International Telecommunication Union

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Radiocommunication Sector of ITU

Report ITU-R SA.2429-0

(09/2018)

Studies related to proposed change in 460-470 MHz secondary allocation for METSAT (space-to-Earth) to primary and addition of primary allocation to EESS (space-to-Earth)

SA Series

Space applications and meteorology

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R SA.2429-0

Studies related to proposed change in 460-470 MHz secondary allocation for METSAT (space-to-Earth) to primary and addition of primary allocation to EESS (space-to-Earth)

(2018)

1 Introduction

Resolution **766 (WRC-15)** "*resolves to invite the 2019 World Radiocommunication Conference* to consider, based on the results of ITU Radiocommunication Sector (ITU-R) studies, the possibility of upgrading the secondary meteorological-satellite service (MetSat) (space-to-Earth) allocation to primary status and adding a primary Earth exploration-satellite service (EESS) (space-to-Earth) allocation in the frequency band 460-470 MHz, while providing protection and not imposing any additional constraints on existing primary services to which the frequency band is already allocated and to services in the adjacent frequency bands". Resolution **766 (WRC-15)** also states that future MetSat (space-to-Earth) and EESS (space-to-Earth) earth stations will not claim protection from stations in the fixed and mobile services.

This Report therefore considers only interference to incumbent systems operating under allocations to primary services. In addition, the power flux density (pfd) criteria determined by the studies will be no less restrictive than –152 dB (W/ $(m^2 \cdot 4$ kHz)) for all angles of arrival. This Report provides results of studies evaluating the potential for radio frequency (RF) interference (RFI) from spacecraft operating in the MetSat (space-to-Earth) service and EESS (space-to-Earth) using the 460-470 MHz frequency band to incumbent systems in primary allocated services. Adjacent bands are similarly evaluated and include the 450-460 MHz band in all regions and the 470-694 MHz frequency band in Region 1; 470-512 MHz in Region 2, and 470-585 MHz in Region 3.

This Report determines relevant pfd masks from the EESS and MetSat spacecraft required to protect incumbent systems based on static and/or dynamic analyses.

1.1 Relevant ITU-R references

ITU-R Radio Regulations (2016)

Recommendation ITU-R BT.419-3 – Directivity and polarization discrimination of antennas in the reception of television broadcasting

Recommendation ITU-R F.699-7 – Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz

Recommendation ITU-R F.758-6 – System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference

Recommendation ITU-R F.1107-2 – Probabilistic analysis for assessing interference into the fixed service from satellites using the geostationary orbit

Recommendation ITU-R F.1108-4 – Determination of the criteria to protect fixed service receivers from the emissions of space stations operating in non-geostationary orbits in shared frequency bands

Recommendation ITU-R M.1174-3 – Technical characteristics of equipment used for on-board vessel communications in the bands between 450 and 470 MHz

Recommendation ITU-R F.1245-2 – Mathematical model of average and related radiation patterns for line-of-sight point-to-point fixed wireless system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz

Recommendation ITU-R F.1336-4 – Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile services for use in sharing studies in the frequency range from 400 MHz to about 70 GHz

Recommendation ITU-R M.1808-0 – Technical and operational characteristics of conventional and trunked land mobile systems operating in the mobile service allocations below 869 MHz to be used in sharing studies

Recommendation ITU-R M.2009-1 – Radio interface standards for use by public protection and disaster relief operations in some parts of the UHF band in accordance with Resolution **646 (Rev.WRC-12)**

Report ITU-R M.2014-3 – Digital land mobile systems for dispatch traffic

Report ITU-R M.2110-0 – Sharing studies between radiocommunication services and IMT systems operating in the 450-470 MHz band

1.2 Current regulatory situation for MetSat service (space-to-Earth) and EESS (space-to-Earth) in the frequency band 460-470 MHz

The frequency band 460-470 MHz is currently allocated to the fixed and mobile services on a primary basis and the meteorological-satellite (space-to-Earth) service on a secondary basis. RR No. **5.289**, states that EESS (space-to-Earth) applications, other than the meteorological-satellite service, may also be used in the frequency band 460-470 MHz for space-to-Earth transmissions subject to not causing harmful interference to stations operating in accordance with the Table. However, it is to be noted that in accordance to RR No. **5.290**, MetSat (space-to-Earth) service has primary allocations in some countries subject to agreement obtained under RR No. **9.21**.

In the frequency band 460-470 MHz, the footnotes RR Nos. **5.286AA**, **5.287**, **5.288**, **5.289**, **5.290** are relevant to this Report.

The frequency band 460-470 MHz is used for systems of the fixed service including point-to-point, point-to-multipoint systems, and mesh networks such as RF central station alarm (CSA) systems and of the mobile service including maritime mobile, IMT and precursors, land mobile, MetSat (space-to-Earth) service for data collection systems (DCS) and EESS (space-to-Earth) downlinks.

In this Report, the existing and planned terrestrial systems having primary allocations are referred to as “incumbent systems” and are potential victims of RFI from MetSat (space-to-Earth) and EESS (space-to-Earth) downlinks.

2 MetSat and EESS Systems characteristics

2.1 Background Information on MetSat (space-to-Earth) and EESS (space-to-Earth)

Data collection systems operates from geosynchronous orbiting (GSO) and non-GSO spacecraft in the MetSat and EESS services in the frequency bands 401-403 MHz (uplink), 460-470 MHz (downlink), and 1 675-1 710 MHz (downlink). For example, the 460-470 MHz frequency band is currently used by the DCS to interrogate and command terrestrial platforms from GSO and non-GSO spacecraft. DCS are dedicated to study oceanic and atmospheric conditions, preserve and monitor wildlife, volcanoes, fishing fleets, shipments of dangerous goods, humanitarian applications, weather forecasting, earthquake/tsunami prediction, flood level monitoring, maritime security, and manage water resources. DCS is essential for monitoring and predicting climate change, and, for example, improving maritime security.

DCS platforms (DCP) gather scientific information on activity related to the Earth, the environment, weather, and environmental observation. The data, which are collected by ground platforms, are transmitted to GSO or non-GSO satellites that retransmit the retrieved information to dedicated earth stations. DCS are particularly useful for the collection of data from remote and inhospitable locations where it may provide the only possibility for data relay. Even so, the system has very many uses in areas with a highly developed infrastructure. The installations required for relay of the data tend to be inexpensive, unobtrusive and normally blend easily into the local environment.

DCS help the scientific community to better monitor and understand our environment, but also helps industry to comply with environmental protection regulations implemented by various governments. This positioning capability also permits applications such as monitoring drifting ocean buoys and studying wildlife migration paths.

2.2 Technical characteristics for MetSat (space-to-Earth) and EESS (space-to-Earth) Systems

This section includes technical characteristics for MetSat (space-to-Earth) and EESS (space-to-Earth) systems currently operating or planned in the 460-470 MHz band.

MetSat (space-to-Earth) DCS in this band are used for transmitting commands and interrogations to the DCPs. Using this service is optional for the platform owners. However, transmissions are continuous even without specific messages. It is noted that the MetSat (space-to-Earth) and EESS (space-to-Earth) systems have varying frequencies within the band with some overlaps, and the amount of aggregation depends on frequency and never has more than three satellites transmitting on the same frequency. Further, within any given non-GSO system, no more than one satellite will be transmitting at a time in any area.

2.2.1 GSO DCS Downlink Characteristics

Satellite downlink transmitters and antennas are described in Table 1.

TABLE 1

System parameters for GSO MetSat (space-to-Earth) downlinks in the band 460-470 MHz

Parameters/System	Satellite A	Satellite B	Units or values
Function	DCPI (1)	DCPC	
Orbital height (above earth)	35786	35786	km
Orbit inclination	<0.3	<0.3	degrees
Carrier frequency	468.8125 468.8250 468.8375	468.775 468.825	MHz
Information data rate	5 500	350	bit/s
Necessary bandwidth	0.011	0.0445	MHz
Modulation	BPSK	PSK	
Coding	None	DCPC	
Encoded data rate	NA	22.225	kHz
Minimum elevation angle (2)	5	5	degrees
Satellite antenna input power	5.2	3.1	dBW
Satellite Antenna Type	Planar cup dipole	Planar cup dipole	

TABLE 1 (*end*)

Parameters/System	Satellite A	Satellite B	Units or values
Satellite antenna gain at nadir	10.6	14.5	dBi
Satellite maximum antenna gain	10.6	14.5	dBi
Satellite antenna polarization	RHCP	RHCP	
Satellite antenna radiation diagram	Earth coverage	Earth coverage	
Emissions spectrum bounds	Not available	dB BW –3 23 kHz –20 44.5 kHz –20 150 kHz –60 410 kHz	

(1) DCPI is an acronym for data collection platform interrogate and DCPC for data collection platform command.

(2) Terrestrial platforms are designed for such elevation angles.

2.2.2 Non-GSO MetSat (space-to-Earth) Service DCS downlink characteristics

Tables 2 and 3 present the characteristics for the operating non-GSO DCS satellites. These systems are employed on spacecraft operated by several administrations. In order to have reduced pfd levels on the ground, future satellites may implement spread spectrum multiple access (SSMA) transmission techniques.

Figure 1 presents the maximum and minimum antenna gain patterns for the non-GSO DCS.

TABLE 2

Non-GSO DCS Technical Characteristics

Parameter	Value	Units or values
Spacecraft	Satellite C	
Altitude	831	km
Inclination	98.3	º
Modulation	SSMA/OQPSK	
Coding	NRZ-M	
Frequency	465.9875 (±5 kHz)	MHz ±5 kHz)
Transmitter power	10	W (or 10 dBW)
Data bit rate	977.52	bit/s
Chip rate	1	Mbit/s
Chip duration	10^{-6}	seconds
Bandwidth	2	MHz
Antenna gain	Maximum: –9.2 to 1.3 Minimum: –14 to –6.8 (90 to 5 degrees elevation angle: the angles are from the edge of the earth to the nadir angle)	dBi

TABLE 2 (*end*)

Parameter	Value	Units or values
DCS OOBE [(1)] limits	**Frequency (MHz)**	**Max DCS transmit power (dBm)**
	405.9-406.2	< –115 [(2)]
	406.2-411	< –96 [(2)]
	411-425	< –72 [(2)]
	425-461.9875	< –42 [(2)]
	469.9875-1 175.0	< –29 [(2)]

(1) OOBE = Out of band emissions.

(2) The maximum signal level includes all discrete signals and broadband noise in any 1000 Hz bandwidth within the specified band.

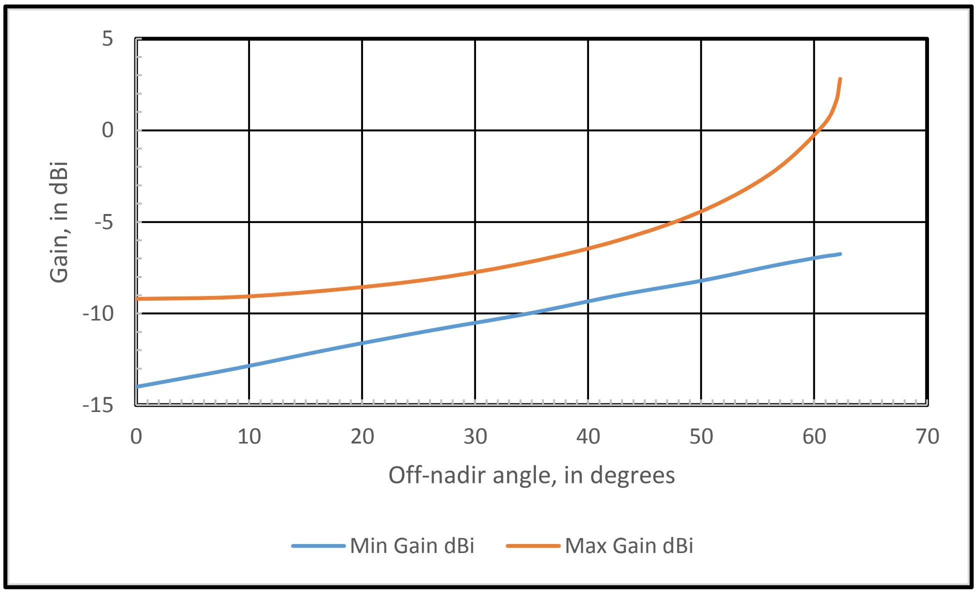
TABLE 3

Non-GSO Satellite D technical characteristics

Parameter	Value	Units
Spacecraft	Satellite D	
Modulation	8PSK/QPSK/BPSK	
Frequency	468.1	MHz (±5 kHz)
Transmitter power	5	dBW
Symbol rate	0.03375	Mbit/s
Bandwidth	50	kHz
Symbol duration	0.03×10^{-3}	seconds
Antenna gain (see Fig. 2)	Max. 5 dBi at 46 degrees; 2.3 dBi at boresight	dBi
DCS OOBE Limits	< –50	dBc

FIGURE 1

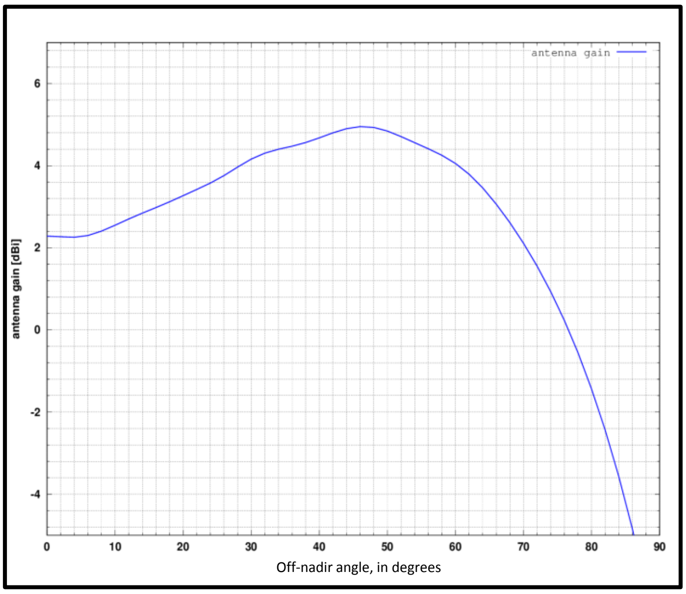
Antenna gain patterns for non-GSO DCS



The Satellite D antenna pattern is presented in Fig. 2.

FIGURE 2

Satellite D antenna gain pattern



2.2.3 Non-GSO EESS (space-to-Earth) systems

Table 4 presents the incumbent non-GSO EESS (space-to-Earth) Satellite E system characteristics.

TABLE 4

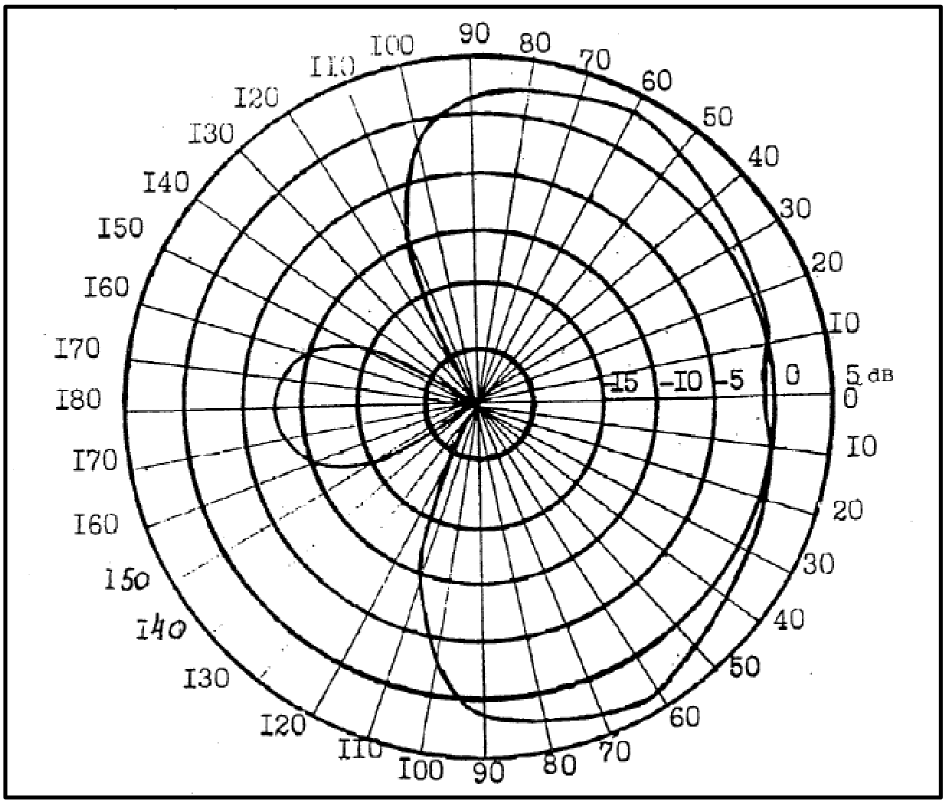
Non-GSO Satellite E Technical Characteristics

Parameter	Value	Units
Spacecraft	Satellite E	
Orbit altitude	1 000	km
Orbit inclination	99.4	degree
Carrier frequency	465	MHz
Emission class	4M00G1D	
Antenna power	10	dBW
Power spectral density	–55	dB(W/Hz)
Max. antenna gain	3.3	dBi
Antenna pattern	See Fig. 3	

The Satellite E system antenna pattern in the considered frequency band is presented in Fig. 3.

FIGURE 3

Satellite E antenna pattern



Another existing non-GSO EESS (space-to-Earth) satellite system is Satellite F. Launched in 2013, it was followed by the revised second Satellite G launched in 2017. The mission of Satellite FG satellites is monitoring sea ice, typhoons, hurricanes and volcanic eruptions for safe navigation of vessels and airplanes all over the world. The narrowband downlink signal in the frequency band 460-470 MHz is used in the service area over Japan to transmit obtained data on Earth magnetic field that affects aircraft rerouting in case of solar storms, and meta-information of Earth images to optimize their transmission and processing. With this downlink Satellite FG spacecraft also send telemetry data to report their own health status and attitude.

Table 5 presents Satellite FG satellite system characteristics.

TABLE 5

Non-GSO EESS (space-to-Earth) Satellite FG Technical Characteristics

Parameter	Value	Units
Spacecraft	Satellite FG	
Orbit altitude	593	km
Orbit inclination	97.6	degree
Centre frequency	467.674	MHz
Modulation	GFSK	
Transmitting power	3	dBW
Symbol rate	9.6	kbit/s
Bandwidth	20	kHz
Power spectral density	−34.8	dB(W/Hz)
Max. antenna gain	2.1	dBi
Antenna pattern	See Fig. 4	

Satellite FG system antenna pattern in the considered frequency band is presented in Fig. 4.

FIGURE 4

Satellite FG system antenna pattern

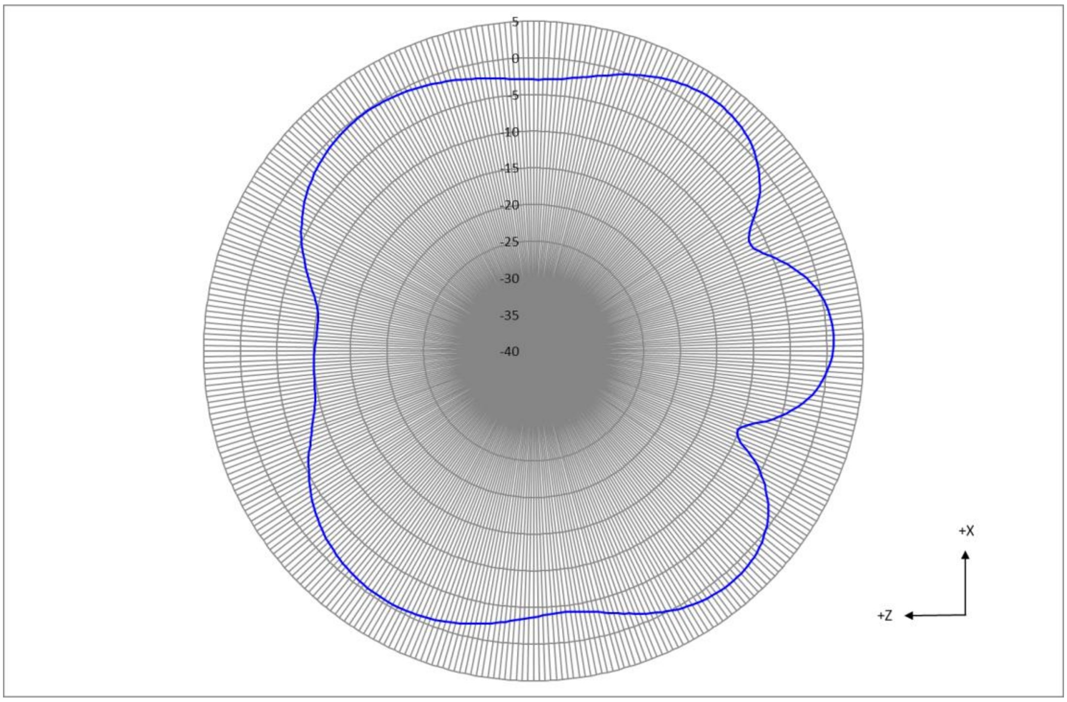


Table 6 presents the parameters for two typical satellites of one administration in the EESS (space-to-Earth), Satellite H and Satellite I which are not sun-synchronous.

TABLE 6

Non-GSO EESS (space-to-Earth) Technical Characteristics

Parameter	Value	
Spacecraft	Satellite H	Satellite I
Orbit altitude (km)	400	500
Orbit inclination (degree)	51.6	85
Carrier frequency (MHz)	468	468
Emission class (Designator)	3M00G1D	3M00G1D
Antenna power (dBW)	0.79181 (1.2 Watt)	1.76091 (1.5 Watt)
Power spectral density (dBW/Hz)	–64	–61.8
Maximum antenna gain (dBi)	–1	1.5
Antenna pattern	Dipole	Monopole

3 Incumbent system characteristics

The following subsections present the technical RF characteristics for current and planned systems with primary allocations in the frequency band 460-470 MHz. These characteristics have been used for these studies.

3.1 Fixed service systems

System characteristics for the fixed service systems operating in-band (460-470 MHz) and in the lower adjacent band (450-460 MHz) were extracted from ITU-R Reports and Recommendations and are presented in this section.

The fixed service in the 450-470 MHz frequency band is used for point-to-point (P-P) and point-to-multipoint (P-MP) systems. In addition, RF Central Station Alarm (CSA) mesh network systems are deployed by at least one administration.

3.1.1 Characteristics of point-to-point (P-P) and point-to-multipoint (P-MP) fixed systems

P-P digital fixed service (FS) systems are deployed in the 450-470 MHz band. These systems use 4-FSK and QPSK modulation.

Recommendation ITU-R F.758 provided the necessary technical characteristics of the P-P and P-MP FS systems. Table 7 provides the relevant RF parameters of digital fixed systems.

TABLE 7

Fixed service parameters in the frequency band 457-464 MHz

Parameter	Recommended value	Used value
Channel spacing (kHz)	12.5	
Reference bandwidth for pdf ((4kHz)	4	
Feeder/multiplexer loss range (dB)	0 to 4	2
Gain (dBi)	P-P	11
		17
	P-MP	8
		11
I/*N* (dB)	−6	
FDP limit (%) [(1)]	25	
Nominal long term criteria (dB(W/12.5kHz))	–159 + *I*/*N*	
Polar loss (dB)	1.5	

(1) Per Rec. ITU-R F.1108-4.

3.1.1.1 Fixed service antenna pattern

Recommendations ITU-R F.699 and ITU-R F.1245 are used to model fixed service antennas in point-to-point (P-P) configuration (directional in azimuth), whereas Recommendation ITU-R F.1336 is preferred in the case of point-to-multipoint (P-MP) links, considering the multipoint antenna (omnidirectional in azimuth). In the directional link, Recommendation ITU-R F.699 is useful to model antenna patterns of fixed service systems in scenarios with just a single interferer (peak sidelobe envelope) between 0.1 to 100 GHz frequency ranges. On the other hand, Recommendation ITU-R F.1245 (average sidelobe envelope) is more appropriate for simulation with aggregate interference sources in the frequency range from 1 to 100 GHz.

In this assessment, the FS is studied with several sources of potential interference from space at a frequency below 1 GHz. In this condition, the assumption has been taken to use Recommendation ITU-R F.1245 at 460 MHz although this pattern is not clearly defined for this frequency range. Figure 5 provides a comparison of Recommendations ITU-R F.699, ITU-R F.1245 and a measured Yagi antenna pattern. This Figure shows clearly that the use of Recommendation ITU-R F.1245 seems to be relevant even if the frequency used is lower than the frequency limit of the model (dash brown line versus full yellow line). Table 8 provides the different configurations of antenna used in the dynamic simulation.

FIGURE 5

Antenna pattern for each case of simulation

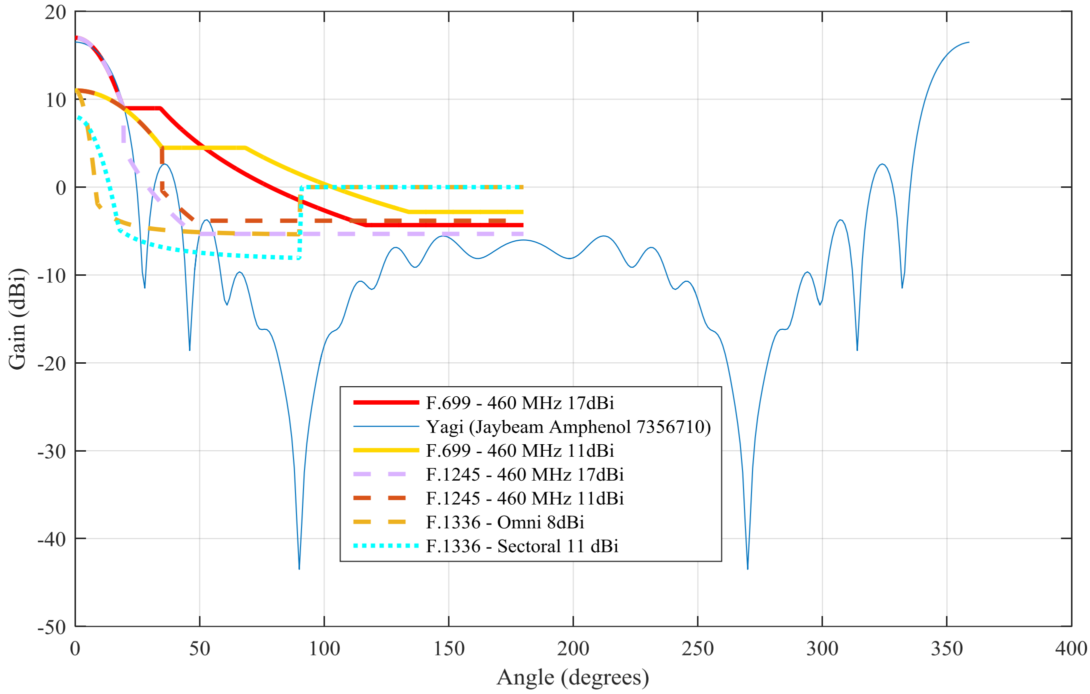


TABLE 8

Antenna pattern configuration used in dynamics simulations with P-P and P-MP links

Link	Recommendation	Gain (dBi)
P-P	ITU-R F.1245	11
		17
P-MP	ITU-R F.1336 (Omni)	8
	ITU-R F.1336 (Sectoral)	11

3.1.2 Fixed Service RF Central Station Alarm (CSA) mesh network systems

RF CSA systems are deployed by several administrations. These systems use mesh a mesh network topology to relay burglar and fire alarms and housekeeping messages to IP link stations (also called concentrator nodes) or to the central station. They operate in the frequency band 460-470 MHz at frequencies specified in the Table below. Each subscriber unit operates on one channel only. Due to the nature of the networks, received signal strengths may be less than ideal, hence the measured interference criteria are based on the minimum discernible signal. RF CSA system characteristics obtained from industry representatives and measurements are presented in Table 9. CSA systems on certain frequencies may operate mobile units similarly to the P-MP systems above.

TABLE 9

Technical characteristics for RF CSA systems

Parameter	Value
Frequency range (MHz)	450-470
Centre frequencies employed in the 460-470 MHz band (MHz) (increment by 0.00625 MHz)	460.90625-461.0185 and 465.90625-466.01875
Channel spacing and receiver noise bandwidth (MHz)	0.0125
Maximum antenna gain range (dBi)	2 (typical subscriber), 10 (central station and IP link)
Interference criteria (measured at transceiver terminals) (dB(W/12.5 kHz))	–159.2
Losses (dB) for IP link and central stations For subscriber units	3 1

3.2 Mobile service systems

This section presents the characteristics of the mobile service (MS) systems studied. The frequency bands between 450 and 470 MHz are used for conventional and trunked land mobile systems. These bands are also used by public safety agencies, utilities and transportation companies because the propagation characteristics at these frequencies allow large area coverage with little infrastructure. This study considered the values contained in Recommendation ITU-R M.1808-0 and in Report ITU-R M.2110-0 that are typical of the conventional and trunked land mobile systems. Conventional systems allow only one channel per user and channel management is done by the users. Trunked systems employ access control techniques to share channel capacity and include a control channel.

Mobile systems such as the PMR/PAMR, public protection and disaster relief (PPDR) and conventional and trunked land mobile systems, cellular mobile and maritime mobile systems are deployed widely in the 450-470 MHz bands. The two most widely deployed PMR/PAMR systems were considered in this sharing study. These include the terrestrial trunked radio access (TETRA) and the FM land mobile radio systems.

3.2.1 Technical and operational characteristics of conventional and trunked land mobile systems

Recommendation ITU-R M.1808 provides the protection criteria to be used for interference assessment for base stations and mobile stations in the mobile service. The Recommendation notes that generally a signal from another service resulting in an I/N ratio of below –6 dB is acceptable by the fixed and mobile systems for interfering signals with continuous-wave or noise-like type modulation. For later analysis purposes, only digital systems are considered, because the interference criteria are essentially the same. In this study, the term wideband (WB) is used to refer to the systems with 1 230 or 1 250 kHz bandwidth, and narrowband (NB) to refer to the remainder, with bandwidths less than or equal to 25 kHz. Table 10 presents the characteristics for the mobile service systems.

Report ITU-R M.2014 contains information on the digital land mobile systems for land mobile services including PPDR. Radio interface standards for PPDR are included in Recommendation ITU-R M.2009. The main PPDR technologies that can be used for this study are Analogue, Project 25, TETRA and LTE. Technical parameters of Analogue (FM), Project 25 (Digital C4FM) and TETRA (BPSK, QPSK, 8-PSK, 16-QAM) technologies are all included within Recommendation ITU-R M.1808, and in Table 10.

The BS and MS system are distributed randomly on the ground surface (no MS/BS on ocean/sea). For each location of BS/MS, the azimuth follows a uniform distribution between 0 and 359 degrees by step of 1 degree (referenced from North). The elevation is taken as equal to 0 degree (pointing on the horizon).

TABLE 10

Technical characteristics of the mobile service systems

Parameters						
Origin of the parameters	Rec. ITU-R M.1808 Analogue	Rec. ITU-R M.1808 Digital	Rec. ITU-R M.1808 Rep. ITU-R M.2110 Digital	Rec. ITU-R M.1808 Analogue	Rec. ITU-R M.1808 Digital	Rec. ITU-R M.1808 Rep. ITU-R M.2110 Digital
Type of receiving stations	BS	BS	BS (CDMA450 as in Rep. ITU-R M.2110)	MS	MS	MS (CDMA450 as in Rep. ITU-R M.2110)
Frequency band (MHz)	450-470	450-470	450-460	450-470	450-470	460-470
Channel bandwidth (kHz)	12.5/25	6.25/12.5	1250	12.5/25	5.5	1250
Noise figure (dB)	7	7	5	7	7	8
Antenna gain (dBd)	9	9	9.85	Handheld: –6 Vehicular: 0	Handheld: –6 Vehicular: 0	0
Antenna polarization	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
***I*/*N* Protection criteria (dB)**	–6	–6	–6	–6	–6	–6
Total losses (dB)	3	4	3 (from Rep. ITU-R M.2110)	Handheld: 0 Vehicular: 1	Handheld: 0 Vehicular: 1	2 (from Rep. ITU-R M.2110)

Recommendation ITU-R M.1808 indicates that the antenna radiation pattern for base stations using narrow-band channels is omnidirectional. Such patterns were modelled as prescribed in Recommendation ITU-R F.1336.

Narrow band systems (systems having bandwidths such as 6.25, 12.5 or 25 kHz), both mobile stations (MS) and base stations (BS) can receive in the 460-470 MHz frequency band. For systems having larger bandwidths (1 250 kHz in Recommendation ITU-R M.1808 or 1 230 kHz in Report ITU-R M.2110 referenced as CDMA450) only the mobile stations receive in the frequency band 460-470 MHz and the base stations in the band 450-460 MHz.

3.2.2 Parameters applicable for IMT Advanced & IMT-2000 mobile systems

Table 11 indicates the characteristics of IMT 2000 and IMT Advanced systems for PPDR applications that were considered by in sharing studies under this agenda item within the frequency band 460-470 MHz. These characteristics were applied for all IMT systems.

TABLE 11

IMT terminal characteristics

IMT terminals characteristics	Values
Bandwidth (MHz)	3, 5
Antenna gain (dBi)	0
Noise power (dBm)	–96.7
Noise power (dB(W/4 kHz))	–155.5
I/*N*	–6
Permissible power (dB(W/4kHz))	–161.5

Report ITU-R M.2014 contains information on the digital land mobile systems for land mobile applications including PPDR. Radio interface standards for PPDR are included in Recommendation ITU-R M.2009. The main PPDR technologies that can be used for this study are Analogue, Project 25, TETRA and IMT. Technical parameters of Analogue (FM), Project 25 (Digital C4FM) and TETRA (BPSK, QPSK, 8-PSK, 16-QAM) technologies are all reflected within Recommendation ITU-R M.1808.

Table 11 can also be used for typical parameters for PPDR applications.

3.2.3 Maritime mobile systems

Maritime mobile system characteristics conform to those in Recommendation ITU-R M.1174-3.The maritime mobile service in the frequency band 460-470 MHz is limited to on-board communication in accordance with RR No. **5.287** and the characteristics used are described in Table 12.

TABLE 12

Maritime mobile service parameters

Type of receiving stations	MS	MS
Centre frequency range (MHz)	467.525-467.575	467.515625-467.584375
Channel bandwidth (kHz)	12.5/25	6.25
Noise figure (dB)	7	7
Antenna gain (dBd)	–6	–6
Antenna polarization	Vertical	Vertical
I/*N* Protection criteria (dB)	–6	–6
Total losses (dB) (1)	0	0

(1) The total losses include receiver loss and feeder loss, except polarization loss.

3.3 Broadcast systems

A number of broadcast system types are widely used worldwide (see Fig. 6) in the adjacent 470-862 MHz frequency band. Generically, these systems are referred to as digital television (DTV) in this study. The characteristics for DTV were extracted from Recommendations ITU-R BT.2036, ITU-R BT.1368 and ITU-R BT.2033.

FIGURE 6

Worldwide Distribution of broadcast TV system types

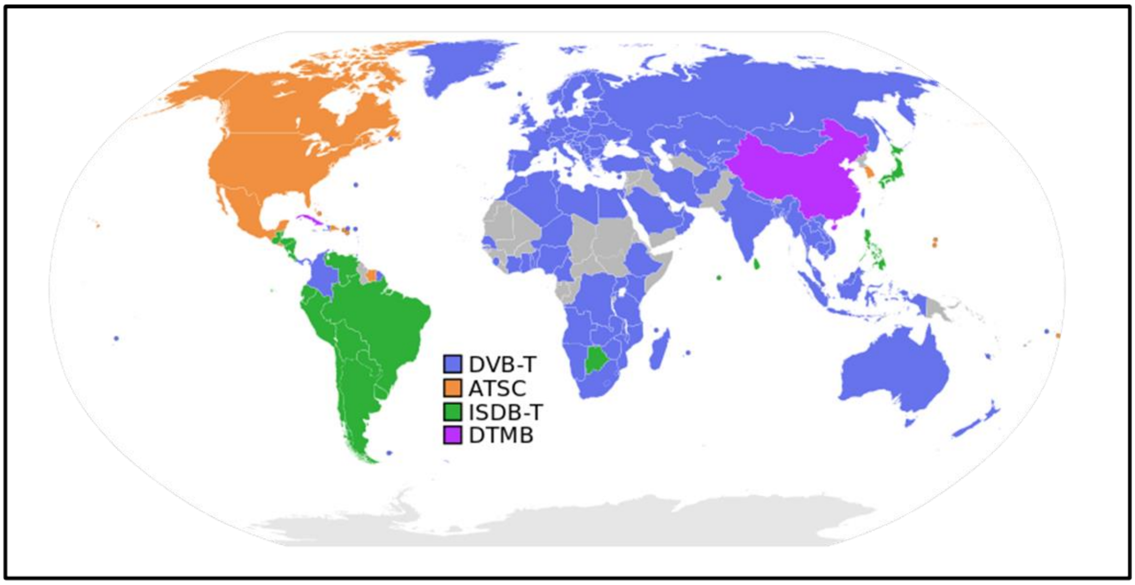


Table 13 gives the parameters used in this study for DTV and Table 14 provides protection ratios.

TABLE 13

DTV parameters

Signal Format	**ATSC**	**DVB-T**		**DVB-T2**		**ISDB-T**	**DTMB**
Bandwidth (MHz)	6	7	8	7	8	6	8
Receiver noise figure (dB)	7	7	7	6	6	7	7
Antenna gain; Fixed roof top reception (dBd)	10	10	10	10	10	10	10
Antenna gain, Portable reception (dBd)	0	0	0	0	0	0	0
Antenna pattern for fixed rooftop	Rec. ITU-R BT.419	Rec. ITU-R BT.419	Rec. ITU-R BT.419	Rec. ITU-R BT.419	Rec. ITU-R BT.419	Rec. ITU-R BT.419	Rec. ITU-R BT.419
Feeder loss; Fixed roof top reception (dB)	4	3	3	3	3	3	3

The studies in this Report considered system ISDB-T.

TABLE 14

Protection ratios for DTV from MetSat (space-to-Earth) or EESS systems (space-to-Earth)

Victim	**Source**	**Delta-F (MHz) or adjacent channel No.**	**DTV bandwidth (MHz)**	**Protection ratio *I*/*N* (dB)**
DTV	WB DCS	−5.125	6 and 8	−10
DTV	NB DCS	−3.5 (N-1 channel)	6, 7 and 8	−10

3.4 Radio Astronomy

The Radio Astronomy service is currently in operation within the 406.1 to 410 MHz frequency band. According to Recommendation ITU-R RA.769 (Table 1), the protection criteria is −255 dB (W/(m^2·Hz)) (equivalent to −219 dB (W/ (m^2·4 kHz))). Taking into account the desirable additional 15 dB reduction for GSO emissions leads to −234 dB (W/(m^2·4 kHz)).

4 Static and Dynamic Analysis Methods

4.1 Methodology to determine the pfd thresholds

The methodology used determines the pfd threshold in order to protect the receivers of fixed and mobile equipment deployed in the band 460-470 MHz. The pfd thresholds determined in this study are based on the protection required for the victim services and are equally applicable to GSO and non-GSO systems. This pfd threshold is a function of the angle of arrival at the incumbent system station and is calculated as follows in the direction θ of the interfering satellite.

$$\text{pfd}(\theta) = I_{th} - A_e(\theta) \text{ in dB (W/ (m}^2 \cdot 4 \text{ kHz))} \quad (1)$$

where:

- pfd (θ) : Power flux density threshold at the angle θ
- I_{th} : $N_{sys} + I/N_{Crit} + L + FDR$, or $I_r + L + FDR$
- θ : angle between main lobe of receiver antenna and direction of the interferer
- N : noise power density (dB(W/4 kHz)) of the receiver:

$$N = 10\log(k\, T_0\, B_{ref}) + F$$

- N_{sys} : System noise (dBW)
- N_{sys} : $10 \log_{10} (t_{ant}/l_{feed} + t_0(1-1/l_{feed})+t_e)$
- B_{ref} : reference bandwidth, in Hertz
- F : noise figure (dB)
- k : Boltzmann constant (J/K)
- t_0 : Reference noise temperature (290 K)
- t_{ant} : antenna noise temperature (K)
- t_{feed} : feed noise temperature (K)
- t_e : system noise temperature (K)
- I/N_{Crit} : Interference-to-noise ratio protection criteria (dB)
- I_r : Interference level at the receiver input (dBW)
- $A_e(\theta)$: equivalent surface area of an antenna in dB-m^2 having an antenna gain

$$A_e(\theta) = G(\theta) + 10\log\frac{\lambda^2}{4\pi}$$

- $G(\theta)$: antenna gain (dBi)
- λ : wavelength in metres
- L : losses (dB) i.e. feeder or total loss of the victim receiver when applicable, body loss, propagation path loss, polarization loss. l = loss (linear – not in dB)
- FDR : frequency dependent rejection (dB), when applicable. FDR was not applied in the 460-470 MHz band but was applied in studies in adjacent bands.

Polarization loss of 1.5 dB has been applied only within the 3 dB beamwidth.

Table 10 provides only the necessary parameters to perform the simulation for different MS systems. The permissible interference into the receiver (P_i) is calculated as:

$$P_i = 10\log\left(10^{\left(\frac{F}{10}\right)}\, k\, TB\right) + PR$$

where:

- F : noise figure (dB)
- k : Boltzmann constant (J/K)
- T : noise temperature (Kelvin)
- B : Receiver bandwidth (Hz)
- PR : protection criteria (dB).

4.2 Methodology to determine requirement for Dynamic analysis (GSO and non-GSO)

Dynamic analysis was performed for the cases where the static analysis resulted in pfd criteria more restrictive than (less than) −152 dB (W/ (m^2 ·4kHz)). This was the case for fixed service P-P, P-MP, RF CSA, and mobile service narrowband base station systems.

The dynamic analysis includes modelling GSO and one or more non-GSO satellites in several orbits, as used by the systems described in § 2 as well as terrestrial stations for the systems under investigation. Based on the static analysis pfd criteria an initial pfd mask was applied to protect that service.

For each simulated satellite an antenna was created to radiate at levels that met the pfd mask for all angles of arrival. Through successive runs the mask was modified to determine pfd levels that meet the sharing criteria for the service/system under investigation, with the constraint that they are no less restrictive (greater) than −152 dB (W/(m^2 · 4 kHz)). pfd masks were set to apply to GSO and non-GSO satellites and to protect all incumbent systems without constraint. Further details are provided in § 5 for each service studied.

5 Study 1: GSO and non-GSO assessment

5.1 Methodology to determine the power flux density mask (GSO and non-GSO) required to protect incumbent systems

Both static and dynamic analyses have been performed. The static analysis assumes that the azimuth of the satellite relative to the victim site is aligned with the azimuth of the victim antenna pointing (if directional in azimuth). Thus the satellite rises at the same azimuth as the victim antenna and travels along that azimuth providing a worst case alignment for every angle of arrival. If main beam coupling is possible (antenna elevation not less than 0 degrees), it will occur in this scenario. When the static analysis indicates that the required pfd mask is more restrictive than −152 dB (W/ (m^2·4 kHz)) dynamic analysis was performed to determine more accurate results and including appropriate percentages or lengths of time for each service examined. Multiple runs were performed, incrementally making the mask more or less restrictive as necessary. 384 terrestrial station locations were arranged in a 12×34 grid with latitudes between 0º and 60º degrees and longitudes from –155ºW to 5ºE and within the view of the GSO satellite modeled at 75ºW. The final pfd mask was set to protect to all incumbent services without constraint.

5.2 Summary of pfd masks (GSO and nonGSO)

The pfd criteria is based on the most restrictive results for the pfd levels required to protect incumbent service systems in the 460-470 MHz and adjacent bands from MetSat/EESS (space-to-Earth) satellite downlinks.

There were four cases of static analysis that presented criteria more stringent than −152 dB (W/ (m^2·4 kHz)). Dynamic analysis was performed for systems where the static analysis resulted in pfd criteria more restrictive than −152 dB (W/ (m^2·4 kHz)) and time constraints for the RFI were known, and included aggregation of one GSO and three non-GSO spacecraft. For the mobile service case there were no time constraints, but dynamic analysis was performed due to the complexity of aggregating GSO and non-GSO spacecraft using static techniques.

The assessed pfd mask for the downlink emission of non-GSO satellites is provided in terms of angle of arrivals α as:

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4 \text{ kHz})) = \begin{cases} -157 & 0° \leq \alpha \leq 5° \\ -157 + 0.5(\alpha - 5) & 5° < \alpha \leq 15° \\ -152 & 15° < \alpha \leq 90° \end{cases}$$

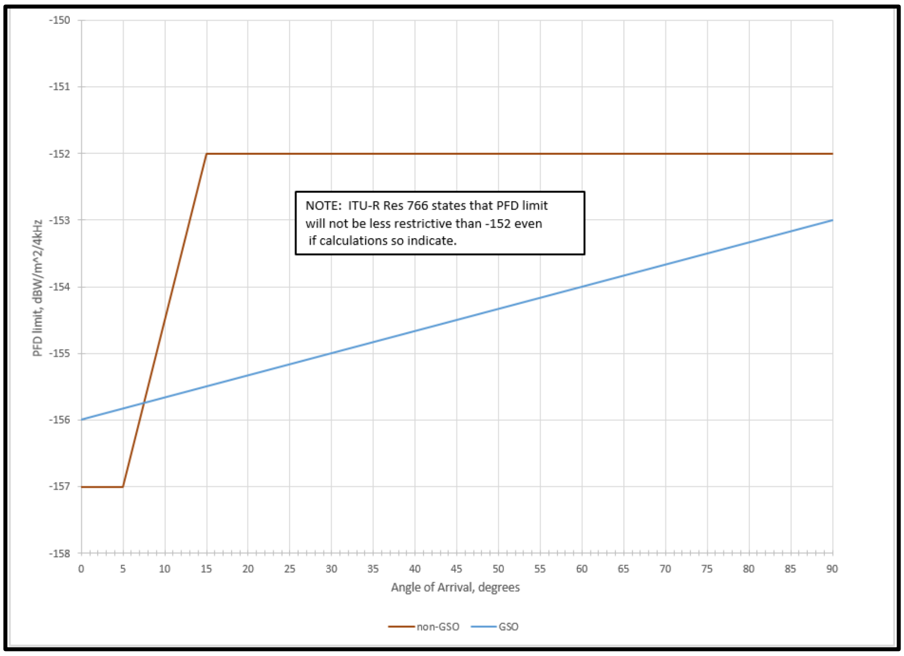
The assessed pfd mask for the downlink emission of GSO satellites is provided in terms of angle of arrivals α:

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4 \text{ kHz})) = -156 + 0.033 \times \alpha \qquad 0° \leq \alpha \leq 90°$$

These masks are presented in Fig. 7.

FIGURE 7

GSO and non-GSO pfd masks



5.2.1 Results summary of dynamic studies (GSO and non-GSO)

In any region there are at most two active GSO satellites (A and B in Fig. 9). The two GSO satellites do not overlap in frequency and will only affect less than 100 kHz of bandwidth, 1% of the total 460-470 MHz frequency band. Therefore, assuming that the incumbent service systems are evenly distributed in frequency, only 1% of the terrestrial stations have the potential to overlap with GSO.

For the 1% of the band where overlap occurred between GSO and NON-GSO satellites, the FS PP resulted in *I*/*N* of greater than –6 dB 3.7% of the simulation time. In the 99% of the band where overlap does not occur between GSO and non-GSO satellites, *I/N* was greater than −6 dB 1.3% of the simulation time.

For FS PMP, for the 99% of stations with only non-GSO RFI, exceedance was 3.2% (8 dBi antenna) and 0.4% (11 dBi antenna). For the 1% of stations with GSO and non-GSO overlap, exceedance was 14.6% (8dBi antenna). For this case it should be noted that the exceedance is only greater than 3 dB 1% of the time. The exceedance is 2% with the 11 dBi antenna.

For FS RF CSA systems the exceedance criteria is not a percent of the time, rather it is specified that the events do not exceed 1.5 minutes in duration. For the stations with GSO and non-GSO overlap exceedance events occur less than 0.002% of the time. There were no cases in the analysis where the RFI threshold was exceeded for 90 seconds.

For MS NB BS, in the 99% of the band with NON-GSO satellites, the analysis resulted in *I*/*N* of greater than −6 dB 3.8% of the simulation time. In 1% of the band where overlap does occur between GSO and non-GSO satellites, *I/N* was greater than −6 dB, 12% of the simulation time. The exceedance is less than 3 dB in all but 1% of the overlapped stations (0.01% of the stations). No cases resulted in *I*/*N* of greater than 0 dB.

5.2.2 Mitigating factors (GSO and non-GSO)

There are some factors that were not considered in the study that could mitigate the results. For low angles of arrival terrain and clutter could reduce interference levels in many practical cases. The GSO satellite downlinks only use a few 25 kHz channels, but have been treated as if they could be at any frequency in the band and aggregated with three non-GSO satellite downlinks in the dynamic analysis. The incumbent system interference thresholds are 6 dB below the noise level and it was assumed that the links are at the minimum usable signal due to length or other impairments.

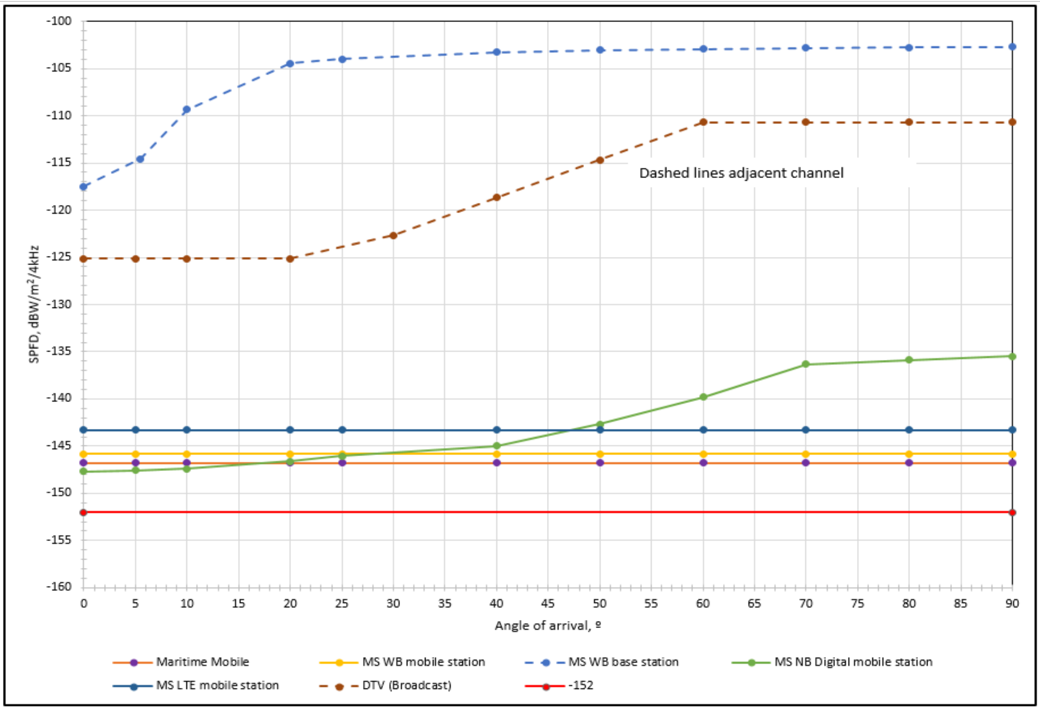
5.3 Static analysis summary (GSO and non-GSO)

This section presents the detailed results of the static analysis, corresponding to the data for the incumbent systems in the main body of the Report. The essence of the static analysis was to determine worst case pfd levels corresponding to the interference criteria. The elevation to the satellite was varied, but the azimuth was aligned with the terrestrial system antenna.

Figure 8 summarizes the static calculation results. A red line has been drawn to indicate the pfd threshold already used by one administration, −152 dB (W/ (m^2·4 kHz)). If the protection required is less restrictive than this value (above the line) then no reduction in the threshold is necessary to protect the incumbent system without constraining its operations. Figure 8 presents the cases where dynamic analysis was not required because the pfd criteria were calculated to be less restrictive than −152 dB(W/ (m^2·4 kHz)). Dynamic analysis is presented in § 5.3. The cases where dynamic analysis was performed for FS P-P and P-MP, FS mesh networks, and MS narrowband base stations.

FIGURE 8

Static results summary chart



5.3.1 Power flux density mask to protect incumbent fixed P-P and P-MP systems (GSO and non-GSO)

Terminal stations for P-MP have the same technical characteristics as P-P, except gain, thus the results are generated using the same analysis. Central stations are evaluated here. The antenna was modelled using Recommendation ITU-R F.1245. Results for the worst case (17 dBi gain) are presented in Table 15. The pfd based on static analysis required to protect P-P and P-MP stations is more restrictive than −152 dB(W/ (m^2·4 kHz)) and is further considered in dynamic analysis. The worst case considering the 17 dBi P-P antenna gain is presented in Table 15.

TABLE 15

Power flux density to protect FS P-P systems

Parameter	Units	Value										
Victim noise fig.	dB	4.0										
Body Loss	dB	0.0										
I/*N* criteria	dB	-6.0										
Feeder losses	dB	3.0										
Polarization loss	dB	1.5										
FDR	dB	0.0										
Angle of arrival	degrees	0	5	10	25	30	40	50	60	70	80	90
G (angle of arrival)	dBi	17.0	16.5	14.4	1.3	1.6	−0.5	−2.5	−3.6	−5.9	−9.8	−12.7
Interference threshold	dB(W/4 kHz)	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9
Effective aperture	dBm^2	2.2	1.7	−0.4	−13.5	−13.2	−15.3	−17.3	−18.4	−20.7	−24.6	−27.5
pfd criteria	dB (W/(m^2·4 kHz))	−167.6	−167.1	−165.5	−153.4	−153.8	−151.6	−149.6	−148.5	−146.2	−142.3	−139.4

5.3.2 Power flux density mask (GSO and non-GSO) to protect fixed service mesh systems

Fixed service RF CSA mesh network systems were analysed. The worst case is presented in Table 16, applicable to central stations and IP-links with a 10 dBi omnidirectional in azimuth antenna, modelled using Rec. ITU-R F.1336 § 2.2. Polarization loss was not applied outside the vertical 3 dB beamwidth for the 10 dBi antenna. For this case, the interference threshold was available (Table 9), therefore noise calculations were not required. Feeder loss was based on 30 feet of RG58 cable for central stations and IP-links. Static analysis of RF CSA stations resulted in more restrictive criteria than −152 dB(W/m^2/4 kHz) below approximately 10º, to be further considered in the dynamic analysis in setting the pfd criteria.

TABLE 16

Power flux density level to protect FS RF CSA systems

Parameter	Units	Value										
Feeder losses	dB	3.0										
Polarization loss	dB	1.5										
Angle of arrival	degrees	0	5	10	20	25	40	50	60	70	80	90
G (elevation angle)	dBi	10.0	7.4	−0.4	−4.6	−5.1	−5.8	−6.0	−6.1	−6.2	−6.3	−6.3
Interference threshold	dBW in RX BW	−154.7	−154.7	−156.2	−156.2	−156.2	−156.2	−156.2	−156.2	−156.2	−156.2	−156.2
Interference threshold	dB(W/4 kHz)	−159.6	−159.6	−161.1	−161.1	−161.1	−161.1	−161.1	−161.1	−161.1	−161.1	−161.1
Effective aperture	dBm^2	−4.8	−7.4	−8.5	−19.4	−19.9	−20.6	−20.8	−20.9	−21.0	−21.1	−21.1
pfd criteria	dB (W/ (m^2·4 kHz))	−154.8	−152.3	−152.6	−141.7	−141.3	−140.6	−140.4	−140.2	−140.2	−140.1	−140.0

5.3.3 Power flux density level (GSO and non-GSO) required to protect MS systems

Mobile service narrowband (6.25-25 kHz) mobile and base stations and wideband (1 250 kHz CDMA) base stations were analysed. The wideband base stations operate in the adjacent 450-460 MHz frequency band and therefore FDR must be considered. The antenna for MS wideband mobile station systems was modelled as omnidirectional and the base station antenna was modelled as omnidirectional in azimuth. Results are presented in Table 17 and Table 18. Because the pfd for wideband mobile stations and base stations is less restrictive than −152 dB (W/ (m^2·4 kHz)), they are not considered further in this study. Mobile service narrowband base stations resulted in the more restrictive criteria in Table 17, and dynamic analysis was performed. Although there is no time based criteria, dynamic techniques allowed aggregation of GSO with non-GSO spacecraft to be applied to the interference criteria.

TABLE 17

pfd to protect MS wideband mobile station systems

Parameter	Units	Value										
Victim noise figure	dB	8.0										
Body loss	dB	4.0										
I/*N* criteria	dB	-6.0										
Feeder losses	dB	2.0										
Polarization loss	dB	1.5										
FDR	dB	0.0										
Angle of arrival	degrees	0	5	10	20	25	40	50	60	70	80	90
G (angle of arrival)	dBi	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Interference threshold	dB(W/4 kHz)	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4	−158.4
Effective aperture	dBm^2	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6
pfd criteria	dB(W/(m^2·4 kHz))	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8	−145.8

TABLE 18

pfd to protect MS narrowband base station systems

Parameter	Units	Value										
Victim noise figure	dB	7.0										
Body Loss	dB	0.0										
I/*N* criteria	dB	−6.0										
Feeder losses	dB	3.0										
Polarization loss	dB	1.5										
FDR	dB	0.0										
Angle of arrival	degrees	0	4	7	20	25	40	50	60	70	80	90
G (angle of arrival)	dBi	11.2	8.3	3.7	−4.0	−4.4	−4.9	−5.0	−5.1	−5.2	−5.2	−5.2
Interference threshold	dB(W/4 kHz)	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9	−163.9
Effective aperture	dBm^2	−3.6	−6.5	−11.1	−18.8	−19.2	−19.7	−19.8	−19.9	−20.0	−20.0	−20.0
pfd criteria	dB(W/(m^2·4 kHz))	−158.8	−156.0	−146.9	−145.2	−144.8	−144.3	−144.2	−144.1	−144.0	−144.0	−144.0

5.3.4 pfd level (GSO and non-GSO) required to protect MS IMT mobile station systems

The mobile service narrowband mobile station antenna was modelled as omnidirectional (same gain in all directions). Results are presented in Table 19. The pfd for this case was determined to be less restrictive than −152 dB (W/(m^2 · 4 kHz)) and is not considered further in the studies.

TABLE 19

pfd level to protect IMT mobile station systems

Parameter	Units	Value										
Victim noise power	dBW	−126.7										
Body Loss	dB	4.0										
I/*N* criteria	dB	−6.0										
Feeder losses	dB	0										
Polarization loss	dB	1.5										
FDR	dB	0										
Angle of arrival	degrees	0	5	10	20	25	40	50	60	70	80	90
G (angle of arrival)	dBi	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Interference threshold	dB(W/4 kHz)	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0	−160.0
Effective aperture	dBm^2	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6	−12.6
pfd criteria	dB(W/(m^2·4 kHz))	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3	−147.3

5.3.5 pfd level (GSO and non-GSO) required to protect maritime mobile service systems

The maritime mobile service systems are in band. The antennas were modelled as omnidirectional. Note that body loss applies but is not included in these results. Results are presented in Table 20. The pfd level for this case was determined to be less restrictive than −152 dB(W/(m^2·4 kHz)) at all angles of arrival and is not considered further in the studies.

TABLE 20

pfd to protect maritime mobile service, mobile station systems

Parameter	Units	Value										
Victim noise figure	dB	7.0										
Body loss	dB	0.0										
I/*N* criteria	dB	−6										
Feeder losses	dB	0.0										
Polarization loss	dB	1.5										
FDR	dB	0.0										
Angle of arrival	degrees	0	5	10	20	25	40	50	60	70	80	90
G (elevation angle)	dBi	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9	−3.9
Interference threshold	dB(W/4 kHz)	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9	−166.9
Effective aperture	dBm^2	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6	−18.6
pfd criteria	dB(W/(m^2·4 kHz))	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8	−146.8

5.3.6 pfd (GSO and non-GSO) required to protect Broadcast Service systems

The broadcast service systems are in the adjacent bands above 470 MHz and therefore FDR applies. It is assumed that the FDR will be greater than 40 dB. The rooftop antennas were modelled using Recommendation ITU-R BT.419. Results are presented in Table 21. The pfd for this case was determined to be less restrictive than −152 dB(W/m^2/4 kHz) and is not considered further in the studies.

TABLE 21

pfd to protect broadcast service systems

Parameter	Units	Value										
Victim noise figure	dB	6.0										
Body loss	dB	0.0										
I/*N* criteria	dB	−10.0										
Feeder losses	dB	3.0										
Polarization loss	dB	1.5										
FDR	dB	40.0										
Elevation angle	degrees	0	5	10	20	25	40	50	60	70	80	90
G (elevation angle)	dBi	12.5	12.5	12.5	12.5	8.5	4.5	0.5	−3.5	−3.5	−3.5	−3.5
Interference threshold	dB(W/4 kHz)	−127.5	−127.5	−127.5	−127.5	−129.0	−129.0	−129.0	−129.0	−129.0	−129.0	−129.0
Effective aperture	dBm^2	−2.3	−2.3	−2.3	−2.3	−6.3	−10.3	−14.3	−18.3	−18.3	−18.3	−18.3
pfd criteria	dB(W/(m^2·4 kHz))	−125.2	−125.2	−125.2	−125.2	−122.7	−118.7	−114.7	−110.7	−110.7	−110.7	−110.7

5.3.7 pfd (GSO and non-GSO) to protect Radio Astronomy

Given that the EESS and MetSat pfd level in all cases is less than or equal to −152 dB(W/(m^2/4 kHz)), or −188 dB(W/m^2/Hz), and assuming that out of band attenuation at 410 MHz is greater than 80 dB, the pfd level above 410 MHz is then −268 dBW/m^2/Hz and hence meets the Radio Astronomy protection criteria of −255 dB(W/(m^2/Hz)) as given in Recommendation ITU-R RA.769 (Table 1).

5.4 Dynamic analysis (GSO and non-GSO)

Dynamic analysis was performed where the static analysis resulted in pfd criteria more restrictive (less than) −152 dB(W/m^2/MHz) and time constraints for the RFI were known. Dynamic techniques were also used for cases where GSO and non-GSO satellites were aggregated together due the complexity of static calculations.

5.4.1 Aggregate interference from GSO and non-GSO

Aggregate interference from three non-GSO and one GSO satellites as described in § 2.2 is included. The aggregate interference level is calculated at the receiver using:

$$\frac{I}{N} = \frac{1}{N_{sys}} \sum (pfd_i + a_e - L)$$

where:

$\frac{I}{N}$: resulting aggregate *I*/*N* from all visible geostationary satellites at the FS receiver

pfd_i : pfd at the FS station from visible GSO or non-GSO satellite i for the angle of arrival, dB (W/(m^2·4 kHz))

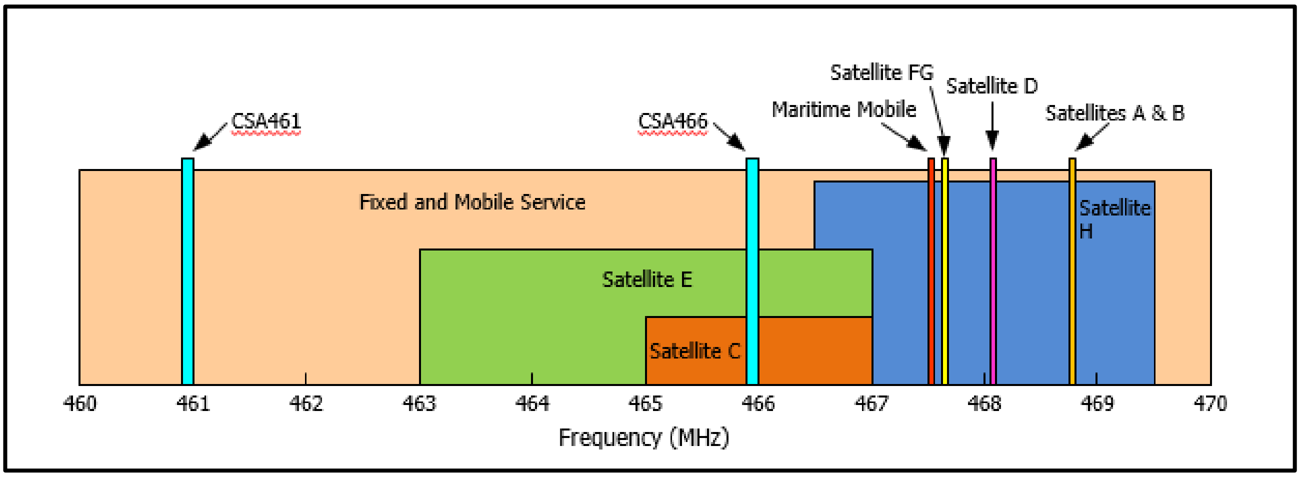
L = feeder loss, dB.

The terrestrial stations were arranged in a grid covering the portion of the northern hemisphere visible from the GSO satellite in the study, in the latitude range from 0º to 60ºN. Due to symmetry, it was not necessary to model both hemispheres. Stations were deployed without consideration of terrain or even where there are bodies of water. The terrestrial stations were given random azimuths and elevations, unless the antenna pattern was omnidirectional in azimuth. The intent of this deployment was to ensure that the worst interference cases were captured, and the study was not limited to the territory of any particular administration including interference at low elevation angles. The simulations were run for 90 days to capture multiple repetition cycles and ensure stability of the results.

Figure 9 is included, below, to illustrate the frequency overlap considerations. It is noted that MetSat (space-to-Earth) and EESS (space-to-Earth) satellite frequency assignments have a long lead time for spacecraft design, development, and manufacturing and can extend for 10-15 years. Figure 9 shows the frequency ranges used by the satellites included in this study. The incumbent systems were assumed to operate on any frequency in the 460-470 MHz band for this purpose. A maximum of three non-GSO (satellites C, E, and H) can aggregate (in the frequency range 466.5 to 467 MHz). Nonetheless, aggregation was assumed to occur for one GSO and three non-GSO satellite systems throughout the frequency band 460-470 MHz as an upper bound for potential interference. In any region there are at most two active GSO satellites (A and B in Fig. 9). The GSO satellites do not overlap in frequency and will only affect less than 100 kHz of bandwidth, or less than 1% of the 460-470 MHz frequency band. Therefore, assuming that the incumbent service systems are evenly distributed in frequency, only 1% of the stations have the potential to overlap with GSO.

FIGURE 9

Frequency overlap considerations for 460-470 MHz



For P-P and P-MP dynamic studies were performed to assess the aggregate impact of GSO and non-GSO satellites. The FS systems meet both the short term criteria of BER less than or equal to 10^{-6} and fractional degradation of performance less than or equal to 25%. In a statistical interference assessment, it is necessary to establish a certain percentage of stations or routes for which the aggregate interference may exceed the interference criterion. In difficult sharing situations, such as this case, it is extremely difficult to adopt a very small allowable percentage. In such situations, recognizing the stringent nature of the interference criteria and mitigating factors not included in this study (see § 5.2.1), a higher percentage of FS receivers under survey might be prepared to accept interference exceeding the preferred interference criterion. The FDP was determined in accordance with Recommendations ITU-R F.1108 and ITU-R F.1107, using equation (4).

$$FDP = \frac{i_{av}}{n_T} \times 100, \text{ or } FDP = 10^{\left(I_{av}/N_T/_{10}\right)} \times 100 \qquad (4)$$

where:

- FDP : Fractional degradation of performance, in percent
- i_{av} : Average interference in W/4kHz (I_{av} is in dBW/4 kHz)
- n_T : Thermal noise in W/4kHz (N_T is in dBW/4 kHz).

As described in Recommendation ITU-R F.1107, a large number of FS stations (to ensure stability and convergence of the statistics) are distributed in an area from 0 to 60 latitude and −155 to +5 longitude, covering the line-of-sight range from a GSO satellite at 75W longitude. The effects of land and water on the locations of the FS stations was ignored in order to ensure that all potential coupling levels were included in the study. The station azimuths were randomly selected between −180 and +180 degrees and the station elevation angles were randomly selected between −5 and +5 degrees, and the runs were re-randomized and performed multiple times to ensure stability of the results. The grid consisted of 384 satellites evenly spaced between 32 longitudes and 12 latitudes.

In this study there are certain mitigating factors that were not considered. See § 5.2.2 for additional information on interference mitigating factors.

5.4.2 Dynamic analysis of pfd (GSO and non-GSO) required to protect fixed service P-P and P-MP networks

Three non-GSO orbits were applied with one satellite in each orbit and one GSO satellite. GSO satellites only overlap with less than 1% of the stations (see Fig. 10), therefore the analysis is performed both with and without one GSO aggregating with three non-GSO satellites.

The pfd masks used for GSO and non-GSO are given in § 5.2. For the P-P analysis the 17 dBi antenna was modeled using Recommendation ITU-R F.1245. For this case, the overall average FDP was 7.7%. The cumulative distribution function (CDF) of the results is presented in Fig. 10. Exceedance for the 1% of stations with potential overlap with GSO spacecraft occurs 3.7% of the time and for the remaining 99% of the stations 1.3%.

Similarly, P-MP analysis was performed. The antennas modelled per Recommendation ITU-R F.1336 was 8 dBi omnidirectional in azimuth, and 11 dBi sectoral (k=0.3). The resulting CDF is presented in Fig. 11. The FDP for the cases including aggregation of GSO with non-GSO spacecraft was 3.2% ($Iav/N = -15$ dB) for the 8 dBi antenna and 9.6% ($Iav/N = -10.2$ dB) for the 8 dBi antenna. For the 99% of stations with only non-GSO RFI, exceedance was 3.2% (8 dBi antenna) and 0.4% (11 dBi antenna). For the 1% of stations with GSO and non-GSO overlap, exceedance was 14.6% (8 dBi antenna) but and the exceedance is 2% with the 11 dBi antenna. For the case of GSO and non-GSO overlap with the 8 dBi antenna it should be noted that the exceedance is greater than 3 dB only 1% of the time.

FIGURE 10

Cumulative probability distribution of aggregate interference for P-P narrowband systems with 17 dBi antennas

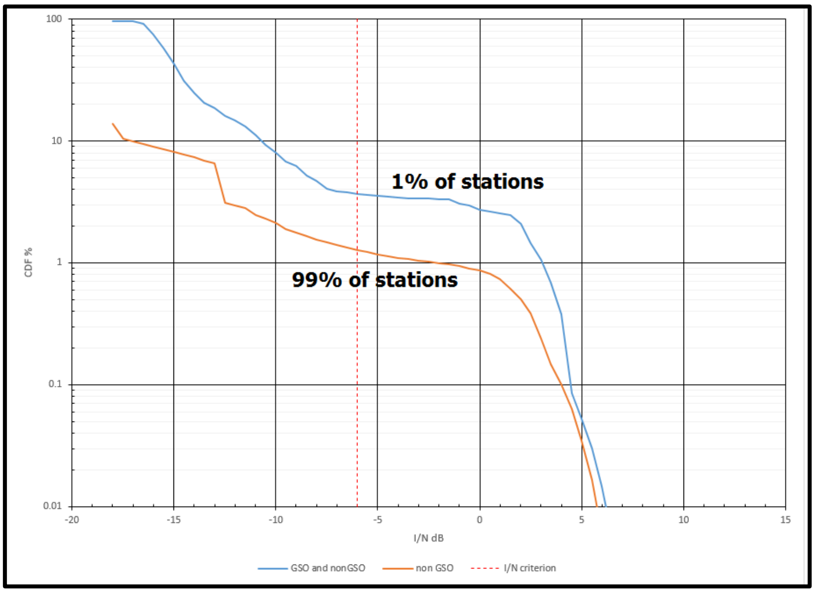
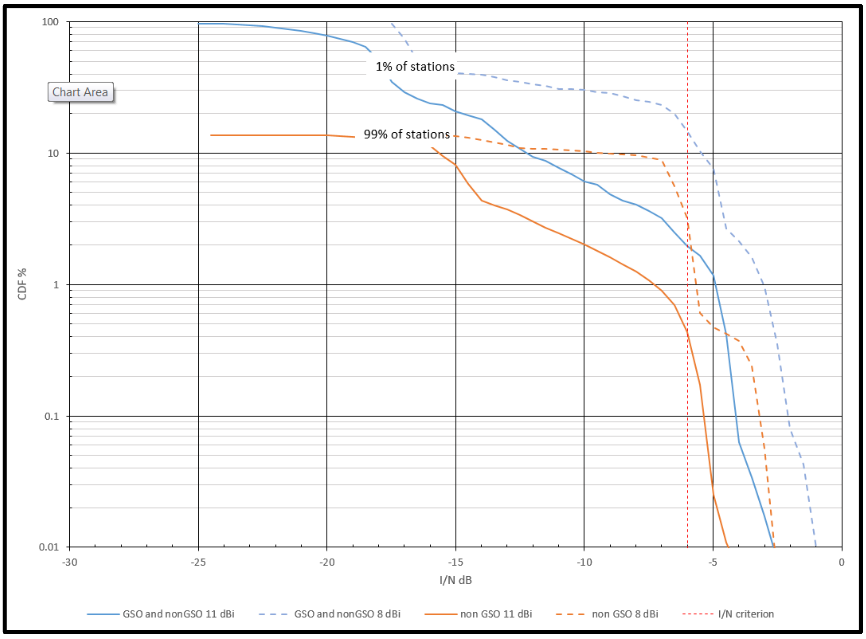


FIGURE 11

CDF for aggregate interference to P-MP stations

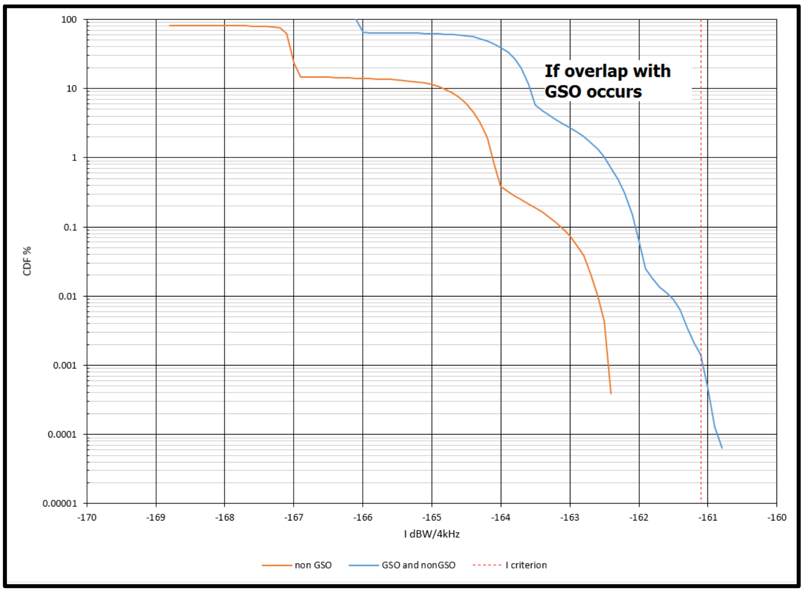


5.4.3 Dynamic analysis of pfd (GSO and non-GSO) required to fixed service mesh network (RF CSA)

Dynamic studies were performed to further investigate the allowable pfd criteria under aggregate conditions. Three non-GSO spacecraft were considered in the aggregate dynamic analysis. As shown in the static analysis, the interference criteria are −161.1 dB(W/4 kHz) measured at the transceiver terminals. The pfd mask used for GSO and non-GSO are given in § 5.2. The time requirement for interference in this case is not a percent of the time, it is specified that the events do not exceed 1.5 minutes in duration. To increase time resolution, this dynamic simulation was performed using a 5 second interval, for 90 days, and shows there were six exceedance events, lasting at most 9, 5 second time steps (between 45 and 50 seconds) where the interference threshold was not met. Exceedance events occur less than 0.002% of the time. There were no cases in the analysis where the RFI threshold was exceeded for 90 seconds. RF CSA systems therefore meet the criteria with the pfd masks described. It is noted that the exceedance was less than 0.5 dB for all cases. RF CSA systems are not expected to overlap with GSO satellite downlinks in this frequency band, but aggregate RFI calculations with and without GSO satellites and with non-GSO satellites have been performed. The cumulative distribution function for both cases is plotted in Fig. 12.

FIGURE 12

Cumulative probability distribution of aggregate interference to FS mesh networks (RF CSA)



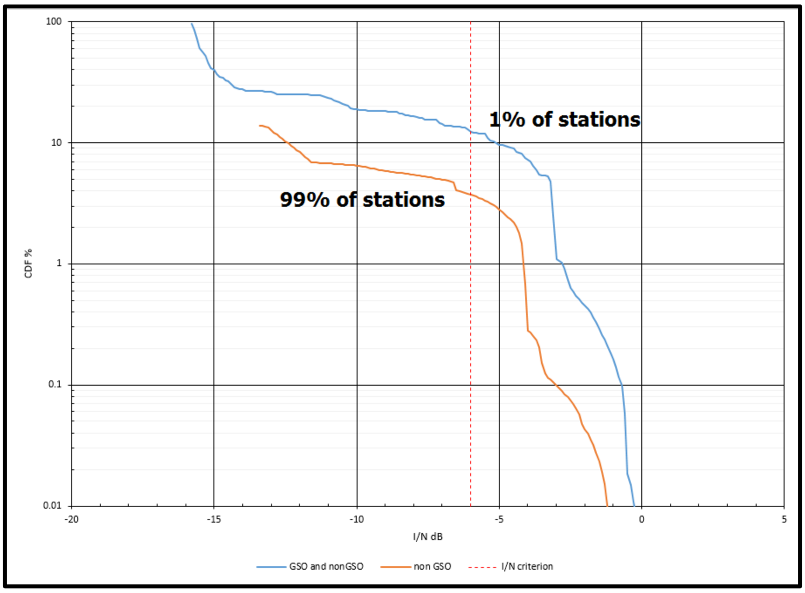
5.4.4 Dynamic analysis of pfd (GSO and non-GSO) required to protect mobile service narrowband base station (MS NB BS)

MS NB BS station characteristics for analogue and digital relevant to this study are essentially the same. The 3 dB total loss value in Table 10 for narrowband analogue base stations was used as the most restrictive case. The omnidirectional in azimuth antenna was used for the stations as the worst case. The analysis used the same grid as for the FS PP case described in § 5.3.1. Three non-GSO spacecraft were aggregated both with and without one GSO spacecraft in the simulation, each transmitting at the pfd specified in § 5.2 for all angles of arrival. As was the case for FS P-P and P-MP, only 1% of the stations can overlap with GSO satellites. GSO satellites do not overlap in frequency and will only affect less than 100 kHz of bandwidth, less than 1% of the total 460-470 MHz frequency band. Therefore, assuming that the incumbent service systems are evenly distributed in frequency, only 1% of the terrestrial stations have the potential to overlap with GSO.

For MS NB BS, in the 99% of the band with NON-GSO satellites (not overlapped), the analysis resulted in *I*/*N* of greater than -6 dB 3.8% of the simulation time. In 1% of the band where overlap does occur between GSO and NON-GSO satellites, *I*/*N* was greater than −6 dB, 12% of the simulation time. The exceedance is less than 3 dB in all but 1% of the overlapped stations (0.01% of the stations). No cases resulted in *I*/*N* of greater than 0 dB. Refer to Fig. 13.

FIGURE 13

Cumulative probability distribution of aggregate interference to MS NB BS



6 Study 2: GSO and non-GSO assessments

6.1 Radio Astronomy

The protection of the frequency band 406.1-410 MHz from the non-GSO DCS downlink emissions is ensured through the filtering pattern as described in Table 2. The transmitted power within the 460-470 MHz is 10 dBW per 2 MHz or −23 dB(W/kHz). The output power within the radio astronomy band equals −126 dB(W/kHz), which implies a decrease of 103 dB.

Considering the pfd threshold on the ground ranges from −158 to −152 dB(W/m²/4 kHz) in the 460-470 MHz band, it is therefore expected that the pfd level in the radio astronomy band will not exceed –255 dB(W/m²/4 kHz), which is 36 dB under the threshold to protect the radio astronomy service in the 406.1-410 MHz band. Therefore, the EESS (space-to-Earth) for non-GSO DCS emissions will not cause interference to the radio astronomy stations.

6.2 Mobile service (MS) Static Analysis (GSO and non-GSO)

6.2.1 pfd (GSO and non-GSO) required to protect incumbent MS narrowband base station (NB BS) systems

The following Table provides a worst-case analysis based on the parameters as provided by Recommendation ITU-R M.1808-0.

TABLE 22

pfd to protect NB BS

Necessary bandwidth (kHz)	12.50
Noise factor (dB)	7.00
Background noise temperature (K)	290.00
Noise temperature (K)	1453.44
Noise level (dBm)	–126.01
Noise level (dB(W/4 kHz))	−160.96
Antenna gain (dBd)	9
Antenna gain (dBi)	11
Effective aperture (m^2)	0.44
Effective aperture (dBm^2)	−3.55
I/*N* (dB)	−6.00
Losses (dB)	4.00
Polar losses (dB)	3.00
Body losses (dB)	0.00
pfd level (dB(W/m^2/4 kHz))	−156.40

6.2.2 pfd (GSO and non-GSO) required to protect incumbent mobile service narrowband mobile station systems

Table 23 provides a worst-case analysis based on the parameters as provided by Recommendation ITU-R M.1808.

TABLE 23

pfd to protect NB MS

Necessary bandwidth (kHz)	5.50		Necessary bandwidth (kHz)	5.50
Noise factor (dB)	7.00		Noise factor (dB)	7.00
Background noise temperature (K)	290.00		Background noise temperature (K)	290.00
Noise temperature (K)	1453.44		Noise temperature (K)	1453.44
Noise level (dBm)	−129.57		Noise level (dBm)	−129.57
Noise level in dB(W/4 kHz)	−160.96		Noise level (dB(W/4 kHz))	−160.96
Antenna gain (dBd) (handheld)	−6		Antenna gain (dBd) (vehicular)	0
Antenna gain (dBi)	−4		Antenna gain (dBi)	2
Effective aperture m^2	0.01		Effective aperture (m^2)	0.06
Effective aperture (dBm^2)	−18.55		Effective aperture (dBm^2)	−12.55
I/*N*	−6.00		*I*/*N*	−6.00
Losses (dB)	0.00		Losses (dB)	1.00
Polar losses (dB)	3.00		Polar losses (dB)	3.00
Body losses (dB)	4.00		Body losses (dB)	4.00
pfd level (dB(W/m^2/4 kHz))	−141.40		pfd level (dB(W/m^2/4 kHz))	−146.40

6.2.3 pfd (GSO and non-GSO) required to protect incumbent mobile service Wide Band (WB) mobile station systems

Studies performed regarding the MS wideband mobile station systems show that show that the needed pfd level is above −152 dB(W/m²/4kHz).

Mobile wideband base stations are adjacent band and therefore FDR applies. Because the pfd for wideband mobile stations and base stations is less restrictive than −152 dB(W/m²/4 kHz), they are not considered further in this study.

The following Table provides a worst-case analysis based on the parameters as provided by Recommendations ITU-R M.1808 and ITU-R M.2110. This Table is also valid for systems using CDMA technology.

TABLE 24

pfd to protect WB MS

Necessary bandwidth (kHz)	1250.00
Noise factor (dB)	8.00
Background noise temperature (K)	290.00
Noise temperature (K)	1829.78
Noise level (dBm)	−105.01
Noise level (dB(W/4 kHz))	−159.96
Antenna gain (dBd)	0
Antenna gain (dBi)	2
Effective aperture (m²)	0.06
dBm²	−12.55
I/*N*	−6.00
Losses (dB)	2.00
Polar losses (dB)	3.00
Body losses (dB)	4.00
pfd level (dB(W/m²/4 kHz))	−144.40

6.2.4 Power flux density (GSO and non-GSO) required to protect incumbent IMT-2000 mobile station systems and LTE

Studies performed regarding the incumbent IMT-2000 mobile station systems and LTE MS wideband mobile station systems show that show that the needed pfd level is above −152 dB (W/m²/4kHz).

Table 25 provides a worst-case analysis based on the parameters as provided in § 3.2.2. This Table is also valid for systems using PPDR technology.

TABLE 25

pfd to protect IMT-2000

Necessary bandwidth (kHz)	5 000.00
Noise level (dBm)	−96.70
Noise level (dB(W/4 kHz))	−118.82
Antenna gain (dBi)	0
Effective aperture (m^2)	0.03
Effective aperture (dBm^2)	−14.70
I/*N* (dB)	−6.00
Losses (dB)	0.00
Polar losses (dB)	3.00
Body losses (dB)	4.00
pfd level (dB(W/m^2/4 kHz))	−141.96

6.3 Dynamic analysis (non-GSO case)

6.3.1 Fractional Performance Degradation (FDP)

The methodology used in order to perform the simulation between non-GSO satellite and fixed service has been linked to the FDP. This methodology is described in Recommendation ITU-R F.1108. If an interferer caused an interference power I_i for a fraction of a month, f_i, and was absent for the remainder of the month, the incremental FDP due to this interference would be given by:

$$\Delta P_{0,i} = \frac{I_i f_i}{N_T}$$

N_T represents the noise power. The FDP due to a set of events, where the i^{th} event consists of the fraction of time that the interference had a power I_i, is given as:

$$FDP = \sum \Delta P_{0,i} = \sum \frac{I_i f_i}{N_T}$$

Where the summation is taken over all interference events. The summation over I_i f_i is the discrete equivalent to the first moment of the probability distribution of the interference power into the receiver since f_i is the probability that the interference power has a value between I_i and $I_i \pm \Delta I_i$.

6.3.2 Simulations with non-GSO systems and fixed service

Dynamics simulations were performed in order to derive the CDF of interference in the FS receiver considering all satellites with ARGOS payload (six non-GSO satellites). Figure 14 displays the simulated scenario. The following summarizes parameters used in the simulations:

1 The dynamic simulation is made on a time basis of 15 days with simulation steps of 10 s.

2 All satellites have a polar orbit (around 98°).

3 The pfd mask provided below is applied to each satellite.

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4\text{kHz})) = \begin{cases} -157 & 0° \leq \alpha \leq 5° \\ -157 + 0.5(\alpha - 5) & 5° < \alpha \leq 15° \\ -152 & 15° < \alpha \leq 90° \end{cases}$$

4 The FS system is placed in Nançay, a city in the middle of France. The P-MP and P-P scenarios are studied by changing the antenna diagram from respectively omnidirectional to

directional. In the case of P-P link, different configuration of pointing direction are performed (from North, to East, to South).

5 The antenna patterns used for FS systems are extracted from:

a) Recommendation ITU-R F.1245 for P-P link.

b) Recommendation ITU-R F.1336 for P-MP link.

6 The simulations take into account the potential aggregation of interference (for the rare case in time for which the FS is in the field of view of different satellites).

7 In each case of scenario (P-P and P-MP) the CDF of interference is built and the FDP is applied by considering, in linear, the weighted sum of the distribution.

8 In each case of FS equipment, the results of the FDP is compared to the threshold of 25% (equivalent to $I/N = -6$ dB).

9 No polarization is used within the simulation.

Figure 14 shows some satellite positions used to perform the simulation.

FIGURE 14

Representation of some satellite positions (Metop A, B and NOAA 15) in visibility of FS (Yellow pin) during the 15 days of simulation

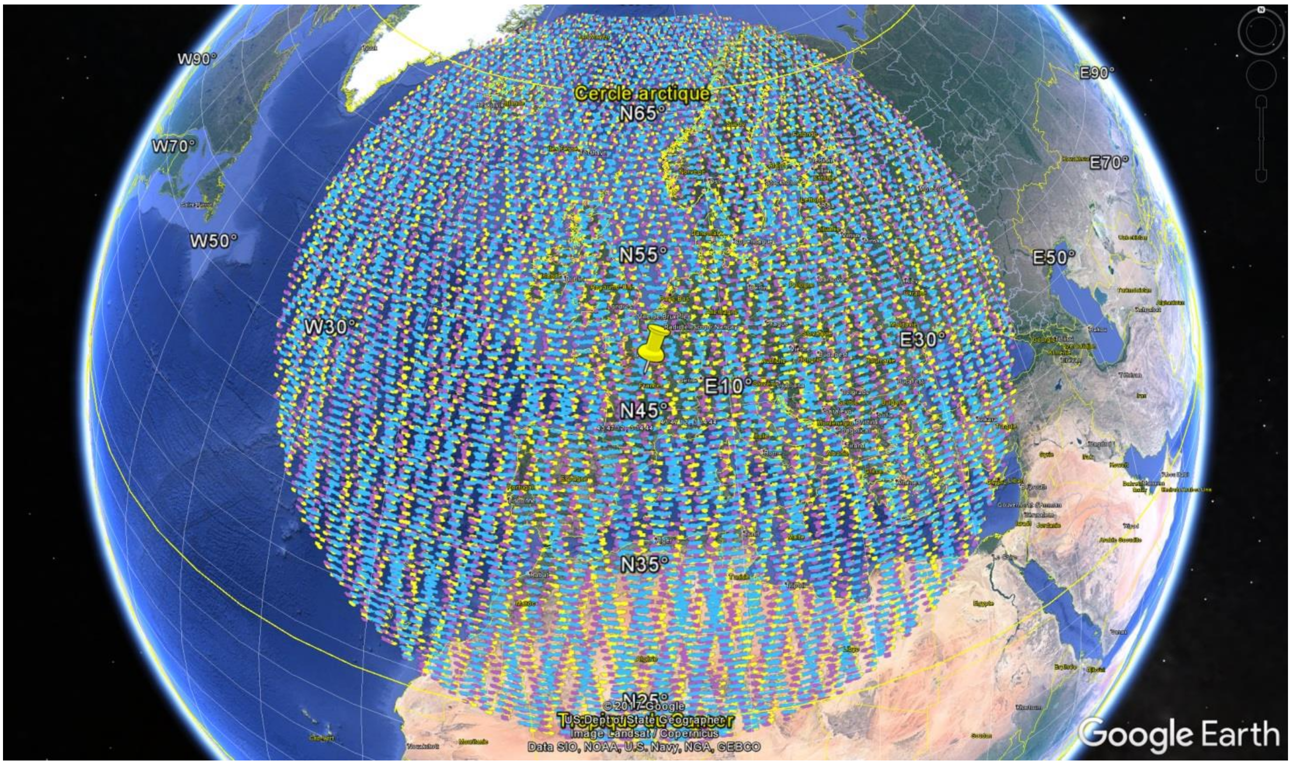


Figure 15 and Table 26 present the results of simulation and show clearly that all results are compliant with the protection criteria of fixed service (FDP is lower than 25%).

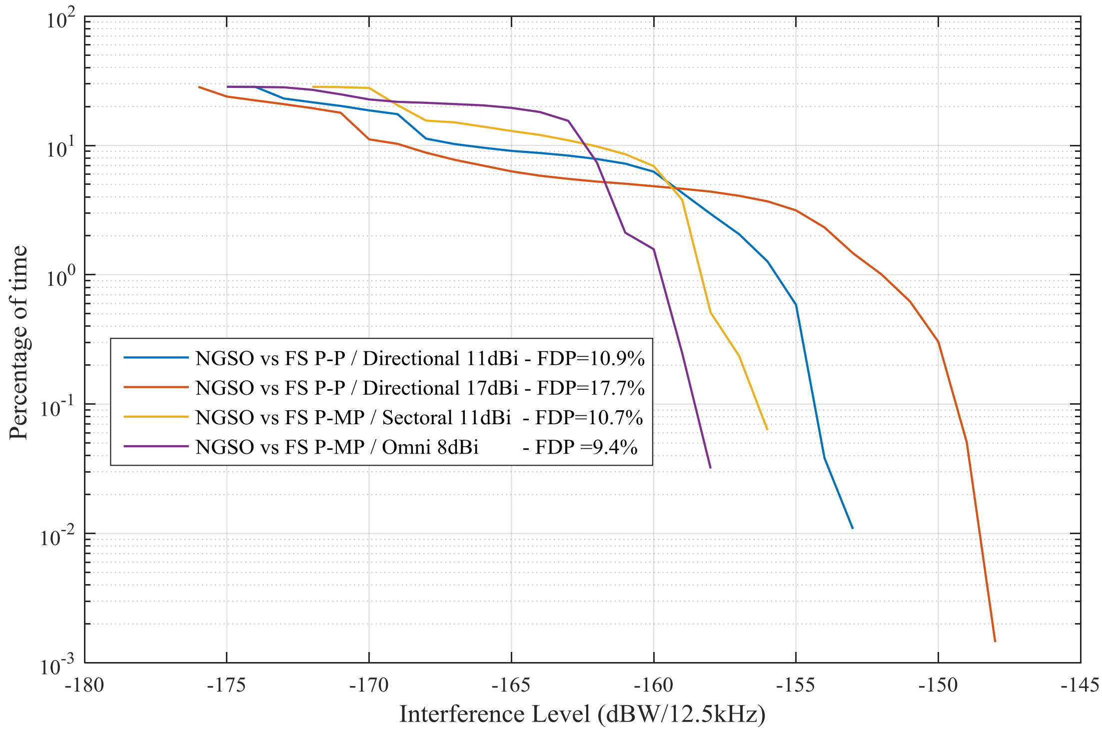
TABLE 26

FDP results

Link	Recommendation	Gain (dBi)	FDP (%)
P-P	ITU-R F.1245	11	10.9
		17	17.7
P-MP	ITU-R F.1336 (Omni)	8	10.7
	ITU-R F.1336 (Sectoral)	11	9.4

FIGURE 15

Results of simulation for each case of scenario (non-GSO only)



As a conclusion, considering the assumed parameters for the fixed service and the MetSat/EESS (space-to-Earth) pfd mask used in this study, these simulations show that the FDP is never exceeded regardless of the scenario taken into account.

6.3.3 Simulations with non-GSO systems and mobile service

The following listed parameters are used in the simulations:

1 The dynamics simulation is made on a 15 days basis with time steps of 10 s.

2 All satellites use a polar orbit (around 98°).

3 The pfd mask provided below is applied to each satellite.

$$pfd \text{ values in dB(W/ }(m^2 \cdot 4\text{ kHz})) = \begin{cases} -157 & 0° \leq \alpha \leq 5° \\ -157 + 0.5(\alpha - 5) & 5° < \alpha \leq 15° \\ -152 & 15° < \alpha \leq 90° \end{cases}$$

4 The satellites emit in circular polarisation. The polarisation losses are taken equal to 3 dB du to the fact that the mobile station (BS or UE) receive in vertical polarisation.

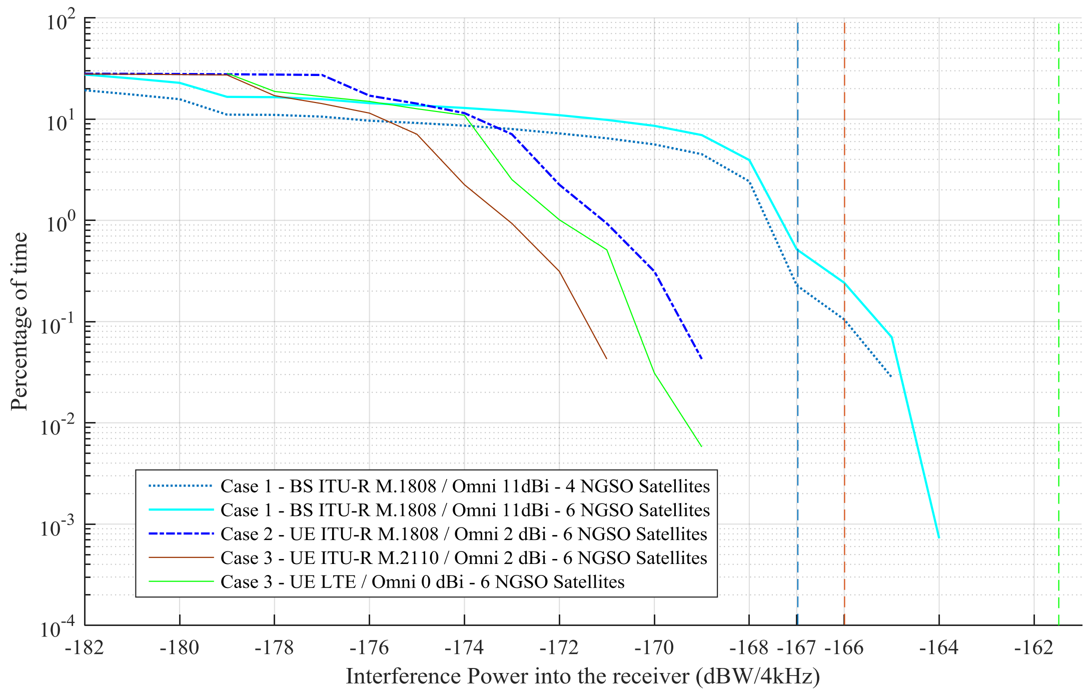
5 The mobile service (UE or BS) is placed in middle North latitude. The MS (UE or BS) antenna is always considered as omnidirectional. In the case of BS, the pattern is described by Recommendation ITU-R F.1336 with k = 0.3. No tilt is applied, which is a worst case assumption.

6 The simulations take into account the potential aggregation of interference (for the rare case in time for which the FS is in the field of view of different satellites).

Figure 16 provides the results of simulation considering all the equipment (case 1 to 4) defined above.

FIGURE 16

Dynamic simulation results for each kind of MS equipment



Considering the pfd mask defined in § 4, the previous results show that:

- The protection criteria of LTE UE system (case 3, green line) is never exceeded.
- The protection criteria of CDMA 450 UE (case 3, brown line) is never exceeded.
- The protection criteria of UE described in Recommendation ITU-R M.1808 are never exceeded.
- The protection criteria of BS described in Recommendation ITU-R M.1808 are exceeded by 3 dB, 0.6% of the time if six satellites are considered and by 2 dB 0.2% of the time for four satellites which is well below the outage probability generally assumed for mobile service (e.g. 2%).

In addition, these simulations do not consider terrain profile for low elevation angle and no tilt of BS were used.

6.4 Statistical simulation (GSO case)

6.4.1 The employed methodology for both services (MS and FS)

The methodology used, considering in first approximation a certain pfd, is linked to the assessment of the total interference provided by one GSO satellite emission in the band 460-470 MHz. The interference could be assessed for each receiver *n* on ground as:

$$I_n = pfd + G_{R_n} + 10\log\left(\frac{\lambda^2}{4\pi}\right) + 10\log\left(\frac{4}{NB}\right) \quad \text{(dBW)}$$

where:

pfd: pfd of satellite *n* in direction of receiver (dBW/m²/4 kHz)

G_{rn}: antenna gain of the receiver *n* in direction of GSO satellite (dBi)

λ: wavelength (m)

NB: necessary bandwidth of the receiver (kHz).

6.4.2 Mobile service characteristics

Table 27, below provides only the necessary parameters to perform the simulation for different MS systems. The permissible interference into the receiver (P_i) is calculated as:

$$P_i = 10\log\left(10^{\left(\frac{F}{10}\right)}\, k\, TB\right) + PR$$

where:

F : noise figure (dB)

k : Boltzmann constant (J/K)

T : noise temperature (Kelvin)

B : Receiver bandwidth (Hz)

PR : protection criteria (dB).

TABLE 27

Mobile service parameter in band 457-464 MHz

Parameters	Case 1		Case 2		Case 3
Origin of the parameters	M.1808 Analogue	M.1808 Digital	M.1808 Analogue	M.1808 Digital	M.1808 M.2110 Digital
Type of receiving stations	BS	BS	UE	UE	MS (CDMA450 as in M.2110)
Channel bandwidth (CB) (kHz)	12.5/25	6.25/12.5	12.5/25	5.5	1250
Noise figure (dB)	7	7	7	7	8
Antenna gain (dBd/dBi)	9/11	9/11	Handheld: −6/−4 Vehicular: 0/2	Handheld: −6/−4 Vehicular: 0/2	0/2
Antenna polarization	Vertical	Vertical	Vertical	Vertical	Vertical
I/*N* protection criteria (dB)	−6	−6	−6	−6	−6
Permissible power (dB(W/4 kHz))	−167				−166
Total losses (dB)	4	4	Handheld: 0 Vehicular: 1	Handheld: 0 Vehicular: 1	2 (from M.2110)
Body losses (dB)	0	0	4	4	4

TABLE 28

LTE UE Parameter in band 460-470 MHz / Case 4

LTE terminals characteristics	Values
Bandwidth (MHz)	3
Antenna gain (dBi)	0
Noise power (dBm)	−96.7
Noise power (dBW/4 kHz)	−155.5
I/*N*	−6
Permissible power (dBW/4 kHz)	−161.5

Table 28 indicates the characteristics of LTE systems used by WP 7B for sharing studies under this agenda item for PPDR applications within the frequency band 460-470 MHz.

The BS and MS system are distributed randomly on the ground surface (no MS/BS on ocean/sea). For each location of BS/MS, the azimuth follows a uniform distribution between 0 and 359 degrees by step of 1 degree (referenced from North). The elevation is taken as equal to 0 degree (pointing on the horizon).

6.4.3 Fixed service characteristics

6.4.3.1 Fixed service criteria

The fixed service characteristic of point to point (P-P) and point to multipoint (P-MP) are found in § 3.1. The protection criteria of FS links to −165 dBW/12.5 kHz.

6.4.3.2 Fixed service antenna pattern

Considerations on the antenna pattern to use in simulation are describes in § 3.1. Table 29 summarize the pattern used in the simulations.

TABLE 29

Antenna pattern configuration used in dynamics simulations with P-P and P-MP links

Link	Recommendation	Gain (dBi)
P-P	ITU-R F.1245	11
		17
P-MP	ITU-R F.1336 (Omni)	8
	ITU-R F.1336 (Sectoral)	11

6.4.4 GSO satellites characteristics

This analysis is based on only one position of GSO satellite in 0°. The study considers that GSO and NGSO satellites do not operate in the same frequency band. The following pfd mask is proposed to enable the protection of fixed service and mobile service, provided in terms of elevation angle α as:

$$pfd\ (dBW/4\ kHz) = \begin{cases} -162 & 0° \leq \alpha \leq 15° \\ -162 + 0.5(\alpha - 15) & 15° < \alpha < 35° \\ -152 & 35° \leq \alpha \leq 90° \end{cases}$$

6.4.5 Simulation for terrestrial services

In this contribution, some statistical simulations were performed in order to derive the CDF of interference in the FS receivers considering only one GSO satellite, the following element summarize the parameter of the simulations:

1 The GSO satellite is placed in the GSO arc in 0°.

2 The pfd limit described in § 6.4.4 is applied to the GSO satellite.

3 The satellites emit in circular polarisation. The polarisation losses are taken equal to 3 dB due to the fact that the mobile and fixed services (BS or UE) receive in vertical polarisation.

4 The mobile (UE or BS) and fixed services are placed randomly in different position in the visibility area of the satellite (taken as a half sphere). The terrestrial services (FS and MS) are placed only on ground surface (no equipment on the ocean or sea).

5 The MS (UE or BS) antenna is always considered as omnidirectional. In the case of BS, the pattern is described by Recommendation ITU-R F.1336 with k = 0.3. No tilt is applied, which is a worst case assumption.

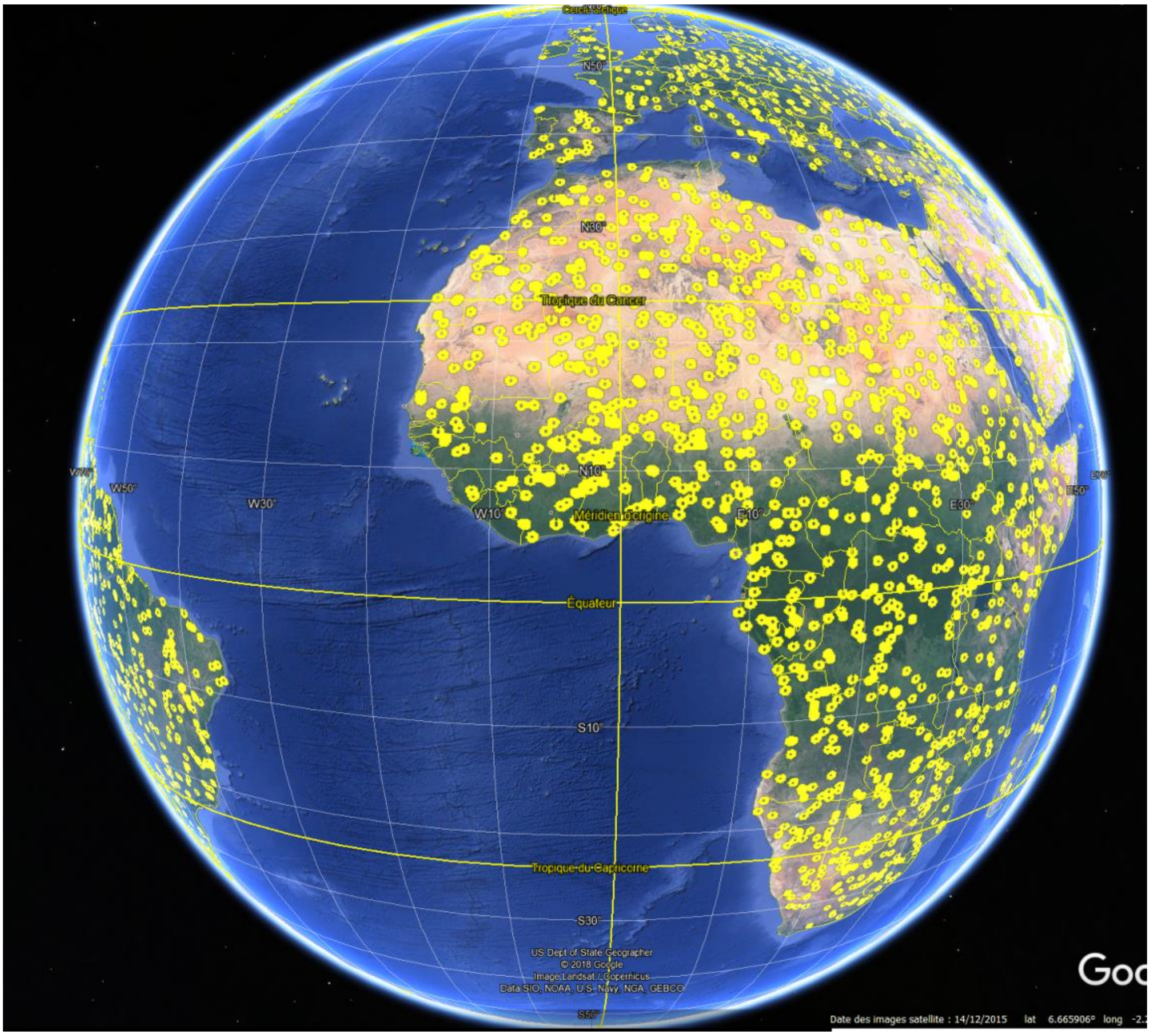
6 The FS antenna is taken as described in Table 29.

7 The CDF is derived, considering all the potential location, elevation and azimuth of terrestrial systems.

The following Fig. 17 shows some terrestrial location used to perform the simulation and the following §§ 6 and 7 provide the results of these simulations.

FIGURE 17

Representation of some terrestrial location in visibility of the GSO satellite (Yellow pin)

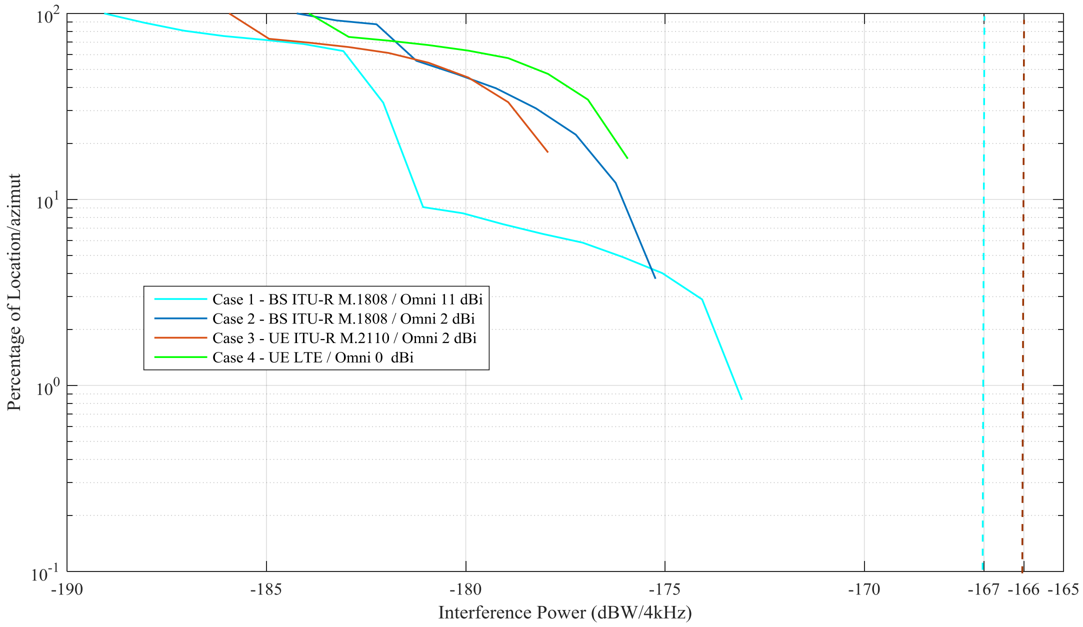


6.4.6 Results for MS

Figure 18 provides the results of simulation considering all the equipment (case 1 to 4) defined in Table 27 and Table 28.

FIGURE 18

Simulation results for each kind of equipment defined in Tables 27 and 28



Considering the pfd mask defined in § 6.4.4, the previous results show that, for all MS systems considered, the protection criteria is never exceeded.

It should be noted that these simulations do not consider terrain profile and clutter for low elevation angle and Base Stations tilt.

6.4.7 Results for FS

Figure 19 provides the results of simulation considering all links of FS defined in § 4.

Considering the pfd mask defined in § 5, the following results show that:

– The protection criteria of FS P-MP with sectorial antenna with a maximum gain of 17 dBi is never exceeded

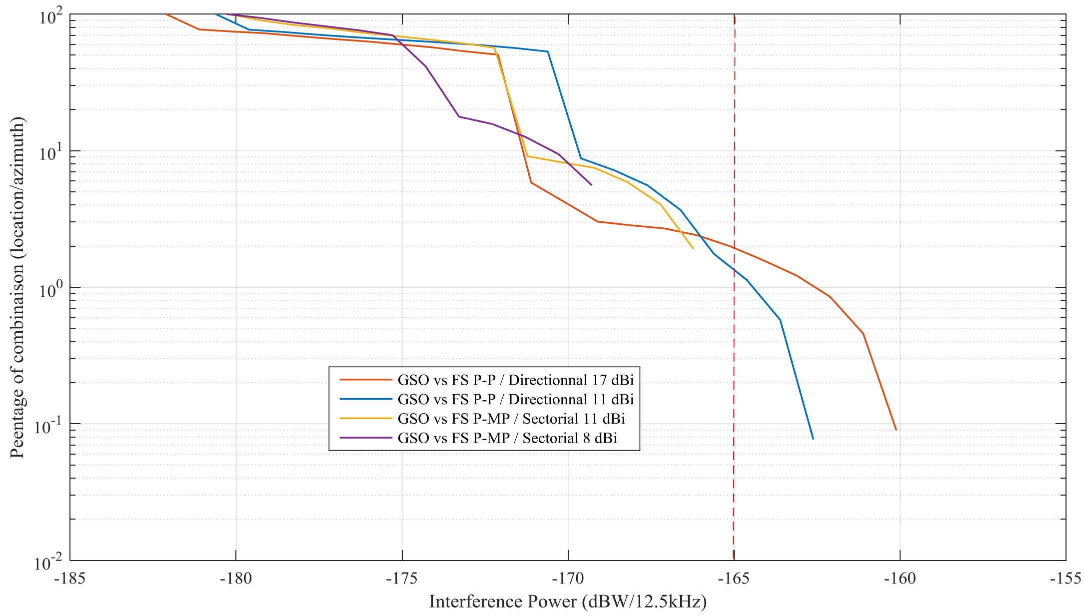
– The protection criteria of FS P-MP with sectorial antenna with a maximum gain of 11 dBi is never exceeded

– The protection criteria of FS P-P with directional antenna with a maximum gain of 17 dBi could be exceeded for 2% of the combination of localisation/azimuth. Only FS pointing directly to the geostationary arc could be interfered.

– The protection criteria of FS P-P with directional antenna with a maximum gain of 11 dBi could be exceeded for 1.2% of the combination of localisation/azimuth. Only FS pointing directly to the geostationary arc could be interfered.

FIGURE 19

Simulation results for each kind of FS equipment



It should be noted that FS pointing directly to the geostationary arc occurs at low elevation angles. For these cases for low elevation angle, these simulations do not consider terrain profile and clutter.

6.4.8 Conclusion (GSO case)

The MetSat/EESS pfd mask proposed for GSO satellite operating in MetSat/EESS to ensure protection of the mobile and fixed services in the band 460-470 MHz is the following, provided in terms of elevation angle α as:

$$pfd\ (dBW/4kHz) = \begin{cases} -162 & 0° \leq \alpha \leq 15° \\ -162 + 0.5(\alpha - 15) & 15° < \alpha < 35° \\ -152 & 35° \leq \alpha \leq 90° \end{cases}$$

7 Conclusions

Studies contained in this Report determined METSAT and EESS pfd masks in the 460-470 MHz band which will ensure protection of incumbent primary allocated services operating in this band and adjacent bands.

The required pfd mask for non-GSO satellites is, provided in terms of elevation angle α:

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4 \text{ kHz})) = \begin{cases} -157 & 0° \leq \alpha \leq 5° \\ -157 + 0.5(\alpha - 5) & 5° < \alpha \leq 15° \\ -152 & 15° < \alpha \leq 90° \end{cases}$$

The result of studies did not converge on a single pfd mask for the GSO case.

The required pfd mask for the GSO satellites as determined by study 1 is, provided in terms of elevation angle α:

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4 \text{ kHz})) = -156 + 0.033 \times \alpha \qquad 0° \leq \alpha \leq 90°$$

The required pfd mask for the GSO satellites as determined by study 2 is, provided in terms of elevation angle α:

$$pfd \text{ values in dB(W/ } (m^2 \cdot 4 \text{ kHz})) = \begin{cases} -162 & 0° \leq \alpha \leq 15° \\ -162 + 0.5(\alpha - 15) & 15° < \alpha < 35° \\ -152 & 35° \leq \alpha \leq 90° \end{cases}$$

8 Definitions and abbreviations

DCP	Data collection system platform
DCS	Data collection system
BS	Base station
BPSK	Binary phase shift keying
BW	Bandwidth
CDMA	Code division multiple access
CDMA450	CDMA-MC system operating in the 450-470 MHz band
CDMA-MC	CDMA multi-carrier
CPM	Conference Preparatory Meeting
CS	Central Station
CSA	Central Station Alarm
dB	Decibels
dBi	Gain in dB relative to an isotropic antenna
DCPI	Data collection platform interrogate
DCPC	Data collection platform command
DTV	Digital television
DSSS	Direct sequence spread spectrum
e.r.p.	Effective radiated power (relative to a dipole)
e.i.r.p.	Effective isotropically radiated power
FDP	Fractional degradation in performance
FDR	Frequency dependent rejection ratio
FM	Frequency modulation
FS	Fixed service
GMSK	Gaussian minimum shift keying
GSO	Geostationary Orbit
IF	Intermediate frequency
kHz	Kilohertz
km	Kilometres
kW	Kilowatt
LTE	Long-Term Evolution

MS	mobile station (physical entity) or mobile service (allocation)
MHz	Megahertz
non-GSO	Non-geostationary orbit
NMT	Nordic mobile telephone
OOBE	Out of band emissions
PAMR	Public access mobile radio
pfd	Power flux density
PMR	Private mobile radio
P-MP	Point-to-multipoint
PPDR	Public Protection and Disaster Relief
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RF	Radio frequency
RFI	Radio frequency interference
Rx	Receiver
SSMA	Spread spectrum multiple access