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| **US Radiocommunication Sector****FACT SHEET** |
| **Working Party:** ITU-R WP 5C | **Document No:** USWP5C32-XX |
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| **Purpose/Objective:** The purpose of this document is to continue sharing and compatibility studies for WRC-27 Agenda Item 1.10 in accordance with Resolution 775 (WRC-23). |
| **Abstract:** This contribution defines the dynamic simulation scenario between FS/AMS and FSS GSO systems in the 71-76 and 81-86 GHz range. The contribution also provides an analysis for static, single interference scenarios.  |
| **Fact Sheet Preparer:** Victory Nguyen  |

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| **Radiocommunication Study Groups** | A blue logo with a black background  AI-generated content may be incorrect. |
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| **Working document on sharing studies under agenda item 1.10** |
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**Introduction**

WRC-27 Agenda Item 1.10 considers developing power flux-density and equivalent isotropically radiated power limits for inclusion in Article 21 of the Radio Regulations for the fixed-satellite, mobile-satellite and broadcasting-satellite services to protect the fixed and mobile services in the frequency bands 71-76 GHz and 81-86 GHz, in accordance with Resolution 775 (Rev.WRC-23).

This contribution provides an update to the sharing studies of FSS GSO system with FS and AMS systems operating in the 71-76 and 81-86 GHz frequency range presented in Annex 2.4 of the WP 5C Chair’s Report, Document 5C/152.

Attachment: 1

|  |
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| **ATTACHMENT****Annex 2.4 to Working Party 5C Chair’s Report** |
| WORKING DOCUMENT ON SHARING STUDIES UNDER AGENDA ITEM 1.10 |

Editor's Note: The content of this document has been briefly discussed but was not reviewed in detail during official sessions and is not agreed. Moreover, specific critical issues have been identified with respect to the short-term protection criterion, which should be carefully reviewed, as well FS characteristics for sharing studies, in particular elevation angles of the FS stations.

# [Introduction

WRC-23 approved WRC-27 agenda item 1.10 by Resolution **813 (WRC-23)**, in which point 1.10 is:

*1.10 to consider developing power flux density and equivalent isotropically radiated power limits for inclusion in Article* ***21*** *of the Radio Regulations for the fixed-satellite, mobile-satellite and broadcasting-satellite services to protect the fixed and mobile services in the frequency bands 71-76 GHz and 81-86 GHz, in accordance with Resolution* ***775 (Rev.WRC-23)****;*

In Resolution **775 (WRC-23)**, the World Radiocommunication Conference (Dubai, 2023),

resolves to invite the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference

*the appropriate studies to determine power flux-density (pfd) and equivalent isotropically radiated power (e.i.r.p.) limits to be included in Article* ***21*** *for satellite services (fixed-satellite service (FSS), mobile-satellite service (MSS) and broadcasting-satellite service (BSS)) to protect the current and planned fixed and mobile services in the frequency bands 71-76 GHz and 81-86 GHz, …*

This document contains the result of the studies under WRC-27 agenda item 1.10, in response to Resolution **775 (Rev.WRC-23)**.

# Provisions of the Radio Regulations

The extracts from Article **5** of the Radio Regulations (RR), edition 2024, is presented in Tables 1 and 2 for the frequency ranges 71-76 GHz and 81-86 GHz, respectively.

Table 1

Extract from Article 5 of Radio Regulations for 71-76 GHz band

|  |
| --- |
| Allocation to services |
| Region 1 | Region 2 | Region 3 |
| 71-74 FIXED FIXED-SATELLITE (space-to-Earth) MOBILE MOBILE-SATELLITE (space-to-Earth) |
| 74-76 FIXED FIXED-SATELLITE (space-to-Earth) MOBILE BROADCASTING BROADCASTING-SATELLITE Space research (space-to-Earth) 5.561 |

Table 2

Extract from Article 5 of Radio Regulations for 81-86 GHz band

|  |
| --- |
| Allocation to services |
| Region 1 | Region 2 | Region 3 |
| 81-84 FIXED 5.338A FIXED-SATELLITE (Earth-to-space) MOBILE MOBILE-SATELLITE (Earth-to-space) RADIO ASTRONOMY Space research (space-to-Earth)  5.149 5.561A |
| 84-86 FIXED 5.338A FIXED-SATELLITE (Earth-to-space) 5.561B MOBILE RADIO ASTRONOMY 5.149 |

Based on the information provided above, the appropriate studies could be carried out taking into account the nature of frequency bands and the service allocation in these frequency bands, to determine related PFD and E.I.R.P limits, as shown below:

– PFD limit for fixed-satellite service (space-to-Earth) to protect mobile service and fixed service in 71-76 GHz;

– PFD limit for mobile-satellite service (space-to-Earth) to protect mobile service and Fixed Service in 71-74 GHz;

– PFD limit for broadcasting-satellite service to protect mobile service and fixed service in 74-76 GHz;

– E.I.R.P limit for fixed-satellite service (Earth-to-space) to protect mobile service and fixed service in 81-86 GHz;

– E.I.R.P limit for mobile-satellite service (Earth-to-space) to protect mobile service and fixed service in 81-84 GHz.

# Propagation conditions

Document [5C/74](https://www.itu.int/md/R23-WP5C-C-0074/en) from WPs 3J and 3M contains references to the following recommendations:

**Recommendation** [**ITU-R P.452**](https://www.itu.int/rec/R-REC-P.452/en) **is applicable for sharing studies between stations on the surface of the Earth.** **While the models have been tested up to 50 GHz, it is considered that it can be used for frequencies up to 100 GHz with the following caveats:**

1 The free space loss component is applicable for all frequencies without limit.

2 The gaseous attenuation component, based on Recommendation [ITU-R P.676](https://www.itu.int/rec/R-REC-P.676/en), is applicable to 1 000 GHz.

3 The prediction method for diffraction loss is applicable for frequencies to at least 100 GHz although the input data required, such as terrain profiles, may not be detailed enough at the higher frequencies. However, the loss due to diffraction at these frequencies is quite large, so once a path is fully transhorizon, the only significant propagation mechanism is troposcatter.

4 While the troposcatter and anomalous propagation methods are based on measurements up to 50 GHz and have not been tested at higher frequencies, there is nothing intrinsic in the methods that would prevent their use between 50 and 86 GHz.

**Recommendation** [**ITU-R P.619**](http://www.itu.int/rec/R-REC-P.619/en) **is applicable for sharing studies between stations in space and stations on the Earth’s surface from of 100 MHz to 100 GHz.**

**Recommendation** [**ITU-R P.2108**](https://www.itu.int/rec/R-REC-P.2108/en) **– *Prediction of clutter loss from 30 MHz and 100 GHz*.**

1 § 3.1: For situations in which both end terminals are below “representative” clutter heights, the model is valid for frequency ranges between 0.03-3 GHz.

2 § 3.2: For situations in which terrestrial terminal(s) is(are) imbedded within clutter, the model is valid for frequency ranges between 0.5 - 0.67 GHz

3 § 3.3: For situations in which one terminal is within the clutter and the other is a satellite, aeroplane, or other platform above the surface of the Earth, the model is valid for frequency ranges between 10-100 GHz.

**Recommendation** [**ITU-R P.2109**](https://www.itu.int/rec/R-REC-P.2109/en) **– *Prediction of building entry loss from 80 MHz and 100 GHz*.**

In addition to the propagation models mentioned above, the studies also consider the use of the SRTM V3 (3 arc second, 90m) terrain profile data where necessary.

Notwithstanding the elements received from WPs 3J and 3M, in Section V of RR Article **21**, the limit of power flux-density from space-stations relates to the power flux-density which would be obtained under assumed free-space propagation conditions.

# Characteristics and protection criteria of FS stations

Editor’s note: Further discussion is necessary to determine what range of values should be used for FS characteristics, if single or ranges of typical values should be considered, and if the characteristics represent representative or worst-case values. The tables below provide a compilation of the characteristics proposed by input contributions to the Nov 2024 meeting of WP 5C.

The following ITU-R Recommendations contain relevant technical and operational characteristics as well as protection criteria for FS systems:

– ITU-R [F.758-7](https://www.itu.int/rec/R-REC-F.758/recommendation.asp?lang=en&parent=R-REC-F.758-7-201911-I) contains the principles for the development of sharing criteria of digital systems in the FS. It also contains information on representative technical characteristics of digital fixed wireless systems (FWS) in the FS for use in sharing studies above about 30 MHz. For agenda item (AI) 1.10, the following table abstracted from Table 11 contains the system parameters for PP FS systems in allocated bands from 71-76 GHz and 81-86 GHz.

Table 3

Typical values for FS point-point system parameters in the frequency band 71-76 and 81-86 GHz

|  |  |
| --- | --- |
| Frequency range(GHz) | 71-76/81-86 |
| Reference ITU-R Recommendation | F.2006 |
| Modulation | QPSK | 64-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 250, 500, 750, 1 000, **1 250**, 1 500, 1 750, 2 000, 2 250 | 500, 700, 1 000 |
| Tx output power range (dBW)  | –10 | –20 |
| Tx output power density range (dBW/MHz)(1) | –41 | –47…-50 |
| Feeder/multiplexer loss range (dB)  | 0 | 0 |
| Antenna gain range (dBi) | 54 | 44…50 |
| e.i.r.p. range (dBW) | 44 | 24…30 |
| e.i.r.p. density range (dBW/MHz)(1) | 13 | –6…3 |
| Receiver noise figure typical (dB)  | 10 | 8 |
| Receiver noise power density typical (=*NRX*) (dBW/MHz) | –134 | –136 |
| Normalized Rx input level for 1 × 10–6 BER (dBW/MHz)  | –120.5 | –94…-91 |
| Nominal long-term interference power density (dBW/MHz)(2) | –134 + *I*/*N* | –136 + *I*/*N* |

– ITU-R [F.699-8](https://www.itu.int/rec/R-REC-F.699/en) provides reference radiation patterns for, and information on, point-to-point FWS antennas in the frequency range from 100 MHz to 86 GHz. This information may be used in single-entry analyses and interference assessments when information concerning the FWS antenna is not available.

– ITU-R [F.1245-3](https://www.itu.int/rec/R-REC-F.1245/en)provides average sidelobes and related reference radiation patterns for point-to-point FWS antennas in the frequency range from 1 GHz to 86 GHz. This information may be used for aggregate coordination and interference assessment studies when information concerning the FWS antenna is not available.

Typical FS station parameters are provided in the following table, to facilitate the sharing study.

Editor’s note: Table 1 is the result from offline discussion on typical parameters.

Table 4

Typical values for FS point-point system parameters in the frequency band 71-76 and 81-86 GHz

|  |  |
| --- | --- |
| System parameters | Typical Value |
| Channel spacing and receiver noise bandwidth (MHz) | 500 |
| Modulation | 128 QAM |
| Feeder/multiplexer loss (dB) | 0 |
| Antenna gain (dBi)  | 51 |
| Antenna size (m) | 0.6 |
| Receiver noise figure (dB) | 7 |
| Antenna height(m)  | 30 |
| Antenna RPE | F.699-8 and F.1245-3 |
| Link length (km)  | 3 |
| Elevation angle (degree) | -5-5 |

The following protection criteria used in study of AI 1.10 are:

‒ for the long-term, the *I/N* at the input of the FS receiver should not exceed –10 dB for more than 20% of the time;

‒ for the short-term, the *I/N* at the input of the FS receiver should not exceed +11 dB for more than 0.00128% of the time. The derivation methodology is in Attachment 1 and Attachment 2, from different source.

Editor’s note: The values of short-term protection criteria need further study, and relevant contributions are invited to submitted to next WP 5C meeting.

# Characteristics and protection criteria of MS stations

The following table contains relevant technical and operational characteristics for the Aeronautical Mobile Service (AMS) systems. The airborne system operates at elevations between 10 000 and 50 000 feet (3 048 to 15 240 m). Ground stations operate with a minimum elevation angle of 5 degrees and a maximum elevation angle of 45 degrees.

Table 5

Representative receiver technical characteristics of the AMS systems in the frequency band 71-76 and 81-86 GHz

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Units** | **Airborne Receiver** | **Ground Receiver** |
| Tuning range | GHz | 81-86 | 71-76 |
| RF selectivity | 3 dB | MHz | 100 | 100 |
| 20 dB | MHz | 500/750/1 000 | 500/750/1 000 |
| 60 dB | MHz | 5 000 | 5 000 |
| IF selectivity | 3 dB | MHz | 100 | 100 |
| 20 dB | MHz | 500/750/1 000 | 500/750/1 000 |
| 60 dB | MHz | 5 000 | 5 000 |
| NF | dB | 7 | 7 |
| Sensitivity  | dBm | −75 to −80 | −80 to −90 |
| Image rejection  | dB | 20 | 20 |
| Spurious rejection  | dB | 20 | 20 |
| Antenna gain  | dBi | 51 | 51 |
| 1st sidelobe | dBi | 5 @ 0.7° for horizontal5 @ 1.1° for vertical | 5 @ 0.7° for horizontal5 @ 1.1° for vertical |
| Polarization |  | RHCP& LHCP[[1]](#footnote-2) | RHCP & LHCP |
| Antenna pattern/type |  | Parabolic or phased array | Horn |
| Horizontal BW  | degrees | 0.5 | 0.5 |
| Vertical BW  | degrees | 0.9 | 0.5 |
| Antenna model |  | RecommendationITU-R F.699 | RecommendationITU-R F.699 |

# Characteristics of FSS & BSS stations

Tables in Attachment 3 summarize system characteristics, sent by WP 4A in Document 5C/142, that could be used in sharing studies within the context of WRC-27 AI 1.10. Satellite systems and networks in BR IFIC (Space services) with frequency assignments in the 71-76 GHz and 81‑86 GHz bands could also be used for sharing studies.

With respect to the question on how to model multiple systems to perform aggregate interference calculations, WP 4A recommends conducting simulations with the systems listed in the Attachment 3 noting that (1) additional satellite systems and networks in BR IFIC (Space services) could be included in aggregate interference calculations and (2) multiple co-frequency GSOs can operate over the same area from different longitudes on the GSO arc.

Moreover, WP 4A notes that non‑GSO systems may implement mitigation measures among themselves. Normally, these measures, if applied, are confidential, but one possible technique to model these measures is to use avoidance angle between co-frequency beams. That is, for instance, on a given frequency, System A’s beam will need to have at least 1.5° angular separation with System B’s beam if they are serving the same area on Earth. It is not feasible to serve the same spot on the same frequency from satellites that are in close proximity of each other.

When considering aggregate interference from GSO satellites, a minimum longitude difference between satellites of 1° could be used.

Table 2 and 3 of Attachment 3, as well as BR IFIC (Space Service) contains characteristics of earth stations to be considered by WP 5C to determine appropriate e.i.r.p. limits.

Files attached to the liaison statement (5C/142) of WP 4A are placed on the SharePoint as [link](https://extranet.itu.int/rsg-meetings/sg5/wp5c/Share/WG%205C-2%20Sharing%2C%20compatibility%20aspects%20and%20WRCs%20issues/AI%201.10/R23-WP5C-C-0142%21%21MSW-E%20Attacehed%20file%20FE86C782.zip).

# Characteristics of MSS stations

Editor’s note: Consultation with BR is necessary to provide the necessary information from the data filings that can be used for the sharing studies, as 4C did not provide any MSS characteristics. Upon received proper and workable information from BR, that may be conveyed to 4C.

Upon request of WP 4C (see Document 5C/143), BR reviewed the satellite filings to gather characteristics of MSS networks or systems in the frequency bands 71-74 GHz and 81-84 GHz and sent them directly to WP 5C. The data can be found [here](https://eur01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fextranet.itu.int%2Frsg-meetings%2Fsg5%2Fwp5c%2FShare%2FForms%2FColumn%2520view.aspx%3FRootFolder%3D%252Frsg-meetings%252Fsg5%252Fwp5c%252FShare%252FWG%25205C-2%2520Sharing%252C%2520compatibility%2520aspects%2520and%2520WRCs%2520issues%26FolderCTID%3D0x0120003D12FDCA4AB21246A058EC9F73544730%26View%3D%257BD767BD77-F6D3-429A-BA07-6B1F103BD607%257D&data=05%7C02%7CNasarat.Ali%40ofcom.org.uk%7C5acfc255dc794d30b57008dd08bc1371%7C0af648de310c40688ae4f9418bae24cc%7C0%7C0%7C638676326146941601%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C&sdata=iqYDdAt934iliKA%2Ba7L9h9c4iRGk4FAUyxXK9wa2qTs%3D&reserved=0). It includes orbital parameters of satellite systems published by administration in BR IFIC (Space Services). BR has also provided information on characteristics of FSS and MSS networks and systems in Document 5C/148.

Attachment 4 in this working document presents 4 systems extracted from that dataset, to be used as possible examples of MSS systems for studies under this agenda item.

# Methodology for sharing study

## Methodology for the determination of power flux-density (pfd) limits

Determination of pfd limits for possible inclusion in RR Article **21** may result in the addition of one or several entries in Table **21-4** which defines pfd limits in dB(W/m2) for angles of arrival (δ) above the horizontal plane.

To calculate this angle of arrival, and hence, the pfd limits, positions of the interfering satellite and of the victim station are necessary.

Recommendation [ITU-R F.1108-4](https://www.itu.int/rec/R-REC-F.1108/en) – *Determination of the criteria to protect fixed service receivers from the emissions of space stations operating in non-geostationary orbits in shared frequency bands* contains various methodologies to determine the criteria to protect fixed service receivers from emissions of space stations operating in non-geostationary orbits in shared frequency bands. Annex 1 of this Recommendation contains the necessary formulas to evaluate the satellite elevation and angular distance from the victim antenna main beam.

The following sections provides different study scenario to assess sharing between FS and FSS.

### Sharing with GSO satellites

As the interference from GSO satellites is steady, the long-term protection criterion of Recommendation ITU-R F.758 is used.

The following GSO FSS characteristics were extracted from Attachment 3 of this document.

Table 6

Parameters of the GSO FSS System

|  |  |  |
| --- | --- | --- |
| Parameter | System C (Satellite) | System C (Earth Station) |
| Frequency (GHz) | 71-76 | 81-86 |
| Altitude (km) | 35,786 | N/A |
| Number of planes | 1 | N/A |
| Satellites per plane | 1 | N/A |
| Inclination angle (deg) | 0 | N/A |
| RAAN | N/A | N/A |
| Antenna Pattern | Appendix 7 Annex 3 Section 3G1= ‒13 dBBeamwidth = 0.42 deg | S.580 |
| Peak antenna gain (dBi) | 50 | 50 (D:0.6 m) |
| Input power density (dBW/Hz) | ‒77.8[[2]](#footnote-3)  | -77.8 |
| Minimum Elevation Angle (degrees) | 3 | 3 |
| Bandwidth (MHz) | 180 | 180 |
| Out of band emission mask | SM.1541-6 | SM.1541-6 |
| Number of co-frequency beams (N\_co) | 1 | 1 |
| Max Power Flux Density on the grounddBW/m2/MHz | -129.85 | N/A |
| Worst[[3]](#footnote-4) Earth station density per 2 000 000 km2  | N/A | 25 |

#### Scenario 1

Station(s) of the fixed service are defined with the parameters of the following table.

Table 7

Parameters of the station of the fixed service

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Latitude (°) | 0, 25, 50, 75 |  |
| Longitude (°) | 0 |  |
| Altitude (m) | 30 |  |
| Antenna elevation (0) | 0, 2.5, 5 | Rec. ITU-R F.2086 |
| Azimuth (°) | 0 to 180 |  |
| Antenna diameter (cm) | 20, 30 or 60 |  |
| Antenna diagram |  | Rec. ITU-R F.1245 |
| Max antenna gain |  | Rec. ITU-R F.699 |
| *I/N* (dB) long-term | ‒10 | Rec. ITU-R F.758 |
| Nominal long-term interference power density (dBW/MHz) | ‒146 | Rec. ITU-R F.758 |

GSO satellites are separated from 10, 4, or 1°.

Exceedance over the nominal long-term interference power density is assessed with several tentative pfd masks.

{Editor’s note: The following figure provides an example of such assessment

}

#### Scenario 2: Single Interferer (GSO Satellite, Dynamic Analysis)

Station(s) of the fixed service are defined with the parameters of the following table.

Table 8

Parameters of the station of the fixed service

|  |  |
| --- | --- |
| Frequency range(GHz) | 71-76/81-86 |
| Reference ITU-R Recommendation | F.2006 |
| Antenna Pattern | Rec. ITU-R F.699 |
| Antenna Height (m) | 30 |
| Modulation | QPSK | 64-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 250, 500, 750, 1 000, **1 250**, 1 500, 1 750, 2 000, 2 250 | 500, 700, 1 000 |
| Tx output power range (dBW)  | –10 | –20 |
| Tx output power density range (dBW/MHz)(1) | –41 | –47…-50 |
| Feeder/multiplexer loss range (dB)  | 0 | 0 |
| Antenna gain range (dBi) | 54 | 44…50 |
| e.i.r.p. range (dBW) | 44 | 24…30 |
| e.i.r.p. density range (dBW/MHz)(1) | 13 | –6…3 |
| Receiver noise figure typical (dB)  | 10 | 8 |
| Receiver noise power density typical (=*NRX*) (dBW/MHz) | –134 | –136 |
| Normalized Rx input level for 1 × 10–6 BER (dBW/MHz)  | –120.5 | –94…-91 |
| Nominal long-term interference power density (dBW/MHz)(2) | –134 + *I*/*N* | –136 + *I*/*N* |

The analysis was conducted assuming that both the FS and AMS were operating at locations at the following latitude/longitude: 39.73° N, and 107° W. The location of the FS and AMS systems were randomized within a 100 km radius of the aforementioned location.

The analysis produced a series of cumulative distribution function (CDF) curves for the I/N levels received by the FS and AMS which were then compared to the I/N protection criteria of FS and AMS respectively.

The following assumptions were made during the analysis:

* There is only 1 ES deployed
* The GSO satellite is pointing at the ES
* The location of the GSO satellite is X° N and Y° W
* The beamwidth of the FS is 0.33 degrees
* The AMS ground receiver’s antenna can point at either the AMS ground or airborne transmitter
* The AMS ground system and FSS ES antenna heights are X m
* The AMS airborne system is operating at 9 km above ground
* The polarization of the FSS GSO satellite, FSS ES, and AMS systems is RHCP. The polarization of the FS is linear

Figure 1 below depicts the GSO satellite antenna pattern.

Figure X: GSO satellite antenna pattern



Study results

The results are presented in the following plots. In the following figures, the FS receiving station I/N is plotted as a cumulative distribution function (CDF).

Figure X: FS receiver I/N CDF plot (TBD)

### Sharing with non-GSO satellites

Recommendation ITU-R F.1108-4 – *Determination of the criteria to protect fixed service receivers from the emissions of space stations operating in non-geostationary orbits in shared frequency bands* contains equations to simulate the operation of a non-GSO satellite and thereby the statistics necessary to determine how often a satellite will be visible in any direction for a particular terrestrial station or position.

#### Scenario 1

Station(s) of the fixed service are defined with the parameters of the following table.

Table 9

Parameters of the station of the fixed service

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Latitude (°) | 0, 25, 50, 75 |  |
| Longitude (°) | 0 |  |
| Altitude (m) | 30 |  |
| Antenna elevation (0) | 0, 2.5, 5 | Rec. ITU-R F.2086 |
| Azimuth (°) | 0, 60, 120, 180 |  |
| Antenna diameter (cm) | 20, 30 or 60 |  |
| Antenna diagram |  | Rec. ITU-R F.1245 |
| Max antenna gain |  | Rec. ITU-R F.699 |
| *I/N* (dB) long-term | ‒10 | Rec. ITU-R F.758 |
| Nominal long-term interference power density (dBW/MHz) | ‒146 | Rec. ITU-R F.758 |
| *I/N* (dB) short-term | [TBD] |  |
| Nominal short-term interference power density (dBW/MHz) | [TBD] |  |

Compliance with the short-term and long-term protection criteria is assessed for several tentative pfd masks.

A sensitivity analysis is provided to assess the influence of:

‒ the number of satellites in the non-GSO system (1, 10, 100, 1 000, 10 000, 100 000), or other numbers of satellites in line with the elements provided by WP 4A, and

‒ altitude of the non-GSO satellites.

## Methodology for the determination of equivalent isotropically radiated power (e.i.r.p.) limits

The following GSO FSS characteristics were extracted from Attachment 3 of this document.

Table 10

Parameters of the GSO FSS System

|  |  |  |
| --- | --- | --- |
| Parameter | System C (Satellite) | System C (Earth Station) |
| Frequency (GHz) | 71-76 | 81-86 |
| Altitude (km) | 35,786 | N/A |
| Number of planes | 1 | N/A |
| Satellites per plane | 1 | N/A |
| Inclination angle (deg) | 0 | N/A |
| RAAN | N/A | N/A |
| Antenna Pattern | Appendix 7 Annex 3 Section 3G1= ‒13 dBBeamwidth = 0.42 deg | S.580 |
| Peak antenna gain (dBi) | 50 | 50 (D:0.6 m) |
| Input power density (dBW/Hz) | ‒77.8[[4]](#footnote-5)  | -77.8 |
| Minimum Elevation Angle (degrees) | 3 | 3 |
| Bandwidth (MHz) | 180 | 180 |
| Out of band emission mask | SM.1541-6 | SM.1541-6 |
| Number of co-frequency beams (N\_co) | 1 | 1 |
| Max Power Flux Density on the grounddBW/m2/MHz | -129.85 | N/A |
| Worst[[5]](#footnote-6) Earth station density per 2 000 000 km2  | N/A | 25 |

#### Scenario 1: Single Interferer (GSO FSS ES, Dynamic Analysis)

Station(s) of the fixed service are defined with the parameters of the following table.

Table 11

Parameters of the station of the fixed service

|  |  |
| --- | --- |
| Frequency range(GHz) | 71-76/81-86 |
| Reference ITU-R Recommendation | F.2006 |
| Antenna Pattern | Rec. ITU-R F.699 |
| Antenna Height (m) | 30 |
| Modulation | QPSK | 64-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 250, 500, 750, 1 000, **1 250**, 1 500, 1 750, 2 000, 2 250 | 500, 700, 1 000 |
| Tx output power range (dBW)  | –10 | –20 |
| Tx output power density range (dBW/MHz)(1) | –41 | –47…-50 |
| Feeder/multiplexer loss range (dB)  | 0 | 0 |
| Antenna gain range (dBi) | 54 | 44…50 |
| e.i.r.p. range (dBW) | 44 | 24…30 |
| e.i.r.p. density range (dBW/MHz)(1) | 13 | –6…3 |
| Receiver noise figure typical (dB)  | 10 | 8 |
| Receiver noise power density typical (=*NRX*) (dBW/MHz) | –134 | –136 |
| Normalized Rx input level for 1 × 10–6 BER (dBW/MHz)  | –120.5 | –94…-91 |
| Nominal long-term interference power density (dBW/MHz)(2) | –134 + *I*/*N* | –136 + *I*/*N* |

The analysis was conducted assuming that both the FS and AMS were operating at locations at the following latitude/longitude: 39.73° N, and 107° W. The location of the FS and AMS systems was randomized within a 40 and 400 km radius, respectively, of the FSS ES that is stationed at the aforementioned location.

The analysis produced a series of cumulative distribution function (CDF) curves for the I/N levels received by the FS and AMS which were then compared to the I/N protection criteria of FS and AMS respectively.

The following assumptions were made during the analysis:

* There is only 1 ES deployed
* The ES is pointing at the GSO satellite
* The location of the GSO satellite is X° N and Y° W
* The beamwidth of the FS is 0.53 degrees
* The beamwidth of the FSS ES is 0.41 degrees
* The AMS airborne receiver’s antenna can point at either the AMS ground or airborne transmitter
* The AMS ground system and FSS ES antenna heights are X m
* The AMS airborne receiver is operating at 9 km above ground
* The polarization of the FSS GSO satellite, FSS ES, and AMS systems is RHCP. The polarization of the FS is linear

#### Scenario 2: Aggregate Interferers (GSO FSS ES, Dynamic Analysis)

The analysis and simulation for the aggregate FSS ES is the same mentioned in Scenario 2: Single Interferer (GSO FSS ES, Dynamic Analysis), but with the following changes:

* 25 FSS ES are deployed, evenly, in a 2,000,000 km2 area
* All the FSS ES are pointing at the GSO satellite

# Studies for FSS & BSS stations

TBD

# Studies for MSS stations

TBD

# Summary of the results of studies

TBD

Editor’s note: Option 1 from contribution 5C/117

[Attachment 1 (Option 1)

Derivation of short-term protection criteria for agenda item 1.10

# 1 Introduction

The derivation of short-term protection criteria is according to Recommendations ITU-R F.1606-0 and ITU-R F.1495-2.

The methodology presented in this Attachment is based on the assumption that fading in the 71-76 GHz and 81-86 GHz (E-band) is dominated by rain and that, therefore, even if long-term interference has an effect on the performance of the link, the main way to have an outage of the FS link is to have an interference level higher than the fade margin of the link, whatever the propagation conditions may be.

On this basis, the following apportionment of the effect of interference on the degradation of the link (and on the EPOs) has been assumed:

– 20% of FS link degradation due to long-term interference;

– 80% of FS link degradation due to short-term interference.

# 2 EPOs

The allowable degradation in performance of real FWS due to interference from other services sharing the same frequency bands on a primary basis are expressed as a permissible fraction (10%) of the total EPOs and are defined in Recommendation ITU-R F.1565.

Fixed satellite systems are currently used in the E-band for the backhaul links of wireless access networks for point-to-point (P-P) applications. The service transmitted via E-band FS systems is packet service only.

The corresponding EPO values are given in Table 1, and correspond to the following assumptions:

– Access network section (Table 10 of Recommendation ITU-R F.1565-1, as shown in Fig. 1, for convenience);

– Rate from 160 to 3500 Mbit/s in Tables 10 of Recommendation ITU-R F.1565-1;

– *C*  8%.

Table 7

|  |  |
| --- | --- |
|  | EPO (fraction of any month) based on the application of Recommendation ITU-R F.1565-1 |
|  | Total allowable to interference | Short-term interference (80%) |
| Errored second ratio | For further study | N/A |
| Severely errored second ratio | 1.6  10–5 | 1.28  10–5 |

Figure 1

Table 10 of Recommendation ITU-R F.1565-1



Please note, EPO based on ESR is more stringent and is more appropriate to protect FS. However, consider there is no ESR value for high capacity in Table 10, EPO at E-band based on only SESR is provided in this contribution. Update of EPO at E-band should be considered if ESR value for high capacity is supplemented in the future.

# 3 Short-term criteria

## 3.1 Methodology

As explained in § 1, the main way to have an outage of the FS link, considering short-term interference, is to have an interference level higher than the fade margin of the link, whatever the propagation conditions may be. That means, the permissible I/N for short-term protection is the largest value that will not cause SES in the absence of fading.

The definition of short-term criteria is then linked to both values of fade margin (or net fade margin considering ATPC[[6]](#footnote-7)1) and EPO allocated to short-term interference as defined in Table 1, considering that the fade margin is allocated to the short-term criteria.

## 3.2 Fixed satellite fade margins

In the E-band, since link lengths are likely to be short and AM is normally enabled to high modulation, and also BCA applications would decrease the fade margin, an FS fade margin of 10 dB was considered representative of conventional links.

As the EPO are referenced to ITU-T Recommendations G.826 definitions, it is necessary to extrapolate the fade margin corresponding to SES levels. On the basis of agreed assumptions (for detailed derivation, please refer to Recommendation ITU-R F.1606-0), the fade margin for SES is 1 dB higher than the fade margin referenced to the BER 1 ×10–6 level. Table 2 summarizes these different values of fade margins and, associated with the correspondent EPO ratios, allows to define short-term criteria for the FS.

Table 8

|  |  |  |
| --- | --- | --- |
|  | Fade margin (dB) | EPO ratio |
| BER 1 ×10–6  | 10 |  |
| SES | 11 | 1.28 × 10–5 |

Thus, the short-term criteria proposed to be used in E-band have been defined associating the SES EPO (see Table 2) and the corresponding I/N as defined in Table 3.

Table 9

|  |  |  |
| --- | --- | --- |
|  | I/N(dB) | Percentage of time not to be exceeded (%) |
| Criterion | 11 | 0.00128 |

*Editor’s note: Option 2 from contribution 5C/130*

Attachment 2 (Option 2)

Derivation of short-term protection criteria for agenda item 1.10

The allowable degradation in performance of FS systems due to interference from other services sharing the same frequency bands on a primary basis are expressed as a permissible fraction (10%) of the total Error Performance Objectives (EPO) and are defined in Recommendation ITU-R F.1565 and ITU-R F.1495 for the real FS systems which may form part of the national portion of a 27 500 km HRP, assumed to be representative of the 71-76 GHz and 81-86 GHz FS links.

The total corresponding EPO value is calculated to be 1.6  10–5 for severely errored second ratio, and correspond to the following assumptions:

– Access network section (Tables 10 of Recommendation ITU-R F.1565-1 below);

– Only SESR applies here as there is no ESR value in this table for 160 to 3 500 Mbit/s;

– Rate from 160 to 3 500 Mbit/s in Tables 10 of Recommendation ITU-R F.1565-1;

– *C*  8%.



Table 10 from Recommendation ITU-R F.1565-1.

It is well-known that rain is the dominating factor in fading at 71-76 GHz and 81-86 GHz. Therefore, even if long-term interference has an effect on the performance of the link, the main way to have an outage of the FS link is to have an interference level higher than the fade margin of the link, whatever the propagation conditions may be.

On this basis, the following apportionment of the effect of interference on the degradation of the link (and on the EPOs) has been assumed:

– 20% of FS link degradation due to long-term interference;

– 80% of FS link degradation due to short-term interference.

Then the corresponding EPO value for short-term is calculated to be 1.3  10–5, with the rounding value to the nearest decimal number, according to the total EPO value calculated in above paragraphs.

Considering that in the 71-76 GHz and 81-86 GHz band FS links, rain is dominating factor in fading, then adaptive modulation is often used, and band carrier aggregation technologies are also often used to facilitate effective transmission by using 71-76 GHz and 81-86 GHz and lower band such as 18 GHz, 23 GHz etc. together, an FS fade margin of 8 dB is thought to be the typical value at this band.

As this fade margin is given for a BER of 1 × 10–6 and as the EPO are referenced to SES in Recommendation ITU-T G.826 definition, it is necessary to extrapolate the fade margin corresponding to SES levels. On the basis of the agreed assumptions that the fad margins for SES is 1 dB higher than the FM referenced to the BER 1 ×10–6 level.

Then the short-term protection criteria proposed for agenda item 1.10 is ***I/N* not exceed +9 dB for more than 1.3  10–5 of the time**.]

ATTACHMENT 3

Proposed examples of FSS satellite systems to be considered
for studies under WRC-27 agenda item 1.10

Table 10

Orbit configuration

| Parameter | System A[[7]](#footnote-8) | System B | System C | System D | System E | System F | System G | System H | System I | System J | System K | System L | System M[[8]](#footnote-9) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Height (km) | 525, 530, 535 | 590, 610, 630 | 35786 | 1050 | 1414 | 450 to 900 | 340 to 614 | 600, 1200 | 8 062 | 1 175 | 355, 347 | 500, 500, 600, 600, 700, 700, 800, 800, 900, 900, 1000, 1000, 1100, 1100, 1200, 1200, 1300, 1300, 1400, 1400, 8100, 8100, 8100, 8100, 8100, 8100, 8100, 8100, 12000, 12000, 12000, 12000, 12000, 12000, 12000, 12000, 16000, 16000, 16000, 16000, 16000, 16000, 16000, 16000, 20000, 20000, 20000, 20000, 20000, 20000, 20000, 20000, 23222, 23222, | 340, 345, 350, 360, 525, 530, 535, 604, 614 |
| Number of planes | 28, 28, (24,4) | 28, 36, 34 | 1 | 12 | 8 | 81 | 794 | 132 | 1, 4, 6 | 18 | 24, 24 | 36, 36, 36, 36, 34, 34, 30, 30, 28, 28, 24, 24, 24, 24, 22, 24, 20, 20, 18, 18, 1, 12, 12, 12, 12, 12, 12, 12, 1, 12, 12, 12, 12, 12, 12, 12, 1, 12, 12, 12, 12, 12, 12, 12, 1, 12, 12, 12, 12, 12, 12, 12, 1, 12 | 12, 18, 48, 48, 48, 30, 28, 28, 28 |
| Satellites per plane | 120, 120, (28,27) | 28, 36, 34 | 1 | 28 | 6 | 1 to 8 | 12 to 120 | 36 to 72 | 32, 16, 12 | 48 | 124 | 36, 36, 32, 32, 32, 32, 32, 32, 30, 30, 24, 24, 24, 24, 24, 24, 24, 24, 20, 20, 96, 10, 10, 10, 10, 10, 10, 10, 96, 10, 10, 10, 10, 10, 10, 10, 96, 10, 10, 10, 10, 10, 10, 10, 96, 10, 10, 10, 10, 10, 10, 10, 96, 9 | 110, 110, 110, 120, 120, 120, 120, 12, 18 |
| Inclination angle (deg) | 53, 43, 33 | 33, 42, 51.9 | 0 | 89 | 52 | 0 to 98.9 | 33 to 148 | 40 to 87.9 | 0, 90, 45 | 86.5 | 50, 50.2 | 50, 85, 50, 85, 50, 85, 50, 85, 50, 85, 50, 85, 50, 85, 50, 89, 50, 85, 50, 85, 0, 15, 45, 60, 65, 70, 75, 80, 0, 15, 45, 60, 65, 70, 75, 80, 0, 15, 45, 60, 65, 70, 75, 80, 0, 15, 45, 60, 65, 70, 75, 80, 0, 56 | 53, 46, 38, 97, 53, 43, 33, 148, 116 |
| RAAN | Equally spaced | Equally spaced |  | Equally spaced | Equally spaced | Equally spaced | Equally spaced | Equally spaced | Equally spaced  | Equally spaced | Equally spaced | Equally spaced | Equally spaced |

Table 11

Other characteristics for systems A to C

| Parameter | System A | System A | System B | System B | System C | System C |
| --- | --- | --- | --- | --- | --- | --- |
| Frequency (GHz) | 71-76 | 81-86 | 71-76 | 81-86 | 71-76 | 81-86 |
| Peak antenna gain (dBi) | 52 | 60.9 (D: 1.85 m) | 41.9 or 48 | 53.6 (D: 1 m, 59.6 (D: 2 m, ), 64.5 (D: 3.5 m) | 50 | 50 (D:0.6 m) |
| Antenna Pattern | Rec S.1528Recommend 1.2 for main beamRecommend 1.4 for side lobes (beyond 15°) | Recommendation ITU‑R S.580-6 | Rec. S.1528 Recommend 1.2 for main beamRecommend 1.4 for side lobes (beyond 15°) | Recommendation ITU‑R S.580-6 | For satellite: Appendix 7 Annex 3 Section 3G1= ‒13 dBBeamwidth = 0.42 deg | For earth station: S.580 |
| Input power density (dBW/Hz) | ‒103 to ‒83.57 Max power only used while compensating for low elevation angles or rain fade attenuation | ‒93 to ‒80.8Max power only used while compensating for low elevation angles or rain fade attenuation | ‒106.2 to ‒86.2Max power only used while compensating for low elevation angles or rain fade attenuation | ‒97 to ‒77Max power only used while compensating for low elevation angles or rain fade attenuation | ‒77.8[[9]](#footnote-10) | ‒77.8 |
| Minimum Elevation Angle (degrees) | 15 | 15 | 20 | 20 | 3 | 3 |
| Bandwidth (MHz) | 1 250 | 1 250 | 100 | 100 | 180 | 180 |
| Out of band emission mask | SM.1541-6 | SM.1541-6 | SM.1541-6 | SM.1541-6 | SM.1541-6 | SM.1541-6 |
| Number of co-frequency beams (N\_co) | 32 | 32 | 32 | 32 | 1 | 1 |
| Max Power Flux Density on the grounddBW/m2/MHz | ‒106 | N/A | ‒104 | N/A | ‒129.85 | N/A |
| Worst[[10]](#footnote-11) Earth station density per 2 000 000 km2 | N/A | 76 | N/A | 5 | N/A | 25 |

Table 12

Other characteristics for systems D to H

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| System | System D | System E | System F | System G | System H |
| Frequency (GHz) | 71-76 | 81-86 | 71-76 | 81-86 | 71-76 | 81-86 | 71-76 | 81-86 | 71-76 | 81-86 |
| Peak Antenna Gain (dBi) | 34.1 | 40.9 to 61.3 | 25 to 45 | 35.4 to 72 | 59 | 30 to 70.5 | 35 to 60 | 35 to 71 | 39.4 to 55.9 | 41.9 to 68.3 |
| Antenna pattern | Rec S.1528 | Rec 580-6 | Rec S.1528 | AP8 | Rec S.1528 | Rec 580-6 | Rec S.1528 | AP8 | Rec S.1528 | AP8 |
| Beamwidth |  | 0.13 to 1.65 |  | 0.04 to 2.79 |  | 0.05 to 5.6 |  | 0.05 to 3 |  | 0.07 to 1.41 |
| Input Power Density (dBW/Hz) | −36.1 to −30.1 |  | −82.1 to −45.9 |  | −83 to −74 |  | −80 to −55 |  | −94.6 to −72.3 |  |

ATTACHMENT 4

Proposed examples of MSS satellite systems to be considered
for studies under WRC-27 agenda item 1.10

Table 13

Orbit configuration

| Parameter | System N | System O | System P | System Q |
| --- | --- | --- | --- | --- |
| Perigee (km) | 21000 | 3800, 3000, 1776, 1215, 6400 | 540, 21028.6, 23136.8, 25245, 25245, 27353.2, 29461.4, 30726.3, 35786.1 | 340, 345, 350, 360, 525, 528, 530, 535, 540, 550, 560, 560, 570, 604, 614 |
| Apogee (km) | 21000 | 9000, 9800, 11024, 11585, 6400 | 540, 50543.5, 48435.2, 46327, 46327.1, 44218.9, 42110.6, 40845.7, 35786.1 | 340, 345, 350, 360, 525, 528, 530, 535, 540, 550, 560, 560, 570, 604, 614 |
| Number of planes | 6 | 31, 1, 9, 9, 9 | 9, 256, 256, 256, 1, 255, 512, 512, 128, 256, 128, 128 | 96, 96, 96, 60, 56, 28, 56, 56, 72, 72, 4, 6, 36, 24, 36 |
| Satellites per plane | 6 | 7, 7, 21, 21, 21 | 23, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 | 110, 110, 110, 120, 120, 120, 120, 120, 22, 22, 43, 58, 20, 12, 18 |
| Inclination angle (deg) | 55 | 63, 64, 45, 50, 52 | 98, 63, 41, 46, 46, 46, 63, 63, 38, 42, 20, 25 | 53, 46, 38, 97, 53, 43, 43, 33, 53, 53, 98, 98, 70, 148, 116 |
| RAAN | Equally spaced | Equally spaced | Equally spaced | Equally spaced |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_**]**

1. RHCP = Right hand Circular Polarization. LHCP = Left Hand Circular Polarization [↑](#footnote-ref-2)
2. This is an average input power spectral density meaning there could be higher and lower power spectral densities employed by the System C satellite. [↑](#footnote-ref-3)
3. The worst density is provided in the table. To scale for larger area, the density should be considered together with a factor of 0.65 to account for the fact that the worst density isn’t feasible on a wider scale. For instance, density of 10 in 2 million km2, if scaled to 10 million km2 is: 10 × 10 000 000/2 000 000 × 0.65 = 32.5 [↑](#footnote-ref-4)
4. This is an average input power spectral density meaning there could be higher and lower power spectral densities employed by the System C satellite. [↑](#footnote-ref-5)
5. The worst density is provided in the table. To scale for larger area, the density should be considered together with a factor of 0.65 to account for the fact that the worst density isn’t feasible on a wider scale. For instance, density of 10 in 2 million km2, if scaled to 10 million km2 is: 10 × 10 000 000/2 000 000 × 0.65 = 32.5 [↑](#footnote-ref-6)
6. 1 For an FS link using ATPC, the net fade margin  total fade margin – ATPC range. [↑](#footnote-ref-7)
7. Altitude 535 km, Inclination 33 deg, 24 planes with 28 satellites per plane and 4 planes with 27 satellites per plane. [↑](#footnote-ref-8)
8. Systems A and M are variations of the same system and as such, they shouldn’t be aggregated in studies. [↑](#footnote-ref-9)
9. This is an average input power spectral density meaning there could be higher and lower power spectral densities employed by the System C satellite. [↑](#footnote-ref-10)
10. The worst density is provided in the table. To scale for larger area, the density should be considered together with a factor of 0.65 to account for the fact that the worst density isn’t feasible on a wider scale. For instance, density of 10 in 2 million km2, if scaled to 10 million km2 is: 10 × 10 000 000/2 000 000 × 0.65 = 32.5 [↑](#footnote-ref-11)