigation Satellite (space-to-Earth) (space-to-space)
  - Space research(active)
- Footnote Allocation within various Countries
  - 5.330 Fixed
  - 5.330 Mobile
  - 5.331 Radionavigation

In the frequency band 1 240-1 300 MHz radionavigation satellite service (RNSS) systems such as GLONASS, Galileo, Beidou & QZSS are either operational, or becoming operational in various parts of the world with the expectation of enhancing the accuracy, reliability and positional accuracy of the current systems as well as offering additional features. However, there have been confirmed reports of harmful interference to the RNSS being caused by amateur service systems. This agenda item seeks to identify additional technical and operational measures that could be implemented to improve the protection of those RNSS from amateur and amateur-satellite systems operating under the secondary allocations to the amateur and amateur-satellite service without removing those amateur allocations.

2.4 Within the frequency band 1 240-1 300 MHz aviation currently operates primary surveillance radars used in the provision of air traffic control services. Past research has indicated that RNSS systems such as those indicated above can cause harmful interference to radars. The concern is that action taken under this agenda item could adversely affect the provision of those primary radar services with a consequential impact on air traffic control.

ICAO Position:

To ensure that ~~ITU-R studies under Resolution **774 (WRC-19)** address whether potential~~any mitigation measures taken under this agenda item will not impact theprotection of aeronautical radar systems operating under the existing aeronautical radionavigation or radiolocation service allocations.

WRC-23 Agenda Item 9.2

Agenda Item Title:

To consider and approve the report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Convention:

on any difficulties or inconsistencies encountered in the application of the Radio Regulations[5].

The relevant ITU-R working parties are invited to carry out the requested studies, indicated below, and to report the results of the studies to the Director of the Radiocommunication Bureau to be considered as the Director deems appropriate.

From Resolution **427 (WRC-19)** "Updating provisions related to aeronautical services in the Radio Regulations – resolves to invite ITU-R States "to study the Articles, limited to Chapters IV, V, VI and VIII of Volume I of the Radio Regulations and their associated Appendices, as appropriate, in order to identify outdated aeronautical provisions with respect to ICAO Standards and Recommended Practices and to develop examples of regulatory texts for updating these provisions, while ensuring that potential changes to such provisions will not impact any other systems or services operating in accordance with the Radio Regulations". (Responsible Group: WP 5B).

ICAO Position:

~~Participate in ITU-R studies to ensure any proposed changes to the Radio Regulations recommended in the Director's Report to the WRC do~~<u>Any potential regulatory actions taken under this agenda item, should</u> not ~~impact~~<u>affect</u> current or planned aeronautical systems or applications.

[5] This agenda sub-item is strictly limited to the Report of the Director on any difficulties or inconsistencies encountered in the application of the Radio Regulations and the comments from administrations. Administrations are invited to inform the Director of the Radiocommunication Bureau of any difficulties or inconsistencies encountered in the Radio Regulations.

WRC-23 Agenda Item 10

Agenda Item Title:

to recommend to the ITU Council items for inclusion in the agenda for the next world radiocommunication conference, and items for the preliminary agenda of future conferences, in accordance with Article 7 of the ITU Convention and Resolution 804 (Rev.WRC-19),

Discussion:

ITU-R Resolution **812 (WRC-19)** contains the preliminary agenda for the 2027 World Radiocommunication Conference (WRC-27). Section 2.9 resolves: "*to consider possible additional spectrum allocations to the mobile service in the frequency band 1 300-1 350 MHz to facilitate the future development of mobile-service applications, in accordance with Resolution **250 (WRC-19)***".

The frequency band 1300-1350 MHz is used by multiple ICAO Member States for various types of long-range radar systems that measure range, bearing, and velocity of aircraft, and perform missions critical to safe and reliable air traffic control (ATC) as considered in Resolution **250 (WRC-19)**. These radar systems ensure the safe transportation of people and goods, encourage the flow of commerce, and provide for State air surveillance requirements. Long-range radars are operated in this frequency band due to the minimal atmospheric effects such as loss from rain and fog, and the low external background noise levels.

While Resolution **250 (WRC-19)** resolves to conduct sharing and compatibility studies to ensure protection of existing services to which the frequency band is allocated on a primary basis, the studies performed to date have not shown any potential for compatibility with the systems operated in this band. Furthermore, studies under WRC-15 Agenda Item 1.1 with IMT and the same incumbent radar systems demonstrated that co-frequency sharing was not possible. Therefore, there is significant concern for a new WRC-27 Agenda Item to add a Mobile Service allocation to the 1300-1350 MHz band that causes harmful interference to these incumbent radar systems and the potential for harm to public safety.

ICAO Position:

To oppose a new agenda item for WRC-27 for an additional spectrum allocation to the mobile service in the frequency band 1 300-1 350 MHz.

ATTACHMENT*

Agenda for the 2023 World Radiocommunication Conference

The World Radiocommunication Conference (Sharm el-Sheikh, 2019),

considering

a) that, in accordance with No. 118 of the ITU Convention, the general scope of the agenda for a world radiocommunication conference (WRC) should be established four to six years in advance and that a final agenda shall be established by the ITU Council two years before the conference;

b) Article 13 of the ITU Constitution relating to the competence and scheduling of WRCs and Article 7 of the Convention relating to their agendas;

c) the relevant resolutions and recommendations of previous world administrative radio conferences (WARCs) and WRCs,

recognizing

a) that this conference has identified a number of urgent issues requiring further examination by WRC-23;

b) that, in preparing this agenda, some items proposed by administrations could not be included and have had to be deferred to future conference agendas,

resolves

to recommend to the Council that a WRC be held in 2023 for a maximum period of four weeks, with the following agenda:

1 on the basis of proposals from administrations, taking account of the results of WRC-19 and the Report of the Conference Preparatory Meeting, and with due regard to the requirements of existing and future services in the frequency bands under consideration, to consider and take appropriate action in respect of the following items:

1.1 to consider, based on the results of ITU-R studies, possible measures to address, in the frequency band 4 800-4 990 MHz, protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories, and to review the power flux-density criteria in No. **5.441B** in accordance with Resolution **223 (Rev.WRC-19)**;

1.2 to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution **245 (WRC-19)**;

1.3 to consider primary allocation of the frequency band 3 600-3 800 MHz to the mobile service in Region 1 and take appropriate regulatory actions, in accordance with Resolution **246 (WRC-19)**;

* The text of the resolution included in this Annex has been copied from the ITU Radio Regulations, Edition of 2020, Volume III.

1.4 to consider, in accordance with Resolution **247 (WRC-19)**, the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT, on a global or regional level;

1.5 to review the spectrum use and spectrum needs of existing services in the frequency band 470-960 MHz in Region 1 and consider possible regulatory actions in the frequency band 470-694 MHz in Region 1 on the basis of the review, in accordance with Resolution **235 (WRC-15)**;

1.6 to consider, in accordance with Resolution **772 (WRC-19)**, regulatory provisions to facilitate radiocommunications for sub-orbital vehicles;

1.7 to consider a new aeronautical mobile-satellite (R) service allocation in accordance with Resolution **428 (WRC-19)** for both the Earth-to-space and space-to-Earth directions of aeronautical VHF communications in all or part of the frequency band 117.975-137 MHz, while preventing any undue constraints on existing VHF systems operating in the aeronautical mobile (R) service, in the aeronautical radionavigation service, and in adjacent frequency bands;

1.8 to consider, on the basis of ITU-R studies in accordance with Resolution **171 (WRC-19)**, appropriate regulatory actions, with a view to reviewing and, if necessary, revising Resolution **155 (Rev.WRC-19)** and No. **5.484B** to accommodate the use of fixed-satellite service networks by control and non-payload communications of unmanned aircraft systems;

1.9 to review Appendix **27** of the Radio Regulations and consider appropriate regulatory actions and updates based on ITU-R studies, in order to accommodate digital technologies for commercial aviation safety-of-life applications in existing HF bands allocated to the aeronautical mobile (R) service and ensure coexistence of current HF systems alongside modernized HF systems, in accordance with Resolution **429 (WRC-19)**;

1.10 to conduct studies on spectrum needs, coexistence with radiocommunication services and regulatory measures for possible new allocations for the aeronautical mobile service for the use of non-safety aeronautical mobile applications, in accordance with Resolution **430 (WRC-19)**;

1.11 to consider possible regulatory actions to support the modernization of the Global Maritime Distress and Safety System (GMDSS) and the implementation of e-navigation, in accordance with Resolution **361 (Rev.WRC-19)**;

1.12 to conduct, and complete in time for WRC-23, studies for a possible new secondary allocation to the Earth exploration-satellite service (active) for spaceborne radar sounders within the range of frequencies around 45 MHz, taking into account the protection of incumbent services, including in adjacent bands, in accordance with Resolution **656 (Rev.WRC-19)**;

1.13 to consider a possible upgrade of the allocation of the frequency band 14.8-15.35 GHz to the space research service, in accordance with Resolution **661 (WRC-19)**;

1.14 to review and consider possible adjustments of the existing frequency allocations or possible new primary frequency allocations to the Earth exploration-satellite service (passive) in the frequency range 231.5-252 GHz, to ensure alignment with more up-to-date remote-sensing observation requirements, in accordance with Resolution **662 (WRC-19)**;

1.15 to harmonize the use of the frequency band 12.75-13.25 GHz (Earth-to-space) by earth stations on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service globally, in accordance with Resolution **172 (WRC-19)**;

1.16 to study and develop technical, operational and regulatory measures, as appropriate, to facilitate the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by non-geostationary fixed-satellite service earth stations in motion, while ensuring due protection of existing services in those frequency bands, in accordance with Resolution **173 (WRC-19)**;

1.17 to determine and carry out, on the basis of ITU-R studies in accordance with Resolution **773 (WRC-19)**, the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate;

1.18 to consider studies relating to spectrum needs and potential new allocations to the mobile-satellite service for future development of narrowband mobile-satellite systems, in accordance with Resolution **248 (WRC-19)**;

1.19 to consider a new primary allocation to the fixed-satellite service in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2, while protecting existing primary services in the band, in accordance with Resolution **174 (WRC-19)**;

2 to examine the revised ITU-R Recommendations incorporated by reference in the Radio Regulations communicated by the Radiocommunication Assembly, in accordance with *further resolves* of Resolution **27 (Rev.WRC-19)**, and to decide whether or not to update the corresponding references in the Radio Regulations, in accordance with the principles contained in *resolves* of that Resolution;

3 to consider such consequential changes and amendments to the Radio Regulations as may be necessitated by the decisions of the conference;

4 in accordance with Resolution **95 (Rev.WRC-19)**, to review the Resolutions and Recommendations of previous conferences with a view to their possible revision, replacement or abrogation;

5 to review, and take appropriate action on, the Report from the Radiocommunication Assembly submitted in accordance with Nos. 135 and 136 of the ITU Convention;

6 to identify those items requiring urgent action by the radiocommunication study groups in preparation for the next world radiocommunication conference;

7 to consider possible changes, in response to Resolution 86 (Rev. Marrakesh, 2002) of the Plenipotentiary Conference, on advance publication, coordination, notification and recording procedures for frequency assignments pertaining to satellite networks, in accordance with Resolution **86 (Rev.WRC-07)**, in order to facilitate the rational, efficient and economical use of radio frequencies and any associated orbits, including the geostationary-satellite orbit;

8 to consider and take appropriate action on requests from administrations to delete their country footnotes or to have their country name deleted from footnotes, if no longer required, taking into account Resolution **26 (Rev.WRC-19)**;

9 to consider and approve the Report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the ITU Convention;

9.1 on the activities of the ITU Radiocommunication Sector since WRC-19:

– In accordance with Resolution **657 (Rev.WRC-19)**, review the results of studies relating to the technical and operational characteristics, spectrum requirements and appropriate radio service designations for space weather sensors with a view to describing appropriate recognition and protection in the Radio Regulations without placing additional constraints on incumbent services;

– Review the amateur service and the amateur-satellite service allocations in the frequency band 1 240-1 300 MHz to determine if additional measures are required to ensure protection of the radionavigation-satellite service (space-to-Earth) operating in the same band in accordance with Resolution **774 (WRC-19)**;

– Study the use of International Mobile Telecommunication systems for fixed wireless broadband in the frequency bands allocated to the fixed service on a primary basis, in accordance with Resolution **175 (WRC-19)**;

9.2 on any difficulties or inconsistencies encountered in the application of the Radio Regulations;[1] and

9.3 on action in response to Resolution **80 (Rev.WRC-07)**;

10 to recommend to the ITU Council items for inclusion in the agenda for the next world radiocommunication conference, and items for the preliminary agenda of future conferences, in accordance with Article 7 of the ITU Convention and Resolution **804 (Rev.WRC-19)**,

invites the ITU Council

to finalize the agenda and arrange for the convening of WRC-23, and to initiate as soon as possible the necessary consultations with Member States,

instructs the Director of the Radiocommunication Bureau

1 to make the necessary arrangements to convene meetings of the Conference Preparatory Meeting (CPM) and to prepare a report to WRC-23;

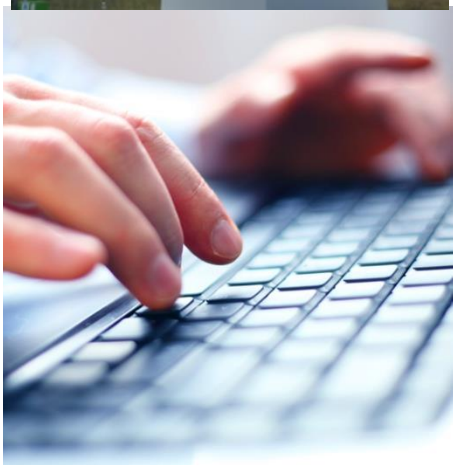
2 to submit a draft report on any difficulties or inconsistencies encountered in the application of the Radio Regulations referred in agenda item 9.2 to the second session of the CPM and to submit the final report at least five months before the next WRC,

instructs the Secretary-General

to communicate this Resolution to international and regional organizations concerned.

— END —

[1] This agenda sub-item is strictly limited to the Report of the Director on any difficulties or inconsistencies encountered in the application of the Radio Regulations and the comments from administrations. Administrations are invited to inform the Director of the Radiocommunication Bureau of any difficulties or inconsistencies encountered in the Radio Regulations.



Satellite VHF Coordination Group (CG-SV)

QUESTIONS AND ANSWERS ABOUT AMS(R)S concept

Date: 12/08/2022

Contents.

1 Doppler shift

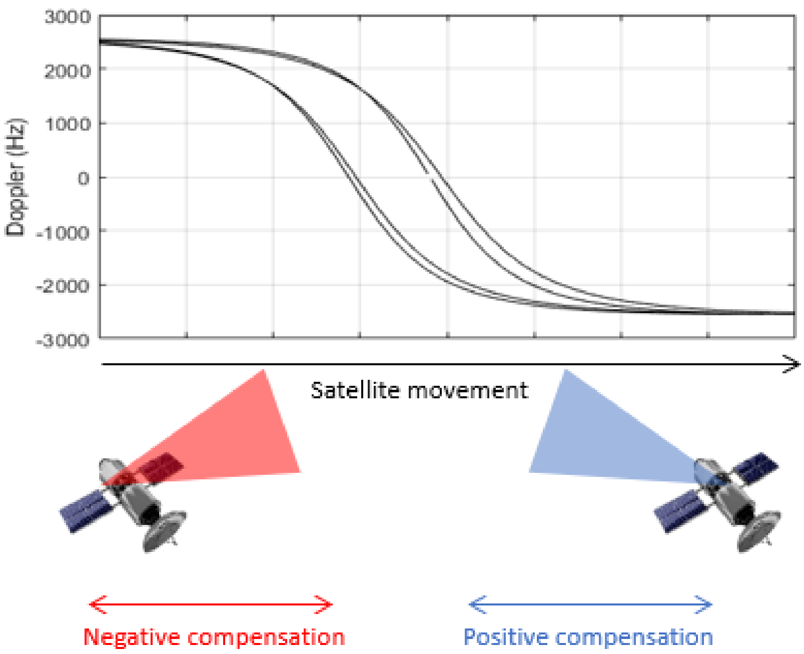
1.1 Given that the VHF analog voice use case assumes a “party line” for flight crew situational awareness in a particular airspace sector, and VDL Mode 2 utilizes Carrier Sense Media Access (CSMA) to minimize data packet collisions, any Doppler compensation by the satellite would have to ensure that all aircraft in the intended coverage area would still be able to correctly receive the satellite signal on the intended frequency. However, if the satellite shifts its transmitting frequency to compensate for Doppler shift for aircraft in front of the satellite, won’t that make it more problematic for aircraft behind the satellite to correctly receive the signal, since they would require a frequency shift in the opposite direction? Preliminary ITU studies have shown that it will be necessary to use LEO satellites which will result in a Doppler effect of up to +/-4kHz, which is incompatible with the Eurocae ED92C standards and therefore not consistent with considering (a) of Res 428 (…without modification to aircraft equipment).

[Answer] A key driver of the design of the LEO satellite system is that it has to behave in such a way that not any modification will be required in the aircraft equipment. In this sense, and concerning the 4kHz Doppler shift, a Doppler shift pre-compensation mechanism is being defined to guarantee the compatibility of the satellite transmissions with the specified maximum frequency error. Basically, the transmissions from the satellite will be shifted in frequency in order to compensate the Doppler shift for the targeted aircraft (and a large area around it) in order to comply with the standards and messages can be received without modification to aircraft equipment.

The Doppler introduced by the satellite varies from -3.2 kHz to +3.2 kHz in the satellite footprint and in the direction of the satellite movement, that is in latitude. On the other hand, the variation for the same latitude is much lower (see figure). It is then clear that aircrafts located in front or behind will be affected by a Doppler shift with a different sign, being necessary to apply a Doppler pre-compensation mechanism to guarantee that the aircraft receives correctly.

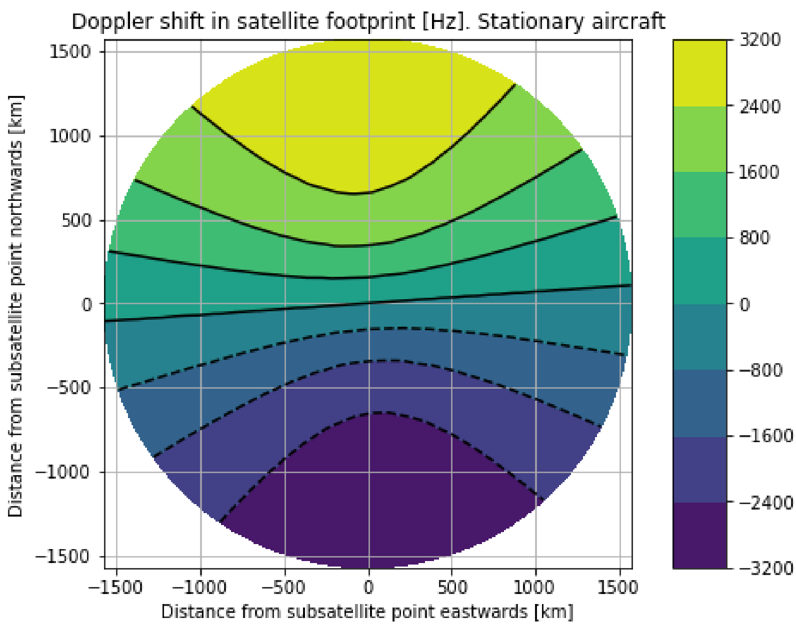
Several potential solutions are possible to do that, avoiding entering in technical details to save Intellectual Properties:

- For point to point communications:
  - Using beam forming or directional antenna to create an oblique footprint with radiation that is adapted to the Doppler effect observed by the aircraft. i.e, the satellite could radiate only in forward or rear direction with a negative or positive pre-compensated shift in frequency as shown in the figure below.



- Alternatively, a combined solution, which is omnidirectional radiation with multiple pre-compensated shift frequencies.

- for point-to-point connection, the needed shifted frequency could be calculated using several solutions.



1.2 Doppler Compensation issues and difficulties coming from it: the decoders used, and, error rate over doppler calculation are not available and similarly many calculation are missing power etc. How this may be solved?

[Answer] It is understood that the question is asking for BER or FER measurements when Doppler shift is introduced to VHF data service. Such measurements are on going, as they take some time to be carried out due to its statistical nature. However, it has been monitored the link status while Doppler shift is present, both a fix one and a Doppler variation and the link is not lost with the VHF2100 radios. The test carried out have been for different receiver input power.

1.3 If you looked at the Technical Standard Order (TSO) for VHF comm there are different TSO classes for radios that support or do not support offset carrier.

[Answer] For VHF voice service, offset carrier mode (also known as CLIMAX) is widely used in Europe and some parts of the world. It allows the same frequency to be shared between 2 or more VHF stations in accordance with ICAO Annex 10 specification.

For 2 carrier offsets on 25 kHz channel spacing, it is not necessary to apply Doppler pre-compensation as the effective acceptance bandwidth of +/- 8 kHz based on ICAO Annex 10, Volume III section 2.3.2.3 specification is higher than the maximum Doppler. More carriers offset could be implemented with Doppler pre-compensation and better frequency stability at the satellite.

For 8.33 kHz channel spacing, Doppler pre-compensation mechanism will be needed with or without carrier offset.

1.4 The voice and data issues with the compensation how this is resolved?

[Answer] For the voice service, based on ICAO Annex 10, it is more tolerant to Doppler shift and could work with or without pre-compensation. For the data service, a pre-compensation mechanism will be implemented.

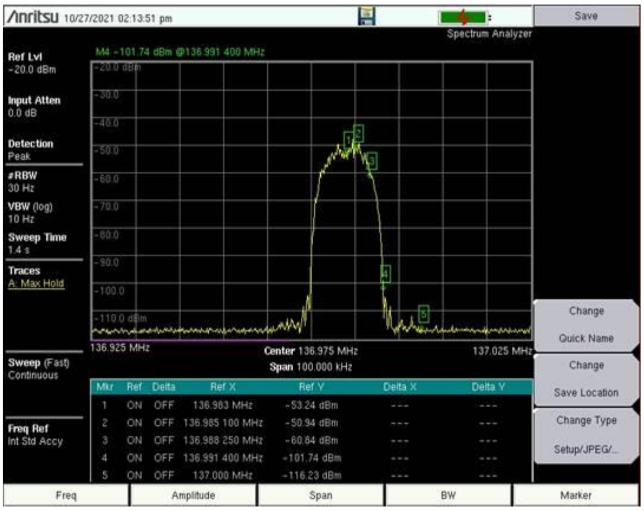
1.5 CSMA behavior when applying Doppler pre-compensation: if a pre-compensation is applied addressed to one specific aircraft, would other aircrafts with different Doppler be able to detect the channel busy even in case of not being able to decode the packet?

[Answer] The Doppler pre-compensation is valid for an area around the specific aircraft. Aircraft for which the pre-compensation is not valid are far away. For those aircraft, even if their CSMA did not detect the channel as busy and decided to transmit, their transmissions are unlikely to affect the original transmission (because of the distance) and will be received normally by the satellite receiver.

1.6 An aircraft needs to receive the last channel 136.975Mhz (CSC) to get into the VDL2 Network, a possible compensation of the Doppler effect on satellite emission would make the emission of the VDL2 CSC channel (136.975MHz) closer to the edge of the band (137MHZ).

[Answer] The satellite transmitter mask is designed to comply with the out of band emissions taking into account the Doppler shift. We presented the transmitted signal of a COTS equipment with a shift of two time the Doppler and there was not emission in the adjacent band. In the worst case it will be shifted 8 kHz (two times the Doppler shift). This moves the last channel to 136.983 MHz max, still more than 60 dBc of out of band attenuation. We presented plots of COTS equipment exhibiting this out of band level. See Figure 7 in the ITU-R PNDR for AI 1.7.

Note that the necessary bandwidth for the VDL-2 signal (worst case) is assumed to be 14.0 KHz corresponding to a 14K0G1DE class type signal (DO-224 Signal-In-Space Minimum Aviation System Performance Standards (MASPS) For Advanced VHF Digital Data Communications Including Compatibility with Digital Voice Techniques section 3.2.1.2.4) and R-REC-SM.1138.



2 VDLm2

2.1 Can you explain in general how satellite-based VDLm2 stations are working assuring fully interoperability with ground-based VDLm2 ones? What protocol will SATCOM VDLM2 use (FANS/ATN?) If ATN, how will the network avoid aircraft attempting to connect on their own initiative? What is the function that moves an aircraft from a terrestrial to a SATCOM network (and vice versa) when each network is a different Communication Service Provider (CSP)? Both on entering and exiting oceanic regions. What are the technical and operational conditions that would initiate such a move? How a handover from the terrestrial VDL network to the satellite VDL network through the CVME (Central VHF Management Entity) and vice versa will happen seamlessly for the aircrafts? In a multi service providers environment, how the transferring of frequencies will work between those entering oceanic and coming into terrestrial between service providers, and what are the conditions under that is initiated?

[Answer] The Space Based VHF is agnostic to the protocols running on top of the Aviation VHF Link Control ("AVLC") layer. It will use the same AVLC protocol as on the ground-based VDLm2 radio. The protocols that will be used on top of this are transparent (just as they are for the ground-based VDLm2 radio). The Ground Station Information Frames ("GSIF") will indicate the available services (AOA and/or ATN) over space-based VDL radio.

The VDLm2 system is based on a CSMA (Carrier Sense Multiple Access) protocol which senses or listens whether the channel for transmission is busy or not and, transmits in the event the channel is idle. Nevertheless, when deploying a ground network based on this CSMA protocol, there is a well-known problem which is caused by the fact that the ground stations are not able to detect the transmissions done by the other stations as they are not in line-of-sight and they cover the sky. This issue can produce collisions due to simultaneous transmission and potentially degrading the performance. However, in the case of the space-based VDLm2 station which will cover a very wide area on the ground, the issue of the hidden transmitter would not happen, simply because the space-based VHF system would be in line-of-sight with the ground station. In the event, the ground-based VDL station transmits, the space-based VHF station would not transmit unless the signal received is below the detection threshold.

The airborne system only receives and processes VDL frames and it cannot tell the difference between VDL frames originating from a ground-based VDL station and a space-based VDL station.

Handoff between a ground-based VDL station and a space-based VDL station is identical to a handoff between two ground-based VDL stations. In the CVME, the space-based VDL station is simply just another station that it is being managed, albeit with a much larger coverage map.

Ground-based and space-based VDL services can be provided using the same or different DSP ID. However, it is suggested to use the "same DSP ID" because it does not require any changes in avionics configuration (no software modifications would ever be needed in the avionics). It should be noted that in case the space-based VDL service is required to operate with its own

DSP ID that is different from the existing DSP IDs then the transfer from space-based to ground-based station would happen exactly in the same way as it is done currently on the ground. When an aircraft configured to be allowed to access the VDL service of different service providers for example Collins and SITA, loses datalink service when it flies outside the coverage area of one service provider but, it then detects the availability of VDL service from the other service provider and it will switch to that service provider. Such mechanism is already actively being used on the current aircraft fleet.

As currently done on the ground, an overlap between the ground and satellite coverage should be ensured to guarantee the continuity of service and to avoid any loss of connection.

The space-based VHF system will work exactly in the same manner as the ground-based system and it should be seen as a complementary component to the ground-based network, allowing to cover remoter or oceanic area.

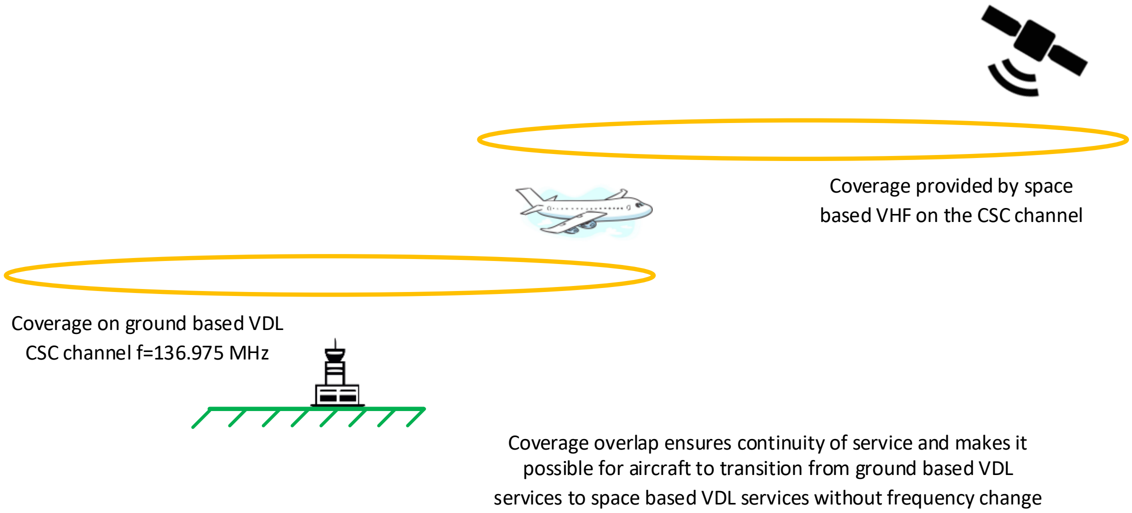
In terms of the channel allocation for the operation of the space-based VHF system, it can be envisaged several scenarios:

- The use of the CSC

The airborne system is connected to the ground Common Signalling Channel. The aircraft flies from the continental to the oceanic area. The airborne system will remain connected to the ground CSC until that the receiver signal or the quality of signal reach a certain threshold and at that point, the airborne system will decide on its own to switch on the space-based VHF station.

In general, the aircraft LME (Link Management Entity) will monitor the signal quality parameter values of all transmissions from ground stations. When it determines that a ground station change is needed, it will send an XID to the selected (new) ground station. The same logic will be used for the space-based VHF system

It should be noted that the use of CSC is subject to the compatibility with the services operating above 137 MHz. Such constraints would not apply or will be less by using an alternate frequency, although the outcome of the studies is not finalised yet, some technical constraints may be imposed on the operation of the CSC.



- The use of an alternate frequency

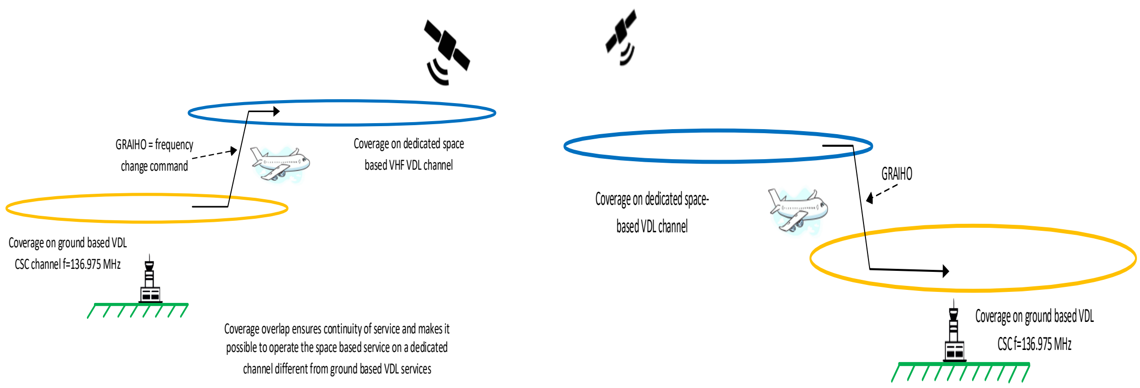
The principle is similar to the ground:

- The airborne system is initially connected on the CSC

The airborne system is connected to the ground CSC frequency, and it flies from the continental area to the oceanic one. When the aircraft arrives close to the edge of the coverage, the Central VHF Management Entity ("CVME") will send a Ground-based requested aircraft-initiated handoff ("GRAHIO") command to indicate to the airborne system to switch to the alternate frequency (either the same as on the ground allocated to the CSP or a dedicated channel for the space operation)

- The airborne system is connected to an alternate frequency

The Central VHF Management Entity ("CVME") will send a GIHO command to the airborne system to indicate to switch to the channel allocated to the space-based VHF system (either a specific channel or a channel belonging to the CSP)



2.2 How will assignments to SATCOM stations be coordinated with terrestrial channel plans? What requirements will be placed on planning criteria for new or modified terrestrial assignments?

[Answer] Coordination of the channel assignments for Space Based VHF (either dedicated or shared) are expected to be performed through the existing mechanisms for frequency management for VHF spectrum.

Additionally, the following aspects should also be taken into account. Firstly, it should be similar to how terrestrial stations are being coordinated amongst the assignees of the channel and at the borders. Secondly, upon filing of satellite, the ITU will request coordination between satellite service providers and those Administrations' that will be within the satellite coverage. To follow on that ITU notification, there may be a need for internal coordination between the national telecom regulator and the aviation regulator/ANSP within those Administrations. It should be no different from how terrestrial/satellite coordination are being done at national level.

The current proposal is to handle satellite frequency assignments like any other, thus a study will be made for each channel-region assignment considering adjacent frequencies.

For a better planning and coordination, there should be a minimal period for effective coordination between affected users/parties. In any radiocommunication services, any planned/new/modification to frequencies shall require coordination between the different users. It will be necessary for the aviation regulator/ANSP to highlight this to its national telecom regulator to trigger coordination with the affected users. Furthermore, it is not appropriate to 'reserve' frequency unless they are put into use within a short period of time, which is to avoid spectrum hoarding. This is consistent with many national telecom regulators' principles on the use of frequency, "use it or lose it".

2.3 What will be the coverage/signal strength over land for administrations that are not using the system in terrestrial airspace (i.e. if it only operates in neighboring oceanic areas)?

[Answer] The satellite system will be deployed guaranteeing its compatibility with terrestrial networks, not impacting the ones not using it even being under the satellite coverage. This will be achieved with proper frequency coordination as it is done for terrestrial networks.

2.4 What agreements are needed to have in place, if any, if the ground-based and the space-based operators are different?

[Answer] Terrestrial-based and space-based VDL services can be provided using the same DSP ID or a different DSP ID. The "same DSP ID" approach is preferred because it does not require any changes in avionics configuration (no software modifications would ever be needed in the avionics).

2.5 If the SATCOM and Ground Station (GS) appear to be same CSP to the aircraft, does this introduce a risk with the current VDLM2 connection orientated protocol letting an aircraft potentially jump between sub-optimal stations as seen on terrestrial ground stations?

[Answer] The risk already exists in existing networks either given to specific user terminals behavior or in areas where two or more stations (either two GS or one GS and the Space Station) appear to have similar signal quality from an aircraft terminal point of view. Geographical areas in which this can happen are limited.

The addition of Space Based VHF, given the high coverage areas that the satellite radio will have, is likely not to increase this situation. The areas in which special attention should be taken are the boundaries of the satellite transmitters and the terrestrial transmitters coverage, respectively.

2.6 What is the compatibility between terrestrial VDL and satellite VDL in terms of co-channel operation?

[Answer] For the co-channel operation, it should be seen the space-based VHF system as a complementary component to the ground-based VDL station. It means that in area where it is impossible to deploy a ground-based VDL station, hence no coverage from the ground, the space-based VHF station will take the hand-over. As both systems are similar (same modulation, same CSMA protocol), both systems will co-exist as it is already the case for the ground-based VDL stations which use the same channel.

It should be noted that the impact is greater if considering only the ground component as there is the issue of the hidden transmitter. In the case between the space-based VDL system and the ground-based VDL station, this issue does not exist as both are in line-of-sight.

The satellite-based VDL station covers a very wide area, hence by design there are no hidden transmitters. The reason being that the satellite will be in light-of-sight with ground-based VDL station. In the event, the ground-based VDL station transmits, the space-based VHF station would not transmit unless the signal received is below the detection threshold.

2.7 This bullet point addresses a few scenarios to consider for space-based VDL OPS, notably the switchover mechanism between space-based VDL and ground-based VDL:

2.7.1 Aircraft from Europe to USA are on different channels.

[Answer] Aircraft flying between Europe and USA operate on exactly the same VDL CSC channel but with large gaps in coverage. Satellite-based VDL can fill the gaps in coverage. The underlying principle of the space-based VDL is that it appears to the aircraft as "just another VDL station" hence all the same, existing handoff mechanisms apply.

Additionally, in the specific case of oceanic coverage, it should be mentioned that as this area is considered international, an alternate frequency can be different to the one used in the USA and Europe.

2.7.2 Aircraft up to within 250nm from a terrestrial VDL system

[Answer] For coverage near the coasts of continents the space-based VDL station allows the VDL service to be extended out to the oceanic region in a seamless fashion. The space-based VDL service can be provided on the same frequency as the terrestrial-based VDL stations or it can be provided on an alternate frequency to which the aircraft would be commanded to switch by the CVME, as it is done currently in the scope of VDL multi-frequency management.

2.7.3 GRAIHO (Role of the CVME for the space-based VDL stations)

[Answer] Space-based VDL stations will be managed by the CVME just as the existing terrestrial-based VDL stations are already managed. The space-based VDL stations will be simply added to the inventory of VDL stations managed by the CVME with their own, appropriate coverage maps.

2.8 Behavior in case of potential collisions. What happens if the aircraft does not detect the busy channel state, could it cause a significate increase of collisions?

[Answer] If they occur, transmissions from the aircraft performed while the channel is being used by another transmitter are likely to increase the level of collisions. It is important however to mitigate this by the fact that, as highlighted in previous answers, the broadcast nature of the satellite signal transmission and the low blockage of the Line of Sight of the satellite signal for aircrafts in flight lowers the probability of such events where an aircraft is transmitting while the channel is busy. The increase in collisions, if any, will thus likely not be significant.

An aircraft (a2) may not detect packets with a Doppler pre-compensation addressed to another aircraft (a1), not detecting a busy channel state. In this situation this aircraft (a2) may transmit, but it will not affect the aircraft (a1) caption from the satellite as they will be far from each other. On the other hand, aircraft (a2) could transmit to the satellite as it sees the channel free, but it would be received by the satellite always listening.

2.9 Is it required that all aircrafts receive the packets addressed to all aircrafts? This is obvious for broadcast packets but may not be needed for unicast ones?

[Answer] It is not necessary that all unicast transmissions be received by all aircrafts in the coverage area for the system to function. However, the reception of the signal by a subset of the aircrafts could lead the transmitters of the aircrafts not receiving the transmission to believe the channel is not busy and initiating a transmission themselves, which could result in collisions lowering the overall offered capacity of the VHF service volume. It is thus desirable that all aircrafts are able to sense the presence of energy on the channel for CSMA purposes.

3 Operations

3.1 Referring to ENAIRE/Indra's trials proposal, what assumptions of the bands did you use for these tests, etc.? Can the current avionics work without modification?

[Answer] This is a key design driver for the satellite system, it will be designed and implemented to guarantee that no modification is needed in the avionics. As examples:

a. The satellite EIRP will guarantee the minimum power flux density at the aircraft VHF antenna input for both voice and data services.

b. Doppler effect will be pre-compensated

c. Detailed link budget has been computed and documented in draft PDNR M. [SPACE VHF] for WRC-23 AI1.7 where feasible solution is found to work with current avionics, taking into consideration the aircraft VHF antenna pattern, signal propagation loss, scintillation effect etc. in both space to Earth and Earth to space direction.

3.2 Given that the VHF analog voice use case assumes a "party line" for flight crew situational awareness in a particular airspace sector, and VDL Mode 2 utilizes Carrier Sense Media Access (CSMA) to minimize data packet collisions, any Doppler compensation by the satellite would have to ensure that all aircraft in the intended coverage area would still be able to correctly receive the satellite signal on the intended frequency. Please, clarify or justify this.

[Answer] For CSMA / VDL2, this situation will happen when the aircrafts are flying in regions located very far from each other, to note that in terrestrial networks the situation is equivalent, aircrafts located in places that are far from each other will not listen among them due to terrestrial coverage limits.

For VHF voice, based on ICAO Annex 10, it is more tolerant to Doppler shift and could work with or without Doppler pre-compensation.

3.3 Is it necessary to assign only unused/less used frequency spectrum to space-based VHF?

[Answer] With good understanding of the coverage footprint and proper frequency planning, it is not necessary to restrict the assignment to unused/less used frequency spectrum. The reuse of frequency will allow optimal usage of the VHF channel so long as it does not cause interference to other users. Also, the sharing of same frequency between satellite and terrestrial VHF stations will optimize the VHF voice channel utilization and ease the workload of both air traffic controllers and pilots. However, it requires the implementation of offset carrier mode (CLIMAX).

3.4 Will there an issue due to latency?

[Answer] The one-way latency of voice signals from ATC to aircraft (or vice versa) via LEO satellite is about 4 ms (at zenith) and 18.9 ms (at horizon) due to the longer signal propagation path for satellite at 600km altitude as compared to terrestrial station. This is far below the current latency of a remote VHF radio station relayed via VSAT (Geo-Stationary Satellite, GSS), which is about 250ms each way (one-way).

For Voice service, there is no issue for single carrier mode. To implement multi-carrier offset between satellite and terrestrial station, the latency should be less than 10ms to avoid significant inter-symbol interference effect. These could be mitigated by implementing best signal selection for the signals received at ATC. For the signals transmitted to aircraft, a time delay could be introduced at the terrestrial station to match the signal transmitted by satellite.

3.5 Is there any concern with capacity?

[Answer] Capacity management will be similar to current practices.

For Voice service, ATC controllers will be managing the usage of the channel. Users listening to the “party line” will know when the usage is reaching full capacity and will be mindful to use of the “line” efficiently. Re-sectorization of FIR may also help to rebalance the capacity and workload of the ATC controllers.

3.6 The satellite orientation can be dynamic and complex. How to ensure that its coverage does not exceed the approved area?

[Answer] Satellite orbit, position, orientation, antenna pointing, transmission power can be constantly monitored and corrected by ground control centre to achieve the desired coverage.

Modern technologies allow satellite positions to be reasonable stabilized to ensure that their VHF coverages will not exceed their respective approved areas.

3.7 We have concerns about the management of the boundary condition handoff. What is the design concept? At the land/oceanic boundary it's a common event to see aircraft move back-n-forth between a VHF radio and Satellite communication media causing ATC delays. Will there be the possibility of satellite-based station and a ground radio causing ping-pong bouncing issues and comm. gaps at these boundaries? This situation is not really a VGS handoff, but a media handoff, which tends to be problematic.

[Answer] Satellite infrastructure is an extension of ground infrastructure, and it will be used as additional VHF ground stations. CSP will decide when to use Ground or Space infrastructure, and if Space is used, constellation management will route the information dynamically to the best satellite to be used at each circumstance and time for the transmission to Aircrafts.

3.8 How will the handing of the actual message content work for data link messaging? Will the SB-CNS Service Provider deploy their own ATN ground network infrastructure for ATN CPDLC connectivity or use the existing networks of ARINC and or SITA? What is the expected relationship here?

[Answer] SB-CNS Service Provider will reuse the existing ATN ground network infrastructure deployed by SITA and ARINC. SB-CNS Service Provider will reach an agreement to get connected to this ground infrastructure. Constellation will have capacity for FANS 1/A as well as for ATN.

3.9 How will SB-CNS Service Provider handle all the AOC message content for airlines that use ARINC or SITA exclusively as their CSP? Same question, but for customers that use ARINC as Primary (SITA is backup only) or SITA as Primary (ARINC is backup only). Will SB-CNS Service Provider have an ACARS GMP or send all this content to the ARINC/SITA central processor for A/G conversion and routing? What is the expected relationship here?

[Answer] Relationship with Airlines will remain as it´s now. Constellation will deliver the information to the pertinent CSP. SB-CNS Service Provider does not plan to provide an independent AOC service.

3.10 How will SB-CNS Service Provider handle all of the ATC (FANS) message content? Today ANSPs address FANS Gateways which act as message brokers and communicate with the ACARS central processors. For this to work, must ARINC/SITA develop a new interface to Indra and identify this as a new connection media that must be tracked and managed?

[Answer] Constellation is an extension of Ground infrastructure and is managed as if another Ground VHF station were available. SB-CNS Service Provider does not plan to provide an independent ATC (FANS) ACARS service.

3.11 VHF Voice: Will the SB-CNS Service Provider Voice service use a new frequency so that ARINC/SITA existing domestic and semi-oceanic services are protected?

[Answer] For voice services with offset configuration, the transitions between space and terrestrial VHF stations are transparent to users (ATC and pilots) as the operating frequency remains the same. Otherwise, users will carry out normal frequency change procedures (which is common and current practice).

3.12 What is the operational concept for SB-CNS Service Provider's Voice service? Is it a stand-alone service & totally managed by the SB-CNS Service Provider, or it is ARINC/SITA existing call centers considered a part of the solution for G-to-A calls, phone patches and so on? What is the expected relationship here?

[Answer] SB-CNS Service Provider VHF Voice communication services for ATC purposes should be agreed and coordinated with ANSPs managing the airspaces.

SB-CNS Service Provider VHF Voice communication services for AOC purpose (if given the case) should be agreed and coordinated with CSPs managing their airlines.

3.13 For VHF voice, how do aircraft transit between space-based and terrestrial based systems/coverages?

[Answer] For voice services with offset configuration, the transitions between space and terrestrial VHF stations are transparent to users (ATC and pilots) as the operating frequency remains the same. Otherwise, users will carry out normal frequency change procedures (which is common and current practice).

3.14 Space-based VHF voice may have a much larger coverage, would it have sufficient capacity for the entire coverage?

[Answer] Space-based VHF voice will be mainly used in oceanic or remote continental regions where traffic volumes are expected to be low. As non-surveillance services are usually provided in these regions, voice transmissions will mainly be for position reporting. For this reason, it is unlikely such system will have insufficient capacity. In the event that there is capacity limitation due to the large coverage, the space-based VHF service provider could consider reducing the coverage and resizing the sector.

3.15 Would space-based VHF voice aggravate the current VHF frequency congestion in some regions?

[Answer] Space-based VHF voice will be mainly used in oceanic or remote continental regions where VHF voice is not currently available. So, it should not affect the terrestrial systems except for those operating near the coast of busy continents. For coverage near the coasts of busy continents, careful frequency planning and management are needed.

3.16 Would space-based VHF voice reduce the number of VHF frequencies available for terrestrial based systems?

[Answer] Space-based VHF voice will be mainly used in oceanic or remote continental regions where VHF voice is not currently available. So, it can reuse those frequencies, which are currently used in areas that are far away, say 600 NM away, from the edge of its coverage. For coverage near the coasts of continents, offset carrier systems should be implemented wherever possible to reduce the number of VHF frequencies needed.

ANSPs should also consider sharing secondary frequencies between adjacent sectors. This will reduce the number of VHF frequencies deployed and can be implemented using the large coverage of space-based system.

4 System Design Checklist

4.1 Considering the following high-level requirements for space-based VHF ATC Voice system:

- ✓ A space-based VHF ATC voice system must allow a full integration into given ATM procedures for the pilots and the controllers as well.
- ✓ It must be possible for aircraft to participate without any modification of their comms equipment.
- ✓ The used radio waveform AM DSB does not know any identity of aircrafts or satellites, it is just analog broadcast.

4.1.1 How a 24/7 operation can be ensured for any sector by just selecting one frequency mapped to this sector?

[Answer] Satellite coverage will be overlapped up to a certain area, so a collateral satellite could service just in case. Moreover, there will be a number of backup satellites. Space-Earth links will be at least duplicated.

In terms of frequency management point of view, there will be several different channels to be assigned to collateral sectors. Then at a certain distance, channels will be reused.

4.1.2 How can we also operate at least one backup frequency within the sector?

[Answer] Each satellite will handle several frequencies.

4.1.3 How can we also monitor the guard channel 121,5Mhz within the sector?

[Answer] The satellite payload receiver will have the capability to listen to several voice channels simultaneously.

4.1.4 What antenna characteristic is used for the space segment to ensure a stable uplink from the AC to space? What coverage is given for the downlink if the "uplink characteristic" of the receiving antenna is also used for transmitting into the downlink?

[Answer] There are several solutions for the satellite antenna. To guarantee a stable solution the antenna just shall guarantee enough gain in all the defined coverage. It can be achieve using omnidirectional antennas, isoflux antennas, or more complex antennas like array or reconfigurable antennas. The purpose of this study is not to define the technological solution of the antenna but to evaluate the feasibility of establishing communication with the required parameters. The final solution will depend on each manufacturer and will be a solution that combines the satellite solution with the satellite constellation solution that guarantees continuity of coverage and service.

4.1.5 Aircraft antenna presents a nule on its vertical and this will produce los of coverage when the satellites are located on top of it. How this problem will be solved in order to ensure smooth coverage?

[Answer] In terms of Doppler shift, the worst solution is to transmit to aircrafts right below them, as this is the moment when doppler rate of change is bigger. This effect is present and different technical solutions can be used to avoid this effect, in terms of different satellite configurations (antenna type, antenna orientation, constellation design, beamformimg).

By design, consellation shall ensure enough overlapping coverage in order to ensure that gaps are not produced in the coverage, it´s a question of constellation and satellite design.

4.2 Which radios have been tested for the Doppler shift as there are many different radios?

[Answer] Voice: Collins VHF 2100; Jotron TR-7750(ground radio), Dittel; Data: Collins VHF-2100, IDTS MTP-200; Jotron TR-7750(ground radio)

4.3 What frequencies will be used for the demonstration phase with the HAPS and the IOD1 LEO satellite?

[Answer] The tests will use a frequency for voice and frequency for data inside the AM(R)S band (117.975 to 137 MHz). A frequency coordination analysis has been carried out to select VHF frequencies not currently used in the demonstration region.

To be completed with other statements already captured in other documents since this is an important question and has been already sufficiently addressed.

4.4 There are different technical aspects that have to be considered for a highly reliable and high-performance data link service (Link Budget related questions, antenna location matters, etc.) For instance, for Airbus fleets data antennas are top mounted while voice antennas are bottom mounted. Will this negatively affect voice operations? For Boeing fleets, Data link antennas are typically bottom mounted. Will this cause shadowing issues and result in unreliable data link communications?

[Answer] Constellation design is done envisioning a communication between satellite and aircrafts in a horizontal (or quasi horizonal) plane, in order to minimize this shadowing effects.

4.5 In the USA we have the CSC and two VDL Alternates used by each CSP (ARINC / SITA). How many VHF transceivers are carried on each Satellite (ignoring spares)? Will there be sufficient capacity to manage all the expected growth in VDL Data Link Messaging?

[Answer] Satellite includes capacity to operate with several VHF simultaneous channels to ensure capacity.

4.6 If the Satellites will contain multiple VDLM2 radios and channels how will the channels be effectively managed? Today our GMP issues the commands to move aircraft from ACARS to VDL and VDL to ACARS. GSIFs cause this to occur. Over the oceans there will be no POA service. If the aircraft fall off VDL how will it return to VDL?

[Answer] Constellation will provide POA & VDLM2 services in oceanic. If Aircraft connects either VDLM2 or POA will be in function of Aircraft´s settings regarding connectivity, given that aircraft settings can be adjusted for priority and geographical areas.

4.7 Additional system design questions:

4.7.1 What is the TX Output Power of the VHF satellite radio? If not 25w, any concerns about asymmetric link RSSI?

[Answer] Transmitted power is a trade-off with satellite antenna gain. It will between 20 to 85 watts as is being discussed in ITU-R studies, in order to ensure the proper link budget.

Link budget is more beneficial for Aircraft to Satellite (uplink) than for Satellite to aircraft (downlink). In the downlink, the satellite ensures enough power for the required budget link.

4.7.2 Where is SB-CNS Service Provider getting the radio's ICAO Address from? Will each satellite have its own ICAO address? If each satellite has unique ICAO, how often does SB-CNS Service Provider anticipate the aircraft being in range of satellite? (How often will the aircraft need to do a HO?)

[Answer] Pending to define, very low level detail.

One option is that every aircraft should transmit to a single ICAO radio address and Constellation will manage changes of satellites ICAO addresses, but more options are possible. This is transparent for the constellation.

Satellites don´t have a fixed ICAO address. Handover between satellites will be handled by constellation. Aircraft connection to Constellation should be seen as a connection with a single radio, independent of which satellite is used.

4.7.3 How many satellites does SB-CNS Service Provider anticipate the aircraft being in range of at any one time? (we typically are required to have at least 2)

[Answer] Constellation ensures a minimum of 2 satellites at any time, depending on the position. In most cases, number of satellites in view is higher than that.

In normal operation a single satellite is providing the service to an aircraft, and this is managed by the constellation.

4.7.4 How to prevent interference caused by faulty satellite transmitters?

[Answer] Space-based VHF system shall be designed with the capability of automatic and/or remotely manual switching off any faulty transmitters on board its satellites.

Acronyms

Acronym	Description
AC	Aircraft
ACC	Area Control Center
ADS-B	Automatic Dependent Surveillance – Broadcasting
ADSP	ATM Data Service Provider
AM(R)S	Aeronautical Mobile (Route) Service
AMS(R)S	Aeronautical Mobile Satellite (Route) Service
ANSP	Air Navigation Service Provider
AOA	ACARS over AVLC
AOC	Airlines Operational Control
ATCO	Air Traffic Controller Operator
ATM	Air Traffic Management
AVLC	Aviation VHF Link Control
CPDLC	Controller to Pilot Data Link Communications
CSC	Common Signalling Carrier
CSP	Communications Service Provider
CVME	Central VHF Management Entity
D/U	Desired / Undesired
FIR	Flight Information Region
GSIF	Ground Station Information Frames (“
HAPS	High Altitude Platform System
HSL	High Speed Link
ICAO	International Civil Aviation Organization
IOD	In Orbit Demonstration
ITU	International Telecommunication Union
LEO	Low Earth Orbit
LME	Link Management Entity
MSS	Mobile Satellite Service
NM	Nautical Miles
OoB	Out of Band
POA	Plain Old ACARS
PFD	Power Flux Density
RF	Radiofrequency
SAL	Sal Oceanic ACC
SB-CNS	Space-based Communication, Navigation and Surveillance

SB VHF	Space-based VHF
SC	SpaceCraft
TBC	To Be Confirmed
Tx	Transmission
VDL	VHF Data Link
VDLm2	VDL Mode 2
VDR	VHF Data Radio
VHF	Very High Frequency
VLD	Very Large Demonstration