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| **Radiocommunication Study Groups** |  |
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| **4 October 2022** |
| **English only  SPECTRUM ASPECTS &  WRC‑23 PREPARATIONS** |
| Saudi Arabia (Kingdom of) | |
| WORKING DOCUMENT ON SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS IN THE FREQUENCY BAND 6 425-7 125 MHz  ATTACHMENT 4 | |
| Sharing and compatibility of FSS (Earth-to-space) operating in the frequency band 6 425-7 075 MHz and IMT operating  in the frequency band 6 425-7 125 MHz | |

At its June 2022 meeting, Working Party (WP) 5D developed further a working document for sharing and compatibility studies of IMT systems in the frequency band 6 425-7 125 MHz in response to WRC-23 agenda item 1.2 (Resolution **245 (WRC-19)**). The working document was attached to the WP 5D Chairman’s Report of the June 2022 meeting (Annex 4.19 to Doc. [5D/1361](https://www.itu.int/md/R19-WP5D-C-1361/en)).

This contribution provides further revision to the sharing and compatibility studies between IMT and incumbent Fixed Satellite Service (E-s) in the frequency band of 6 425-7 075 MHz. Changes are only being proposed in Attachment 4, Study C of the document. Proposed changes to the existing document are shown in track changes, in yellow.

|  | Parameters from expert WPs and WP 5D | | Study A  Source: Doc 5D/782, 1231 (CME & al) | Study B  Source: Doc 5D/806, 1021, 1082 & 1303 (J) | Study C  Source: Doc 5D/835 (ARS & al), 1124, 1291 (ARS ) | Study D  Source: Doc 5D/874 & 1069 (CHN) |
| --- | --- | --- | --- | --- | --- | --- |
| **Methodology** | | | | | | |
| Number of IMT stations considered | Single-entry or Multiple-entry (aggregate) | | Multiple-entry (aggregate) | Multiple-entry (aggregate) | Multiple-entry (aggregate) | Multiple-entry (aggregate) |
| Type of interference evaluation method | Deterministic study or  Statistical study | | Statistical study  (Monte Carlo) | Statistical study (Monte Carlo) | Statistical study | Statistical study  (Monte Carlo) |
| If statistical, based on Rec. [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf)? | | based on Rec. ITU-R  [M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) | Based on Rec. ITU-R M.2101 | [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) | based on Rec. ITU-R M.2101 |
| **Technical and operational characteristics of IMT‑2020 systems** | | | | | | |
| Deployment scenario | Urban/suburban macro, Small cell (outdoor)/Micro cell, Indoor (small cell), rural | | Urban/suburban macro | Urban/suburban macro | Urban and suburban macro | Urban/suburban macro |
| IMT stations | BS and UE | | BS only | BS only | BS and UE | BS only |
| Method to deploy multiple IMT stations for the aggregate interference analysis over a relatively large area (as applicable to scenarios for the studies) | Ra and Rb method:  Ra: Ra1, Ra 2  Rb: Rb1, Rb2, Rb3  Additional guidance (or further clarification) is found in section 3.3 of Annex 4.4 to 5D/716 | | Ra and Rb method:  Ra: Ra1  Rb: Rb3  Carrier #7 (2.9°E pointing at 8°E, 2°S)  Removal of area of the Sahara desert where the population density is 1 person per km2 or less, an area of 6.2 million km2  from the Sahara Desert being removed from the model.  Carrier #8 (2.9°E pointing towards 3 locations which are assessed separately)  No removal of unpopulated landmass.  AP**30B** allotments for Cameroon and Nigeria  Satellite visible area excluding the areas in Region 2 and Region 3.  No removal of unpopulated landmass area. | Ra and Rb method:  Ra: Ra1  Rb: Rb1   Carrier #1 (agnostic satellite orbit location)  Removal of 51% of area within a satellite footprint, assuming the land ratio of 0.49 for the case of the land hemisphere.  Carrier #1 (128°E)  Removal of 76% of area within a satellite footprint, assuming the land ratio of 0.24 excluding sand area (1.2% of the landmass).  Carrier #2 (128°E pointing at 119°E, 26°N)  Removal of 47% of area within a satellite footprint, assuming the land ratio of 0.53 excluding sand area (2.6% of the landmass).  Carrier #3 (128°E pointing at 121°E, 31°N)  Removal of 46% of area within a satellite footprint, assuming the land ratio of 0.54 excluding sand area (0.38% of the landmass).  Within visible area (128°E)  Removal of 76% of area within visible area, assuming the land ratio of 0.24 excluding sand area (3.2% of the landmass). | Ra and Rb method  Ra: Ra2  Rb: Rb2 | Ra and Rb method:  Ra: Ra1  Rb: Rb1  Removal of unpopulated area i.e. some portion of Sahara Desert |
| Number of simultaneously transmitting IMT‑2020 stations deployed in the footprint | – | | Carrier #7 : 79,336  Carrier #8 pointing at (24°E, 23°S): 11,557  Carrier #8 pointing at (11°E, 7°N): 11,985  Carrier #8 pointing at (38°E, 0°N): 12.357  AP**30B** allotments for Cameroon: 115,149  AP**30B** allotments for Nigeria: 129,844 | Carrier #1 (agnostic satellite orbit location)  Urban: 97,346  Suburban: 11,682  Urban and suburban: 109,027  Carrier #1 (128°E)  Urban: 47,900  Suburban: 5,748  Urban and suburban: 53,648  Carrier #2 (128°E pointing at 119°E, 26°N)  Urban: 19,079  Suburban: 2,289  Urban and suburban: 21,368  Carrier #3 (128°E pointing at 121°E, 31°N)  Urban: 10,009  Suburban: 1,201  Urban and suburban: 11,211  Within visible area (128°E)  Urban: 104,713  Suburban: 12,566  Urban and suburban: 117,278 | Within 3 dB:  Average active IMT stations in Suburban 2,028  Average active IMT stations in Urban 19,012  Within and beyond 3 dB:  Average active IMT stations in Suburban 467,610  Average active IMT stations in Urban 4,383,900 | Urban: 66,160  Suburban : 7,939  Urban and Sub-urban:  74,099 |
| Network loading factor for BS and UE (%) | 20 | | 20 | 20 | 20 | 20 |
| TDD activity factor (%) | BS: 75  UE: 25 | | BS: 75  UE: 25 | BS: 75  UE: 25 | BS: 75  UE: 25 | BS: 75  UE: 25  If UE is not considered, the interference of BS is reduced by 1.25 dB considering the 75% activity factor. |
| UE power control factor (dB) | Refer to section 4.1 in Annex 1 to Rec. [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) and Items in Table 7-2 in Annex 4.4 to Doc. 5D/716 | | Not considered | UE interference is not simulated | Refer to section 4.1 in Annex 1 to Rec. [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) and Items in Table 7-2 in Annex 4.4 to Doc. 5D/716 | UE interference not simulated in this study,  UE power control not considered |
| UE body loss (dB) | 4 | | 4 | 4 | 4 | 4 |
| IMT Antenna pattern | Rec [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) Annex 1, section 5 | | Rec [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) Annex 1, section 5 | Rec ITU-R M.2101 Annex 1, section 5 | Rec [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) Annex 1, section 5 | Rec [ITU-R M.2101](https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf) Annex 1, section 5 |
| BS antenna pointing | Mechanical pointing in elevation angle (downtilt angle of 10 degrees urban and 6 degrees suburban) and random in azimuth - See Table 10 in Annex 4.4 to Doc. [5D/716](https://www.itu.int/md/R19-WP5D-C-0716/en) | | Mechanical pointing in elevation angle (downtilt angle of 10 degrees urban and 6 degrees suburban) and random in azimuth - See Table 10 in Annex 4.4 to Doc. 5D/716 | Mechanical pointing in elevation angle (downtilt angle of 10 degrees urban and 6 degrees suburban) and random in azimuth | Mechanical pointing in elevation angle (downtilt angle of 10 degrees urban and 6 degrees suburban) and random in azimuth - See Table 10 in Annex 4.4 to Doc. 5D/716 | Mechanical pointing in elevation angle (downtilt angle of 10 degrees urban and 6 degrees suburban) and random in azimuth - See Table 10 in Annex 4.4 to Doc. 5D/716 |
| UE antenna pointing |  | | Not considered. | UE interference is not simulated |  | UE interference is not simulated |
| **Technical and operational characteristics of FSS** | | | | | | |
| Carriers | #1; #7; #8; #11 | #2; #3; #4; #12 | #7; #8  AP**30B** allotments for Cameroon and Nigeria | #1; #2; #3 | Carrier 4 | #1 |
| Space station noise bandwidth (MHz) | 1; 0.024-72; 0.024-72; 1.8/ 4.2/ 13; | 1; 1; 1; 0.004-1; | 1 MHz | 1 | 1 | 1 MHz |
| Space station peak receive antenna gain (dBi) | 22; 22; 32; 30.8; | 28; 32; 38; 20 (global)/36;4 (spot) | 22; 32; 37.7; 38.4 | 22; 28; 32 | 38 | 22 dBi |
| Beamwidth, degree | 15 (global beam); 14; 4.5; -; | Hemi beam (ellipse, 6x7 deg); Zone beam (ellipse, 3x7 deg); Multispot beam (circular, 0.8 deg); 17.7º / 2.6º; | 14(global beam);  4.5(zone beam)  2.5x1.9 (AP**30B** allotments for Cameroon);  2.5x1.6 (AP**30B** allotments for Nigeria) | 15 (global beam);  Hemi beam (ellipse, 6x7 deg);  Zone beam (ellipse, 3x7 deg) | 0.8 for the footprint area Scenario 1: only IMT stations withing the 3dB footprint Scenario 2: IMT stations within and beyond the 3dB footprint. | 15 (global beam) |
| Space station system noise temperature (K) | 630; 500-900; 500-900; 900 | 400 | 900; 900; 500; 500 | 630; 400; 400 | 400 | 630 |
| Normalization of FSS receiver antenna gain |  |  | No | No | No | Yes.  2.7 dB loss is considered |
| FSS receiver antenna efficiency |  |  | No | No | No | Real antenna efficiency should be taken into account by sharing studies.  But the exact efficiency value and correction factor will be provided later based on 5D discussions. |
| FSS receiver feederloss |  |  | No | No | No | No |
| Earth station diameter (m) | 1.2; 1.2; 7; 11.3 | 1.8; 16; 32; 13.2 | N/A | N/A | N/A | N/A |
| Earth station peak transmit antenna gain (dBi) | N/A; 36; 51; 56.6 | N/A (for carriers #2, 3, 4); 57.2 (for carrier #12); | N/A | N/A | N/A | N/A |
| Earth station peak spectral density (dBW/Hz) | N/A; -33; -33; -33 (4 kHz BW)/-43(1 MHz BW); | N/A (for carriers #2, 3, 4); -32.5 (for carrier #12); | N/A | N/A | N/A | N/A |
| Earth station antenna gain pattern | Recommends 2 of Recommendation ITU-R S.524-9; Rec. ITU-R S.465-6; Rec. ITU-R S.580-6 ; Rec ITU-R S.672 | Recommends 2 of Recommendation ITU-R S.524-9 (for carriers #2, 3, 4); Rec. ITU-R S.465-6 (for carrier #12) | N/A | N/A | N/A | N/A |
| Earth station minimum elevation angle (degrees) | See Liaison Statement, Table 1, Note 2 | See Liaison Statement, Table 1, Note 2 | N/A | N/A | N/A | N/A |
| Earth station height (m) | Not provided | Not provided | N/A | N/A | N/A | N/A |
| Other remarks, if any | Carrier Bandwidth is 1-50 MHz | Feeder links for GSO MSS |  |  | N/A | N/A |
| Protection criterion *I/N* (dB)[[1]](#footnote-1) | -10.5 for 20%  -2.33 for 0.001%  -6 for 0.03% | -10.5 for 20%  -2.33 for 0.001%  -6 for 0.03% | -10.5 for 20%  -2.33 for 0.001%  -6 for 0.03% | -10.5 for 20%  -2.33 for 0.001%  -6 for 0.03% | -10.5 for 20%  -2.33 for 0.001%  -6 for 0.03% | -10.5 for 20% |
| **Apportionment of interference between services** | | | | | | |
| Apportionment value (dB) | Case-by-case | Case-by-case | 0 | 0 | 0 dB and 3 dB | 0 dB |
| Propagation model | | | | | | |
| Baseline | See Document [5D/722](https://www.itu.int/md/R19-WP5D-C-0722/en) | | See Document 5D/722 | ITU-R P.619 | ITU-R P.619 | See [Document 5D/722](https://www.itu.int/md/R19-WP5D-C-0722/en) |
| Beam Spreading | See Document 5D/722 Rec. | | ITU-R P. 619 | ITU-R P.619 | ITU-R P.619 | ITU-R P. 619 (Section 2.4.2) |
| Atmospheric gases loss | See Document 5D/722 | | ITU-R P.676 | ITU-R P.619 | ITU-R P.619 | ITU-R P.676-12 (Section 2.2.1) |
| Clutter loss | See Document 5D/722 | | 3K/178 | Annex 6 to Document 3K/178 | [ITU-R P.2108](http://www.itu.int/rec/R-REC-P.2108/en) | Revised clutter loss model, Hs = 25 m  Annex 6 to Working Party 3K Chairman’s Report, Document 3K/178  (applied to 100% of IMT urban and suburban BSs) |
| Building entry loss | See Document 5D/722 | | Not considered | UE interference is not simulated | ITUR-R P.2109 | Rec. ITU-R P.2109  UE interference not simulated |
| Cross-polarization loss (dB) |  | | 3 | 3 | 3 dB | 3 dB |
| **Results of studies** | | | | | | |
| Level of interference |  | | Carrier #7 :  20%: −26.69 dB  0.001%: −26.16 dB  0.03%: −26.16 dB  Carrier #8 pointing at (24°E, 23°S):  20%: −23.3 dB  0.001%: −21.81 dB  0.03%: −21.81 dB  Carrier #8 pointing at (11°E, 7°N):  -10.5 for 20%: −29.14 dB  -2.33 for 0.001%: −24.43 dB  -6 for 0.03%: −24.43 dB  Carrier #8 pointing at (38°E, 0°N):  20%: −22.30 dB  0.001%: −20.31 dB  0.03%: −20.31 dB  AP**30B** allotments for Cameroon:  20%: −28.8 dB  0.001%: −26.7 dB  0.03%: −26.7 dB  AP**30B** allotments for Nigeria:  20%: −16.1 dB  0.001%: −14.7 dB  0.03%: −14.7 dB | **Within 3 dB footprint**  Carrier #1 (agnostic satellite orbit location)  I/N = -19.3 dB for 20%,  -18.6 dB for 0.001%,  -18.7 dB for 0.03%   Carrier #1 (128°E)  I/N = -22.2 dB for 20%,  -20.9 dB for 0.001%,  -21.0 dB for 0.03%  Carrier #2 (128°E pointing at 119°E, 26°N)  I/N = -18.6 dB for 20%,  -17.0 dB for 0.001%,  -17.3 dB for 0.03%  Carriers #3 (128°E pointing at 121°E, 31°N)  *I/N* = -17.7 dB for 20%,  -16.1 dB for 0.001%,  -16.4 dB for 0.03%  **Within visible area**  Carrier #1 (128°E)  *I/N* = -17.9 dB for 20%,  -17.3 dB for 0.001%,  -17.3 dB for 0.03%  Carrier #2 (128°E pointing at 119°E, 26°N)  *I/N* = -12.9 dB for 20%,  -12.3 dB for 0.001%,  -12.4 dB for 0.03%  Carriers #3 (128°E pointing at 121°E, 31°N)  *I/N* = -12.1 dB for 20%,  -11.6 dB for 0.001%,  -11.7 dB for 0.03% | See Tables 7 and 8 of Study C | Urban: -27.5 dB  Suburban: -38 dB  Combined: -27.2 dB |
| Level of exceedance of the protection | – | | Carrier #7 :  20%: −16.19 dB  0.001%: −23.83 dB  0.03%: −20.16 dB  Carrier #8 pointing at (24°E, 23°S):  20%: −12.73 dB  0.001%: −19.48 dB  0.03%: −15.81 dB  Carrier #8 pointing at (11°E, 7°N):  20%: −18.64 dB  0.001%: −22.10 dB  0.03%: −18.43 dB  Carrier #8 pointing at (38°E, 0°N):  20%: −11.80 dB  0.001%: −17.98 dB  0.03%: −14.31 dB  AP30B allotments for Cameroon:  20%: −18.3 dB  0.001%: −20.7 dB  0.03%: −24.37 dB  AP**30B** allotments for Nigeria:  20%: −5.6 dB  0.001%: −8.7 dB  0.03%: −12.37 dB | **Within 3 dB footprint**  Carrier #1 (agnostic satellite orbit location)  -8.8 dB for 20%  -16.2 dB for 0.001%  -12.3 dB for 0.03%   Carrier #1 (128°E)  I/N = -11.7 dB for 20%,  -18.6 dB for 0.001%,  -15.0 dB for 0.03%  Carrier #2 (128°E pointing at 119°E, 26°N)  -8.1 dB for 20%  -14.6 dB for 0.001%  -11.3 dB for 0.03%  Carriers #3 (128°E pointing at 121°E, 31°N)   -7.2 dB for 20%  -13.7 dB for 0.001%  -10.4 dB for 0.03%  **Within visible area**  Carrier #1 (128°E)  *I/N* = -7.4 dB for 20%,  -14.9 dB for 0.001%,  -11.3 dB for 0.03%  Carrier #2 (128°E pointing at 119°E, 26°N)  *I/N* = -2.4 dB for 20%,  -9.9 dB for 0.001%,  -6.4 dB for 0.03%  Carriers #3 (128°E pointing at 121°E, 31°N)  *I/N* = -1.6 dB for 20%,  -9.3 dB for 0.001%,  -5.7 dB for 0.03% | Protection criteria exceedance  Scenario 1 for 5o elevation:  No apportionment:  8.7 dB for 20%  4.8 dB for 0.03%  1.2 dB for 0.001%  With apportionment:  11.7 dB for 20%  7.8 dB for 0.03%  4.2 dB for 0.001%  Scenario 2 for 5o elevation:  No apportionment:  10.2 dB for 20%  6.8 dB for 0.03%  2.8 dB for 0.001%  With apportionment:  13.2 dB for 20%  9.8 dB for 0.03%  5.8 dB for 0.001% | Urban: -17 dB  Suburban: -27.5 dB  Combined: -16.7 dB |
| Results based on parameters from concerned/ involved groups  Level of interference |  | | Carrier #7 :  20%: −26.69 dB  0.001%: −26.16 dB  0.03%: −26.16 dB  Carrier #8 pointing at (24°E, 23°S):  20%: −23.3 dB  0.001%: −21.81 dB  0.03%: −21.81 dB  Carrier #8 pointing at (11°E, 7°N):  -10.5 for 20%: −29.14 dB  -2.33 for 0.001%: −24.43 dB  -6 for 0.03%: −24.43 dB  Carrier #8 pointing at (38°E, 0°N):  20%: −22.30 dB  0.001%: −20.31 dB  0.03%: −20.31 dB |  |  | N/A |
| Level of exceedance of the protection |  | | Carrier #7 :  20%: −16.19 dB  0.001%: −23.83 dB  0.03%: −20.16 dB  Carrier #8 pointing at (24°E, 23°S):  20%: −12.73 dB  0.001%: −19.48 dB  0.03%: −15.81 dB  Carrier #8 pointing at (11°E, 7°N):  20%: −18.64 dB  0.001%: −22.10 dB  0.03%: −18.43 dB  Carrier #8 pointing at (38°E, 0°N):  20%: −11.80 dB  0.001%: −17.98 dB  0.03%: −14.31 dB |  |  | N/A |
| Sensitivity analysis |  | | AP**30B** allotments |  |  | N/A |
| Sensitivity analysis results |  | | Aggregated I/N levels  AP**30B** allotments for Cameroon:  20%: −28.8 dB  0.001%: −26.7 dB  0.03%: −26.7 dB  AP**30B** allotments for Nigeria:  20%: −16.1 dB  0.001%: −14.7 dB  0.03%: −14.7 dB |  |  | N/A |
| Other studies |  | | N/A |  |  | N/A |
| Other studies results Level of interference |  | | N/A |  |  | N/A |
| Level of exceedance of the protection |  | | N/A |  |  | N/A |
| Additional notes |  | | N/A |  |  | N/A |

## 2.3 Study C (ARS& al (835), ARS (1124), (1291))

[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.]

This section contains an in-band, compatibility and sharing study analysing interference from IMT stations (BS & UE) towards FSS (E-s) in the 6 425-7 075 MHz frequency range.

This study analyses aggregate interference from a large number of IMT stations to FSS space station receivers. The IMT deployment is based on macro-urban and macro-suburban cells and the FSS (E-s) characterises are based on GSO satellite, carrier 4.

Two scenarios were considered in these studies, one consider only IMT stations inside the 3 dB beamwidth (footprint area) of the FSS satellite and the second one consider IMT stations inside and beyond the 3 dB beamwidth, hereafter called Beyond 3 dB. The latter include IMT stations that are in a secondary or side-lobe of the satellite’s antenna that can still contribute to the interference.

This study intends to be responsive to *resolves* 2 of Resolution **245 (WRC‑19)** under WRC-23 agenda item 1.2.

### 2.3.1 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.]

This section describes the technical characteristics of IMT 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 to guarantee the protection of the incumbent service.

#### 2.3.1.1 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.]

The tables below provide technical and operational characteristics of IMT taken from Tables 7-1, 7‑2, and 10 of Annex 4.4 of WP 5D Chairman’s Report ([5D/716](https://www.itu.int/md/R19-WP5D-C-0716/en)) 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.

The Ra and Rb values for the Beyond 3 dB Beamwidth are the highest values according to WP 5D and the comments from GSOA (see Document [5D/1135](https://www.itu.int/md/R19-WP5D-C-1135/en)).

Table 1

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 3 dB Beamwidth | | Beyond 3 dB Beamwidth | |  |
| Parameter | Value – Macro urban | Value – Macro suburban | Macro Urban | Macro Suburban | Unit |
| Duplex method | TDD | TDD | TDD | TDD |  |
| Channel bandwidth | 100 | 100 | 100 | 100 | MHz |
| Deployment density | 10 | 2.4 | 10 | 2,4 | BSs/km2 |
| Ra | 45 | 20 | 45 | 20 | % |
| Rb | 5 | 5 | 5 (inside 3 dB beamwidth)  3 (outside 3dB beamwidth) | 5 (inside 3 dB beamwidth)  3 (outside 3 dB beamwidth) | % |
| Antenna height | 18 | 20 | 18 | 20 | M |
| Number of sectors | 3 | 3 | 3 | 3 |  |
| Sector coverage | 120 | 120 | 120 | 120 | Degree |
| Network loading factor | 20 | 20 | 20 | 20 | % |
| BS TDD factor | 75 | 75 | 75 | 75 | % |
| Antenna type | AAS only | AAS only | AAS only | AAS only |  |
| Antenna pattern | ITU-R M.2101 | ITU-R M.2101 | ITU-R M.2101 | ITU-R M.2101 |  |
| Element gain | 5.5 | 6.4 | 5,5 | 6,4 | dBi |
| Horizontal 3 dB beamwidth | 90 | 90 | 90 | 90 | Deg |
| Vertical 3 dB beamwidth | 90 | 65 | 90 | 65 | Deg |
| Horizontal front-to-back ratio | 30 | 30 | 30 | 30 | dB |
| Vertical front-to-back ratio | 30 | 30 | 30 | 30 | dB |
| Horizontal element spacing | 0.5 | 0.5 | 0,5 | 0,5 | d/lambda |
| Vertical element spacing | 0.5 | 0.7 | 0,5 | 0,7 | d/lambda |
| Array number of rows | 16 | 16 | 16 | 16 |  |
| Array number of columns | 8 | 8 | 8 | 8 |  |
| Mechanical downtilt | 10 | 6 | 10 | 6 | Degree |
| Array ohmic losses | 2 | 2 | 2 | 2 | dB |
| Conducted power | 22 | 22 | 22 | 22 | dBm |

Table 2

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

|  | 3 dB Beamwidth | | Beyond 3 dB Beamwidth | |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Value – Macro urban | Value – Macro Suburban | Macro Urban | Macro Suburban | Unit |
| Duplex method | TDD | TDD | TDD | TDD |  |
| Channel bandwidth | 100 | 100 | 100 | 100 | MHz |
| Indoor terminal usage | 70 | 70 | 70 | 70 | % |
| UEs per sector | 3 | 3 | 3 | 3 |  |
| Antenna height | 1.5 | 1.5 | 1,5 | 1,5 | M |
| UE TDD factor | 25 | 25 | 25 | 25 | % |
| Power control | Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1 | Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1 | Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1 | Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1 |  |
| Maximum output power | 23 | 23 | 23 | 23 | dBm |
| Antenna type | Omnidirectional | Omnidirectional | Omnidirectional | Omnidirectional |  |
| Antenna gain | -4 | -4 | -4 | -4 | dBi |
| Body loss | 4 | 4 | 4 | 4 | dB |
| Building entry loss | ITU-R P.2109 | ITU-R P.2109 | ITU-R P.2109 | ITU-R P.2109 |  |

#### 2.3.1.2 Technical and operational characteristics of FSS (Earth-to-space) operating in the frequency band 6 425-7 025 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.]

The FSS S/S parameters shown in Table below are FSS parameters to Carriers 4 provided by WP 4A to WP 5D (see Document [5D/734](https://www.itu.int/md/R19-WP5D-C-0734/en)).

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 | 35 786 | km |
| Minimum elevation angle | 5 | deg |
| Short term I/N value 1 | -2.33 | dB |
| Short term time percentage value 1 | 0.001 | % |
| Short term I/N value 2 | -6 | dB |
| Short term time percentage value 2 | 0.03 | % |
| Long term I/N | -10.5 | dB |
| Long term time percentage | 20 | % |

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](https://www.itu.int/rec/R-REC-M.2101/en), 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.

According to Article **5** of the ITU Radio Regulations, in this frequency range, Fixed and Mobile services are allocated on a primary basis. Considering the wide coverage of the FSS satellite systems, these two services will exist within the FSS coverage. Therefore, for this study the FSS protection criteria is apportioned by 3 dB among the two potential sources of interference, i.e., the FS and MS.

#### 2.3.1.3 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.]

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 4 below.

Table 4

FSS propagation parameters

|  |  |  |
| --- | --- | --- |
| Ground to Space | | |
| Parameter | Value |  |
| Model | Rec. ITU R P.619 |  |
|  |  |  |
| Polarization | Vertical |  |
| Building entry loss (indoor stations only) | ITU-R P.2109 |  |
| Building type | Traditional |  |
| Building entry loss percentage | Random per link |  |
| Clutter loss | The slant path clutter loss model as described in Annex 6 to Working Party 3K Chairman’s Report, Document 3K/178 |  |

### 2.3.2 Methodology

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

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 and sub-urban cell IMT deployments were analysed. 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.

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

Different scenarios were analysed, as described in section 2.3.3. All scenarios follow the methodology described in this section.

##### 2.3.2.1.1 Footprint area modelling

In order to evaluate the interference from the IMT system into the FSS space station, the whole area covered by the satellite beam has been calculated assuming a curved earth model and follows the methodology described here.

The methodology can be divided in two stages:

• First, the model approximates the coverage area as an ellipse, in order to obtain coarse estimates on the coverage area size and location.

• Then, rejection sampling is used in a spherical patch that contains the coverage area to generate the position of uniformly distributed IMT stations inside the coverage area.

The 3 dB footprint of the FSS satellite at a given elevation cannot be assumed as an ellipse on the surface of the Earth, since that doesn’t produce a good area approximation for angles lower than 20º. However, the ellipse approximation provides estimates used to generate latitude and longitude coordinates of points inside the exact coverage region. To this end, a rejection sampling method was chosen to estimate not only the area but also the elevation angle for every IMT station inside the footprint area, respecting a minimum elevation angle.

The following figure gives an overview of the ellipse approximation initially used in the method.

FIGURE 1

Illustration of the satellite coverage footprint and geometry related

Diagram, schematic

Description automatically generated

The major and minor axes of the ellipse are 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 approximation.

FIGURE 2

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, for different minimum elevation angles, the major axis is calculated and presented in table 5.

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:

This formula doesn’t apply for the case where . In other cases, the cosine law is used instead:

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

When applying the above method, for different minimum elevation angles, b is calculated and presented in table 5.

Table 5

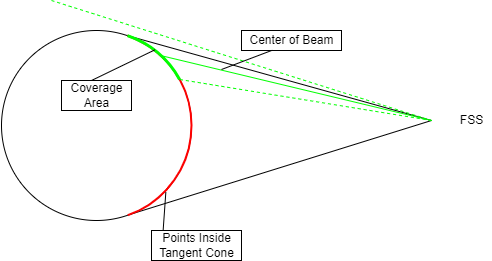
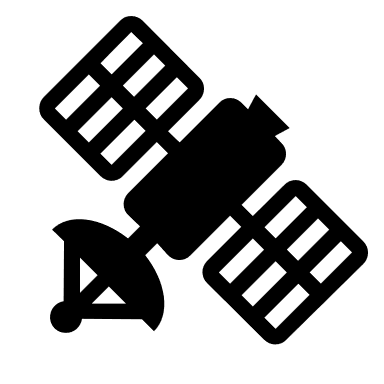
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Minimum Elevation Angles [degrees]** | | | |
|  | 5 | 20 | 45 | 90 |
| a [km] | 1,964.7 | 1,781.7 | 741.04 | 499.87 |
| b [km] | 574.1 | 552.2 | 522.35 | 499.67 |

Using the elliptical approximation for the footprint of the FSS satellite described above, a more precise method is then used to estimate the footprint area and distribute the IMT stations inside this area.

The rejection sampling method used to generate uniform points inside a patch of the spherical surface only selects the points inside the tangent cone and inside the satellite beam. A tangent cone is a cone that defines the total visibility of the satellite station, i.e., it is a cone with its vertex at the satellite station and surface tangent to the spherical Earth. This method produces an exact distribution of users inside the desired region. By counting the points inside and outside the coverage area a Monte Carlo estimate of the coverage area can be computed. Figure 3 depicts the geometry considered.

FIGURE 3

Illustration of the considered geometry to compute elevation angle and slant path



A spherical patch with latitudes (in radians) and longitudes is defined. The elliptical approximation presented before is exact in terms of , but not in terms of , hence the slack factor of 1.5. Note that in the case part of the beam misses the earth, then is the angle at which the beam is tangent to the earth.

A point inside this patch is uniformly generated and the off-axis angle , at the satellite, towards this point is computed. The elevation at which a station in this point would see the FSS satellite station is also calculated. If , where BW is the satellite’s beamwidth, and , then the point is inside the beam cone and visible to the satellite. The following figure presents one of the random generated IMT station deployments inside the satellites’ 3 dB beamwidth. The random deployment of all the IMT stations is generated at each snapshot.

FIGURE 4

IMT deployment inside the satellite 3 dB beamwidth

Chart, scatter chart

Description automatically generated

This process is repeated until the desired amount points inside the coverage region is obtained. The total patch area is

Using the ratio of the number of points inside the coverage region to the total number of points generated inside the patch an approximation for the coverage area can be obtained.

This results in the following areas for different elevation angles are presented in table 6.

Table 6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Elevation Angles [degrees]** | | | |
|  | 5 | 20 | 45 | 90 |
| Footprint Satellite Area [ km2] | 991,220 | 759,520 | 305,400 | 197,120 |

##### 2.3.2.1.2 Beyond 3 dB beamwidth modelling

In this scenario, the interference from the IMT system into the FSS space station is calculated considered the entire line of sight of surface on Earth. Hence, IMT stations that are in a secondary side-lobe of the satellite’s antenna are also considered in the interference calculation.

The proposed modeling distributes IMT stations uniformly on the surface of a spherical cap (or dome). The global beam area represents almost half size of the earth with approximate 216.490.348 square kilometers. The satellite sees the Earth in a cone of approximately 8.7 degrees. Figure 5 presents examples of IMT stations distribution for different satellite elevation angles. Red and blue areas represent IMT stations deployments inside and outside the satellites’ 3 dB beamwidth, respectively.

FIGURE 5

**IMT deployment inside the satellite visible area**



The FSS satellite gain towards every IMT station in the spherical cap is calculated and it’s determined by the antenna radiation pattern given by ITU-R S.672. Figure 6 shows 2 different patterns with Ls=-20 and Ls=-30. The Ls=-30 was used for the spot beam coverage scenario.

Figure 7 shows the antenna gain heatmap over the earth surface for the satellite elevation angle of 50.

FIGURE 6

Antenna Radiation Pattern ITU-R S.672

Chart, line chart

Description automatically generated

FIGURE 7

Satellite Antenna Gain

Chart, bubble chart

Description automatically generated

##### 2.3.2.1.3 Simulation Methodology

A coexistence static system-level simulator using the Monte Carlo method was developed in order to perform the studies. At each simulation snapshot, the IMT BS and IMT UE are randomly generated and located within a satellite footprint area and also over the entire line of sight surface on Earth using the method described above. All relevant losses are calculated between the IMT and FSS space station.

The main key performance indicator obtained from these simulations is the aggregate interference generated by the IMT base stations or user equipment into the satellite system. The aggregate interference-to-noise ratio *I/N* is calculated and compared with FSS space station protection criteria. Aggregate interference is a summation of interfering signals sourced from all active BSs and UEs for urban and suburban.

Once the study area is calculated, the interference into the GSO satellite receiver is estimated following these steps:

**Step 1:** Generating IMT station deployment seen by the satellite main beam and beyond 3 dB at the minimum elevation using the method described in Section 2.3.2.1.1 and considering the deployment density and ratio of coverage areas and built areas of region in study.

**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 (note: power control is applied for IMT UE simulation cases).

– 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*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 gain towards the IMT stations: in Scenario 1 peak gain is considered towards all IMT stations which are inside the 3dB beamwidth (refer to Figure 5); in Scenario 2, antenna radiation pattern ITU-R S.672 with Ls=-30dB is used; is propagation model loss based on Rec. ITU‑R P.619 and clutter loss (Document 3K/178), and body loss for IMT UE case. Building entry loss was considered for indoor user, modelled 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, 50 000 iterations were performed for scenario 1, and around 1000 iterations were performed for scenario 2.

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).

### 2.3.3 Study results

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

As explained below and summarized in Table 7, different simulation scenarios were considered. The impact of the interference from different variables, such as the IMT stations outside the FSS satellite footprint, the satellite side-lobe level Ls, the IMT base station down tilt and a correction for seas and oceans was estimated through the results here presented. Table 8 summarizes the apportioned protection criteria exceedance for each one of the studied scenarios.

Table 7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scenario | IMT stations outside footprint? | Satellite antenna Ls | IMT BS down tilt | Correction for seas/oceans? |
| **1** | No | -30 dB | Table 1 | No |
| **2** | Yes | -30 dB | Table 1 | No |
| **3** | Yes | -20 dB | Table 1 | No |
| **4** | Yes | -20 dB | 0 degrees | No |
| **5** | Yes | -30 dB | Table 1 | Yes |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Table 8 |  |  | **Protection Criteria Exceedance [dB]** | | | | |
| FSS SS [degree] | Probability of time | *I/N* criteria with apportionment [dB] | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
| 5 | 0.001% | -148 | 4.2 | 5.8 | 5.07 | 6.21 | 5.39 |
| 0.03% | -152 | 7.8 | 9.8 | 9.07 | 10.21 | 9.39 |
| 20% | -156 | 11.6 | 13.2 | 12.62 | 13.83 | 13.06 |
| 20 | 0.001% | -148 | 1 | 0.7 | 2.63 | 3.5 | 0.49 |
| 0.03% | -152 | 4.7 | 4.7 | 6.63 | 7.5 | 4.49 |
| 20% | -156 | 8.7 | 8.5 | 10.49 | 11.4 | 8.37 |
| 45 | 0.001% | -148 | -7.4 | -6.3 | -3.27 | -1.92 | -6.98 |
| 0.03% | -152 | -3.7 | -2.3 | 0.73 | 2.08 | -2.98 |
| 20% | -156 | 0.2 | 1.5 | 4.62 | 6.01 | 0.94 |
| 90 | 0.001% | -148 | -19 | -14 | -9.4 | -6.94 | -18.05 |
| 0.03% | -152 | -15.4 | -10 | -5.4 | -2.94 | -14.05 |
| 20% | -156 | -11.6 | -6.1 | -1.42 | 1.03 | -10.02 |

Scenario 1: Footprint area

Simulations with the space station at 5°, 20°, 45°, and 90° with centre of beam elevation angles were performed and the following figure presents the aggregate IMT (BS and UE) interference CDF towards the FSS space station (FSS S/S) receiver for macro urban and suburban IMT deployments. As shown in the Figure below, for elevation angles of 5° and 20° the FSS S/S short-term and long-term protection criteria are exceeded. In addition, the FSS long-term protection criteria (with apportionment) is exceeded for elevation angle of 45°.

Figure 8

Table

Description automatically generated with medium confidence

Table 9 below summarizes the achieved I/N values for the simulation cases shown above. The column labelled as “Exceedance” indicates the level of exceedance of the protection criteria with and without apportionment.

Table 9

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| FSS SS | Probability of time | *I* criteria [dBW/MHz] | *I* criteria with apportionment [dBW/MHz] | *IMT*  *I* result [dBW/MHz] | Exceedance [dB] (without apportionment) | Exceedance [dB] (with apportionment) |
| 50 | 0.001% | -144.9 | -147.9 | -143.7 | 1.2 | 4.2 |
| 0.03% | -148.6 | -151.6 | -143.8 | 4.8 | 7.8 |
| 20% | -153.1 | -156 | -144.4 | 8.7 | 11.6 |
| 200 | 0.001% | -144.9 | -147.9 | -146.9 | -2 | 1 |
| 0.03% | -148.6 | -151.6 | -146.9 | 1.7 | 4.7 |
| 20% | -153.1 | -156 | -147.3 | 5.8 | 8.7 |
| 450 | 0.001% | -144.9 | -147.9 | -155.3 | -10.4 | -7.4 |
| 0.03% | -148.6 | -151.6 | -155.3 | -6.7 | -3.7 |
| 20% | -153.1 | -156 | -155.8 | -2.7 | 0.2 |
| 900 | 0.001% | -144.9 | -147.9 | -166.9 | -22 | -19 |
| 0.03% | -148.6 | -151.6 | -167 | -18.4 | -15.4 |
| 20% | -153.1 | -156 | -167.6 | -14.5 | -11.6 |

Scenario 2: Within and beyond the 3 dB beamwidth

In the same way as scenario 1, but now considering the entire visible area at the satellite station, which represents half the size of the Earth, simulations with the space station beam centre at 5°, 20°, 45°, and 90° were performed and the following Figure presents the aggregate IMT (BS and UE) interference CDF towards the FSS space station (FSS uplink direction) receiver for macro urban and suburban IMT deployments.

Scenario 2 shows similar results to Scenario 1 as shown in Figure 8 and Figure 9. The FSS S/S short-term and long-term protection criteria are exceeded for elevation angles of 5° and 20°. In addition, the FSS long-term protection criteria (with apportionment) is exceeded for elevation angle of 45°

Figure 9



Table 10 below summarizes the achieved *I/N* values for the simulation cases shown above. The column labelled as “Exceedance” indicates the level of exceedance of the protection criteria with and without apportionment.

Table 10

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| FSS SS [degree] | Probability of time | *I/N* criteria [dB] | *I/N* criteria with apportionment [dB] | IMT - *I/N* result [dB] | Exceedance [dB] (without apportionment) | Exceedance [dB] (with apportionment) |
| 50 | 0,001% | -145 | -148 | -142.2 | 2.8 | 5.8 |
| 0,03% | -149 | -152 | -142.2 | 6.8 | 9.8 |
| 20% | -153 | -156 | -142.8 | 10.2 | 13.2 |
| 200 | 0,001% | -145 | -148 | -147.3 | -2.3 | 0.7 |
| 0,03% | -149 | -152 | -147.3 | 1.7 | 4.7 |
| 20% | -153 | -156 | -147.5 | 5.5 | 8.5 |
| 450 | 0,001% | -145 | -148 | -154.3 | -9.3 | -6.3 |
| 0,03% | -149 | -152 | -154.3 | -5.3 | -2.3 |
| 20% | -153 | -156 | -154.5 | -1.5 | 1.5 |
| 900 | 0,001% | -145 | -148 | -162.0 | -17.0 | -14.0 |
| 0,03% | -149 | -152 | -162.0 | -13.0 | -10.0 |
| 20% | -153 | -156 | -162.1 | -9.1 | -6.1 |

Scenario 3: Ls of -20 dB

Figure 10 shows the Scenario 2 aggregate interference but now the satellite antenna pattern parameter Ls set to -20 dB (refer to Figure 6 for antenna radiation patterns). Table 11 summarizes the achieved *I/N* values. Looking at the results it clear that a less selective radiation pattern increases the aggregate interference of IMT stations to the FSS S/S. The FSS S/S short-term and long-term protection criteria are exceeded for elevation angles of 5° and 20°. In addition to the Ls-30 dB case, the FSS short-term protection criteria for *I/N* = -6.0 dB (with apportionment) is exceeded for elevation angle of 45°. For this elevation angle the increase in interference is in the order of 3 dB compared to the Ls = -30 dB case.

Figure 10

A picture containing chart

Description automatically generated

Table 11

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| FSS SS [degree] | Probability of time | *I/N* criteria [dB] | *I/N* criteria with apportionment [dB] | IMT - *I/N* result [dB] | Exceedance [dB] (without apportionment) | Exceedance [dB] (with apportionment) |
| 50 | 0,001% | -145 | -148 | -142.93 | 2.07 | 5.07 |
| 0,03% | -149 | -152 | -142.93 | 6.07 | 9.07 |
| 20% | -153 | -156 | -143.38 | 9.62 | 12.62 |
| 200 | 0,001% | -145 | -148 | -145.37 | -0.37 | 2.63 |
| 0,03% | -149 | -152 | -145.37 | 3.63 | 6.63 |
| 20% | -153 | -156 | -145.51 | 7.49 | 10.49 |
| 450 | 0,001% | -145 | -148 | -151.27 | -6.27 | -3.27 |
| 0,03% | -149 | -152 | -151.27 | -2.27 | 0.73 |
| 20% | -153 | -156 | -151.38 | 1.62 | 4.62 |
| 900 | 0,001% | -145 | -148 | -157.40 | -12.40 | -9.40 |
| 0,03% | -149 | -152 | -157.40 | -8.40 | -5.40 |
| 20% | -153 | -156 | -157.42 | -4.42 | -1.42 |

Scenario 4: Ls of -20dB and down tilt analysis

Figure 11 shows the interference from IMT stations within and outside the satellite footprint, considering a satellite antenna pattern parameter Ls set to -20 dB (refer to Figure 6 for antenna radiation patterns). As a sensitivity analysis, no down tilt was considered in the IMT base stations. Table 12 summarizes the achieved *I/N* values. Looking at the results it clear that a less selective radiation pattern increases the aggregate interference of IMT stations to the FSS S/S. The FSS S/S short-term and long-term protection criteria are exceeded for elevation angles of 5° and 20°. In addition, the IMT BS down tilt has a significant impact on the interference. For that reason, either down tilt or emission limits towards of above the horizon must be specified in the case of an IMT identification.

Figure 11

A picture containing graphical user interface

Description automatically generated

Table 12

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| FSS SS [degree] | Probability of time | *I/N* criteria [dB] | I/N criteria with apportionment [dB] | IMT - *I/N* result [dB] |  | Exceedance [dB] (without apportionment) | Exceedance [dB] (with apportionment) | Increase in *I/N* compared to Scenario 2 |
| 5 | 0.001% | -145 | -148 | -141.79 |  | 3.21 | 6.21 | 0.383 |
| 0.03% | -149 | -152 | -141.79 |  | 7.21 | 10.21 | 0.383 |
| 20% | -153 | -156 | -142.17 |  | 10.83 | 13.83 | 0.622 |
| 20 | 0.001% | -145 | -148 | -144.50 |  | 0.50 | 3.50 | 2.81 |
| 0.03% | -149 | -152 | -144.50 |  | 4.50 | 7.50 | 2.81 |
| 20% | -153 | -156 | -144.60 |  | 8.40 | 11.40 | 2.92 |
| 45 | 0.001% | -145 | -148 | -149.92 |  | -4.92 | -1.92 | 4.423 |
| 0.03% | -149 | -152 | -149.92 |  | -0.92 | 2.08 | 4.423 |
| 20% | -153 | -156 | -149.99 |  | 3.01 | 6.01 | 4.559 |
| 90 | 0.001% | -145 | -148 | -154.94 |  | -9.94 | -6.94 | 7.103 |
| 0.03% | -149 | -152 | -154.94 |  | -5.94 | -2.94 | 7.103 |
| 20% | -153 | -156 | -154.97 |  | -1.97 | 1.03 | 7.179 |

Scenario 5: Within and beyond the 3 dB beamwidth with sea/ocean correction

Same as scenario 2, but a correction factor of 33% was applied to the satellite line of sight area that is beyond the 3 dB beamwidth to account for actual land area. Simulations with the space station at 0°, 5°, 20°, 45°, and 90° center of beam elevation angles were performed and Figure 12 presents the aggregate IMT (BS and UE) interference CDF towards the FSS space station receiver (FSS uplink direction) for macro urban and suburban IMT deployments.

Scenario 5 shows similar results for elevation angles below 20º. This is because the satellite antenna gain towards the IMTs stations outside the spot beam is very low for lower elevation angles and their impact on total interference is very attenuated (refer to Figure 5 and Figure 6). On the other hand, for elevation angles above 45º the impact of IMT stations outside the spot beam on overall interference is higher because they have less attenuation from the satellite antenna side lobes.

Table 13 below summarizes the achieved *I/N* values for the simulation scenario 5. The column labelled as “Exceedance” indicates the level of exceedance of the protection criteria with and without apportionment.

Figure 12

Graphical user interface

Description automatically generated

Table 13

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| FSS SS [degree] | Probability of time | *I/N* criteria [dB] | *I/N* criteria with apportionment [dB] | IMT - *I/N* result [dB] | Exceedance [dB] (without apportionment) | Exceedance [dB] (with apportionment) |
| 50 | 0,001% | -145 | -148 | -142.6 | 2.39 | 5.39 |
| 0,03% | -149 | -152 | -142.6 | 6.39 | 9.39 |
| 20% | -153 | -156 | -142.9 | 10.06 | 13.06 |
| 200 | 0,001% | -145 | -148 | -147.5 | -2.51 | 0.49 |
| 0,03% | -149 | -152 | -147.5 | 1.49 | 4.49 |
| 20% | -153 | -156 | -146.6 | 5.37 | 8.37 |
| 450 | 0,001% | -145 | -148 | -154.9 | -9.98 | -6.98 |
| 0,03% | -149 | -152 | -154.9 | -5.98 | -2.98 |
| 20% | -153 | -156 | -155.1 | -2.06 | 0.94 |
| 900 | 0,001% | -145 | -148 | -166.1 | -21.05 | -18.05 |
| 0,03% | -149 | -152 | -166.1 | -17.05 | -14.05 |
| 20% | -153 | -156 | -166.0 | -13.02 | -10.02 |

### 2.3.4 Summary and analysis of the results of Study C

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

For all studied scenarios, the results show that without apportionment aggregate interference from IMT stations into FSS space stations exceeds the two short-term criteria and the long-term criterion in some cases. Including apportionment, the results show that aggregate interference from IMT stations into FSS space stations exceeds both short-term criteria for FSS beams at elevation angles below 20o and the long-term protection criterion is exceeded at elevations below 45 degrees in some cases and below 20 degrees in all cases. The long-term criterion is exceeded at any elevation angle in one of the studied cases. This analysis used a conservative approach, i.e. underestimates the IMT interference, considering that the transmit power of the IMT base station serves only three UEs at all times and considering cases of IMT deployment with a fixed mechanical down tilt for all base stations.

# 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.]

[In total, 17 studies have been conducted and are contained in this Report. The studies have used common assumptions for many of the parameters, but diverge in the assumptions for others, including:

1. IMT deployment details (e.g. number of base stations, deployment in rural areas)

2. IMT deployment locations (e.g. consideration of all visible IMT stations or IMT stations only within the 3 dB contour)

3. FSS satellite characteristics (e.g. location of satellite, beam pointing, whether to adjust the characteristics provided by the expert group, WP 4A, and whether apportionment of the interference criteria is applied)

4. Clutter model parameterisation and how to apply to IMT base stations in different environments.

There is a range of results, with some studies showing interference below the protection criterion and others showing interference above the criterion. Table 3-1 summarises the key differences in assumptions.

The FSS protection criteria (without apportionment) in this band are, for the long term, -10.5 dB *I/N* (exceeded up to 20% of time) and, for the short term, -6 dB *I/N* exceeded 0.03% and -2.33 dB *I/N* exceeded 0.001% of time, location or probability, for example, for Monte Carlo simulations, the percentage of probability can be expressed in terms of a number of snapshots.

There are in total of 17 studies assessing the interference from IMT stations into FSS space stations in a geostationary orbit with the WP 4A specified satellite carriers as in Doc 5D/734, covering global beam, hemi beam, zone beam and spot beam.

XX among the total of 17 studies provided also results for both long term and short term interference; all have shown that long term interference is more critical than short term interference. The results for long term criterion are used for summary and comparison of all the studies.

The studies have been carried out with various methodologies, some statistical and some static / part statistical. The differences in the methodologies and assumptions that have been identified as influencing the results are the FSS boresight elevation angle of the satellite when viewed from the earth, the density of base stations and their deployment environment, the simulation area and satellite footprint, the realistic modelling of the FSS receiver antenna gain, the use of clutter loss and the apportionment considerations. The combination of these assumptions can cause large variation in the results.]

Table 3-1

Summary of key differences in assumptions among the studies

**\*\* Beam designators: G: Global, H: Hemispherical (Hemi), Z: Zone, S: Spot**

| **Study** | Source | Deployment density (Ra/Rb) | Rural Scenario  (Optional) | BS deployment area | Removal of "low populated areas" | Clutter model | Satellite carriers \*\* | Adjustment to FSS parameters/  TIG Scaling Factor | Apportionment of FSS criterion | Study Results  (excess interference/Interference Margin/i/N Levels with respect to the criterion, dB) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | [Examples | Rb=1%  Ra\_Suburban=x%  Ra\_Urban=y% | Yes/No | Within 3dB contour / Full visibility/Including/Excluding Oceans | Yes / No | Annex 6, urban and suburban / Full clutter loss applied to all BSs below rooftop | #7(G); #8(Z) (noise temp=xxxK) | Yes / No | Yes / No | (G): -aa to –bb (Z): -cc to –dd |
| A | (CME & al) |  |  |  |  |  |  |  |  |  |
| -B | J |  |  |  |  |  |  |  |  |  |
| C | KSA | Rb=5% inside 3 dB footprint, 3% outside.  Ra\_Suburban=20%  Ra\_Urban=45% | No | Within 3dB contour and Full visibility | No | Annex 6 to Working Party 3K Chairman’s Report, Document 3K/178 | #4 | No | Yes | (S): -14.5 dB to 8.7 dB  (H): -9.1 dB to 10.1 dB |
| D | CHN |  |  |  |  |  |  |  |  |  |
| E | BEN & al) |  |  |  |  |  |  |  |  |  |
| F | IAFI |  |  |  |  |  |  |  |  |  |
| G | GSOA |  |  |  |  |  |  |  |  |  |
| H | Ericsson |  |  |  |  |  |  |  |  |  |
| I | F |  |  |  |  |  |  |  |  |  |
| J | RUS |  |  |  |  |  |  |  |  |  |
| K | Nokia |  |  |  |  |  |  |  |  |  |
| L | UAE et al |  |  |  |  |  |  |  |  |  |
| M | [5D/1215](https://www.itu.int/md/R19-WP5D-C-1215/en) (Reliance Jio & al) |  |  |  |  |  |  |  |  |  |
| N | [5D/1224](https://www.itu.int/md/R19-WP5D-C-1224/en)  (MLI & al) |  |  |  |  |  |  |  |  |  |
| O | [5D/1244](https://www.itu.int/md/R19-WP5D-C-1244/en) (RUS) |  |  |  |  |  |  |  |  |  |
| P | [5D/1299](https://www.itu.int/md/R19-WP5D-C-1299/en)  (BOT & al) |  |  |  |  |  |  |  |  |  |
| Q | [5D/1322](https://www.itu.int/md/R19-WP5D-C-1322/en) (Huawei T.S.) |  |  |  |  |  |  |  |  |  |
| R | [5D/1323](https://www.itu.int/md/R19-WP5D-C-1323/en) (SEN) |  |  |  |  |  |  |  |  |  |

## 3.1 Interference into FSS space stations

### 3.1.1 Interference into FSS space stations – baseline cases

[Global beam

Among the 13 studies assessing the global beam (carrier #1, #7 and #12 in Doc 5D/734), 10 studies (Study B, D, H, I, K for carrier#1; Study A, J for carrier#7; Study L, M, R for carrier#12) found long-term *I/N* values in the range XX dB to XX dB (assuming Ra1Rb1/Ra1Rb3 or Ra2Rb1) that are below the protection criterion using full statistical Monte Carlo simulation and 3K/178 and/or P.2108 clutter loss model, assessing the interference from IMT deployments within 3dB contour or entire satellite visible area with and w/o rural deployment; 3 other studies (Study E, F, G for carrier#12) found long-term *I/N* values in the range -2 dB to 1.5 dB (assuming Ra1Rb1) and in the range 6.5 dB to 7.5 dB (assuming Ra2Rb2) that are above the protection criterion using part statistical Monte Carlo simulation and P.2108 clutter loss model and assessing the interference from the IMT deployment within the entire satellite visible area including rural deployment with density of 0.003 BS per square km and assuming 3dB protection criterion apportionment.

Hemi beam

Among the 7 studies assessing the hemi beam (carrier #2 in Doc [5D/734](https://www.itu.int/md/R19-WP5D-C-0734/en)), 4 studies (Study B, R, H, M) found long-term *I/N* values in the range XX dB to XX dB (assuming Ra1Rb1) that are below the protection criterion using the full statistical Monte Carlo simulation and 3K/178 and/or P.2108 clutter loss model assessing the interference from IMT deployments within 3dB contour or entire satellite visible area; 3 studies (E, F, G) found long-term *I/N* values in the range XX dB to XX dB (assuming Ra1Rb1) and in the range XX dB to XX dB (assuming Ra2Rb2) that are above the protection criterion using part statistical Monte Carlo simulation and P.2108 clutter loss model and assessing the interference from the IMT deployment within the entire satellite visible area including rural deployment with density of 0.003 BS per sq km and assuming 3dB protection criterion apportionment.

Zone beam

Among the 5 studies assessing the zone beam (carrier #3 and #8 in Doc 5D/734), all studies (Study B, M for carrier#3; Study A, H, J for carrier#8) found that long-term *I/N* values in the range XX dB to XX dB that are below the protection criterion; no study found that long-term *I/N* value is above the protection criterion.

Spot beam

Among the 6 studies assessing the spot beam (carrier #4 and #12 in Doc [5D/734](https://www.itu.int/md/R19-WP5D-C-0734/en)), 3 studies (Study M, Q for carrier#4; Study L for carrier#12) found long-term *I/N* values in the range XX dB to XX dB (assuming Ra1Rb1) that are below the protection criterion using the full statistical Monte Carlo simulation and 3K/178 and/or P.2108 clutter loss model assessing the interference from IMT deployments within entire satellite visible area. 2 studies (Study G, F for carrier#4) found long-term *I/N* values in the range XX dB to XX dB (assuming Ra1Rb1) and in the range XX dB to XX dB (assuming Ra2Rb2) that are above the protection criterion using part statistical Monte Carlo simulation and P.2108 clutter loss model and assessing the interference from the IMT deployment within the entire satellite visible area including rural deployment with density of 0.003 BS per square km and assuming 3dB protection criterion apportionment. 1 study (Study C for carrier#4) found long-term *I/N* values in the range from XX toXX dB (assuming Ra2Rb2) depending on elevation angle using full statistical Monte Carlo simulation and 3K/178 clutter loss model assessing the interference from IMT deployments within 3dB contour and assuming 3dB interference apportionment, and similarly found long-term *I/N* values in the range from XX to XX dB assuming Ra2Rb2 for IMT deployment within and beyond the 3 dB contour.

The results summarized above do not take into account any TIG adjustment factors, which are needed to ensure that the total integrated gain of satellite antenna gain pattern is less than 0 dBi and consistent with the antenna efficiency. XX among the total of 17 studies considered TIG adjustment factor and accordingly derived the long-term *I/N* values in the range from XX dB to XX dB for global beam, from XX dB to XX dB for hemi beam, from XX dB to XX dB for zone beam and from XX dB to XX dB for spot beam.

### 3.1.2 Interference into FSS space stations – non-baseline cases

9 studies evaluated the interference to 13 specific satellite RR AP**30B** allotments other than those provided by the ITU-R WP 4A in Document 5D/734. 7 studies (Study A, J, M, N, P, Q, R) found long-term *I/N* values in the range of XX dB to XX dB that are below the protection criterion and 2 studies (Study E, F) found long-term *I/N* values in the range of XX dB to XX dB that are above the protection criterion .

One study (Study H) considered a sub-array configuration for the IMT base station antenna. Comparison of coexistence between the baseline single element and the sub-array model indicates that while there is a reduction in margin in some cases, in other cases the margin increases indicating is not significantly different between the single element configuration and the sub array configuration. Specifically, for the cases where the footprint area corresponding to low elevation angles are large, the sub-array configuration provides additional margin as compared to the baseline single element case.

One study (Study O) examined the Eb/No+Io criterion for the global beam carrier #7 and the zone beam carrier #8 taking into account the wanted signal, modulation, and code rate. The degradation of the signal-to-noise ratio of a wanted link is less than 0.1 dB and the bit error rate (BER) of different links is less than 10-6 for QPSK modulation. Thus, it can be concluded that the deployment of IMT-2020 systems will not have any negative impact on the real performance of the FSS (Earth-to-space) network.

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1. See [Document 5D/734](https://www.itu.int/md/R19-WP5D-C-0734/en). [↑](#footnote-ref-1)