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SPECTRUM ASPECTS&
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SHARING AND COMPATIBILITY STUDIES OF IMT SYSTEMS WITH FSS SATELLITES IN THE FREQUENCY BAND 6 425-7 125 MHZ

WRC-23 Agenda items 1.2

1 Introduction

WRC-23 agenda item 1.2 to consider identification of the frequency bands 3 300-3 400 MHz, 3 600-3 800 MHz, 6 425-7 025 MHz, 7 025-7 125 MHz, and 10.0-10.5 GHz for International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution **245 (WRC-19).**

Resolves 1 of Resolution 245 states 'Conduct and complete in time for WRC-23 the appropriate studies of technical, operational, and regulatory issues about the possible use of the terrestrial component of IMT in the frequency bands in resolves 2, taking into account the following

– evolving needs to meet emerging demands for IMT;
– technical and operational characteristics of terrestrial IMT systems;
– the deployment scenarios envisaged for IMT systems and the related requirements;
– of balanced coverage and capacity;
– the needs of developing countries;
– the time-frame in which spectrum would be needed;

Resolves 2 of Resolution 245 states 'to conduct and complete the sharing and compatibility studies, to ensure the protection of services to which the frequency band is allocated on a primary basis, without imposing additional regulatory or technical constraints on those services, and also, as appropriate, on services in adjacent bands, for the frequency bands as follows:

- 3 600-3 800 MHz and 3 300-3 400 MHz (Region 2);
- 3 300-3 400 MHz (amend footnote **5.429B** in Region 1);
- **7 025-7 125 MHz (Globally);**
- **6 425-7 025 MHz (Region 1);**
- 10 000-10 500 MHz (Region 2),

This input contribution presents sharing and compatibility studies conducted on IMT systems in the frequency band 6 425-7 125 MHz concerning receiving FSS satellites.

2 Allocation and Use of 6 GHz band

2.1 Use of the band 6 425 MHz to 7 125 MHz

The frequency band under consideration for agenda item 1.2 is differentiated into the following sub-bands for a variety of applications in use by the Administrations as follows: -

i. 6 425-6 725 MHz: this frequency band is allocated to the FSS globally (Earth-to-space) and is not subject to a Plan. The band is used for the uplinks by large numbers of GSO FSS networks covering all regions, including the Asia Pacific Region. MSS satellite systems also utilize the band as uplink feeder links from gateway stations to satellite to support the L-band MSS services from several GSO satellites, including coverage of the Asia Pacific. These systems use this link spectrum to help safety-related L-band services, including the GMDSS and AMS(R)S. Interference to these satellites feeder uplinks could harm those critical L-band services.

ii. 6 725-7 025 MHz: this frequency band is allocated to the FSS globally (Earth-to-space) and used for FSS as per the provisions of Appendix **30B** (RR No. **5.441**). The band is used for the uplinks by GSO FSS networks in the Plan and the List covering all Regions. The main objective of the App 30B plan is to guarantee, in practice, for all countries, equitable access to the geostationary-satellite orbit in the frequency bands of the FSS. The satellite used in this frequency range must be respected and protected by all countries in Region 1.

iii. 6 700-7 025 MHz: this frequency band is allocated to the FSS globally (space-to-Earth); this allocation is limited to feeder links for non-geostationary satellite systems of the mobile-satellite service. It is subject to coordination under RR No. **9.11A**. The use of this band by feeder links for non-geostationary satellite systems in the mobile-satellite service is not subject to RR No. **22.2** as per footnote RR No. **5.458B**. Co-existence issues between IMT and receiving FSS earth stations would be similar to those studied in Report ITU-R S.2368, i.e., separation distances and coordination contours would be necessary around receiving FSS earth stations to achieve co-existence.

Iv (a). 7 025-7 075 MHz: this frequency band is allocated to the FSS globally (Earth-to-space) and is not subject to a Plan.

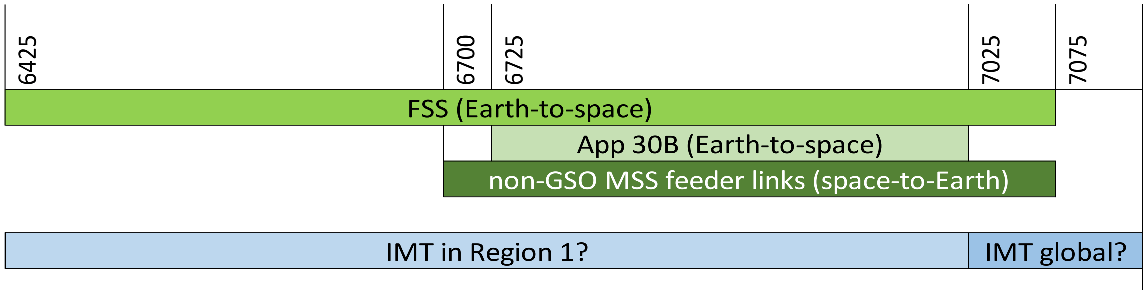
Iv (b). 7 025-7 075 MHz: this frequency band is for FSS globally (space-to-Earth); this allocation is limited to feeder links for non-geostationary satellite systems of the mobile-satellite service. It is subject to coordination under RR No**. 9.11A**. The use of this band by feeder links for non-geostationary satellite systems in the mobile-satellite service is not subject to RR No. **22.2** as per footnote RR No. **5.458B**.

V. 7 075-7 125 MHz: there is no FSS allocation, so no direct impact.

Figure 1 below outlines the current uses of the upper 6 GHz band by various services and applications.

FIGURE 1

Current uses of the band from 6 425 MHz to 7 125 MHz and bands considered for IMT identification



2.2 Findings from Existing studies and Future studies requirement

	IMT-Advanced (4G)	IMT-2020 (5G)
ITU studies	Report ITU-R S.2367	To be done under AI1.2

ITU-R studies to date have been carried out in the adjacent band 5 925-6 425 MHz between IMT-Advanced (4G) and FSS as outlined in the ITU-R Report 2.2367. FSS characteristics used in ITU-R Report S.2367 are similar to those in the band adjacent band 6 425-6 575 MHz.

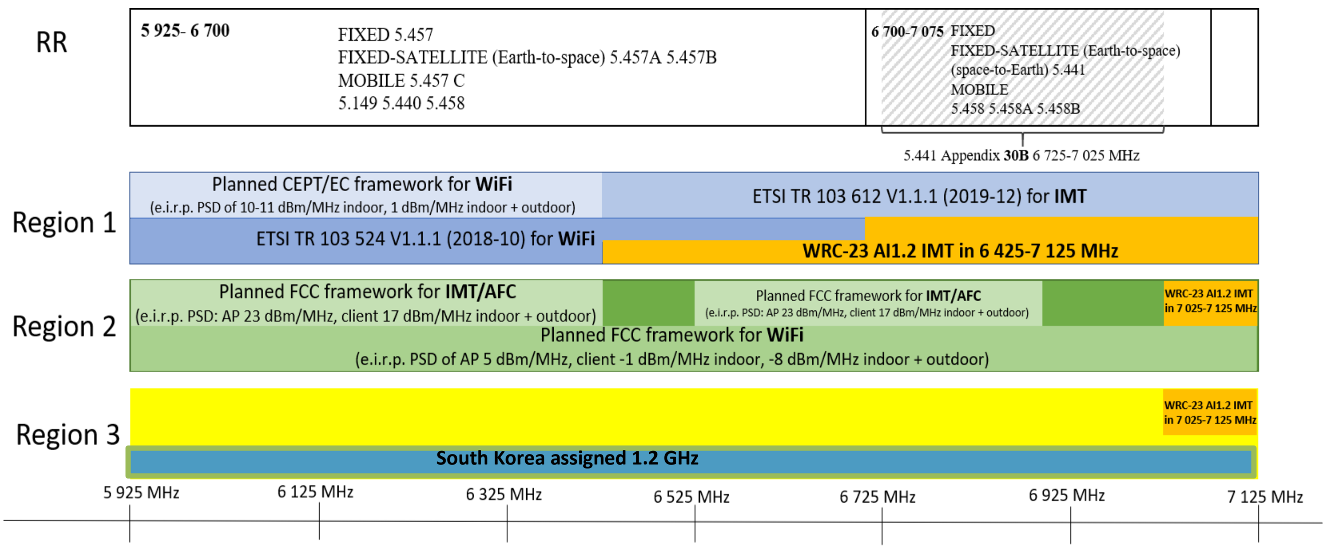
The existing studies conducted by the ITU-R for the frequency range 5 850-6 425 MHz are related to IMT-Advanced and show minimal potential for IMT operations whilst protecting FSS uplinks. The studies concluded that FSS space receivers would be subjected to excessive interference from the aggregate operation of IMT base stations, irrespective of whether they are deployed outdoors or indoors. It was stated that necessary conditions for deployment of IMT systems would include indoor and establishing strict limits (indoor use only, 10-15 dBm e.i.r.p. limit critical) on maximum allowable e.i.r.p. for IMT stations.

Studies conducted by CEPT between RLAN and FSS as outlined in the ECC report 302 for the adjacent frequency range 5 925-6 425 MHz. To ensure compatibility with FSS uplinks, CEPT established limits for RLANs, including limits for "low power" indoor applications (maximum 23 dBm) and "very low power" outdoor applications (maximum 14 dBm). Standard power and low power devices are not permitted for use outdoors. The studies were conducted for a representative set of satellites currently operating, some of which work above 6 425 MHz.

Also, regional regulatory and standardization initiatives on using C-band uplink for both Wi-Fi and IMT type usage are shown in Figure 2 below.

FIGURE 2

Regional regulatory and standardization



This document covers sharing and compatibility studies conducted as follows

a) For the band 6 425 – 7025 FSS earth to space operations – to examine the results of aggregate interference from IMT base stations into receiving FSS space stations.

b) For the band 6 725 to 7 025 MHz concerning the planned band’s Appendix **30B** to examine studies on interference from IMT to planned national allotments;

Studies should also be conducted to evaluate the feasibility of IMT operations in the context of interference from transmitting earth stations to IMT systems and from IMT systems to receiving earth stations (used for non-GSO MSS feeder links). Additional studies on these aspects may be submitted at a later time.

3 Modelling methodology and parameter assumptions

3.1 Description of the methodology

The methodology simulates a distribution of IMT stations throughout the visible earth surface, as seen from a given GSO satellite. The Earth’s surface is divided into a grid of 10x10 deg in latitude and longitude (referred to here as a grid “square”, even though they are not square). Two “reference stations” are placed in the centre of each square; one represents the rural and suburban IMT stations, and another means the urban IMT macro base stations. In the current simulation, small cell and microcell base stations, indoor and outdoor, are not modelled. Also, interference from IMT user equipment is not modelled.

The EIRP of the reference station is determined by first simulating a single IMT sector, communicating with three UEs randomly located within the industry. For a given elevation angle to the satellite, the statistics of the interference in the direction of the satellite is determined through a monte Carlo simulation. The CDF of the interference from a single sector is applied to 500 identical stations. Random sampling from the CDF of each station is used to determine the interference from each one, which is then summed to obtain the aggregate interference from 500 base stations.

The number of base stations in each square is proportional to the land area within that square. The land area of each square is determined, and the number of rural, suburban, and urban macro base stations is determined from the agreed density figures (see below). The interfering power from each reference station is set according to the number of stations in the square, relative to 500. For example, for 1 000 base stations, the interfering power is increased by 3 dB.

When all reference stations have been assigned the appropriate CDF of interference, a monte carlo simulation is performed. For each sample, the power radiated by the reference station is obtained and used to calculate the interference from the reference station at the satellite receiver. This considers the propagation path loss and the satellite antenna gain pattern. The aggregate interference at each sample is determined by summing the contributions from all reference stations. Repeating the analysis for multiple pieces allows for a distribution (cdf) of interference at the satellite to be obtained.

FIGURE 3

Simulation area and reference stations

3.2 IMT base station characteristics

Base station characteristics are taken from Table 7-1 of Annex 4.4 to Document 5D/716. The following notes and clarifications apply:

- In TDD, 75% of the time transmission is from BS; this is modelled by reducing transmit power by 1.25 dB corresponding to 10*log(0.75)
- 20% network load is assumed, which is (-7 dB) is taken into account in the transmit power
- 3 dB polarisation loss is considered in the transmit power configuration.
- The antenna pattern follows the Recommendation ITU-R M.2101 model, and currently, the sub-array model has not been implemented.

3.3 Number of IMT Stations

An essential assumption for modelling interference to satellite receivers is the number of IMT stations. WP 5D did not agree on any single set of assumptions for the deployment of IMT BS in Rural, Suburban, and Urban areas.

For Rural deployment, the range of deployment is given as 0.001 to 0.006 sectors per sq km, where Rural is included in the modelling.

The values for Suburban and Urban areas are as outlined in Table 11 from annex 4.4 to Document 5D/716, shown below. The parameters to determine areas of Suburban/Urban coverage are:

- Rb: Fraction of the area that is "built."
- Ra: Fraction of the "built" area that has IMT coverage

TABLE 11

Values for Ra and Rb to be used in studies involving IMT deployments for frequency bands between 6 and 8 GHz

	Options *	Macro	Micro
Ra	1	30% Urban (area < 200 000 km^2) 10% Urban (area > 200 000 km^2) 10% Suburban (area < 200 000 km^2) 5% Suburban (area > 200 000 km^2)	10% Urban (area < 200 000 km^2) 5% Urban (area > 200 000 km^2)
	2	45% Urban, 20% Suburban	10% Urban
Rb (depending on the area under study)	1	5% (area < 200 000 km^2) 2% (200 000 - 1 000 000 km^2) 1% (area > 1 000 000 km^2)	5% (area < 200 000 km^2) 2% (200 000 - 1 000 000 km^2) 1% (area > 1 000 000 km^2)
	2	5% (area < 3 500 000 km^2) 3% (area > 3 500 000 km^2)	5% (area < 3 500 000 km^2) 3% (area > 3 500 000 km^2)
	3	2.5% (area < 200 000 km^2) ** 2% (200 000 - 1 000 000 km^2) 1% (area > 1 000 000 km^2)	2.5% (area < 200 000 km^2) ** 2% (200 000 - 1 000 000 km^2) 1% (area > 1 000 000 km^2)

* The Ra and Rb values used in the sharing and compatibility studies should be provided together with the results of studies, for the purpose of comparison, as well as information on which specific geographical location the analysis is applicable to.

** The value is applicable for Region 1, for bands considered globally the value of 5% should be used.

For Suburban Microcells: Density of sectors is 2.4 sectors per sq km, in Suburban coverage areas
For Urban Microcells: the density of sectors is ten sectors per sq km in Urban coverage areas.

For these studies, values of IMT BS density in the ranges as agreed by WP 5D are used to assess the impact to the satellite receiving station; hence for Urban/Suburban, Ra and Rb using the lowest values (option 1-Ra1/Rb1) and the highest values (option 2-Ra2/Rb2) for the large areas in the ranges provided by WP 5D. The simulations consider IMT deployment over a large area (e.g., the entire visible Earth surface). Hence, only the large area values for Ra and Rb are considered (e.g. figures for Ra for area < 200 000 km^2 are not considered).

Considering the large area modelled for the rural base station density, the middle range value for Rural average density of 0.003 sectors per sq km is used.

The simulation area considers IMT coverage over Europe, the Middle East, Africa, and much of Asia. The total land area is 91,632,815 sq km, and the total number of BSs arrives at 433,729, as shown in Table 1 below. Note that the percentage of the land area for IMT coverage ranges from 0.22% for the lower values for Ra/Rb to 2.02% for the higher values for Ra/Rb.

TABLE 1

Number of base stations in the simulation area

	The total land area covered (sq km):				91,632,815
		Ra1/Rb1		**Ra2/Rb2**	
	Rural Macro	**Suburban Macro**	**Urban Macro**	**Suburban Macro**	**Urban Macro**
Number of IMT sectors	274898	109959	916328	1319513	12370430
Number of IMT BSs	91633	36653	305443	439838	4123477

Area covered (sq km)	64279	45816	91633	549797	1237043

Ra1/Rb1	**Total IMT Macro BSs**	**433,729**
	% Area covered by IMT	**0.22%**
Ra2/Rb2	**Total IMT Macro BSs**	**4,654,947**
	% Area covered by IMT	**2.02%**

3.4 Clutter Modelling

The recommended clutter loss model assumed is given by Recommendation ITU-R P.2108 for these sharing and compatibility studies, even though the current version does not cover the 6 GHz band. For the time being, the P.2018 model has not been applied, but a simplified approach is implemented for all BSs. Clutter loss does not apply to those base stations above the height of surrounding rooftops, and hence for those stations, no clutter loss is applied. The BSs below the rooftop are assumed to have infinity clutter loss and are discounted. This is an optimistic assumption (likely to underestimate interference) and is one area that may be improved in the future.

3.5 Interference Criteria and Apportionment

The interference criteria to be applied to the receiving space station have been provided by WP 4A in document 5D/734 as outlined in the table below, along with some of the relevant notes.

Protection Criteria (see Notes 1, 2, 3, 4, 5, 6, 7 and 8)

Frequency Ranges	Percentage of time for which the *I/N* value could be exceeded (%)	*I/N* Criteria (dB)
3 600-3 800 MHz	20% 0.005%	-10.5 -1.3
6 425-7 075 MHz (E-s)	20% 0.001% 0.03%	-10.5 -2.33 -6
6 700-7 075 MHz (s-E)	20% 0.005%	-10.5 -1.3

Note 1: The noise *N* in the *I/N* criteria as specified above is the system receiver noise (i.e. thermal noise) and is equal to the receiver antenna noise plus the receiver noise referred to the antenna. Hence studies conducted by WP 5D should only use the values presented above when evaluating the compliance with the protection criteria.

Note 3: It is worth to mention that apportionment of the *I/N* protection criteria that apply to other co-primary services should be done on a case-by-case basis by WP 5D. Such apportionment decided needs to be clearly specified in the study performed. The protection criteria values given in this document correspond to the total *I/N* contributions present at the satellite or earth station receiver.

For these studies, to allow for possible simultaneous use of the 6 GHz band by the fixed service, the apportionment applied is 3 dB apportionment to the long-term criterion and 50% apportionment applied to the short-term criterion as shown in the table below.

TABLE 2

Interference criteria

	Interference criteria provided by WP 4A		**With apportionment**	
	Percentage of time that criteria may be exceeded	I/N (dB)	Percentage of time that standards may be exceeded	I/N (dB)
Long term	20%	-10.5	20%	-13.5
Short term (1)	0.03%	-2.33	0.015%	-2.33
Short term (2)	0.001%	-6	0.0005%	-6

These criteria are used to assess the impact of interference on FSS satellites.

3.6 Satellite characteristics

All satellites modelled are geostationary satellites. Based on the parameters provided by WP 4A, an example of a satellite global coverage and hemispherical coverage beam are used.

TABLE 3

Non-planned satellite characteristics

	Peak receive antenna gain (dBi)	**Antenna pattern**	**System receive noise temperature (K)**
Global beam	20	ITU-R S.672-4 Annex 1Ls = -25	400
Hemi beam	28	ITU-R S.672-3 Ln = -25	400
Spot Beam	38	Circular beam, ITU-R S.672, Ls = -25	400

Examples of satellite characteristics based on RR Appendix **30B** allotments have also been used, as shown in Table 4.

TABLE 4

Example planned satellite characteristics.

	India
Allotment	INDA00000
Nominal orbital position (deg)	74
Longitude of the boresight (deg)	82.7
Latitude of the boresight (deg)	18.90
Major axis (deg)	6.20
Minor axis (deg)	4.90
Orientation of the ellipse (deg)	120
G_{max}(dBi)	29.6
Receiver temp (K)	500

Note that in modelling interference to satellites following the RR App **30B** allotment characteristics, it is assumed that the country in question does not deploy IMT stations within their territory. Hence all interference is contributed from IMT stations assumed to be deployed in other countries.

4 Simulation Results

The Visualyse simulation tool was used for the studies conducted to run the Monte-Carlo simulation based on a set of assumptions and methodology as outlined above. Results are presented in cdfs of aggregate interference from IMT stations, with the three criteria included.

Some simplifying assumptions have been made which will tend to underestimate the interference, for example:

- Ignoring the contribution from small cells
- Ignoring the contribution from IMT user equipment
- Ignoring the contribution from IMT base stations below the rooftop
- Modelling only the M.2101 antenna model (the use of the sub-array model is expected to lead to higher interference)

If necessary, improvements to the modelling, including these factors, may be made in the future.

The results show that interference exceeds the criteria in all cases.

4.1 GSO Satellite with global coverage

FIGURE 4

Global beam coverage

The plot below shows the -3 dB contour of a global beam and the IMT BS deployment within the visible areas of the satellite coverage.

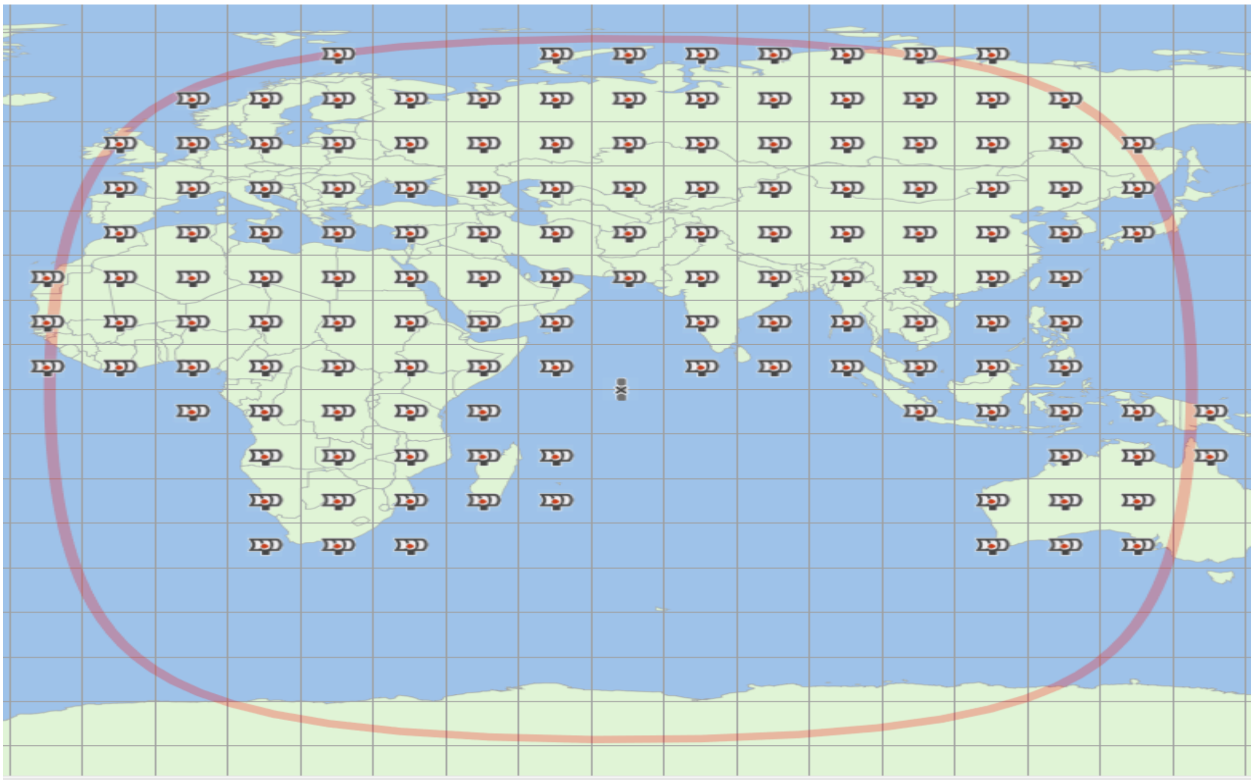
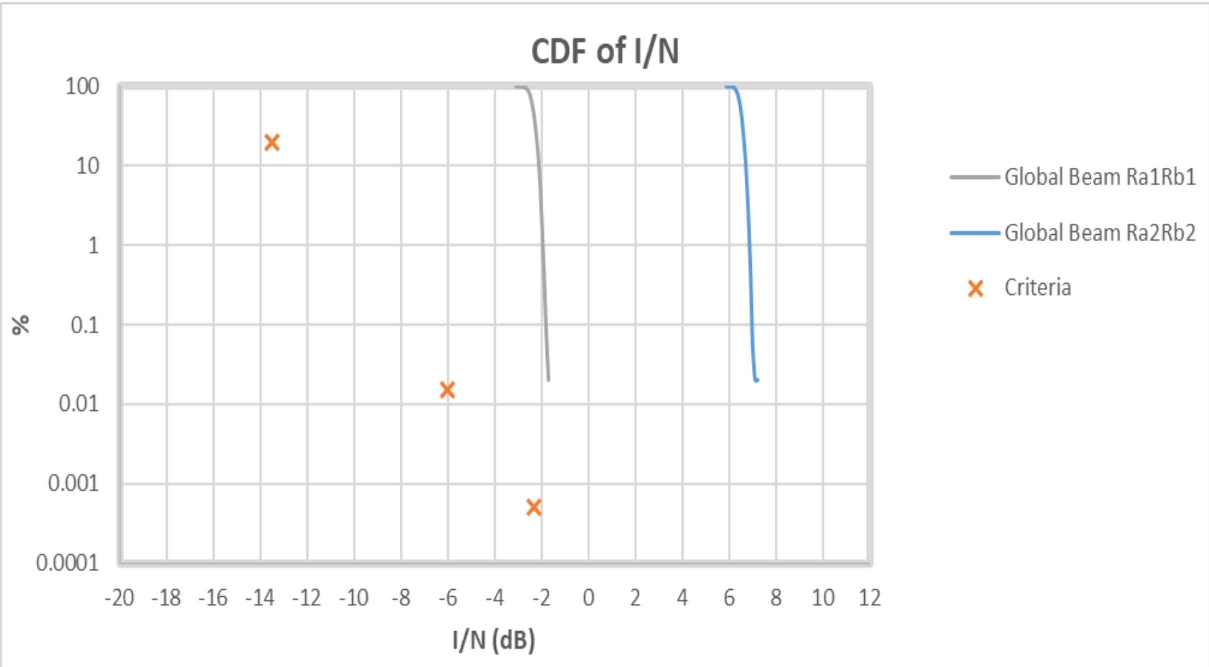


FIGURE 5

Global beam simulations results



4.2 GSO satellite with Regional (Hemispherical) beam

The plot below shows a regional beam coverage and the IMT BS deployment within the visible areas of the satellite coverage.

FIGURE 6

Regional (Hemispherical) beam coverage

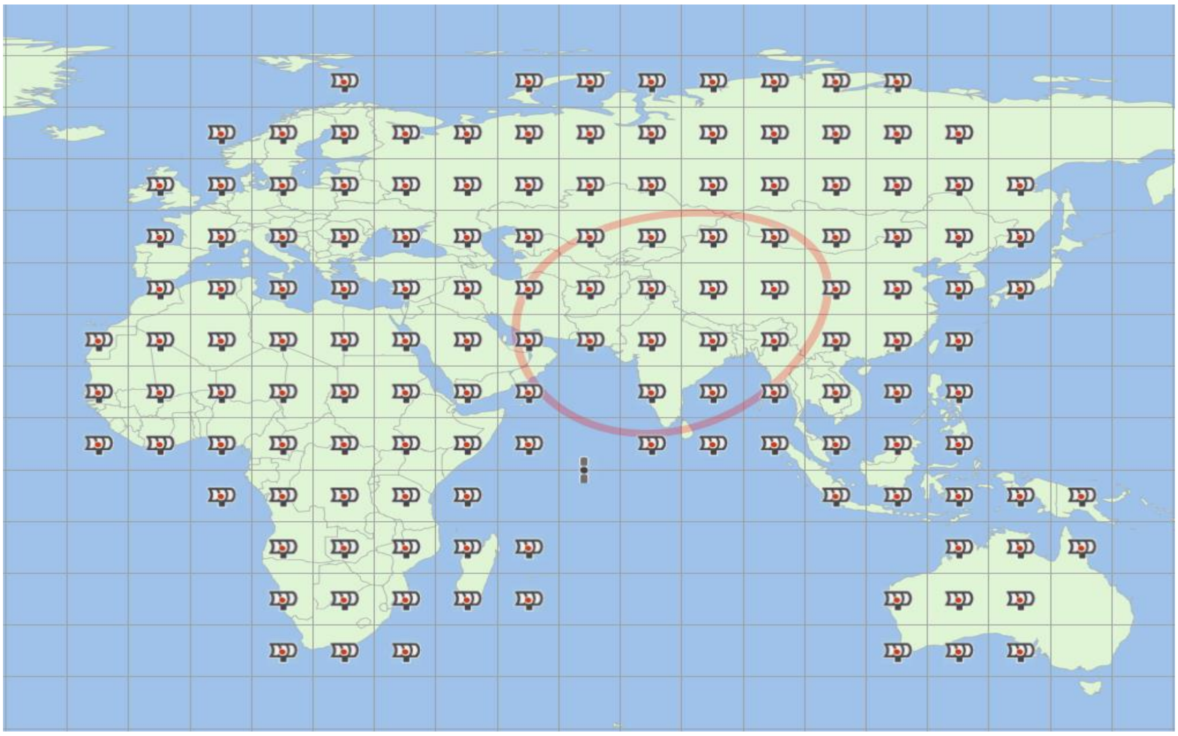
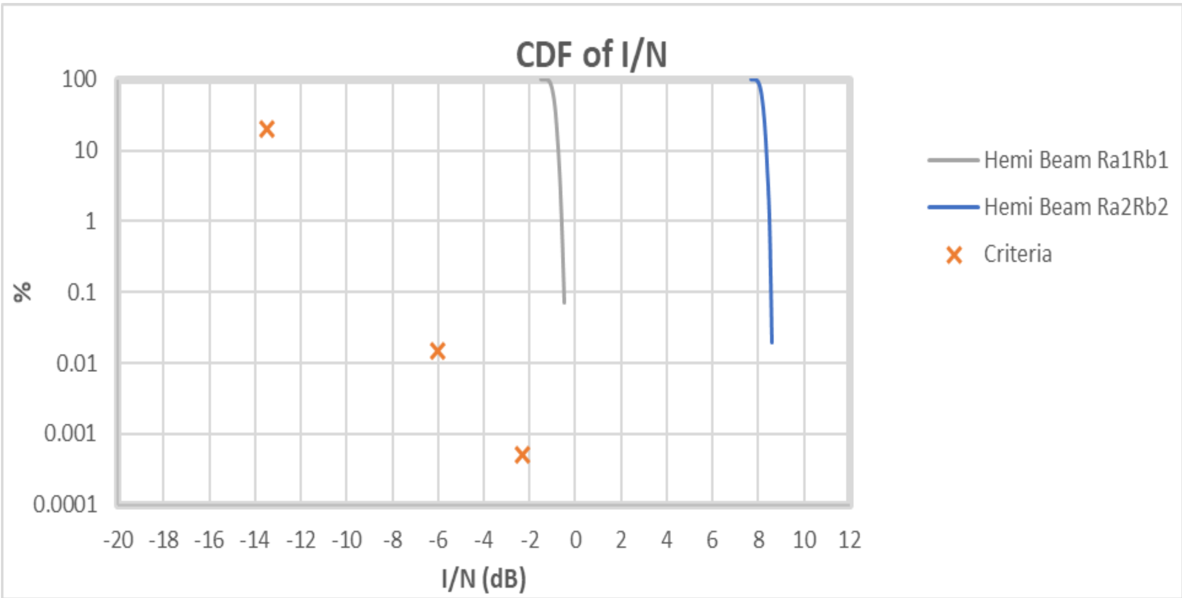


FIGURE 7

Hemispherical beam simulations results



4.3 GSO satellite with Spot beam

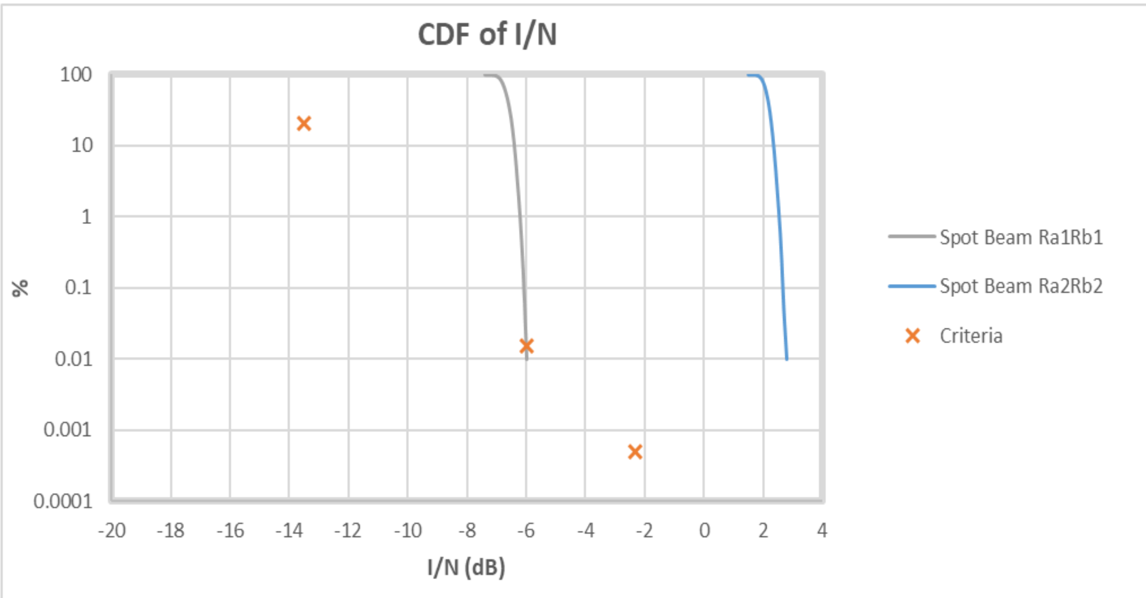
The plot below shows a spot beam coverage and the IMT BS deployment within the visible areas of the satellite coverage.

FIGURE 8

Spot beam coverage

FIGURE 9

Spot beam simulations results



4.4 App 30B allotments – India

FIGURE 10

India allotment coverage

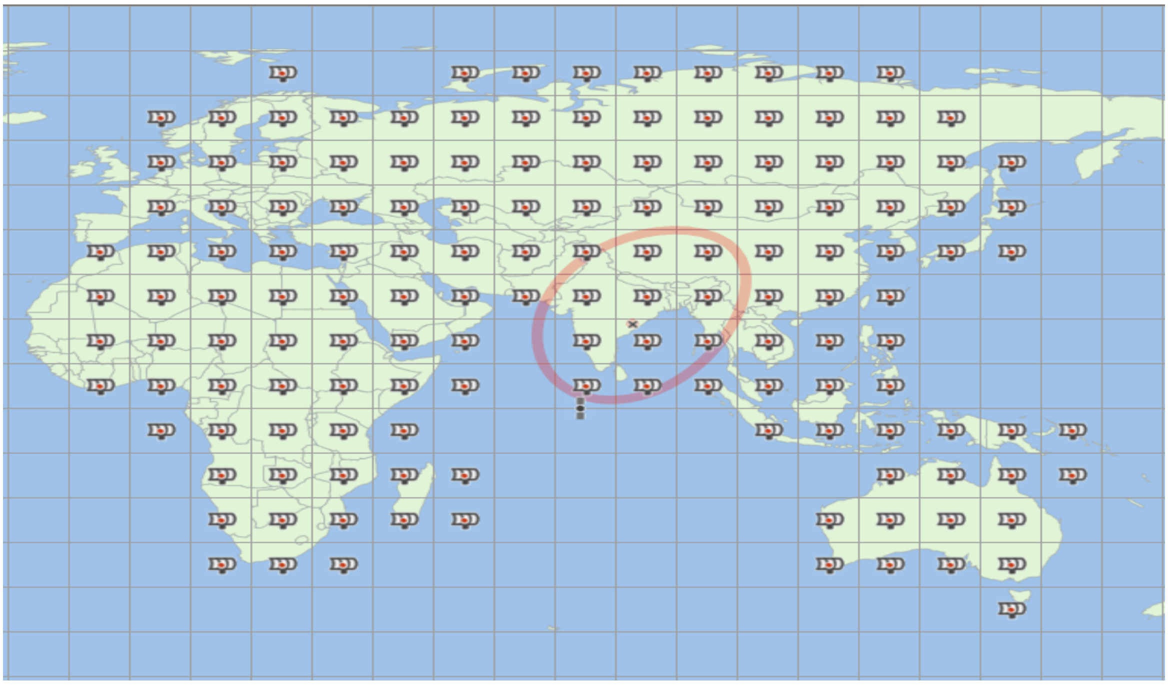
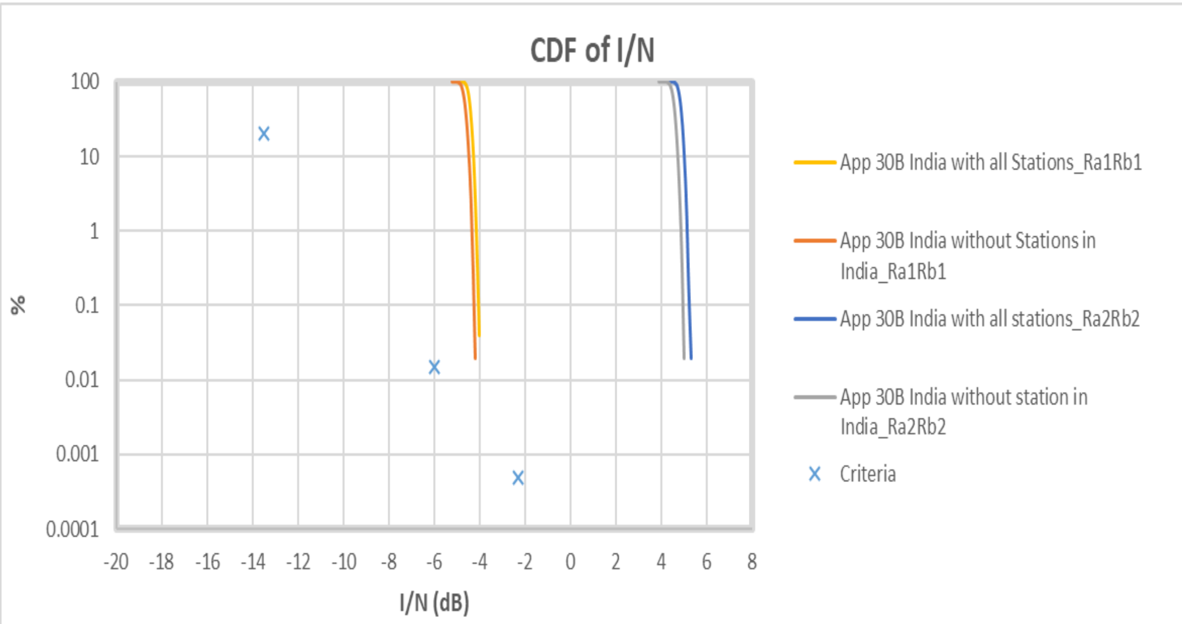


FIGURE 11

India allotment simulations results



4.5 Summary of results

The I/N results show that aggregate interference from IMT base stations exceeds both the long-term and short-term criteria of FSS receivers for all cases, i.e. for both the highest and lowest IMT deployment densities and for all three satellite beams considered, as well as for RR Appendix **30B** allotment for India. The curves of the CDF plots are near vertical, indicating an almost constant level of aggregate interference. Table 5 summarises the I/N results.

TABLE 5

Approximate I/N results for the scenarios simulated.

	I/N results in dB			
Deployment scenario	Global beam	Hemispherical beam	Spot beam	App **30B** allotment
Ra2 Rb2	6.5	9	3	5
Ra1 Rb1	-2.5	-1	-6	-4

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