Radiocommunication Study Groups

Source: Annexure-4.38 of 50th WP-5D Chairman Report

Subject: WRC-27 Agenda 1.13 (DC-MSS-IMT)

Document 5D/xxx-E
20 January 2026
English only

IAFI[1]

FURTHER UPDATES TO WORKING DOCUMENT ON STUDIES FOR THE REGULATORY CONSIDERATIONS TO PROTECT TERRESTRIAL IMT SYSTEMS UNDER WRC-27 AGENDA ITEM 1.13

1 Introduction:

During the 50th meeting of Working Party 5D (WP 5D), the "Working document regarding studies on the regulatory considerations to protect terrestrial IMT systems under WRC-27 Agenda Item 1.13" was further advanced. This document consolidated the text from Annex 4.6 to the Chair's Report of the 49th WP-5D meeting, along with 13 input contributions received during the session. The document currently captures preliminary technical characteristics and identifies potential interference scenarios between the Direct-to-Cell Mobile-Satellite Service (DC-MSS) and terrestrial IMT networks. Specifically, it focuses on the protection of IMT Base Stations (BS) and User Equipment (UE) from satellite downlink emissions (Scenario B2).

2. Proposal:

IAFI hereby submits further updates to this Working Document to reflect recent developments and ensure technical clarity. The proposed modifications are primarily focused on:

- Section 1 (Introduction): Refining the scope to better align with the progress of sharing studies.
- Section 2.1 (ITU-R Relevant Materials): Updating the list of References, Recommendations and Reports to include the latest versions of Rec. ITU-R M.1036 and Rec. ITU-R M.2101.
- Section-3

IAFI proposes that WP 5D should consider these updates during the current meeting to further improvement in the Working Document. The proposed changes are highlighted in Grey

Attachment: 1

---

[1] IAFI is a sector member of ITU-R, ITU-T and ITU-D

Attachment

Annex 4.38 to Working Party 5D Chair's Report

Formatted: Centered

WORKING DOCUMENT ON STUDIES FOR THE REGULATORY CONSIDERATIONS TO PROTECT TERRESTRIAL IMT SYSTEMSUNDER WRC-27 AGENDA ITEM 1.13

NOTE: This document was not reviewed and not agreed, therefore its inclusion is for information purposes only

Note: This working document contains a compilation of contributions on received at the February, June and October 2025 WP 5D meetings containing studies on the regulatory examples to address the protection of terrestrial IMT systems relevant to WRC-27 studies. These studies have not been fully reviewed and are considered as preliminary and not agreed by WP 5D. It is expected that once completed, WP 5D will provide the final results of these studies and any regulatory considerations to WP 4C to be included directly into the draft CPM text for agenda item 1.13. Therefore, it is attached to the Chair's Report for information.

Note: The structure of this Working document was changed without discussion of such changes in the Sub-working group.

Note: This Document is capturing the text from documents Annex 4.6 to WP 5D Chair's Report, 5D/823 (CHN), 5D/824(CHN), 5D/825(CHN), 5D/827(CHN), 5D/844 (RUS), 5D/849 (IND),5D/885 (AUS), 5D/897 (KOR), 5D/898 (KOR), 5D/914 (TON), 5D/927 (Multi Country), 5D/941 (F), 5D/968 (Ericsson)

1 Introduction

This Report presents technical and regulatory studies aimed at ensuring the protection of terrestrial International Mobile Telecommunications (IMT) systems, from potential interference caused by Direct-to-Cell Mobile-Satellite Service (DC-MSS-IMT) operations under WRC-27 Agenda Item (AI) 1.13. Pursuant to Resolution 253 (WRC-23), the scope of AI - 1.13 involves studies on possible new allocations to the Mobile-Satellite Service (MSS) for the implementation of Direct-to-Cell (DC-MSS-IMT) in various frequency bands between 694/698 MHz and 2.7 GHz. The study process is a collaborative effort within the ITU-R:

While Working Party 4C (WP 4C) - is the lead group responsible for conducting sharing and compatibility studies regarding the MSS allocations, utilizing technical characteristics of DC-MSS-IMT systems, Working Party 5D (WP 5D) - acts as the contributing group, providing the necessary technical and operational characteristics of terrestrial IMT systems. These are based on the frequency arrangements established in the most recent version of Recommendation ITU-R M.1036.

Formatted: No bullets or numbering

The primary objective is to establish regulatory measures such as Power Flux Density (pfd) or Equivalent Power Flux Density (epfd) limits, to ensure that the introduction of DC-MSS-IMT does not cause harmful interference to, nor constrain the future development of, existing terrestrial IMT networks.

Formatted: Justified

Formatted: English (United States)

2 Technical and operational aspects

2.1 ITU-R Relevant materials

Following WRC Resolutions, ITU-R Recommendations and Reports provide the parameters, methodologies, and protection criteria necessary to conduct the sharing and compatibility studies between satellite and terrestrial components.

- **Resolution 253 (WRC-23) -** The primary legal basis for the study. It "resolves to invite the ITU-R" to conduct sharing and compatibility studies for the frequency range between 694/698 MHz and 2.7 GHz.
- **Recommendation ITU-R M.1036 -** The most critical document for WP 5D. It defines the Frequency Arrangements (FDD and TDD) for terrestrial IMT. The DC-MSS-IMT studies must align with the arrangements, as specified in the latest version (M.1036-7) to ensure coexistence.
- **Recommendation ITU-R M.2101 - :** Provides the methodology for modelling and simulation of IMT networks, guide for WP 5D to simulate interference scenarios.
- **Recommendation ITU-R S.1503 -** Provides the functional description for software tools used to determine the **epfd (equivalent power flux-density)** produced by non-GSO satellite systems. This is vital for calculating the aggregate interference from a satellite constellation into terrestrial base stations.
- **Recommendation ITU-R M.1635 -** General methodology for assessing the potential for interference between IMT and other services.
- **Recommendation ITU-R M.2109 -** Specifically used for sharing studies between IMT and satellite networks (FSS), providing a template for interference calculations.
- **Report ITU-R M.2292 -** Contains the detailed Technical Characteristics of terrestrial IMT-Advanced systems (e.g., antenna heights, noise figures, and sectorization) used for interference analysis.

~~…~~

2.2 Technical and operational characteristics

WP 5D/	Source	Services/Applications/Models
77 (Annex 4.8)	45th WP 5D	International Mobile Telecommunications (IMT)
~~TBD~~379	WP 4C	DC-MSS-IMT

Note 1: Working Party 4C is expected to provide the DC-MSS-IMT technical and operational parameters to WP 5D by its next meeting in October 2025. Studies should be updated to reflect this DC-MSS-IMT information.

Note 2: In addition to the IMT UE baseline parameters provided in Document 5D/792 Annex 4.32, additional analyses can be conducted using different values as below;

Parameter	***Value***
Antenna g`+ain	*0 dBi**
Body Loss	*0 dB*

**In some cases, 5 dBi antenna gain and 6dB noise figure can be considered.*

Formatted: Highlight

Formatted: Line spacing: Multiple 1.08 li, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: List Paragraph,Bulleted Para,CAB - List Bullet,CV text,Dot pt,F5 List Paragraph,FooterText,L,List Paragraph11,List Paragraph111,List Paragraph2,Medium Grid 1 - Accent 21,NFP GP Bulleted List,Recommendation,Table text,numbered,列出段落,列出段落1, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: Line spacing: Multiple 1.08 li, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: List Paragraph,Bulleted Para,CAB - List Bullet,CV text,Dot pt,F5 List Paragraph,FooterText,L,List Paragraph11,List Paragraph111,List Paragraph2,Medium Grid 1 - Accent 21,NFP GP Bulleted List,Recommendation,Table text,numbered,列出段落,列出段落1, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: List Paragraph,Bulleted Para,CAB - List Bullet,CV text,Dot pt,F5 List Paragraph,FooterText,L,List Paragraph11,List Paragraph111,List Paragraph2,Medium Grid 1 - Accent 21,NFP GP Bulleted List,Recommendation,Table text,numbered,列出段落,列出段落1, Left, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: Font: English (United Kingdom), Superscript

Formatted: English (United States)

2.3 IMT bands to be protected

[All IMT bands to be considered for sharing studies to be protected from DC-MSS-IMT]

Formatted: Pattern: Clear (Accent 3)

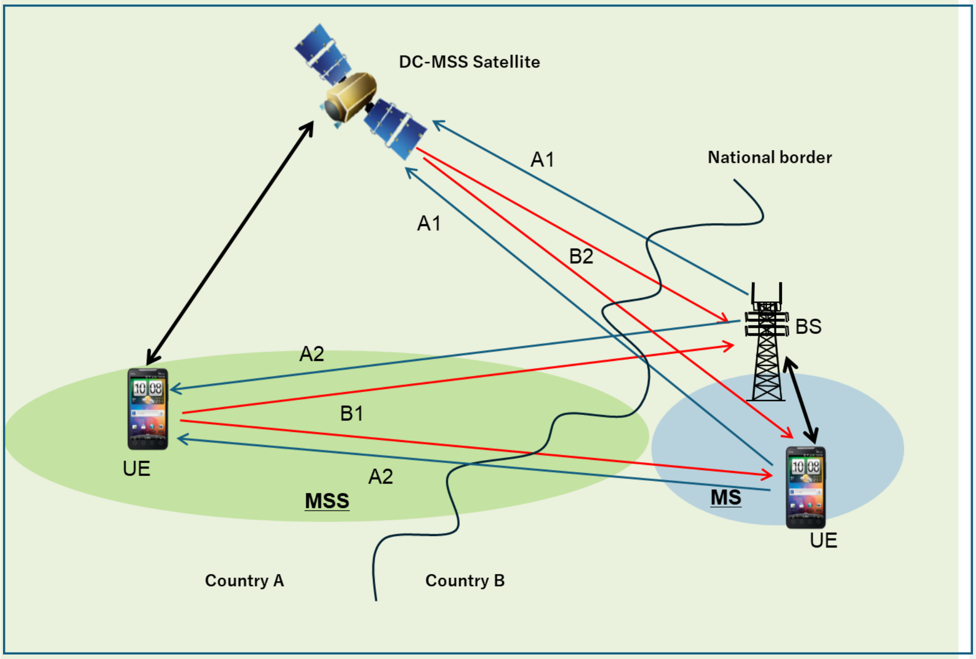
3 Potential interference scenarios

[Document 5D/520 (J)]

The possible interference path directions, which are categorized as A1, A2, B1 and B2, are shown in the figure below. It should be noted that the categorized interference path directions are of indicative nature and not all the interference path directions are to be studied under the agenda item 1.13.

FIGURE 1

Concept of possible interference path directions for DC-MSS-IMT operation



Pursuant to the Resolution 253 (WRC-23), DC-MSS-IMT satellite stations shall not claim protection from stations operating in the mobile service, so no study is needed (see A1 above), Similarly, ~~U~~user equipments connecting to DC-MSS-IMT satellite stations shall not claim protection from stations operating in the mobile service, so no study is needed (see A2 above).

Aspects related to studies in WP 5D for WRC-27 agenda item 1.13, for the scenarios in Figure 1 for protection of terrestrial component of IMT from DC-MSS-IMT using the same frequency bands are as follows:

B1) Considering that the same technical parameters apply to UEs of both DC-MSS-IMT and IMT, so no study is needed since the interference situation is the same as that between existing terrestrial IMT networks in neighbouring countries.

Formatted: English (United States)

IAFI suggestion: for more clarity, above text can be replaced by -

Regarding **Scenario B1** (interference from DC-MSS-IMT UE to terrestrial IMT receivers), it is considered that if the technical and operational parameters of the DC-MSS-IMT UE are identical to those of a conventional terrestrial IMT UE, the resulting interference environment would be equivalent to that currently existing between terrestrial IMT networks in neighboring countries. Consequently, no additional sharing studies for Scenario B1 are required at this stage, provided that the DC-MSS-IMT UEs comply with existing terrestrial IMT technical specifications.

[Note: The paragraph below needs to be confirmed.]

No additional regulatory/technical measure would be required in the MSS uplink (Earth-to-space) direction for the protection of terrestrial IMT network.

IAFI suggestion: for more clarity, above text can be replaced by -

With respect to the **MSS uplink (Earth-to-space) direction**, considering that the technical characteristics and power levels of DC-MSS-IMT user equipment are expected to be aligned with those of terrestrial IMT UEs, no additional regulatory or technical measures, beyond those already applicable to the mobile service, are required for the protection of terrestrial IMT networks. Interference from DC-MSS-IMT UEs into terrestrial IMT base stations (Scenario B1) is managed through existing cross-border coordination frameworks

In ~~scenario~~ B2, there are three ~~two~~ patterns depending on whether the frequency arrangement ~~(FDD)~~ of the terrestrial IMT in the neighbouring country with respect to the ~~is the same as the~~ DC-MSS-IMT.

B2-1) Study is needed to protect UE receivers in neighbouring countries

(The case that satellite transmission frequency of DC-MSS overlaps with the base station transmission frequency of the terrestrial IMT frequency arrangement in the neighbouring country.)

B2-2) Study is needed to protect IMT BS receivers in neighbouring countries

(The case that satellite transmission frequency of DC-MSS-IMT overlaps with the terrestrial IMT BS receiving ~~user equipment~~ frequency ~~of the terrestrial IMT frequency arrangement~~ in the neighbouring country

and

The case DC-MSS-IMT satellite stations unwanted emissions is within the terrestrial IMT BS receiving frequency in the neighbouring country~~.~~)

B2-3) Study is needed to protect both UE and BS receivers in neighbouring countries

(The case that satellite transmission frequency of DC-MSS-IMT overlaps with both the user equipment and base station transmission frequency of the terrestrial IMT frequency arrangement in the neighbouring country due to TDD operation.

And

The case DC-MSS-IMT satellite stations unwanted emissions is within the terrestrial IMT BS & UE receiving frequency in the neighbouring country)

The analysis of those interference cases is summarized in the table below.

Formatted: Pattern: Clear (Accent 3)

Formatted: Not Highlight

Commented [SA1]: While we understand this, we propose the inclusion of a further diagram to support this text for clarity. The text alone may be insufficient.

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: English (United States)

TABLE 1

Interference path directions between DC-MSS-IMT and terrestrial components of IMT

	From	**To**	**Conclusion**
A1	Terrestrial IMT base station or user equipment	DC-MSS-IMT space station	No study is needed
A2	Terrestrial IMT base station or user equipment	DC-MSS-IMT user equipment	No study is needed
B1	DC-MSS-IMT user equipment	Terrestrial IMT base station or user equipment	No study is needed
B2	DC-MSS-IMT space station	Terrestrial IMT user equipment and/or~~or~~ base station	Study is needed

As mentioned above, it is clear that B2-1), ~~and~~ B2-2) and B2-3) should be considered in the ~~sharing study~~ studies ~~between~~ to protect the terrestrial component of IMT ~~and DC-MSS-IMT~~.

4 Methodologies to protect terrestrial IMT networks from downlink of DC-MSS-IMT

[Editor's Note: Several proposed methodologies are presented in this section. Further discussions are needed to reduce/consolidate these methods.]

[Annex 4.15 to WP 5D Chair's Report]

4.1 Possible Approaches

Note: Any action relating to implementation of further resolves of the Resolution 253 (WRC-23) is pending until the time that necessary information on the functionality of DC-MSS-IMT is formally provided by WP 4C. That also requires to have clear indication of modelling and potential interference management techniques of DC-MSS-IMT systems that will be provided by WP4C.

There are multiple options to define the pfd limit which need further consideration on potential aggregate impact:

~~[~~1) Pfd per satellite

Editor's note: Concerns were raised by a number of administrations regarding the applicability of PFD per satellite to define the possible measures for protection of terrestrial IMT systems. However, there was no agreement on the deletion of this option. Therefore, it will be retained in square brackets until the time that information on the technical characteristics of DC-MSS-IMT systems/networks will be provided by WP 4C. By considering multibeam per satellite the term PFD per satellite or PFD per satellite cell will be considered.

Defining pfd per satellite requires to assess the aggregation factor, based on typical MSS/D2D deployment. [It has to be noted that for MSS/D2D, a given area can only be covered by one spot in a given block of spectrum, thus making easier to assess the aggregation factor in particular for high arrival angles.]

Defining pfd per satellite will make easier for the BR and the administrations to check/control the conformity. In addition, it avoids having to make assumptions on the number of systems which could be actively transmitting in visibility of the border (i.e. avoiding to assume the aggregation factor over different systems).

Formatted Table

Formatted: Font: 10 pt, Highlight

Formatted: Font: 10 pt, Highlight

Formatted: Font: 14 pt, Bold, Pattern: Clear (Accent 3)

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Justified

Formatted: Not Highlight

Formatted: Font: Italic

Formatted: Justified

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Pattern: Clear (Accent 6)

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: English (United States)

Formatted: English (United States)

[However, ~~T~~the pfd limit per satellite ~~limits~~ is not suitable for the DC-MSS-IMT system application requirement related to the DC-MSS-IMT satellite station unwanted emissions need further consideration]

~~.~~]

2~~a~~) Aggregate pfd per system ~~when protecting UEs~~

From a technical point of view, ~~potential BS and UE victims~~ terrestrial IMT receivers can potentially receive interference from multiple satellites within one DC-MSS-IMT system. ~~Consequently,~~ starting from an agreed IMT protection criterion ~~and IMT receiver characteristics, the maximum aggregate pfd value to avoid harmful interference to IMT UE is defined (this value is the aggregate pfd limit for multiple systems when protecting UEs which is expressed in (3a)). Using that value and taking into account a multi-system aggregation factor~~, it is possible to define an aggregate pfd ~~mask~~ limit that each potential DC-MSS-IMT system will have to respect. The aggregate pfd level is ~~then~~ correlated to the way that the considered DC-MSS-IMT systems are operated. Consequently, when conducting sharing studies, it is essential to take into account accurate modelling of DC-MSS-IMT operations, as well as studying options of potential interference management techniques (pending conclusions of the sharing studies) that may be used in operations. ~~Finally, with respect to the way to model aggregate pfd, in the case of the UEs, the pfd equation is equivalent to the linearly adding pfd contributions, i.e. aggregate pfd. With respect to the protection of terrestrial IMT BS, the epfd equation would be equivalent to the epfd formula used in ArticleRR No. **22.5C.1**.~~

*Comments: 1. For the second sentence, we prefer the original wording, because this Approach is the aggregate pfd **per system**, but not **for multiple system** that is different and is included the Approach in 3);*

2. For the word "mask" or "limit", we prefer the word "level" to keep consistent;

3. We agree to reinstate the previously deleted last sentence with some modifications, noting this section relates to both terrestrial IMT UE and BS.

~~2b) *epfd* per system when protecting base stations~~

~~In RR, epfd limits are used to protect GSO satellite systems and Radio Astronomy receivers from the aggregate interference due to non-GSO satellite constellations when victims have directional antennas.~~

~~Starting from the IMT protection criterion and IMT BS receiver characteristics, the maximum aggregate epfd value to avoid harmful interference to IMT BE is defined (this value is the aggregate epfd limit for multiple systems when protecting BSs which is expressed in (3b)). Using aggregate epfd limits and considering a multi-system aggregation factor, epfd per system can be defined.~~

Comments: Because of the similar reason, we propose to delete the proposed new subsection 2b).

~~2b) Aggregate pfd per system when protecting base stations~~

~~Epfd was used in RR to protect GSO satellite systems and Radio Astronomy receivers from the aggregate interference due to non-GSO satellite constellations when victims have directional antennas. Aggregate epfd could be used to protect IMT base stations in case of potential aggregate interference from multiple DC-MSS-IMT systems.~~

3~~a~~) Aggregate pfd for multiple systems ~~when protecting UEs~~

Under some ~~special cases~~ specific scenarios, terrestrial IMT receivers can potentially receive interference from multiple DC-MSS-IMT systems operating in the same frequency bands. In such situations, the protection of IMT receivers may involve the consideration of an aggregate pfd level

Formatted: (Asian) Japanese, Not Expanded by / Condensed by

Formatted: (Asian) Japanese, Not Expanded by / Condensed by

Formatted: (Asian) Japanese, Not Expanded by / Condensed by

Formatted: Not Expanded by / Condensed by

Commented [SA2]: This draws a conclusion which conflicts the editor's note. We recommend deleting it or include a note in the editor's note that some administrations share this preliminary view.

Formatted: Not Expanded by / Condensed by

Formatted: Highlight

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Pattern: Clear (Accent 6)

Formatted: Font: Bold

Formatted: Font: Bold

Formatted: Font: Times New Roman, 12 pt, Italic, (Asian) Japanese, Pattern: Clear

Formatted: Highlight

Formatted: Highlight

Formatted: Pattern: Clear (Accent 6)

Formatted: Space After: 6 pt

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 4)

Formatted: English (United States)

~~should then be taken into account for the protection of terrestrial IMT UE accordingly~~ or other interference-management techniques, as may be determined by the results of the sharing studies. ~~With respect to the protection of terrestrial IMT BS, the epfd equation would be equivalent to the epfd formula used in RR No. **22.5C.1**~~.

AST Comments:

The intent of this revision is to avoid implying that consideration of aggregate PFD levels is mandatory in all cases. Depending on the operational and regulatory context, other interference-management techniques may provide equivalent or better protection for terrestrial IMT systems. The proposed text maintains flexibility and aligns with previous discussions that emphasize evaluating different mitigation options based on the outcomes of the sharing studies.

[3b) **A~~Epfd per system and a~~ggregate epfd for multiple systems when protecting base stations**

~~Epfd was used in RR to protect GSO satellite systems and Radio Astronomy receivers from the aggregate interference due to non-GSO satellite constellations when victims have directional antennas. The idea of the epfd builds on the concept of pfd and considers the aggregate interference due to all contributing transmitting stations within a satellite constellation (epfd is a limit per constellation).~~

Aggregate epfd could be used to protect IMT base stations in case of potential aggregate interference from multiple DC-MSS-IMT systems operating in the same frequency bands.

Epfd and aggregate epfd are metrics that could be used to protect IMT from satellite networks considering the aggregate interference from various satellites within a satellite system/constellation and potential aggregate interference from multiple DC-MSS-IMT systems.

These limits are defined only based on IMT protection criteria and IMT characteristics and different DC-MSS-IMT systems would need to ~~make sure~~ the limits are met ~~however their systems are or whatever interference mitigation techniques they use~~.]

Comments: We propose to suppress the above words of 3b) because no need to repeat.

AST Comments:

The intent of this revision is to strengthen the precision of the text by clarifying that the situation refers to DC-MSS-IMT systems *operating in the same frequency bands*, and to frame EPFD as a possible analytical tool rather than a compulsory regulatory metric. We also propose to strike out the last sentence, as the preceding text already captures the necessary context and objectives without repetition.

Further notes:

Views expressed about the potential aggregate interference from multiple DC-MSS-IMT systems:

– It has to be validated in terms of its applicability and likelihood. Working Party 5D welcomes studies at upcoming meetings.

~~– Is not of global nature depending on the BS location and orbital parameters of the constellation, the number of visible satellites contributing to the interference will vary, and also potentially corresponds to niche cases, e.g. small landlocked countries.~~

4.1.1 ~~Issue of~~ limits compliance verification

Currently, there are several options with respect to ensuring compliance with applicable ~~aggregate~~ limits for protection of terrestrial IMT:

Formatted: English (United States)

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 6)

Formatted: Highlight

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 6)

Formatted: Pattern: Clear (Accent 6)

Formatted: English (United States)

Formatted: Pattern: Clear (Accent 4)

Formatted: Highlight

Formatted: Highlight

Formatted: English (United States)

- An ITU verification methodology is needed to determine the conformity of DC-MSS-IMT systems with regulatory measures for protection of terrestrial IMT.
- Verification by field measurement may be performed.
- No ITU verification methodology is needed in order to verify compliance of a system with aggregate limits. Administrations who submit the envisaged new DC-MSS-IMT filings will commit to respect the limits

[Editor's note: views were expressed that~~GSMA:~~ ~~i~~It is important to have a suitable verification mechanism and associated compliance process that can work in practice for protection of terrestrial IMT. Therefore, we propose to delete the text above that no verification is needed]~~.~~

~~and that will suffice~~

~~A methodology is needed~~

4.2 Equation

Comment: We propose merging this section with section 4.1 and adding the precise equations for different regulatory measures (pfd per satellite, aggregate pfd, and epfd) in appropriate places or having it as a separate Annex.

4.2.1 PFD equation

Document 5D/322 (D), Document 5D/378 (F), Documents 5D/533 (Multi MNOs) & 5D/775 (Orange), 5D/885 (AUS)

Comment: As we explained in section 4.1, we propose adding the precise equations under different regulatory options in section 4.1.

When developing a regulatory/technical measure to protect terrestrial IMT system, a pfd baseline limit should first be derived using:

~~The following formula was used to calculate the pfd levels in dB (W/ (m² · MHz)):~~

$$pfd(\theta) = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + \mathrm{L} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right)$$

where:

k: Boltzmann's constant ($1.380649 \times 10^{-23}\ J/K$)

T: receiver noise temperature in K

B: reference bandwidth (1 MHz)

NF: receiver noise figure in dB

I/N: protection criteria in dB

$G_r(\theta)$: effective antenna gain in dBi of the receiver antenna in the direction of the interferer

θ: is the antenna off-axis angle (°) towards the direction of the interferer~~the elevation angle~~

L: Receiver antenna feeder loss for IMT BS and body loss for IMT UE.

$10\log_{10}\left(\frac{\lambda^2}{4\pi}\right)$ is the antenna aperture (dB.m^2) at the wavelength, λ (m).

For the protection of terrestrial IMT UE, the receiver antenna gain $G_r(\theta)$ could be replaced with a fixed constant representing the nominal IMT UE antenna gain and does not have directivity.

Formatted: Highlight

Formatted: Indent: Left: 0 cm, Hanging: 2 cm, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: Highlight

Formatted: Highlight

Formatted: Highlight

Formatted: Indent: Left: 0 cm, Hanging: 2 cm, Bulleted + Level: 1 + Aligned at: 0.63 cm + Indent at: 1.27 cm

Formatted: Font: Bold, English (United States)

Formatted: English (United States)

Formatted: Font: Bold, French (France)

Formatted: Font: Bold, French (France)

Formatted: French (France)

Formatted: French (France)

Formatted: French (France)

Formatted: Font: Italic, Highlight

Formatted: Font: Italic

Formatted: Font: Italic, Highlight

Formatted: English (United States)

For the protection of terrestrial IMT BS, the receiver antenna gain $G_r(\theta)$ should take into account the typical downtilt configuration of IMT BS. There does not appear to be the case where the terrestrial IMT BS while receiving uplink from IMT UE (UE-to-BS) direction would point its maximum antenna gain at boresight towards an operational DC-MSS-IMT satellite that is transmitting in the downlink (space-to-Earth) direction. Therefore, it is not realistic to assume the use of the maximum antenna gain of IMT BS in place of G_r (θ) in equation (1).

Comment: this "baseline" pfd equation is derived assuming only one interfering satellite. So, it can be used to derive pfd limits when there is only one interfering satellite. However, in case of protecting IMT from multiple interfering satellites within one or multiple DC-MSS-IMT systems, this equation needs some modifications. Doc 5D/525 discusses this issue in detail. In summary, this pfd equation can be used for defining limits for protection of IMT UE if pfd is replaced by aggregate pfd. In case of protecting BSs, the main problem with this equation is $G_r(\theta)$ which is defined as the antenna gain of the victim receiver towards the direction of the interferer. The question is what is θ when there are multiple interfering satellites? Therefore, instead of having this equation here, we propose adding the precise equations under different regulatory options listed below or in a separate Annex.

Comment: from the baseline PFD equation, it could understand that the required baseline PFD value is calculated based on IMT protection criteria I/N, which the I/N is corresponding to the aggregate interference effect received by the IMT receiver, therefore the baseline PFD equation could be used to evaluate the aggregate interference from DC-MSS-IMT.

Comments: To replace the above words under 4.2.1 by saying "See Section 4.1".

4.2.2 EPFD equation

Document 5D/739 (Ericsson)

~~Defining EPFD like the definition of EPFD in Article **22.5C.1**, using gain of BS toward horizon ($G_{BS}(\varphi = 0)$) as the maximum gain of the BS toward interfering satellites, we have~~

~~$\mathrm{EPFD} = 10\log_{10}\sum_i\left(\frac{10^{\frac{P_i}{10}}\,G_{Sat}(\theta_i)}{4\pi d_i^2}\,\frac{G_{BS}(\varphi_i)}{G_{BS}(\varphi=0)}\right)$ (3)~~

See RR 22.5C.1; it should also be considered that IMT base station antennas are down-tilted and do not point toward satellites with their main lobe. Since satellites are located above the horizon, the received interference would occur mainly through side-lobes, and this should be properly reflected in the application of the equation, with Gr(θ) representing the actual off-axis gain toward the satellite direction.

*Comments: The above proposed concept is not correct. The equation should be same as RR No. **22.5C.1** noting the down tilt angle should be considered. So, we can say "See RR No. **22.5C.1**".*

Comment: In the proposed definition of epfd, G_BS (φ=0) is the gain of BS toward horizon. Considering the down tilt of BS, G_BS (φ=0) is smaller than the mas gain of BS. So, with this definition, it is possible to include the down tilt of BS.

AST Comments:

The proposed EPFD formulation using GBS(φ=0) in the denominator is inconsistent with the definition in RR 22.5C.1. In the RR formulation, the normalization is done by the maximum gain of the victim antenna, which is a fixed constant, while any down-tilt is properly accounted for within the antenna pattern term GBS(φi). Putting tilt into the denominator via GBS(0∘) double counts or misplaces the effect and inflates EPFD numerically. Moreover, using the gain toward the horizon

Formatted: Font: Italic, Highlight
Formatted: Font: Italic, Highlight
Formatted: Font: Italic, Highlight
Formatted: Highlight
Formatted: Highlight
Formatted: Highlight
Formatted: Font: Italic, Highlight
Formatted: Highlight
Formatted: Font: Italic, Highlight
Formatted: Font: Italic
Formatted: Font: Italic, Not Highlight
Formatted: Font: Italic
Formatted: Font: Italic, Not Highlight
Formatted: Space Before: 18 pt, Pattern: Clear (Accent 6)
Formatted: Font: Bold, French (France)
Formatted: Font: Bold, French (France)
Formatted: French (France)
Formatted: French (France)
Formatted: Not Highlight
Formatted: Pattern: Clear (Accent 4)
Formatted: Pattern: Clear (Accent 4)
Formatted: Font: Italic, Not Highlight
Formatted: Font: Italic
Formatted: Font: Bold, Italic
Formatted: Font: Italic
Formatted: Font: Bold, Italic
Formatted: Font: Italic
Formatted: Font: Italic, Highlight
Formatted: Font: Italic
Formatted: Font: Bold, Italic
Formatted: Font: Italic
Formatted: Normal, Pattern: Clear (Accent 4)
Formatted: English (United States)

as a reference is not physically representative, since interfering satellites generally arrive from elevation angles well above the horizon.

Document 5D/914 (F)

The equivalent power flux density (epfd) is defined, according to Radio Regulations (RR) Article **22.5C.1**, as a measure to protect geostationary satellite system from a non-geostationary satellite system. Similarly, this approach could be applied as a regulatory measure to protect terrestrial IMT BS from a DC-MSS-IMT system (including both non-geostationary satellite systems and geostationary satellite systems).

Similarly to RR Article **22.5C.1**, epfd is defined as the sum of the power flux densities produced at an IMT BS on the Earth's surface, by all the visible transmit stations within the DC-MSS-IMT system, taking into account the off-axis discrimination of a reference receiving antenna assumed to be pointing in its nominal direction. The epfd (dB(W/m^2)) in the reference bandwidth is calculated using the following formula:

$$epfd = 10 \log_{10} \left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4 \pi d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}} \right]$$

where:

P_i: RF power at the input of the antenna of the transmit station, considered in the non-geostationary-satellite system (dBW) in the reference bandwidth

θi: off-axis angle between the boresight of the transmit station and the direction of receive station (IMT BS)

Gt(θi): transmit antenna gain (as a ratio) of the transmit station in the direction of the receive station

di: distance (m) between the transmit station and the receive station

φi: off-axis angle between the boresight of the antenna of the receive station and the direction of the i-th transmit station

Gr(φi): receive antenna gain (as a ratio) of the receive station in the direction of the i-th transmit station

Gr,max: maximum gain (as a ratio) of the antenna of the receive station.

While P_i and $G_t(\theta_i)$ depends on the DC-MSS-IMT system characteristics, the reference antenna gain pattern G_r needs to be defined based on the IMT characteristics.

4.3 Calculation method

4.3.1 Deterministic calculation-based method

Documents 5D/477 (CHN), 5D/715 (CHN)

Deterministic calculation-based method is used to evaluate the aggregate PFD value per system from DC-MSS-IMT space stations to protect IMT system consideration the IMT protection criterion *I/N* =−6 dB without any probability (which means the non-exceedance probability of *I/N* = −6 dB is 100%).

Comment: here, we propose referring to the precise equations to define different pfd options for protection of UE and BS included in section 4.1. On Section 4.3.1 and 4.3.2. We think this should be a part of the study in an Annex and not in the main body. Also, the dynamic method does not make much sense for UE with same gain in all directions while it is relevant to calculate aggregate PFD

Formatted: Font: Italic, Not Highlight

Formatted: Font: Not Bold, Not Highlight

Formatted: Font: Not Bold, Not Highlight

Field Code Changed

Formatted: Font: Not Bold, Not Highlight

Formatted: Font: Not Bold, French (France)

Formatted: French (France)

Formatted: Font: Not Bold, Italic, Highlight

Formatted: Font: Not Bold, Italic

Formatted: Font: Not Bold, Italic, Highlight

Formatted: Font: Not Bold, Italic

Formatted: English (United States)

for BS and that is system specific. Other studies may consider different systems and derive appropriate limits.

Comment: Besides the equation in Section 4.2 of the basic PFD calculation, the methodologies on how to implement the equation are also needed. For the dynamic simulation method to protect IMT UE and BS, an important aspect is to model the dynamic movement of DC-MSS-IMT satellites and its satellite selection and pointing strategy, which could lead to different aggregate interference level from all the satellites to IMT UE and BS due to different satellite number causing interference and its antenna gain towards victim IMT at each time and location. These two sections provide the methodologies to obtain the required aggregate PFD values to protect IMT UE and BS, which are also valid for other systems if required. Other studies considering different systems are not precluded.

4.3.2 Dynamic simulation-based method

Documents 5D/477 (CHN), 5D/715 (CHN)

Dynamic simulation-based method is used to evaluate the aggregate PFD value per system from DC-MSS-IMT space stations to protect IMT system at the border between neighboring countries with additional isolation required to satisfy the IMT protection criterion with specific non-exceedance probability of $I/N = -6$ dB. Main steps of the simulation are listed as follows.

Step1: Determine the range of simulation area

In this study, DC-MSS-IMT space stations serve DC-MSS-IMT UEs in Country A which shares a border with Country B.

The size of Country A is set to 2442 km in length and 2 442 km in width, with the center located at 109°E, 30°N.

Step2: Generate DC-MSS-IMT space stations/DC-MSS-IMT UEs and IMT BSs/UEs

The spatial topology of DC-MSS-IMT space stations is generated at time T based on the parameters of orbital configuration.

DC-MSS-IMT UEs are generated within Country A randomly, and adopts highest elevation satellite selection and pointing strategy to connect to DC-MSS-IMT space stations. The center of space station beam can only point within the territory of Country A.

IMT BSs/UEs are generated along the border of Country B. Based on the deployment-related parameters of IMT system, the inter-site distance is 600m. IMT UEs are generated within IMT base station sectors randomly.

Step3: Simulate the positions of satellite constellation over a period of time and calculate aggregate interference from DC-MSS-IMT space stations to IMT system at each time step

The aggregate interference level is determined by all visible space stations serving DC-MSS-IMT UEs in Country A.

$$I_{total} = 10\,log\left(\sum_n^N \sum_j^J 10^{I_{n,j}/10}\right)$$

$$I_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - PL_n + G_{rx}(\theta_{rx})_{n,j} - L_{other}$$

where:

I_{total}: Aggregate interference power density from DC-MSS-IMT space stations, dBW/MHz

$I_{n,j}$: Interference power density from j-th beam of n-th space station, dBW/MHz

Formatted: Font: Italic

Formatted: Pattern: Clear (Accent 6)

Formatted: Font: (Asian) Japanese

Formatted: Font: (Asian) Japanese, Not Highlight

Formatted: French (France)

Formatted: English (United States)

P_{tx}: DC-MSS-IMT space station transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of MSS space station is pointing to its serving DC-MSS-IMT UE, dBi

$G_{rx}(\theta_{tx})_{n,j}$: IMT station antenna gain in the direction of MSS space station, dBi

PL_n: Propagation loss, dB

L_{other}: Feeder loss for IMT BS, Body Loss for IMT UE dB

N: The number of DC-MSS-IMT space stations in the interference calculation

J: The number of beams of one DC-MSS-IMT space station.

Furthermore, the required additional isolation could be derived based on the received aggregate interference and maximum allowed interference level based on protection criteria I/N=−6dB at different probabilities(X%) of CDF.

$$ISO = I_{total} - I_{max}$$

ISO: The required additional isolation that may be needed to protect IMT system to satisfy the protection criteria I/N= −6 dB at different probabilities(X%) of CDF.

I_{max}: The acceptable maximum interference power derived based on the protection criteria and receiver noise, dBW/MHz.

Step4: Calculate required PFD values from DC-MSS-IMT constellation at the border between neighboring countries

Aggregate PFD is calculated by simulation using the following formulas:

$$PFD = 10\,log\left(\sum_n^N \sum_j^J 10^{PFD_{n,j}/10}\right)$$

$$PFD_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - 10log_{10}(4\pi d_n^2)$$

where:

PFD: Aggregate PFD from DC-MSS-IMT space stations, dB(W/m²·MHz)

$PFD_{n,j}$: PFD from j-th beam of n-th space station, dB(W/(m²·MHz))

P_{tx}: DC-MSS-IMT space station transmit power density$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of DC-MSS-IMT space station is pointing to its serving DC-MSS-IMT UE, dBi

d_n: Distance between n-th transmit DC-MSS-IMT space station and IMT receiver station, m.

Based on the additional isolation obtained in Step 3, the required PFD values are derived using the following formula:

$$PFD_{value} = PFD - ISO$$

where:

PFD_{value}: Required PFD values of DC-MSS-IMT constellation to protect IMT system at the border between neighbouring countries, dB(W/(m²·MHz)).

Comment: the proposed dynamic method, provides the same value as the deterministic method if used for defining limits for protection of UE. In case of protection of BSs, the pfd value obtained by

Formatted: Font: Italic, Highlight

Formatted: English (United States)

the dynamic method is the aggregate pfd and depends on the DC-MSS-IMT system parameters used in the calculation, meaning that different DC-MSS-IMT systems gives different pfd value.

Formatted: Font: Italic, Highlight

Comment: For the dynamic simulation method, if different non-exceedance probabilities of IMT protection criterion are considered, the evaluation results of PFD value to protect IMT UE are different from deterministic method.

Formatted: Font: Italic, (Asian) Japanese

Formatted: Normal, Pattern: Clear (Accent 6), Tab stops: 2.25 cm, Left

Formatted: Font: Italic, (Asian) Japanese

Formatted: Font: Italic, (Asian) Japanese, Not Highlight

Step5: Analyse the study results

Comment There is no agreement to include the section below on 'Throughput loss calculation' as it is not an applicable limit for evaluating the cross-border protection of terrestrial IMT.

4.3.3 Throughput loss calculation

Document 5D/483(RUS)

Comment: This analysis is related to the discussion on the protection criterion of IMT and not a calculation method to define regulatory measures (pfd/epfd limits) for protection of IMT from DC-MSS-IMT systems. So, we propose removing this subsection.

Formatted: Font: Italic, Highlight

Formatted: Font: Italic, Highlight

Formatted: Font: Italic, Highlight

Nokia: Due to the range of the bands considered under discussion in AI 1.13 different countries may have different implementation of mobile generations in the same band. The S(I)NRmin and S(I)NRmax of each generation differ. As such, the use of the metric of 5% throughput loss, compared to directly using the I/N metric, to calculate PFD/EPFD levels, becomes much more complicated to generalise and account for, thus not recommended for 1.13. The S(I)NR formula is a simplified mapping formula and is not meant to be used for accurate modelling of the performance of IMT network. Thus, any possible results using this mapping should be used only for comparison purposes.

Typically, an acceptable threshold for throughput loss in IMT networks is 5%. The following equations approximate the throughput over a channel based on the signal-to-interference-plus-noise ratio (SINR, measured in dB) when employing link adaptation:

$$SE\ (SINR), bps/Hz = \begin{cases} 0 & for\ SINR < SINR_{MIN} \\ \alpha \cdot S(SINR) & for\ SINR_{MIN} \le SINR < SINR_{MAX} \\ \alpha \cdot S(SINR_{MAX}) & for\ SINR \ge SINR_{MAX} \end{cases}$$

where:

$S(SINR)$ Shannon bound, $S(SINR) = \log_2(1 + 10^{SINR/10})$ (bps/Hz)

α Attenuation factor, representing implementation losses

$SINR_{MIN}$ Minimum SINR of the code set, dB

$SINR_{MAX}$ Maximum SINR of the code set, dB.

TABLE A1-3

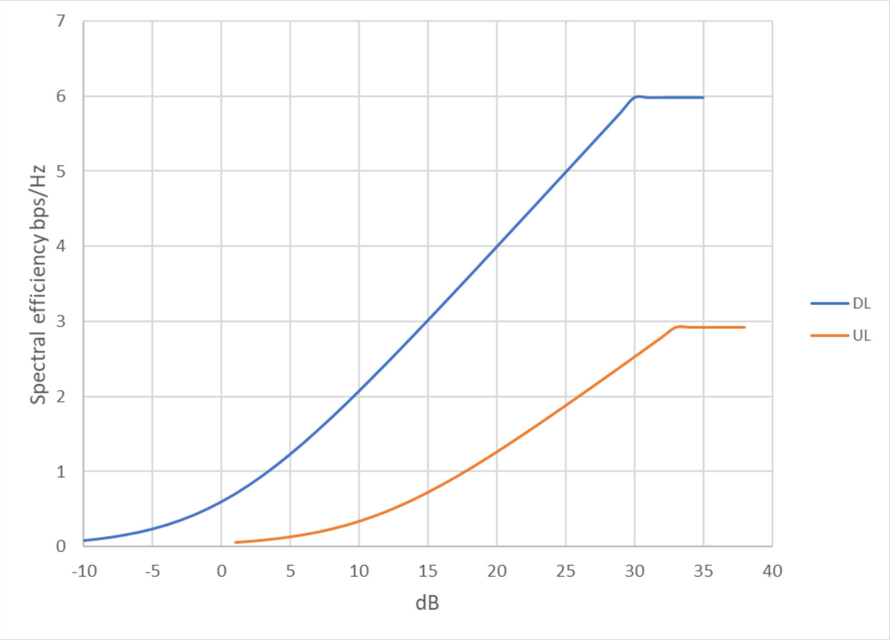
Parameters describing baseline Link Level performance for 5G NR

Parameter	**DL**	**UL**	**Notes**
α	0.6	0.4	Represents implementation losses
$SINR_{MIN}$, dB	−10	−10	Based on QPSK, 1/8 rate (DL) & 1/5 rate (UL)
$SINR_{MAX}$, dB	30	22	Based on 256-QAM, 0.93 rate (DL) & 64-QAM, 0.93 rate (UL)

Formatted: English (United States)

FIGURE A1-7

Spectral efficiency of UL and DL depending on the SINR levels



Formatted: Font:

Knowing the values of spectral efficiency when 5% throughput reduction occurs and using base Shannon expression taking into account implementation losses:

$$SE(SINR) = log_2\left(1 + 10^{SINR/10}\right) \cdot \alpha$$

It is possible to derive SINR from that expression. First it is needed to rearrange the formula to isolate log_2:

$$\frac{SE(SINR)}{\alpha} = log_2\left(1 + 10^{SINR/10}\right)$$

Convert base-2 logarithm to base-10 logarithm:

$$log_2(y) = \frac{log_{10}(y)}{log_{10}(2)}$$

So:

$$\frac{SE(SINR)}{\alpha} = \frac{log_2\left(1 + 10^{SINR/10}\right)}{log_{10}(2)}$$

Simplify to log_{10}:

$$log_{10}\left(1 + 10^{SINR/10}\right) = \frac{SE(SINR)}{\alpha} \cdot log_{10}(2)$$

Exponentiate to solve for $10^{SINR/10}$:

Formatted: English (United States)

$$C = \frac{SE(SINR)}{\alpha} \cdot log_{10}(2)$$

Then, SINR can be calculated using the following expression:

$$SINR = 10 \cdot log_{10}(10^{C} - 1)$$

After SINR values that correspond to the 5% throughput losses are calculated, it is possible to calculate *I/N* for each case of baseline SNR when 5% throughput losses occur using the following expression:

$$I/N = 10log_{10}\left(\frac{10^{SNR/10} + 10^{SINR/10}}{10^{SINR/10}}\right)$$

Knowing *I/N* values that are linked to the 5% throughput loss of DL and UL it is possible to derive necessary pfd limits.

Alternatively, the 5% throughput losses may be linked to the epfd limits.

[4.~~2~~4 Factors impacting the aggregate interference from DC-MSS-IMT to terrestrial IMT

[Editor’s note: The content of this section will be provided by the Offline on the Aggregation factor]

4.~~2~~4.1 Aggregate interference from multiple satellites of one DC-MSS-IMT system

The density of DC-MSS-IMT satellite constellation ~~has a high~~ may have an impact on the aggregate interference received by IMT victim receiver. Depending on the density of the satellite constellation and configuration parameters, the satellites ~~seen by IMT victim receiver at low and mid elevation angles~~ illuminating the same service area in the same frequency block simultaneously might contribute ~~more~~ to the overall aggregate interference. Therefore, when performing coexistence studies, it is important to have a complete and realistic model of the satellite constellation and consider interference consistent with operational conditions~~the interference from all visible satellites~~.

Comments: The comments are as follows:

1) For DC-MSS-IMT system, the intra-system compatibility shall be met;

2) From all the available information so far from WP4C, the minimum elevation-angle for satellite selection is 20 degrees. So, no possibility for a satellite UE to choose a satellite under 0 and/or 10-degree elevation-angles. Therefore, this mentioned satellite UE and the relevant satellite beam downlink transmission under such low elevation-angle could not be at a place near a neighboring terrestrial IMT receiver in a neighboring territory. And accordingly, the simulation analysis is not correct;

3) Based on its studies, WP 5D thinks a given area can only be served by one spot beam in a given block of spectrum. Together with authorization mechanism acquired in advance, it is not possible for different spot beams from different DC-MSS-IMT systems to serve a territory in a given block of spectrum at the same time,

AST Comments:

For a single DC-MSS-IMT system, although many satellites may be geometrically visible at a given location, it is not typical for multiple satellites to illuminate the same service beam in the same frequency block at the same time. System design (spot-beam planning, frequency-reuse patterns, and per-beam power control) ensures that, under normal operation, a given area is served by one active spot beam per block. Only in specific transient situations (such as handover or service

Formatted: Not Highlight

Formatted: Font: Italic

Formatted: Font: Italic, Not Highlight

Formatted: Not Highlight

Formatted: Pattern: Clear (Accent 4)

Formatted: Pattern: Clear (Accent 4), Not Highlight

Formatted: Not Highlight

Formatted: Pattern: Clear (Accent 4), Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Font: Italic

Formatted: Font: Italic, English (United States)

Formatted: Pattern: Clear (Accent 4)

Formatted: English (United States)

continuity) might more than one satellite momentarily contribute energy toward the same service area.

Accordingly, coexistence assessments for intra-system cases would be better based on PFD per beam rather than per satellite, with aggregation applied only in situations when two or more beams are intentionally and simultaneously active over the same pixel in the same block. This approach reflects operational reality, avoids artificially summing contributions from non-serving satellites, and provides a stable, verifiable metric for protection studies.

4.~~2~~4.2 Aggregate interference from multiple DC-MSS-IMT systems

See Annex 2 for studies]

Comments: To make it terse, we propose to suppress subsection 4.4, and the relevant contents could be merged to subsection 4.1 if the offline discussion could not solve the issue. In addition, Annex 2 may also need to be modified accordingly.

[4.5 PFD equation when considering intercell interference]

~~[~~*Note: Views were expressed that t~~T~~he method below suggests I/N values must be based on receiver noise plus intercell interference. But Cellular systems are optimised to have almost no intercell interference. Protection criteria must be based on I/N where N is the noise floor and not noice floor plus intercell interference. Other views were expressed that IMT and secondary DC-MSS-IMT are separate networks. ICI on the TN is marginal and varies. This is therefore not an option that could be under consideration. As a consequence, intercell should not be considered. We propose to delete this section.~~]~~*

Nokia: Although the below PFD equation uses as a basis an existing, verified PFD equation, there has been no justification of how the Inter-cell interference factor is being incorporated. The equation mixes a network management aspect (Inter-cell interference) with a regulatory protection metric (I/N). Section 6 of ITU-R M.2292 states that the I/N=-6 dB protection criterion is irrespective of the number of cells and independent of the number of interferers. This means that I/N =-6dB is the IMT protection criterion for even a single IMT cell, where no inter-cell interference exists. Section 2.9 of ITU-R M.2101 states that the I/N is the ratio of the allowed inter-system interference level received in the IMT receiver, meaning that no intra-system (inter-cell) interference is part of its derivation and use.

[When intercell interference is considered together with the thermal noise, the proposed PFD formula is the following:

$$PFD(\theta) = 10\log_{10}\left(kT_{ref}B * 10^{\frac{NF}{10}} + 10^{\frac{I_{inter-cell}}{10}}\right) + \frac{I}{N} - G_r(\theta) + \mathrm{L}_{feeder} + \mathrm{L}_{body} + \mathrm{L}_{misc} - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k is Boltzmann's constant (1.380649×10^{-23} J/K)

T_{ref} is the reference noise temperature (300 Kelvin)

B is the reference bandwidth (1 MHz)

NF is the receiver noise figure (dB)

$I_{inter-cell}$ is the inter-cell interference (dBW/MHz)

Formatted: Font: Not Bold, Italic

Formatted: Font: Italic

Commented [SA3]: As per our comments, we don't share the view that intercell interference can be considered given that IMT and secondary DC-MSS-IMT are separate networks. ICI on the TN is marginal and varies. This is therefore not an option that could be under consideration. We therefore propose that the deletion of this formulae.

Formatted: Font: Not Bold, Italic

Formatted: Font: Not Bold, English (United States)

Formatted: English (United States)

$\frac{I}{N}$ is the receiver interference to noise ratio limit (dB) considering intercell interference

$G_r(\theta)$ is the effective antenna gain (dBi) of the receiver antenna towards the direction of the interferer

θ is the elevation angle (°) towards the direction of the interferer

L_{feeder} is the receiver antenna feeder loss for IMT BS (dB)

L_{body} IMT UE body loss (dB)

L_{misc} atmospheric losses and polarization losses (dB)

$10\log_{10}\left(\frac{\lambda^2}{4\pi}\right)$ is the antenna aperture (dB.m^2) at the wavelength, λ (m).]

[Editor's note: views were expressed that~~AUS Comments:~~w

When using the PFD equation based on I/N protection criterion, the equation proposed by TON aims to derive the maximum interfering signal, I, from a DC-IMT-MSS system relative to the combined level of the IMT receivers noise level plus inter-cell interference. However, the I/N protection criterion for IMT is the ratio based on the allowed inter-system interference level received in the IMT receiver relative to the receiver's noise level – where N is typically calculated based on N = kTB (thermal noise) + NF (system noise figure), refer to section 2.9 of Rec. ITU-R M.2101. It is not appropriate to consider inter-cell interference as another noise component when calculating N. The effect of inter-cell interference of terrestrial IMT network is usually addressed through network resource coordination scheme and power control.]

4.~~2 3~~5 Compilations of ~~sharing and compatibility~~ studies ~~between terrestrial IMT and DC-MSS-IMT~~to determine the limits for protection of terrestrial IMT

See Annex 1 for studies

Formatted: Font: Italic

Formatted: Pattern: Clear (Green)

Formatted: Font: Bold, Highlight

Formatted: English (Australia)

Formatted: English (United States)

TABLE 1

Calculation of limits for protection of terrestrial IMT user equipment

	Study B (Multi MNOs&Orange – 5D/533&775)	**Study C (RUS – 5D/483)**	**Study E (CHN -5D/477 &715 & 823)**	**Study E -(CHN -5D/477 &715 & 823)**	**Study G (D, G – 5D/639)**	**Study I -(Ericsson-Doc 5D/739)**
Type of calculation method	Deterministic	Throughput loss	Deterministic	Dynamic simulation	Deterministic	Deterministic
Frequency bands	738 MHz (Band 1) 1 475 MHz (Band 2) 2 620 MHz (Band 3)	-	800 MHz (Band 1) 1450 MHz (Band 2) 1 80~~0~~5 MHz (Band 3) 2 155 MHz (Band 4) 2 350 MHz (Band 5) 2 600 MHz (Band 6)	~~2 110~~1 710-2 200 MHz	700, 800, 900 MHz (Band 1) 1 400 MHz (Band 2) 1 800, 1 900, 2 100 MHz (Band 3) 2 300, 2 600 MHz (Band 4)	700 MHz (Band 1) 1 500 MHz (Band 2) 2 000 MHz (Band 3)
Technical and operational characteristics of IMT						
Antenna gain (dBi)	0	-3	-3/0	-3/0	-3	-3
Body loss (dB)	0	4	4/0	4/0	4 & 0	-
Thermal noise density (dBW/MHz)	-	-	−143.98	−143.98	-144	-
Noise figure (dB)	9	-	9	9	9	9
I/N (dB)	-6	Calculated	-6	-6	-6	[-20]
Additional values						
Multi-satellite aggregation factor (dB)	[11.6] (for Band 2)	-	-	-	-	[TBD]
Multi-system aggregation factor (dB)	3	[3-5]	-	-	-	3
Results						
Single-entry PFD (dBW/m^2/MHz)	−125 – α (Band 1) [−130.6] (Band 2) −114 – α (Band 3)	[TBD]		-	-	−137 (Band 1) −130 (Band 2) −127 (Band 3)
Aggregate PFD (dBW/m^2/MHz)	−125 (Band 1) −119 (Band 2) −114 (Band 3)	[TBD]	For 4dB body loss, -3dBi antenna gain: −114.47 (Band 1) −109.30 (Band 2) −107.40 (Band 3)	~~−105.0961 (99.99% of probability)~~ ~~−103.2767 (99.9% of probability)~~ ~~−97.7445 (99.5% of~~	For 0 dB body loss: −119 (Band 1) −113 (Band 2) −111 (Band 3) −108 (Band 4)	−134 (Band 1) −127 (Band 2) −124 (Band 3)

Formatted Table
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted

	Study B (Multi MNOs&Orange – 5D/533&775)	Study C (RUS – 5D/483)	Study E (CHN -5D/477 &715 & 823)	Study E -(CHN -5D/477 &715 & 823)	Study G (D, G – 5D/639)	Study I -(Ericsson-Doc 5D/739)
			−105.86 (Band 4) −105.11 (Band 5) −104.23 (Band 6) For 0dB body loss, 0dBi antenna gain: −121.47~~−105.86~~ (Band 1) −116.30 (Band 2) −114.40 (Band 3) −112.86 (Band 4) −112.11 (Band 5) −111.23 (Band 6)	~~probability)~~ For 4dB body loss, -3dBi antenna gain: −107.4 (100% of probability) For 0dB body loss, 0dBi antenna gain: −114.4 (100% of probability)	For 4 dB body loss: –115 (Band 1) –109 (Band 2) –107 (Band 3) –104 (Band 4)	

Formatted Table

Formatted: Font: 9 pt, English (United States)

Formatted: Font: 9 pt

Formatted: Font: 9 pt, English (United States)

Formatted: Font: 9 pt

Formatted: Font: 9 pt

Formatted: Font: 9 pt, English (United States), Not Highlight

Formatted: Font: 9 pt, German (Germany), Not Highlight

Formatted: Font: 9 pt

Formatted: English (United States)

	Study J (CHN -5D/824)	
Type of calculation method	Dynamic simulation	
Frequency bands	694/698-960 MHz (Band 1)	
Technical and operational characteristics of IMT		
Antenna gain (dBi)	-3	
Body loss (dB)	4	
Thermal noise density (dBW/MHz)	–143.98	
Noise figure (dB)	9	
I/N (dB)	-6	
Additional values		
Multi-satellite aggregation factor (dB)	-	
Multi-system aggregation factor (dB)	-	
Results		
Single-entry PFD	-	
Aggregate PFD	–115.63 (100% of probability) (Band 1)	

Formatted: Font: (Default) Times New Roman Bold, 10 pt, Bold, English (United States), Not Highlight

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted: English (United States), Not Highlight

Formatted ...

Formatted: English (United States), Not Highlight

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted: Font: (Asian) Japanese, Not Highlight

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted: (Asian) Japanese, Not Highlight

Formatted ...

Formatted: (Asian) Japanese, Not Highlight

Formatted ...

Formatted ...

Formatted: Font: (Asian) Japanese, Not Highlight

Formatted ...

Formatted: Not Highlight

Formatted ...

Formatted: English (United States)

TABLE 2

Calculation of limits for protection of terrestrial IMT base stations

	Study B (Multi MNOs&Orange-5D/533&775)	**Study C (RUS – 5D/483)**	**Study F (D-5D/633)**	**Study H (Doc. 5D/712 (CHN), 5D/827(CHN))**	**Study I (Ericsson-Doc 5D/739)**	**Study …**
Type of calculation method	Deterministic	Throughput loss	Deterministic, worst-case scenario	Simulation	Deterministic	
Frequency bands	703 MHz (Band 1) 1 710 MHz (Band 2) 2 500 MHz (Band 3)	-	Below 1 GHz 1 GHz to 2.2 GHz 2.3-2.4 GHz 2.5-2.69 GHz	1 880-1 920 MHz and 2 620-2 690 MHz	700 MHz (Band 1) 1 500 MHz (Band 2) 2 000 MHz (Band 3)	
	Technical and operational characteristics of IMT					
Deployment	-	Rural macro	Rural macro	Rural Macro	-	
Antenna pattern	AAS and Non-AAS	AAS	AAS and Non-AAS	AAS	Non-AAS	
AAS antenna characteristics	Element gain: 6.4 dB Element beam width: 90º for H 65º for V config: 4x8 sub-array, Msub =3 dv,sub=0.71 dh,sub=0.51	Element gain: 6.4 dB Element beam width: 90º for H 65º for V Front to back ratio: 30 dB for both H/V Polariz: Linear ±45º config: 4x8 dh = 0.5 dv = 2.1 sub-array, Msub = 3 dv,sub = 0.7 θsubtilt =3 degrees Ohmic loss =2 dB H coverage range (degrees) ±60 V coverage range (degrees) 90-100	Element gain: 6.4 dBi Element beam width: 90º for H 65º for V Front to back ratio: 30 dB for both H/V Polariz: Linear ±45º config: 4x8 dh = 0.5 dv = 2.1 sub-array, Msub = 3 dv,sub = 0.7 θsubtilt =3 degrees Ohmic loss =2 dB H coverage range (degrees) ±60 V coverage range (degrees) 90-100	lement gain: 6.4 dBi Element beam width: 90º for H 65º for V Front to back ratio: 30 dB for both H/V Polariz: Linear ±45º config: 4x8 dh = 0.5 dv = 2.1 sub-array, Msub = 3 dv,sub = 0.7 θsubtilt =3 degrees Ohmic loss =2 dB H coverage range (degrees) ±60 V coverage range (degrees) 90-100	-	
Non-AAS maximum antenna gain (dBi)	15 (Band 1) 18 (Band 2 and 3)	-	18	-	18	
Antenna gain toward horizon ($G_{BS}(\varphi = 0)$)	-	-	-	-	16	

Formatted: Font: (Default) Times New Roman Bold, 9 pt, Bold, English (United States), Not Highlight

Formatted: Font: 9 pt, Bold, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, Not Highlight

Formatted: Font: 9 pt, English (United States), Not Highlight

Formatted Table

Formatted: Font: 9 pt, German (Germany)

Formatted: Font: 9 pt, English (United States), Not Highlight

Formatted: Font: 9 pt, German (Germany)

Formatted: Font: 9 pt, German (Germany)

Formatted: Font: 9 pt, (Asian) Japanese, Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, English (United States)

Formatted: Font: 9 pt, English (United States)

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: Font: 9 pt, (Asian) Japanese, Not Highlight

Formatted ...

Formatted: English (United States)

	Study B (Multi MNOs&Orange-5D/533&775)	**Study C (RUS – 5D/483)**	**Study F (D-5D/633)**	**Study H (Doc. 5D/712 (CHN), 5D/827(CHN))**	**Study I (Ericsson-Doc 5D/739)**	**Study …**
Non-AAS antenna feeder loss (dB)	1	-	3	-	3	
Noise spectral density (dBW/MHz)	-	-	−143.8	-144	-	
Noise figure (dB)	3	-	5	5	5	
Noise temperature (K)	-	-	300	-	-	
Downtilt (degrees)	0	3	3	3	3	
I/N (dB)	-6 [-10]	Calculated	-6	-6	[-20]	
	Additional values					
Multi-beam/satellite aggregation factor (dB)	[TBD]	-	-	-	[TBD]	
Multi-system aggregation factor (dB)	[TBD]	[3-5]	-	-	3	
	Results					
Single-entry PFD	[TBD]	[TBD]	See Table 2-1	-126.472 dB(W/m2· MHz) (1 880-1 920 MHz) -124.012 dB(W/m2· MHz) (2 620-2 690 MHz)	$-157 - 10\log_{10}[\alpha]$ (Band 1) $-150 - 10\log_{10}[\alpha]$ (Band 2) $-147 - 10\log_{10}[\alpha]$ (Band 3)	
Aggregate PFD	[TBD]	[TBD]	-	-	$-154 - 10\log_{10}[\alpha]$ (Band 1) $-147 - 10\log_{10}[\alpha]$ (Band 2) $-144 - 10\log_{10}[\alpha]$ (Band 3)	
Single-entry EPFD	[TBD]	[TBD]		-	–157 (Band 1) –150 (Band 2) –147 (Band 3)	
Aggregate EPFD	[TBD]	[TBD]	-		–154 (Band 1) –147 (Band 2) –144 (Band 3)	

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted ...

Formatted: Font: 9 pt, (Asian) Japanese, (Other) English (United States), Not Highlight

Formatted: English (United States)

TABLE 2-1

Envelope pfd mask equations for protection of IMT BS in rural macro scenario (Study F)

Frequency range	**Pfd equation per frequency range (dB(W/(m² · MHz)))**
Below 1 GHz	$pfd_{mask}(\theta) = \begin{cases} -0.21 * \theta^2 + 1.26 * \theta - 139.6 & for\ \theta \leq 4 \\ 5.017 * e^{-4} * \theta^3 - 0.03379 * \theta^2 + 0.8451 * \theta - 133.8 & for\ 4 < \theta \leq 27.5 \\ -3.740 * e^{-7} * \theta^4 + 9.845 * e^{-5} * \theta^3 - 0.01053 * \theta^2 + 0.6512 * \theta - 137.5 & for\ 27.5 < \theta \leq 90 \end{cases}$
1 GHz to 2.2 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 142.8 & for\ \theta \leq 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 122.9 & for\ 26.7 < \theta \leq 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 606.49 & for\ 31.25 < \theta \leq 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 127.6 & for\ 67.2 < \theta \leq 90 \end{cases}$
2.3-2.4 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 138.6 & for\ \theta \leq 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 118.7 & for\ 26.7 < \theta \leq 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 610.64 & for\ 31.25 < \theta \leq 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 123.5 & for\ 67.2 < \theta \leq 90 \end{cases}$
2.5-2.69 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 137.9 & for\ \theta \leq 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 118 & for\ 26.7 < \theta \leq 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 611.36 & for\ 31.25 < \theta \leq 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 122.8 & for\ 67.2 < \theta \leq 90 \end{cases}$

]

Formatted: English (United States)

5 Regulatory limits for the frequency bands within the range 694-2700 MHz

5.1 Below 1 GHz

5.2 1.5 GHz

5.3 Above 2 GHz

Formatted: Heading 2,Sub-section,H2,h2,h21,Heading Two,R2,l2,UNDERRUBRIK 1-2,Head 2,List level 2,Sub-Heading,A,1st level heading,level 2 no toc,2nd level,Titre2,h:2,h:2app,2,level 2,Head2A,PA Major Section,Major Section,Head2,Header 2,Level 2 Head,T2,X

6 Regulatory measures considerations

[Editor's Note: Feasibility analyses of technical and operational measures to ensure protection of IMT and additional regulatory considerations could be included in this section.]

Formatted: English (United Kingdom)

See Annex 4 for studies

Formatted: English (United Kingdom)

Formatted: Normal

7 Summary of Results

…

TBD

ANNEX 1

Calculation of limits for protection of terrestrial IMT

Study A (Doc. 5D/550 (Nokia))

[Note: Questions were raised with regards to the assumption and methodology used in the study.]

Formatted: Font: Bold, Italic

Formatted: Normal

Document 5D/322 has proposed a methodology to calculate the maximum pfd levels on the ground to protect IMT receivers, based on the following equation in dB (W/(m^2 · MHz)):

$$PFD(\theta) = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + \mathrm{L} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k: Boltzmann's constant ($1.380649 \times 10^{-23}\,J/K$)
T: receiver noise temperature in K
B: reference bandwidth (1 MHz)
NF: receiver noise figure in dB
I/N: protection criteria in dB
$G_r(\theta)$: antenna gain in dBi of the receiver antenna in the direction of the interferer
θ: the elevation angle
L: Losses.

The resulting PFD from the above equation is dependent on the angle of the IMT receiver gain $G_r(\theta)$. This implies that the equation produces the maximum aggregate PFD for the protection of IMT receivers from all possible interfering sources at a specific angle θ.

Formatted: English (United States)

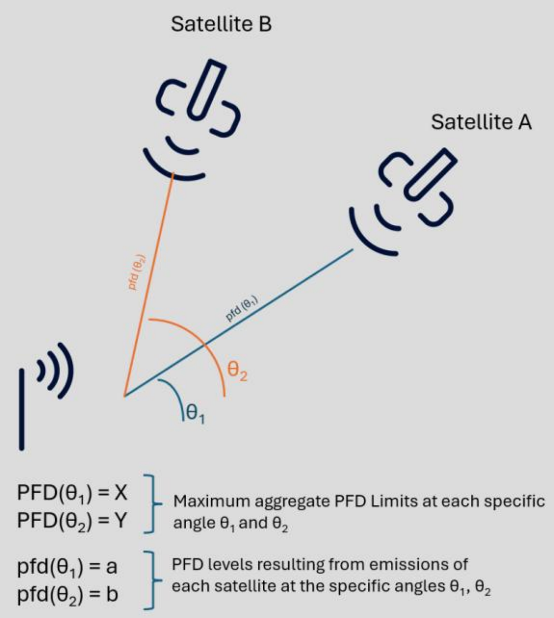
Suitability considerations of Equation 1 for the protection of IMT BS

IMT BS have directional non-AAS or AAS antennas. Therefore, if this angle dependent equation is considered as the basis of the methodology to derive the maximum aggregate pfd limits to protect IMT uplinks (i.e. IMT BSs), the derived result will be the maximum aggregate pfd limit from all possible interfering sources at a specific angle θ. When more than one non-GSO satellite of one or more satellite constellations are visible from different angles at an IMT BS, this equation produces the maximum aggregate pfd limits at each of those different visible angles. As it is shown in the analysis below, the presence of two or more satellites visible from different angles at the IMT BS, may result in exceeding the maximum aggregate pfd limits produced by Equation 1 at each angle θ, pfd(θ), even if individually, each satellite complies with the respective pfd(θ) limits of Equation 1 at their visible angles to the IMT BS.

To further demonstrate the issue, we assume that two satellites are visible by the IMT BS at two different angles θ_1 and θ_2 and we use Equation 1 to derive the maximum aggregate pfd limits at each of those θ_1 and θ_2 angles. These resulting maximum aggregate pfd limits at each angle are pfd(θ_1) and pfd(θ_2) as seen in Figure 1.

FIGURE A1-1

pfd limits and pfd levels for two satellites at visible angles θ1 and θ2 at the IMT BS



The individual pfd levels caused by Satellite A and Satellite B at the visible angles θ_1 and θ_2 at the IMT BS receiver are pfd(θ_1) = a and pfd(θ_2) = b.

For simplicity, assuming that the individual pfd levels caused by each satellite are equal to the maximum aggregate pfd limit at each visible angle at the IMT BS, we have that:

$$\mathrm{pfd}(\theta_1) = a = \mathrm{PFD}(\theta_1) = X$$

Formatted: English (United States)

and

$$\text{pfd}(\theta_2) = \text{b} = \text{PFD}(\theta_2) = \text{Y}$$

While the above pfd levels at each angle θ are compliant with the maximum aggregate pfd limits at each respective angle, the effect of their aggregate emissions generates total aggregate pfd levels which are higher than each of the maximum aggregate pfd limits at each angle.

This is further demonstrated in the equations below:

$$\begin{aligned} total\ aggregate\ pfd\ at\ the\ IMT\ BS\ &= pfd(\theta 1) + pfd(\theta 2) \\ &= PFD(\theta 1) + PFD(\theta 2) \\ &= X + Y \end{aligned}$$

$$\boldsymbol{which\ is\ higher\ than\ X = PFD(\theta 1)}$$

$$\boldsymbol{and\ also\ higher\ than\ Y = PFD(\theta 2)}$$

As it can be seen from the above, although the emissions of each satellite are compliant with the maximum aggregate pfd limits visible at each angle θ_1 and θ_2 at the IMT BS, their total aggregate effect causes higher pfd levels than the maximum aggregate pfd limits at each specific angle, risking interference at the IMT BS receiver.

Suitability considerations of Equation 1 for the protection of IMT UEs

In contrast to the IMT BSs, IMT UEs are expected to be assumed to have an omnidirectional antenna pattern. In such cases where $G_r(\theta)$ refers to the gain of an omnidirectional pattern, the consideration of angle θ becomes obsolete since the IMT UE receiver gain could be considered the same in all directions. In such case, the Equation 1 takes the format shown below:

$$PFD = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_r + \text{L} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \tag{2}$$

where:

G_r: omnidirectional antenna gain in dBi of the IMT UE.

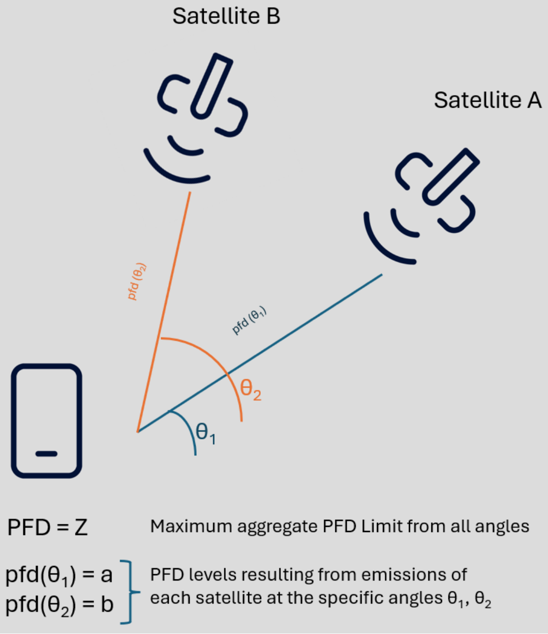
The resulting pfd limit would be independent of the angle of arrival at the IMT UE and it would be a single value representing the maximum aggregate pfd limit from all possible sources from all visible angles.

A recreation of the scenario of Figure 1, but now for the case of protecting the IMT UE, is demonstrated in Figure 2.

Formatted: English (United States)

FIGURE A1-2

pfd limit and pfd levels for two satellites at visible angles θ1 and θ2 at the IMT UE



In the case of using the above Equation 2 as a methodology to derive a pfd limit to protect IMT UEs, the technical regulatory requirement for the maximum aggregate pfd limit produced by Equation 2 would be that:

$$\mathrm{pfd}(\theta 1) + pfd(\theta 2) \leq PFD$$

and the resulting pfd levels from all possible interfering sources from all visible angles would be compliant with both the pfd regulatory limit and the total maximum aggregate pfd level that can be handled at the IMT UE.

Conclusion - Proposal

From the above analysis it can be seen that the angle dependent pfd(θ) equation, in combination with the fact that IMT BSs have directional antenna patterns, as well as with the fact that the effect of aggregate emissions from multiple satellites of one or more satellite constellations needs to be considered, render Equation 1, in the format presented in Document 5D/322, not to be a suitable methodology to derive confident pfd limits for the protection of IMT uplinks (i.e. IMT BS). Therefore, we invite the group to consider the above analysis in the discussions for defining a methodology suitable for deriving the maximum aggregate pfd limit to protect IMT BS from all possible interfering sources from all possible angles.

Formatted: English (United States)

Study B (Doc. 5D/533 (Multi MNOs), Doc 5D/775 (Orange))

[Note: Questions were raised with regards to the assumption, methodology and result.]

Formatted: Font: Bold, Italic

Formatted: Normal

1 Introduction

WRC-27 agenda item 1.13 deals with direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage using the IMT frequency bands between 694/698 MHz and 2.7 GHz.

This document discusses the protection of the terrestrial IMT networks from potential interferences from DC-MSS-IMT satellite stations.

2 Protection of Terrestrial IMT Networks

2.1 Frequency bands consideration

It is assumed DC-MSS-IMT will be operated in FDD bands. Terrestrial IMT networks operating in both TDD and FDD frequency bands need to be protected.

It is proposed to group the frequency bands into three frequency ranges in the calculation of pfd limits for the protection of the terrestrial IMT networks:

1) Band Group_1: 694/698 MHz ~ 1 GHz.
2) Band Group_2: 1 ~ 2.2 GHz.
3) Band Group_3: 2.2 ~ 2.7 GHz.

For all of the three Band Groups, both non-AAS and AAS BS antennas should be considered.

2.2 Protection of terrestrial IMT networks

The protection of the terrestrial IMT networks need to take into account all interfering sources. There are many satellite stations per satellite system, and there are also multiple satellite systems using IMT frequency bands.

The aggregation effects of interferences from multiple satellites per system and the interference apportionment between multiple DC-MSS-IMT systems need to be taken into account in the study of protection of the terrestrial IMT networks.

2.2.1 Relation between pfd value and victim receiver parameters

The pfd value in dB(W/(m² · MHz)) can be calculated with the receiver characteristics of the IMT base station and IMT UE using the equation (1) below:

$$pfd(\theta) = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + L_{feeder} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k: Boltzmann's constant (-228.6 dB(W/(K · Hz)))
T: receiver noise temperature (300 K)
B: reference bandwidth (1 MHz)
NF: receiver noise figure in dB
I/N: protection criteria in dB
$G_r(\theta)$: effective antenna gain in dBi of the receiver antenna in the direction of the interfering satellite
θ: the elevation angle direction towards the satellite
L_{feeder}: receiver antenna feeder loss.

Formatted: English (United States)

2.2.2 Protection of terrestrial IMT network downlink

As illustrated in Figure 1, an UE antenna is modelled as omni-directional, all of the interferences from multiple satellites above the horizontal plan are received by the UE. Some may come from the satellite station main-beams, some others from satellite stations side-lobes.

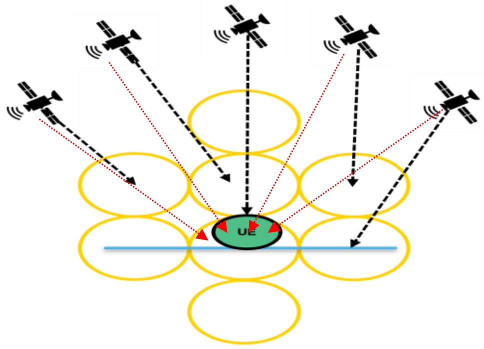
If the interference from a satellite k is denoted as I_k, the total interference I_{system} from a DC-MSS-IMT system at the UE is

$$I\_{system} = \sum_{k=1}^{n} I_k \qquad (2)$$

where n is the total number of satellites seen by an UE from a given DC-MSS-IMT system using IMT frequency band.

FIGURE A1-3

Illustration of multiple interferences from multiple satellites to an UE



As shown in Figure 1, for an omni-directional antenna, gain G(θ) is not elevation angle dependant. If I_{system} /N is used in the equation (1), the calculated pfd value is aggregated pfd value. If I_k /N is used in the equation (1), the calculated pfd value is a single entry pfd value. Without a detail knowledge on number of satellites nor the satellites space distribution, a simple solution is to calculate the total interference level with an assumed aggregation factor α, where I_k is the k^{th} interferer in dB, β is the apportionment factor for DC-MSS-IMT multiple systems.

$$I\_{total} = I\_{system} + \beta = I_k + \alpha + \beta \qquad (3)$$

IMT UE parameters and calculated pfd values for protecting IMT downlinks are given in Table 3.

Formatted: English (United States)

TABLE A1-1

IMT UE parameters and calculated pfd values for the protection of the IMT network downlink

MSS IMT Frequency range	694/698- 1 GHz	1 ~ 2.2 GHz	2.2 ~ 2.7 GHz	
UE antenna gain (dBi)	0 dBi	0 dBi	0 dBi	
Body loss (dB):	0 dB	0 dB	0 dB	
Noise figure (dB)	9	9	9	ITU-R M.2039, M.2292 Many UEs have typical Noise figure of 7 dB 9 dB is used in the pfd calculation
I/N (dB)	–6	–6	–6	ITU-R M.2039, M.2292
Multi-beam/satellite aggregation. factor α (dB)	[tbd]	[11.6]	[tbd]	The simulation method and results are described in Annex 1
Multi-system apportionment factor β (dB)	β =10 log (2)=3 dB	β =10 log (2) = 3 dB	β =10 log (2)=3 dB	This proposed factor would be applicable at the border area with three neighbouring countries. This factor will be updated following the outcome of ITU-R WP 5D discussions
Frequency (MHz) for calculating pfd value	738	1475	2620	Lowest DL frequency from each band group
Aggregated pfd dB(W/(m² · MHz))	**−125**	**−119**	**−114**	With β = 3 dB
Single entry pfd with α dB(W/(m² · MHz))	**−125 - α**	**[−130.6]**	**−114-α**	With β = 3 dB

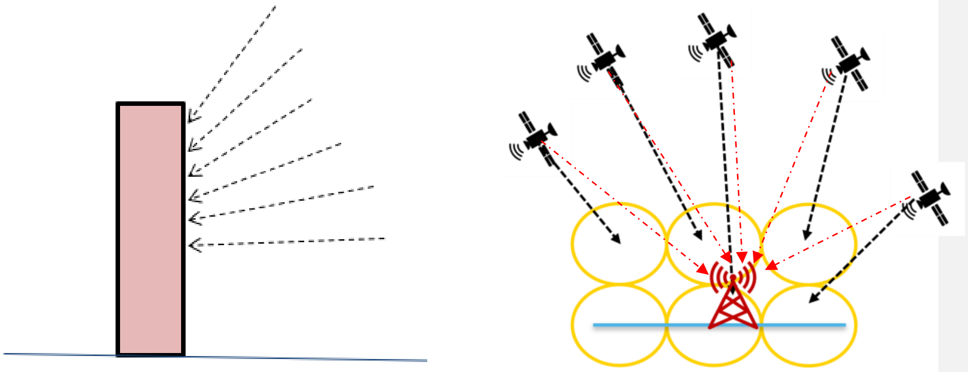
2.2.3 Protection of terrestrial IMT network uplink

As illustrated in Figure 2, a BS antenna (non-AAS and/or AAS) has a directional antenna pattern, the BS antenna gain G(q) is function of the elevation angle. The interference contributions from different satellites at different elevation angles are not the same, it is elevation angle dependent, and in consequence BS antenna gain dependent. The equation (1) can not be used directly to calculate the UL pfd levels, since the uplink protection criterion I_total/N=−6 dB (or −10 dB) where I_$_{\text{total}}$ is the total interference received by the BS from all angles.

Formatted: English (United States)

FIGURE A1-4

Illustration of multiple interferences from multiple satellites to a BS



The interference from DC-MSS-IMT satellite stations to the terrestrial IMT network uplink can happen at three situations:

1) Co-frequency interference in case of the band plan incompatibility between regions, some regional band plan uplink is within the downlink block of another region.
2) Adjacent band case due to out of band emissions from satellite stations.
3) Inter-band case related to the unwanted emissions from satellite stations.

IMT networks are deployed with typical antenna downtilts of 0°, –3°, –6°, –10°. Annex 2 provides the distribution of a French Mobile network BS donwtilts over an area of 20 km from the north-east borderline. It shows that downtilts >=-3° represent 60% to 80% depending on the frequency band, downtilts <=0° and >-3° represent 20% to 40% depending on the frequency band.

In order to cover all of the cases, in the calculation/simulation of the pfd values for IMT network uplink protection, 0° downtilt should be considered for the most adequate protection levels.

There are two possible solutions on IMT TN uplink protection:

1) Epfd

Or

2) UL Pfd mask by considering the aggregation of interferences from multiple satellites within each elevation angle class under the condition that the I_total/N=−6 dB (or −10 dB) where I_{total} is the total interference received by the BS from all angles.

IMT uplink parameters for simulating pfd mask on IMT network uplink protection are summarized in Table 4. It should be pointed out that all of the IMT base stations deployed in the field have noise figure < 3 dB.

Formatted: English (United States)

TABLE A1-2

IMT uplink parameters for simulaing pfd values for the protection of the IMT network uplink

MSS IMT Frequency range	694/698 ~ 1 GHz	1 ~ 2.2 GHz	2.2 ~ 2.7 GHz	
Uplink frequency (MHz) for calculating pfd value	703	1710	2500	
BS antenna type	Non-AAS ITU-R F.1336 (*recommends* 3.1 & 3.2) with ka = 0.7, kp = 0.7, kh = 0.7, and kv = 0.3	Non-AAS ITU-R F.1336 (*recommends* 3.1 & 3.2) with ka = 0.7, kp = 0.7, kh = 0.7, and kv = 0.3	Non-AAS ITU-R F.1336 (*recommends* 3.1 & 3.2) with ka = 0.7, kp = 0.7, kh = 0.7, and kv = 0.3	
IMT BS non-AAS maximum antenna gain (dBi)	15	18	18	ITU-R M.2039, ITU-R M.2292
BS non-AAS antenna feeder loss (dB)	1	1	1	For RRH (Remote Radio Head)
BS AAS antenna	Element gain: 6.4 dB Element beam width: 90º for H 65º for V config: 4x8 sub-array, M_{sub} =3 $d_{v,sub}$=0.7l $d_{h,sub}$=0.5l	Element gain: 6.4 dB Element beam width: 90º for H 65º for V config: 4x8 sub-array, M_{sub} =3 $d_{v,sub}$=0.7l $d_{h,sub}$=0.5l	Element gain: 6.4 dB Element beam width: 90º for H 65º for V config: 4x8 sub-array, M_{sub} =3 $d_{v,sub}$=0.7l $d_{h,sub}$=0.5l	Table 9 of Annex 4.4 to the WP 5D Chair's Report Doc. 5D/716
IMT BS noise figure (dB)	3	3	3	IMT BS in the field has typical noise figure < 3 dB
I/N (dB)	–6 [–10]	–6 [–10]	–6 [–10]	The UL protection threshold will be further revised based on the out of 5D IMT protection threshold

3 Summary and way-forward

This document discusses the terrestrial IMT network downlink and uplink protection from potential interferences due to DC-MSS-IMT satellite stations operating in IMT frequency bands.

It is proposed to consider three band groups in the definition of pfd limits for the protection of terrestrial IMT networks:

1) Band Group_1: 694/698 MHz ~ 1 GHz.
2) Band Group_2: 1 ~ 2.2 GHz.
3) Band Group_3: 2.2 ~ 2.7 GHz.

Based on the principle that the protection of the terrestrial IMT networks need to take into account all interfering sources, single entry pfd or aggregated pfd can be defined for protecting the terrestrial IMT networks downlink.

Formatted: English (United States)

The calculated aggregated pfd limits for protecting the terrestrial IMT network downlink are summarised in Table 3 above. In order to define the single entry DL pfd, the interference aggregation factor was simulated for the frequency band 1800 MHz with the very preliminary assumptions, the preliminary simulation result for the 1800 MHz band is a= 11.6 dB at 99% of probability. The interference aggregation factor simulation will be updated with the progress on the discussions on the assumptions for DC-MSS-IMT satellite stations such as number of satellites per constellation, altitude of satellite stations, satellite antenna patterns, etc.

There are two possible solutions on the IMT TN uplink protection:

1) Epfd

Or

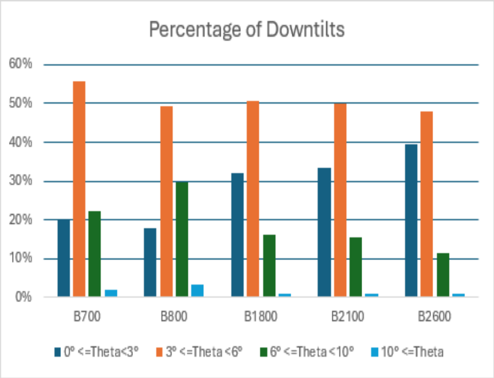
2) UL pfd mask by considering the aggregation of interferences from multiple satellites within each elevation angle class under the condition that the I_total/N= –6 dB (or –10 dB) where I_total is the total interference received by the BS from all angles.

Terrestrial IMT network BS antenna downtilt

The distribution of a French IMT network in the north-east country border area over 20 km from the borderline is given in Figure A2-1, it shows that downtilts >=-3° represent 60% to 80% depending on the frequency band, downtilts <=0° and >-3° represent 20% to 40% depending on the frequency band.

FIGURE A1-5

Distribution of IMT TN BS antenna downtilt in France country border Area



Formatted: English (United States)

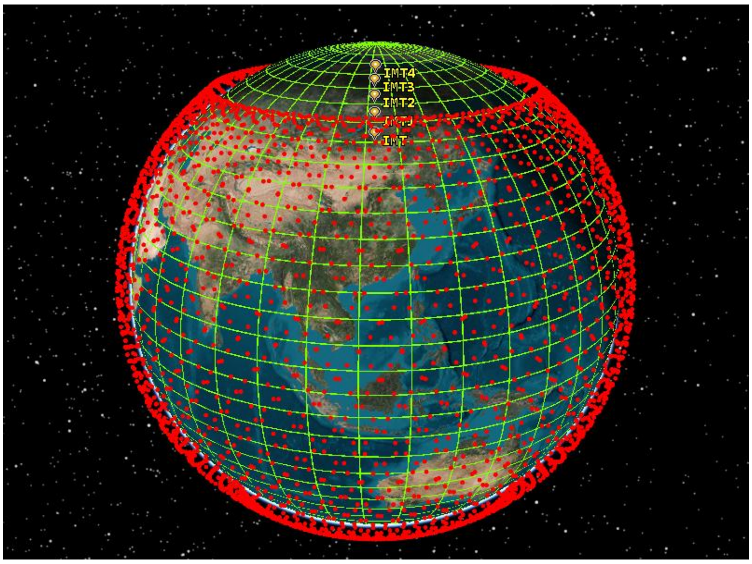
Study C (Doc 5D/483(RUS))

When implementing MSS within the frequency bands identified for terrestrial segment of IMT, it is crucial to ensure the protection of IMT stations. This protection is particularly important in cross-border scenarios, where Country A deploys MSS, and Country B uses the same frequency bands solely for terrestrial IMT stations. It also taken into account that the level of interference largely depends on the separation distances between the IMT stations and the coverage area of MSS in adjacent countries.

Figure 1 illustrates a potential scenario, highlighting that the separation distances between IMT stations and MSS can vary depending on the latitude. This variability underscores the need for careful coordination to minimize interference while enabling effective MSS deployment.

FIGURE A1-6

One of the possible configurations of IMT and MSS when MSS will interfere IMT



Typically, an acceptable threshold for throughput loss in IMT networks is 5%. The following equations approximate the throughput over a channel based on the signal-to-interference-plus-noise ratio (SINR, measured in dB) when employing link adaptation:

$$SE\ (SINR), bps/Hz = \begin{cases} 0 & for\ SINR < SINR_{MIN} \\ \alpha \cdot S(SINR) & for\ SINR_{MIN} \le SINR < SINR_{MAX} \\ \alpha \cdot S(SINR_{MAX}) & for\ SINR \ge SINR_{MAX} \end{cases}$$

where:

$S(SINR)$	Shannon bound, $S(SINR) = \log_2(1 + 10^{SINR/10})$ (bps/Hz)
α	Attenuation factor, representing implementation losses
$SINR_{MIN}$	Minimum SINR of the code set, dB
$SINR_{MAX}$	Maximum SINR of the code set, dB.

Formatted: English (United States)

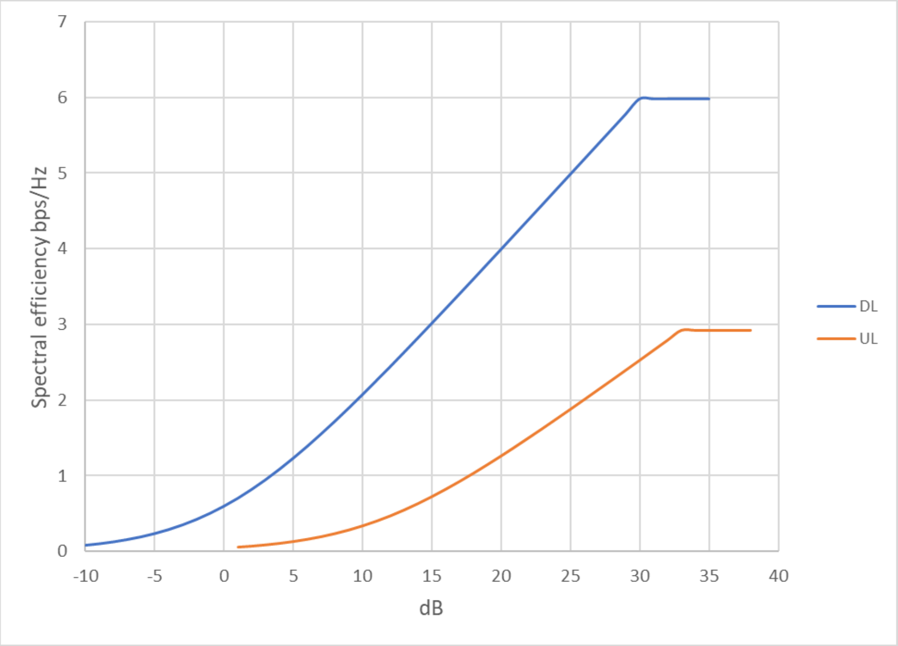
TABLE A1-3

Parameters describing baseline Link Level performance for 5G NR

Parameter	DL	UL	Notes
α	0.6	0.4	Represents implementation losses
$SINR_{MIN}$, dB	−10	−10	Based on QPSK, 1/8 rate (DL) & 1/5 rate (UL)
$SINR_{MAX}$, dB	30	22	Based on 256-QAM, 0.93 rate (DL) & 64-QAM, 0.93 rate (UL)

FIGURE A1-7

Spectral efficiency of UL and DL depending on the SINR levels



Formatted: English (United States)

TABLE A1-4

Downlink spectral efficiency values for each SNR and when 5% throughput losses occur

SNR (dB)	SE (bps/Hz)	SE with 5% reduction (bps/Hz)
–10	0.082502	0.078377009
–9	0.102641	0.097509409
–8	0.127347	0.120979504
–7	0.157479	0.149604883
–6	0.19398	0.184280614
–5	0.237845	0.225953222
–4	0.290085	0.275580723
–3	0.351662	0.334079238
–2	0.423431	0.402259859
–1	0.506066	0.48076298
0	0.6	0.57
1	0.705382	0.670112882
2	0.822063	0.780959662
3	0.949609	0.902128942
4	1.087348	1.032980329
5	1.234424	1.172702729
6	1.389874	1.320380022
7	1.552689	1.475054193
8	1.721872	1.635778715
9	1.896483	1.801658522
10	2.075659	1.971876023
11	2.258637	2.145704789
12	2.444751	2.322513584
13	2.633435	2.501763611
14	2.824212	2.68300155
15	3.016685	2.865850374
16	3.210526	3.049999408
17	3.405468	3.235194544
18	3.601294	3.421229173
19	3.797827	3.607936102
20	3.994927	3.795180545
21	4.192478	3.982854172
22	4.39039	4.170870121
23	4.588588	4.359158883
24	4.787016	4.547664914
25	4.985625	4.736343887
26	5.184379	4.925160462
27	5.383249	5.11408648
28	5.58221	5.303099523
29	5.781244	5.49218175
30	5.980336	5.681318968

Formatted: English (United States)

TABLE A1-5

Downlink spectral efficiency values for each SNR and when 5% throughput losses occur

SNR (dB)	SE (bps/Hz)	SE with 5% reduction (bps/Hz)
–10	0.055001	0.052251339
–9	0.068428	0.065006273
–8	0.084898	0.080653002
–7	0.104986	0.099736589
–6	0.12932	0.122853743
–5	0.158564	0.150635481
–4	0.19339	0.183720482
–3	0.234442	0.222719492
–2	0.282288	0.268173239
–1	0.337378	0.320508654
0	0.4	0.38
1	0.470255	0.446741921
2	0.548042	0.520639775
3	0.633073	0.601419295
4	0.724898	0.688653553
5	0.822949	0.781801819
6	0.926582	0.880253348
7	1.035126	0.983369462
8	1.147915	1.090519143
9	1.264322	1.201105681
10	1.383773	1.314584015
11	1.505758	1.430469859
12	1.629834	1.548342389
13	1.755624	1.667842408
14	1.882808	1.7886677
15	2.011123	1.910566916
16	2.14035	2.033332939
17	2.270312	2.156796363
18	2.400863	2.280819449
19	2.531885	2.405290735
20	2.663285	2.530120363
21	2.794985	2.655236114
22	2.926926	2.780580081

Knowing the values of spectral efficiency when 5% throughput reduction occurs and using base Shannon expression taking into account implementation losses:

$$SE(SINR) = log_2\left(1 + 10^{SINR/10)}\right) \cdot \alpha$$

Formatted: English (United States)

It is possible to derive SINR from that expression. First it is needed to rearrange the formula to isolate log_2:

$$\frac{SE(SINR)}{\alpha} = log_2\left(1 + 10^{SINR/10}\right)$$

Convert base-2 logarithm to base-10 logarithm:

$$log_2(y) = \frac{log_{10}(y)}{log_{10}(2)}$$

So:

$$\frac{SE(SINR)}{\alpha} = \frac{log_2\left(1 + 10^{SINR/10}\right)}{log_{10}(2)}$$

Simplify to log_{10}:

$$log_{10}\left(1 + 10^{SINR/10}\right) = \frac{SE(SINR)}{\alpha} \cdot log_{10}(2)$$

Exponentiate to solve for $10^{SINR/10}$:

$$C = \frac{SE(SINR)}{\alpha} \cdot log_{10}(2)$$

Then, SINR can be calculated using the following expression:

$$SINR = 10 \cdot log_{10}(10^{C} - 1)$$

After SINR values that correspond to the 5% throughput losses are calculated, it is possible to calculate *I/N* for each case of baseline SNR when 5% throughput losses occur using the following expression:

$$I/N = 10log_{10}\left(\frac{10^{SNR/10} + 10^{SINR/10}}{10^{SINR/10}}\right)$$

TABLE A1-6

Dependence of SNR and *I/N* for 5% throughput lossSNR (dB)	**DL** ***I/N* for 5% throughput loss (dB)**	**UL** ***I/N* for 5% throughput loss (dB)**
–10	–12.58205191	–12.58205191
–9	–12.53234092	–12.53234092
–8	–12.47160011	–12.47160011
–7	–12.39787616	–12.39787616
–6	–12.30909749	–12.30909749
–5	–12.20316949	–12.20316949
–4	–12.07810826	–12.07810826
–3	–11.93220748	–11.93220748
–2	–11.76422289	–11.76422289
–1	–11.57354833	–11.57354833
0	–11.36035123	–11.36035123

Formatted: English (United States)

Dependence of SNR and *I/N* for 5% throughput lossSNR (dB)	**DL** ***I/N* for 5% throughput loss (dB)**	**UL** ***I/N* for 5% throughput loss (dB)**
1	–11.12563661	–11.12563661
2	–10.87122046	–10.87122046
3	–10.5996119	–10.5996119
4	–10.31382384	–10.31382384
5	–10.01714594	–10.01714594
6	–9.71291723	–9.71291723
7	–9.40432991	–9.40432991
8	–9.094282982	–9.094282982
9	–8.785291541	–8.785291541
10	–8.479446934	–8.479446934
11	–8.17841717	–8.17841717
12	–7.883475126	–7.883475126
13	–7.595543031	–7.595543031
14	–7.315244103	–7.315244103
15	–7.042954889	–7.042954889
16	–6.778854261	–6.778854261
17	–6.522966945	–6.522966945
18	–6.275200709	–6.275200709
19	–6.035377251	–6.035377251
20	–5.803257224	–5.803257224
21	–5.578560131	–5.578560131
22	–5.360979847	–5.360979847
23	–5.150196527	-
24	–4.945885576	-
25	–4.747724264	-
26	–4.555396504	-
27	–4.368596178	-
28	–4.187029354	-
29	–4.010415661	-
30	–3.838489027	-

To protect IMT user equipment and base stations pfd limits may be used and knowing *I/N* values that are linked to the 5% throughput loss of DL and UL it is possible to derive necessary pfd limits by:

$$PFD = 10log_{10}(kTB) + NF + \frac{I}{N} - 10log_{10}[G_{receiver}] + L_{feeder} - 10log_{10}\left(\frac{\lambda^2}{4\pi}\right)$$

Alternatively, the 5% throughput losses may be linked to the epfd limits.

Formatted: English (United States)

Determining epfd/pfd limits for the frequency bands within the range 694-2700 MHz

To determine the appropriate level of *I/N* for pfd calculations, it is necessary to simulate the SINR of IMT DL and UL channels for each frequency band. This involves considering deployment-related IMT parameters and analyzing the average SINR. The corresponding *I/N* value for the calculated SINR will then be used to establish pfd limits for each frequency band.

This contribution provides a simulation example for the 2–3 GHz frequency band. In this scenario, IMT DL and UL channels are subject to interference from non-GSO in a rural deployment case, which represents the worst-case scenario. For urban and suburban deployments, the likelihood of interference is significantly lower due to clutter shielding and the fact that a large portion of user UEs (up to 70%) will be indoors. Consequently, the rural case, where less Ues are indoors, and no clutter shielding has been simulated.

TABLE A1-7

BS parameters for bands between 2 and 3 GHz

	Rural macro
Cell radius / Deployment density (for bands between 2 and 3 GHz)	4 km
Antenna height	30 m
Sectorization	3 sectors
Typical channel bandwidth	10 or 20 MHz
Element gain (dBi)	6.4
Horizontal/vertical 3 dB beam width of single element (degree)	90º for H 65º for V
Horizontal/vertical front-to-back ratio (dB)	30 for both H/V
Antenna polarization	Linear ±45º
Antenna array configuration (Row × Column)	4 × 8 elements
Horizontal/Vertical radiating element/sub-array spacing, d_h /d_v	0.5 of wavelength for H, 2.1 of wavelength for V
Number of element rows in sub-array, M_{sub}	3
Vertical radiating element spacing in sub-array, $d_{v,sub}$	0.7 of wavelength of V
Pre-set sub-array down-tilt, $\theta_{subtilt}$ (degrees)	3
Array Ohmic loss (dB)	2
Conducted power (before Ohmic loss) per antenna element/sub-array (dBm)	28
Base station horizontal coverage range (degrees)	±60
Base station vertical coverage range (degrees)	90-100
Mechanical downtilt (degrees)	3
Maximum base station output power/sector (e.i.r.p.) (dBm)	72.28

Formatted: English (United States)

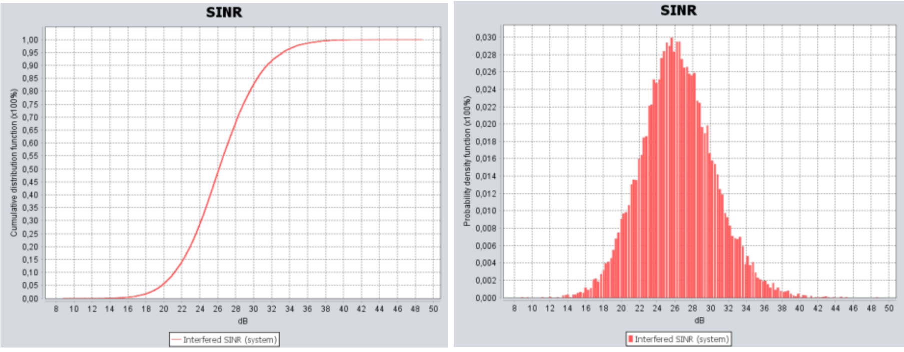
TABLE A1-8

UE parameters for bands between 2 and 3 GHz

	Rural macro
User terminal characteristics	
User equipment density for terminals that are transmitting simultaneously (Note 1)	3 Ues per sector
UE height (Note 2)	1.5 m
Average user terminal output power	Use transmit power control
Typical antenna gain for user terminals	−3 dBi
Body loss	4 dB
UE TDD activity factor	25%
Transmit power control	
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1
Maximum user terminal output power, PCMAX	23 dBm
Power (dBm) target value per RB, P0_PUSCH (Note 3)	−92.2
Path loss compensation factor, α (same as “balancing factor” mentioned in Rec. ITU-R M.2101)	0.8

FIGURE A3-8

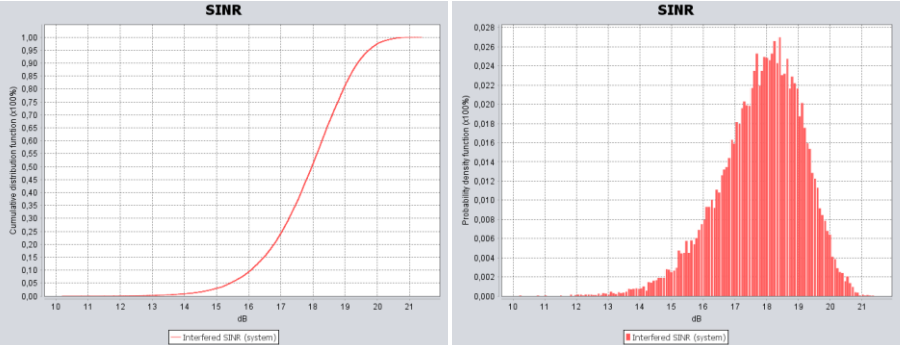
SINR CDF and PDF for DL in 2-3 GHz



Formatted: English (United States)

FIGURE A4-9

SINR CDF and PDF for UL in 2-3 GHz



The results indicate that for LoS conditions with Rural deployment in 2-3 GHz, the average SINR for DL is 26 dB whereas for the UL is 18 dB.

Based on the above, it is possible to derive the average epfd/pfd limits to protect IMT BS and UE in the frequency bands within the range 694-2 690 MHz, knowing that based on the Table 4 *I/N* values for the downlink case the average *I/N* = –4.55 dB and for the uplink case the average *I/N* would be *I/N* = –6.2 dB.

As can be noted, for the UL case pdf/epfd values should be based on the *I/N* = –6 dB criterion, whereas for the DL it is possible to mitigate the pfd/epfd levels using the *I/N* = –4.5 dB.

Formatted: English (United States)

Study D (Doc 5D/525 (Ericsson))

[Note: Questions were raised with regards to the methodology used in the study.]

Formatted: Font: Bold, Italic, (Asian) Chinese (Simplified, Mainland China)

Formatted: Normal, Space After: 0 pt

PFD limits for Protection of terrestrial IMT

PFD levels for protection of terrestrial IMT (IMT UE and IMT BS) are defined based on the IMT protection criterion and the characteristics of IMT receivers. The regulatory measures (PFD limits) need to be defined based on these PFD levels taking into account the functionality and characteristics of the aggressor (DC-MSS-IMT).

DC-MSS-IMT systems contain of hundreds or thousands of satellites in low-Earth orbit. Thus, the terrestrial IMT receives interference from multiple satellites, either in one constellation or in multiple constellations. This aggregate interference must be considered when defining regulatory measures for protection of terrestrial IMT from DC-MSS-IMT.

Multiple options to define the PFD limits are identified for further consideration in the last WP 5D meeting in October 2024 (Annex 4.15 to WP 5D Chair's Report):

- PFD per satellite (PFD produced by each satellite of DC-MSS-IMT system)
- Aggregate PFD per system (summation of PFDs produced by all satellites in an DC-MSS-IMT system)
- EPFD per system and aggregate EPFD for multiple systems (EPFD as defined in Article No. **22.5C.1** of RR)

Defining PFD per satellite would require prior assessment of two factors:

1. One factor based on DC-MSS-IMT deployment to consider the aggregate interference from multiple satellites in one system (multi-satellite aggregation factor), noting that this aggregation factor needs to take into account future development of the DC-MSS-IMT system.
2. Another factor to consider is the aggregate interference from different DC-MSS-IMT systems which could be actively transmitting in visibility of the border (multi-system aggregation factor).

To estimate these factors, information on the functionality and characteristics of the DC-MSS-IMT system is required.

In the following the options to define PFD limits for protection of IMT UE and IMT BS starting from the maximum tolerable interference obtained from IMT protection criterion and the characteristics of IMT UE and IMT BS are discussed.

Protection of IMT UE from DC-MSS-IMT

PFD levels to protect IMT UE can be derived based on the IMT UE characteristics and IMT protection criterion:

$$\text{PFD level to protect IMT UE} = 10\,log_{10}(kTB) + NF + \frac{I}{N} - 10\log_{10}[G_{\mathrm{UE}}] - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k: Boltzmann's constant (-228.6 dB(W/(K · Hz)))
T: receiver noise temperature (300 K)
B: reference bandwidth (1 MHz)
NF: receiver noise figure in dB
I/N: protection criterion in dB

Formatted: English (United States)

G_{UE}: antenna gain of IMT UE in in linear scale.

To protect IMT UE from harmful interference due to DC-MSS-IMT, the aggregate interference due to all visible satellites operating co-frequency (either in one constellation or in multiple constellations) should not exceed the value obtained by equation (1). This value can be seen as an interference budget to protect IMT UE from harmful interference and can be used as the aggregate EPFD limit for protection of IMT UE.

The value obtained by equation (1) is the aggregate PFD limit or EPFD limit per system if only one DC-MSS-IMT system causes interference. In case of having potential interference from multiple systems, the interference budget must be partitioned between different systems, meaning that a multi-system aggregation factor must be estimated and subtracted from the value obtained by equation (1) to achieve the aggregate PFD limit or EPFD limit per system.

$$\text{Aggregate PFD limit per system} = \text{PFD level to protect IMT UE} - \text{multi system aggregation factor}$$

$$\text{EPFD limit per system} = \text{PFD level to protect IMT UE} - \text{multi system aggregation factor}$$

To define the PFD limit per satellite, an aggregation factor to consider the aggregate interference from multiple satellites in one MSS-SC system must be estimated and subtracted from the aggregate PFD limit per system.

$$\begin{aligned}\text{PFD limit per satellite} &\\ &= \text{PFD level to protect IMT UE} - \text{multi system aggregation factor}\\ &- \text{multi satelite aggregation factor}\end{aligned}$$

Protection of IMT BS from DC-MSS-IMT

To protect IMT BS from harmful interference due to DC-MSS-IMT, the aggregate interference received by IMT BS due to all visible satellites operating co-frequency (either in one constellation or in multiple constellations) should not exceed

$$I_{\max} = 10\,log_{10}(kTB) + NF + \frac{I}{N}.$$

If only one satellite caused interference, PFD mask to protect IMT BS could be derived as:

$$PFD(\varphi) = 10\,log_{10}(kTB) + NF + \frac{I}{N} - 10\log_{10}[G_{BS}(\varphi)] + L_f - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (2)$$

where:

φ is the elevation angle toward the interfering satellite

$G_{BS}(\varphi)$ is the antenna gain of BS in the direction of the interfering satellite (in linear scale), and

L_f is the BS antenna feeder loss (in dB).

However, in case of DC-MSS-IMT, the interfering signal comes from multiple satellites and since the IMT BS has a directional antenna, the impact of PFDs from different satellites on its performance depends upon the relative gain towards these interfering satellites. This means the total interference received by the IMT BS is (see Figure 1 for a case with 3 interfering satellites)

$$I_{total} = 10\log_{10}\sum_i I_i - L_f = 10\log_{10}\sum_i \left(\frac{10^{\frac{P_i}{10}}\,G_{Sat}(\theta_i)}{4\pi d_i^2}\,G_{BS}(\varphi_i)\,\frac{\lambda^2}{4\pi}\right) - L_f \qquad (3)$$

where:

P_i: transmit power of the i-th interfering satellite in dBW

Formatted: English (United States)

$G_{Sat}(\theta_i)$: the gain of the i-th interfering satellite toward the victim receiver

$G_{BS}(\varphi_i)$: antenna gain of the victim receiver antenna in the direction of the i-th interfering satellite

θ_i and φ_i: angles to specify the direction between the victim receiver and the i-th interfering satellite

d_i: the distance between the victim receiver and the i-th interfering satellite.

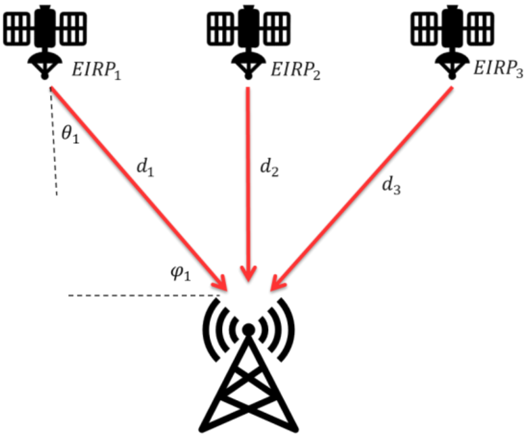
This total interference received by the BS should be equal to the maximum tolerable interference ($I_{\max}$). Therefore,

$$10\log_{10}\sum_i\left(\frac{10^{\frac{P_i}{10}}G_{Sat}(\theta_i)}{4\pi d_i^2}G_{BS}(\varphi_i)\right)=10\,log_{10}(kTB)+NF+\frac{I}{N}+L_f-10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (4)$$

The left-hand side of equation (4) looks like the EPFD (equivalent power flux density) equation in Article No. **22.5C.1** of ITU-R Radio Regulations. Therefore, EPFD which considers the aggregate interference due to all transmitting stations within a satellite constellation taking into account the directional antenna gain of the victim receiver towards interfering satellites is a proper metric to protect IMT BS. Further consideration is needed on the BS antenna gain when deriving the regulatory limits for protection of AAS base stations as the antenna pattern of AAS BSs vary.

FIGURE A5-10

An IMT BS receiving interference from three satellites



The aggregate PFD from a constellation at the location of IMT BS is (see Figure 1 for a case with 3 interfering satellites)

$$\text{Aggregate PFD}=10\,log_{10}\sum_i\frac{EIRP_i(\theta_i)}{4\pi d_i^2}=10\log_{10}\sum_i\left(\frac{10^{\frac{P_i}{10}}G_{Sat}(\theta_i)}{4\pi d_i^2}\right) \qquad (5)$$

It is unclear how this aggregate PFD can be related to the characteristics of IMT BS to ensure protection. Further consideration is needed in this regard.

Formatted: English (United States)

The EPFD level which can be obtained using equation (4) is the “EPFD limit per system” if only one DC-MSS-IMT system causes interference. In case of having potential interference from multiple DC-MSS-IMT systems, either the EPFD level obtained using equation (4) should be defined as “Aggregate EPFD limit”, or the interference budget should be partitioned between the systems, meaning that a multi-system aggregation factor must be estimated and applied as following:

$$\text{EPFD limit per system} = \text{Aggregate EPFD limit to protect IMT BS} - \text{multi system sgregation factor}$$

Conclusion and summary of the three options

A comparison of all the options are summarized in the table below. It show that a multi-system aggregation factor should be estimated and used when defining “Aggregate PFD limit per system” or “EPFD limit per system” to consider the aggregate interference due to multiple DC-MSS-IMT systems.

“PFD limit per satellite” does not seem suitable for protection of IMT BS as there are multiple interfering satellites that their impact on IMT BS depends on the gain of BS antenna in the direction of interfering satellites. In case of defining “PFD limit per satellite” for protection of IMT UE, in addition to the multi-system aggregation factor, the multi-satellite aggregation factor to model the aggregate interference from multiple satellites in one MSS-SC system must be applied. To estimate these aggregation factors, the information on the functionality and characteristics of DC-MSS-IMT systems is needed.

While EPFD limit seems a proper metric for protection of IMT BS which has directional antennas, it is unclear how “Aggregate PFD limit” can be defined for protection of IMT BS. Further study and consideration are needed in this regard.

Since the aggregate EPFD limit considers the aggregate interference from multiple DC-MSS-IMT systems as well as all the satellites in each system, there is no need to apply any aggregation factor when using aggregate EPFD limit as the regulatory measure.

TABLE A1-9

	Protection of IMT UE	**Protection of IMT BS**
PFD levels/masks based on total amount of tolerable interference	$10\,log_{10}(kTB) + NF + \frac{I}{N} - 10\log_{10}[G_{\text{UE}}] - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right)$	$10\,log_{10}(kTB) + NF + \frac{I}{N} - 10\log_{10}[G_{BS}(\varphi)] + L_{feeder} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right)$ If there is only one interfering satellite
PFD limit per satellite	PFD levels – multi system aggregation factor – multi satellite aggregation factor	Not suitable when we have multiple interfering satellites
Aggregate PFD limit per system	PFD levels – multi system aggregation factor	Needs further consideration
EPFD limit per system	PFD levels – multi system aggregation factor	Aggregate EPFD limit – multi system aggregation factor

Formatted: English (United States)

Aggregate EPFD limit	PFD levels	Can be calculated using equation (4)

Study E (Document 5D/477 (CHN), 5D/715 (CHN), 5D/823 (CHN))

[Note: Questions were raised regarding the number of assumptions and methodology]

1 Introduction

This attachment provides a deterministic calculation-based methodology and a dynamic simulation-based methodology for deriving the aggregate PFD value per system to protect IMT system at the border between neighboring countries from DC-MSS-IMT space stations for possible new MSS allocation on a primary or secondary basis. Based on technical characteristics of DC-MSS-IMT and IMT system, the preliminary results of PFD values for protecting IMT UE are provided.

2 Technical characteristics

2.1 Technical characteristics of DC-MSS-IMT

The technical characteristics of DC-MSS-IMT of System 2 and System 3 in the following Tables coming from Annex 7 to the Chair's Report of WP 4C (See ~~Annex 7 to~~ Doc. 4C/356) ~~provides the technical characteristics of DC-MSS-IMT towards WRC-27 agenda item 1.13 which could be used as the basis of~~are used in the study. ~~Detailed technical characteristics are summarized in Table 1 and Table 2.~~

2.1.1 System 2

TABLE A1-10

Parameters of orbital configuration

Altitude (km)	Inclination (deg)	Planes	Sats per plane	RAAN spacing (deg)	Total number of sats
500	55	60	60	6	3 600

Formatted: English (United States)

TABLE A1-11

Parameters of DC-MSS-IMT

	Parameter	**Unit**	**Frequency**				
Downlink (Space-to-Earth)	Frequency band	MHz	694/698-960	1 427-1 518	1 805-1 880 /2 110-2 170 /1 880-1 920	2 300-2 400	2 500-2 690
	Typical Emission Bandwidth	MHz	5	5	5	5	5
	S/S Transmitter power per beam	Dbw	9	13	13	13	13
	S/S EIRP per beam	Dbw	39.9	46.2	48.2	50.4	51.1
	EIRP spectral density per beam	dBW/Hz	-27.1	-20.8	-18.8	-16.6	-15.9
	S/S Antenna pattern	n/a	M.2101	M.2101	M.2101	M.2101	M.2101
	Single element antenna gain	DBi	2	3.92	4.11	4.15	4.15
	Antenna array configuration (Row×Column)		28×28	29×29	36×36	46×46	50×50
	Horizontal 3dB beamwidth of single element	°	120	118	118	110	110
	Vertical 3dB beamwidth of single element	°	120	118	112	110	110
	Horizontal radiating element spacing	dH/λ	0.5	0.5	0.5	0.5	0.5
	Vertical radiating element spacing	dV /λ	0.5	0.5	0.5	0.5	0.5
	Horizontal Front-to-back ratio	Db	30	30	30	30	30
	Vertical Front-to-back ratio	dB	30	30	30	30	30
	ACLR	dB	25	25	25	25	25
Uplink (Earth-to-space)	Frequency band	MHz	694/698-960	1 427-1 518	1 710-1 785 /1 920-1 980 /2 010-2 025	2 300-2 400	2 500-2 690
	Emission Bandwidth (s)	MHz	1.4	1.4	1.4	1.4	1.4
	Polarization	n/a	Linear polarization	Linear polarization	Linear polarization	Linear polarization	Linear polarization
	E/S Transmitter power	dBW	−7	−7	−7	−7	−7

Formatted: English (United States)

	Parameter	Unit	Frequency				
	Antenna gain	dBi	−3	−3	−3	−3	−3
	E/S EIRP	dBW	−10	−10	−10	−10	−10
	Antenna Pattern		Omni direction	Omni direction	Omni direction	Omni direction	Omni direction
	Spectral mask	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.2, Table 6.5.2.2-1.				
	ACLR	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.4.1.				
	Out of band emissions	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.3.1.				
	Min Elevation	°	35	35	35	35	35

*Note: There is currently no available ITU-R recommendation in force to simulate satellite phased array antenna for DC-MSS-IMT system sharing and compatibility studies. The satellite engineering design and antenna gain simulation is based on Recommendation ITU-R M.2101 complimented with antenna orientation parameter.

Formatted: English (United States)

2.1.2 System 3

2.1.2.1 525 km orbital constellation

TABLE A1-12

Parameters of orbital configuration

Altitude (km)	**Inclination (deg)**	**Planes**	**Sats per plane**	**RAAN spacing (deg)**	**Total number of sats**
525	53	28	120	12.9	3 360

TABLE A1-13

Parameters of DC-MSS-IMT

	Parameter	**Unit**	**Frequency**					
Downlink (Space-to-Earth)	Frequency band	MHz	694/698-960	1 427-1 518	1 710-2 025	2 110-2 200	2 300-2 400	2 500-2 690
	Typical Emission Bandwidth	MHz	5	5	5	5	5	5
	EIRP spectral density per beam	dBW/Hz	–28.1 dBW/Hz @EL 90° . In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust	–22.5dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust	–20.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust	–20.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust	–18.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust	–18.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust

Formatted: English (United States)

	Parameter	Unit	Frequency					
			eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	eirp at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases
	maximum PFD on the ground per satellite	dBW/ m^2/MHz	–93.4	–87.9	–85.5	–85.5	No info	–83.5
	S/S Antenna pattern	n/a	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528
	S/S Peak antenna gain	dBi	The following assumptions should	The following assumptions should	The following assumptions should	The following assumptions should	The following assumptions should	The following assumptions should

Formatted: English (United States)

	Parameter	**Unit**	**Frequency**					
			be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.	be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.	be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.	be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.	be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.	be used: G_max=34.1 dBi, L_r=L_t=1.6 m, SLR=20 dB, l=2, λ=0.15 m.
	ACLR	dB	No info	No info	No info	No info	No info	No info
	Out of band emissions		EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)
Uplink (Earth-to-	Frequency band	MHz	694/698-960	1 427-1 518	1710-2025	210-2200	2 300-2 400	2 500-2 690
	Min Elevation	°	20	20	20	20	20	20

Formatted: English (United States)

2.1.2.2 340 km orbital constellation

TABLE A1-14

Parameters of orbital configuration

Altitude (km)	**Inclination (deg)**	**Planes**	**Sats per plane**	**RAAN spacing (deg)**	**Total number of sats**
340	53	48	110	7.5	5 280

TABLE A1-15

Parameters of DC-MSS-IMT

	Parameter	**Unit**	**Frequency**					
Downlink (Space-to-Earth)	Frequency band	MHz	694/698-960	1 427-1 518	1 710-2 025	2 110-2 200	2 300-2 400	2 500-2 690
	Typical Emission Bandwidth	MHz	5	5	5	5	5	5
	EIRP spectral density per beam	dBW/Hz	–28.1 dBW/Hz @EL 90° . In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite	–22.5dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite	–20.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite	–20.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite	–18.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite	–18.1dBW/Hz @EL 90°. In terms of modelling the variation of PFD with slanth path, several options can be considered, and correspond to several ways operators manager real-world operations: • Keep PFD constant on the ground, i.e. adjust eirp at the satellite

Formatted: Font: Times New Roman, 10 pt, Not Bold, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, Not Bold

Formatted: Font: Times New Roman, 10 pt, Not Bold, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, Not Bold, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, Not Bold, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, Not Bold, English (United Kingdom)

Formatted: English (United States)

	Parameter	**Unit**	**Frequency**					
			to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases	to ensure a constant PFD on the ground regardless of the slant path / arrival angle • Keep eirp constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases • Hybrid mode: some systems adjust the eirp to ensure constant PFD on the ground only up to a certain elevation angle, after which the eirp is not increased more, thus the PFD decreases as the elevation angle decreases
	maximum PFD on the ground per satellite	dBW/m^2/MHz	–92.4	–86.9	–84.5	–84.5	No info	–82.5
	S/S Antenna pattern	n/a	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528	Recommends 1.4 of ITU-R S.1528
	S/S Peak antenna gain	dBi	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,	The following assumptions should be used: G_max=34.1 dBi, L_r=L_t=1.6 m,

Formatted: Centered, Indent: Left: 0 cm, First line: 0 cm, Don't keep lines together, Tab stops: Not at 14 cm + 16.8 cm

Formatted: English (United States)

	Parameter	**Unit**	**Frequency**					
			SLR=20 dB, l=2, λ=0.15 m.	SLR=20 dB, l=2, λ=0.15 m.	SLR=20 dB, l=2, λ=0.15 m.	SLR=20 dB, l=2, λ=0.15 m.	SLR=20 dB, l=2, λ=0.15 m.	SLR=20 dB, l=2, λ=0.15 m.
	ACLR	dB	No info	No info	No info	No info	No info	No info
	Out of band emissions		EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)	EIRP_1 (f,θ)=-55.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_2 (f,θ)=-73.6+20log10(f/2000)+10 log10cos(θ) (dBW/Hz) EIRP_3 (f,θ)=-83.6+20log10(f/2000)+10log10cos(θ) (dBW/Hz)
Uplink (Earth-to-	Frequency band	MHz	694/698-960	1 427-1 518	1 710-2 025	210-2 200	2 300-2 400	2 500-2 690
	Min Elevation	°	20	20	20	20	20	20

Formatted: Table_fin

Formatted: English (United States)

2.2 Technical characteristics of IMT

Technical characteristics of IMT systems operating in the frequency bands below 1GHz and 1-3GHz can be found in Section 4 of the working document on characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27 (Annex 4.2 to Doc. 5D/413).

2.2.1 Deployment-related parameters of IMT

Detailed deployment-related parameters of IMT systems are summarized as follows~~:~~.

Formatted: English (United States)

TABLE A1-16~~2~~

Deployment-related parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**	**Small cell (outdoor)/Micro cell**	**Indoor (small cell)**
Base station characteristics/Cell structure				
Cell radius / Deployment density (for bands between 1 and 2 GHz) (Report ITU-R M.2292)	> 3 km (typical value to be used in sharing studies 5 km)	0.25-1 km urban / 0.5-3 km suburban (typical value to be used in sharing studies for urban macro 0.5 km and for suburban macro 1 km)	1-3 per urban macro cell <1 per suburban macro site	Depending on indoor coverage/ capacity demand
Cell radius / Deployment density (for bands between 2 and 3 GHz) (Report ITU-R M.2292)	> 2 km (typical value to be used in sharing studies 4 km)	0.2-0.8 km urban / 0.4-2.5 km suburban (typical value to be used in sharing studies for urban macro 0.4 km and for suburban macro 0.8 km)	1-3 per urban macro cell <1 per suburban macro site	Depending on indoor coverage/ capacity demand
Antenna height (Report ITU-R M.2292)	30 m	25 m urban / 30 m suburban (1-2 GHz) 20 m urban / 25 m suburban (2-3 GHz)	6 m	3 m
Sectorization	3 sectors	3 sectors	Single sector	Single sector
Indoor base station deployment	n.a.	n.a.	n.a.	100%
Indoor base station penetration loss	n.a.	n.a.	n.a.	Rec. ITU-R P.2109
Below rooftop base station antenna deployment (Report ITU-R M.2292)	0%	Urban: 30% (1-2 GHz), 50% (2-3 GHz) Suburban: 0%	100%	n.a.
Typical channel bandwidth	10 or 20 MHz	10 or 20 MHz	10 or 20 MHz	10 or 20 MHz
Network loading factor (base station load probability X%) (see section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6)	20%, 50%	20%, 50%	20%, 50%	20%, 50%
TDD / FDD	Depending on band	Depending on band	Depending on band	Depending on band
BS TDD activity factor	75%	75%	75%	75%

Formatted: English (United States)

TABLE A1-13

UE parameters for bands between 1 and 3 GHz

	Rural macro	**Urban/suburban macro**	**Small cell (outdoor)/Micro cell**	**Indoor (small cell)**
User terminal characteristics				
Indoor user terminal usage (Report ITU-R M.2292)	50%	70%	70%	100%
Indoor user terminal penetration loss	Rec. ITU-R P.2109	Rec. ITU-R P.2109	Rec. ITU-R P.2109	Rec. ITU-R P.2109
User equipment density for terminals that are transmitting simultaneously (Note 1)	3 UEs per sector	3 UEs per sector	3 UEs per sector	3 UEs per sector
UE height (Note 2)	1.5 m	1.5 m	1.5 m	1.5 m
Average user terminal output power	Use transmit power control	Use transmit power control	Use transmit power control	Use transmit power control
Typical antenna gain for user terminals	−3 dBi	−3 dBi	−3 dBi	−3 dBi
Body loss	4 dB	4 dB	4 dB	4 dB
UE TDD activity factor	25%	25%	25%	25%
Transmit power control				
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1			
Maximum user terminal output power, PCMAX	23 dBm	23 dBm	23 dBm	23 dBm
Power (dBm) target value per RB, P0_PUSCH (Note 3)	−92.2	−92.2	−87.2	−87.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8	0.8	0.8	0.8

Formatted: English (United States)

2.2.2 Beamforming antenna characteristics of IMT

Detailed beamforming antenna characteristics of IMT systems are provided as follows. IMT AAS BSs are considered in this study.

TABLE A1-174

Beamforming antenna characteristics for IMT in 1 710-4 990 MHz

		Rural macro	**Suburban macro**	**Urban macro**	**Urban small cell (outdoor)/Micro cell**	**Indoor (small cell)**
1	**Base station antenna characteristics**					
1.1	Antenna pattern	Refer to the extended AAS model in Table A of Annex 3			Refer to section 5 of Rec. ITU-R M.2101	N/A
1.2	Element gain (dBi) (Note 1)	6.4	6.4	6.4	6.4	N/A
1.3	Horizontal/vertical 3 dB beam width of single element (degree)	90º for H 65º for V	90º for H 65º for V	90º for H 65º for V	90º for H 65º for V	N/A
1.4	Horizontal/vertical front-to-back ratio (dB)	30 for both H/V	30 for both H/V	30 for both H/V	30 for both H/V	N/A
1.5	Antenna polarization	Linear ±45º	Linear ±45º	Linear ±45º	Linear ±45º	N/A
1.6	Antenna array configuration (Row × Column) (Note 2)	4 × 8 elements	4 × 8 elements	4 × 8 elements	8 × 8 elements	N/A
1.7	Horizontal/Vertical radiating element/sub-array spacing, d_h /d_v	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 2.1 of wavelength for V	0.5 of wavelength for H, 0.7 of wavelength for V	N/A
1.7a	Number of element rows in sub-array, M_{sub}	3	3	3	N/A	N/A
1.7b	Vertical radiating element spacing in sub-array, $d_{v,sub}$	0.7 of wavelength of V	0.7 of wavelength of V	0.7 of wavelength of V	N/A	N/A
1.7c	Pre-set sub-array down-tilt, $\theta_{subtilt}$ (degrees)	3	3	3	N/A	N/A
1.8	Array Ohmic loss (dB) (Note 1)	2	2	2	2	N/A
1.9	Conducted power (before Ohmic loss) per antenna element/sub-array (dBm) (Note 5, 6)	28	28	28	16	N/A
1.10	Base station horizontal coverage	±60	±60	±60	±60	N/A

Formatted: English (United States)

		Rural macro	**Suburban macro**	**Urban macro**	**Urban small cell (outdoor)/Micro cell**	**Indoor (small cell)**
	range (degrees)					
1.11	Base station vertical coverage range (degrees) (Notes 3, 4, 7)	90-100	90-100	90-100	90-120	N/A
1.12	Mechanical downtilt (degrees) (Note 4)	3	6	6	10	N/A
1.13	Maximum base station output power/sector (e.i.r.p.) (dBm)	72.28	72.28	72.28	61.53	N/A

Formatted: English (United States)

2.3 Propagation models

Based on the liaison statement from WPs 3L/3M to WP 5D (Doc. 5D/627~~5D/167~~), Recommendation ITU-R P.619-5 is used to calculate the propagation loss between stations in space and those on the surface of the Earth.

2.4 Protection criteria

When considering DC-MSS-IMT as the interfering system with the possible new MSS allocation on a primary or secondary basis, the IMT protection criterion *I/N* = −6 dB with 100% non-exceedance ~~without any~~ probability ~~(which means the non-exceedance probability of I/N =−6dB is 100%)~~ is considered in this study~~used for the deterministic calculation-based method and the IMT protection criterion with specific non-exceedance probability of I/N =−6dB is used for dynamic simulation-based method~~.

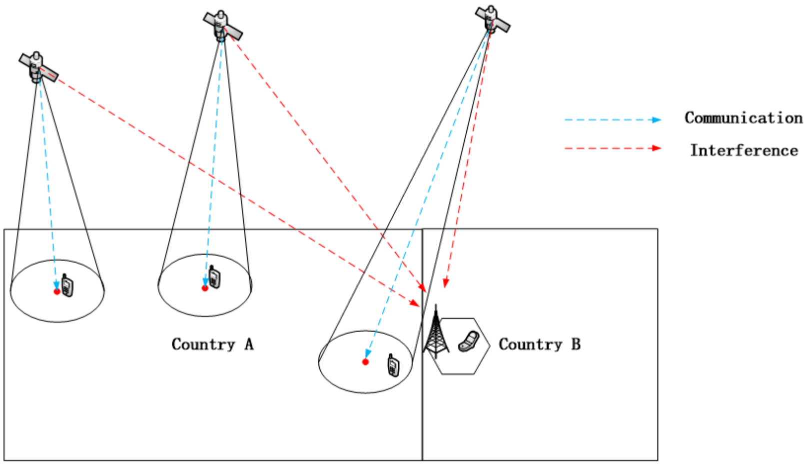
3 Methodology

3.1 Scenario

The scenario of the sharing study to evaluate the aggregate PFD value per system from DC-MSS-IMT space stations to protect IMT system at border between neighboring countries is shown in Figure 1.

FIGURE A6-11

Sharing scenario between DC-MSS-IMT space stations interfere with IMT stations at border between neighboring countries



3.2 Methodology

3.2.1 Deterministic calculation-based method

Deterministic calculation-based method is used to evaluate the aggregate PFD value per system from DC-MSS-IMT space stations to protect IMT system consideration the IMT protection criterion I/N =−6dB without any probability (which means the non-exceedance probability of I/N =−6dB is 100%). Deterministic calculation is derived using the following formula:

Formatted: English (United States)

$$PFD = 10\ log(KTB) + \frac{I}{N} + NF - 10\ log\frac{\lambda^2}{4\pi} - G_{rx}(\theta_{rx}) + OtherLoss$$

where:

PFD:Aggregate PFD from DC-MSS-IMT space stations, dB(W/m^2·MHz)

K:Boltzmann constant, 1.38×10^{-23}J/K

T:Equivalent noise temperature, 290K

B:System bandwidth, MHz

$\frac{I}{N}$:IMT system protection criteria, dB

NF:Receive station noise figure, dBW/MHz

λ:Wavelength, m

$G_{rx}(\theta_{rx})$: IMT receiver station antenna gain in the direction of DC-MSS-IMT space station, dBi

$OtherLoss$: Feeder loss for IMT BS, Body Loss for IMT UE, dB.

3.2.2 Dynamic simulation-based method

Dynamic simulation-based method is used to evaluate the aggregate PFD value per system from DC-MSS-IMT space stations to protect IMT system at the border between neighboring countries with additional isolation required to satisfy the IMT protection criterion with specific non-exceedance probability of I/N =–6dB. Main steps of the simulation are listed as follows.

Step1: Determine the range of simulation area

In this study, DC-MSS-IMT space stations serve DC-MSS-IMT UEs in Country A which shares a border with Country B.

The size of Country A is set to 2442 km in length and 2442 km in width, with the center located at 109°E, 30°N.

Step2: Generate DC-MSS-IMT space stations/DC-MSS-IMT UEs and IMT BSs/UEs

The spatial topology of DC-MSS-IMT space stations is generated at time T based on the parameters of orbital configuration.

DC-MSS-IMT UEs are generated within Country A randomly, and adopts highest elevation satellite selection and ~~pointing strategy~~random satellite selection strategy to connect to DC-MSS-IMT space stations.~~ The center of space station beam can only point within the territory of Country A.~~ When DC-MSS-IMT satellites fly over Country A, this satellite could still provide service to the DC-MSS-IMT user in Country A by locating its main beam towards this user until the minimum elevation angle requirement is not satisfied.

IMT BSs/UEs are generated along the border of Country B. Based on the deployment-related parameters of IMT system, the inter-site distance is 600 m. IMT UEs are generated within IMT base station sectors randomly.

Step3: Simulate the positions of satellite constellation over a period of time and calculate aggregate interference from DC-MSS-IMT space stations to IMT system at each time step

The aggregate interference level is determined by all visible space stations serving DC-MSS-IMT UEs in Country A.

$$I_{total} = 10\ log\left(\sum_n^N \sum_j^J 10^{I_{n,j}/10}\right)$$

Formatted: English (United States)

$$I_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - PL_n + G_{rx}(\theta_{rx})_{n,j} - L_{other}$$

where:

I_{total}: Aggregate interference power density from DC-MSS-IMT space stations, dBW/MHz

$I_{n,j}$: Interference power density from j-th beam of n-th space station, dBW/MHz

P_{tx}: DC-MSS-IMT space station transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of MSS space station is pointing to its serving DC-MSS-IMT UE, dBi

$G_{rx}(\theta_{tx})_{n,j}$: IMT station antenna gain in the direction of MSS space station, dBi

PL_n: Propagation loss, dB

L_{other}: Feeder loss for IMT BS, Body Loss for IMT UE dB

N: The number of DC-MSS-IMT space stations in the interference calculation

J: The number of beams of one DC-MSS-IMT space station.

Furthermore, the required additional isolation could be derived based on the received aggregate interference and maximum allowed interference level based on protection criteria *I/N* = −6 dB at ~~different~~ 100% non-exceedance probabilities~~(X%) of CDF~~.

$$ISO = I_{total} - I_{max}$$

ISO: The required additional isolation that may be needed to protect IMT system to satisfy the protection criteria *I/N* = −6 dB at ~~different~~ 100% non-exceedance probabilities~~(X%) of CDF~~.

I_{max}: The acceptable maximum interference power derived based on the protection criteria and receiver noise, dBW/MHz.

Step4: Calculate required PFD values from DC-MSS-IMT constellation at the border between neighboring countries

Aggregate PFD is calculated by simulation using the following formulas:

$$PFD = 10\,log\left(\sum_n^N \sum_j^J 10^{PFD_{n,j}/10}\right)$$

$$PFD_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - 10log_{10}(4\pi d_n^2)$$

where:

PFD: Aggregate PFD from DC-MSS-IMT space stations, dB(W/m^2·MHz)

$PFD_{n,j}$: PFD from j-th beam of n-th space station, dB(W/(m²·MHz))

P_{tx}: DC-MSS-IMT space station transmit power density

$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of DC-MSS-IMT space station is pointing to its serving DC-MSS-IMT UE, dBi

d_n: Distance between n-th transmit DC-MSS-IMT space station and IMT receiver station, m.

Based on the additional isolation obtained in Step 3, the required PFD values are derived using the following formula:

$$PFD_{value} = PFD - ISO$$

Formatted: English (United States)

where:

PFD_{value}: Required PFD values of DC-MSS-IMT constellation to protect IMT system at the border between neighbouring countries, dB(W/(m²·MHz)).

Step5: Analyse the study results

4 Study results

This section provides the preliminary aggregate PFD value per system for protecting IMT UE from MSS space station based on the methodologies described in Section 3 above.

4.1 PFD values using deterministic calculation-based method for protecting IMT UE

The aggregate PFD values per system using deterministic method mentioned in section 3.2.1 for protecting IMT UE are as follows:

4.1.1 General assumption

IMT UE with body loss 4 dB and antenna gain –3 dBi is considered.

TABLE A1-18

Aggregate PFD values per system using deterministic method for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	800	1450	1 805	2 155	2 350	2 600
λ(m)	0.375	0.2069	0.16667	0.13921	0.12766	0.11538
I/N (dB)	−6	−6	−6	−6	−6	−6
G (dBi)	−3	−3	−3	−3	−3	−3
BodyLoss (dB)	4	4	4	4	4	4
K	1.38E-23	1.38E-23	1.38E-23	1.38E-23	1.38E-23	1.38E-23
T (K)	290	290	290	290	290	290
B (MHz)	1	1	1	1	1	1
NF (dB)	9	9	9	9	9	9
N(dBW/MHz)	−143.98	−143.98	−143.98	−143.98	−143.98	−143.98
PFD(dBW/m^2/MHz)	−114.47	−109.30	−107.40	−105.86	−105.11	−104.23

4.1.2 Other assumption

Specific UE with body loss 0 dB and antenna gain 0 dBi is considered.

TABLE A1-19

Aggregate PFD values per system using deterministic method for protecting IMT UE with body loss 0 dB and antenna gain 0 dBi

Frequency band (MHz)	800	1450	1 805	2 155	2 350	2 600
λ(m)	0.375	0.2069	0.16667	0.13921	0.12766	0.11538
I/N (dB)	−6	−6	−6	−6	−6	−6
G (dBi)	0	0	0	0	0	0

Formatted: English (United States)

Frequency band (MHz)	800	1450	1 805	2 155	2 350	2 600
BodyLoss (dB)	0	0	0	0	0	0
K	1.38E-23	1.38E-23	1.38E-23	1.38E-23	1.38E-23	1.38E-23
T (K)	290	290	290	290	290	290
B (MHz)	1	1	1	1	1	1
NF (dB)	9	9	9	9	9	9
N(dBW/MHz)	−143.98	−143.98	−143.98	−143.98	−143.98	−143.98
PFD(dBW/m^2/MHz)	−121.47	−116.30	−114.40	−112.86	−112.11	−111.23

4.2 PFD values using dynamic simulation–based method for protecting IMT UE

Based on the parameters of DC-MSS-IMT in Section 2.1 of Attachment, this section provides the preliminary simulation results of the aggregate interference contributed by DC-MSS-IMT space stations to different IMT UEs that are located at the border between neighbouring countries in the frequency band ~~2 110~~1710-2 200 MHz. Due to the wide frequency range where different center frequency may lead to different simulation results, the frequency 1 805 MHz is used in this study. According to the simulation results, the aggregate PFD values per system of DC-MSS-IMT space stations at border between neighbouring countries to protect IMT UE are provided.

4.2.1 General assumption

In the general assumption, IMT typical UE with body loss 4 dB and antenna gain –3 dBi are considered.

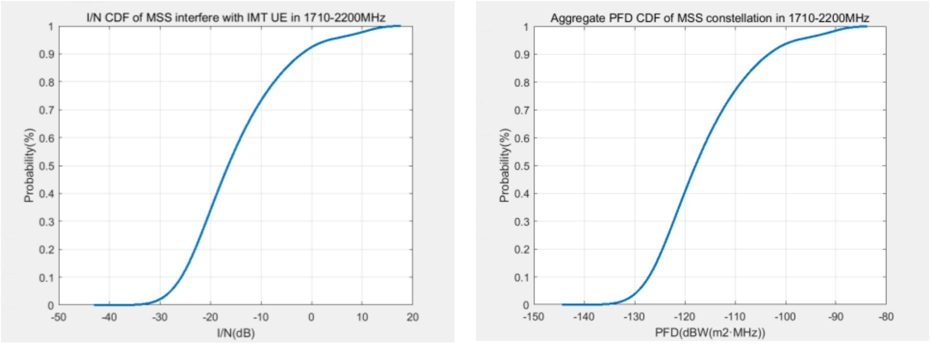
4.2.1.1 System 2

4.2.1.1.1 Highest elevation satellite selection strategy

FIGURE A7-12

(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band ~~2110~~1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band ~~2110~~1 710-2 200 MHz



Formatted: English (United States)

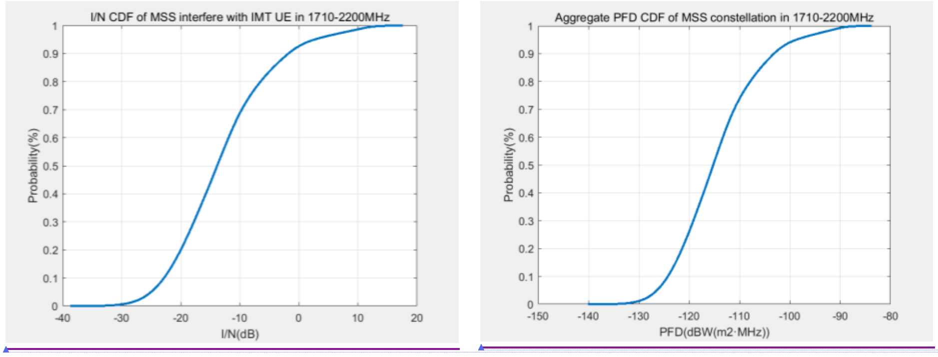
TABLE A1-20~~16~~

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	X% of I/N CDF (%)	*I/N* (dB)	Additional isolation (dB)	PFD value (dBW(m²·MHz))
1 710~~2110~~-2 200	100	17.65~~16.0935~~	23.65~~22.0935~~	–107.4~~-105.86~~
	~~99.99~~	~~15.3296~~	~~21.3296~~	~~-105.0961~~
	~~99.9~~	~~13.5102~~	~~19.5102~~	~~-103.2767~~
	~~99.99~~	~~15.3296~~	~~21.3296~~	~~-105.0961~~

4.2.1.1.2 Random satellite selection strategy

FIGURE A8-13



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

TABLE A1-21

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	X% of I/N CDF (%)	*I/N* (dB)	Additional isolation (dB)	PFD value (dBW(m²·MHz))
1 710-2 200	100	17.62	23.62	–107.4

4.2.1.2 System 3

4.2.1.2.1 Highest elevation satellite selection strategy

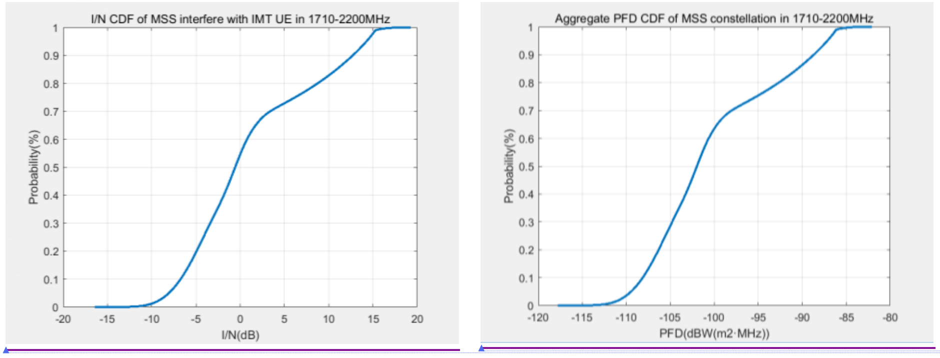
The simulation results for 525 km orbital constellation are as follows.

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: English (United States)

FIGURE A9-14



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

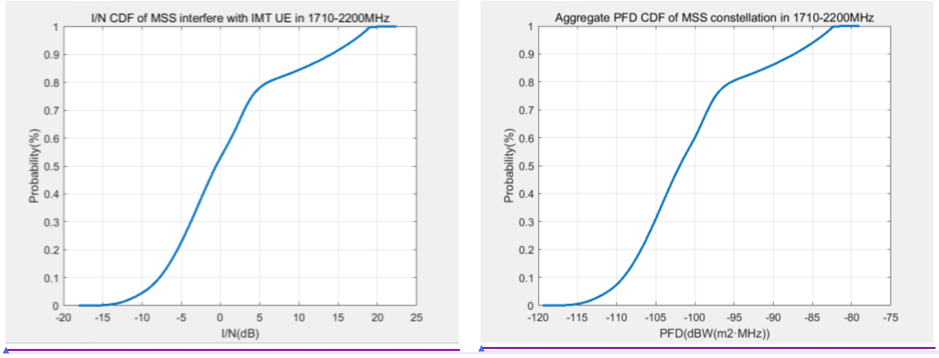
TABLE A1-24

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m^2·MHz))**
1 710-2 200	100	19.29	25.29	–107.4

The simulation results for 340 km orbital constellation are as follows.

FIGURE A10-15



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: English (United States)

TABLE A1-25

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m²·MHz))**
1 710-2 200	100	22.42	28.42	–107.4

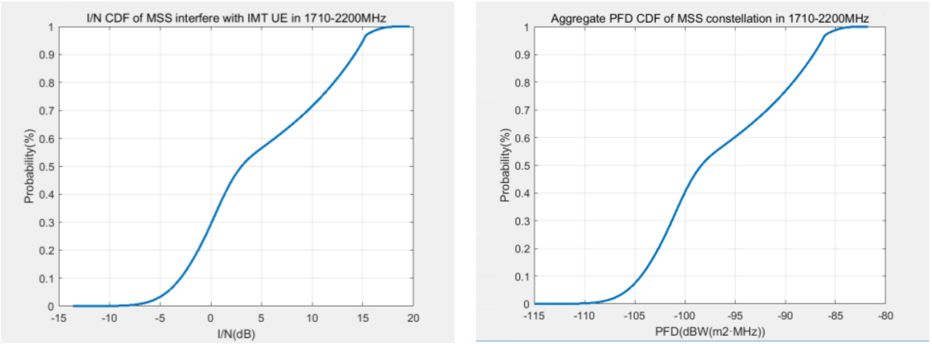
4.2.1.2.2 Random satellite selection strategy

The simulation results for 525 km orbital constellation are as follows.

FIGURE A11-16

(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz



Formatted: Font: Calibri

Formatted: Font: Calibri

TABLE A1-26

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m²·MHz))**
1 710-2 200	100	19.65	25.65	–107.4

Formatted: Font: (Default) Times New Roman Bold, 10 pt, Bold, Italic

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: (Default) Times New Roman, 10 pt

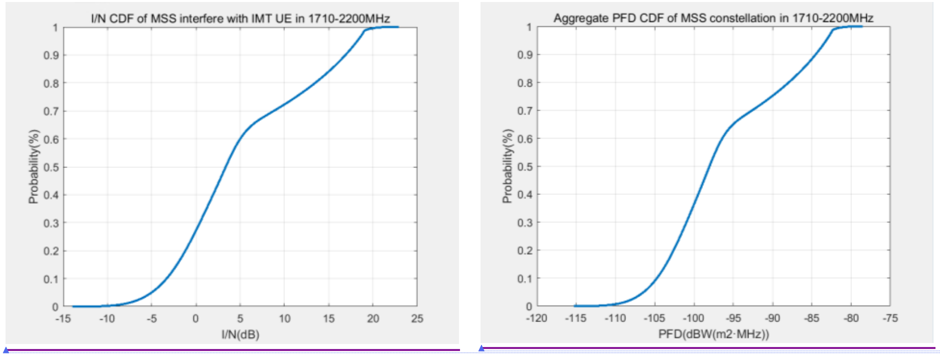
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Table_fin

The simulation results for 340 km orbital constellation are as follows.

Formatted: English (United States)

FIGURE A12-17



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

TABLE A1-27

Simulation results for protecting IMT UE with body loss 4 dB and antenna gain –3 dBi

Frequency band (MHz)	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m^2·MHz))**
1 710-2 200	100	22.88	28.88	–107.4

4.2.2 Other assumption

In other assumption, IMT specific UE with body loss 0 dB and antenna gain 0 dBi are considered.

4.2.2.1 System 2

4.2.2.1.1 Highest elevation satellite selection strategy

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

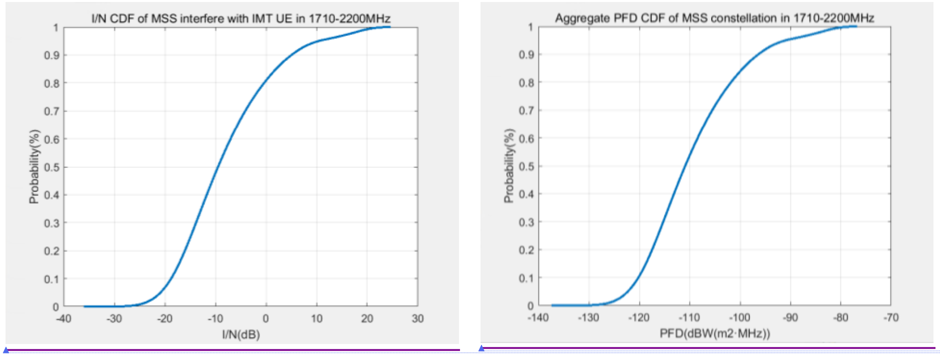
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Table_fin

Formatted: English (United States)

FIGURE A13-13



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

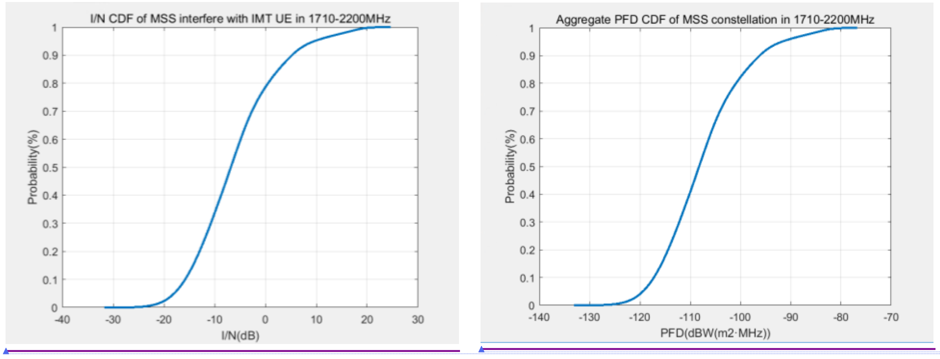
TABLE A1-22

Simulation results for protecting IMT UE

Frequency band (MHz)	IMT UE antenna gain	IMT UE body loss	X% of I/N CDF (%)	*I/N* (dB)	Additional isolation (dB)	PFD value (dBW(m^2·MHz))
1 710-2 200	0	0	100	24.65	30.65	–114.4

4.2.2.1.2 Random satellite selection strategy

FIGURE A14-13



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Table_fin

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: English (United States)

TABLE A1-22

Simulation results for protecting IMT UE

Frequency band (MHz)	**IMT UE antenna gain**	**IMT UE body loss**	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m^2·MHz))**
1 710-2 200	0	0	100	24.62	30.62	–114.4

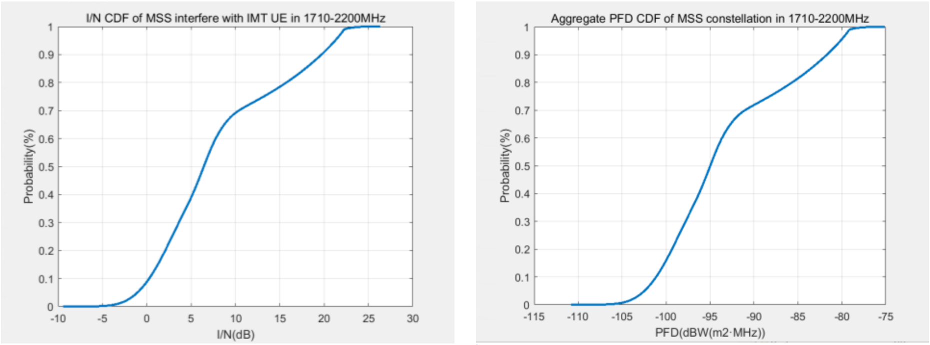
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Table_fin
Formatted: Font: Calibri
Formatted: Font: Calibri

4.2.2.2 System 3

4.2.2.2.1 Highest elevation satellite selection strategy

The simulation results for 525 km orbital constellation are as followed:

FIGURE A15-13



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz

TABLE A1-28

Simulation results for protecting IMT UE

Frequency band (MHz)	**IMT UE antenna gain**	**IMT UE body loss**	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m^2·MHz))**
1 710-2 200	0	0	100	26.29	32.29	–114.4

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)
Formatted: Table_fin
Formatted: English (United States)

The simulation results for 340 km orbital constellation are as follows.

FIGURE A16-13

(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz **(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz**

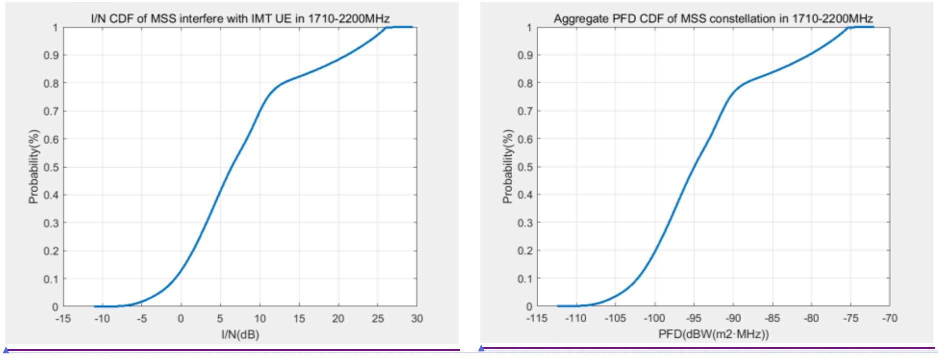


TABLE A1-29

Simulation results for protecting IMT UE

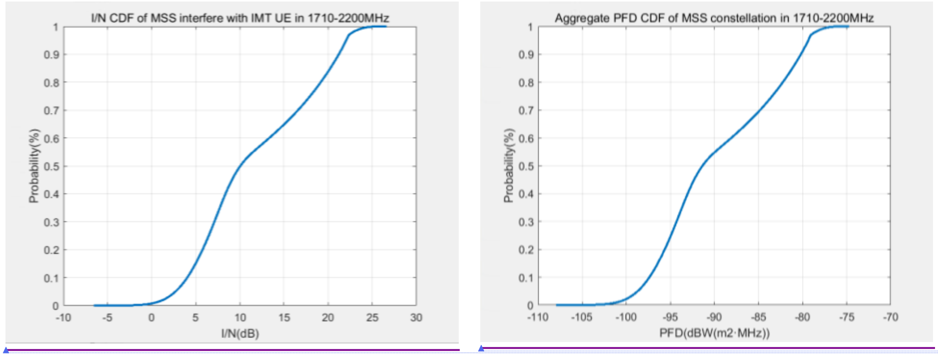
Frequency band (MHz)	**IMT UE antenna gain**	**IMT UE body loss**	**X% of I/N CDF (%)**	***I/N* (dB)**	**Additional isolation (dB)**	**PFD value (dBW(m^2·MHz))**
1 710-2 200	0	0	100	29.42	35.42	–114.4

4.2.2.2.2 Random satellite selection strategy

The simulation results for 525 km orbital constellation are as follows.

FIGURE A17-13

(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz **(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz**



Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Table_fin

Formatted: None

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: English (United States)

TABLE A1-30

Simulation results for protecting IMT UE

Frequency band (MHz)	IMT UE antenna gain	IMT UE body loss	X% of I/N CDF (%)	*I/N* (dB)	Additional isolation (dB)	PFD value (dBW(m^2·MHz))
1 710-2 200	0	0	100	26.65	32.65	–114.4

The simulation results for 340 km orbital constellation are as follows.

FIGURE A18-13

(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 1 710-2 200 MHz **(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 1 710-2 200 MHz**

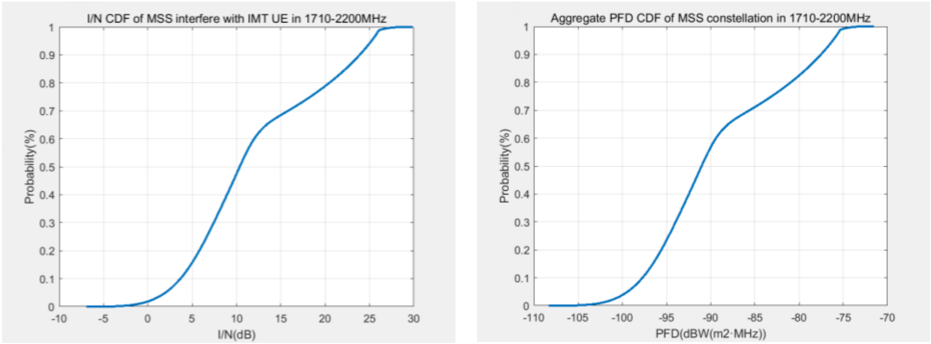


TABLE A1-31

Simulation results for protecting IMT UE

Frequency band (MHz)	IMT UE antenna gain	IMT UE body loss	X% of I/N CDF (%)	*I/N* (dB)	Additional isolation (dB)	PFD value (dBW(m^2·MHz))
1 710-2 200	0	0	100	29.88	35.88	–114.4

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Table_fin

Formatted: Font: Calibri

Formatted: Font: Calibri

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: Font: Times New Roman, 10 pt, English (United Kingdom)

Formatted: English (United States)

5 Summary

~~This study results based on deterministic calculation method and dynamic simulation method for deriving the aggregate PFD value per system to protect IMT UEs from DC-MSS-IMT space stations at the border between neighboring countries in the frequency band 2110-2200MHz are as follows:~~The aggregate PFD value per system derived from deterministic calculation and dynamic simulation using IMT protection criterion *I/N* = −6 dB with 100% non-exceedance probability to protect IMT UE from DC-MSS-IMT space stations at the border between neighboring countries in the frequency band 1 710-2 200 MHz with centre frequency 1 805 MHz are summarised as follows.

Formatted: Normal

Formatted: Font: Italic

Formatted: All caps

(1) General assumption for IMT typical UE with body loss 4 dB and antenna gain –3 dBi

– Deterministic calculation result

The required aggregate PFD value per system is −107.4 dBW/m^2/MHz.

– Dynamic simulation

The required aggregate PFD value per system is -107.4 dB(W/m^2·MHz).

(2) Other assumption for IMT specific UE with body loss 0 dB and antenna gain 0 dBi

– Deterministic calculation

The required aggregate PFD value per system is −114.4 dBW/m^2/MHz.

– Dynamic simulation

The required aggregate PFD value per system is –114.4 dBW/m^2/MHz.

This study provides the preliminary study result, ~~O~~other assumptions and methodologies~~ and associated non-exceedance probability~~, as appropriate, could also be further discussed and considered in the future.

~~It should be noted that Working Parties (WPs) 3J,3K and 3M are working on updating Recommendation ITU-R P.2108-1 (Section 3.3) for the frequency band below 10GHz based on the liaison statement from WP 3L and 3M (see Doc. 5D/167). If the study on the clutter loss model is concluded by WPs 3J,3K and 3M, the simulation results could be further updated accordingly.~~

Formatted: English (United States)

Study F (Document 5D/633 (D))

1 Introduction

This contribution provides the maximum pfd levels on the ground required for protection of IMT BS in the context of WRC-27 agenda item 1.13 taking into account the IMT BS receiver characteristics respectively. The pfd masks for protection of IMT stations were calculated and plotted for each scenario (i.e. urban, sub-urban and rural) for the frequency bands preliminarily considered under WRC-27 agenda item 1.13. The technical characteristics of IMT were extracted from Annex 4.4 to Document 5D/716 which was developed based on Report ITU-R M.2292 and contains the characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation of WRC-23. Once IMT characteristics for sharing and compatibility studies in preparation of WRC-27 are finalized in Working Party (WP) 5D, the pfd masks contained herein could be updated, if necessary.

2 Technical characteristics of IMT BS

2.1 Frequency ranges

The frequency bands considered under WRC-27 agenda item 1.13 have been grouped into four frequency ranges as seen in Table 2 below to reduce the number of pfd plots and formulas. The lower end of the band is used to plot the pfd masks for protection of IMT BS and UE, i.e. the worst case pfd is calculated for each range.

TABLE A1-17

Frequency ranges used for calculation of pfd levels

Frequency ranges	Lower end (MHz)	Upper end (MHz)	Frequency bands covered
Below 1 GHz	698	960	698-960 MHz
1-2.2 GHz	1427	2 200	1 427-1 518 MHz 1 710-1 785 MHz 1 805-2 025 MHz 2 110-2 200 MHz
2.3-2.4 GHz	2300	2 400	2 300-2 400 MHz
2.5-2.69 GHz	2500	2 690	2 500-2 690 MHz

Formatted: (Asian) Japanese

Formatted: Font: Not Bold, (Asian) Japanese

Formatted: Heading 2,Sub-section,H2,h2,h21,Heading Two,R2,l2,UNDERRUBRIK 1-2,Head 2,List level 2,Sub-Heading,A,1st level heading,level 2 no toc,2nd level,Titre2,h:2,h:2app,2,level 2,Head2A,PA Major Section,Major Section,Head2,Header 2,Level 2 Head,T2,X, Space Before: 0 pt, After: 6 pt

Formatted: Normal

Formatted: Font: Bold

Formatted

Formatted: Normal

Formatted: Font: Bold

Formatted

Formatted: English (United States)

2.2 Technical characteristics of IMT BS using Non-AAS antenna pattern

Formatted: Font: Bold

Formatted

Formatted: Normal

The technical characteristics of IMT non-AAS BS (urban, suburban and rural) extracted from Annex 4.4 to Document 5D/716 which was developed based on Report ITU-R M.2292 are provided in Table 2 below. For IMT BS using frequency range below 1 GHz only the non-AAS antenna pattern in used.

TABLE A1-18

Technical characteristics of IMT non-AAS BS used for calculating the pfd levels

Parameter	**Value**		
	Rural macro	**suburban macro**	**urban macro**
Noise spectral density in dBW/MHz	−143.8		
Noise figure in dB	5		
Noise temperature in K	300		
Protection criterion (*I/N*) in dB	−6		
Peak Non-AAS BS antenna gain (G_0) in dBi	18	16	16
Non-AAS BS antenna pattern	Recommendation ITU-R F.1336 (*recommends* 3.1) ka = 0.7 kp = 0.7 kh = 0.7 kv = 0.3 Horizontal 3 dB beamwidth (φ_3): 65 degrees Vertical 3 dB beamwidth (θ_3): determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. $\theta_3 = \frac{31000 \times 10^{-0.1G_0}}{\varphi_3}$		
Feeder loss in dB	3		
Downtilt	3°	6°	10°

Formatted: English (United States)

2.3 Technical characteristics of IMT BS using extended AAS antenna model

Formatted

Antenna characteristics for IMT-2020 AAS base stations in 1 710-4 990 MHz were taken from section 3.2.1.6 of Annex 4.4 to Document 5D/716 and summarised in Tables 3 and 4. Both non-AAS and AAS antenna patterns are used for developing the pfd mask for protection of IMT BS using frequency range above 1 GHz. IMT AAS BS using 1427-1518 MHz band are assumed to use the same characteristics provided in Tables 3 and 4.

TABLE A1-19

Beamforming antenna characteristics for IMT AAS BS in 1 710-4 990 MHz

Parameter	**Value**		
	Rural macro	**Suburban macro**	**Urban macro**
Antenna pattern	Refer to the extended AAS model in **Table 4**		
Element gain (dBi) **(Note 1)**	6.4		
Horizontal/vertical 3 dB beam width of single element (degree)	90º for H 65º for V		
Horizontal/vertical front-to-back ratio (dB)	30 for both H/V		
Antenna polarization	Linear ±45º		
Antenna array configuration (Row × Column) **(Note 2)**	4 × 8 elements		
Horizontal/Vertical radiating element/sub-array spacing, dh /dv	0.5 of wavelength for H, 2.1 of wavelength for V		
Number of element rows in sub-array, M_{sub}	3		
Vertical radiating element spacing in sub-array, $d_{v,sub}$	0.7 of wavelength of V		
Pre-set sub-array down-tilt, $\theta_{subtilt}$ (degrees)	3		
Array Ohmic loss (dB) **(Note 1)**	2		
Base station horizontal coverage range (degrees)	±60		
Base station vertical coverage range (degrees) **(Notes 3, 4, 5)**	90-100		
Mechanical downtilt (degrees) **(Note 4)**	3	6	6

Note 1: The element gain includes the array ohmic loss and is per polarization. This means that array ohmic loss is not needed for the calculation of the BS composite antenna gain.

Note 2: For the extended AAS model case, 4 × 8 means there are 4 vertical and 8 horizontal radiating sub-arrays.

Note 3: The vertical coverage range is given in global coordinate system, i.e. 90° being at the horizon.

Note 4: The vertical coverage range includes the mechanical downtilt.

Note 5: In sharing studies, the UEs that are below the base station vertical coverage range can be considered to be served by the "lower" bound of the electrical beam, i.e. beam steered towards the max. coverage angle. A minimum BS-UE distance along the ground of 35 m should be used for urban/suburban and rural macro environments.

Formatted: English (United States)

TABLE A1-20

Extended AAS model

Description	Equation
Peak normalized element radiation pattern	$A(\theta,\varphi) = -\min\left[-\left(-\min\left[12\left(\frac{\varphi}{\varphi_{3dB}}\right)^2, A_m\right] - \min\left[12\left(\frac{\theta-90}{\theta_{3dB}}\right)^2, SLA_v\right]\right), A_m\right]$
Peak gain normalized element radiation pattern	$A_E(\theta,\varphi) = G_{E,max} + A(\theta,\varphi)$
Sub-array excitation	$w_m = \frac{1}{\sqrt{M_{sub}}}\exp\left(j2\pi(m-1)\frac{d_{v,sub}}{\lambda}\sin(\theta_{subtilt})\right)$
Sub-array radiation pattern	$A_{sub}(\theta,\varphi) = A_E(\theta,\varphi) + 10\log_{10}\left(\left\lvert\sum_{m=1}^{M_{sub}} w_m v_m\right\rvert^2\right)$, where $v_m = \exp\left(j2\pi(m-1)\frac{d_{v,sub}}{\lambda}\cos(\theta)\right)$
Array excitation	$w_{m,n} = \frac{1}{\sqrt{MN}}\exp\left(j2\pi\left((m-1)\frac{d_v}{\lambda}\sin(\theta_{etilt}) - (n-1)\frac{d_h}{\lambda}\cos(\theta_{etilt})\sin(\varphi_{escan})\right)\right)$ Where *M* and *N* is corresponding to (Row × Column) provided in Table 3
Composite array radiation pattern	$A_A(\theta,\varphi) = A_{sub}(\theta,\varphi) + 10\log_{10}\left(\left\lvert\sum_{m=1}^{M}\sum_{n=1}^{N} w_{m,n} v_{m,n}\right\rvert^2\right)$, where $v_{m,n} = \exp\left(j2\pi\left((m-1)\frac{d_v}{\lambda}\cos(\theta) + (n-1)\frac{d_h}{\lambda}\sin(\theta)\sin(\varphi)\right)\right)$ Where *M* and *N* is corresponding to (Row × Column) provided in Table 3

3 Antenna patterns

3.1 IMT BS antenna patterns

Based on the receiver characteristic values of IMT base station provided in Annex 4.4 to Document 5D/716, the non-AAS base station antenna pattern was calculated by applying Recommendation ITU-R F.1336.

The gain versus elevation angle for IMT non-AAS BS deployed in urban, sub-urban and rural macro scenarios are provided in Figure 1 below based on Recommendation ITU-R F.1336 using *recommends* 3.1.1 which represents the peak side-lobe pattern. The gain versus elevation angle for IMT AAS BS deployed in urban, sub-urban and rural macro scenarios are provided in Figure 2 below based on Extended ASS model.

Formatted: Font: Bold

Formatted

Formatted: Normal

Formatted: Font: Bold

Formatted

Formatted: English (United States)

FIGURE A19-13

IMT non-AAS BS gain versus elevation angle for urban, sub-urban and rural macro scenarios based on Recommendation ITU-R F.1336 (recommends 3.1.1)

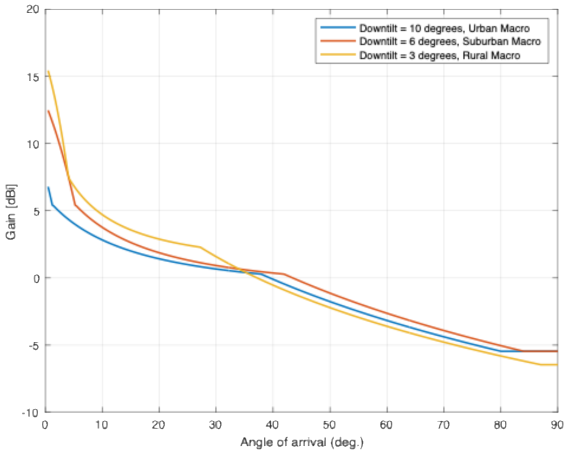
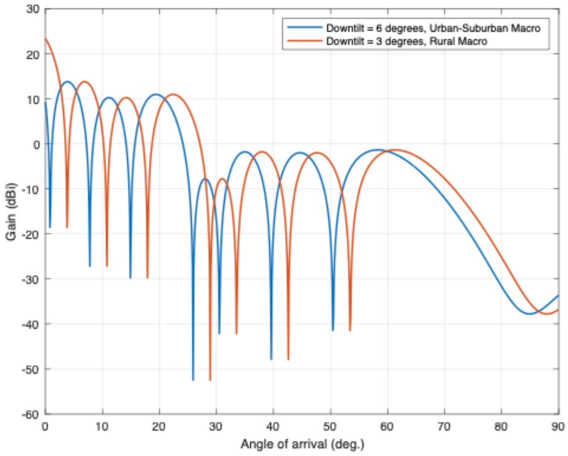


FIGURE A20-14

IMT AAS BS gain versus elevation angle for urban, sub-urban and rural macro scenarios based on Extended AAS model



Formatted: English (United States)

4 Methodology

Formatted: Font: Bold

Formatted

Formatted: Normal

The maximum pfd levels on the ground that protect IMT receivers are calculated at various frequencies preliminarily considered for WRC-27 agenda item (AI) 1.13, based on IMT BS receiver characteristics extracted from Annex 4.4 to Document 5D/617 which was developed based on Report ITU-R M.2292.

The following formula was used to calculate the pfd levels in dB (W/ (m^2 · MHz)):

$$\boldsymbol{pfd(\theta) = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + \mathrm{L} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right)}$$

where:

k: Boltzmann's constant ($\boldsymbol{1.380649 \times 10^{-23}\, J/K}$)

$\boldsymbol{T}$: receiver noise temperature in K

B: reference bandwidth (1 MHz)

NF: receiver noise figure in dB

I/N: protection criteria in dB

$\boldsymbol{G_r(\theta)}$: effective antenna gain in dBi of the receiver antenna in the direction of the interferer

$\boldsymbol{\theta}$: the elevation angle in degree

λ: wavelength in m

$\boldsymbol{L}$: Receiver antenna feeder/cable loss for IMT BS using non-AAS/AAS antenna and body loss for IMT UE in dB.

Other losses such as polarization isolation, ionospheric scintillation losses and atmospheric losses, and MSS system characteristics that impact sharing conditions between interfering and victim systems are to be considered during sharing and compatibility studies.

This equation allows the computation of the maximum allowable pfd value in a single direction above the horizon ($\boldsymbol{\theta}$). However, if this maximum allowed pfd value is reached in a single direction, the whole margin for I/N is consumed. For interfering sources coming from different directions and contributing to the overall interference perceived by the IMT receiver, further investigations are needed to establish a model to calculate the total amount of pfd allowed over all elevations. WP 4C needs to clarify NGSO systems characteristics, sharing scenarios, as well as whether more than one satellite system would operate co-channel with an IMT terrestrial service in the same geographical area and if any aggregation factor is needed due to multiple satellites in visibility of the terrestrial IMT receiver from multiple elevation angles.

5 PFD masks

5.1 The pfd masks for protection of IMT BS

Formatted: Font: Bold

Formatted

Formatted: Normal

Formatted: Font: Bold

Formatted

PFD masks that protect IMT BS are calculated and plotted for the following scenarios:

1 pfd masks for protection of IMT non-AAS BS in rural macro scenario (see Figure 4 below)

2 pfd masks for protection of IMT non-AAS BS in suburban macro scenario (see Figure 5 below)

3 pfd masks for protection of IMT non-AAS BS in urban macro scenario (see Figure 6 below)

Formatted: English (United States)

4 pfd masks for protection of IMT AAS BS operating in frequency bands above 1 GHz assuming urban/suburban macro scenario (see Figure 7 below)

5 pfd masks for protection of IMT AAS BS operating in frequency bands above 1 GHz assuming rural macro scenario (see Figure 8 below)

FIGURE A21-15

pfd masks for protection of IMT non-AAS BS in rural scenario

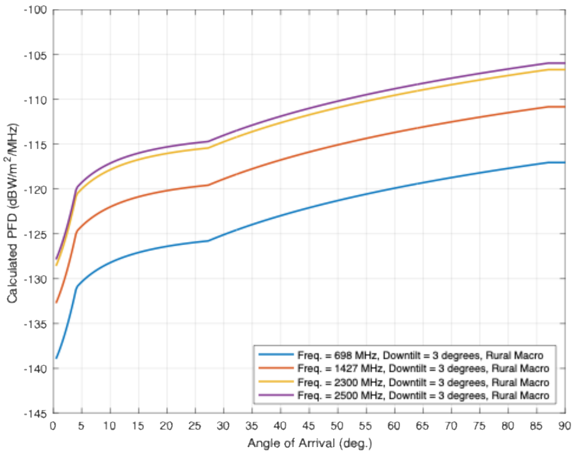
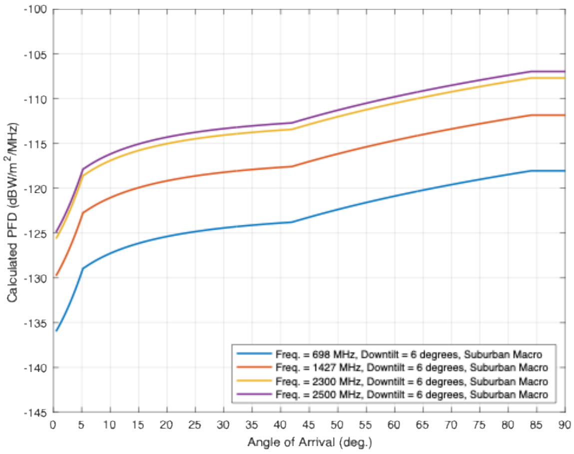


FIGURE A22-16

pfd masks for protection of IMT non-AAS BS in suburban scenario



Formatted: English (United States)

FIGURE A23-17

pfd masks for protection of IMT non-AAS BS in urban scenario

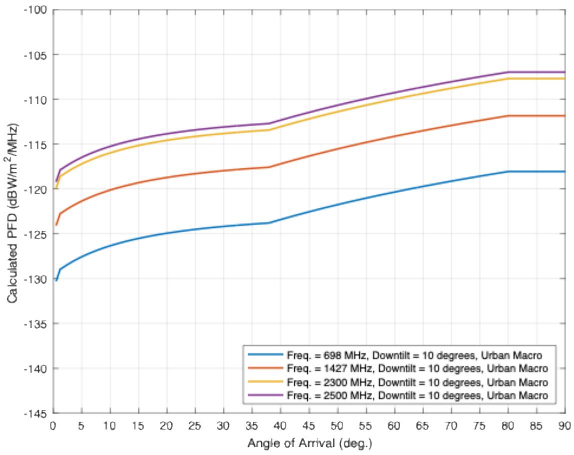
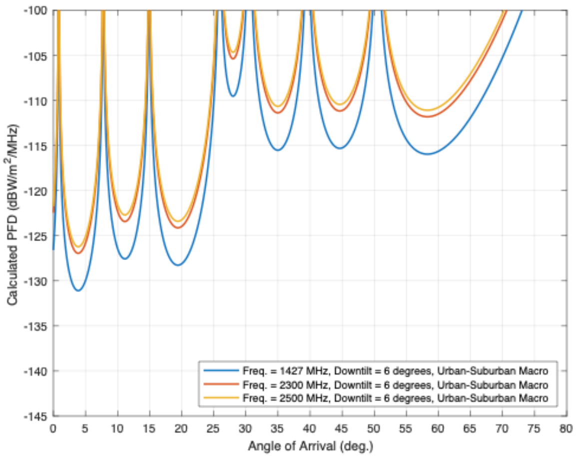


FIGURE A24-18

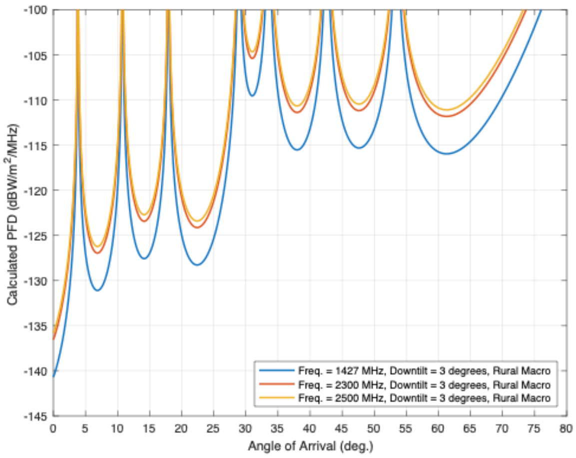
pfd masks for protection of IMT AAS BS operating in frequency bands above 1 GHz assuming urban/suburban scenario



Formatted: English (United States)

FIGURE A25-19

pfd masks for protection of IMT AAS BS in frequency bands > 1 GHz assuming rural scenario



As evident from figures above, the most stringent pfd masks are the ones calculated based on rural macro IMT BS scenarios.

5.2 The envelope PFD mask to protect IMT BS

As seen from the pfd plots above, the most stringent pfd masks are the ones calculated based on rural macro IMT BS scenarios. As such, to develop an envelope pfd mask, 10 000 IMT UEs are randomly located within a single 500-meter IMT macro-BS cell using extended AAS antenna model in rural scenario (see Figure 9 below). The altitude of IMT BS is assumed to be 20 meters, and all the IMT UEs assumed to be at an altitude of 1.5 meters.

Formatted: Font: Bold

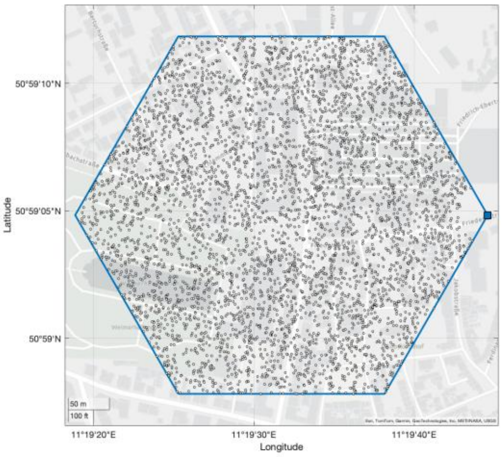
Formatted

Formatted: Normal

Formatted: English (United States)

FIGURE A26-20

A single sector with 10 000 IMT UEs



The AAS antenna beam is steered towards 10 000 UE positions within this sector, and the resulting pfd is calculated for each UE position using the same methodology as before. Out of this 10 000 pfd snapshots, the most stringent one is selected as the worst-case pfd needed to protect the IMT BS using the extended AAS antenna pattern.

Figure 10 summarizes the following scenarios in one plot:

1 Sub-GHz range: Single pfd mask for protection of IMT BS using non-AAS antenna pattern

2 1 GHz to 2.2 GHz: the worst-case pfd masks for protection of IMT BS using extended AAS and non-AAS antenna patterns

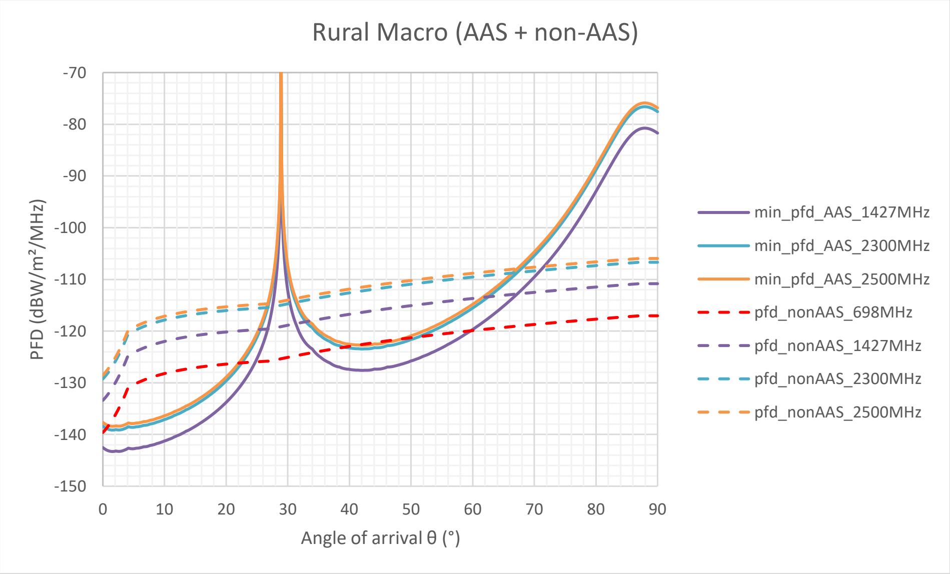
3 2.3-2.4 GHz: the worst-case pfd masks for protection of IMT BS using extended AAS and non-AAS antenna patterns

4 2.5-2.69 GHz: the worst-case pfd masks for protection of IMT BS using extended AAS and non-AAS antenna patterns.

Formatted: English (United States)

FIGURE A27-21

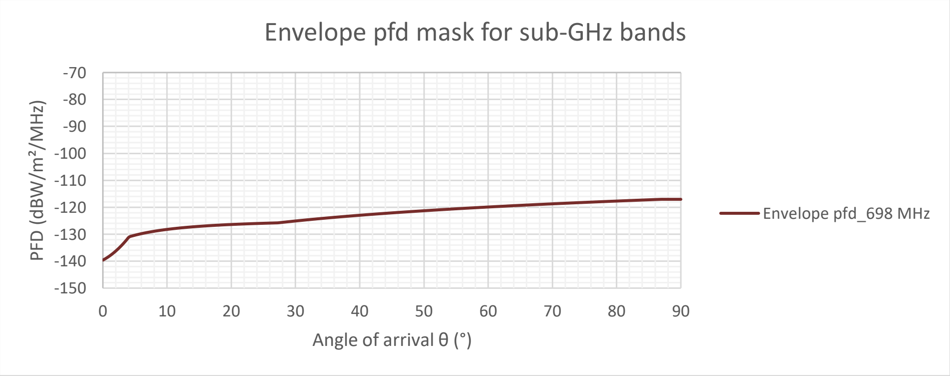
pfd masks for protection of AAS and non-AAS IMT BS in rural macro scenario



Considering the pfd masks provided in Figure 10 are the most stringent pfd (i.e. rural scenario), an envelope pfd mask can be calculated per frequency range to protect IMT BS, irrespective of the type of antenna used. The envelope pfd mask should describe the worst-case pfd per frequency range, merging the curves calculated using the AAS and non-AAS antenna patterns (see Figures 11 and 12 below).

FIGURE A28-22

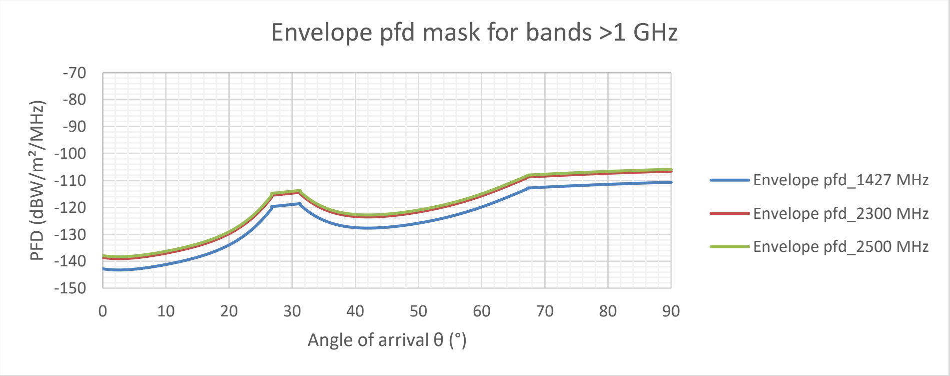
Envelop pfd for protection of IMT BS (<1 GHz)



Formatted: English (United States)

FIGURE A29-23

Envelop pfd for protection of IMT BS (>1 GHz)



The equations describing the envelop pfd masks in Figures 11 and 12 are provided in Table 6 below.

Formatted: English (United States)

TABLE A1-21

Envelope pfd mask equations for protection of IMT BS in rural macro scenario

Frequency range	**Pfd equation per frequency range (dB(W/(m² · MHz)))**
Below 1 GHz	$pfd_{mask}(\theta) = \begin{cases} -0.21 * \theta^2 + 1.26 * \theta - 139.6 & for\ \theta \le 4 \\ 5.017 * e^{-4} * \theta^3 - 0.03379 * \theta^2 + 0.8451 * \theta - 133.8 & for\ 4 < \theta \le 27.5 \\ -3.740 * e^{-7} * \theta^4 + 9.845 * e^{-5} * \theta^3 - 0.01053 * \theta^2 + 0.6512 * \theta - 137.5 & for\ 27.5 < \theta \le 90 \end{cases}$
1 GHz to 2.2 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 142.8 & for\ \theta \le 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 122.9 & for\ 26.7 < \theta \le 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 606.49 & for\ 31.25 < \theta \le 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 127.6 & for\ 67.2 < \theta \le 90 \end{cases}$
2.3-2.4 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 138.6 & for\ \theta \le 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 118.7 & for\ 26.7 < \theta \le 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 610.64 & for\ 31.25 < \theta \le 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 123.5 & for\ 67.2 < \theta \le 90 \end{cases}$
2.5-2.69 GHz	$fd_{mask}(\theta) = \begin{cases} 1.106 * e^{-4} * \theta^4 - 4.47 * e^{-3} * \theta^3 + 0.08494 * \theta^2 - 0.353 * \theta - 137.9 & for\ \theta \le 26.7 \\ 3.896 * e^{-3} * \theta^2 + 1.585 * e^{-2} * \theta - 118 & for\ 26.7 < \theta \le 31.25 \\ -1.6055 * e^{-6} * \theta^5 + 4.338 * e^{-4} * \theta^4 - 4.6637 * e^{-2} * \theta^3 + 2.5139 * \theta^2 - 67.94 * \theta + 611.36 & for\ 31.25 < \theta \le 67.2 \\ -1.396 * e^{-3} * \theta^2 + 0.3137 * \theta - 122.8 & for\ 67.2 < \theta \le 90 \end{cases}$

Formatted: English (United States)

6 Conclusion

This contribution proposes maximum pfd levels on the Earth's surface, as a function of angle of arrival, required to protect IMT BS. Germany proposes that WP 5D considers the pfd masks provided in this contribution for protection of IMT under WRC-27 agenda item 1.13.

Note that the IMT parameters outlined in this document may need to be revised if WP 5D agrees different IMT characteristics under AI 1.13.

It should be noted that the pfd calculation formula proposed in this document allows the computation of the maximum allowable pfd value in a single direction above the horizon (θ). However, if this maximum allowed pfd value is reached in a single direction, the whole margin for *I/N* is consumed. For interfering sources coming from different directions and contributing to the overall interference perceived by the IMT receiver, further investigations are needed to establish a model to calculate the total amount of pfd allowed over all elevations. WP 4C needs to clarify NGSO systems characteristics, sharing scenarios, as well as whether more than one satellite system would operate co-channel with an IMT terrestrial service in areas adjacent to the IMT coverage area and if any aggregation factor is needed due to multiple satellites in visibility of the terrestrial IMT receiver from multiple elevation angles.

Once WP 4C responds to the liaison statement from WP 5D (Document 5D/231), additional measures may need to be adopted to account for aggregation factors.

Study G (Doc. 5D/639 (D, G))

1 Introduction

WRC-27 AI 1.13 is intended to study possible new allocations to the mobile-satellite service for direct connectivity between space stations and unmodified IMT UEs. WP 5D is responsible for developing regulatory measures to protect terrestrial IMT systems for inclusion in the draft CPM text for WRC-27 AI 1.13.

2 Method

The method proposed in this contribution is used to determine required pfd limits for ensuring protection of terrestrial IMT networks from DC-MSS-IMT (s-E) transmission.

$$PFD(\theta) = 10\log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + \mathrm{L} - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k is Boltzmann's constant (1.380649×10^{-23} J/K)

T is the receiver noise temperature (Kelvin)

B is the reference bandwidth (1 MHz)

NF is the receiver noise figure (dB)

$\frac{I}{N}$ is the receiver interference to noise ratio limit (dB)

$G_r(\theta)$ is the effective antenna gain (dBi) of the receiver antenna towards the direction of the interferer

θ is the elevation angle (°) towards the direction of the interferer

L is the receiver antenna feeder loss for IMT BS (dB)

$10\log_{10}\left(\frac{\lambda^2}{4\pi}\right)$ is the antenna aperture (dB.m^2) at the wavelength, λ (m).

We note that the method presented in Equation 1 is based on the victim's perspective w. r. t. the incoming interference power corresponding to the given *I/N* ratio for a single-entry interferer. However, in case of interference from DC-MSS-IMT (s-E) transmissions, terrestrial IMT stations could receive interferences from multiple satellites (multiple interferers) of the same constellation and/or different constellations.

For the terrestrial IMT UE, the pfd limits obtained using Equation 1 has been adopted as the total pfd from all DC-MSS-IMT satellite emissions from all visible angles measured in a 1 MHz bandwidth at the ground level because $G_r(\theta)$ will not vary for different satellites. This total pfd can be apportioned between different operators depending on how many satellite operators are in a mobile band serving the same point on earth in the same frequency. The apportioned levels must then be met considering the total emissions from all the satellites of an operator for any area that requires protection.

With respect to the terrestrial IMT BS, Equation 1 can be used to investigate how the pfd limits vary with the victim terrestrial BS antenna pattern for a single satellite interferer. Unlike the UE, the BS antenna gain varies with elevation and so there is an off-axis angle dependency in the BS pfd equation. Therefore the locations of the satellites in the sky need to be known in order to calculate the total interference from multiple visible satellites. As a result, the calculation of the uplink pfd limits for protection of the terrestrial IMT BS is more complex and needs further consideration.

We note that aggregation and apportionment is being discussed at ITU WP 4C. When aggregation and apportionment factors have been agreed by ITU WP 4C, the aggregate pfd limits proposed in this contribution can be calculated on a per satellite basis.

3 Technical Characteristics

In this section, the technical characteristics for the terrestrial IMT UE are presented.

3.1 Terrestrial IMT UE

In Table 1, the values and parameters used to determine the pfd limits using Equation 1 for coexistence with a terrestrial IMT UE operating at the centre of the 900 MHz mobile downlink band, 942.5 MHz are provided.

In determining appropriate parameters for terrestrial IMT user equipment (UE), Working Document 5D/563[2] is used, which outlines the characteristics of IMT for sharing and compatibility studies in preparation for WRC-27. It should be noted that the current Working Document 5D/563, related to IMT bands under Agenda Item 1.13 for WRC-27, is based on Document 5D/716[3], which was originally developed for IMT bands under Agenda Item 1.4 for WRC-23.

Our modelling considers that the UE antenna gain is uniform in all directions and so the pfd limits ($PFD(\theta)$) obtained using Equation 1 is the same for all angle of arrivals, hence it is not elevation dependent. For the terrestrial IMT UE, we have adopted:

- –3 dBi for the IMT UE antenna gain,
- 0 and 4 dB for IMT UE body loss.

[Editor's Note: according to Documents 5D/563 and 5D/716, the IMT UE body loss is 4 dB. However, for this contribution, both 0 dB and 4 dB loss values were considered until WP5D makes a final decision on the body loss parameter.]

TABLE A1-22

Determining pfd limits for coexistence with Terrestrial IMT UE (900 MHz band)

Terrestrial mobile (UE)		
Parameter	**Value**	**Comment**
Freq (MHz)	942.5	Centre of the 900 MHz mobile downlink band
$10\log_{10}(kTB)$ (dBW/MHz)	-144	Thermal noise density
NF (dB)	9	This is adopted from 5D/716**Error! Bookmark not defined.**, Table 1, page 3
$10\log_{10}(kTB) + NF$ (dBW/MHz)	-135	UE noise floor density
$\frac{I}{N}$ (dB)	-6	This is adopted from 5D/716**Error! Bookmark not defined.**, Table 13, page 26

---

[2] Chapter 4 - Annex 4.15 - Working document on characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27

[3] Annex 4.4 to Working Party 5D Chairman's Report- Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23

G_r (dBi)	-3	This is adopted from 5D/716**Error! Bookmark not defined.**, Table 5-2, page 12 and represents a typical UE
$10\log_{10}\frac{\lambda^2}{4\pi}$ (dB.m^2)	-21	Antenna aperture
Body loss (dB)	4 & 0	4 dB is based on 5D/716**Error! Bookmark not defined.**

Note that the IMT UE parameters outlined in Table 1 are for a typical device and may need to be revised if WP5D agrees different IMT characteristics under AI 1.13.

3.2 Terrestrial IMT BS

[TBD]

[Editor's Note: This section will be further developed and finalized once Working Party 5D has completed its work on defining the IMT base station characteristics. The content will reflect the finalized parameters and specifications as determined by WP5D.]

4 Pfd limits for Terrestrial IMT

In this section, the pfd limits for protecting terrestrial IMT Ues are provided.

4.1 Pfd limits for protecting Terrestrial IMT UE

The pfd limits presented in Table 2 have been calculated using the parameters in Table 1. For the band groups shown in Table 2, the same parameters have been used to calculate the pfd limits for all the bands considered for DC-MSS-IMT. The only exception to this is the antenna aperture term (10·log10($\lambda^2/4\pi$) which is frequency dependent and so varies between IMT bands.

In order to minimise the number of different pfd limits satellite network operators (SNO) need to comply with, the pfd limits in Table 2 have been grouped such that the spread in the pfd limits calculated is around a few dBs.

TABLE A1-23

Aggregate pfd for protecting terrestrial IMT UE

Mobile Band	**Pfd limits in mobile downlink spectrum (0 dB body loss)**	**Pfd limits in mobile downlink spectrum (4 dB body loss)**
MHz	*dBW / MHz / m^2*	*dBW / MHz / m^2*
700, 800, 900	–119	–115
1400	–113	–109
1800, 1900, 2100	–111	–107
2300, 2600	–108	–104

[Editor's Note: once WP5D agrees on the various IMT characteristics under AI 1.13—particularly regarding IMT UE body loss—the appropriate option listed in the table shall be used to ensure the protection of IMT UE.]

4.2 Equivalent RSRP

We note that administrations do not normally use pfd limits when describing coverage in terrestrial IMT mobile networks. A more common terminology is Reference Signal Received Power ("RSRP"), so we have translated our pfd limits into the equivalent RSRP limit to allow for comparison. We note that this equivalent RSRP limit conversion assumes a noise-limited environment rather than interference-limited environment.

We calculated the equivalent RSRP limit as follows:

$$P_R = 10\log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + \mathrm{L} \qquad (2)$$

where:

P_R	is the power limit at the UE antenna connector, equivalent to the pfd limit at the UE antenna (dBW / MHz).

other terms have the same meaning as in equation 1.

And

$$P_{RSRP} = P_R + 10 \cdot \log_{10}(1000) + 10 \cdot \log_{10}(15/1000) \qquad (3)$$

where:

P_{RSRP}	is the equivalent RSRP limit assuming a noise limited environment (dBm)
P_R	is the power limit at the UE antenna connector, equivalent to the pfd limit at the UE antenna (dBW / MHz).
$10 \cdot \log_{10}(1000)$	is the unit magnitude adjustment factor going from dBW to dBm (dB)
$10 \cdot \log_{10}(15/1000)$	is the bandwidth adjustment factor going from 1 MHz to the bandwidth of a single resource element, 15 kHz (dB)

We note that using the values from Table 1, we get an equivalent RSRP limit of –126 dBm for all mobile bands (because RSRP, unlike pfd, does not have a frequency dependency). This is 6 dB below the minimum useable sensitivity commonly cited for mobile user equipment (-120 dBm RSRP).

4.3 Protecting the Terrestrial IMT BS

[TBD]

[Editor's Note: When aggregation and apportionment factors have been agreed by ITU WP 4C, aggregate or per satellite pfd limits can be proposed for protecting the terrestrial IMT BS]

5 Aggregation And Apportionment

The proposed pfd limits in this contribution are maximum aggregate power pfd limits from multiple satellites and multiple constellations for protection of terrestrial IMT downlink. We also consider that a "per satellite" transmission pfd limit could also be appropriate in order to provide measurable limits. However, a per satellite pfd limit requires knowledge of the aggregation effect.

Furthermore, DC-MSS-IMT is still a relatively new technology, and it is uncertain how many SNOs will provide DC-MSS-IMT services in each mobile band as the market matures, hence further analysis is required to determine whether an apportionment factor is needed.

WP 4C needs to clarify NGSO systems characteristics, sharing scenarios, as well as whether more than one satellite system would operate co-channel with an IMT terrestrial service in the same geographical area and if any aggregation factor is needed due to multiple satellites in visibility of the terrestrial IMT receiver from multiple elevation angles.

Consequently, further work is needed to derive the pfd limits for the protection of the terrestrial IMT BS including determining a per satellite pfd value as it is possible that there are multiple active satellites/beams in view of a terrestrial IMT BS.

6 Conclusion

Based on the analysis presented in this contribution, the aggregate pfd limits below are proposed for protecting terrestrial IMT Ues from DC-MSS-IMT s-E transmissions.

TABLE A1-24

Aggregate pfd limits from multiple satellites and multiple constellations

Mobile Band	Pfd Limit in mobile downlink spectrum (0 dB body loss)	Pfd Limit in mobile downlink spectrum (4 dB body loss)
MHz	*dBW / MHz / m²*	*dBW / MHz / m²*
700, 800, 900	–119	–115
1400	–113	–109
1800, 1900, 2100	–111	–107
2300, 2600	–108	–104

[Editor's Note: once WP5D agrees on the various IMT characteristics under AI 1.13—particularly regarding IMT UE body loss—the appropriate option listed in the table shall be used to ensure the protection of IMT UE.]

Study H (Doc. 5D/712 (CHN), 5D/827(CHN))

[Note: The questions were raised regarding the methodology used in the study.]

1 Introduction

For IMT UE, due to the use of omnidirectional antennas, the interference from satellites to IMT UEs varies synchronously with the generated PFD. This enables the calculation of aggregate PFD limit through the difference between the aggregate interference generated by the satellites and the interference criteria, as well as the aggregate PFD values generated by the satellites.

For IMT BS, due to the use of directional antennas, the interference of satellites to IMT BSs and the PFD generated at IMT BSs will not change synchronously. The methods used for IMT UEs are no longer applicable to IMT BSs. This attachment provides consideration on the method to calculate the aggregate PFD limit value for protecting IMT BS.

2 Consideration on the method to calculate the aggregate PFD limit value for the protection of IMT BS

Step 1: Generate the interference scenario

Two options can be considered as the interference scenarios.

① Considering the scenario that DC-MSS-IMT is only deployed in a specific area, calculate the aggregate PFD limit value based on the interference situation of satellites in this area to the IMT BSs in adjacent areas.

② Considering the scenario that DC-MSS-IMT is only prohibited from operating in a specific area, calculate the aggregate PFD limit value based on the interference of all the visible satellites outside this area to the IMT BSs within that area.

The size and location of the deployment area and the prohibited deployment area in the above scenarios, as well as the location of the IMT BS, can be specifically set according to the simulation scenarios.

Step 2: For a specific scenario, generate all the satellites according to the orbital parameters, and determine the satellites that are visible to the IMT BS and in operation.

Step 3: For a specific time T_i, calculate the aggregate interference to the IMT BS

$$I_{total,Ti} = 10\,log\left(\sum_{n}^{N}\sum_{j}^{J}10^{I_{n,j}/10}\right)$$

$$I_{n,j} = P_{tx} + G_{tx}(\theta_{tx}) - PL + G_{rx}(\theta_{rx}) - L_{other}$$

where:

$I_{total,T1}$: Aggregate interference power density from satellites, dBW/MHz

$I_{n,j}$: Interference power density from j-th beam of n-th satellite, dBW/MHz

P_{tx}: Satellite transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})$: Satellite antenna gain in the direction of IMT BS taking into account the main beam of satellite is pointing to its serving UE, dBi

$G_{rx}(\theta_{tx})$: IMT BS antenna gain in the direction of satellite, dBi

PL: Propagation loss, dB

L_{other}: other losses, such as feeder loss

N: The number of visible satellite from the view of IMT station

J: The number of beams of one satellite.

Step 4: Calculate the difference between the aggregate interference and the protection criteria.

$$ISO_{Ti} = I_{total,T1} - I_{th}$$

ISO_{Ti}: The difference between the aggregate interference and the protection criteria, which is also the required additional isolation that is needed to protect IMT BSs.

Step 5: Calculate the aggregate PFD value produced at the IMT BS

$$PFD_{Ti} = 10\,log\left(\sum_{n}^{N}\sum_{j}^{J}10^{PFD_{n,j}/10}\right)$$

$$PFD_{n,j} = P_{tx} + G_{tx}(\theta_{tx}) - 10log_{10}(4\pi d_n^2)$$

where:

PFD_{Ti}: Aggregate PFD from satellites, dB(W/m^2·MHz)

$PFD_{n,j}$: PFD from j-th beam of n-th satellite, dB(W/(m^2·MHz))

P_{tx}: Satellite transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})$: Satellite antenna gain in direction of IMT BS, dBi

d_n: Distance between n-th satellite and IMT BS, m.

Step 6: Calculate the PDF limit value derived according to the specific scenario at the time T_i

$$PFD_{limit,Ti} = PFD_{Ti} - ISO_{Ti}$$

where:

$PFD_{limit,Ti}$: Required PFD limit to protect IMT BSs at the time T_i, dB(W/(m^2·MHz)).

Step 7: Set the simulation step size of the time as t, advance the time by one step size, regenerate the position of satellites, and repeat Steps 2-6.

Step 8: Simulate M simulation step sizes to ensure that the total simulation duration covers at least one cycle of the constellation's operation.

Step 9: Analyse the study results. According to the M PFD limits that obtained through the above steps, a CDF curve of PFD limits can be obtained. If the non-exceedance probability in the IMT criteria is X%, the PFD limit required should take the point of (100-X)% on the CDF curve.

3 Simulation assumptions

3.1 Technical characteristics of DC-MSS-IMT

The simulation is based on System 2 in the Annex to the Chair's Report of WP 4C (See Annex 7 to Doc 4C/356). The detailed information is as shown in Table H-1 and Table H-2.

TABLE H-1

Parameters of orbital configuration

Altitude (km)	**Inclination (deg)**	**Planes**	**Sats per plane**	**RAAN spacing (deg)**	**Total number of sats**
500	55	60	60	6	3 600

TABLE H-2

Parameters of DC-MSS-IMT

	Parameter	**Unit**	**Values**				
Downlink (Space-to-Earth)	Frequency band	MHz	694/698-960	1 427-1 518	1 805-1 880 /2 110-2 170 /1 880-1 920	2 300-2 400	2 500-2 690
	Typical Emission Bandwidth	MHz	5	5	5	5	5
	S/S Transmitter power per beam	dBW	9	13	13	13	13
	S/S EIRP per beam	dBW	39.9	46.2	48.2	50.4	51.1
	EIRP spectral density per beam	dBW/Hz	-27.1	-20.8	-18.8	-16.6	-15.9
	S/S Antenna pattern	n/a	M.2101	M.2101	M.2101	M.2101	M.2101
	Single element antenna gain	dBi	2	3.92	4.11	4.15	4.15
	Antenna array configuration (Row×Column)		28×28	29×29	36×36	46×46	50×50
	Horizontal 3dB beamwidth of single element	°	120	118	118	110	110
	Vertical 3dB beamwidth of single element	°	120	118	112	110	110
	Horizontal radiating element spacing	dH/λ	0.5	0.5	0.5	0.5	0.5
	Vertical radiating element spacing	dV /λ	0.5	0.5	0.5	0.5	0.5
	Horizontal Front-to-back ratio	dB	30	30	30	30	30
	Vertical Front-to-back ratio	dB	30	30	30	30	30
	ACLR	dB	25	25	25	25	25

Formatted: Font: (Default) Times New Roman Bold, 10 pt, Bold, Not Highlight

	Parameter	**Unit**	**Values**				
Uplink (Earth-to-space)	Frequency band	MHz	694/698-960	1 427-1 518	1 710-1 785 /1 920-1 980 /2 010-2 025	2 300-2 400	2 500-2 690
	Emission Bandwidth (s)	MHz	1.4	1.4	1.4	1.4	1.4
	Polarization	n/a	Linear polarization	Linear polarization	Linear polarization	Linear polarization	Linear polarization
	E/S Transmitter power	dBW	−7	−7	−7	−7	−7
	Antenna gain	dBi	−3	−3	−3	−3	−3
	E/S EIRP	dBW	−10	−10	−10	−10	−10
	Antenna Pattern		Omni direction	Omni direction	Omni direction	Omni direction	Omni direction
	Spectral mask	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.2, Table 6.5.2.2-1.				
	ACLR	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.4.1.				
	Out of band emissions	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.3.1.				
	Min Elevation	°	35	35	35	35	35

3.2 Technical characteristics of IMT

Technical characteristics of IMT systems can be found in Section 4 of the working document on characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27. The Antenna Pattern was considered as Extended AAS.

3.3 Propagation models

Based on the liaison statement from WPs 3L/3M to WP 5D, Recommendation ITU-R P.619-5 is used to calculate the propagation loss between stations in space and those on the surface of the Earth.

3.4 Protection criteria

I/N = –6 dB is considered for the protection criteria of IMT systems, and the non-exceedance probability is mainly considered as 100%.

3.5 Simulation scenario

Simulation scenario option 2 is considered, which is described in Step 1 in Section 2. And the area in which DC-MSS-IMT is prohibited is set as a circle area with the radius of 1 221 km. All the visible DC-MSS-IMT satellites outside this area are considered as the interference source. The victim IMT station is located at the edge of this area.

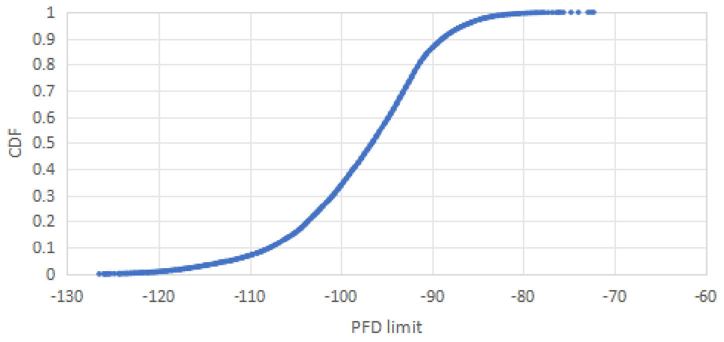
4 Simulation results

The PFD limits value in the frequency band 1 880-1 920 MHz and 2 620-2 690 MHz are simulated, and the results show that the PFD limit values required for the protection of IMT BS in the 1 880-1 920 MHz and 2 620-2 690 MHz frequency band are respectively **-126.472** dB(W/m^2·MHz) and **-124.012** dB(W/m^2·MHz).

The CDF of PFD limit is shown in Figures below.

FIGURE X

CDF of PFD limit in the frequency band 1 880-1 920 MHz



Formatted: Font: 14 pt, Bold, English (United Kingdom)

Formatted: Font: 14 pt, Bold, English (United Kingdom)

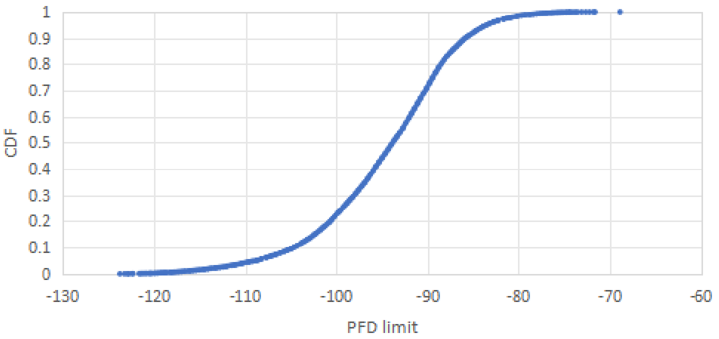
Formatted: Space Before: 12 pt

Formatted: Figure_title

Formatted: English (United States)

FIGURE X+1

CDF of PFD limit in the frequency band 2 620-2 690 MHz



Formatted: Figure

It should be noted that, this study provided preliminary study results. Further studies may be conducted based on some other simulations assumptions or consideration on the method in the future.

Formatted: Centered, Space Before: 6 pt

Formatted: English (United States)

Study I (Doc. 5D/739 (Ericsson))

[Note: Questions were raised with regards to the assumption and methodology used in the study.]

Formatted: Font: Italic

Formatted: Normal, Space After: 0 pt

Introduction

Different regulatory measures (PFD per satellite, aggregate PFD, EPFD and aggregate EPFD) are under discussion for protection of IMT from harmful interference due to DC-MSS-IMT in studies under WRC-27 agenda item 1.13.

In this contribution, we provide some comments on proposed regulatory measures for protection of IMT UE and IMT BS and propose values for PFD/EPFD limits.

Discussion

When defining PFD/EPFD limits for protection of terrestrial IMT from DC-MSS-IMT, the interference budget must be partitioned among all potential interfering satellites (all visible DC-MSS-IMT satellites either in one constellation or in multiple constellations). A simplified approach to partition the interference budget among multiple systems is to define multi-system aggregation factor. Both “maximum aggregate PFD/ EPFD limits” and “PFD /EPFD limits per system (single entry limit)” need to be defined to ensure protection of terrestrial IMT UE and IMT BSs from DC-MSS-IMT systems,

In addition, to ensure protection of terrestrial IMT, verification procedures to examine the compliance of DC-MSS-IMT systems with PFD/EPFD limits must be defined. There is a procedure available in ITU to verify the compliance of non-GSO systems with EPFD limits derived for protection of GSO earth stations. That procedure could potentially be modified to be used for verifying the compliance of DC-MSS-IMT systems with EPFD limits defined for protection of IMT UE and BSs.

Protection of terrestrial IMT from multiple DC-MSS-IMT systems

As discussed in Document 4C/336, there is the potential of receiving interference from at least two DC-MSS-IMT systems at the border of many countries. Therefore, when defining PFD/EPFD limits per system, a procedure to ensure protection of terrestrial IMT from potential interference from multiple DC-MSS-IMT systems must be identified.

A simplified approach could be considering a multi-system aggregation factor, for example 3 dB to reflect the possibility of interference due to two MSS-DC-IMT systems which could be actively transmitting co-frequency in visibility of the border. We have used this approach in this contribution.

Protection of IMT UE from DC-MSS-IMT

Since IMT UE has an isotropic antenna, the values for aggregate PFD and EPFD limits derived from the IMT UE receiver characteristics are equal. While the compliance of MSS systems with aggregate PFD limits are not examined by ITU, there is an ITU procedure to verify the compliance with EPFD limits. Therefore, in case of aggregate PFD limits, a procedure to examine the compliance of DC-MSS-IMT systems with those limits must be defined.

To protect IMT UE from harmful interference due to MSS-DC-IMT, the maximum aggregate PFD/EPFD due to all visible satellites operating co-frequency (either in one constellation or in multiple constellations) should not exceed the value obtained by equation (1).

$$\text{Maximum aggregate PFD/EPFD} = 10\,log_{10}(kTB) + NF + \frac{I}{N} - G_{\text{UE}} - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

Formatted: English (United States)

where:

k: Boltzmann's constant (-228.6 dB(W/(K · Hz)))
T: receiver noise temperature (300 K)
B: reference bandwidth (1 MHz)
NF: receiver noise figure in dB
I/N: protection criterion in dB
G_{UE}: antenna gain of IMT UE in dB.

Considering 3 dB multi-system aggregation factor, aggregate PFD/EPFD limit per system (single entry PFD limit) can be obtained using equation (2)

$$\text{Aggregate PFD/EPFD per system} = \text{Maximum aggregate PFD/EPFD} - 3 \qquad (2)$$

In Table 1, we propose maximum aggregate PFD and EPFD limits (considering interference from multiple DC-MSS-IMT systems) and aggregate PFD and EPFD limits per system for protection of UE. The proposed values are obtained using equation (1) and (2), assuming the lowest frequency in each frequency range and the protection criterion of *I/N* = –20 dB. We note that the protection criterion is still under discussion in WP 5D and the proposed values might need to be updated later.

TABLE A1-25

Aggregate PFD/ EPFD limits in dB(W/(m² . MHz)) for protection of IMT UE

Frequency range	< 1 GHz	1.5 GHz	> 2 GHz
UE antenna gain (dBi)	–3 dBi	–3 dBi	–3 dBi
Noise figure (dB)	9	9	9
I/N (dB)	–20	–20	–20
Frequency (MHz) for calculating PFD values	700	1500	2000
Maximum aggregate PFD/ EPFD limit	**–134**	**–127**	**–124**
Aggregate PFD/ EPFD limit per system	**–137**	**–130**	**–127**

Protection of IMT BS from DC-MSS-IMT

To ensure protection of BSs from DC-MSS-IMT, the total interference received by the BS from all interfering satellites, either belong to one system or multiple systems, should be equal to the BS maximum tolerable interference. The interference received by BS from multiple interfering satellites depends on the gain of the BS towards the satellites. Therefore, to derive the limits for protection of BSs, one has to take into account the effect of the antenna gain correctly (see Doc. 5D/525 for more details and explanation).

As discussed in Document 5D/525, compared to aggregate PFD limits, EPFD limits take into account the aggregate interference due to all transmitting stations within a satellite constellation considering the directional antenna gain of the victim receiver towards interfering satellites. In addition, the ITU procedure to verify the compliance of non-GSO systems with EPFD limits derived for protection of GSO earth stations could potentially be modified to be used for ensuring protection of IMT BSs.

However, when defining aggregate PFD limits for protection of BSs, two issues must be addressed:

Formatted: English (United States)

1) How to take into account the antenna gain of the BS towards different interfering satellites?

2) How can ITU verify the compliance of a MSS system with aggregate PFD limits?

EPFD limits for protection of BSs

Defining EPFD like the definition of EPFD in Article **22.5C.1**, using gain of BS toward horizon ($G_{BS}(\varphi = 0)$) as the maximum gain of the BS toward interfering satellites, we have

$$\text{EPFD} = 10\log_{10}\sum_i\left(\frac{10^{\frac{P_i}{10}}\,G_{Sat}(\theta_i)}{4\pi d_i^2}\,\frac{G_{BS}(\varphi_i)}{G_{BS}(\varphi=0)}\right) \qquad (3)$$

The maximum aggregate EPFD limit for protection of BSs can be obtained from the BS receiver characteristics as:

$$\text{Aggregate EPFD} = 10\,log_{10}(kTB) + NF + \frac{I}{N} + L_f - 10\log_{10}[G_{BS}(\varphi = 0)] - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (4)$$

Considering 3 dB multi-system aggregation factor, EPFD limit per system (single entry EPFD limit) can be obtained as

$$\text{EPFD per system} = \text{Aggregate EPFD} - 3 \qquad (5)$$

Maximum aggregate EPFD and EPFD per system for non-AAS BSs in rural deployment are obtained and summarized in Table 2.

TABLE A1-26

EPFD limits in dB(W/(m² . MHz)) for protection of non-AAS IMT BS

Frequency range	< 1 GHz	1.5 GHz	> 2 GHz
Peak of antenna gain (dBi)	18	18	18
Downtilt (degree)	3	3	3
$G_{BS}(\varphi = 0)$ (dBi)	16	16	16
Noise figure (dB)	5	5	5
Feeder loss (dB)	3	3	3
I/N (dB)	–20	–20	–20
Frequency (MHz) for calculating PFD values	700	1500	2000
Maximum aggregate EPFD	**–154**	**–147**	**–144**
EPFD per system	**–157**	**–150**	**–147**

Aggregate PFD limits for protection of BSs

The aggregate PFD from a constellation at the location of IMT BS is

$$\text{Aggregate PFD per system} = 10\,log_{10}\sum_i\frac{EIRP_i(\theta_i)}{4\pi d_i^2} = 10\log_{10}\sum_i\left(\frac{10^{\frac{P_i}{10}}\,G_{Sat}(\theta_i)}{4\pi d_i^2}\right) \qquad (6)$$

To be able to define aggregate PFD limit for protection of BS, one idea is to model the BS as a receiver with an isotropic antenna with the equivalent gain of $\alpha * G_{BS}(\varphi = 0)$, where $0 < \alpha < 1$ needs to be estimated after doing sharing studies. Note that the value of α depends on the satellite constellation parameters, particularly the number of satellites in the constellation.

Formatted: English (United States)

With this modeling, the maximum aggregate PFD for protection of BSs can be obtained in a way similar to IMT UE. Therefore,

$$\text{Maximum aggregate PFD for protection of BS} =$$

$$10\,log_{10}(kTB) + NF + \frac{I}{N} + L_f - 10\log_{10}(\alpha) - 10\log_{10}[G_{BS}(\varphi = 0)] - 10\,log_{10}\left(\frac{\lambda^2}{4\pi}\right) \quad (7)$$

Considering 3 dB multi-system aggregation factor, aggregate PFD limit per system (single entry limit) can be obtained as

$$\text{Aggregate PFD per system } = \text{Maximum aggregate PFD for protection of BS} - 3 \quad (8)$$

Maximum aggregate PFD and aggregate PFD per system for non-AAS BSs in rural deployment are obtained and summarized in Table 3.

TABLE A1-27

Aggregate PFD limits in dB(W/(m² . MHz)) for protection of non-AAS IMT BS

Frequency range	< 1 GHz	1.5 GHz	> 2 GHz
Peak of antenna gain (dBi)	18	18	18
Downtilt (degree)	3	3	3
$G_{BS}(\varphi = 0)$ (dBi)	16	16	16
α	TBD	TBD	TBD
Noise figure (dB)	5	5	5
Feeder loss (dB)	3	3	3
I/N (dB)	–6	–6	–6
Frequency (MHz) for calculating PFD values	700	1500	2000
Maximum aggregate PFD	$\mathbf{-154} - 10\log_{10}[\alpha]$	$\mathbf{-147} - 10\log_{10}[\alpha]$	$\mathbf{-144} - 10\log_{10}[\alpha]$
Aggregate PFD per system	$\mathbf{-157} - 10\log_{10}[\alpha]$	$\mathbf{-150} - 10\log_{10}[\alpha]$	$\mathbf{-147} - 10\log_{10}[\alpha]$

Proposal

Based on the discussion and analysis presented in this contribution, it is proposed to:

- consider including both "maximum aggregate PFD/ EPFD limits" and "PFD /EPFD limits per system (single entry limit)" for protecting terrestrial IMT UE and IMT BSs from DC-MSS-IMT systems;
- consider 3 dB multi-system aggregation factor when defining PFD/ EPFD limits per system (this value might need to be updated);
- update working document on studies for the regulatory considerations to protect terrestrial IMT systems under WRC-27 agenda item 1.13 (Annex 4.6 to Document 5D/563) as proposed in the attachment. Note that the attachment shows only section 5 "Regulatory limits for the frequency bands within the range 694-2700 MHz" of the of the working document with track changes activated as no changes proposed to the other sections.

Formatted: English (United States)

Study J (Doc. 5D/824 (CHN))

[Note: Questions were raised with regards to the assumptions and methodology]

1 Introduction

This attachment provides a dynamic simulation-based methodology for deriving the aggregate PFD value to protect IMT system at the border between neighboring countries from DC-MSS-IMT space stations for possible new DC-MSS-IMT allocation on a primary or secondary basis. Based on technical characteristics of DC-MSS-IMT and IMT system, the preliminary results of PFD values for protecting IMT UE in 694/698-960 MHz are provided.

2 Technical characteristics

2.1 Technical characteristics of DC-MSS-IMT

Annex to the Chair's Report of WP 4C (see Annex 7 to Doc. 4C/356) provides the technical characteristics of DC-MSS-IMT towards WRC-27 agenda item 1.13 which could be used as the basis of the study. Detailed technical characteristics are summarized in Table 1 and Table 2.

TABLE 1

Parameters of orbital configuration

Altitude (km)	**Inclination (deg)**	**Planes**	**Sats per plane**	**RAAN spacing (deg)**	**Total number of sats**
500	55	60	60	6	3 600

Formatted: English (United States)

TABLE 2

Parameters of DC-MSS-IMT

	Parameter	**Unit**	**Frequency**				
Downlink (Space-to-Earth)	Frequency band	MHz	694/698-960	1 427-1 518	1 805-1 880 /2 110-2 170 /1 880-1 920	2 300-2 400	2 500-2 690
	Typical Emission Bandwidth	MHz	5	5	5	5	5
	S/S Transmitter power per beam	dBW	9	13	13	13	13
	S/S EIRP per beam	dBW	39.9	46.2	48.2	50.4	51.1
	EIRP spectral density per beam	dBW/Hz	–27.1	–20.8	–18.8	–16.6	–15.9
	S/S Antenna pattern	n/a	M.2101	M.2101	M.2101	M.2101	M.2101
	Single element antenna gain	dBi	2	3.92	4.11	4.15	4.15
	Antenna array configuration (Row×Column)		28×28	29×29	36×36	46×46	50×50
	Horizontal 3dB beamwidth of single element	°	120	118	118	110	110
	Vertical 3dB beamwidth of single element	°	120	118	112	110	110
	Horizontal radiating element spacing	dH/λ	0.5	0.5	0.5	0.5	0.5
	Vertical radiating element spacing	dV /λ	0.5	0.5	0.5	0.5	0.5
	Horizontal Front-to-back ratio	dB	30	30	30	30	30
	Vertical Front-to-back ratio	dB	30	30	30	30	30
	ACLR	dB	25	25	25	25	25

Formatted: Space After: 6 pt

	Parameter	**Unit**	**Frequency**				
Uplink (Earth-to-space)	Frequency band	MHz	694/698-960	1 427-1 518	1 710-1 785 /1 920-1 980 /2 010-2 025	2 300-2 400	2 500-2 690
	Emission Bandwidth (s)	MHz	1.4	1.4	1.4	1.4	1.4
	Polarization	n/a	Linear polarization	Linear polarization	Linear polarization	Linear polarization	Linear polarization
	E/S Transmitter power	dBW	−7	−7	−7	−7	−7
	Antenna gain	dBi	−3	−3	−3	−3	−3
	E/S EIRP	dBW	−10	−10	−10	−10	−10
	Antenna Pattern		Omni direction	Omni direction	Omni direction	Omni direction	Omni direction
	Spectral mask	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.2, Table 6.5.2.2-1.				
	ACLR	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.2.4.1.				
	Out of band emissions	n/a	See 3GPP TS 38.101-1 v16.6.0 (2020-12), § 6.5.3.1.				
	Min Elevation	°	35	35	35	35	35

*Note: There is currently no available ITU-R recommendation in force to simulate satellite phased array antenna for DC-MSS-IMT system sharing and compatibility studies. The satellite engineering design and antenna gain simulation is based on Recommendation ITU-R M.2101 complimented with antenna orientation parameter

.

2.2 Technical characteristics of IMT

Technical characteristics of IMT systems operating in the frequency bands below 1 GHz and 1-3 GHz can be found in section 4 of the working document on characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27 (Annex 4.15 to Doc. 5D/563).

2.2.1 Deployment-related parameters of IMT

Formatted: None, Indent: Left: 0 cm, First line: 0 cm, Space Before: 6 pt, Don't keep with next, Don't keep lines together

Detailed deployment-related parameters of IMT systems are summarized as follows:

TABLE 3

Deployment-related parameters for bands below 1 GHz

	Urban/suburban macro	**Rural macro**
Base station characteristics/Cell structure		
Centre frequency	700 MHz	
Cell radius	0.5-5 km (typical value to be used in sharing studies for urban macro 1.5 km and for suburban macro 3 km)	> 5 km (typical value to be used in sharing studies 8 km)
Antenna height	30 m	30 m **(see Note 1)**
Sectorization	3 sectors	3 sectors
Downtilt	3 degrees	3 degrees
Frequency reuse	1	1
Antenna pattern	Recommendation ITU-R F.1336 (*recommends* 3.1) k_a = 0.7 k_p = 0.7 k_h = 0.7 k_v = 0.3 Horizontal 3 dB beam width: 65 degrees Vertical 3 dB beam width: determined from the horizontal beam width by equations in Recommendation ITU-R F.1336. Vertical beam widths of actual antennas may also be used when available.	
Antenna polarization	Linear/±45 degrees	Linear/±45 degrees
Below rooftop base station antenna deployment	Urban: 20% Suburban: 0%	0%
Feeder loss	3 dB	3 dB
Typical channel bandwidth	10 MHz	10 MHz
Maximum base station output power (Report ITU-R M.2292)	46 dBm in 10 MHz	46 dBm in 10 MHz
Maximum base station antenna gain (Report ITU-R M.2292)	15 dBi	15 dBi
Maximum base station output power/sector (e.i.r.p.)	58 dBm in 10 MHz	58 dBm in 10 MHz
Network loading factor (base station load probability X%) (see Section 3.4 below and Rec. ITU-R M.2101 Annex 1, section 3.4.1 and 6)	20%, 50%	20%, 50%
TDD / FDD / SDL	FDD / SDL	FDD / SDL

Note 1: In macro rural cases in various regions, typical antenna heights could vary depending on the notion of rural territory, i.e. population density, actual distribution of settlements, infrastructure availability, etc.

Formatted: English (United States)

TABLE 4

UE parameters for bands below 1 GHz

	Urban/suburban macro	**Rural macro**
User terminal characteristics		
Indoor user terminal usage (Report ITU-R M.2292)	70%	50%
Indoor user terminal penetration loss	Rec. ITU-R P.2109	Rec. ITU-R P.2109
User equipment density for terminals that are transmitting simultaneously **(Note 1)**	3 UEs per sector	3 UEs per sector
UE height **(Note 2)**	1.5 m	1.5 m
Average user terminal output power	Use transmit power control	Use transmit power control
Typical antenna gain for user terminals	−3 dBi	−3 dBi
Body loss	4 dB	4 dB
Transmit power control		
Power control model	Refer to Recommendation ITU-R M.2101 Annex 1, section 4.1	
Maximum user terminal output power, PCMAX	23 dBm	23 dBm
Power (dBm) target value per RB, P0_PUSCH **(Note 3)**	−92.2	−92.2
Path loss compensation factor, α (same as "balancing factor" mentioned in Rec. ITU-R M.2101)	0.8	0.8

Note 1: 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.).

Note 2: In principle, indoor UEs are distributed over different floors of the building. It should be noted that the number of floors of buildings vary within the environment and among the countries. Moreover, the number of floors of buildings is not related to Macro BS antenna height (parameter given in the Table). In particular in small cities, sub-urban and rural areas, many or most of antennas are installed on masts. Therefore, for outdoor BSs, indoor UEs are assumed to be modelled on the ground floor for the sharing study.

Note 3: The target power is defined per Resource Block (RB), considering 180 kHz RB bandwidth corresponding to 15 kHz subcarrier spacing.

2.3 Propagation models

Based on the liaison statement from WPs 3L/3M to WP5D (Doc. 5D/627), Recommendation ITU-R P.619-5 is used to calculate the propagation loss between stations in space and those on the surface of the Earth.

2.4 Protection criteria

When considering DC-MSS-IMT as the interfering system with the possible new DC-MSS-IMT allocation on a primary or secondary basis, the IMT protection criterion of $I/N = -6$ dB is used for dynamic simulation-based method.

3 Methodology

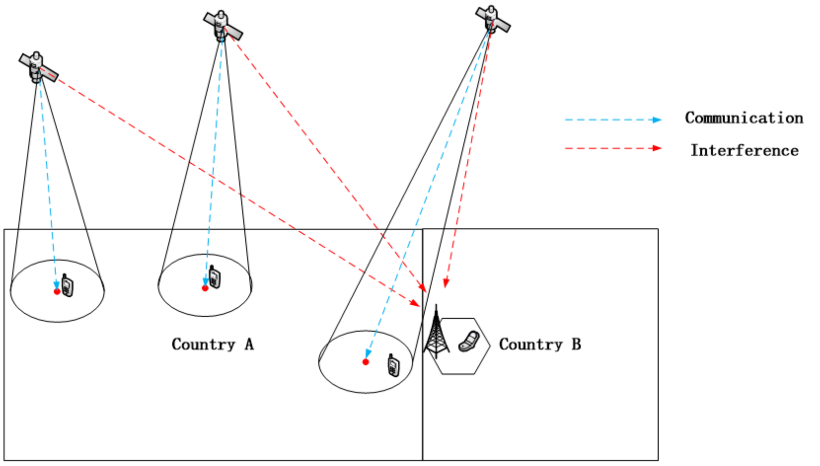
3.1 Scenario

The scenario of the sharing study to evaluate the aggregate PFD value from DC-MSS-IMT space stations to protect IMT system at border between neighboring countries is shown in Figure 1.

Formatted: English (United States)

FIGURE 1

Sharing scenario between DC-MSS-IMT space stations interfere with IMT stations at border between neighboring countries



3.2 Methodology

Dynamic simulation-based method is used to evaluate the aggregate PFD value from DC-MSS-IMT space stations to protect IMT system at the border between neighboring countries with additional isolation required to satisfy the IMT protection criterion of $I/N = -6$ dB. Main steps of the simulation are listed as follows.

Step1: Determine the range of simulation area

In this study, DC-MSS-IMT space stations serve DC-MSS-IMT UEs in Country A which shares a border with Country B.

The size of Country A is set to 2 442 km in length and 2 442 km in width, with the center located at 109°E, 30°N.

Step2: Generate DC-MSS-IMT space stations/MSS UEs and IMT BSs/UEs

The spatial topology of DC-MSS-IMT space stations is generated at time T based on the parameters of orbital configuration.

DC-MSS-IMT UEs are generated within Country A randomly, and adopts highest elevation satellite selection and pointing strategy to connect to DC-MSS-IMT space stations. The center of space station beam can only point within the territory of Country A.

IMT BSs/UEs are generated along the border of Country B. Based on the deployment-related parameters of IMT system, the inter-site distance is 2,250 m. IMT UEs are generated within IMT base station sectors randomly.

Step3: Simulate the positions of satellite constellation over a period of time and calculate aggregate interference from DC-MSS-IMT space stations to IMT system at each time step

The aggregate interference level is determined by all visible space stations serving DC-MSS-IMT UEs in Country A.

Formatted: English (United States)

$$I_{total} = 10\ log\left(\sum_n^N \sum_j^J 10^{I_{n,j}/10}\right)$$

$$I_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - PL_n + G_{rx}(\theta_{rx})_{n,j} - L_{other}$$

where:

I_{total}: Aggregate interference power density from DC-MSS-IMT space stations, dBW/MHz

$I_{n,j}$: Interference power density from j-th beam of n-th space station, dBW/MHz

P_{tx}: DC-MSS-IMT space station transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of DC-MSS-IMT space station is pointing to its serving DC-MSS-IMT UE, dBi

$G_{rx}(\theta_{tx})_{n,j}$: IMT receiver station antenna gain in the direction of n-th DC-MSS-IMT space station, dBi

PL_n: Propagation loss, dB

L_{other}: Feeder loss for IMT BS, Body Loss for IMT UE dB

N: The number of DC-MSS-IMT space stations in the interference calculation

J: The number of beams of one DC-MSS-IMT space station.

Furthermore, the required additional isolation could be derived based on the received aggregate interference and maximum allowed interference level based on protection criteria *I/N* = −6 dB.

$$ISO = I_{total} - I_{max}$$

Formatted: Equation,eq, Left

ISO: The required additional isolation that may be needed to protect IMT system to satisfy the protection criteria *I/N* = −6 dB

I_{max}: The acceptable maximum interference power derived based on the protection criteria and receiver noise, dBW/MHz.

Step4: Calculate required PFD values from DC-MSS-IMT constellation at the border between neighboring countries

Aggregate PFD is calculated by simulation using the following formulas:

$$PFD = 10\ log\left(\sum_n^N \sum_j^J 10^{PFD_{n,j}/10}\right)$$

$$PFD_{n,j} = P_{tx} + G_{tx}(\theta_{tx})_{n,j} - 10log_{10}(4\pi d_n^2)$$

where:

PFD: Aggregate PFD from DC-MSS-IMT space stations, dB(W/m^2·MHz)

$PFD_{n,j}$: PFD from j-th beam of n-th space station, dB(W/(m²·MHz))

P_{tx}: DC-MSS-IMT space station transmit power density, dBW/MHz

$G_{tx}(\theta_{tx})_{n,j}$: n-th DC-MSS-IMT space station antenna gain in the direction of IMT receiver stations taking into account the j-th main beam of DC-MSS-IMT space station is pointing to its serving DC-MSS-IMT UE, dBi

d_n: Distance between n-th DC-MSS-IMT space station and IMT receiver station, m.

Based on the additional isolation obtained in Step 3, the required PFD values are derived using the following formula:

Formatted: English (United States)

$$PFD_{value} = PFD - ISO$$

where:

PFD_{value}: Required PFD values of DC-MSS-IMT constellation to protect IMT system at the border between neighbouring countries, dB(W/(m²·MHz)).

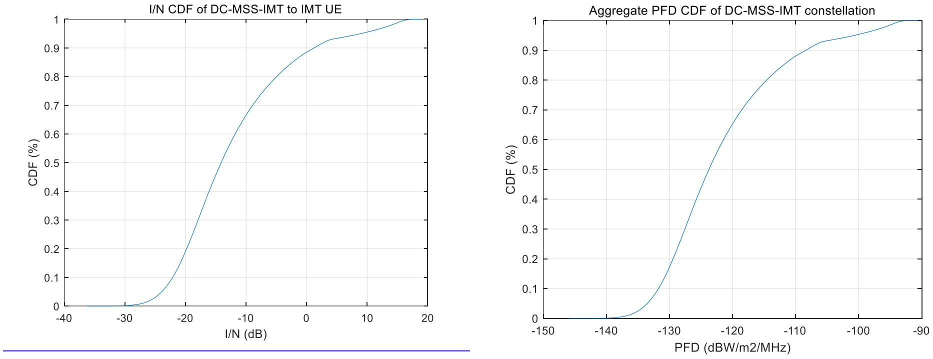
Step5: Analyse the study results

4 Study results

This section provides the preliminary aggregate PFD value for protecting IMT UE from DC-MSS-IMT space station based on the methodologies described in section 3 above.

Based on the parameters of DC-MSS-IMT in section 2.1 of Attachment, this section provides the preliminary simulation results of the aggregate interference contributed by DC-MSS-IMT space stations to IMT UEs that are located at the border between neighbouring countries in the frequency band 694/698-960 MHz. According to the simulation results, the aggregate PFD values of DC-MSS-IMT space stations at border between neighbouring countries to protect IMT UE are provided.

FIGURE 2



(a) I/N CDF of DC-MSS-IMT to protect IMT UE in the frequency band 694/698-960 MHz

(b) Aggregate PFD CDF of DC-MSS-IMT constellation in the frequency band 694/698-960 MHz

TABLE 5

Simulation results for protecting IMT UE

Frequency band (MHz)	***I/N* (dB)**	**Additional isolation (dB)**	**PFD limit (dBW(m²·MHz))**
694/698-960	18.82	24.82	–115.63

Formatted: Table_fin

Formatted: English (United States)

5 Summary

This study derived the aggregate PFD value to protect IMT UEs from DC-MSS-IMT space stations at the border between neighboring countries in the frequency band 694/698-960 MHz based on dynamic simulation method. The required aggregate PFD value is −115.63 dB(W/m^2·MHz), considering satisfying the IMT protection criteria $I/N = -6$ dB with 100% of probability not to be exceeded. This study provided preliminary simulation results, and further research may be conducted based on other simulation assumptions.

Formatted: Font: 12 pt, Not Bold, Superscript

Formatted: Font: 12 pt, Not Bold, Italic

Formatted: English (United States)

Study K (Doc. 5D/897 (KOR))

[Note: Questions were raised with regards to the assumptions and methodology used in the study.]

Formatted: Font: Italic

Formatted: Normal, Space After: 0 pt

1 Introduction

The protection of terrestrial IMT system (IMT user equipment (UE) and IMT base station (BS)) requires defining Power Flux Density (PFD) levels based on IMT protection criteria and receiver characteristics. Regulatory PFD limits should also consider the interference from DC-MSS-IMT systems, which may consist of hundreds or even thousands of low-Earth orbit satellites. It is expected that terrestrial IMT system will be affected by aggregate interference from one or multiple constellations, and this should be addressed in regulatory measures.

Different approaches to defining PFD limit from DC-MSS-IMT have been discussed in WP 5D – PFD levels per satellite, per system and per multiple systems.

This study provides a method for determining the PFD limit per DC-MSS-IMT system. If it is assumed that many non-GSO satellites are transmitting signals in the same frequency band, a PFD limit per satellite may not be suitable to protect terrestrial IMT systems. When considering the PFD limit per non-GSO system, it is expected that the limit can be monitored and maintained by a network control facility of the non-GSO system, which adjusts the aggregate interference from multiple space stations of that system to the Earth's surface. However, when more than one non-GSO system is deployed in same frequency band, the PFD limit per system could be exceeded due to the combined effect of those systems.

Theoretically, applying a PFD limit per multiple non-GSO systems would provide the best protection for IMT systems. However, since different non-GSO systems operate independently, and it is not feasible to determine the interference contributions from other systems, compliance with an aggregate PFD limit across multiple systems is unenforceable.

Taking these observations into account, this contribution proposes establishing a PFD limit per non-GSO system with an apportionment factor, typically defined as β, applied, to ensure the protection of terrestrial IMT system. In particular, a methodology to determine a PFD limit per non-GSO system is presented considering IMT BS receiver characteristics as well as IMT UE, for scenarios involving carrier frequency, receiver characteristics, IMT protection criteria, etc.

2 Methodology for PFD limit per system

The maximum PFD level (in dB) that a terrestrial IMT receiver can tolerate in a direction above the horizon (θ) is given by

$$\mathrm{PFD}(\theta) = 10\log_{10}(kTB) + NF + \frac{I}{N} - G_r(\theta) + L_{\mathrm{feeder}} - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right),$$

where:

k: Boltzmann's constant ($1.380649 \times 10^{-23}\ J/K$)

T: Receiver noise temperature (K); a value of 290 K is considered in our study

B: Reference bandwidth; 1 MHz is considered

NF: Receiver noise figure (dB); 7 dB is assumed for both the IMT BS and the UE

I/N: Protection criteria (dB); -6 dB is applied; details provided in the following section

$G_r(\theta)$: Effective antenna gain (dBi) of the receiver antenna in the direction of the interferer; described in the following section

L_{feeder}: Receiver antenna feeder loss for IMT system (dB); 1 dB is assumed

Formatted: English (United States)

λ: Wavelength (meter); with a carrier frequency of 2 GHz, λ is 0.15 meter in this study.

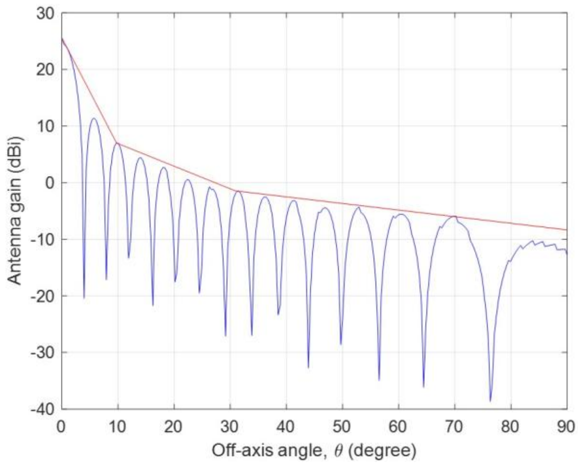
To protect the IMT receiver from aggregate interference generated by multiple satellites of a non-GSO system, the PFD measured in a direction shall not exceed the limit specified by the above equation.

3 I/N of IMT protection criteria and IMT receiver antenna gain

Report ITU-R M.2292-0 (“Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses”) defines the baseline characteristics of terrestrial IMT-Advanced systems and serves as a reference for sharing and compatibility studies with other systems and services. It introduces a protection criterion for IMT-Advanced receiver of I/N = −6 dB, applicable regardless of the number of cells or interferers, which is also adopted in this study.

FIGURE 1

Effective antenna gain of IMT BS as a function of the off-axis angle



The effective gain of the omni-directional IMT UE antenna is considered as a constant across all directions; therefore, this study assumes $G_r(\theta) = 0$ dBi for all θ. For the IMT BS, active antenna systems (AAS) are widely employed with their directional antenna gain characteristics modelled in accordance with ITU-R Recommendation M.2101-0. As depicted in Figure 1, the effective antenna gain of the IMT BS is shown by the blue line, and its envelope is piecewise linearly approximated by the red lines for 2 GHz frequency band. It should be noted that the antenna pattern is subject to change depending on the operational frequency band.

These red line approximations are formulated by $f_1(\theta)$, $f_2(\theta)$ and $f_3(\theta)$:

$$\begin{aligned} f_1(\theta) &= -1.9065 \cdot \theta + 25.5620, && \text{for } 0 \ \leq \theta \leq 9.72 \\ f_2(\theta) &= -0.3994 \cdot \theta + 10.8888, && \text{for } 9.72 \ \leq \theta \leq 31.32 \\ f_3(\theta) &= -0.1167 \cdot \theta + 2.1544, && \text{for } 31.32 \ \leq \theta \leq 90, \end{aligned}$$

where θ is the off-axis antenna angle. These three functions are used for subsequent derivations.

Formatted: English (United States)

4 PFD limit for the protection of IMT-UE

In accordance with the methodology in Section 2, the PFD limit is considered constant value within a given frequency band, owing to the use of an omni-directional IMT UE antenna with 0 dBi gain. Accordingly, the PFD limits for the IMT UE are calculated for selected frequency bands between 700 and 2 700 MHz, as presented below.

Frequency (MHz)	**PFD (dBW/m^2 for 1MHz)**
700	-123.63
1 000	-120.53
2 000	-114.51
2 700	-111.9

5 PFD masks for the protection of IMT-BS

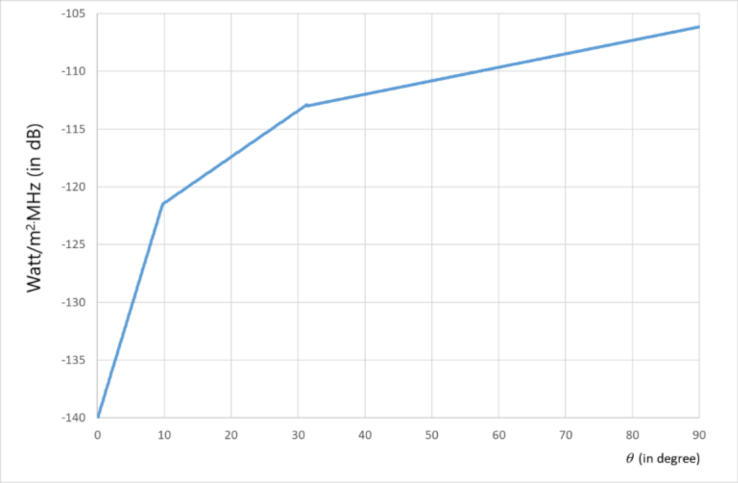
As described in Section 3, applying the piecewise linear approximation of the IMT BS effective antenna gain, the corresponding PFD(θ) limit for the 2 GHz frequency band is expressed in a piecewise linear form,

$$\mathrm{PFD}(\theta) = \begin{cases} 1.9065 \cdot \theta - 140.0677, & \text{for } 0 \ \leq \theta \leq 9.72 \\ 0.3994 \cdot \theta - 125.3945, & \text{for } 9.72 \ \leq \theta \leq 31.32 \\ 0.1167 \cdot \theta - 116.6601, & \text{for } 31.32 \ \leq \theta \leq 90, \end{cases}$$

where θ is the angle of arrival angle of radio-frequency wave (degrees above the horizon). This is depicted in Figure 2 by the blue line.

FIGURE 2

PFD (θ) limit for 2 GHz frequency for the protection of IMT BS



Depending on the interference scenario between the IMT system and the DC-MSS-IMT system, the victim station may be the IMT UE, the IMT BS, or both. For the protection of both the IMT BS and

Formatted: English (United States)

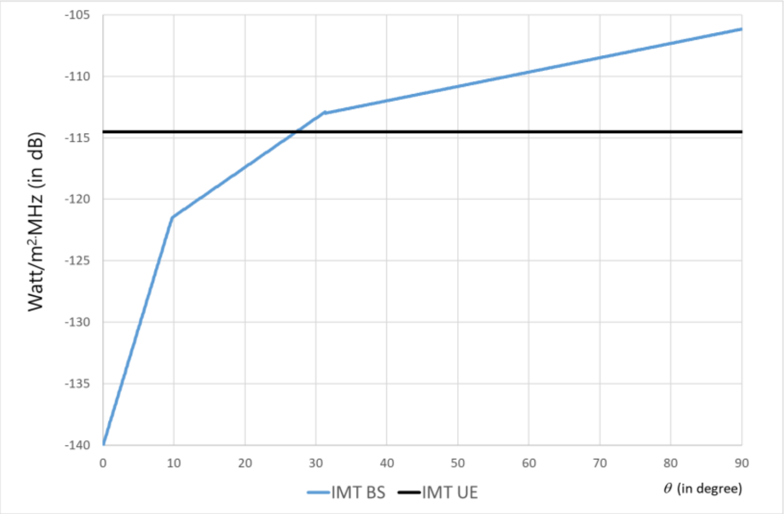
UE against interference from space stations, the PFD limits illustrated in Figure 3 should be applied. These limits are defined by

$$\mathrm{PFD}(\theta) = \begin{cases} 1.9065 \cdot \theta - 140.0677, & \text{for } 0 \leq \theta \leq 9.72 \\ 0.3994 \cdot \theta - 125.3945, & \text{for } 9.72 \leq \theta \leq 27.25 \\ -114.51, & \text{for } 27.25 \leq \theta \leq 90, \end{cases}$$

where θ is the angle of arrival angle of radio-frequency wave, measured in degrees above the horizon.

FIGURE 3

PFD(θ) for the protection of both IMT BS and IMT UE



It should also be noted that these PFD limits are calculated based on the 2 GHz frequency band. Whether a single PFD limit or multiple PFD limits across several frequency bands should be adopted must be considered for the protection of IMT system.

6 Conclusion and further consideration

This study derived PFD limits to protect terrestrial IMT systems from interference generated by a DC-MSS-IMT system. The derivations were based on several factors: a 2 GHz carrier frequency, −6 dB of I/N protection criterion, the antenna radiation pattern of the IMT BS, and the omni-directional IMT UE antenna.

The proposed methodology can be also applied to calculate the PFD limits for multi-system scenarios by introducing an apportionment factor (β) to account for multi-system effects. Several values of β have been proposed to WP 5D, and further consideration is required to determine the appropriate value.

Formatted: English (United States)

Study L (Doc. 5D/914 (TON))

[Note: Number of concerns were expressed regarding the methodology and assumptions used in the study].

Formatted: Font: Not Bold, Italic, English (United Kingdom)

Formatted: Font: Italic, English (United Kingdom)

With respect to the general IMT protection, starting from a baseline protection value of -6 dB I/N, real-world noise includes thermal noise + intercell interference. The following study analyses the effects of intercell interference in a typical rural or suburban IMT deployment.

Simulation Scenario and Methodology

The study uses a Monte Carlo simulation method to assess the impact of intercell interference on outdoor UEs with typical suburban and rural IMT network deployments at nine center frequencies, ranging from 700 to 2600 MHz. The network activity factor is assumed to be 50%. Each system is modelled as being comprised of 19 tri-sector base stations. Other relevant parameters are included in the table below. The propagation model used for both simulations was ITU-R P.1546-6.

TABLE 1

System Parameters

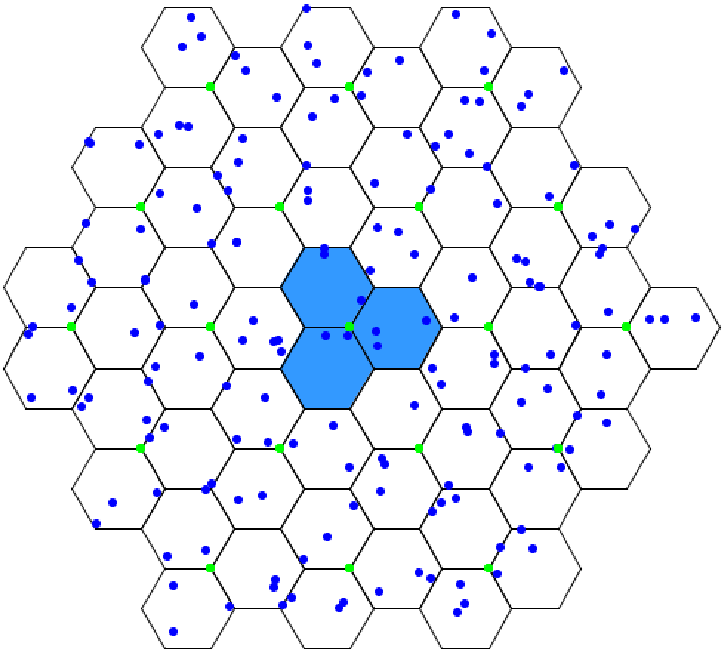
Parameter	Suburban	Rural
System Bandwidth (MHz)	10	10
Base Station (BS) Parameters		
Cell Radius (km)	0.5	2.5
Tx Power (dBm)	46	46
Antenna Peak Gain (dBi)	16	18
Radiation Pattern	ITU-R F.1336-4 rec 3	ITU-R F.1336-4 rec 3
Antenna Height (m)	30	45
Network Activity Factor (%)	50%	50%
User Equipment (UE) Parameters		
Number of UE's per BS	9	9
Noise Figure (dB)	9	9
Antenna Gain (dBi)	-3	-3
Additional Losses (dB)	0	0
Distribution (Indoor/Outdoor)	Outdoor Only	Outdoor Only

An example "event" of the deployments is shown below, whereby the green dots are the BSs and the blue dots are the UEs.

Formatted: English (United States)

FIGURE 30

Example Deployment Event



Simulation Results

The full set of Monte Carlo simulation intercell interference results is presented in Table 1.

TABLE 1

IMT Intercell Interference Results

Mobile Band	Rural Median Intercell Interference (0 dB body loss)	Rural Median Intercell Interference (4 dB body loss)	Suburban Median Intercell Interference (0 dB body loss)	Suburban Median Intercell Interference (4 dB body loss)
MHz	(dBm/MHz)	(dBm/MHz)	(dBm/MHz)	(dBm/MHz)
700	-89.3	-93.3	-68.2	-72.2
800	-90.1	-94.1	-69.6	-73.6
900	-91.9	-95.9	-71.3	-75.3
1400	-95.4	-99.4	-75.9	-79.9
1800	-98.4	-102.4	-78.8	-82.8
1900	-98.8	-102.8	-80.0	-84.0
2100	-99.7	-103.7	-81.1	-85.1
2300	-100.5	-104.5	-82.0	-86.0
2600	-102.1	-106.1	-83.5	-87.5

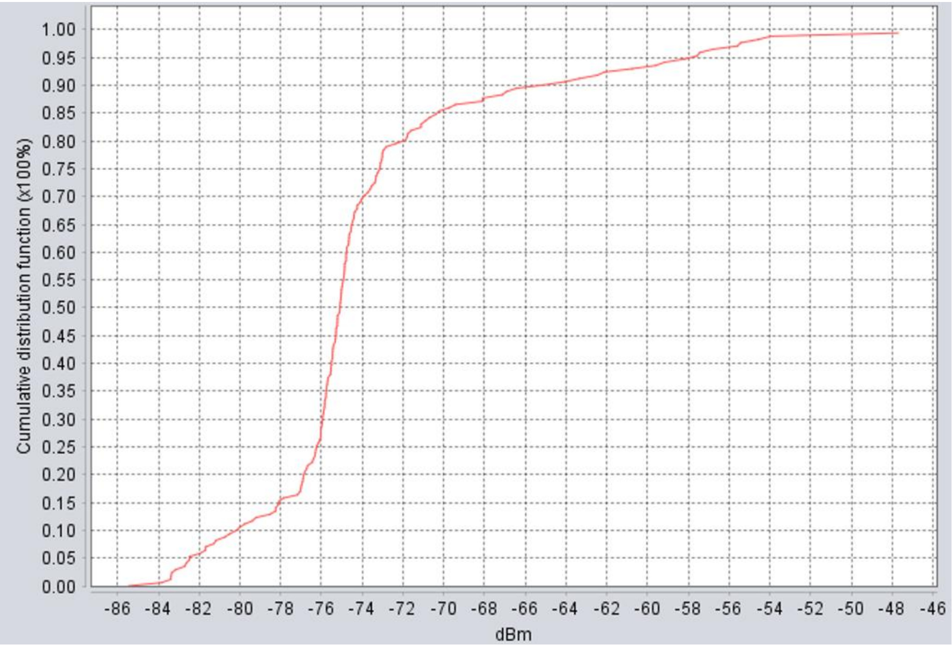
Formatted: English (United States)

1 Suburban Environment

As an example, at 1900 MHz center frequency with 0dB body loss, the suburban environment and deployment case resulted in a median intercell interference value of -75.1 dBm/3.06 MHz or equivalently -80.0 dBm/MHz. The cumulative distribution function (CDF) of the suburban environment case is below:

FIGURE 2

Example Suburban Intercell Interference CDF (dBm/3.06MHz) at 1900 MHz with 0dB body loss



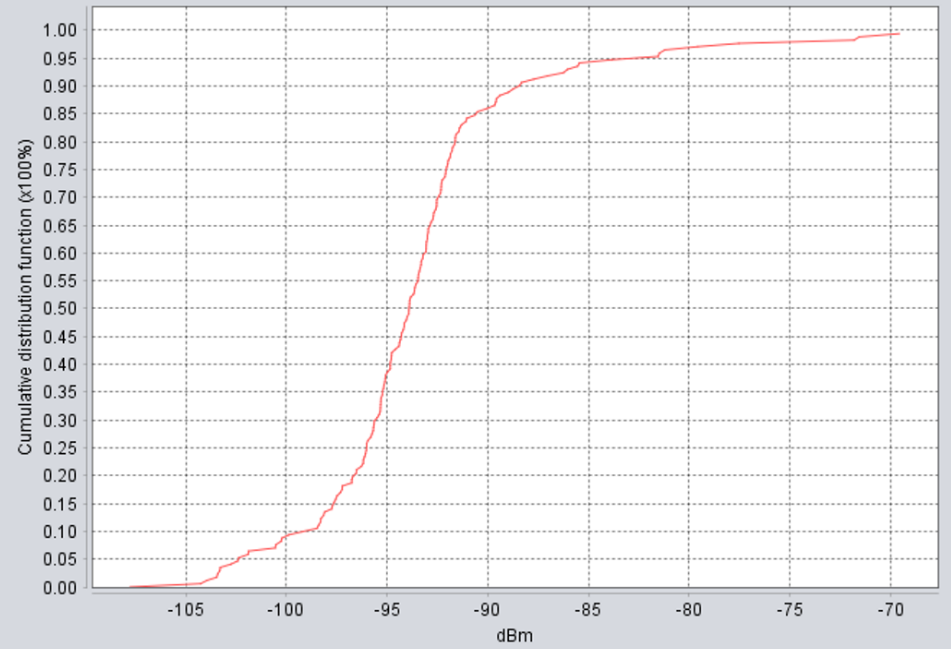
2 Rural Environment

At the same example 1900 MHz center frequency, with 0dB body loss, the rural environment and deployment case resulted in a median intercell interference value of -93.9 dBm/3.06 MHz or equivalently -98.8 dBm/MHz. The cumulative distribution function (CDF) of the rural environment case is below:

Formatted: English (United States)

FIGURE 3

Example Rural Intercell Interference CDF (dBm/3.06MHz) at 1900 MHz with 0dB body loss



The proposed PFD formula is the following:

$$PFD(\theta) = 10\log_{10}\left(kT_{ref}B * 10^{\frac{NF}{10}} + 10^{\frac{I_{inter-cell}}{10}}\right) + \frac{I}{N} - G_r(\theta) + \mathrm{L}_{feeder} + \mathrm{L}_{body} + \mathrm{L}_{misc} - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right) \qquad (1)$$

where:

k	is Boltzmann's constant (1.380649×10^{-23} J/K)
T_{ref}	is the reference noise temperature (300 Kelvin)
B	is the reference bandwidth (1 MHz)
NF	is the receiver noise figure (dB)
$I_{inter-cell}$	is the inter-cell interference (dBW/MHz)
$\frac{I}{N}$	is the receiver interference to noise ratio limit (dB) considering intercell interference
$G_r(\theta)$	is the effective antenna gain (dBi) of the receiver antenna towards the direction of the interferer
θ	is the elevation angle (°) towards the direction of the interferer
L_{feeder}	is the receiver antenna feeder loss for IMT BS (dB)

Formatted: English (United States)

L_{body}	IMT UE body loss (dB)
L_{misc}	atmospheric losses and polarization losses (dB)
$10\log_{10}\left(\frac{\lambda^2}{4\pi}\right)$	is the antenna aperture (dB.m^2) at the wavelength, λ (m).

Our modelling considers that the UE antenna gain is uniform in all directions and so the pfd limits ($PFD(\theta)$) obtained using Equation 1 is the same for all angle of arrivals, hence it is not elevation dependent. For the terrestrial IMT UE, we have adopted:

TABLE 2

UE characteristics

	UE RF parameters	
IMT UE antenna gain	-3 dBi	
IMT UE noise figure	9 dB	
IMT UE feeder loss (L_{feeder})	0 dB	
IMT UE body loss (L_{body})	0 dB	4 dB
Atmospheric losses and polarization losses (L_{misc})[4]	0 dB	
I/N$_{total}$ [5]	-6 dB	

Proposed aggregate PFD values have been calculated below in Table 2, based on the median inter-cell interference in rural and suburban deployments simulated above and listed in Table 1.
Table 3 below summarizes the results by band[6]:

TABLE 3

PFD limits for DC-MSS-IMT system using Linear Polarization*

	Rural		**Suburban**	
Mobile Band	**Pfd limits in mobile downlink spectrum (0 dB body loss)**	**Pfd limits in mobile downlink spectrum (4 dB body loss)**	**Pfd limits in mobile downlink spectrum (0 dB body loss)**	**Pfd limits in mobile downlink spectrum (4 dB body loss)**
MHz	**dBW/m^2/MHz**	**dBW/m^2/MHz**	**dBW/m^2/MHz**	**dBW/m^2/MHz**
700	-103.8	-103.7	-82.8	-82.8
800	-103.4	-103.2	-83.1	-83.1
900	-104.1	-103.8	-83.8	-83.8
1400	-103.6	-102.9	-84.5	-84.5

---

[4] Linear polarization and clear sky conditions assumed

[5] Acceptable UE receiver interference to total noise ratio limit (dB), considering intercell interference

[6] Please note, that the UE body loss influences the total noise + interference floor at the UE antenna and the D2C downlink interference impact towards the UE. Hence, the differences in the PFD limits for body losses of 0 dB and 4 dB are much smaller (up to down to 0 dB).

Formatted: English (United States)

	Rural		**Suburban**	
Mobile Band	**Pfd limits in mobile downlink spectrum (0 dB body loss)**	**Pfd limits in mobile downlink spectrum (4 dB body loss)**	**Pfd limits in mobile downlink spectrum (0 dB body loss)**	**Pfd limits in mobile downlink spectrum (4 dB body loss)**
1800	-104.0	-102.9	-85.2	-85.2
1900	-103.8	-102.7	-86.0	-85.9
2100	-103.6	-102.3	-86.2	-86.2
2300	-103.5	-102.0	-86.3	-86.3
2600	-103.5	-101.7	-86.7	-86.7

* For DC-MSS-IMT systems using circular polarization, the PFD values in this table will increase by 3dB.

Formatted: English (United States)

Study M (Doc. 5D/378 (F), ~~-~~5D/941 (F))

[Note: Questions were raised with regards to the parameters and assumptions used in the calculations of the epfd]

1 Introduction

Given 1) the high number of visible satellites with respect to terrestrial IMT receive station (UE or BS) and 2) its variability according to the constellation size, France is of the view that the approach of admitting an aggregate pfd for UEs and aggregate epfd for BSs is the most appropriate one for the protection of the terrestrial IMT network, considering the aggregate effect of all visible satellites. This approach considers the omnidirectionality of the UE as well as the directionality behavior of the antenna of the BS.

Given that aggregate pfd for protection of UEs is addressed in ~~a previous Contribution~~ doc. 5D/378, France intend ~~here~~ in doc. 5D/941 to initiate discussions on the assessment of epfd values for the protection of IMT UL (BSs).

2 PFD limits for the protection of IMT UE

We note that a body loss of 4 dB is an assumption for voice service when the mobile phone is put close to the head, and a body loss of 0 dB is a more realistic assumption for data service where the mobile phone is usually not put close to the head. Considering the pfd limits of the HIBS for frequency bands higher than 1 GHz, the corresponding results show that the protection limit of I/N=-6 dB is respected with a UE antenna gain of −3 dBi and a body loss of 0 dB. For the lower bands, and to be in coherence, we propose a modified pfd limit with a gap of 4 dB. Consequently, it is considered that the pfd limits given in Table 1 can provide a proper protection to the IMT TN DL with a I/N=−6 dB.

TABLE 1

Pfd limits and field strength values for MSS D2C satellite on protection of IMT TN DL

Frequency bands (FDD)	700, 800, 900 MHz	1800, 2000 MHz	2600 MHz
pfd (dB(W/(m² · MHz))	−118	−111	−109
Field Strength (dBuV/m/5MHz)	34	41	43

3~~2~~ EPFD equation

The equivalent power flux density (epfd) is defined, according to Radio Regulations (RR) Article **22.5C.1**, as a measure to protect geostationary satellite system from a non-geostationary satellite system. Similarly, this approach could be applied as a regulatory measure to protect terrestrial IMT BS from a DC-MSS-IMT system (including both non-geostationary satellite systems and geostationary satellite systems).

Similarly to RR Article **22.5C.1**, epfd is defined as the sum of the power flux densities produced at an IMT BS on the Earth's surface, by all the visible transmit stations within the DC-MSS-IMT system, taking into account the off-axis discrimination of a reference receiving antenna assumed to be pointing in its nominal direction. The epfd (dB(W/m^2)) in the reference bandwidth is calculated using the following formula:

$$epfd = 10\log_{10}\left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4\,\pi\,d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}}\right]$$

Formatted: English (United States)

where:

P_i: RF power at the input of the antenna of the transmit station, considered in the non-geostationary-satellite system (dBW) in the reference bandwidth

θi: off-axis angle between the boresight of the transmit station and the direction of receive station (IMT BS)

Gt(θi): transmit antenna gain (as a ratio) of the transmit station in the direction of the receive station

di: distance (m) between the transmit station and the receive station

φi: off-axis angle between the boresight of the antenna of the receive station and the direction of the i-th transmit station

Gr(φi): receive antenna gain (as a ratio) of the receive station in the direction of the i-th transmit station

Gr,max: maximum gain (as a ratio) of the antenna of the receive station.

While P_i and $G_t(\theta_i)$ depends on the DC-MSS-IMT system characteristics, the reference antenna gain pattern G_r needs to be defined based on the IMT characteristics.

4~~3~~ Reference antenna

The Table below provides information on the reference antenna radiation pattern to be used in the calculation of the epfd. The antenna model depends on the operating frequency band and whether the IMT BS is implementing AAS or non AAS antenna.

TABLE 2~~1~~

Reference antenna radiation pattern to be used in the epfd calculation

Frequency band	Reference antenna radiation pattern	Reference antenna elevation angle (tilt)
< 1 GHz	Rec. ITU-R F.1336 (*recommends* 3.1) for Non AAS antenna	–3°
> 1 GHz	Rec. ITU-R F.1336 (*recommends* 3.1) for Non AAS antenna	–3°
	Rec. ITU-R M.2101 for AAS antenna	–3°

For the reference antenna elevation angle (tilt), we propose to use –3° for non-AAS antennas as this could represent the worst-case scenario for a rural environment and 0° for AAS antennas. We note that for the latter, higher elevation angles could be seen to provide connectivity for aerial UEs.

As the satellites of a non-geostationary DC-MSS-IMT system are continuously moving and/or the beamforming direction of the AAS antenna is continuously varying, the epfd assessment requires a statistical simulation. This could be done using either the peak antenna pattern or, more preferably, the average side-lobe levels of the antenna pattern.

5~~4~~ Potential aggregate interference from multiple DC-MSS-IMT systems

Given that each SNO is responsible to manage the intra-system interference due to the multiple visible satellites, we cannot expect coordination between different SNOs to manage interference

Formatted: English (United States)

between different constellation systems operating co-frequency and covering different neighbouring countries. Consequently, a multi-system aggregation factor requires to be defined and assessed based on the typical deployment of DC-MSS-IMT system.

$$\text{epfd per system} = \text{maximum aggregate epfd} - \text{multi-system aggregation factor}$$

A preliminary assessment of the multi-system aggregation factor is given in Document 5D/754. The results show that 20% of the values are higher than 2.6 dB. We note that these results could be adjusted relative to the DC-MSS-IMT systems provided by Working Party (WP) 4C. However, the accuracy of the results relies on the following assumption: at the countries border, each DC-MSS-IMT system should respect the IMT protection criteria ignoring the existence of any other system, which provides the maximum aggregate epfd. This condition is the minimal requirement to ensure IMT protection from an individual DC-MSS-IMT system.

The analysis of the multi-system interference at the countries border is a principal step before any implementation of mitigation technique at the border. This step helps to define and tune the potential mitigation technique for the coexistence of a multiple DC-MSS-IMT systems with the terrestrial IMT network.

6~~5~~ Issue of limits compliance verification

It is required to define a methodology to check/control the conformity by the BR and the administrations.

7~~6~~ EPFD limits for terrestrial IMT UL protection

With the consideration of the epfd as a regulatory measure for the IMT UL protection, it is not possible to define pfd limits as a function of the elevation angle for the protection of the terrestrial IMT BS.

We have to use all the interference budget (*I/N* of -6 dB) to define a single value epfd limit per frequency band. Hence, the epfd limit could be defined as follows:

$$\text{epfd\_limit} = (10\log_{10}(KTB) + NF + I/N) - G_{r,max} + \text{feeder\_loss} - 10\log_{10}(\lambda^2/4\pi)$$

In Tables 2 and 3, we provide epfd limit calculation for both non-AAS and AAS antenna BSs.

For frequency bands higher than 1 GHz, terrestrial IMT BS may use either a non-AAS antenna or an AAS antenna. Epfd limits for an AAS antenna are lower than those for a non-AAS antenna. Therefore, for frequencies higher than 1 GHz, epfd limits calculated for AAS antennas should be retained.

TABLE 3~~2~~

epfd limit calculation for non-AAS antennas

Frequency band (MHz)	**700**	**800**	**900**	**1 800**	**2 100**	**2 600**
NF (dB)	5	5	5	5	5	5
feeder_loss (dB)	3	3	3	3	3	3
$G_{r,max}$ (dBi)	15	15	15	18	18	18
epfd (dB(W/m^2))	–138	–137	–136	–133	–132	–130

Formatted: English (United States)

TABLE 4~~3~~

epfd limit calculation for AAS antennas

Frequency band (MHz)	1 800	2 100	2 600
NF (dB)	5	5	5
feeder_loss (dB)	0	0	0
Gr, max (dBi)	26	26	26
epfd (dB(W/m2))	–144	–143	–141

8~~7~~ Conclusion

In this contribution, we initiate discussions on parameters that need to be defined for the assessment of the epfd (according to RR Article **22**), as a regulatory approach to protect terrestrial IMT BS. Moreover, we provide values for the epfd limit for the protection of the terrestrial IMT BS.

ANNEX 2

Factors impacting the aggregate interference from DC-MSS-IMT to terrestrial IMT

Study A (Document 5D/543 (F))

[Note: Questions were raised with regards to the assumptions used in the study.]

The factors impacting the aggregated interference from MSS for the Protection of IMT TN under WRC-27 agenda item 1.13

Protection of International Mobile Telecommunication (IMT) terrestrial networks is achieved by considering the number of satellites visible from a given location on Earth, its variation over time due to the constellation satellite motions, and as a function of the minimum elevation angle.

Constellation characteristics

The constellation characteristics are based on [Document 4C/156] and shown in Table 1.

TABLE A2-1

Parameters of orbital configuration

Altitude (km)	Inclination (deg)	Planes	Sats per plane	RAAN spacing (deg)	Total number of sats
500	55	60	60	6	3600

Methodology and results

Formatted: English (United States)

Simulation of the satellite constellation at 5 different epochs (starting from epoch t0 = 2019/08/12 12:00:00), regularly spaced between time t = t0 and t = t0 + 7T, with T being the orbital period (T = 5677s / 94.6 minutes).

Considering an Earth Station at a given location on Earth, e.g., at the French border, given by:

lat = 46.250°, lon = 6.217°, alt = 0 Km

The number of satellites visible from an Earth Station is determined based on the elevation angle relative to the Station's ground location. This can be evaluated for different thresholds of the elevation angle, such as theta>20°, theta>10°, or theta>0°. The results are shown in Table 2.

TABLE A2-2

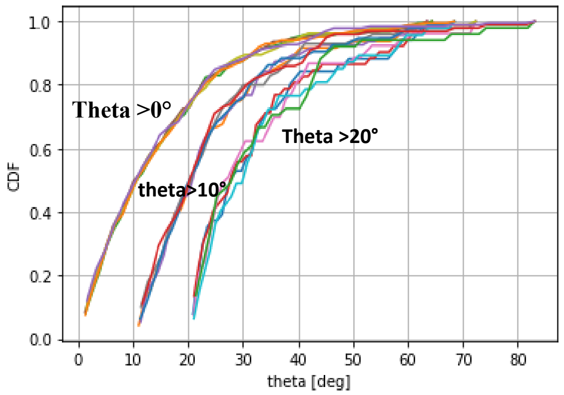
Number of satellites visible from a given location on Earth [lat = 46.250°, lon = 6.217°, alt = 0 Km], according to the elevation angle w.r.t. the ground location

Time	**0**	**1.75T**	**3.5T**	**5.25T**	**7T**
Nb of visible satellites with theta > 0°	188	189	191	186	193
Nb of visible satellites with theta > 10°	96	95	100	95	100
Nb of visible satellites with theta > 20°	51	52	53	47	51
Max theta [°]	64.4	63.5	72.3	68.5	83

The number of visible satellites is almost constant over the time, since the considered constellation is very dense with 60 orbital planes of 60 satellites each. For a visibility defined by theta > 20°, almost 50 satellites are visible from the Earth Station at the given location. For a visibility higher than the horizon (theta > 0°), the number of visible satellites are much higher, almost 188 visible satellites.

FIGURE A2-1

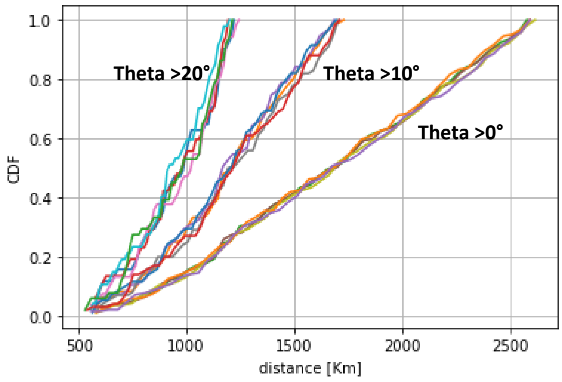
CDF of the elevation angles of satellites which are visible for a given location on Earth



Formatted: English (United States)

FIGURE A2-2

CDF of the distance distribution of satellites which are visible for a given location on Earth



Figures 1 and 2 show the statistical distribution (CDF) of the elevation angles (theta) and the distances between the Earth station's location at the ground and each visible satellite. The probability of high elevation angles, corresponding to small separation distances, is low.

FIGURE A2-3

Number of visible satellites as a function of the latitude of the Earth Station

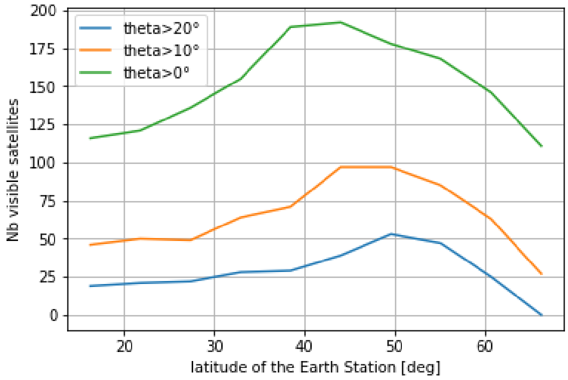


Figure 3 shows that the number of visible satellites varies with the latitude of the Earth Station.

Analysis

The aggregation factor depends on the number of visible satellites. From an UE perspective, all visibility directions are equivalent. However from a BS perspective, it depends on the beam orientation of the BS, which amplifies some directions while attenuating others. In other words, the pfd will be more constraining for low elevation angles than for high elevation angles.

Formatted: English (United States)

The aggregation factor could be based on the assumption that all satellites in visibility are strictly complying with the pfd mask. However, it may be useful to include consideration of how such a dense satellite constellation manage the communications towards the UE when several satellites have good visibility. In addition, the aggregation factor may be distributed over various elevation angles in a differentiated mode (e.g. more for low elevation angles and less for high elevation angles) in order to have a pfd mask fitting better the satellite antenna performance.

Study B (Document 5D/652 (RUS))

Analysis of interference from DC-MSS-IMT multiple satellite systems

In the below analysis, the mutual interference from three DC-MSS-IMT satellite systems operating in the same frequency band in three different neighbouring countries is considered.

Annex 7 to Document 4C/356 provides the preliminary proposed technical characteristics of DC-MSS-IMT systems towards technical studies under WRC-27 agenda item 1.13 which could be used as the basis of the study. Detailed technical characteristics are summarized in Tables 1 and 2.

TABLE A2-3

Parameters of orbital configuration

System ID	Altitude (km)	Inclination (deg)	# Planes	Sats per plane	RAAN spacing (deg)	Total number of sats
System 1 (non-GSO)	680	97	12	60	6	720
System 2 (non-GSO)	500	55	60	60	6	3 600
System 3 (non-GSO)	525	53	28	120	12.9	3 360
	340	53	48	110	7.5	5 280

TABLE A2-4

Parameters of DC-MSS-IMT satellite systems

	Parameter	Unit	System 1	System 2	System 3
Downlink (Space-to-Earth)	Frequency band	MHz	2 620-2 690	2 620-2 690	2 620-2 690
	Emission bandwidth	MHz	5	5	5
	S/S Transmitter power	dBW	–10...16 (min, max)	13	-
	S/S EIRP	dBW	26 … 52 (min, max)	51.1	-
	EIRP spectral density	dBW/Hz	–41 … –15 (min, max)	–15.9	–18.1 dBW/Hz @EL 90°(1)
	S/S antenna pattern	n/a	S.1528	M.2101	S.1528
	S/S peak antenna gain	dBi	38	47.5	34.1
	Single element antenna gain	dBi	-	4.15	-
	Antenna array configuration (Row × Column)	-	-	50×50	-

Formatted: English (United States)

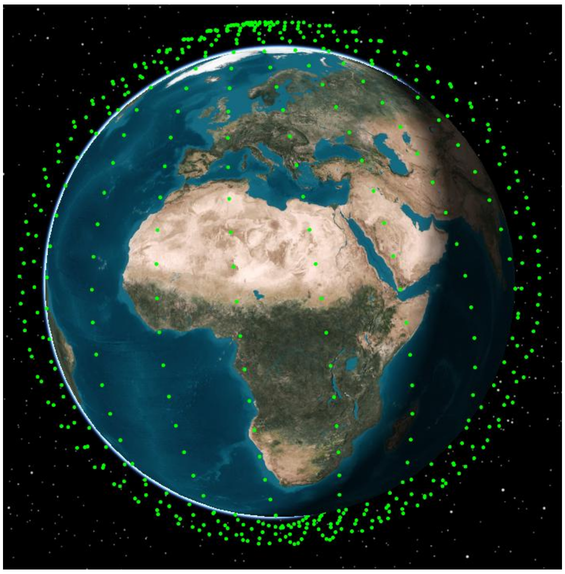
Notes to the Table A2-4:

(1) In terms of modelling the variation of PFD with slant path, several options can be considered, and correspond to several ways operators manager real-world operations:

- Keep PFD constant on the ground, i.e. adjust EIRP at the satellite to ensure a constant PFD on the ground regardless of the slant path / arrival angle.
- Keep EIRP constant at the satellite: this implies that the PFD value contained in Table 1 is only ensured at Nadir, while it will be lower at lower elevation, i.e. as the slant path increases.
- Hybrid mode: some systems adjust the EIRP to ensure constant PFD on the ground only up to a certain elevation angle, after which the EIRP is not increased more, thus the PFD decreases as the elevation angle decreases.

FIGURE A2-4

Modelling of the System 1



Formatted: English (United States)

FIGURE A2-5

Modelling of the System 2

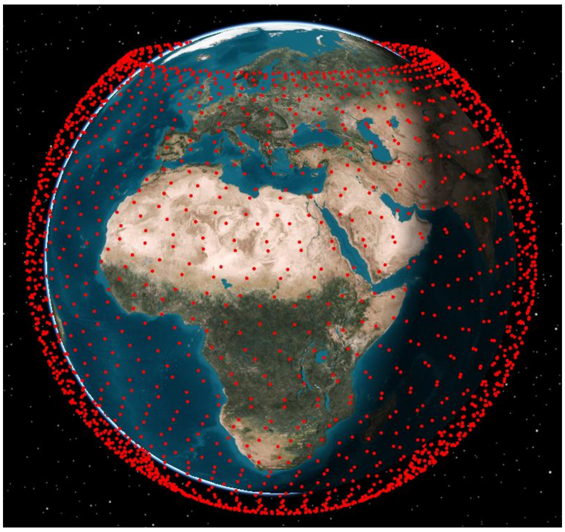
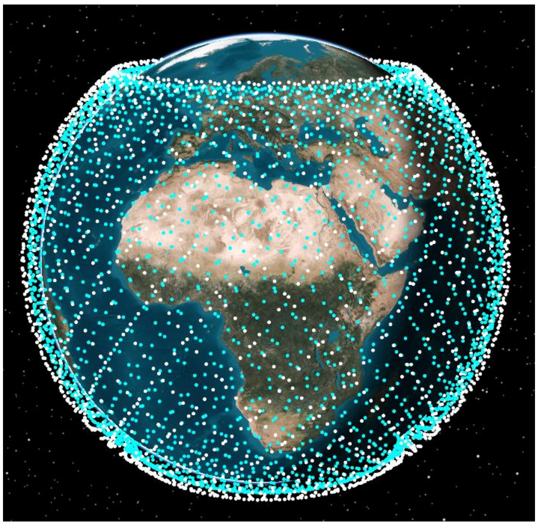


FIGURE A2-6

Modelling of the System 3



Formatted: English (United States)

Methodology of simulation

Interference from the ith active satellite station was calculated using the following expression:

$$I_{iRSS} = \frac{P_{iRSS} \cdot G_{Tx} \cdot G_{Rx} \cdot c^2}{(4\pi d f)^2}$$

where:

P_{iRSS} – power of the ith satellite (in Watts)
G_{Tx} – gain of the transmitting satellite (in absolute)
G_{Rx} – gain of the interference receiving station (in absolute)
d – Distance between transmitter and receiver (in meters)
λ – Wavelength of the signal (in meters)
c – Speed of light
f – Frequency of the signal (in Hz).

The total interference-to-noise ratio from all interfering satellites is calculated using:

$$\frac{I}{N}[\mathrm{dB}] = 10\,log\left(\sum_i 10^{\frac{I_{iRSS}(i)}{10}}\right) - 10\,log(kTB),$$

where:

I_{iRSS} – interfernence power from each ith interfereing satellites (in Watts)
B – bandwidth of the victim receiver (in Hz)
T – noise temperature of the victim receivier (in Kelvin)
k – Bolzmann’s constant.

To calculate the statistical distribution of interference levels, the following algorithm was applied:

Step 1: For each time step during the simulation period, the following are computed:

- The position of each interfering station (DC-MSS-IMT).
- The location of the victim receiving station (DC-MSS-IMT).
- The angle between:
  - the direction from the interfering station to the victim receiver, and
  - the main axis of the antenna of each interfering space or ground station.
- The gain of the transmit antenna of each interfering space/ground station in the direction of the victim receiver.
- The distance between each interfering space station and the victim receiving station.
- The gain of the victim receiver’s antenna in the direction of each interfering station.
- The resulting interference power at the input of the victim receiver from each interfering station.

Step 2: These calculations are repeated for all time steps within the simulation interval, using a fixed time resolution. This process produces a dataset of I/N values over time.

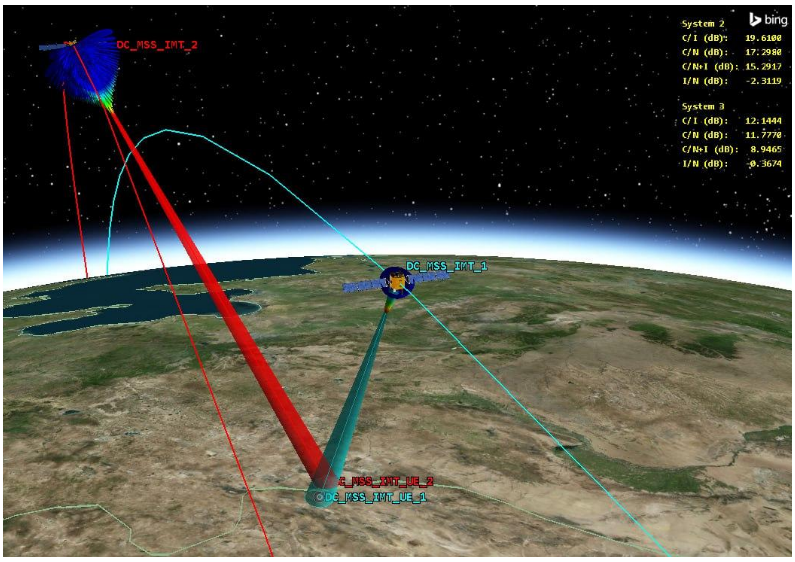
Step 3: Based on the dataset generated in Step 2, the cumulative distribution function (CDF) of the *I/N* for the space-to-Earth link is generated.

Formatted: English (United States)

To estimate possibility of aggregation of interference from multiple satellite systems it was assumed that those systems will operate in the same frequency band and the territory of three neighbouring countries. Each system was operating within the borders of the respective country. Figure 4 illustrates the scenario where two systems operate on the adjacent territories of two countries.

FIGURE A2-7

Scenario of operation of two DC-MSS-IMT systems



```
System 2
C/I (dB):    19.6100
C/N (dB):    17.2980
C/N+I (dB):  15.2917
I/N (dB):    -2.3119

System 3
C/I (dB):    12.1444
C/N (dB):    11.7770
C/N+I (dB):   8.9465
I/N (dB):    -0.3674
```

It was also taken into account that the level of interference largely depends on the separation distances between the DC-MSS-IMT user equipment (UE) and the coverage area of interfering space system in the adjacent countries.

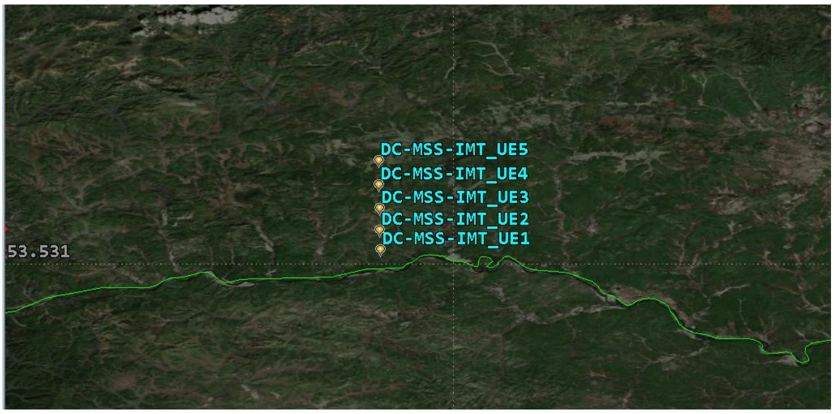
For each system the interference was calculated for different separation distances from border: 10 km, 20 km, 30 km, 40 km and 50 km.

Figure 5 illustrates distribution of user terminals at different distances from the border.

Formatted: English (United States)

FIGURE A2-8

Distribution of DC-MSS-IMT UEs

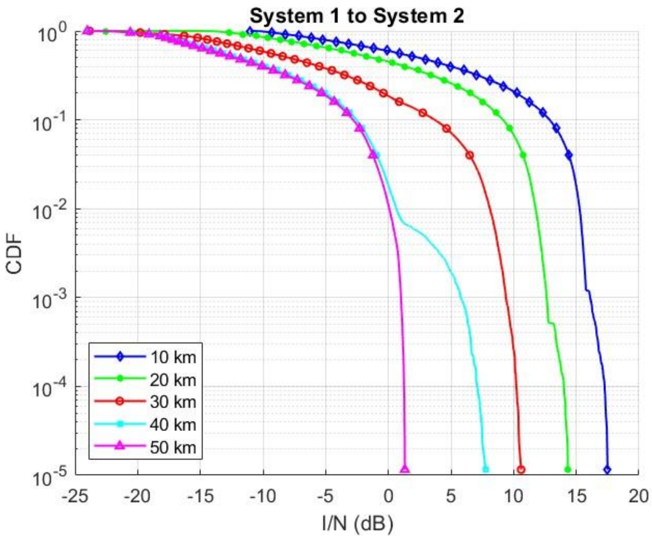


The analysis was based on modelling and simulation of interface from DC-MSS-IMT satellite system operating on the territory of a neighbouring country without implementation of any possible mitigation techniques.

Figures 6-11 show the *I/N* levels cumulative distribution functions obtained for each system simulations for different separation distances.

FIGURE A2-9

***I/N* levels from System 1 towards DC-MSS-IMT UE of System 2**



Formatted: English (United States)

FIGURE A2-10

_I/N_ levels from System 1 towards DC-MSS-IMT UE of System 3

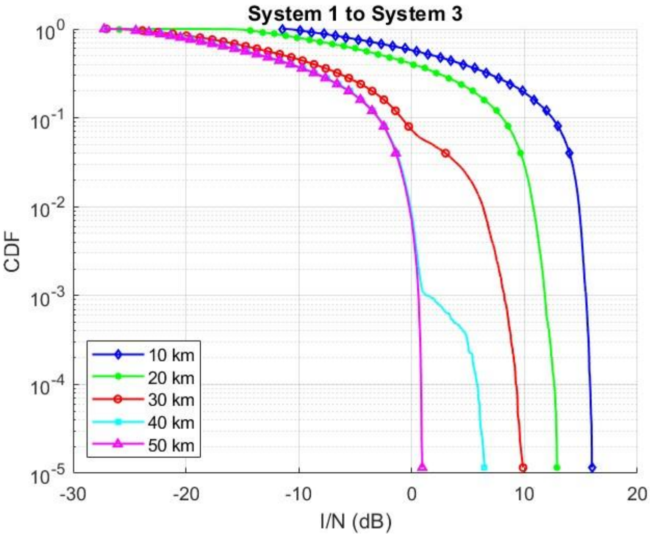
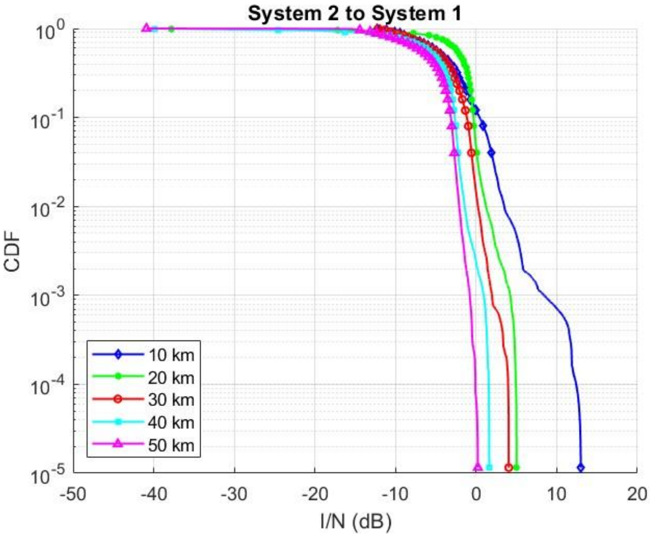


FIGURE A2-11

_I/N_ levels from System 2 towards DC-MSS-IMT UE of System 1



Formatted: English (United States)

FIGURE A2-12

I/N levels from System 2 towards DC-MSS-IMT UE of System 3

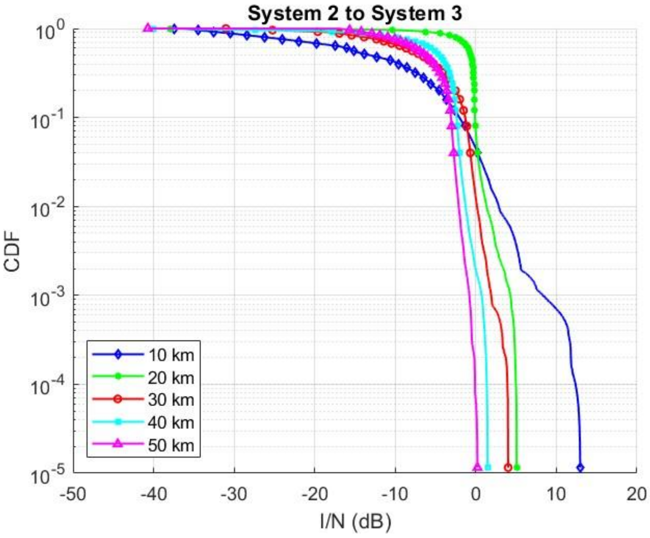
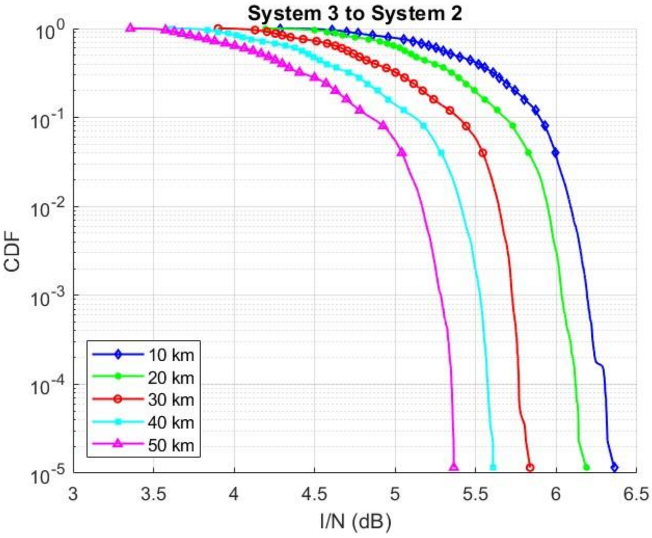


FIGURE A2-13

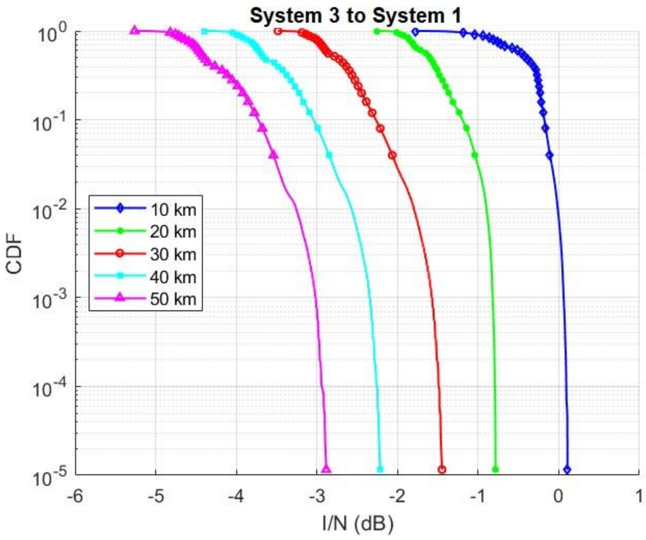
I/N levels from System 3 towards DC-MSS-IMT UE of System 2



Formatted: English (United States)

FIGURE A2-14

I/N levels from System 3 towards DC-MSS-IMT UE of System 1



The results of the simulations showed significant interference levels between different DC-MSS-IMT systems. Such interference levels are due to the dynamic behavior of MSS systems and the use of omnidirectional antennas in user terminals. The use of certain mitigation techniques will ensure the coexistence of such systems. Thus, it can be concluded that for a number of the cases multiple systems will not be able to operate on the same or immediately adjacent territory in the same frequency band without any mitigation techniques.

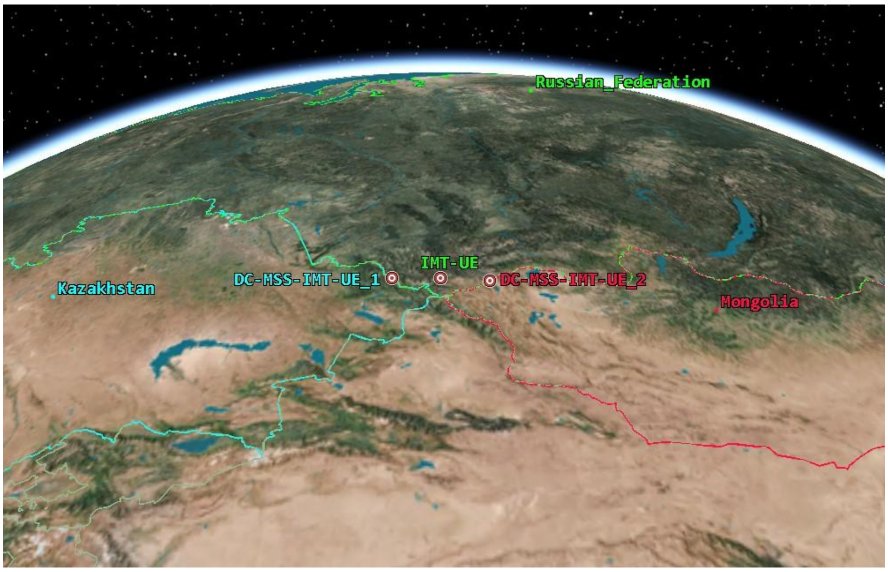
Analysis of a specific geographical case

The analysis presented above illustrates a generic scenario; however, due to the geographical diversity in certain regions, alternative configurations may arise. One such case is shown in Figure 12, where a portion of the Russian Federation lies geographically between Kazakhstan and Mongolia.

Formatted: English (United States)

FIGURE A2-15

Type of configuration where aggregate interference factor may be required



As illustrated in Figure 13, the distance between the DC-MSS-IMT UE of different systems is substantial. This spatial separation facilitates effective coexistence between the two DC-MSS-IMT systems. Nonetheless, interference experienced by terrestrial IMT systems can vary considerably, particularly when comparing aggregate interference from multiple systems to that generated by a single system. Such a situation is plausible in practice—for instance, if Kazakhstan is served by System 3 and Mongolia by System 2.

Formatted: English (United States)

FIGURE A2-16

Distances between protected terrestrial IMT station from DC-MSS-IMT UEs for this example

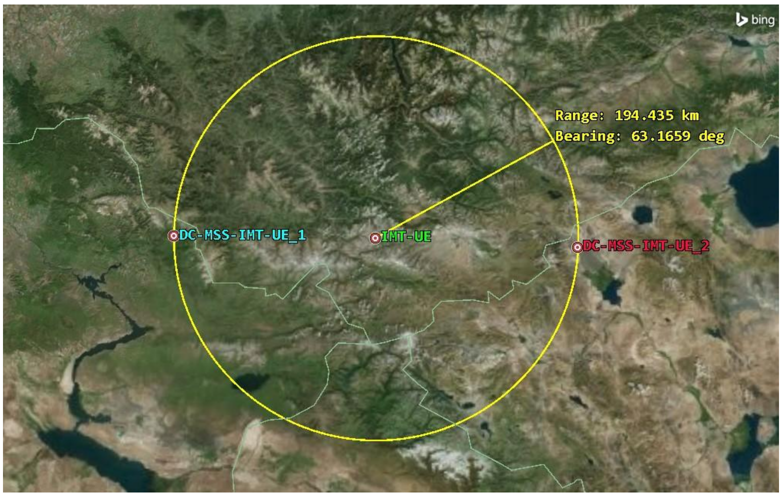
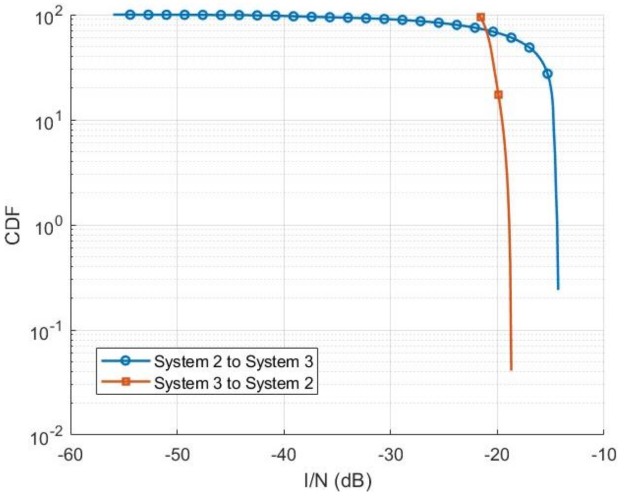


Figure 14 illustrates the mutual interference between System 2 and System 3. The results indicate that in this configuration, both DC-MSS-IMT systems demonstrate compatibility, maintaining sufficient interference margins no matter what protection criterion would be considered.

FIGURE A2-17

Interference between System 2 and System 3

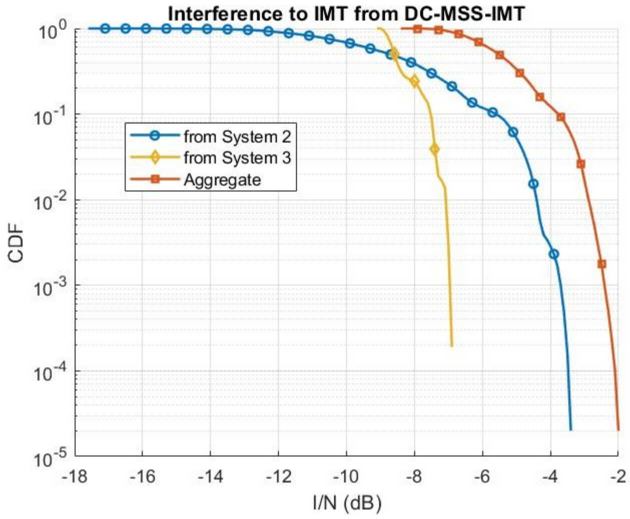


Formatted: English (United States)

However, in scenarios involving the concurrent operation of multiple DC-MSS-IMT systems, there exists a potential for aggregate interference impacting terrestrial IMT systems. Figure 15 quantifies this interference at a terrestrial UE situated equidistantly between the DC-MSS-IMT user terminals. The results highlight the disparity between interference from a single DC-MSS-IMT system and the cumulative effect of both systems operating simultaneously. The results show that aggregate interference difference from single system interference from 3 to 5 dB, which means that aggregate factor may be needed for some cases.

FIGURE A2-18

Interference from System 2, System 3 and aggregate from both systems to terrestrial IMT UE



The results presented above indicate that aggregate interference can be significantly higher than individual contributions. In some cases, interference from a single system may remain below the trigger level for protection for terrestrial IMT systems ($I/N = –6$ dB). However, when aggregated with interference from other sources, this threshold can be exceeded. This demonstrates that evaluating systems in isolation—without considering the cumulative impact — may lead to the incorrect conclusion that DC-MSS-IMT is compatible with terrestrial IMT services. At the same time, it should be taken into account that such cases might be rare in practice, therefore further studies are needed to determine whether aggregation factor is required.

Conclusion

The analysis demonstrates that in a number of cases multiple DC-MSS-IMT satellite systems will not be able to operate on the same or immediately adjacent territory in the same frequency band without causing interference to each other. In order for such systems to co-exist it is necessary to use certain mitigation techniques such as separation distances or operation in the different blocks of spectrum.

Nevertheless, certain configurations demonstrate the potential for compatibility between DC-MSS-IMT systems, albeit with an increased likelihood of aggregate interference to terrestrial IMT networks. Preliminary assessments suggest that in these scenarios, an aggregate factor – ranging from 3 to 5 dB may be required to maintain acceptable performance. Further studies are necessary to refine this estimate, and more comprehensive results will be presented at the next meeting.

Formatted: English (United States)

Study C (Documents 5D/713 (CHN), 5D/825 (CHN))

[Note: The questions were raised regarding assumptions, methodology, and scenario selection.]

Formatted: Font: 12 pt, Not Bold, (Asian) Japanese

1 Introduction

To analyse the aggregate interference from the envisaged MSS systems (designated as “DC-MSS-IMT”) to IMT user equipment (UE), Working Party (WP) 5D asked WP 4C to provide additional information “*that might help in the estimation of the aggregate interference to IMT receivers from different MSS satellites or systems*”.

With respect to aggregate interference from space stations of single and/or multiple DC-MSS-IMT systems into incumbent services, WP 4C has not concluded its assessment as indicated in the initial reply liaison statement to WP 5D from WP4C (Doc. 5D/597). Based on the DC-MSS-IMT technical and operational characteristics as stated in the WP4C reply liaison statement, WP 4C will continue to work toward modelling DC-MSS-IMT systems and to investigate the issue of aggregate interference from single and/or multiple DC-MSS-IMT systems.

~~In t~~This study~~document,~~ provides ~~its~~ considerations and analysis of the aggregate interference from DC-MSS-IMT systems to terrestrial IMT UE in the tri-border area for consideration and discussion in the WP 5D meeting.

2 Discussion

2.1 Consideration on the modelling of DC-MSS-IMT satellite beams

A) Operational management:

It is noted that a DC-MSS-IMT system will manage and control its beam pointing of the satellites through its operation control centre. The satellite downlink beams will direct to specific areas under authorization based on the access requirements of IMT UE, while meeting the regulatory requirements to protect the incumbent services, including terrestrial IMT networks. Therefore, only sidelobe of the satellite beams may contribute to the potential interference to an IMT receiver that is within a neighbouring unauthorized administration’s territory.

B) Intra-system interference avoidance

For a DC-MSS-IMT system, to avoid its intra-system interference adequate distance must be maintained between the co-frequency beams, either from the same satellite or different satellites. This distance can be determined through the intra-system C/I (Carrier-to-Interference) ratio, where “I” represents the aggregate sidelobe interference from co-frequency beams within the same system. To ensure the C/I ratio meets system requirements, an appropriate isolation distance must be maintained between co-frequency beams, which is primarily determined by the sidelobe degradation or suppression characteristics of the satellite antennas.

C) Sharing and compatibility between DC-MSS-IMT systems

For the sharing and compatibility between different DC-MSS-IMT systems, they need to implement interference mitigation techniques, such as service area isolation, frequency segmentation and/or other methods, based on their negotiation under coordination procedure of the RR, to meet their sharing and compatibility. Based on our system simulation, different DC-MSS-IMT systems cannot use the same frequency channel to cover the same area simultaneously and they have to set up enough geographical isolation to ensure the required frequency sharing and compatibility between their systems.

Formatted: English (United States)

2.2 Study on the protection of IMT UE from potential interference of DC-MSS- IMT systems

2.2.1 Technical characteristics

2.2.1.1 Technical characteristics of DC-MSS-IMT systems

The t~~T~~echnical characteristics of DC-MSS-IMT systems are summarized in Tables A2-5~~1~~, A2-6~~2~~ and A2-7~~3~~.

TABLE A2-5

Parameters of orbital configuration

System*	Altitude (km)	Inclination (deg)	Planes	Sats per plane	RAAN spacing (deg)	Total number of sats
System 3~~A~~	525	53	28	120	12.9	3360
System 2~~B~~	500	55	60	60	6	3600
* Note: See WP 4C Chair's Report Doc.356 Annex 7.						

Formatted: Font: 10 pt, Not Bold
Formatted: Font: 10 pt, Not Bold, Not All caps
Formatted: Font: 10 pt, Not Bold
Formatted: Font: 10 pt, Not Bold, Not All caps
Formatted: Font: 10 pt, Not Bold

TABLE A2-6

Parameters of carriers of DC-MSS-IMT~~dc-MSS-imt~~ systems

	Parameter	Unit	System ~~A~~3	System ~~B~~2
Downlink (Space-to-Earth)	Frequency band	MHz	2155	2155
	Emission Bandwidth	MHz	5	5
	S/S Transmitter power	dBW	12.79	13
	S/S Maximum EIRP	dBW	46.89	48.2
	S/S Maximum EIRP density	dBW/Hz	-20.1	-18.8
	S/S Antenna pattern	n/a	*Recommends* 1.4 of ITU-R S.1528	M.2101
	Min Elevation	°	20	35

TABLE A2-7

Parameters of antenna pattern of DC-MSS-IMT~~dc-mss-imt~~

Antenna Model		Parameters	Unit	Value
System ~~A~~3	*Recommends* 1.4 of ITU-R S.1528	S/S Peak antenna gain	dBi	34.1
		radial and transverse sizes of the effective radiating area of the satellite transmit antenna	m	1.6
		side-lobe ratio	dB	20
		number of secondary lobes	/	2

Formatted: English (United States)

Antenna Model		Parameters	Unit	Value
System ~~B~~2	ITU-R M.2101*	Single element antenna gain	dBi	4.11
		Antenna array configuration(Row×Column)	/	36×36
		Horizontal 3dB beamwidth of single element	°	118
		Vertical 3dB beamwidth of single element	°	112
		Horizontal radiating element spacing	dH/λ	0.5
		Vertical radiating element spacing	dV/λ	0.5
		Horizontal Front-to-back ratio	dB	30
		Vertical Front-to-back ratio	dB	30

* Note: There is currently no available ITU-R recommendation in force to simulate satellite phased array antenna for DC-MSS-IMT system sharing and compatibility studies. The satellite engineering design and antenna gain simulation is based on Recommendation ITU-R M.2101 complimented with antenna orientation parameter.

2.2.1.2 Technical characteristics of IMT network

The technical characteristics of IMT networks operating in the frequency bands between 1 and 2.7 GHz are outlined in Section 4 of the Working document (Annex 4.2 to Document 5D/413) on the characteristics of the terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27.

Detailed parameters of IMT networks are as follows.

TABLE A2-8

IMT Network Deployment-related parameters

Parameters	
BS cell radius / deployment density	0.2-0.8 km
BS sector number	3 sectors

TABLE A2-9

IMT UE parameters

Parameters	
UE number per BS sector	3
UE height	1.5 m
Typical antenna gain for UE	−3 dBi
Body loss	4 dB

Formatted: English (United States)

2.2.1.3 Radiowave propagation models

In accordance with the liaison statement from WPs 3L/3M to WP5D (Document 5D/167), Recommendation ITU-R P.619-5 is utilized to assess interference between stations in space and those on the surface of the Earth.

2.2.2 Methodology

2.2.2.1 Scenarios

This study~~contribution~~ presents ~~two~~ three simulation scenarios for analyzing the potential aggregate interference from DC-MSS-IMT systems to IMT network, considering interference from a single DC-MSS-IMT system and multiple DC-MSS-IMT systems respectively.

2.2.2.1.1 Scenario 1: ~~of~~ IMT UEs interfered by a single DC-MSS-IMT system

In Scenario 1, IMT UEs experience interference from a single DC-MSS-IMT system, as illustrated in Figure A2-19~~Figure 1.~~ In this scenario, a DC-MSS-IMT system provides service in country A and country B simultaneously. A terrestrial IMT network of Country C is deployed at the cross-border area of Countries A, B and C, where Country C shares borders with both Country A and Country B. By comparation, the final result needs to choose the severe one in the interference potential to the terrestrial IMT network in Country C.

For the DC-MSS-IMT system, in order to prevent intra-interference, it is necessary to establish an isolation distance between co-frequency beams. The isolation distance is depicted in Figure A2-19~~Figure 1~~, represented by the radius of the dashed circle to indicate that other co-frequency UE could not be set within the circle.

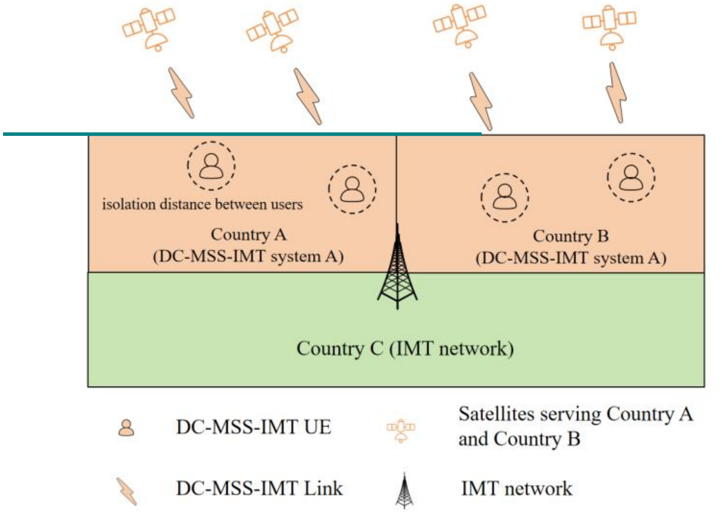
Formatted: English (United States)

FIGURE A2-19

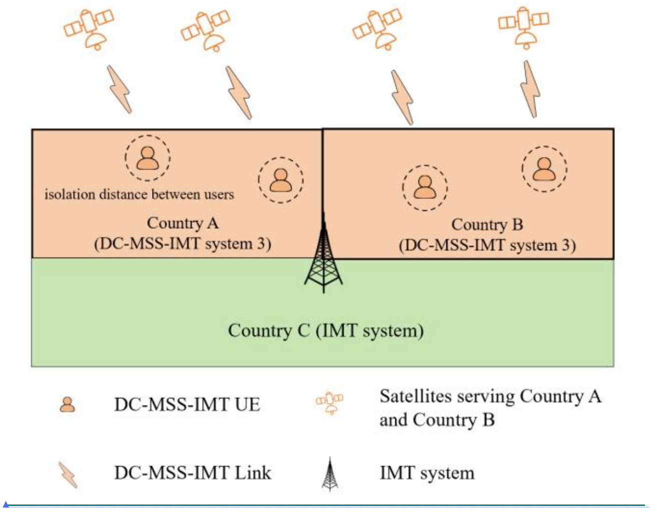
Scenario 1 with IMT UE interfered by a single DC-MSS-IMT system 3

Formatted: Font:

Formatted: Font: Not Bold



Formatted: Font: Not Bold



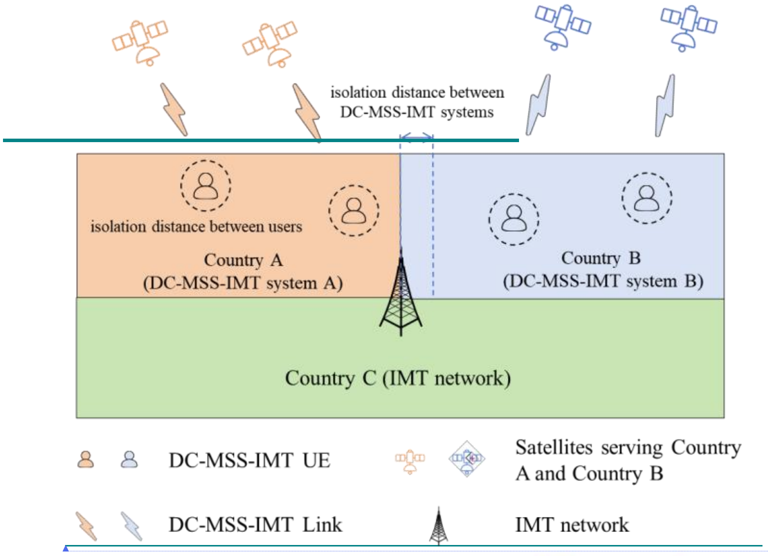
2.2.2.1.2 Scenario 2:~~ of~~ IMT UEs interfered by multiple DC-MSS-IMT systems

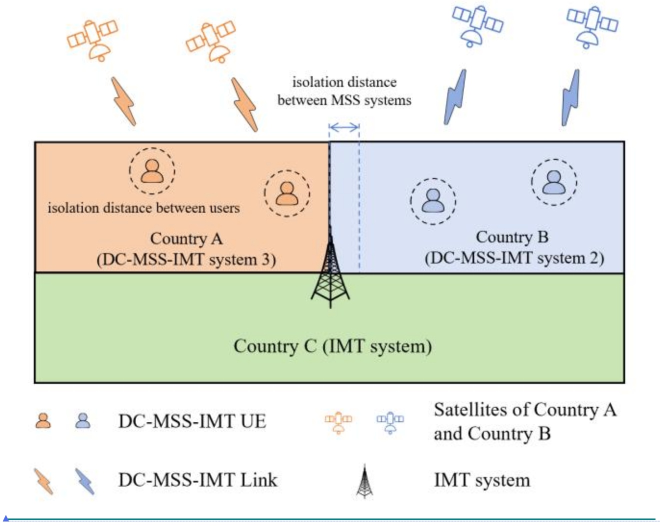
In Scenario 2, IMT UEs experience interference from multiple DC-MSS-IMT systems, as illustrated in Figure A2-20~~Figure 2~~. In this scenario, DC-MSS-IMT system ~~A~~ 3 provides service in Country A and DC-MSS-IMT system ~~B~~ 2 provides service in Country B. IMT network of Country C is also deployed at the cross-border area of Countries A, B and C.

Formatted: English (United States)

FIGURE A2-20

Scenario 2 with IMT UEs interfered by ~~multiple~~ DC-MSS-IMT systems 3 and 2 ~~systems~~





Formatted: Font:

Formatted: Font: Not Bold

Formatted: Font: Not Bold

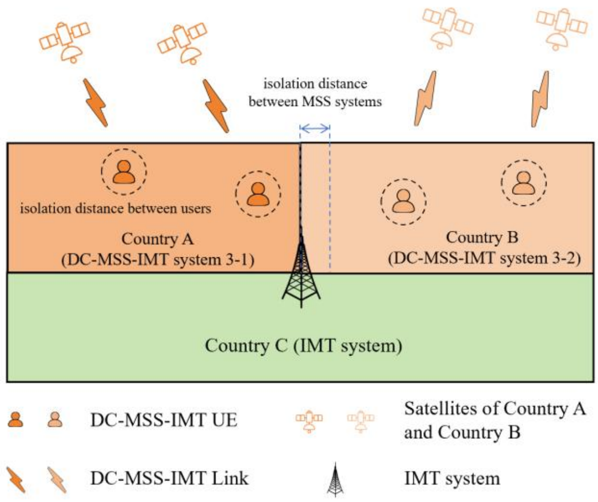
Formatted: English (United States)

2.2.2.1.3 Scenario 3:~~ of~~ IMT UEs interfered by multiple DC-MSS-IMT systems

In Scenario 3, IMT UEs experience interference from multiple DC-MSS-IMT systems, as illustrated in Figure A2-21. In this scenario, DC-MSS-IMT system 3-1 provides service in Country A and DC-MSS-IMT system 3-2 provides service in Country B. System 3-1 and 3-2 use the same system parameters as System 3 (see Tables A2-6 and A2-7 for System 3), but belong to different satellite operators and provide services for Country A and Country B respectively. IMT network of Country C is also deployed at the cross-border area of Countries A, B and C.

FIGURE A2-21

Scenario 3 with IMT UEs interfered by ~~multiple~~ DC-MSS-IMT systems 3-1 and 3-2



Similar to the isolation distance in section 2.2.2.1.1, due to the utilization of the co-frequency beams, different DC-MSS-IMT systems cannot operate simultaneously in the same area. Therefore, an additional isolation distance is required between DC-MSS-IMT systems to ensure compatibility and spectrum sharing, as indicated by the width between the blue dotted lines shown in Figure A2-20~~Figure 2~~ and Figure A2-21.

2.2.2.2 Methodology

A simulation method is used to evaluate the interference from DC-MSS-IMT systems to the IMT network. Main steps of the simulation are listed as follows.

Step 1：Determine the range of simulation area

In the single DC-MSS-IMT system scenario described in section 2.2.2.1.1, a DC-MSS-IMT system serves UEs in Country A and Country B simultaneously. In the multiple DC-MSS-IMT systems scenario described in section 2.2.2.1.2, two DC-MSS-IMT systems serve UEs in Country A and Country B respectively. To comprehensively estimate the potential interference to the IMT network, the aggregate interference from all visible satellites of IMT UE is considered. The size of service area in Country A and Country B is set at 2500 km in length and 2500 km in width.

Formatted: Font: 12 pt, Not Bold, Not All caps

Formatted: Centered

Formatted: Font: Times New Roman

Formatted: Font: Times New Roman

Formatted: Font: Times New Roman

Formatted: Font: Times New Roman

Formatted: Font: Times New Roman

Formatted: Font: Times New Roman

Formatted: English (United States)

It is important to note that the tri-border scenario under current investigation represents a representative case selected based on the satellite visibility range, whose spatial scope is significantly larger than that of real-world tri-border scenarios. Consequently, the results derived therefrom correspond to the aggregate~~d~~ interference effects under the worst-case conditions.

Formatted: Font:

Step 2：Generate DC-MSS-IMT satellites/UEs and IMT BSs/UEs

The spatial topology location of DC-MSS-IMT satellites is generated at time T. The DC-MSS-IMT UEs directly connected with DC-MSS-IMT space stations are randomly deployed within the countries A and B served by the DC-MSS-IMT systems, and may choose and access the satellite having highest elevation angle based on satellite selection strategy. To avoid the intra-system interference from other user links within the DC-MSS-IMT system, we set the required isolation among UEs as mentioned above, the specific value of isolation distance is given in section 3.1.

The IMT BS is deployed at the cross-border interconnected area of Countries A, B, and C, and IMT UEs are randomly generated within the BS sectors.

Step 3：For the multiple DC-MSS-IMT systems scenario mentioned in section 2.2.2.1.2, simulate the isolation distance between DC-MSS-IMT systems

The simulation process of isolation distance between DC-MSS-IMT systems is shown in Figure A2-22~~Figure 3~~.

In Figure A2-22~~Figure 3~~, DC-MSS-IMT UEs colored in orange are deployed along the border between Country A and Country B to directly connect to space stations of DC-MSS-IMT system ~~A~~3. It should be noted that, in real application, whether UEs of System ~~A~~ 3 can deploy to the border of Country B depends on relevant agreement of Country B. Meanwhile, DC-MSS-IMT UEs colored in blue are randomly deployed in Country B, which are served by DC-MSS-IMT system ~~B~~2.

In order to protect DC-MSS-IMT system ~~A~~ 3 from the potential interference of DC-MSS-IMT system ~~B~~2, the geofencing should be configured starting from the border of these two countries, and extending into Country B's territory. In this process, the isolation distance (representing the geofencing width) gradually increases from zero to d_1, d_2, …, until the requirement of spectrum sharing and compatibility is satisfied.

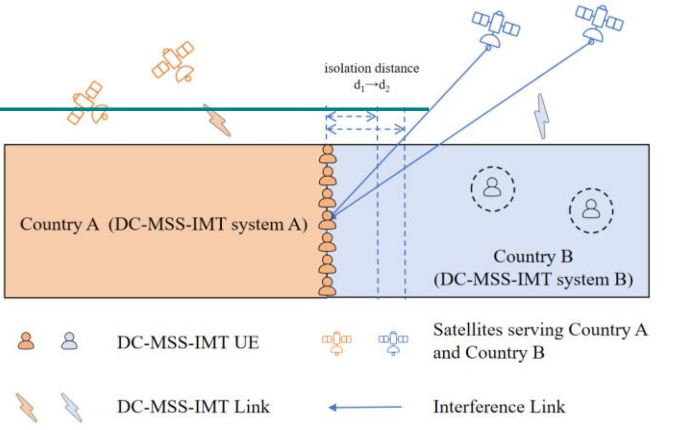
And in the opposite direction, to protect System ~~B~~ 2 from System ~~A~~3, the above process is also applicable.

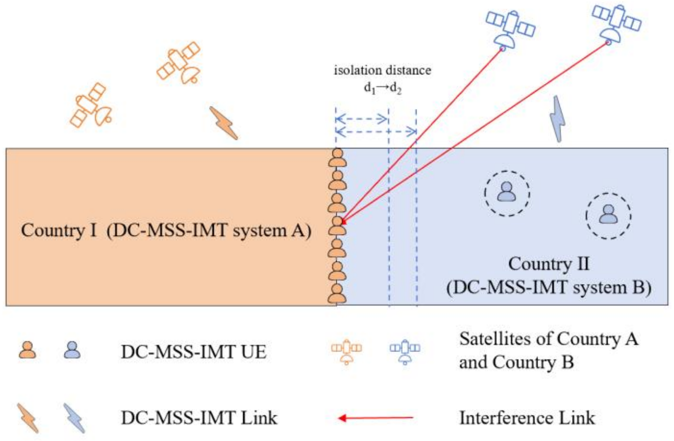
The required isolation distance corresponds to the minimum geofencing extension width at which the maximum interference-to-noise (I/N) ratio meets the -6 dB protection threshold.

Formatted: English (United States)

FIGURE A2-~~21~~22

Simulation process of isolation distance between DC-MSS-IMT systems 3 and 2~~s~~

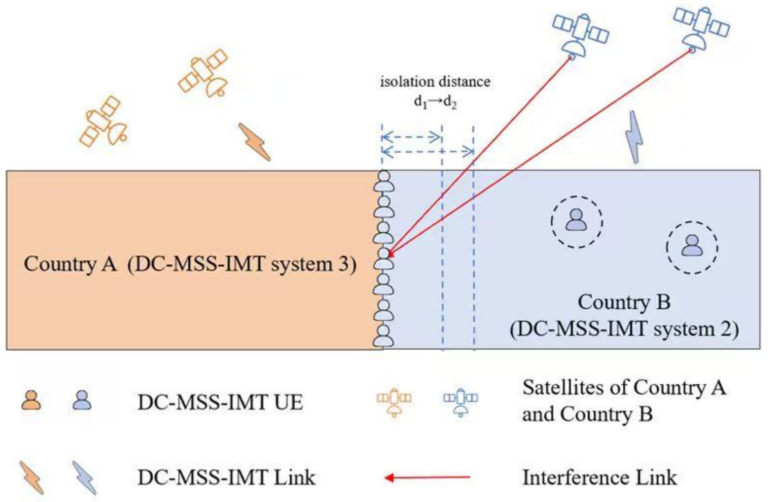




Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

Formatted: Font:

Formatted: English (United States)

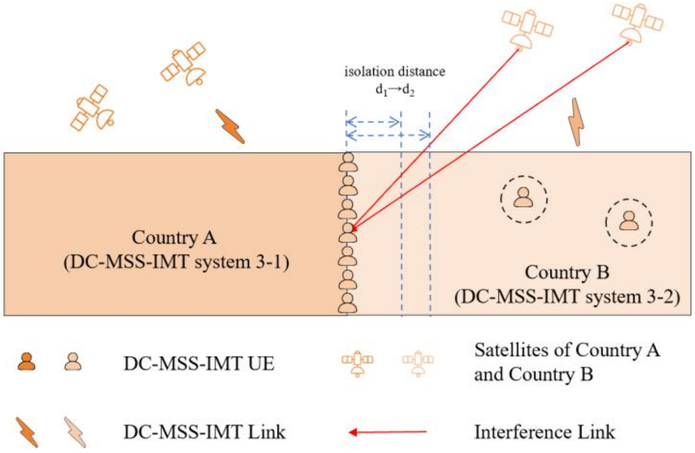


When different satellite operators using similar or identical parameters as Ssystem 3 ~~parameter~~ offer services to Country A and Country B respectively, the methodological approach for determining the isolation distance remains consistent with the previous text.

FIGURE A2-23

Simulation process of isolation distance between ~~multiple~~ DC-MSS-IMT systems 3-1 and 3-2

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)



Formatted: English (United States)

Step 4：Simulate the positions of satellite constellation over a period of time and calculate the aggregate interference from DC-MSS-IMT satellites to IMT network at each time step.

The aggregate interference level is determined by all active satellites in the considered DC-MSS-IMT systems within the visible range of IMT UEs.

$$I_{total} = 10\, log\left(\sum_m^M \sum_n^N \sum_j^J 10^{I_{m,n,j}/10}\right) \tag{1}$$

$$I_{m,n,j} = P_{tx} + G_{tx}(\theta_{tx}) - PL + G_{rx}(\theta_{rx}) - L_{other} \tag{2}$$

where:

I_{total}: Aggregate interference power from DC-MSS-IMT satellites, dBW

$I_{m,n,j}$: Interference power from j-th beam of n-th space station of m-th DC-MSS-IMT system, dBW

P_{tx}: DC-MSS-IMT satellite transmit power, dBW

$G_{tx}(\theta_{tx})$: DC-MSS-IMT satellite antenna gain in the direction of IMT UE taking into account the main beam of DC-MSS-IMT satellite is pointing to its serving DC-MSS-IMT UE, dBi

$G_{rx}(\theta_{tx})$: IMT UE antenna gain in the direction of DC-MSS-IMT space station, dBi

PL: Propagation loss, dB

L_{other}: Body Loss for IMT UE, dB

M: The number of DC-MSS-IMT systems involved in the calculation

N: The number of visible active space stations from the view of IMT UE

J: The number of beams of one satellite.

3 Simulation Results

This section provides the simulation results and analysis of interference from DC-MSS-IMT systems into IMT UEs in the above three~~two~~ scenarios, based on the methodology mentioned in Section 2.2.2.

3.1 Intra-system isolation distance

For the evaluation of intra-system interference, C/N-C/(I+N) < 2 dB was set as the accepted threshold of a DC-MSS-IMT system. The isolation distance for two beams of DC-MSS-IMT systems are given in Figure A2-24~~Figure 4~~ and Figure A2-25~~Figure 5~~. According to the simulation results, the intra-system isolation distance was set at 120 km for DC-MSS-IMT System ~~A~~ 3 and 100 km for System ~~B~~2.

Formatted: English (United States)

FIGURE A2-~~22~~24

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

Intra-system isolation distance (System ~~A~~3)

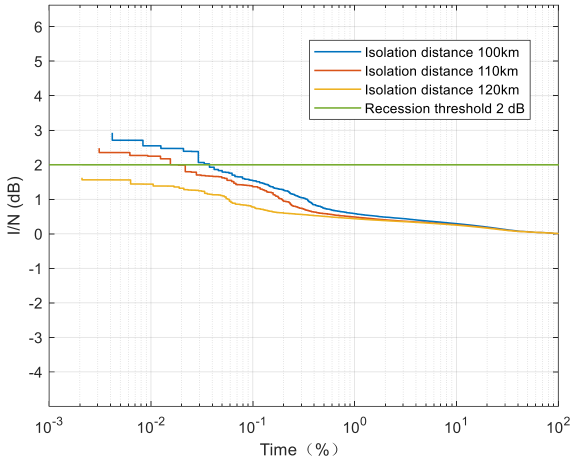
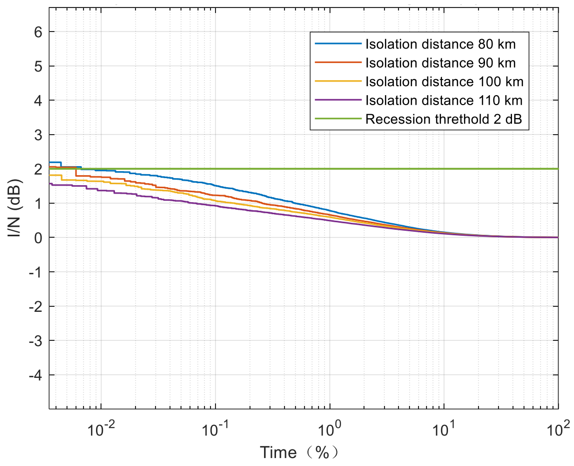


FIGURE A2-~~23~~25

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

Intra-system isolation distance (System ~~B~~2)



3.2 Isolation distance between DC-MSS-IMT systems

With an I/N ~~<~~≤ -6 dB as protection threshold between different DC-MSS-IMT systems, the compatible isolation distances between system ~~A~~ 3 and system ~~B~~ 2 are 160 km and 130 km (shown as Figure A2-26~~Figures 6~~ and Figure A2-27~~7~~), respectively. To ensure the coexistence under mutual interference, the isolation distance between DC-MSS-IMT systems is set at 160km.

Formatted: Font: (Default) Times New Roman

Formatted: Don't keep with next, Don't keep lines together

Formatted: English (United States)

FIGURE A2-~~24~~26

Isolation distance between DC-MSS-IMT systems (Distance of System ~~A~~3)

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

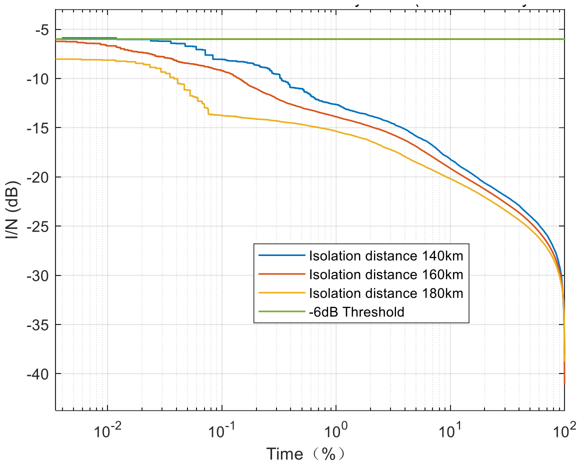
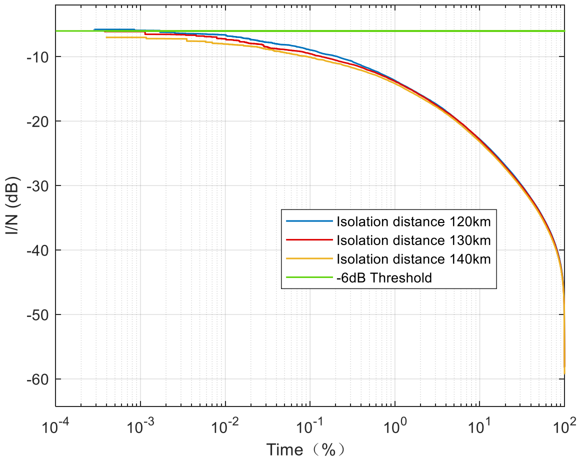


FIGURE A2-~~25~~27

Isolation distance between DC-MSS-IMT systems (Distance of System ~~B~~2)

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)



Formatted: English (United States)

3.3 Results of aggregate Interference in different scenarios

Based on the aforementioned steps, this section presents interference simulation results:

– For Scenario 1, referring to the scenarios described in Section 2.2.2.1.1 and the comparation of the interference potential to the terrestrial IMT network in Country C from system ~~A~~ 3 and ~~B~~2, we consider DC-MSS-IMT system ~~A~~ 3 serves both Country A and Country B ~~that has equivalent number of space stations~~, and calculate their interference to IMT UEs in Country C.

– For Scenario 2, ~~similarly,~~ we consider DC-MSS-IMT system ~~A~~ 3 and ~~B~~ 2 serves Country A and Country B respectively, and calculate the aggregate interference to IMT UEs in Country C.

– For Scenario 3, we consider DC-MSS-IMT system 3-1 and 3-2 serves Country A and Country B respectively, and calculate the aggregate interference to IMT UEs in Country C.

According to the simulation result, Figure A2-28 shows that the aggregate interference from multiple DC-MSS-IMT Systems (3 and 2) in Scenario 2 is not greater than that from a single system (System 3).

~~it shows that the aggregate interference in Scenario 2 from multiple DC-MSS-IMT systems A and B is not greater than the aggregate interference from the space stations coming from a signal DC-MSS-IMT system.~~

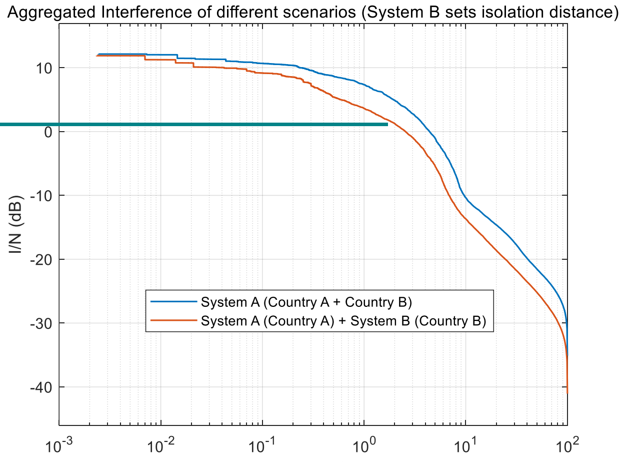
Formatted: Normal, No bullets or numbering, Keep with next, Keep lines together

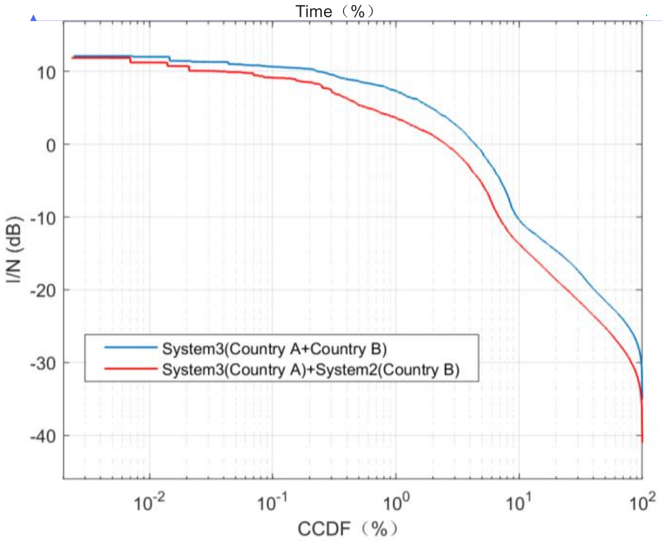
Formatted: Normal, No bullets or numbering

Formatted: English (United States)

FIGURE A2-~~26~~28

Aggregated Interference of different scenarios (System 2 sets isolation distance)





According to the simulation result, Figure A2-29 shows that the aggregate interference from multiple DC-MSS-IMT Systems (3-1 and 3-2) in Scenario 3 is not greater than that from a single system (System 3).

Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

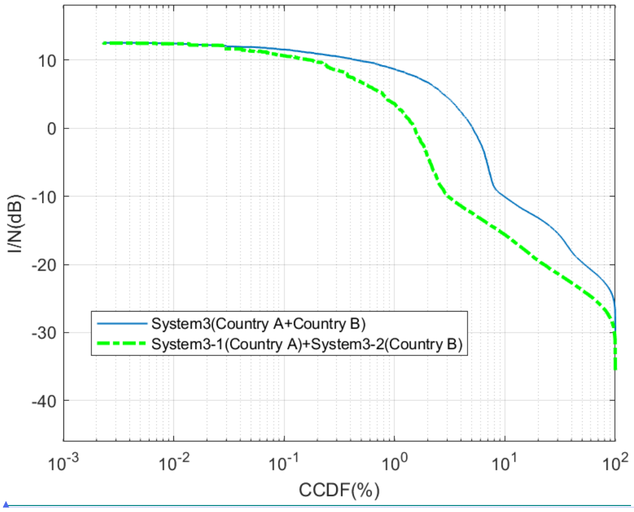
Formatted: Font: (Default) Times New Roman, 12 pt

Formatted: Font: (Default) Times New Roman, 12 pt

Formatted: English (United States)

FIGURE A2-29

Aggregated Interference of different scenarios (System 3 sets isolation distance)



Formatted: Font: (Asian) Chinese (Simplified, Mainland China)

Formatted: Font:

Formatted: Font: (Default) Times New Roman, 10.5 pt

4 Conclusion~~Proposal~~

From a technical point of view, we agree that terrestrial IMT networks can potentially receive interference from multiple satellites within one DC-MSS-IMT system. We also agree that the pfd value for the protection of terrestrial IMT network is defined only based on terrestrial IMT protection criteria and its characteristics.

For the protection of terrestrial IMT network, ~~Based on~~ the above analysis and the simulation result~~,~~ ~~it~~ shows that the potential aggregate interference from multiple DC-MSS-IMT systems is smaller than the aggregate interference coming from the space stations of a ~~signal~~ single DC-MSS-IMT system that has higher interference potential. Therefore, based on the filing of a single DC-MSS-IMT system to model and conduct sharing and compatibility study to protect terrestrial IMT receiver is appropriate where the aggregate interference is already considered and included. T~~where~~ ~~t~~he pfd protection criterion~~level~~, if any, should also be applied to the filing of a single DC-MSS-IMT system and no aggregation factor is needed. ~~Accordingly, no aggregation factor needs to be considered for the protection of IMT network.~~

We also think the interference mitigation measures should be implemented independently from the methodology for analysing the aggregate interference from the DC-MSS-IMT system.

Noting that relevant simulation and research work is still ongoing, further evaluation is needed in the future.

Formatted: English (United States)

Study D (Document 5D/754 (F))

[Note: Questions were raised with regards to the assumptions and methodology used in the study.]

Formatted: Font: Italic

Formatted: Normal

1 Introduction

For the protection of IMT terrestrial network from the envisaged direct communication between MSS and IMT, it is required to decide which approach is the most suitable for this purpose, whether pfd per satellite, epfd, or aggregated pfd. In this context, this contribution aims to:

– Analyse and evaluate the aggregation factor from different satellites within the same constellation system;

– Analyse and evaluate the aggregation factor of interferences from multiple systems at the boundary of at least three countries;

– Propose a regulatory approach to protect the terrestrial IMT networks.

The current study concerns the protection of IMT user equipment (UE).

2 Scenario

Consider the border line shared by three different countries, countries A, B, and C, such as the tri-border area between France, Germany, and Switzerland. The scenario is depicted in Figure 1.

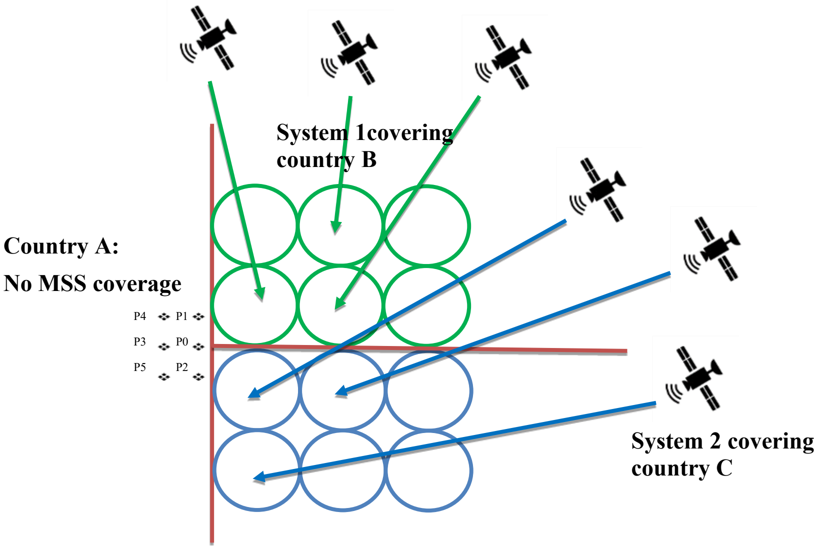
Suppose that countries B and C (such as Germany and Switzerland) each authorizes the direct communication between the MSS and the IMT TN. The MSS operates over the same frequency band in both countries, but each terrestrial cell is covered by a single satellite, single system, at a given frequency band.

The objective of this contribution is to evaluate the aggregated interference, in particular from different systems authorized in neighboring countries. As a starting point, we consider the same constellation characteristics for coverage in both countries (These characteristics are shown in Table I of the Annex 1, referring to System 2 in the Document 4C/356 (Annex 7)). We aim to evaluate the interference at several points distributed along the border region of country A (such as France), as shown in Figure 1. The measurement point P0 corresponds to the border tri-point where the three countries meet. The remaining points are positioned around P0, spaced 5 km apart.

Formatted: English (United States)

FIGURE 27

Cross-border interference scenario to protect IMT TN in country A from two MSS systems covering neighboring countries



3 Methodology and statistical analysis

At each measurement point along the border region, the interference from each constellation system $I_{system\ i}$ results from the integration of the received powers I_l from all visible satellites ($N_{visible}$) covering a neighboring country. The interference is calculated as:

$$I_{system\ i} = \sum_{l=1}^{N_{visible}} I_l$$

We note that the calculation considers the coverage of all the satellites that are visible from the measurement point.

At each cross-border measurement point, the total interference from both systems can be assessed as follows:

$$I_{total} = I_{system\ 1} + I_{system\ 2}$$

The protection criteria to protect the IMT TN is expressed in terms of interference to noise ratio *I/N* with a value of –6 dB.

The protection of IMT TN in a country A relies on whether each MSS system needs to respect the I/N limit independently or jointly. To help in this matter, we propose to evaluate the apportionment/aggregation factor *β*, as follows:

$$\beta = 10 * \log_{10}\left(\frac{I_{total}}{\max(I_{system\ 1}, I_{system\ 2})}\right)$$

Formatted: English (United States)

Similarly, but at the level of a single MSS system, the evaluation of the aggregation factor α from interference powers received from different satellites of the same MSS system could help to understand how the interference power is distributed and whether there is a dominant interference direction. The aggregation factor α is assessed as, where $\mathrm{I_{max}} = \max(I_l)$ is the highest interference received from a visible satellite:

$$\alpha = 10 * \log\left(\frac{\mathrm{I_{system}}}{\mathrm{I_{max}}}\right).$$

4 Scenario settings and parameters

Regarding the functionality of the MSS systems, we consider the following:

- **Beam placement:** fixed beam cells on ground, of a size of 30 km.
- **Satellite selection strategy**: At a given time t, the selected satellite may be at any elevation angle, provided it is higher than a minimum threshold (25° in this study). Consequently, a satellite is randomly selected per grid cell.
- **Satellite Tx power control**: Satellite Tx power is set to maintain a constant pfd at ground level, regardless of the elevation angle and the corresponding slant distance.
- **Satellite antenna model**: ITU-R M.2101, with a single beam per satellite
- **Mitigation technique:** No mitigation techniques or isolation distances are considered in this analysis.

We consider the satellite constellation described in Table I of the Annex 1. The orbital period of this constellation is T = 5677 s / 94.6 minutes. The satellite constellation is simulated at different epochs, regularly spaced at 20 s intervals, starting from time t=0 (12/08/2019 12:00:00) until (12/08/2019 18:18:20), covering a period of nearly 6 hours.

The measurement point P0 corresponds to the cross-border tri-point France-Germany-Switzerland, given by:

lat = 47.590°, lon = 7.589°, alt = 0 km

The operating frequency is 2 600 MHz.

5 Results

Figure 2 shows the CDF of the interference to noise ratio *I/N* from each system, as well as the total interference observed at all measurement points. If each system respects an *I/N* limit of –6 dB at the cross-border area, the aggregated interference may still exceed the protection criteria of the IMT TN UE. Therefore, an aggregation (or apportionment) should be defined to manage interference from multiple systems. This apportionment factor is statistically represented in Figure 3, both per measurement point and across all points combined. The highest apportionment factor of 3 dB should be considered when no percentage for the exceedance of the I/N protection criteria is allowed. However, if a certain percentage is allowed for exceedance, a lower apportionment factor may be considered, for example β= 2.6 dB for 20%- exceedance.

Formatted: English (United States)

FIGURE A2-28

Cdf of *I/N* ratio of each system and the total *I/N* from both systems

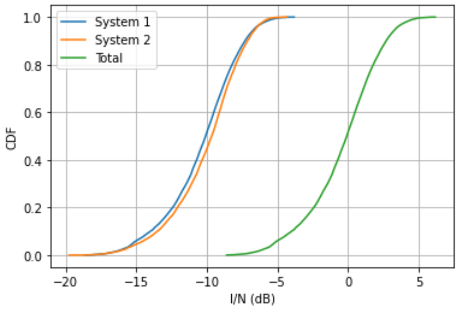


FIGURE A2-29

Cdf of the apportionment factor β at each measurement point and all combined

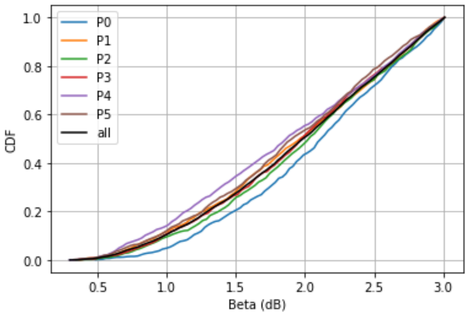
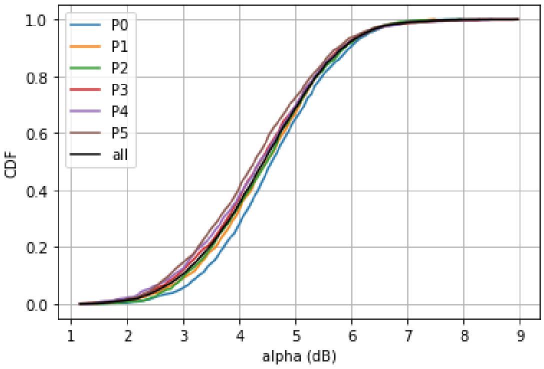


FIGURE A2-30

Cdf of the aggregation factor α at each measurement point and all combined



Formatted: English (United States)

Figure 4 shows the CDF of the aggregation factor α, which is equal to 5.4 dB at 80 %.

6 Conclusion

The results show that an apportionment factor of at least β=2.6 dB is required to protect the terrestrial IMT network with 20% of exceedance of the protection criteria.

Study E (Document 5D/775 (Orange))

[Note: Questions were raised with regards to the assumptions and methodology used in the study.]

Formatted: Font: Italic

Formatted: Normal

Preliminary DL interference aggregation factor simulations

A1 Simulation assumptions

The assumptions used in this preliminary DL interference aggregation factor simulations are summarized in Table A1-1.

TABLE A2-10

Preliminary assumptions

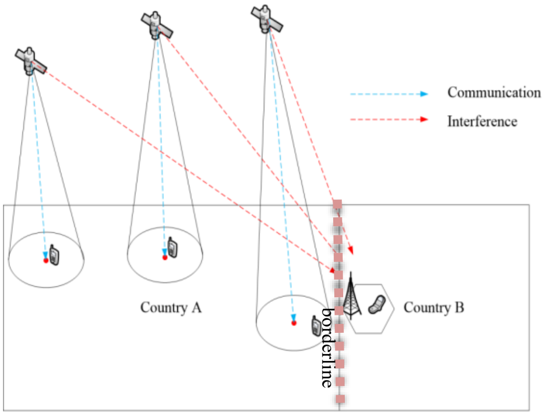
Number of satellites	600
Average satellite station altitude	360 km
Satellite station antenna patterns	Multi-beams (256 per satellite station) Configuration: 30x30 Antenna beam gain: 26 dBi
Frequency	1800 MHz
Minimum elevation angle	25°

A2 Simulation method

The simulation scenario is illustrated in Figure A1-1, the north east borderline between France and Germany was chosen in the simulations. Country A is Germany, and Country B is France.

FIGURE A2-31

Simulation scenario



Formatted: English (United States)

In this preliminary simulation, the link from satellite to ground based UE is considered as Line Of Sight, the clutters around the ground UE was not used.

1) The first step is to simulate the CDF of $I_{\_system} = \sum_{k=1}^{n} I_k$

2) Select the simulation $I_{\_max}$ among the $I_{\_k}$ which meet the condition of 99% of $I_{\_system}/N \le -6$ dB.

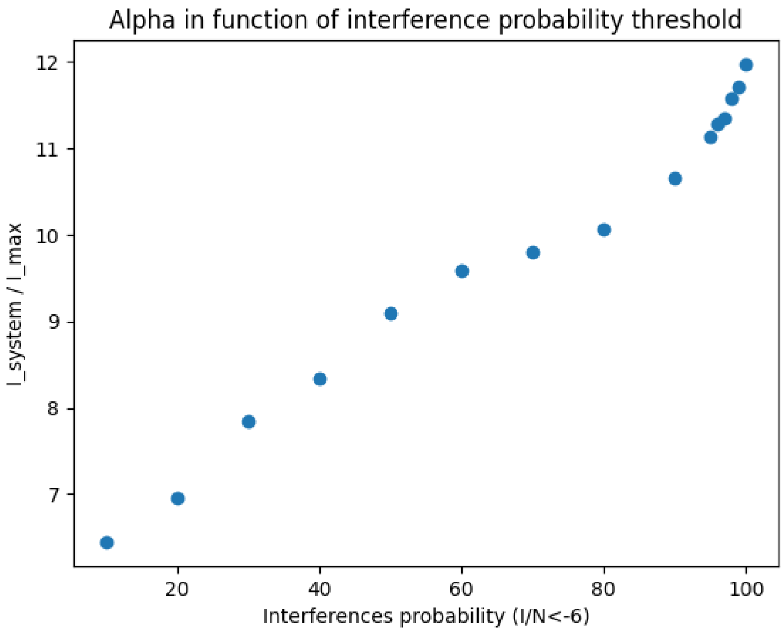
3) Simulate the CDF of $\alpha = 10*\log10(I_{\_system} / I_{\_max})$

A3 Preliminary simulation result

The preliminary simulation result is plotted in Figure A1-1.

FIGURE A2-32

Interference aggregation factor



The preliminary simulation results in Figure A1-2 indicate at 99%, the $\alpha = 10*\log10(I_{\_system} / I_{\_max}) \approx 11.6$ dB.

Formatted: English (United States)

Study F (Document 5D/898 (KOR))

[Note: Questions were raised regarding the assumption, methodology used to evaluate the number of visible satellites and the results.]

Formatted: Font: Not Bold, Italic

Formatted: Font: Not Bold, Italic

Formatted: Font: Not Bold, Italic

Formatted: Font: Italic

1 Introduction

We present considerations and analysis of aggregate interference from DC-MSS-IMT systems to terrestrial IMT user equipment (UE), with particular attention to border areas, for discussion at the Working Party (WP) 5D meeting.

In our study, all visible DC-MSS-IMT satellites with varying elevation angles are taken into account. The aggregate interference is evaluated at the boundary of a DC-MSS-IMT service area. We assume the existence of a defined DC-MSS-IMT service area, within which all visible DC-MSS-IMT satellites provide service. Each satellite is assumed to increase its transmit power until the per-satellite pfd limit is reached at any point outside the service area. Based on these conditions, we derive the aggregate factor (α) which for different scenarios.

2 Scenario

The aggregate interference from satellites to a terrestrial IMT UE is calculated as:

$$I_{aggregate}\ (\text{dB}) = 10 \times \log_{10}\left(\sum_{m=1}^{N_{visible}} I_m\right) = \alpha + I_{per-satellite}\ (\text{dB}),$$

where:

$N_{visible}$: Number of satellites visible to the terrestrial UE under consideration

I_m: Interference from the m-th satellite to the terrestrial UE, expressed in the linear domain, and $m = 1,2,3,\cdots,N_{visible}$

α: Interference aggregation factor, expressed in the dB domain

$I_{per-satellite}$: Maximum interference level that the terrestrial UE can tolerate, assuming only a single satellite is present.

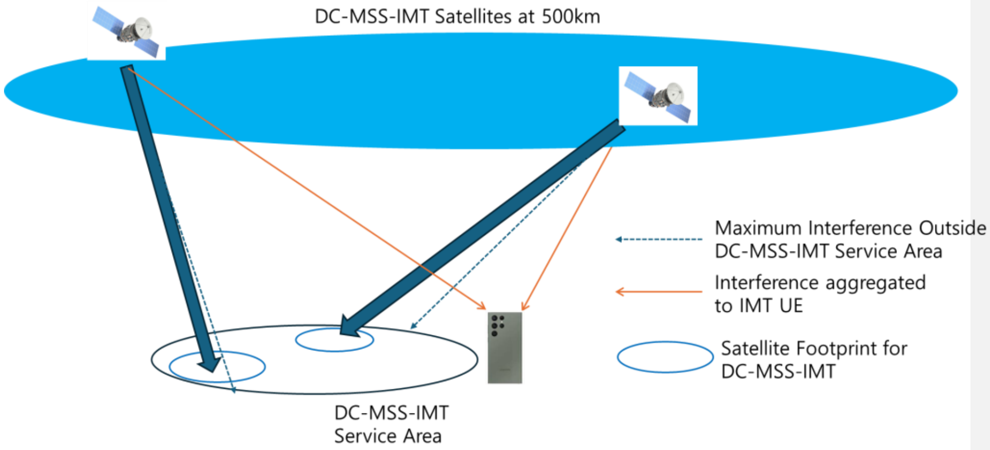
We are interested in the values and distribution of α for various cases, and the aggregate interference scenario is described in Figure 1.

Our focus is on analyzing the values and distributions of interference aggregation factor α under various scenarios. The aggregate interference scenario is illustrated in Figure 1.

Formatted: English (United States)

FIGURE 1

Interference Scenario



The assumptions for the interference scenario are as follows:

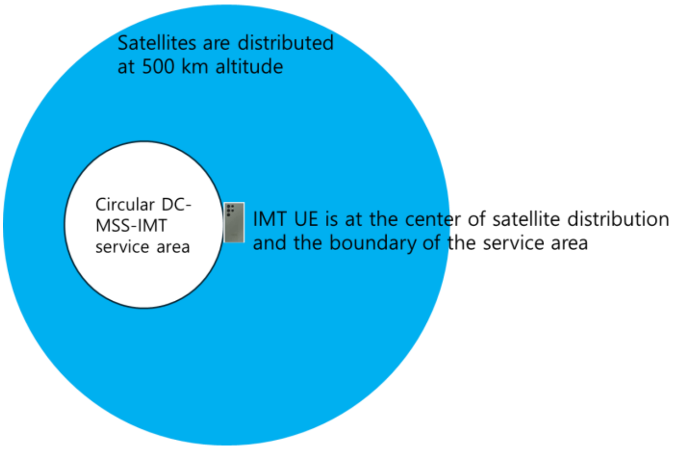
- All visible satellites from the terrestrial UE of interest provide DC-MSS-IMT service within the terrestrial DC-MSS-IMT service area, with each satellite generating a single footprint.
- Satellites are uniformly/randomly distributed at a constant altitude of 500 km. The number of visible satellites depends on elevation angles of 0°, 10°, and 20°.
- The DC-MSS-IMT service area is modelled as a circular region, with the terrestrial UE of interest located at its boundary.
- Satellite footprints are also uniformly/randomly distributed within the service area, and the assignment between satellites and footprints is randomly determined.
- Each satellite transmits at its maximum power while ensuring compliance with the per-satellite *I/N* protection requirement outside the DC-MSS-IMT service area.

The locations of the terrestrial IMT UE, the satellite distribution, and the DC-MSS-IMT service area are illustrated in Figure 2, which provides a vertical view from above. The terrestrial IMT UE is positioned at the center of the satellite distribution circle and simultaneously lies on the boundary of the DC-MSS-IMT service area. In the aggregate interference analysis, multiple configurations of the satellite distribution circle and the DC-MSS-IMT service area are examined.

Formatted: English (United States)

FIGURE 2

Terrestrial IMT UE location, satellite distribution and the DC-MSS-IMT service area from a top-down perspective

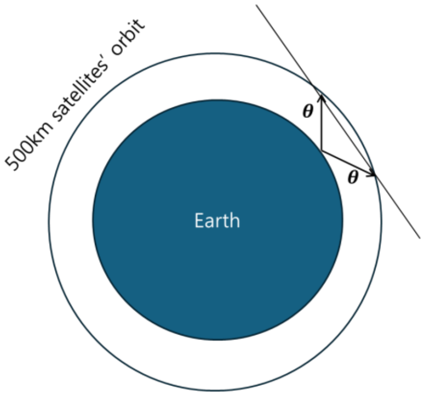


3 Number of visible (interfering) satellites

The number of visible satellites and the corresponding satellite distribution area are derived through geometrical analysis. These values are determined by the elevation angle (0°, 10°, and 20°) and the satellite altitude (assumed to be 500 km in this study), as illustrated in Figure 3.

FIGURE 3

Earth, satellites' orbit of 500 km altitude and the elevation angle θ



Formatted: English (United States)

We assume constellations consisting of 5,000 or 10,000 DC-MSS-IMT satellites in a 500 km orbit. When these satellites are randomly and uniformly distributed over the orbit, only a small fraction is visible at each elevation angle. The average number of visible satellites and the radius of the satellite distribution are summarized in Table 1.

TABLE 1

Average number of visible satellites and the radius of the satellites' distribution

Elevation angle, θ in degree	**0**	**10**	**20**
$N_{visible}$ for 5,000 satellites in the entire sphere	182	74	33
$N_{visible}$ for 10,000 satellites in the entire sphere	363	149	66
Radius of the satellites' distribution area in km	2 574	1 669	1 121

It should be noted that a spherical surface distribution is assumed in these calculations. However, for the interference analysis shown in Figure 1, the same number of satellites is assumed to be distributed over a flat 500 km circular area with the corresponding radius.

4 Antenna radiation pattern and size of the satellite footprint

Recommendation ITU-R S.1528 provides the satellite antenna radiation patterns for non-geostationary orbit (NGSO) satellite antennas operating in the fixed-satellite service below 30 GHz. To model the side-lobe radiation pattern, we applied section 1.3 of Recommendatioin ITU-R S.1528. The corresponding main- and side-lobe gains of the satellite antenna, as a function of angle, can be summarized as follows:

$$G(\psi) = \begin{cases} G_m & \text{dBi} \quad 0 \le \psi \le \psi_b \\ G_m - 3(\psi/\psi_b)^2 & \text{dBi} \quad \psi_b \le \psi \le Y \\ G_m + L_S - 25\log(\psi/Y) & \text{dBi} \quad Y \le \psi \le Z \\ L_F & \text{dBi} \quad Z \le \psi \le 180° \end{cases}$$

In particular, we adopted the numerical values specified in Section 1.3 and in the LEO reference pattern given in Annex 1. These recommended values are:

G_m: Maximum gain in the main lobe (35 dBi)

ψ_b: Half the 3 dB beamwidth in the plane of interest at the largest off-axis angle; the LEO reference pattern in Annex 1 *recommends* 1.6°

Y: Value recommended in Annex 1 LEO reference pattern is $1.5\ \psi_b = 2.4°$

L_S: Cross point between the main beam and near-in side-lobe mask (dB below peak gain); the Annex 1 LEO reference pattern recommends -6.75 dB

Z: Value recommended in Annex 1 LEO reference pattern is 20.4°

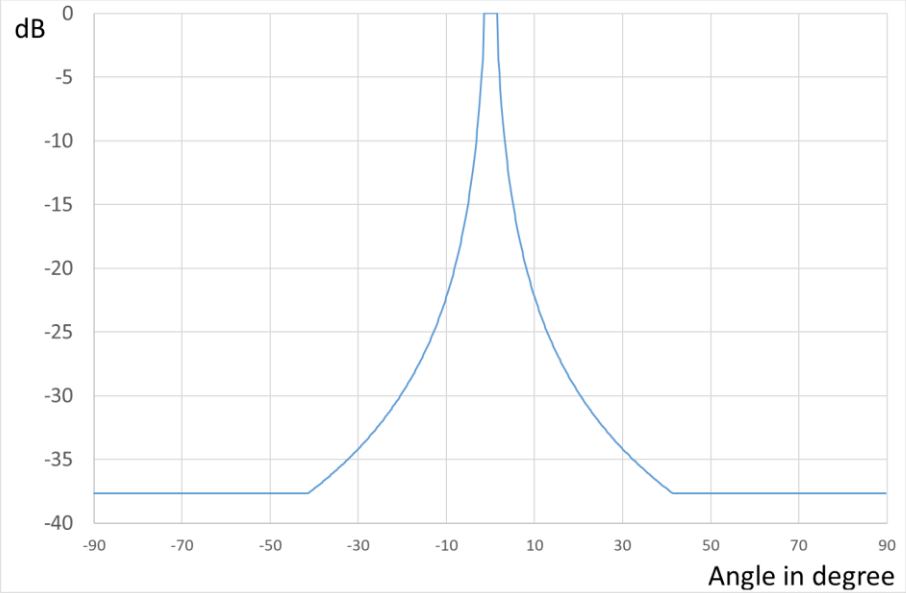
L_F: Far-out side-lobe level; the Annex 1 LEO reference pattern recommends 5 dB

Since our study evaluates the relative aggregate interference generated by multiple satellites compared to a single satellite, we used the maximum main-lobe gain of $G_m = 0$ dBi and applied $L_S = -37.65$ dB instead of 5 dB to maintain continuity of around $\psi = Z$. Figure 4 illustrates the resulting satellite antenna radiation pattern derived from section 1.3 and Annex 1 of Recommendation ITU-R S.1528.

Formatted: English (United States)

FIGURE 4

Satellite antenna radiation pattern used in this study
(based on section 1.3 and Annex 1 LEO reference pattern of Rec. ITU-R S.1528)



From the half 3 dB beamwidth of 1.6° at 500 km altitude, the radius of the 3 dB satellite footprint can be calculated as $500\ \times \tan(1.6^\circ) \approx 14$ km for the case of an elevation angle of 90°. However, at low elevation angles – particularly when the satellite is positioned at the edge of the 2 574 km satellite distribution radius – the 3 dB footprint radius can expand to

$$500 \times \tan\left(\tan^{-1}\left(\frac{2574}{500}\right) + 1.6\right) - 2574 \approx 446 \text{ km}.$$

5 Results and proposal

Table 2 presents the average interference aggregation factor (α) calculated for different values of $N_{visible}$ and the corresponding satellite distribution radii defined in Table 1. Service area radii of 50 km, 100 km, and 200 km are considered.

Significant variations in the average interference aggregation factor are observed, ranging from -6.01 dB to 24.1 dB. When a large number of visible satellites (363) provide DC-MSS-IMT service within a relatively small area (radius of 50 km), an IMT UE located at the edge of the service area may experience interference aggregation close to its maximum, which is 25.6 dB $(= 10 \times \log(363))$. In contrast, when only a small number of satellites (33) serve a much larger area (radius of 200 km), the impact of interference aggregation becomes negligible.

Formatted: English (United States)

To more accurately assess interference aggregation from multiple satellites, improved modeling is required that takes into account the number of satellites, the size of service area, operational characteristics, and other relevant factors. In particular, if the operational characteristics currently included in WP 4C working documents are made available for WP 5D, more accurate calculations would be possible.

TABLE 2

Simulation results

Radius of the satellites' distribution area in km	$N_{visible}$	**Radius of service area in km**	**Average interference aggregation factor (α) in dB**
2 574	363	50	24.10
		100	21.45
		200	16.99
	182	50	21.16
		100	18.52
		200	13.95
1 669	149	50	18.59
		100	13.81
		200	7.83
	74	50	15.53
		100	10.67
		200	4.49
1 121	66	50	11.67
		100	5.63
		200	–1.70
	33	50	8.60
		100	2.27
		200	–6.01

Formatted: English (United States)

Study G (Document 5D/927 (Multi-Country))

[Note: Questions were raised regarding assumptions, methodology, and scenario selection.]

1 Introduction

Working Party 5D (WP 5D) is tasked to provide regulatory considerations on the protection of terrestrial component of IMT. This contribution provides proposals for regulatory limits for the protection of IMT User Equipment (UE) in respect of: 1) aggregate PFD limit per system and 2) PFD limit per satellite.

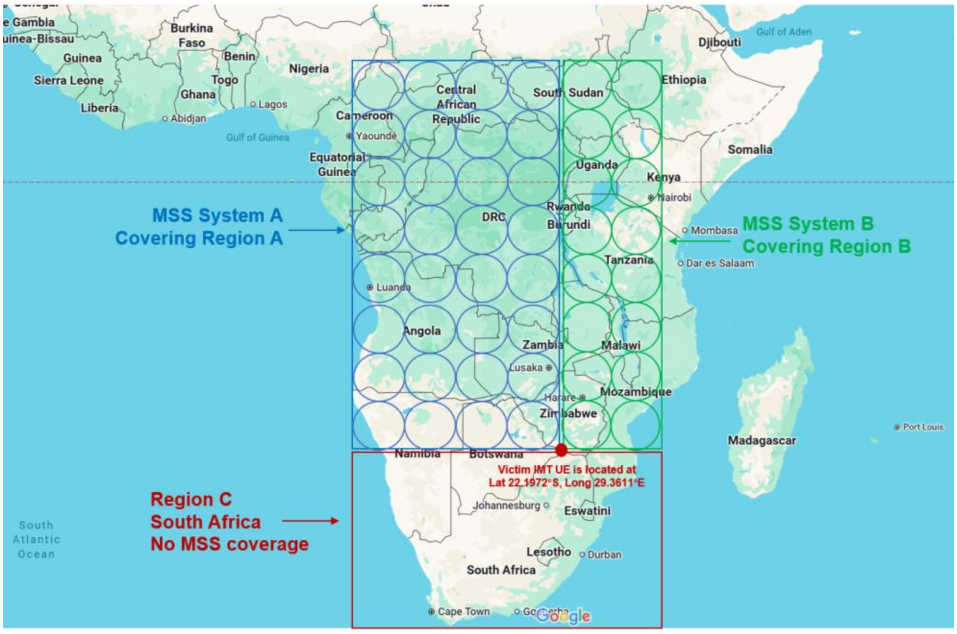
The proposals take into account the potential implications of the aggregation factors due to interference from multiple Mobile Satellite Service (MSS) systems and, from different satellites within the same MSS constellation system, at a UE victim located in South Africa close to the boundaries of Botswana & Zimbabwe.

2 Scenario

Consider the border line shared by three different Regions, Region A, B, and C, such as the tri-border area between South Africa, Botswana and Zimbabwe. An indicative illustration of the scenario is depicted in Figure 1 below.

FIGURE 1

Cross-border interference scenario: IMT UE located in South Africa and two separate MSS systems operating in neighbouring countries



Formatted: English (United States)

Scenario:

Suppose that Region A (Botswana) and B (Zimbabwe) each authorize a DC-MSS-IMT based service. Moreover, a different DC-MSS-IMT system is authorized in each of these regions/territories. The MSS systems operate over the same frequency band in both regions, but each terrestrial cell is covered by a single satellite, single system, at a given frequency band. The victim UE in this study is located at tri-border area of Region A, B and C (inside the territorial borders of South Africa in Region C).

The primary objective of this contribution is to evaluate the regulatory limits required in respect of aggregate PFD per system and PFD per satellite to ensure the protection of terrestrial IMT UE stations. Moreover, it also assesses the impact of potential aggregate interference from different systems authorized in neighbouring countries of South Africa.

This contribution considers two MSS systems (one in each Region). For the purposes of this study, the characteristics of both MSS systems have been assumed to be System 4 as provided by WP 4C in Document 4C/356 (Annex 7) and also consider the different orbital altitudes as also detailed below. The precise location of the victim IMT UE in South Africa is: Lat: 22.1972°S, Long: 29.3611°E.IMT UE as shown in Figure 1.

3 Assumptions

The MSS systems considered in this study is based on System 4 as per Document 4C/356 (Annex 7). However, we have modelled different orbital altitudes for each System as follows:

– MSS System A serving Region A: 520km altitude.

– MSS System B serving Region B: 690km altitude

The parameters of the orbital configurations are noted in Table 1 below.

TABLE 1

Parameters of the orbital configuration of System A and B

System	Frequency range[7] (MHz)	Altitude (km)	Inclination (deg)	# Planes	Sats per plane	RAAN spacing (deg)	Separation between orbital planes (deg)	Total number of sats
System A, Region A	698-960 (Block 2, 520 km, Orbit)	520	53	6	1 × 8 sats 5 × 3 sats	Planes start at 17° and subsequent planes are offset by 60°	*No info*	23
System B, Region B	698-960 (Block 2, 690 km, Orbit)	690	53	96	1	Planes start at 0° and subsequent planes are offset by 3.75°	*No info*	96

The satellite constellation was simulated at different epochs, regularly spaced at 10 sec. intervals, covering a period of nearly 2 days. The orbital period of this constellation is T = 5913s for System B (690km altitude) case and T = 5701s for the 520km altitude case. The operating frequency was assumed as 700MHz (703-713//758-768MHz).

Formatted: English (United States)

The IMT system parameters assumed is based on Annex 4.32 to Document 5D/792 – Working document on characteristics of the terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27. Considering that most IMT systems in border areas are located in rural regions, this study selected parameters and characteristics of rural macro BS. Two typical UE antenna gain values are considered. Body loss is 0dB.

TABLE 2

IMT Parameters

Scenario	**Rural Macro**
Typical antenna gain for user terminals	Case 1: 5 dBi for CPE case Case 2: 0 dBi for smartphone
Body loss	0 dB
UE noise figure	9 dB

The protection criterion for IMT UE is I/N=−6 dB applicable for 100% of the time.

Based on the liaison statement from WPs 3L/3M to WP5D (Document 5D/167), Recommendation ITU-R P.619-5 is used to evaluate interference between stations in space and those on the surface of the Earth. Given that the IMT UE is located in a typically rural area, no clutter loss is considered, as such, the path loss only includes free space loss.

Regarding the functionality of the MSS systems, we consider the following:

- **Satellite selection strategy**: At a given time, the selected satellite may be at any elevation angle, provided it is higher than a minimum threshold (28° for Region A and 32° for Region B in this study as defined in the technical and operational characteristics for System 4 as per Document 4C/356 (Annex 7)). Consequently, a satellite is randomly selected per grid cell.
- **Satellite Tx power control**: Satellite Tx power is set to be the maximum value in Document 4C/356 (Annex 7).
- **Satellite antenna model**: ITU-R S.1528 recommends 1.2, with a single beam per satellite
- **Mitigation technique:** No mitigation techniques (eg: isolation distances etc.) are considered in this analysis.

4 PFD limit for interference from all MSS systems

Based on the I/N protect criterion and IMT UE antenna gain, the PFD limit can be calculated with the following formula.

$$PFD = 10\ log(KTB) + \frac{I}{N} + NF - 10\ log\frac{\lambda^2}{4\pi} - G_{rx}(\theta_{rx}) + OtherLoss$$

The PFD limit is as shown below, for different G_{rx} assumptions.

Formatted: English (United States)

TABLE 3

PFD limit for all MSS systems

Assumption	PFD Limit (dBw/m2/MHz)
5dBi CPE	-127.5
0 dBi UE	-122.5

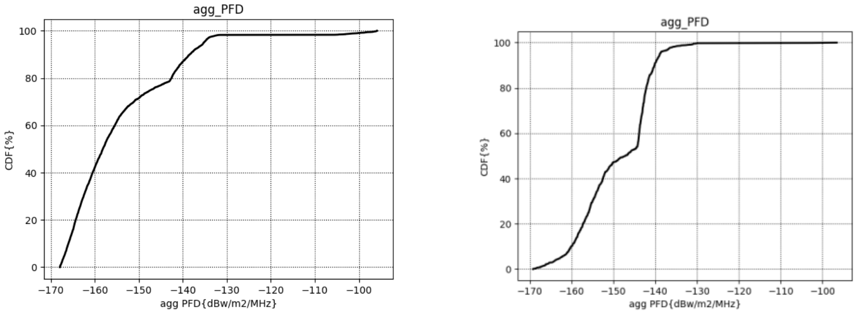
5 Aggregation factors for MSS systems

5.1 Aggregate PFD received at a victim UE from System A and from System B

We have conducted a Monte Carlo simulation using the assumptions in section 4 above and the assumptions on the MSS system characteristics (from WP 4C MSS parameters). The figures below show the CDF of aggregate PFD level received at the victim IMT UE, from each of the MSS systems covering Region A and Region B:

FIGURE 2

CDF of *PFD* level of each system at the victim´ IMT UE



(a) MSS systems A serving Region A (b) MSS system serving Region B

The maximum aggregate PFD level at the victim IMT UE (corresponding to 100% of the CDF curve) is -95.85 dB(W/m2)/MHz, from system A in Region A, and -96.59 dB(W/m2)/MHz), from system B in Region B;

5.2 Multi-MSS System aggregation factor

The interference from each MSS system $I_{system\ i}$ results from the integration of the received powers I_l from all visible satellites in the system ($N_{visible}$) covering a neighboring region. The interference is calculated as:

$$I_{system\ i} = \sum_{l=1}^{N_{visible}} I_l$$

The total interference at the cross-border measurement point, from the two systems covering Region A and Region B can be assessed as follows:

$$I_{total} = I_{system\ \mathrm{A}} + I_{system\ \mathrm{B}}$$

The protection criteria to protect the IMT TN is expressed in terms of interference to noise ratio *I/N* with a value of –6 dB.

Formatted: English (United States)

We propose to evaluate the apportionment/aggregation factor β, as follows:

$$\beta = 10 * \log_{10}\left(\frac{I_{total}}{\max(I_{system\ A}, I_{system\ B})}\right)$$

Based on the PFD calculation formula,

$$PFD = I - 10\ log\frac{\lambda^2}{4\pi} - G_{rx}$$

For the interference calculation of System A and System B, the G_{rx} is 0dBi for smartphone or 5dBi for CPE in this study, so the aggregation factor β can also be calculated based on aggregated PFD value as below,

$$\beta = 10 * \log_{10}\left(\frac{PFD_{total}}{\max(PFD_{system\ 1}, PFD_{system\ 2})}\right)$$

Based on the simulated maximum aggregate PFD values from the two MSS systems in section 5.1, the aggregation factor is 3dB.

6 PFD limit per single MSS system

When there are multiple MSS systems, the PFD limit applicable to a single MSS system can be calculated based on the PFD limit for all MSS systems (as in section 4) and the aggregation factor β (as in section 5), as follows:

PFD_singleMSS = PFD_allMSS - Aggregation factor

Considering the scenario in this study, the PFD limit for single MSS system needs to consider the aggregation factor as discussed in section 5. Using the 3dB aggregation factor for the two MSS systems, the aggregate **PFD limit** for each MSS system is summarized in table 4 below:

TABLE 4

Aggregate PFD limit per MSS system

Assumption	PFD Limit (dBw/m2/MHz)
5dBi CPE	-130.5
0 dBi UE	-125.5

7 Aggregation of interference from multiple satellites within one MSS system

Similarly, but at the level of a single MSS system, the evaluation of the aggregation factor α from interference powers received from different satellites within the same MSS system could help to understand how the interference power is distributed and whether there is a dominant interference direction. The aggregation factor α is assessed as follows, where $\mathrm{I_{max}} = \max(I_l)$ is the highest interference received from a visible satellite:

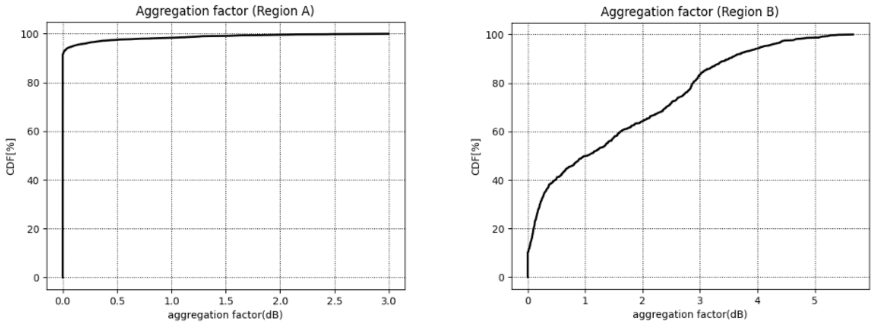
$$\alpha = 10 * \log\left(\frac{\mathrm{I_{system}}}{\mathrm{I_{max}}}\right).$$

Both Region A and Region B satellite systems are evaluated and get aggregation factors as below,

Formatted: English (United States)

FIGURE 3

CDF of aggregation factor α for System A and System B



This aggregation factor is closely related to the number of satellites. Satellite A has fewer satellites, while Satellite B has more, leading to inconsistent trends. Considering that the satellite constellation continues to expand in the future, the value of the aggregation factors will continue to increase. Therefore, we propose to use 5.6 dB obtained from MSS system B at a 100% of the CDF.

8 PFD limit per satellite

PFD limit per satellite can be calculated based on the PFD limit for a single MSS system (as calculated in section 6) and the aggregation factor α (as calculated in section 7):

PFD_perSAT = PFD_singleMSS - Aggregation factor

The resulting **PFD limits** are summarized in the table below, for a value of 5.6 dB for the aggregation factor, and for different values of UE antenna gain

TABLE 5

PFD limit per satellite

Assumption	PFD Limit (dBw/m2/MHz)
5dBi CPE	-136.1
0 dBi UE	-131.1

9 Summary

This contribution has evaluated the impact on the interference on an IMT UE of the aggregation of interference from two MSS systems, and of the aggregation of interference from multiple satellites in the same MSS system. The resulting aggregation factors are as follows:

Aggregation of interference from two MSS systems	β= 3dB
Aggregation of interference from multiple satellites within one MSS system	α=5.6 dB

Formatted: English (United States)

On the basis of these aggregation factors, the resulting regulatory limit for protection of IMT UE in the frequency band of 700 MHz are as follows:

Assumption	**Aggregate PFD limit per single MSS system (dBw/m2/MHz)**	**PFD limit per satellite (dBw/m2/MHz)**
5dBi CPE	-130.5	-136.1
0 dBi UE	-125.5	-131.1

Study H (Document 5D/968 (Ericsson))

[Note: Questions were raised with regards to the coexistence of satellite systems considered in the analysis]

Formatted: Font: Not Bold, Italic

Formatted: Font: Not Bold, Italic

1 Aggregate interference from DC-MSS- IMT systems to IMT UE

We simulate a DC-MSS-IMT system for 24 hours with time steps of 10 seconds and calculate the aggregate interference from all visible satellites to an IMT UE at a fixed location. Visible satellites are satellites seen by IMT UE at elevation angles larger than 0 degree. We assume one satellite UE and one satellite beam for each visible interfering satellite. The whole transmit power of the satellite is transmitting in one beam to the satellite UE located at the center of the beam. By considering a minimum distance between the IMT UE and satellite UEs, we ensure that IMT UE is outside of the DC-MSS-IMT system coverage area.

At each time step, we perform the following steps:

1) Identify all visible satellites to IMT UE (interfering satellites).
2) Identify interfering satellites footprints considering the DC-MSS-IMT system minimum elevation angle.
3) Drop one satellite UE randomly in each interfering satellite footprint considering a minimum distance between satellite UEs and IMT UE.
4) Assume the whole transmit power of the interfering satellite is transmitting in one beam to the satellite UE located at the center of the beam.
5) Calculate the gain of interfering satellites’ antennas towards the IMT UE and the free space propagation loss between the interfering satellites and IMT UE.
6) Calculate the interference received by IMT UE from each interfering satellite.
7) Calculate the aggregate interference received by IMT UE.

For IMT UE, we assume the following parameters from section 4 of the working document (Doc. 5D/792 (Annex 4.32))

IMT UE parameters

Height	1.5 m
Antenna gain	−3 dBi
Noise figure	9 dB

For propagation model, we assume free space propagation loss between interfering satellites and IMT UE. The characteristics of DC-MSS-IMT system and the results are included in the following sections.

Formatted: English (United States)

1.1 Technical characteristics of DC-MSS-IMT system

The orbital characteristics of DC-MSS-IMT systems are summarized in table below. This is system 3 listed in Annex 1 of the working document on sharing and compatibility studies in relation to WRC-27 agenda item 1.13 (Doc. 4C/356 (Annex 7)).

System ID	Altitude (km)	Inclination (deg)	# Planes	Sats per plane	RAAN spacing (deg)	Total number of sats
System 3 (non-GSO)	525	53	28	120	12.9	3 360

For other characteristics of the system, we use additional system information for system 3 provided in the annex of the mentioned working document.

For the satellites antenna pattern, we use *recommends* 1.4 of Recommendation ITU-R S.1528 with the assumptions that simplifies the model to the gain pattern for a reflector antenna with circular aperture (Figure 1).

$$G(u) = G_{max} + 20\,log_{10}\left|\frac{2J_1\left(\left(\frac{\pi D}{\lambda}\right) sin(\theta)\right)}{\left(\frac{\pi D}{\lambda}\right) sin(\theta)}\right|,$$

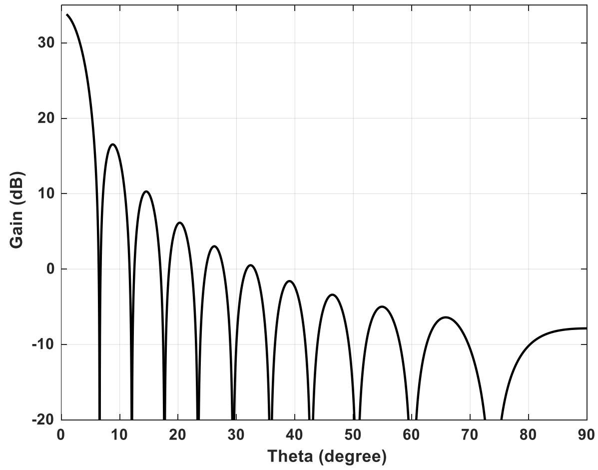
with $G_{\text{max}} = 34.1$ dBi and $D = 1.6$ m, and $\lambda = 0.15$ m ($f = 2$ GHz).

For the satellite selection and beam management, we assume 20 degrees as the minimum elevation angle for satellites, and we consider beam size contour at the 7 dB falloff.

The satellite transmit power is calculated from the maximum pfd on the ground per satellite at 2 GHz for system 3 at 525 km (−85.5 dBW/m^2/MHz). This is the pfd at Nadir. The pfd is lower at lower elevations as we assume constant EIRP at the satellite.

FIGURE 1

Satellite antenna pattern



Formatted: English (United States)

1.2 Results

To obtain results, we consider IMT UE at a fixed location in the middle of Europe (latitude: 47.3769° N, longitude: 8.5417° E).

To understand the contribution of different interfering satellites in the total aggregate interference, we categorize them to the satellites seen by IMT UE at low (0-30 degrees), mid (30-60 degrees), and high (60-90 degrees) elevation angle ranges. The average number of interfering satellites (i.e. visible satellites to IMT UE) is 173, among them 83% (143~144 satellites) are seen at low elevation angles, 15 % (25~26 satellites) are seen at mid elevation angles, and only 2 % (3~4 satellites) are seen at high elevation angles. Table below shows the distance of area where the DC-MSS-IMT system provides service by the satellites in different elevation angle ranges from IMT UE.

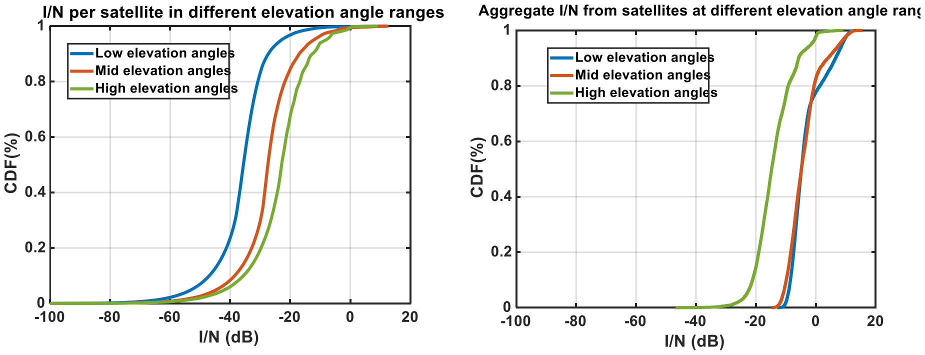
	Low elevation angles	**Mid elevation angles**	**High elevation angles**
DC-MSS-IMT system service area distance from IMT UE [km]	100-3 500	50-1 800	50-1 300

We calculate and plot the CDF of I/N for individual satellites at low, mid, and high elevation angle ranges, as well as the aggregate interference from all satellites seen by IMT UE at low, mid, and high elevation angle ranges (Figure 2). The CDF of total aggregate interference from all interfering satellites and the CDF of contributions of satellites at low, mid, and high elevation angle ranges in the total aggregate interference are shown in Figure 3.

The results demonstrate the impact of number of interfering satellites in the total aggregate interference. Although the satellites seen at higher elevation angles cause higher interference (see left plot in Figure 2), the aggregate interference from satellites at low and mid elevation angle ranges have higher contributions in the total aggregate interference (see right plot in Figure 2) due to the high number of visible satellites at those elevation angle ranges. This also means the satellites providing service to area far from the IMT UE might cause harmful interference to the IMT UE.

FIGURE 2

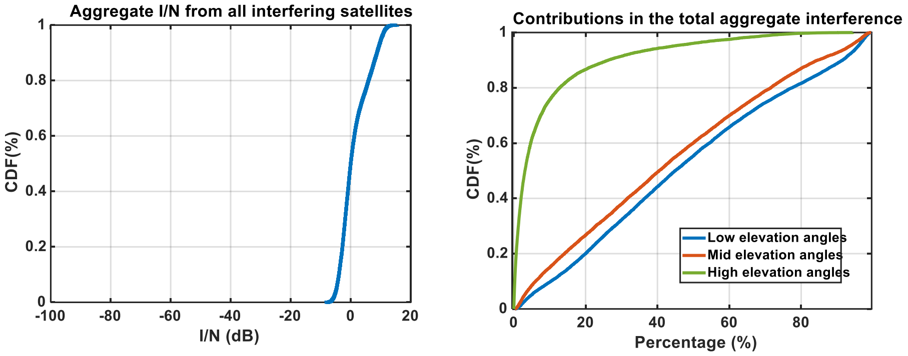
(Left) CDF of I/N for individual satellites and (right) aggregate interference from all satellites seen by IMT UE at low, mid, and high elevation angle ranges



Formatted: English (United States)

FIGURE 3

(Left) CDF of total aggregate interference from all interfering satellites, (right) CDF of contributions of satellites at low, mid, and high elevation angle ranges in the total aggregate interference



ANNEX 3

PFD Levels Field Measurement

[Document 5D/967 (Orange)]

[Note: Questions were raised with regards to the assumption, measurement procedure and conclusion in the analysis]

1 Introduction

WRC-27 agenda item (AI) 1.13 deals with direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage using the IMT frequency bands between 694/698 MHz and 2.7 GHz under condition of without causing harmful interference to the terrestrial IMT network.

Three types of DC-MSS-IMT DL pfd limits are under consideration by Working Party (WP) 5D within the framework of WRC-27 agenda item 1.13 for the protection of the terrestrial IMT network downlink. To make sure there is no harmful interference to the terrestrial IMT network downlink in the border area, administrations may perform field measurement to verify the conformity of regulatory condition: downlink pfd limits. This document provides two possible pfd measurement methods.

Formatted: English (United States)

2 DL PFD measurement methods

2.1 DC-MSS-IMT DL PFD definition

Working Party 5D is considering the following DC-MSS-IMT DL pfd limits within the framework of WRC-27 AI 1.13 for the protection of the terrestrial IMT network downlink:

1) Aggregated pfd per multi-systems

The UEs in the terrestrial IMT network can potentially suffer interferences from multiple DC-MSS-IMT systems operating in the same frequency band, each DC-MSS-IMT system has multiple satellites, each satellite uses multiple beams, and each beam provides a satellite cell.

The aggregated DL pfd per multi-systems can be derived from the protection ratio of $I/N = -6$ dB where I is the aggregated interference from multi-systems, multi-satellites, and multi-beams.

The problem associated with the aggregated DL pfd per multi-systems is that in the case of harmful interference occurrence, it would be impossible to identify which specific system is responsible of the interference.

2) Aggregated pfd per system

Aggregated pfd per system = aggregated pfd per multi-systems - b

Where b is the muti-systems apportionment factor. The study B in the WRC-27 AI 1.13 technical study working document Annex 2 proposed b = 3 ~ 5 dB. Study D in the WRC-27 AI 1.13 technical study working document Annex 2 proposed b = 2.6 dB.

3) Single satellite cell DL pfd

It should be pointed out that a satellite uses multiple beams, each beam provides a satellite cell, it is proposed to use single satellite cell pfd rather than single satellite pfd, since each satellite provides multiple satellite cells.

Single satellite cell pfd = aggregated pfd per multi-systems - b - a

Where b is the muti-systems apportionment factor, a is the multi-satellites and multi-beams aggregation factor. The study D in the AI.1.13 technical study working document Annex 2 proposed a = 5.4 dB at 80% interference probability. Study E in the WRC-27 AI 1.13 technical study working document Annex 2 proposed preliminary a = 11.6 dB.

2.2 Measurement of the aggregated pfd per multi-systems

The multi-systems aggregated DL pfd measurement set-up is illustrated in Figure 1.

1) An omni antenna with gain from 10 dBi to 20 dBi (to ensure the received power level is above the thermal noise floor) on the roof-top of a van connecting to a spectrum analyser.

2) Conducting driving tests or keeping the van at different fixed positions in the border area where there is no coverage from the terrestrial IMT network.

3) Scan different resource blocks of a DC-MSS-IMT frequency channel bandwidth, e.g. 5 MHz, with a measurement bandwidth of 180 kHz which is the resource block size for LTE/NR in low bands.

4) Convert the received power level into pfd.

5) Plot CDF_1 of pfd from all scanned resource blocks.

6) Plot CDF_2 of pfd taking into account only the occupied resource blocks.

Formatted: English (United States)

7) To verify if X% of measured pfd <= apfd0 where the apfd0 is the multi-systems aggregated pfd limit.

Where X% is the percentage of *I/N* = –6 dB agreed for IMT protection criterion. The actual proposed value was [98%] for IMT system downlink protection.

FIGURE 1

Aggregated pfd measurement set-up

2.3 Measurement of the single satellite cell pfd

The single satellite cell pfd measurement set-up is illustrated in Figure 2.

1) A parabolic antenna with gain from 15 dBi to 20 dBi (to ensure the received RSRP is above the minimum RSRP value of –127 dBm/15 kHz) on the roof-top of a van connecting to a LTE or NR analyser to measure the LTE CRS RSRP or NR SSB SS-RSRP.

2) Keep the van at a fixed position in the border area during a sufficient long period, e.g. 1 hour where there is no coverage from the terrestrial IMT network.

3) Select a specific satellite system and satellite cell, e.g. satellite cell covering the nearest area in the neighboring country.

4) The parabolic antenna direction should be aligned with target satellite orbit direction.

5) Measure the received LTE CRS RSRP or NR SSB SS-RSRP power levels over 15 kHz or 30 kHz of the selected satellite cell.

6) Change the test van locations in the border area, and repeat the steps 2) to 5).

7) Convert the received RSRP levels into pfd.

8) Plot CDF of pfd values.

9) To verify if X% of measured pfd <= pfd0 where the pfd0 is single satellite cell pfd limit.

Where X% is the percentage of *I/N* = –6 dB agreed for IMT protection criterion. The actual proposed value was [98%] for IMT system downlink protection.

Formatted: English (United States)

FIGURE 2

Single satellite cell pfd measurement set-up

2.4 Measurement of the aggregated pfd per system

None of the two measurement methods described above is valid for measuring the aggregated pfd per system.

3 Summary

Three types of pfd limits are under consideration for the protection of the terrestrial IMT networks, the determination of the appropriate pfd limit should take into account the feasibility to measure it.

In section 2, two field measurement methods are described. The measurement method 1 with an onmi-directional antenna and a spectrum analyser can measure the aggregated pfd per multi-systems. The measurement method 2 with a parabolic antenna and a LTE or NR analyser can measure the single satellite cell pfd. None of the two measurement methods is valid for measuring aggregated pfd per system.

The aggregated pfd per multi-systems can be measured, but in case of non-conformity is identified, it is impossible to identify which system is responsible by considering that the DC-MSS-IMT system characteristics such as satellite station antenna gain/pattern, number of satellites per system, and number of beams per satellite, etc can be very different.

The single satellite cell pfd can be measured through the measurement of RSRP with a parabolic antenna on a van connecting a LTE or NR analyser.

Formatted: English (United States)

ANNEX 4

Considerations on the regulatory measures

[Document 5D/478 (CHN)]

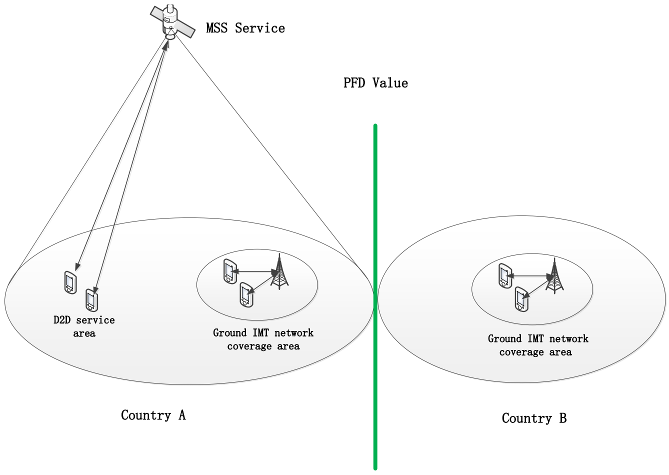
The possible new allocations to the mobile-satellite service (MSS) for direct connectivity between space stations and IMT user equipment (UE) is to complement terrestrial IMT network coverage and may provide direct connectivity to underserved communities in rural and remote areas, in particular in the event of network failures of terrestrial IMT and natural disasters, where the same IMT UE is used.

The possible frequency usage of the new MSS allocation under the above scenario and the management of the MSS network is similar to terrestrial IMT network for which it could be achieved through the cooperation between satellite operator and local terrestrial network operator and then be authorized or directly authorized by the administration within its territory. The application of this kind of MSS system within a country can be implemented according to its own usage requirements and conditions while not causing interference to other administrations.

Therefore, it is necessary to consider the issue of potential harmful interference to terrestrial IMT networks of neighbouring countries from a country where the new MSS application has been authorized (Figure1). The possible regulatory measures for this kind of potential harmful interference could comprehensively refer to the existing bilateral coordination and/or protection requirement of terrestrial IMT networks between neighbouring countries.

FIGURE A3-1

Diagram of the interference scenario of MSS systems to the IMT system between neighbouring countries



Formatted: English (United States)

It is impossible to allow different MSS systems or different beams of the same MSS system to be used in the same frequency and in the same area because of the non-directionality of IMT terminals' antenna. Therefore, in the process of potential harmful interference assessment to protect a neighbouring countries' terrestrial IMT network, it is proposed to set up a PFD value by considering the potential aggregate interference from one MSS system.

And two methods on how to use the calculated PFD value in regulatory measures are under consideration,

Alternative 1: to set up a PFD value as a coordination trigger to initiate the bi-lateral coordination between concerned administrations.

Alternative 2: to set up a PFD limit for protection of the concerned administrations' territorial IMT network.

Additionally, it should be also noted that the 2 GHz band usage is shared between existing MSS and IMT systems and the required compatibility is reached through interference mitigation techniques pursuant to Resolution **212 (Rev.WRC-23)**. Refer to Radio Regulations No. **389F** too.

Formatted: English (United States)