International Civil Aviation Organization

FIFTH MEETING OF SPECTRUM REVIEW WORKING GROUP (SRWG/5)

Video Teleconference, 15 – 17 March 2021

FLIMSY 2 – Agenda Item 2 – Proposal to address Para. 2.19 from SRWG/5 WP02

1. Background

1.1 WP02 of SRWG/5 states the following notes of meeting in para. 2.19 under the topic "Space-based VHF Communications in 117.975-137 MHz Frequency Band", which was put up as WP26 in CNS SG/24 as per requested by ACSICG/7 meeting participants.

"It was noted that further work needs to be done and agreed to recommend States/Administrations who are interested and capable to join the relevant study, and as present ICAO Position for WRC-23 already included space-based VHF agenda. The Secretariat was requested to coordinate with SRWG chair and ACSICG chair to clarify how to track and monitor this initiative, and form an ad hoc group, if necessary, to take the concerns from States on a regional level so as to make the study meaningful, and the outcome of this deliberation will be reported back to CNS SG/25 meeting for consideration."

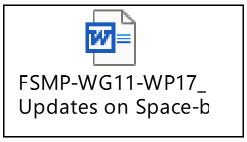
2. Updates on space-based VHF

2.1 The space-based VHF frequency compatibility study has commenced in International Telecommunications Union (ITU) Working Party 5B (WP 5B) meetings, and the ICAO Frequency Spectrum Management Panel (FSMP) is the designated ICAO point of liaison with ITU WP 5B.

2.2 At the FSMP Working Group 11 (FSMP WG/11) meeting held from 1 to 12 March 2021, it was noted that ITU WP5B had requested for technical information pertaining to aircraft VHF and the future space-based VHF system for the purpose of the compatibility study for space-based VHF (WRC-23 Agenda Item 1.7). Please see attached for ITU WP5B Liaison Statement (LS) to ICAO, and proposed response to LS by France, both presented at FSMP WG/11.

FSMP-WG11-WP04-LS_from_WP5B_AI1.7	FSMP-WG11-WP12_ Proposed LS for AI 1

2.3 The latest updates on space-based VHF from Singapore was also presented at the FSMP WG/11, attached below for SRWG/5 information.



3. **Proposed approach for future updates at SRWG**

3.1 As presented in Paragraph 2 of this filmsy, the space-based VHF frequency compatibility topic is being monitored and tracked closely at ICAO FSMP. It is proposed that, if agreeable by the meeting, Singapore can act as the point-of-contact to present key FSMP discussion points on this topic at future SWRG meetings. If required, Singapore will also feedback any comments/concerns expressed from SRWG on this topic, and direct to FSMP for further discussions. This approach is similar to how other WRC-23 topics being discussed at FSMP are presented at SRWG meetings.

3.2 Submitted to SRWG/5 for discussion, please.

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International Civil Aviation Organization

WORKING PAPER

FSMP-WG/11 WP/04
2021-01-18

FREQUENCY SPECTRUM MANAGEMENT PANEL (FSMP)

Eleventh Working Group meeting

Web Meeting, 1 – 12 March 2021

Agenda Item 5: Development of (planned) Material for ITU-R Studies on:

b) WRC-23 AI1.7 VHF AMS(R)S

Liaison Statement from ITU-R WP5B on WRC-23 Agenda Item 1.7

(Presented by the Secretary)

SUMMARY

Attached is a liaison statement from ITU-R WP5B on WRC-23 Agenda Item 1.7.

Action: FSMP WG/11 is invited to review the attached liaison statement and take action as appropriate.

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Radiocommunication Study Groups

Source: Document 5B/TEMP/45(Rev.2)

Subject: WRC-23 agenda item 1.7 LS ICAO

26 November 2020
English only

Working Party 5B

LIAISON STATEMENT TO ICAO

WRC-23 agenda item 1.7

Questions on a space-based aeronautical VHF communications system in 117.975-137 MHz frequency band

In order to meet the evolving requirements of modern civil aviation, satellite systems may be considered within the band 117.975-137 MHz for the relay of aeronautical VHF communications over oceanic and remote areas. Under WRC-23 agenda item 1.7 and Resolution **428 (WRC-19)**, Working Party (WP) 5B is tasked to define the relevant technical characteristics and to study compatibility between such satellite systems and existing primary services in-band and in adjacent bands.

At its last meeting in November 2020, WP 5B has therefore initiated the development of [elements of a working document related to AI 1.7 WRC-23] working document towards a preliminary draft new Report ITU-R M.[Space-VHF] (see Attachment). The preliminary parameters concentrate on the provision of voice communications, considered as the essential application to provide, and on the satellite to aircraft downlink path, as it would be the new active element introduced in the overall picture of aeronautical VHF stations.

In order to duly complete its task on defining the relevant technical characteristics and to perform sharing and compatibility studies, under WRC-23 agenda item 1.7, WP 5B would like to question ICAO on the following elements:

Available measured pattern for aircraft VHF antenna

Available information indicate that aircraft VHF antenna have a relatively low maximum gain (typically 3 to 5 dBi), an omnidirectional radiation pattern in azimuth, and a cosinusoidal radiation pattern in elevation (meaning a theoretical zero is achieved at aircraft zenith).

Working Party 5B would like to know if measured (i.e. taking account of aircraft body) receiving and transmitting VHF antenna radiation patterns can be provided by ICAO, both for upper and lower aircraft VHF antennas. Ideally, several typical patterns would be desirable, for the different classes of aircraft that fly over oceanic and remote areas (from small transoceanic business jets to large aircraft).

Aircraft VHF receiver performance requirement

In terms of aircraft receiver sensitivity, the recommendation contained in section 2.3.2.2.1 of Annex 10 Volume III Part II to the Convention on International Civil Aviation recommends an airborne sensitivity level of 30 microvolts per metre in the case of "extended range VHF facilities", assumed to correspond to the satellite case.

In addition, the "Minimum operational Performance Specification (MOPS) for airborne VHF receiver-transmitter operating in the frequency range 117.975-137 MHz" developed by EUROCAE and RTCA specify that minimal receiver sensitivity to achieve a SINAD of 6 dB is -93 dBm/ 25 kHz.

Working Party 5B would like to get confirmation from ICAO on which sensitivity is the most relevant to be used for the studies in the Attachment.

Required availability performance

Working Party 5B would like to know from ICAO if a reference availability target can be identified for aeronautical VHF voice communications, and if such a reference could depend upon time and location.

Working Party 5B looks forward to continuing fruitful cooperation with ICAO regarding this work.

Status:	For action		
Deadline:	Next WP 5B meeting (May 2021)		
Contact:	Mr. Loftur Jonasson	**E-mail:**	LJonasson@icao.int

Attachment: Working document towards a preliminary draft new Report ITU-R M.[Space-VHF]

R19-WP5B-C-0225!N26!MSW-E.docx

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FSMP-WG/11 WP/12
2021-02-22

International Civil Aviation Organization

WORKING PAPER

ATMRPP-WG/WHL/4-WP/

../../06

FREQUENCY SPECTRUM MANAGEMENT PANEL (FSMP)

Eleventh Working Group meeting

Virtual Meeting, 01 – 12 March 2021

Agenda Item 2 : WRC-23 Preparations (AI 1.7)

Proposal for a reply liaison statement to ITU-R WP5B regarding the agenda item 1.7

(Presented by Alexandre GUIGNOT)

SUMMARY

Studies regarding the agenda item 1.7 (WRC-23) have been launched by WP5B since July 2020.
In this regards, WP5B is informing ICAO on the progress of work and is seeking guidance on the following three topics:

- The aircraft antenna pattern ,
- The VHF receiver minimum sensitivity requirement,
- And the required link availability performance.

This working document offers a material to respond to WP5B on these three topics. Also, we believe that it is beneficial to address from an ICAO point of view the question of compatibility between AM(R)S and AMS(R)S, and propose to indicate to WP5B that such studies wouldn't be required within ITU-R.

1. INTRODUCTION

During the last WP5B held in November 2020, WP5B sent a liaison Statement to ICAO in order to inform on the progress of the work done by ITU-R on agenda item 1.7 (WRC-23).

In particular, WP5B informed ICAO that a working document towards a preliminary draft new Report ITU-R M.[Space-VHF] is currently being developed.

In order to complete its work, WP5B is seeking guidance from ICAO on three main topics:

- The aircraft antenna patterns ,
- The receiver minimum sensitivity requirement,
- And the required link availability performance.

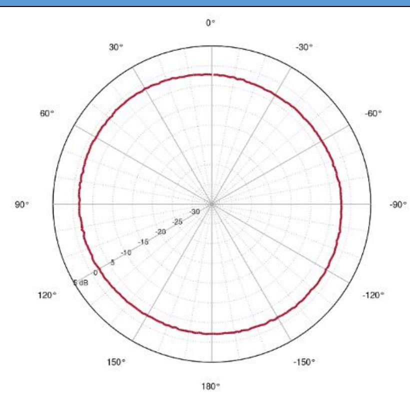
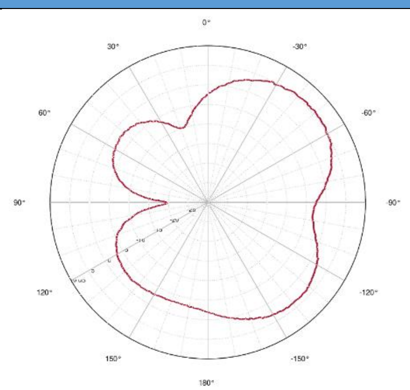
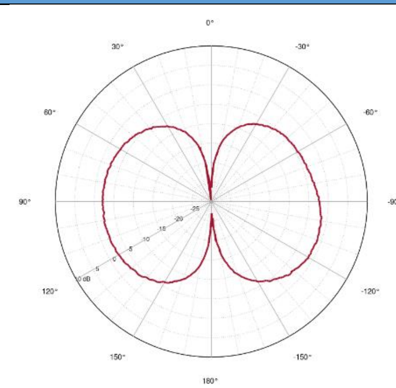
Attached to this document an annex is provided as a proposed basis for a response to WP5B.

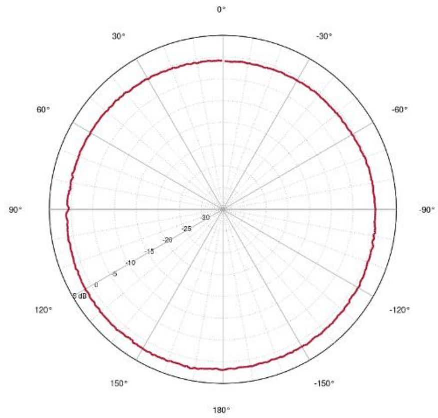
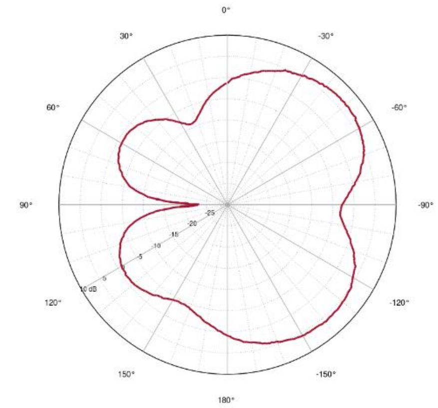
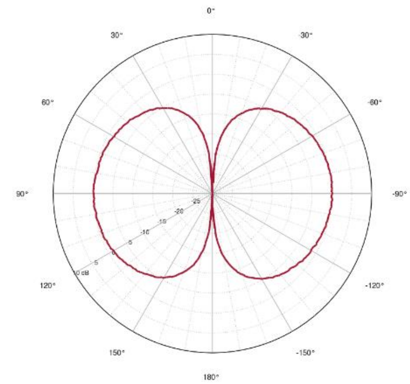
2. Available measured pattern for aircraft VHF antenna

The antenna pattern depicted in the draft new Report ITU-R M.[Space-VHF] takes only into account the behaviour of a dipole antenna without the effect of the plane fuselage reflection . In particular, a cosinusoidal behaviour in elevation is depicted, meaning that a theoretical zero is achieved at aircraft zenith (90° elevation) which would lead to the fact that the direction towards the satellite is highly attenuated.

One can find below example of pattern for the VHF COBHAM Blade type Antenna. Radiation patterns of antenna have been measured in the three main plans at 118 / 127 / 137 MHz. Those patterns were measured on a 2 X 1 meter rectangular metallic reflector. They essentially confirm the information already available to WP5B.

It is believed that a more representative antenna pattern should be used, if available through other contributions to this meeting or at future meetings, that takes into account the fuselage reflection. This would help WP5B in defining a more accurate link budget.

118 MHz, Copolar		
 Horizontal plan	 Longitudinal plan	 Transversal plan
127 MHz, Copolar		

 Horizontal plan	 Longitudinal plan	 Transversal plan
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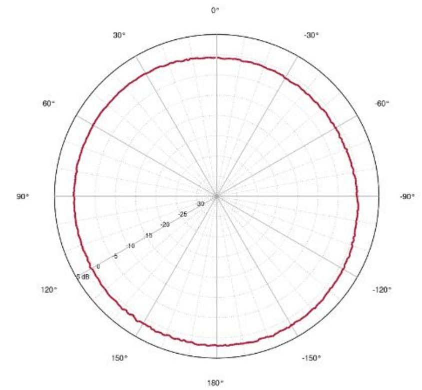
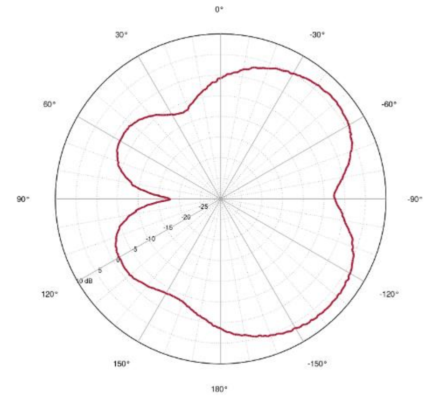
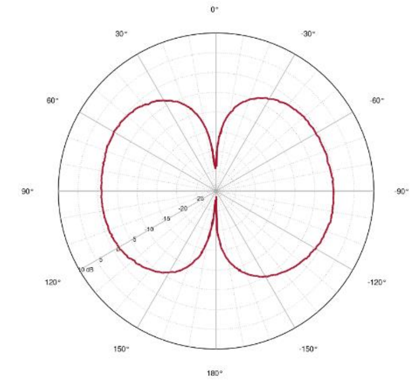
 Horizontal plan	 Longitudinal plan	 Transversal plan

3. **Aircraft VHF receiver performance requirement**

Two different values were noted by ITU-R based on the available literature:

- The first one is coming from the ICAO Annex 10 Volume III Part II (section 2.3.2.2.1). The field strength value of 30 microvolts per meter (- 116 dBW/m2 which becomes -90 dBm through an isotropic antenna) is assumed for planning extended range VHF facilities. The section also recommends a field strength of 75 microvolts per meter (- 109 dBW/m2 which becomes -83 dBm through an isotropic antenna).

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.

Figure 1: Extract from the section 2.3.2.2.1 of ICAO Annex 10 Volume III

- The second one is coming from aeronautical standards were the value of -93 dBm with a SINAD of 6dB is given.

3.1.3 Sensitivity (Signal-Plus-Noise to Noise Ratio)

3.1.3.1 Single Carrier Sensitivity

The level of a single carrier RF input signal, modulated 30 % at 1000 Hz, required to produce a signal-plus-noise to noise ratio of 6 dB shall not exceed -93 dBm with an audio output power not lower than 10 dB below the declared audio output power.

Figure 2: Extract from Aeronautical Standards (ED-23C)

[TBC by Response of the Communication Panel or its working group]

4. Ionospheric propagation losses and required availability performance

In the envisaged frequency band, Faraday rotation and scintillation will be very dimensioning in the VHF satellite system design, as they correspond to very significant propagation losses. These two effects depend on factors such as time of year, time of day, solar cycle, and geomagnetic conditions. Unfortunately, the current available models at ITU-R do not provide a granularity that would allow to split the estimation by region, and possibly between day and night period (for instance 18:00-00:00, and 00:00-18:00), which would be very helpful in order to quantify the link availability per period of the day and per location. WP 5B is seeking information from ICAO if a reference availability target can be identified for aeronautical VHF voice communications, and if such a reference could depend upon time and location.

In France, the availability of the VHF ground stations depends on the operational usage (ATC control or ATC information) of the VHF link. For example:

- ATC information: 99,852%,
- ATC control: 99,9991%.

One can note that these values highly depends on the weaker part of the system which is often the fixed service link used.

A satellite aeronautical VHF voice communications system would represent a breakthrough towards so-called "seamless ATM plan": on the one hand it would possibly make the voice service available worldwide, including over oceanic and remote areas, and on the other hand it could also backup terrestrial stations in case they are affected by a catastrophic event. As such, there is no existing performance requirement for a VHF satellite system, but it is expected that the availability performance should be close to that of the VHF ATC ground stations.

Once a satellite system is designed, its availability performance will be evaluated, and will represent an important input for ANSPs interested by the service. They will define a set of operational measures required in order to reach a given safety objective. It is understood that VHF scintillation is very dimensioning over specific regions (for instance at low latitudes), and is maximum at sunset with very strong variations between day and night periods. Depending on system trade-offs, it may be of interest not to dimension the satellite system to account for the worst case propagation loss, which is very much time and location specific, and to compensate with appropriate measures (like appropriate flight planning) over the concerned regions when affected.

An example of such measure exists in French Polynesia for flights over large oceanic areas using HF communications, which avoid certain time slots in order to avoid facing strong propagation losses.

5. Compatibility study between AM(R)S and AMS(R)S

Even if not covered in the WP 5B's liaison statement, it has to be noted that during the last WP5B, questions were raised about the need to perform a compatibility analysis between the existing terrestrial VHF communications operating under the AM(R)S allocation and the possible future satellite VHF communications that would be operating under a new AMS(R)S allocation.

It should be noted that even if the two services would be used under different "allocations" at ITU-R level, the system on-board the aircraft would not be changed and would communicate with the ground or satellite stations without any discrimination.

A VHF satellite system would likely correspond to relatively low gain and non-directional satellite antennas, which would result in the inability to reuse via satellite any frequency already operated by terrestrial stations within its coverage. In order for interested countries to benefit from a new satellite aeronautical VHF voice communication service, ICAO would have to perform a conventional frequency planning exercise, assigning frequencies to the satellite system over interested regions, so as to ensure compatibility between ground and satellite facilities.

Therefore, from an ICAO perspective there is no need to perform a compatibility study within ITU-R between these two different services, that in reality cover the same system on-board the aircraft.

6. ACTION BY THE MEETING

The meeting is invited to:

a) note and review the contents of this working paper;

b) Complete the elements of the LS to be sent to WP5B.

— END —

Annex

Elements for a liaison to WP5B on SAT VHF (Agenda Item 1.7)

ICAO would like to thank ITU-R WP 5B for its liaison statement related to ongoing studies on space-based aeronautical VHF communications system in the 117.975-137 MHz frequency band, under WRC-23 agenda item 1.7. ICAO reviewed the provided material by WP 5B and would like to provide the following comments and information.

Available measured pattern for aircraft VHF antenna

One can find below example of pattern for the VHF COBHAM Blade type [A1]Antenna. Radiation patterns of antenna have been measured in the three main plans at 118 / 127 / 137 MHz. Those patterns were measured on a 2X1m rectangular metallic reflector. They essentially confirm the information already available to WP5B. It is believed that a more representative antenna pattern should be used in order to obtain a more accurate link budget, that takes into account the fuselage reflection. *[adapt the rest of the text, depending on the availability of additional material regarding measurements of aircraft VHF antenna]*[A2]

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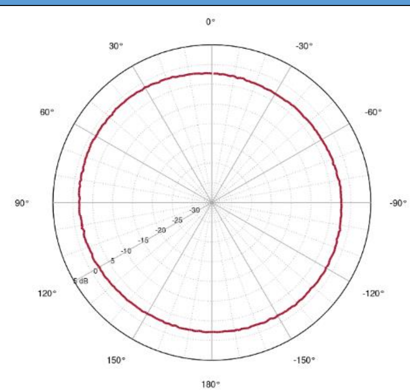
<td>

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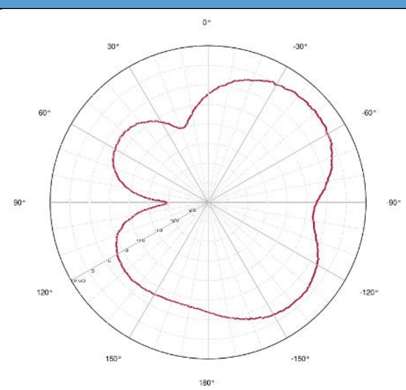
<td>

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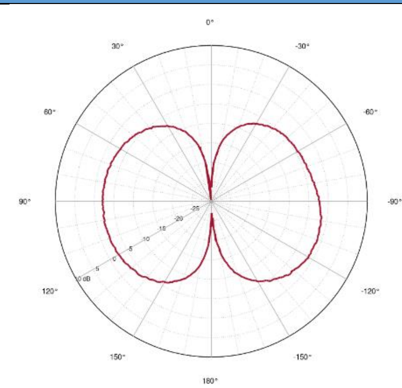
<td>

Transversal plan</td>
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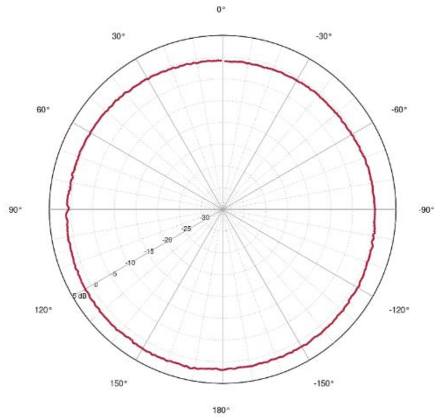
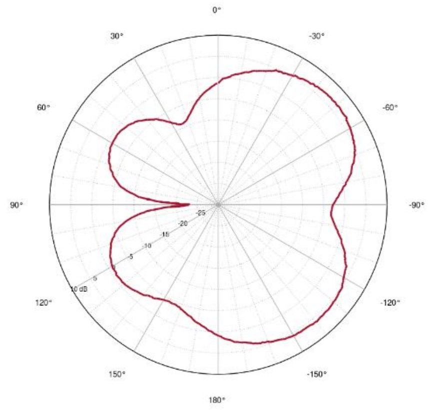
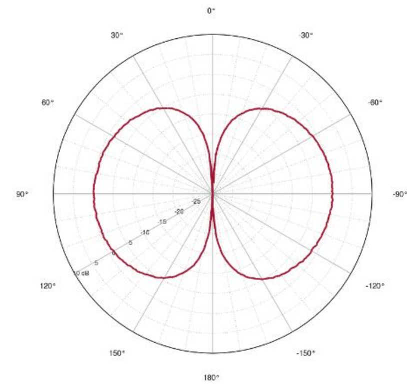
 Horizontal plan	 Longitudinal plan	 Transversal plan
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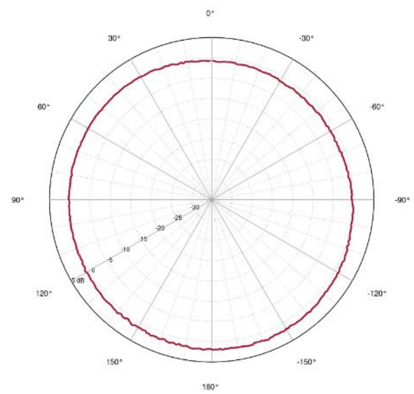
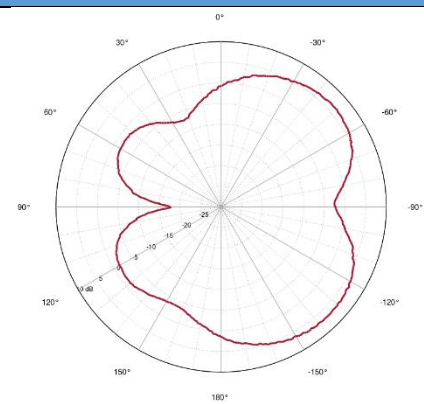
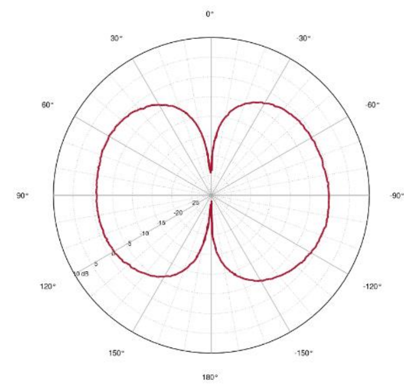
 Horizontal plan	 Longitudinal plan	 Transversal plan

Aircraft VHF receiver performance requirement

The aircraft VHF receiver requirement can be found in ICAO Annex 10 Volume III Part II (section 2.3.2.2.1). [A3]The field strength value of 30 microvolts per meter (- 116 dBW/m^2 which becomes -90 dBm through an isotropic antenna) is assumed for planning extended range VHF facilities. The section also recommends a field strength of 75 microvolts per meter (- 109 dBW/m^2 which becomes -83 dBm through an isotropic antenna) as shown below.

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/m²).*

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

Extract from the section 2.3.2.2.1 of ICAO Annex 10 Volume III

[TBC by the Communication Panel]

Ionospheric propagation losses and required availability performance

No performance requirement exists for a satellite system yet, but it is expected that the VHF service availability performances will depend on the type of operations and airspace types, where the lower and upper bounds of the service availability requirements are the following:

a. Lower bound – 99.9% availability for communications means that correspond to ICAO Performance Based Communications and Surveillance (PBCS) manual;
b. Upper bound – approximately 99.999% availability should be close to that of the VHF ATC ground stationsto comply with radar-like separation standards.

Once a satellite system is designed, its availability performance will be evaluated, and will represent an important input for ANSPs interested inby the service. They will define a set of operational measures required in order to reach a given safety objective. It is understood that VHF scintillation is very dimensioning over specific regions (for instance at low latitudes), and is maximum at sunset with very strong variations between day and night periods. 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 very much time, weather and location specific, and to compensate with appropriate measures (like appropriate flight planning) over the concerned regions when affected. It is also to note that, depending on ANSP 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.

An example of such measure exists in French Polynesia for flights over large oceanic areas using HF communications, which avoid certain time slots in order to avoid facing strong propagation losses.[A4]

AMS(R)S and AM(R)S compatibility

A possible future satellite VHF communications system would be operating under a new AMS(R)S allocation decided by WRC-23 under its Agenda Item 1.7. It is to be noted 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 ATC VHF communications) would be used for ground and satellite communications.

A VHF satellite system would likely correspond to relatively low gain and non-directional satellite antennas, which would may result in the inability to reuse via satellite any frequency already operated by terrestrial stations within its coverage. In order for interested countries to benefit from a new satellite aeronautical VHF voice communication service, ICAO would have to perform a conventional frequency planning exercise, assigning frequencies to the satellite system over interested regions, so as 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 in reality cover the same system on-board the aircraft. However, typical spectral compatibility information which are typically available compatibility studies, such as link-budget parameters, could be presented to ITU-R WP5B, to assure ITU-R that the possible future AMS(R)S system, when allocated the spectrum in accordance to WRC-19 rResolution-428 (WRC-19), is interoperable with the existing AM(R)S services.

ICAO looks forward to continued fruitful cooperation with ITU-R WP 5B regarding this work.

International Civil Aviation Organization

WORKING PAPER

FREQUENCY SPECTRUM MANAGEMENT PANEL (FSMP)

Eleventh Working Group meeting

Virtual Meeting, 1 – 12 March 2021

Agenda Item 5b: WRC-23 AI1.7 VHF AMS(R)S

Updates on Space-based VHF Communication

(Presented by Singapore)

SUMMARY

This paper aims to update the meeting on the preliminary technical study findings till date, and the progress of space-based VHF discussions at ICAO and ITU meetings.

1. INTRODUCTION

1.1 Space-based VHF communication is a concept in which aircraft operating in remote continental regions and oceanic areas could communicate with air traffic control (ATC) via VHF relayed through satellite(s). This concept, when implemented, is expected to be a parallel and complementary system to space-based automatic dependent surveillance-broadcast (ADS-B).

1.2 Currently, while VHF direct controller-pilot communication (DCPC) with aircraft operating in remote continental areas or oceanic regions is not possible, there are other communications available that are dependent on aircraft equipage. These systems range from HF communications to controller pilot data link communications (CPDLC). However, these systems are not recognised in the context of VHF DCPC that are required for ATC to provide reduced separation minima in remote airspace in a similar fashion as to what is provided in dense airspace in areas where terrestrial VHF communications infrastructure is predominant. Therefore, this leads to constraints in airspace capacity and efficiency in oceanic and remote continental areas, where VHF terrestrial infrastructure to provide DCPC communication operations with ATC is either not practical or not cost effective.

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

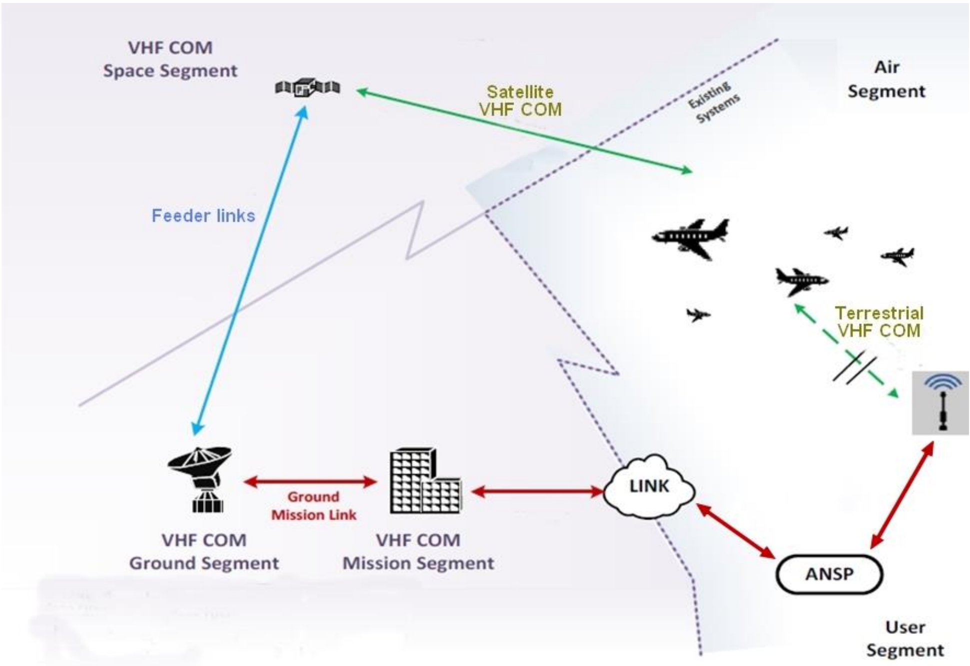


Figure 1 : the space-based VHF communication concept

1.4 Amendments to the ITU Radio Regulations ("RR") are necessary as the space-based VHF will require the ITU to harmonise and allocate the VHF frequency spectrum for aeronautical mobile-satellite (R) service (AMS(R)S) between satellite and aircraft. This approach is similar to the spectrum allocation to space-based ADS-B at the ITU WRC-15. With the support from ICAO and the different Regional Groups of the ITU, the proposed space-based VHF frequency allocation (under AI 10 of WRC-19) was formally accepted as an agenda item for WRC-23, Agenda Item 1.7. In accordance with Resolution 428 (WRC-19), the studies on a possible allocation of AMS(R)S systems operating within the band of 117.975 – 137MHZ will be discussed and sought at WRC-23.

> *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*

1.5 Works on space-based VHF spectrum and technology studies have commenced and are progressing at various ITU and ICAO fora, namely:

a. ITU Working Party 5B (WP 5B) – reviewing the space-based VHF frequency allocation in accordance with ITU-R resolution 428 (WRC-19) for WRC-23, as stated above;

b. ICAO Communications Panel – a new Future VHF Sub-Group (FVSG) was set up in Oct 2020 under the Data Communications Infrastructure Working Group (DCIWG) Project Team – T (PT-T), to review the ICAO Annex 10 SARPs to enable the future global adoption of space-based VHF services, and liaise with ICAO FSMP to address the WRC-23 AI1.7 resolution. The operational aspects of space-based VHF may subsequently be discussed at the Operational Datalink Working Group (OPDLWG) depending on the outcomes of the technical studies; and

c. ICAO Frequency Spectrum Management Panel (FSMP) – drafting/submitting ICAO's positions/support for aviation-related WRC-23 Agenda Items.

2. DISCUSSION

2.1 High-Level Design Objectives

2.1.1 The following objectives and characteristics were proposed for the space-based VHF system under study by Singapore with an industry partner:

- The service provided is primarily VHF voice ATC, as VHF voice is the most critical communication application in terms of safety and dependability
- No change is required on:
    - aircraft avionic equipment, RF antenna setup and applicable specifications.
    - terrestrial base stations specifications, and configuration of base stations located in FIRs which don't make use of the space-based VHF service
- No or minimal change would be required on:
    - operational aspects for pilots and controllers
    - terrestrial base stations configuration in FIRs with space-based VHF service
- Explore using satellite spot beams to optimise the VHF coverage over oceanic and remote continental areas

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

2.2 Aircraft VHF receiver characteristics

2.2.1 Aircraft VHF receiver antenna Aircraft 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. An example is given in Figure 2.

Figure 2 : example of VHF antenna placement on aircraft

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

- Relatively low gains are achieved, typically 3 to 5 dBi maximum
- Radiation patterns are globally omni-directional, and more precisely
  - Omni-directional in azimuth
  - Co-sinusoidal in elevation, meaning a theoretical zero is achieved at aircraft zenith (90° elevation)

2.2.3 Based on similar past ITU-R studies on aeronautical VHF communications *(i.e. document 7B/407 Annex 2 from WRC-2019 cycle)*, the aircraft antenna pattern in Figure 3 has been considered. It can be noted that the co-sinusoidal shape and consequential null at aircraft zenith has important implications on the performance of the satellite VHF link.

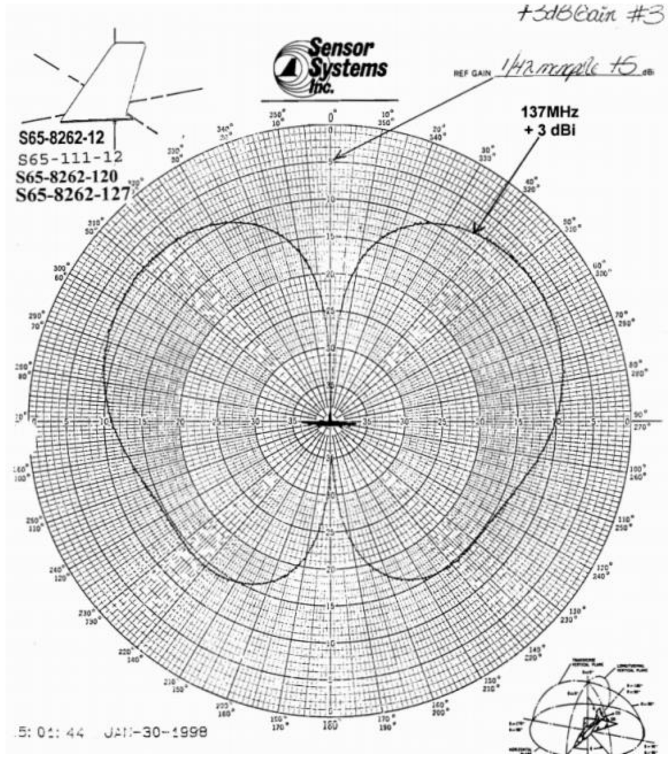


Figure 3 : Typical aircraft VHF antenna pattern – vertical cut (without aircraft body)

2.2.4 Aircraft VHF receiver performance requirement Regarding aircraft VHF receiver sensitivity, ICAO SARPs provide the following reference recommendation 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/m2).*

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

2.2.6 A satellite system relaying aeronautical VHF communications over oceanic and remote continental areas can be considered as one of the “extended range VHF facilities”, hence the underlined 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 of -116.2 dBW/m².**

2.2.7 In addition, the required performance of actual aircraft VHF receiver can be found in available aeronautical industry standards. EUROCAE and RTCA have developed "Minimum operational Performance Specification (MOPS) for airborne VHF receiver-transmitter operating in the frequency range 117.975-137 MHz" (reference: EUROCAE ED 23C dated June 2009 and RTCA DO-186B dated November 2005).
These documents specify that:

- the output audio signal shall have an output Signal plus Noise plus Distortion over Noise plus Distortion (SINAD) of 6 dB.
- the minimal receiver sensitivity to achieve is **-93 dBm**.

2.2.8 Feeder/cable losses on board aircraft shall also be accounted for. It is usually estimated as 2 to3 dB (and confirmed in some ETSI reference), and it is therefore proposed to consider a worst case of **3 dB** in this study.

2.3 Operational Environment for the transmission and reception of satellite VHF

2.3.1 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. At this stage, it is proposed to consider a **maximum 1000 km (540 nm) range** for the reference link budget.

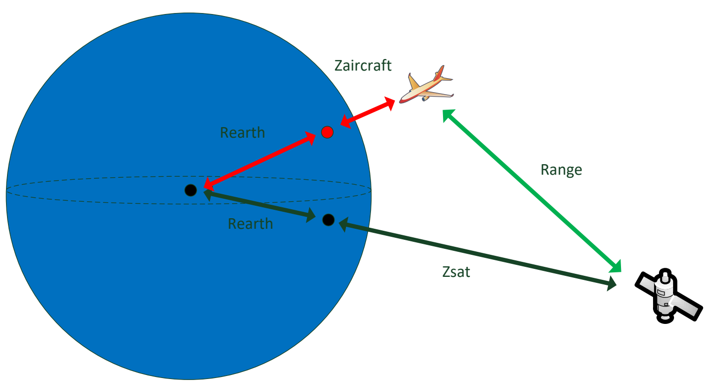


Figure 4 : satellite-aircraft range

2.3.2 Propagation. Satellite transmissions in VHF are known to be significantly affected by scintillation events that occur within the ionospheric layer. The ionosphere causes a delay or attenuation factor 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 (e.g. polar and auroral zones) and within $\pm 20°$ 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. At this stage according to Recommendation ITU-R **P.531-14**, it is recommended that Global Ionospheric Scintillation

Model (GISM) be 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.

Accurate predictions are 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.

In worst cases, at equatorial areas, significant attenuations of about 10 dB could be expected in the extreme worst case (> 15 dB reported for 1.5 GHz, as indicated in Figure 5). The highest intensity are observed, for every longitudinal positions, for a period of time after sunset at 18:00 (local time) and up to 0:00 at the equinox period, and for years of maximal solar activity.

Further work is required in order to appropriately take ionospheric losses into account in the design of an aeronautical VHF satellite system. States/Administrations who have prior experiences on such technical studies are encouraged to share data on scintillation effects on satellite systems. At this stage, it is proposed to take into account the three following reference ionospheric losses:

- A low level of 3 dB attenuation losses for medium latitude regions.
- A medium level of 5 dB attenuation losses for high latitude regions (this medium case is retained in the reference link budget).
- A high level of 10 dB attenuation losses for low latitude regions.

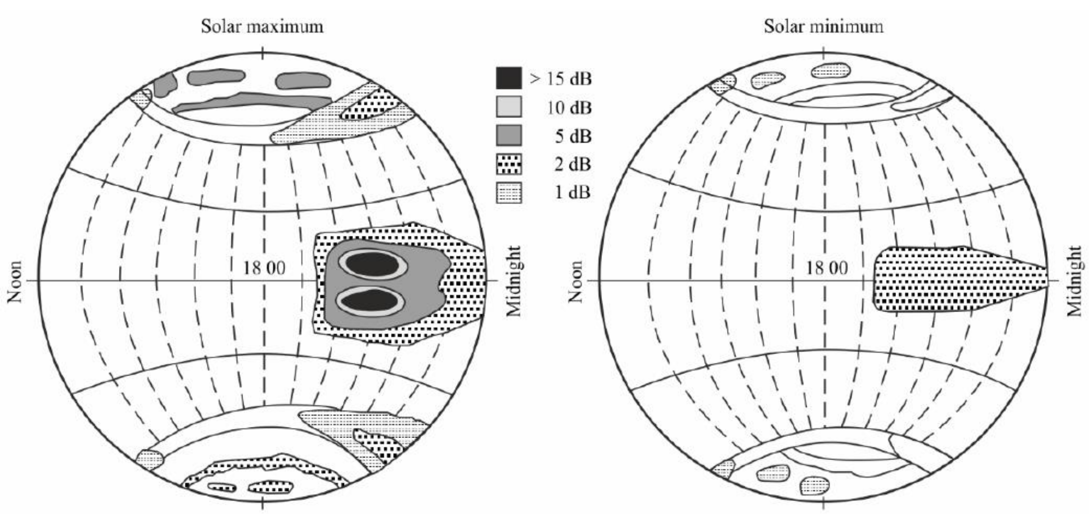


Figure 5 : Ionospheric propagation loss at 1.5 GHz during solar maximum and minimum years (from Recommendation ITU-R **P.531-14**)

2.3.3 Polarization. Emissions of standardised air-ground VHF communication systems are vertically polarized. 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, hence it is 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 at least 3 dB**.

2.4 Satellite Transmitter Characteristics

2.4.1 The output of the link budget considered for satellite downlink will determine the transmission power which in turn determines the size and class of satellites to be deployed. For the purpose of link budget calculations, the downlink is being addressed in more detail given that it has more operating constraints (e.g. aircraft receiver characteristics such as sensitivity cannot be changed) compared to the uplink.

2.4.2 Regarding the gain of the circularly polarized satellite transmitting antenna, a value of 3 dB is considered. Depending on antenna technology, design, number of combined antennas, etc, the typical gain of satellite VHF antenna could range between 0 dB and 6 dB. The proposed value of 3 dB is therefore considered as a realistic intermediate case.

2.4.3 Preliminary downlink link budget is shown below for reference.

Satellite-to-Aircraft Transmission	**Units**	**Value**
Frequency	MHz	137
Range	km	1000
Transmitter		
RF Power	**W**	**330**
Tx Antenna Gain	dB	3
Feeder losses	dB	1
EIRP	dBW	27.2
Signal propagation		
Free space losses	dB	135,2
Additional propagation losses (scintillation)	dB	5
Polar losses to receive V polar	dB	3
Effective received power flux at antenna	dBW/m²	-111.8
Recommended SARPs power-flux for extended range terrestrial transmissions	dBW/m²	-116.2
SARPs power-flux margin (extended range)	dB	4.4
Receiver		
Rx Antenna Gain	dB	-4
Rx feeder losses	dB	3
Rx signal	dBm	-93,0
Rx sensitivity (target SINAD: 6dB)	dBm	-93,0
Receiver Link Margin	**dB**	**0**

2.5 Frequency Coordination Approach

2.5.1 As the future concept evolves, it is foreseen to be an NGSO LEO constellation having global coverage capability as well as the Poles. There will be many areas where existing dense VHF terrestrial infrastructure may negate the need for space-based VHF coverage and in turn will not require the need for space-based VHF frequency coordination. In geographical regions where space-based VHF is required, it would be a normal requirement that coordination of the satellite transmissions occur in advance prior to any satellite passage as per current satellite coordination practices. Importantly, where proper coordination has neither been achieved or agreed upon, then satellite transmissions will not be authorised within the specified area.

3. STATUS UPDATES & NEXT STEPS OF SPACE-BASED VHF

3.1 Technical Feasibility Studies - CAAS and its industry partners will continue with the technical studies, with the primary focus on the design of the satellite constellation, coverage optimisation and other technical parameters (e.g. the VHF radios and antennae), as shown in Section 2 of this paper. The Proof-of-Concept (POC) trials and verification tests may take place following the completion of all the technical studies. For such trials/tests, coordination will be made with the ICAO Regional Offices for the required frequencies in the affected FIRs.

3.2 Frequency Compatibility Studies – The relevant technical study findings to support the ITU-R study analysis work required in accordance with Resolution 428 (WRC-19) as defined in WRC-23 Agenda Item 1.7, are being discussed at APG and WP 5B meetings. France and Singapore commenced the frequency compatibility studies work and submitted an Input Document at the 2020 Nov ITU Working Party 5B (WP 5B) meeting to update on Agenda Item 1.7. The Input Document will be modified and refined as more definite findings arise from the technical studies.

4. ACTION BY THE MEETING

4.1 The meeting is invited to:

a) note and review the contents of this working paper;

b) contribute and provide inputs to Section 2;

c) contribute technical feasibility and compatibility studies; and

d) discuss any relevant matters as appropriate.

— END —