|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Received: 27 September 2021  Source: Annex 4.14 to Document [5D/716](https://www.itu.int/md/R19-WP5D-C-0716/en)  Subject: WRC-23 agenda item 1.2 | **Document 5D/835-E** |
| **28 September 2021** |
| **English only**  **SPECTRUM ASPECTS &  WRC‑23 PREPARATIONS** |
| Saudi Arabia (Kingdom of), Jordan (Hashemite Kingdom of) | |
| Working document for sharing and compatibility studies of IMT systems in the frequency band 6 425-7 125 MHz | |
|  | |

# Introduction

Working Party 5D is responsible for conducting sharing and compatibility studies of IMT systems in frequency bands 3 300-3 400 MHz (Region 2 and amend footnote in Region 1), 3 600-3 800 MHz (Region 2), 6 425-7 025 MHz (Region 1), 7 025-7 125 MHz (Globally) and 10.0-10.5 GHz (Region 2) with other services operating in same bands.

This contribution initiates sharing and compatibility studies between IMT and incumbent Fixed Satellite Service (E-s)(s-E) in the frequency band of 6 425-7 075 MHz, based on the working document in Annex 4.14 of 38th Working Party 5D Chairman’s Report (5D/716). Changes are only being proposed in Attachment 4 of the document.

Proposed changes to the existing document are shown in track changes and are highlighted in yellow.

**Attachment**: 1

Attachment

Annex 4.14 to Working Party 5D Chairman’s Report

WORKING DOCUMENT ON SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS IN THE FREQUENCY BAND 6 425-7 125 MHZ

[Editor’s note: The contents of this working document have not been fully discussed nor agree to by WP 5D. Participants are invited to submit input contributions to the next WP 5D meeting to progress the work. ]

# 1 Introduction

# 2 Allocation information in 6 425-7 125 MHz and in adjacent frequency bands, as appropriate

*[Editor’s note: Resolution* ***245 (WRC-19)*** *calls for studies with respect to services in adjacent band, as appropriate, and these need to be considered on a case-by-case basis.]*

**5 925-7 145 MHz**

|  |  |  |
| --- | --- | --- |
| **Allocation to services** | | |
| **Region 1** | **Region 2** | **Region 3** |
| **5 925-6 700** FIXED 5.457  FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B  MOBILE 5.457C  5.149 5.440 5.458 | | |
| **6 700-7 075** FIXED  FIXED-SATELLITE (Earth-to-space) (space-to-Earth) 5.441  MOBILE  5.458 5.458A 5.458B | | |
| **7 075-7 145** FIXED  MOBILE  5.458 5.459 | | |
| **7 145-7 190** FIXED  MOBILE  SPACE RESEARCH (deep space) (Earth-to-space)  5.458 5.459 | | |

For allocation details and footnotes text, please refer to the Radio Regulations, Edition of 2020.

# 3 Technical characteristics

## 3.1 **Technical** and operational characteristics of services and systems operating in 6 425-7 125 MHz and in adjacent frequency bands, as appropriate

*[Editor’s note: This section provides the sources of technical and operational characteristics of IMT from WP 5D and other services from other expert groups.]*

|  |  |  |
| --- | --- | --- |
| WP 5D # | Source | Services/Application/Models |
| [245](https://www.itu.int/md/R19-WP5D-C-0245/en) | WPs 3K and 3M | Propagation models |
| [377](https://www.itu.int/md/R19-WP5D-C-0377/en) | WP 4C | Mobile Satellite Service |
| [227](https://www.itu.int/md/R19-WP5D-C-0227/en), [398](https://www.itu.int/md/R19-WP5D-C-0398/en) | WP 5B | Aeronautical Mobile (AMS)  Radiodetermination (RDS)  Radiolocation (RLS) |
| [233](https://www.itu.int/md/R19-WP5D-C-0233/en), [583](https://www.itu.int/md/R19-WP5D-C-0583/en) | WP 5C | Fixed (FS) |
| [150](https://www.itu.int/md/R19-WP5D-C-0150/en), [559](https://www.itu.int/md/R19-WP5D-C-0559/en) | WP 7B | Space Operation (SOS)  Space Research (SRS)  Earth Exploration-Satellite (EESS)  Inter-Satellite (ISS) |
| [151](https://www.itu.int/md/R19-WP5D-C-0151/en), [353](https://www.itu.int/md/R19-WP5D-C-0353/en), [573](https://www.itu.int/md/R19-WP5D-C-0573/en) | WP 7C | Earth Exploration-Satellite (passive) (EESS (passive))  Space Research (passive) (SRS (passive)) |
| [561](https://www.itu.int/md/R19-WP5D-C-0561/en) | WP 7D | Radio astronomy |
| [734](https://www.itu.int/md/R19-WP5D-C-0734/en) | WP 4A | Fixed Satellite Service |

3.2 Propagation models for sharing and compatibility studies for IMT operating in 6 425-7 125 MHz

*[Editor’s note: This section provides the propagation models for sharing and compatibility studies from SG 3.]*

# 4 Sharing and compatibility studies

*[Editor’s note: This section includes the sharing and compatibility studies for IMT operating in 6 425-7 125 MHz.]*

The sharing and compatibility studies are contained in the Attachment to this Annex.

**5 Abbreviations and acronyms**

**Attachment 1:**  Sharing and compatibility of the SRS operating in the frequency band 7 145-7 190 MHz and IMT operating in the frequency band 6 425-7 125 MHz

**Attachment 2:**  Sharing and compatibility of the SOS operating in the frequency band 7 100-7 155 and IMT operating in the frequency band 6 425-7 125 MHz

**Attachment 3:**  Sharing and compatibility of the fixed service and IMT operating in the frequency band 6 425-7 125 MHz

**Attachment 4:**  Sharing and compatibility of the Fixed Satellite Service operating in the frequency band 6 425- 7 075 MHz and IMT operating in the frequency band 6 425-7 175 MHz

ATTACHMENT 1

Sharing and compatibility of SRS operating in the frequency band 7 145-7 190 MHz and IMT operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This Attachment contains sharing and compatibility studies of the SRSoperating in the frequency band 7 145-7 190 MHz and IMT operating in the frequency band 6 425-7 125 MHz. Note the technical characteristics are provided in Section 3 in the main body of the document.]*

# 1 Technical characteristics

1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz

*[TBD]*

1.2 Technical and operational characteristics of SRS operating in the frequency band 7 **145-7 190 MHz**

The following ITU-R Report and Recommendation contain relevant technical and operational characteristics as well as protection criteria for incumbent systems:

– Report [ITU-R SA.2309-0](https://www.itu.int/pub/R-REP-SA.2309) – *Compatibility between EESS (Earth-to-space) and the space research service or the space operation service in the band 7 100-7 235 MHz;*

– Recommendation ITU-R SA.1157-1 – *Protection criteria for deep-space research*.

– Recommendation [ITU-R SA.1014-3](https://www.itu.int/rec/R-REC-SA.1014/en) – *Radiocommunication requirements for manned and unmanned deep space research;*

– Recommendation [ITU-R SA.1015-1](https://www.itu.int/rec/R-REC-SA.1015/en) – *Bandwidth requirements for deep-space research.*

TABLE X

Technical characteristics representative of SRS missions uplinks   
in the frequency band 7 145-7 190 MHz

|  | Deep-space SRS (7 145-7 190 MHz) |
| --- | --- |
| DS |
| Representative orbits | Mission D |
| **Orbit description** |  |
| Type of orbit | Orbiting Mars |
| Orbit altitude | Range to Earth  54 to 400 M-km |
| Inclination | 86.3 degrees (Mars orbit) |
| **Earth station** |  |
| Location | Cebreros (Spain) |
| Power supplied to the input of antenna (dBW) | 43 to 49  (20 to 80 kW) |
| Antenna diameter (m) | 35, 70 |
| Antenna gain (dBi) | 66, 72 |
| Antenna pattern | Rec. ITU-R F.1245 |
| Min elevation angle | 10° |
| e.i.r.p. (dBW) | 115 max |
| Uplink signal: | TC + Ranging |
| • Telecommand   (data rate & modulation) | Rb up to 1 kbit/s  (64 kHz BW) |
| PCM(NRZ)/PSK/ PM  16 kHz subcarrier |
| • Ranging | Ft = 1 MHz |
| **Satellite** |  |
| a) Low gain antenna (dBi) | *G* = –2 @ 90°  *G* = +7 @ ±10° |
| b) Medium gain antenna (dBi) | *G* = +13 @ ±15°  *G* = +18 @ ±3° |
| c) High gain ant (dBi) | *G* = +48 (3.7 m) |
| System noise temp (K) | 350 |
| Protection criteria | –190 dB(W/20 Hz) ITU-R SA.1157-1 |

In addition to above ITU-R deliverables, based on information received from WP 7B (Doc. [5D/559](https://www.itu.int/md/R19-WP5D-C-0559/en)) following technical and operational characteristics of SRS space stations for deep-space missions, operating in the frequency band 7 145-7 190 MHz, which could be used during launch and early orbit phase (at parking orbit), as well as the return phase for manned or sample return missions:

**Orbital parameters for early/return mission phase**: Elliptical orbit with perigee ≥ 200 km and apogee ≤ 5 000 km, inclination of 51.6°;

**Space station receiving beam gain**: 0 dBi for non-directional beam, 48 dBi for directional beam (in case of intentional off-pointing, the maximum off-axis gain towards Earth surface is 15.8 dBi);

**Polarization**: LHCP/RHCP;

**System noise temperature**: 330 K for non-directional beam, 170 K for directional beam.

# 2 Technical Analysis

2.1 Study A

*[Editor’s note: The chapter structure of each study depends on the input contribution of the ITU members. The following chapter structure in each study can be used as a reference.]*

### 2.1.1 Technical characteristics

*[Editor’s note: This section provides the specific parameters used in the included study/studies, as provided by the contributing groups to WP 5D.]*

2.1.1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This section provides specific characteristics of IMT systems provided by WP 5D for sharing/interference analyses used in the study.]*

2.1.1.2 Technical and operational characteristics of SRS operating in the frequency band 7145-7190 MHz

*[Editor’s note: This section provides specific characteristics of SRS provided by other expert group for sharing/interference analyses used in the study.]*

2.1.1.3 Propagation models for sharing and compatibility studies for IMT operating in 6 425-7 125 MHz

*[Editor’s note: This section provides specific propagation models and related parameters for sharing/interference analyses used in the study.]*

### **2.1.2 Methodology**

*[Editor’s note: This section provides the methodology used in this study.]*

### 2.1.3 Study results

*[Editor’s note: This section provides the sharing and compatibility study results of this study.]*

### 2.1.4 Summary and analysis of the results of Study A

*[Editor’s note: This section provides the summary and analysis of the results of this study.]*

# 3 Summary and analysis of the results of studies

*[Editor’s note: This section provides the summary and analysis of the results of studies. The text here can be used in the Section 1/1.2/3 “Summary and analysis of the results of ITU-R studies” of Draft CPM Text.]*

ATTACHMENT 2

Sharing and compatibility of the SOS operating in the frequency band 7 100‑7 155 and IMT operating in the frequency band 6 425-7 125 MHz

[Editor’s note: This Attachment contains sharing and compatibility studies of the SOS operating in the frequency band 7100-7155 MHz and IMT operating in the frequency band 6 425-7 125 MHz. Note the technical characteristics are provided in Section 3 in the main body of the document.]

# 1 Technical characteristics

**1.1** Technical **and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz**

*[TBD]*

**1.2** Technical **and operational characteristics of SOS operating in the frequency band 7 100-7 155 MHz**

The following ITU-R Report and Recommendation contain relevant technical and operational characteristics as well as protection criteria for incumbent systems:

– Report ITU-R SA.2309-0 – *Compatibility between EESS (Earth-to-space) and the space research service or the space operation service in the band 7 100-7 235 MHz;*

– Recommendation ITU-R SA.363-5 – *Space operation systems*.

TABLE x

**Technical characteristics representative of SOS mission uplinks in the frequency band 7 100-7 155 MHz**

| Representative orbits | System A | System B | System C |
| --- | --- | --- | --- |
| Orbit description |  |  |  |
| Type of orbit | Low-Earth, circular | Low-Earth, circular | Low-Earth, elliptical |
| Orbit altitude (km) | 550 | 350 | 450-200 |
| Inclination (°) | 85.5 | 70 | 70 |
| Earth station |  |  |  |
| Location | Moscow (Russia) Krasnoyarsk (Russia) | Russian Federation | Russian Federation |
| Power range at antenna input (dBW) *(Note: Adaptive power control is applied)* | +20 to 0 | –14 to –34 (mode 1)\*  –3 to –23 (mode 2)\*\* | –14 to –34 (mode 1)\*  –3 to –23 (mode 2)\*\* |
| Antenna diameter (m) | 5 | 5 | 5 |
| Antenna gain (dBi) | 47 | 47 | 47 |
| Antenna pattern | Rec. ITU-R S.465 | Rec. ITU-R S.465 | Rec. ITU-R S.465 |
| Minimum elevation angle (°) | 5 | 5 | 5 |
| Max e.i.r.p. range (dBW) | 67 / 47 | 33 / 13 (mode 1) 44 / 24 (mode 2) | 33 / 13 (mode 1) 44 / 24 (mode) |
| Uplink signal | Telecommand | Telemetry, Tracking and Telecommand | Telemetry, Tracking and Telecommand |
| Necessary bandwidth (MHz) | 2 | 1.2 | 1.2 |
| • Telecommand Data rate (kbit/s) | 2.0 | (\*\*\*) | (\*\*\*) |
| • Telecommand Modulation | BPSK/spread spectrum | (\*\*\*) | (\*\*\*) |
| • Ranging | N/A | (\*\*\*) | (\*\*\*) |
| Space station |  |  |  |
| a) Low gain antenna (dBi) | +2 | +1 (mode 2) | +1 (mode 2) |
| b) High gain antenna (dBi) | N/A | +12 (mode 1) | +12 (mode 1) |
| System noise temperature (°K) | 450 | 1 000 | 1 000 |
| Protection criteria | The ratio of signal power to total interference power in each band 1 kHz wide must not fall below 20 dB for more than 1% of the time, each day  (Recommendation [ITU-R SA.363-5](http://www.itu.int/rec/R-REC-SA.363/en)), NOTE – See § 5.3. | | |
| \* Mode 1 – Operation with a narrow-beam tracking space-borne antenna (see Fig. 2).  \*\* Mode 2 – Operation with a nadir pointed wide-beam space-borne antenna (see Fig. 3).  \*\*\* This information has not been provided by the relevant administration, therefore only a worst-case analysis has been considered. | | | |

Figure 2

Mode 1 antenna pattern



Figure 3

Mode 2 antenna pattern



# 2 Technical Analysis

**2.1** Study **A**

*[Editor’s note: The chapter structure of each study depends on the input contribution of the ITU members. The following chapter structure in each study can be used as a reference.]*

### 2.1.1 Technical characteristics

*[Editor’s note: This section provides the specific parameters used in the included study/studies, as provided by the contributing groups to WP 5D.]*

2.1.1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This section provides specific characteristics of IMT systems provided by WP 5D for sharing/interference analyses used in the study.]*

2.1.1.2 Technical and operational characteristics of SOS operating in the frequency band 7100-7155 MHz

*[Editor’s note: This section provides specific characteristics of SOS provided by other expert group for sharing/interference analyses used in the study.]*

2.1.1.3 Propagation models for sharing and compatibility studies for IMT operating in 6 425-7 125 MHz

*[Editor’s note: This section provides specific propagation models and related parameters for sharing/interference analyses used in the study.]*

### 2.1.2 Methodology

*[Editor’s note: This section provides the methodology used in this study.]*

### 2.1.3 Study results

*[Editor’s note: This section provides the sharing and compatibility study results of this study.]*

### 2.1.4 Summary and analysis of the results of Study A

*[Editor’s note: This section provides the summary and analysis of the results of this study.]*

# 3 Summary and analysis of the results of studies

*[Editor’s note: This section provides the summary and analysis of the results of studies. The text here can be used in the Section 1/1.2/3 “Summary and analysis of the results of ITU-R studies” of Draft CPM Text.]*

ATTACHMENT 3

Sharing and compatibility of FS and IMT operating   
in the frequency band 6 425-7 125 MHz

*[Editor’s note: This Attachment contains sharing and compatibility studies of the fixed service and IMT operating in the frequency band 6 425-7 125 MHz. Note the technical characteristics are provided in Section 3 in the main body of the document.]*

# 1 Technical characteristics

1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz

*[TBD]*

1.2 Technical and operational characteristics of FS operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This section provides characteristics of FS for sharing/interference analyses used in the study, as received from the expert group WP 5C.]*

*[Editor’s note: This section needs to be further reviewed based on input from WP5C.]*

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

– Recommendation 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.

– Recommendation 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.

– Recommendation 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.

– Recommendation ITU-R [F.1336-5](https://www.itu.int/rec/R-REC-F.1336/recommendation.asp?lang=en&parent=R-REC-F.1336-5-201901-I)gives reference models of antennas used in the FS and in the mobile service. It gives peak and average sidelobes of omnidirectional and sectoral antennas in the frequency range 400 MHz to about 70 GHz.

The following digital fixed system parameters are from Recommendation 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). Tables 1 to 3~~4~~ show selected examples of digital FS systems parameters that are in use in the relevant band 6 425-7 125 MHz in which the FS systems are operating. [For detailed sharing studies accurate criteria must be derived in accordance with the principles in Recommendation ITU-R F.758.]

**Digital FS system parameters for sharing/compatibility studies**

TABLE 1

Digital P-P FS system parameters for FS operating in ~~[3 and 7.2]~~ 6.425-7.125 GHz  
(ITU-R F.758-7)

|  |  |  |
| --- | --- | --- |
| Frequency range (GHz) | 6.425-7.125 | |
| Reference ITU‑R Recommendation | F.384 | |
| Modulation | QPSK | 64-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 5, 10, **20**, 30, 40,80 | 5, 10, 20, 30, **40**,80 |
| Tx output power range (dBW) | −13…4 | −15…3 |
| Tx output power density range (dBW/MHz) | −26…−9 | −31…−13.0 |
| Feeder/multiplexer loss range (dB) | 1.2…2.8 | 0…6.3 |
| Antenna gain range (dBi) | 35.3…43.9 | 32.6…47.4 |
| e.i.r.p. range (dBW) | 27.1…42.2 | 15.8…48.8 |
| e.i.r.p. density range (dBW/MHz) | 14.1…29.1 (Mode 21.7) | −0.2…32.7(Mode 8.2...24.2) |
| Receiver noise figure typical (dB) | 5 | 4.5…5 |
| Receiver noise power density typical (=*NRX*) (dBW/MHz) | −139 | −139.5… −139 |
| Normalized Rx input level for 1 × 10−6 BER (dBW/MHz) | −125.5 | −113… −112.5 |
| Nominal long-term interference power density (dBW/MHz) | −139 + *I*/*N* | −139.5… −139 + *I*/*N* |

TABLE 2

**Digital P-P FS system parameters for FS operating in ~~[7.1 and 14]~~ 7.110-7.900 GHz   
(ITU-R F.758-7)**

| Frequency range (GHz) | 7.110-7.900 | |
| --- | --- | --- |
| Reference ITU‑R Recommendation | F.385 | |
| Modulation | 16-QAM | 128-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 3.5, 5, 7, 10, 14, 20, 28, 30(3), 40(3), 60(3), 80(3) | 3.5, 5, 7, 10, 14, 20, 28, 30(3), 40(3), 60(3), 80(3) |
| Tx output power range (dBW) | −6.5… 13 | −6.5…13 |
| Tx output power density range (dBW/MHz) | −25.5…3 | −25.5…3 |
| Feeder/multiplexer loss range (dB) | 0…3.0 | 0…3.0 |
| Antenna gain range (dBi) | 12…48.6 | 12…48.6 |
| e.i.r.p. range (dBW) | 5.5…55 | 5.5…55 |
| e.i.r.p. density range (dBW/MHz) | −13.5…45 | −13.5…45 |
| Receiver noise figure typical (dB) | 2.5…6 | 2.5…6 |
| Receiver noise power density typical (=*NRX*) (dBW/MHz) | −141.5… −138.0 | −141.5… −138.0 |
| Normalized Rx input level for 1 × 10−6 BER (dBW/MHz) | −121.0… −117.5 | −112.5… −115.0 |
| Nominal long-term interference power density (dBW/MHz)(2) | −141.5… −138.0 + *I*/*N* | 138.0 + *I/N* |

TABLE 3~~4~~

**Interference criteria (ITU-R F.758-7)**

|  |  |  |  |
| --- | --- | --- | --- |
| *I*/*N* (1) | Frequency range | Sharing/compatibility conditions | Comments and relevant ITU-R Recommendations |
| ≤ –10 dB | Above 3 GHz | Sharing with more than one co-primary service | Apportionment of ITU-R F.1094 objectives (see § 2 in Annex 1 of this Recommendation)  −6 dB or –10 dB, as appropriate, may be applicable where the risk of simultaneous interference from the stations of the other co-primary allocations is negligible. In other cases, a more stringent criterion may be required to account for aggregate interference from all interfering co-primary services (i.e. −6 dB or −10 dB should be intended as maximum aggregate *I*/*N* from all other co-primary services). |
| (1) These values of *I*/*N* apply to the aggregate interference from the operations of the shared service. | | | |

# 2 Technical Analysis

2.1 Study A

*[Editor’s note: The chapter structure of each study depends on the input contribution of the ITU members. The following chapter structure in each study can be used as a reference.]*

### 2.1.1 Technical characteristics

*[Editor’s note: This section provides the specific parameters used in the included study/studies, as provided by the contributing groups to WP 5D.]*

*[TBD]*

2.1.1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This section provides specific characteristics of IMT systems provided by WP 5D for sharing/interference analyses used in the study.]*

2.1.1.2 Technical and operational characteristics of fixed services operating in the frequency band 6 425-7 125 MHz

*[Editor’s note: This section provides specific characteristics of [Service type z] provided by other expert group for sharing/interference analyses used in the study.]*

2.1.1.3 Propagation models for sharing and compatibility studies for IMT operating in 6 425-7 125 MHz

*[Editor’s note: This section provides specific propagation models and related parameters for sharing/interference analyses used in the study.]*

### 2.1.2 Methodology

*[Editor’s note: This section provides the methodology used in this study.]*

### 2.1.3 Study results

*[Editor’s note: This section provides the sharing and compatibility study results of this study.]*

### 2.1.4 Summary and analysis of the results of Study A

*[Editor’s note: This section provides the summary and analysis of the results of this study.]*

# 3 Summary and analysis of the results of studies

*[Editor’s note: This section provides the summary and analysis of the results of studies. The text here can be used in the Section 1/1.2/3 “Summary and analysis of the results of ITU-R studies” of Draft CPM Text.]*

ATTACHMENT 4

**Sharing and compatibility of the Fixed Satellite Service operating in the frequency band 6 425- 7 075 MHz and IMT operating   
in the frequency band 6 425-7 175 MHz**

# 1 Technical characteristics

**1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz**

[See Document [5D/716](https://www.itu.int/md/R19-WP5D-C-0716/en)]

**1.2 Technical and operational characteristics of FSS operating in the frequency band 6 425-7 025 MHz**

[See Document [5D/734](https://www.itu.int/md/R19-WP5D-C-0734/en)]

# 2 Technical Analysis

**2.1 Study A**

This section contains four sets of, in-band, compatibility and sharing studies as follow:

• IMT base stations (BSs) towards FSS (E-s) in the 6 425-7 075 MHz frequency range;

• IMT user equipment (UEs) towards FSS (E-s) in the 6 425-7 075 MHz frequency range;

• IMT base stations (BSs) towards FSS (s-E) in the 6 700‑7 025 MHz frequency range;

• IMT user equipment (UEs) towards FSS (s-E) in the 6 700‑7 025 MHz frequency range.

This study analyses aggregate interference from a large number of IMT stations to FSS station receivers. These studies intend to be responsive to *resolves* 2 of Resolution **245 (WRC‑19)** under WRC-23 agenda item 1.2. The results shown here indicate that the interference caused by IMT systems would be harmful to FSS operations in the 6 425 –7 075 MHz frequency range.

### 2.1.1 Technical characteristics

This section describes the technical characteristics of IMT, FSS earth station (E/S), and FSS space station (S/S) analysed in this study. Provided a range of values available for the IMT and FSS parameters, the conservative values were chosen as a way to guarantee the protection of the incumbent service.

**2.1.1.1 Technical and operational characteristics of IMT systems operating in the frequency band 6 425-7 125 MHz**

The tables below provide technical and operational characteristics of IMT taken from Tables 7-1, 7‑2, and 10 of Annex 4.4 of WP5D Chairman’s Report (5D/716) for the 6 425-7 125 MHz frequency range. Implementation of AAS is considered for IMT base stations in these frequency bands. Implementation of AAS is not considered in IMT user equipment.

Table 1

IMT BS parameters in the 6 425 – 7 125 MHz frequency range

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Value – Macro urban | Value – Micro | Value - Indoor | Unit |
| Duplex method | TDD | TDD | TDD |  |
| Channel bandwidth | 100 | 100 | 100 | MHz |
| Deployment density | 10 | 30 | 30 | BSs/km2 |
| Ra | 45 | 10 | 10 | % |
| Rb (Area < 3500000km2) | 5 | 5 | 5 | % |
| Antenna height | 18 | 6 | 3 | M |
| Number of sectors | 3 | 1 | 1 |  |
| Sector coverage | 120 | 120 | 360 | Degree |
| Network loading factor | 50 | 50 | 50 | % |
| BS TDD factor | 75 | 75 | 75 | % |
| Antenna type | AAS only | AAS only | AAS only |  |
| Antenna pattern | ITU-R M.2101 | ITU-R M.2101 | ITU-R M.2101 |  |
| Element gain | 5.5 | 5.5 | 5.5 | dBi |
| Horizontal 3 dB beamwidth | 90 | 90 | 90 | Deg |
| Vertical 3 dB beamwidth | 90 | 90 | 90 | Deg |
| Horizontal front-to-back ratio | 30 | 30 | 30 | dB |
| Vertical front-to-back ratio | 30 | 30 | 30 | dB |
| Horizontal element spacing | 0.5 | 0.5 | 0.5 | d/lambda |
| Vertical element spacing | 0.5 | 0.5 | 0.5 | d/lambda |
| Array number of rows | 16 | 8 | 4 |  |
| Array number of columns | 8 | 8 | 4 |  |
| Mechanical downtilt | 10 | 10 | 90 | Degree |
| Array ohmic losses | 2 | 2 | 2 | dB |
| Conducted power | 22 | 16 | 9 | dBm |

Table 2

IMT UE parameters in the 6 425‑7 125 MHz frequency range

| Parameter | Value – Macro urban | Value - Micro | Value - Indoor | Unit |
| --- | --- | --- | --- | --- |
| Duplex method | TDD | TDD | TDD |  |
| Channel bandwidth | 100 | 100 | 100 | MHz |
| Indoor terminal usage | 70 | 70 | 100 | % |
| UEs per sector | 3 | 3 | 3 |  |
| Antenna height | 1.5 | 1.5 | 1.5 | M |
| UE TDD factor | 25 | 25 | 25 | % |
| Power control | Constant max. power | Constant max. power | Constant max. power |  |
| Maximum output power | 23 | 23 | 23 | dBm |
| Antenna type | Omnidirectional | Omnidirectional | Omnidirectional |  |
| Antenna gain | -4 | -4 | -4 | dBi |
| Body loss | 4 | 4 | 4 | dB |
| Building entry loss | ITU-R P.2109 | ITU-R P.2109 | ITU-R P.2109 |  |

**2.1.1.2 Technical and operational characteristics of fixed satellite services operating in the frequency band 6 425-7 025 MHz**

The FSS S/S and E/S parameters shown in Table 1 and Table 2 below. FSS parameters to Carriers 2 and 4 provided by WP4A to WP5D (see Document 5D/734).

Table 3

FSS S/S parameters (interfered) – Carrier 4

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Unit |
| Bandwidth | 1 | MHz |
| Noise temperature | 400 | K |
| Peak gain | 38 | dBi |
| Beamwidth | 0.8 | deg |
| Antenna pattern | ITU-R S.672 |  |
| Altitude | 1000 | km |
| Minimum elevation angle | 5 | deg |
| Short term I/N value 1 | -2.33 | dB |
| Short term percentage value 1 | 0.001 | % |
| Short term I/N value 2 | -6 | dB |
| Short term percentage value 2 | 0.03 | % |
| Long term I/N | -10.5 | dB |
| Long term percentage | 20 | % |

Table 4

FSS E/S parameters (interfered) – Carrier 2

| Parameter | Value | Unit |
| --- | --- | --- |
| Bandwidth | 1 | MHz |
| Noise temperature | 100 | K |
| Antenna peak gain | 38.4 | dBi |
| Antenna diameter | 1.4 | m |
| Antenna efficiency | 0.68 |  |
| Antenna 3dB bandwidth | 1.78 | degree |
| Antenna pattern | ITU-R S.465-6 |  |
| Minimum elevation | 5 | degree |
| Height above ground | 5 | m |
| Short term I/N | -1.3 | dB |
| Short term percentage | 0.005 | % |
| Long term I/N | -10.5 | dB |
| Long term percentage | 20 | % |

Note: In a single BS sector, UEs share equally the channel bandwidth, i.e., each UE is allocated 1/3 of the channel bandwidth (see Rec. ITU-R M.2101, Section 3.4.1, item 1e-f.). For this study a bandwidth of 100 MHz for IMT is considered (i.e., bandwidth of 33.3 MHz per UE), overlapping with the FSS bandwidth of 1 MHz. To account for this overlap, results are presented in the form of interference power spectral density and the protection criteria above were converted to absolute interference values over 1 MHz FSS stations.

**2.1.1.3 Propagation models for sharing and compatibility studies for IMT operating in 6 425-7 125 MHz**

Propagation models used to estimate the path loss between the interferer IMT stations and the interfered with satellite and earth stations are described in the Table 3 below.

Table 5

FSS propagation parameters

|  |  |  |
| --- | --- | --- |
| Ground to Space | | |
| Parameter | Value | Unit |
| Model | Free space path loss |  |
| Gaseous attenuations | Rec. ITU-R P.676 |  |
| Polarization | Vertical |  |
| Building entry loss (indoor stations only) | ITU-R P.2109 |  |
| Building type | Traditional |  |
| Building entry loss percentage | Random per link |  |
| Ground to Ground | | |
| Parameter | Value | Unit |
| Model | ITU-R P.452-16 |  |
| Time percentage | 20 | % |
| Polarization | Vertical |  |
| Latitude of Tx station | 51.2 | deg |
| Latitude of Rx station | 50.73 | deg |
| Average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere (DN) | 53 | N-units/km |
| Sea-level surface refractivity (N0) | 328 | N-units |
| Dry air pressure | 1013 | hPa |
| Air temperature | 15 | Celsius |
| Distance over land to the coast | 500 | km |
| Clutter loss | ITU-R P.2108 |  |
| Clutter loss percentage | Random per link |  |
| Building entry loss (indoor stations only) | ITU-R P.2109 |  |
| Building type | Traditional |  |
| Building entry loss percentage | Random per link |  |

### 2.1.2 Methodology

This study performs a Monte Carlo analysis, which allows for the estimation not only of interference levels but also the deployment percentage. Additionally, urban macro cell, micro cell and indoor IMT deployments were analysed separately. Rural deployment was not considered for this study as, according to [Annex 4.4 to Document 5D/716](https://www.itu.int/md/R19-WP5D-C-0716/en), contiguous coverage is not expected in this frequency range in rural areas.

**2.1.2.1 Interference from IMT to FSS (space-to-Earth) in the band 6 700-7 075 MHz**

The area considered for the study between the FSS E/S and IMT stations corresponds to an area within which an IMT station and the E/S can operate and still be in line-of-sight (LoS). The maximum distance at which the two stations can perceive each other is calculated with the approximated equation:

where:

height of the E/S station in metres (5 meters);

height of the IMT station in metres (depends on the IMT deployment and station type).

The maximum line-of-sight distances for each of the deployment cases are as shown in Table 6, below.

Based on this distance, the spherical cap area of study can be determined with the following formula:

Where is the radius of the Earth. The number of IMT stations deployed in that area is determined by multiplying the above surface area with the IMT density. The following formula was used:

The LoS distance, the simulation area, and the number of IMT stations in the area are described in Table 6 below. It is important to note that the height of the IMT UEs does not depend on the deployment, and thus the LoS distance and study areas will not vary for different deployments. Additionally, for the urban macro cell deployment, IMT BSs will serve three different sectors and each sector can serve one UE on the same communications channel. Thus, for this deployment, the density of IMT UEs is three times the density of IMT BSs.

Table 6

IMT BS and UE density parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | IMT BS | IMT UE |
| **Indoor** | LoS distance | 17.5 km | 15.7 km |
| Area | 959 km2 | 771 km2 |
| Ra | 0.1 | 0.1 |
| Rb | 0.05 | 0.05 |
| Ds | 30 / km2 | 30 / km2 |
| Number of stations | 144 | 116 |
| **Micro cell** | LoS distance | 20.0 km | 15.7 km |
| Area | 1261 km2 | 771 km2 |
| Ra | 0.1 | 0.1 |
| Rb | 0.05 | 0.05 |
| Ds | 30 / km2 | 30 / km2 |
| Number of stations | 189 | 116 |
| **Urban macro cell** | LoS distance | 23.1 km | 15.7 km |
| Area | 1681 km2 | 771 km2 |
| Ra | 0.45 | 0.45 |
| Rb | 0.05 | 0.05 |
| Ds | 10 / km2 | 30 / km2 |
| Number of stations | 378 | 519 |

Those stations are deployed randomly within the above defined line-of-sight spherical cap. The following figure is an example of an IMT BS deployment scheme for a given iteration around an FSS earth station. This deployment will be randomized and generated at each new iteration.

FIGURE 1

Example deployment density for outdoor microcell scenario around an Earth station

Chart, scatter chart

Description automatically generated

The following steps have been followed to derive the aggregate interference CDF received at a non‑GSO FSS earth station (interfered with) from IMT transmissions (interferer).

**Step 1:** Compute the FSS E/S antenna gain towards each IMT station (the deployment of the IMT stations is randomized and generated at each iteration) based on the following input parameters:

– the azimuth of the earth station towards North is randomized between -180o and +180o;

– earth station above the horizontal plane randomized between 0o and 90o;

– off-axis angle at which the earth station perceives the *n*th IMT station is calculated;

**Step 2:** Compute the IMT antenna gain for each station towards the FSS E/S based on the following input parameters:

– IMT BS station antenna pointing azimuth is random variable with a uniform distribution between -180° to 180°;

– IMT BSs are considered to have a fixed mechanical down tilt that depends on the deployment type;

– the elevation and azimuth angle at which the IMT BS perceives the FSS E/S is calculated for each deployment of theIMT BS considered;

– IMT BS electrical steering elevation is based on the Rayleigh distribution shown below. It defines the distribution of distances between the BS and the UE, and has σ=32.

FIGURE 2

IMT-2020 Rayleigh distribution of distances between IMT BS and UE

Chart, histogram

Description automatically generated

From this distance distribution, the beam electrical tilt angle distribution of the BS can easily be

The following distribution is obtained:

FIGURE 3

IMT-2020 BS electrical tilt distribution

Chart, histogram

Description automatically generated

– IMT BS electrical azimuth: random variable with a distribution presented in the figure below.

FIGURE 4

IMT phi-scan

Chart, histogram

Description automatically generated

– IMT UEs are considered to have omnidirectional antennas with fixed gain in all directions, so their antenna pointing has no impact on the results.

**Step 3:** Define which IMT stations are active based on TDD and loading factors. According to these two factors, some IMT stations are considered to be inactive and are not accounted for in the interference calculation.

**Step 4:** Compute the aggregate interference (dB(W/MHz)) from the IMT stations towards the FSS E/S as follows:

Iaggregate =

where *Ii*is the interference of interferer *i*:

+

is the IMT station power spectral density.

is the IMT station antenna gain towards the FSS E/S.

is the FSS E/S antenna gain towards the IMT station.

is the loss from the propagation model based on Recommendation ITU-R P.452 (*p* = 20%) with clutter loss (Recommendation ITU-R P.2108) and building entry loss for indoor stations (Recommendation ITU-R P.2109).

is the ohmic loss.

*θ* represents the off-axis or azimuth/elevation angles between the FSS E/S and IMT station, as appropriate.

**Step 5:** Store the calculated aggregate interference and repeat steps 1 through 3 for 100 000 iterations. Plot interference distribution. Calculation of the FS protection criteria was achieved as follows:

where:

: I/N protection criteria.

: Noise temperature.

: 1 MHz reference.

: Boltzmann constant.

Note: this methodology is based on the studies considered for Agenda Item 1.13 (WRC-19), see [Annex 12 to Document 5 1/478](https://www.itu.int/md/R15-TG5.1-C-0478/en).

2.1.2.2 Interference from IMT to FSS (Earth-to-space) in the band 6 425-7 075 MHz

The coverage area of the satellite beam has been calculated assuming a curved earth model and follows the methodology described here. The 3 dB footprint of the FSS satellite at a given elevation can be assumed as an ellipse on the surface of the Earth. The following figure gives an overview of the case studied in this document.

FIGURE 5

Illustration of the satellite coverage footprint and geometry related

Diagram, schematic

Description automatically generated

To calculate the area of the satellite 3 dB footprint at a specific elevation angle (in red in the above figure), the major and minor axes of the ellipse must be calculated first. The following figure introduces the geometry considered and the variables that will be used to calculate the major axis of the FSS satellite 3 dB contour.

FIGURE 6

Illustration of the considered geometry and introduction of the variables

A computer screen capture

Description automatically generated with low confidence

To calculate the major axis of shown in the above figure based on the elevation , the following steps must be applied (note that all angles are expressed in degrees):

**Step 1:** Calculation of the corresponding off‑nadir pointing angles of the satellite (angle between the satellite pointing and the sub‑nadir point): , and .

Apply the sine law:

From the FSS satellite beamwidth , and can be calculated as follows:

**Step 2:** Calculation of the elevation boundaries of the 3 dB footprint area: and .

Apply the sine law:

Similarly,

**Step 3:** Calculation of the corresponding angles at the centre of the Earth: , and :

**Step 4:** Calculation of major axis :

When applying the above steps to the analysed carrier, the major axis is calculated as 282 km.

To calculate the minor axis of the ellipse corresponding to the close approximation of the FSS satellite 3 dB footprint for a given elevation, the slant path distance (i.e., distance between the satellite and the ground for a specific elevation) needs to be calculated.

The slant path distance can be calculated by again applying the sine law:

Once the slant path is calculated, the minor axis can be approximated by:

When applying the above method, b is calculated as 22.3 km. The main assumption made here is that the 3 dB footprint is assumed to be an ellipse of major axis  and minor axis . Therefore, the area is calculated as follows:

This results in an area of 19801 km2. Once the study area is calculated, the interference into the non-GSO satellite receiver is estimated following these steps:

**Step 1:** Generating a random IMT station deployment (urban) seen by the satellite main beam at the minimum elevation.

− Considering a coverage for the satellite at the lowest elevation for worst case analysis.

− The number of IMT stations in the area is calculated using the method described in Section 2.1.2.1

The following figure presents one of the random generation of an IMT base station deployment for both the considered IMT deployments inside the satellites’ 3 dB beamwidth. The random deployment of all the IMT base stations will be generated at each iteration.

FIGURE 7

IMT base station deployment inside the satellite 3 dB beamwidth

Chart, scatter chart

Description automatically generated

**Step 2:** Deactivate a proportion of IMT stations based on the TDD and loading factors. Deactivated stations are not considered in the interference calculation.

**Step 3:** Determining the aggregate interference form the IMT station deployment to the FSS satellite.

– The power spectral density (PSD) of an IMT station is assumed.

– The off‑axis gain for each of the IMT stations towards the FSS satellite is calculated following the methodology described in Section 2.1.2.1 of this study.

– The aggregate interferenceis calculated using the following formula:

where *Ii*is isthe interference of interferer *i*

is the IMT station power spectral density;

is the i‑th IMT station gain towards the FSS satellite;

is the FSS satellite main beam gain towards the IMT stations, as a 3 dB spotbeam coverage study area is considered and Recommendation ITU-R S.672 *recommends 1* does not define antenna gains for off-axis angles below the 3 dB beamwidth, peak gain is considered towards all IMT stations;

is propagation model loss based on Rec. ITU‑R P.525, with the gaseous attenuation based on Rec. ITU‑R P.676. Building entry loss was considered for indoor stations, modeled by Rec. ITU-R P.2109;

is the ohmic loss (2 dB). For interference from IMT UEs, 4dB body loss was also considered;

*θ* is the off‑axis between the FSS satellite’s beam incidence angle and IMT BS.

– The result is stored.

**Step 4:** redo steps 1 to 3 sufficiently to obtain a stable cumulative distribution function curve and store it. In this study, 100000 iterations were performed.

Note: This methodology is based on the studies considered for Agenda Item 1.13 (WRC-19), see [Annex 13 to Document 5 1/478](https://www.itu.int/md/R15-TG5.1-C-0478/en).

2.1.3.1 Results: Interference from IMT to FSS (space-to-Earth) in the band 6 425-7 025 **MHz**

The following figure presents the aggregate IMT BS interference CDF towards the FSS E/S receiver for the three studied IMT deployments, i.e., urban macro cell, micro cell, and indoor. As shown in the figure below, all three studied deployments exceed the FSS E/S short-term protection criteria. Moreover, the urban macro cell deployment exceeds the FSS E/S long-term protection criteria.

FIGURE 8

IMT BS to the FSS E/S, aggregate interference CDF (dB(W/MHz))- urban macro cell, micro cell,   
and indoor deployments



The following figure presents the aggregate interference from UEs towards the FSS E/S receiver for the three studied IMT deployments, i.e., urban macro cell, micro cell, and indoor. The FSS E/S short-term criteria exceeds for both IMT BS and UE cases.

FIGURE 9

IMT UE to the FSS E/S, aggregate interference CDF (dB(W/MHz)) - urban macro cell, micro cell,   
and indoor deployments



2.1.2.2 Results: Interference from IMT to FSS (Earth-to-space) in the band 6 425‑7 075MHz

The following figure presents the aggregate IMT BS interference towards the FSS S/S receiver for the three studied IMT deployments, i.e., urban macro cell, micro cell, and indoor. As shown in the figure below, both FSS short-term and long-term protection criteria are exceeded by urban macro cell and micro cell IMT deployments.

It is important to note that interference from indoor base stations is attenuated not only by building entry losses but also by the fact that indoor BSs are ceiling mounted and their antennas are physically pointing down, hence, they will only cause interference to the FSS space stations with very low gain antenna back lobes.

FIGURE 10

IMT BS to the FSS S/S, aggregate interference CDF (dB(W/MHz)) - urban macro cell, micro cell,  
 and indoor deployments



The following figure presents the aggregate interference from UEs towards the FSS S/S receiver for the studied IMT deployments, i.e., urban macro cell, micro cell, and indoor. The FSS long-term protection criteria is exceeded for the urban macro cell and micro cell IMT deployments. Unlike base stations, user equipment stations have omnidirectional antennas, so their antenna orientation has no impact on the interference measured at the satellite station. Indoor base stations’ antenna orientation reduces the interference they cause to the satellite station, but the same cannot be said about user equipment stations. For this reason and the fact that no power control was considered in this study, the interference caused by indoor UEs is larger than the one caused by indoor base stations.

FIGURE 11

IMT UE to the FSS S/S, aggregate interference CDF (dB(W/MHz)) - urban macro cell, micro cell,   
and indoor deployments



### 2.1.4 Summary and analysis of the results of Study A

Aggregate interference simulations from the IMT towards FSS earth and space stations have been performed in the 6 425 – 7 075 MHz frequency range. The results show that the operations of IMT BS and UE systems in this band would cause interference to incumbent fixed satellite service. Indoor, micro cell, and urban macro cell IMT deployments were analyzed.

For the BS case:

• the short-term protection criteria of the FSS E/S was exceeded for all three deployments, while the long-term protection criteria exceeded only for the urban macro cell deployment.

• Both the long-term and short-term protection criteria of the FSS S/S were exceeded for microcell and urban macro cell deployments.

For the UE case:

• the short-term protection criteria of the FSS E/S was exceeded for all three IMT deployments.

• the long-term protection criteria of FSS S/S was exceeded by the micro cell and urban macro cell deployments.

It is important to note that urban deployment was considered for the macro cell case. If suburban deployment was considered, the interference estimated in the results presented here would be larger. Rural deployment was not considered for this study as contiguous coverage is not expected in this frequency range in rural areas

# 3 Summary and analysis of the results of studies

*[Editor’s note: This section provides the summary and analysis of the results of studies. The text here can be used in the Section 1/1.2/3 “Summary and analysis of the results of ITU-R studies” of Draft CPM Text.]*

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_