International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R M.2360-0

(06/2015)

Sharing between GSO MSS and other services in the allocations in the 22-26 GHz range

M Series

Mobile, radiodetermination, amateur and related satellite service

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1865 - 2015

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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.*

Electronic Publication
Geneva, 2015

REPORT ITU-R M.2360-0

Sharing between GSO MSS and other services in the allocations in the 22-26 GHz range*

(2015)

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* New studies of the potential impact of MSS emissions on RAS, EESS (passive) and FS were incorporated into this Report without the opportunity for the concerned ITU-R expert working parties to review and comment on the contents or conclusions of these studies prior to WRC-15.

1 Introduction

WRC-15 agenda item 1.10 calls for consideration of spectrum requirements and possible additional spectrum allocations for the mobile-satellite service in the Earth-to-space and space-to-Earth directions in portions of the bands between 22 GHz and 26 GHz. This consideration must ensure protection of existing services within these bands, as well as take into account RR No. **5.340** and RR No. **5.149** in accordance with the provisions of Resolution **234 (WRC-12)**.

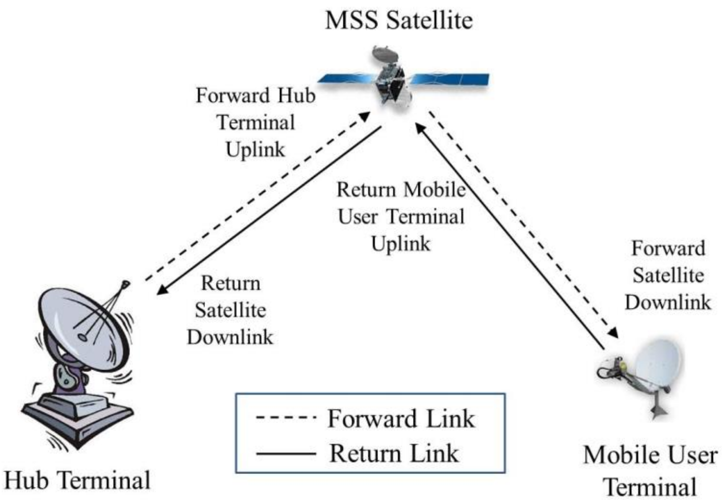
This Report provides information on sharing between existing services in the allocations in the spectrum range 22-26 GHz and the geostationary-satellite orbit (GSO) type of mobile-satellite service (MSS) network proposed to operate in the uplink and downlink directions.

2 MSS system characteristics

This section includes the characteristics of the envisioned MSS network. A reference architecture defining the elements and RF links in the network is depicted in Fig. 2-1 below.

FIGURE 2-1

MSS Network Reference Architecture



2.1 GSO MSS user terminal characteristics

The proposed GSO MSS user terminal characteristics are provided in Table 2.1-1.

TABLE 2.1-1

GSO MSS user terminal transmit and receive characteristics

Characteristics of user terminal	Units	User terminal	Network hub terminal
Transmitter centre frequency	(GHz)	24	24
Transmitter bandwidth	MHz	4.05	16.2
Transmit antenna diameter	(m)	0.33	2.4
Transmit antenna peak gain	(dBi)	37.4	53.7
Transmit equivalent isotropically radiated power e.i.r.p. per carrier	(dBW)	39.85	57.23
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		See Figs 2.1-1A, 2.1-1B (Note: Rec. S.580 can be used)	Rec. S.580
Transmit antenna minimum elevation angle	(degrees)	5-10	5-10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		linear	linear
Transmit losses	(dB)	0.77	0.77
Receiver centre frequency	(GHz)	24	24
Receive antenna diameter (If different from transmit)	(m)	0.33	2.4
Receive antenna peak gain, G_R (If different from transmit)	(dBi)	36.4	52.7
Receive antenna polarization (RHC, LHC, VL, HL or offset linear)		linear	linear
System noise temperature, Tsys	(K)	246.2	263.2
OMT loss, L_O	(dB)	0.64	0.96
Receiver IF bandwidth at –3 dB	(MHz)	16.2	4.05
Receiver Losses	(dB)	1.1	1.1
G/T (G_R – L_O – 10log(Tsys))	(dB/K)	11.84	27.54

* Value to be calculated using Recommendation ITU-R SM.1541.

FIGURE 2.1-1A

GSO MSS user terminal antenna pattern – Tx azimuth pattern

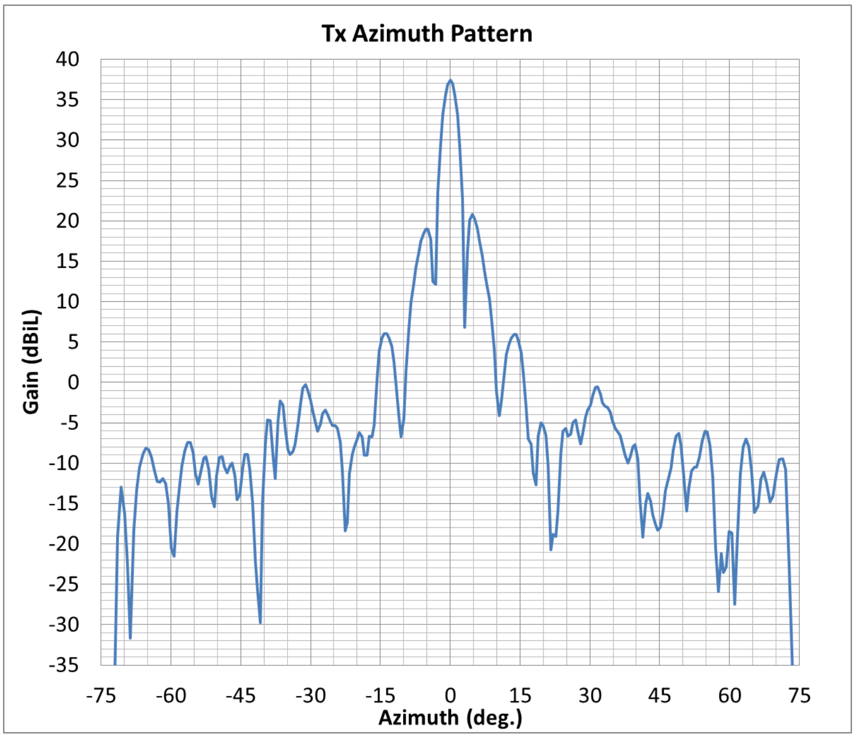
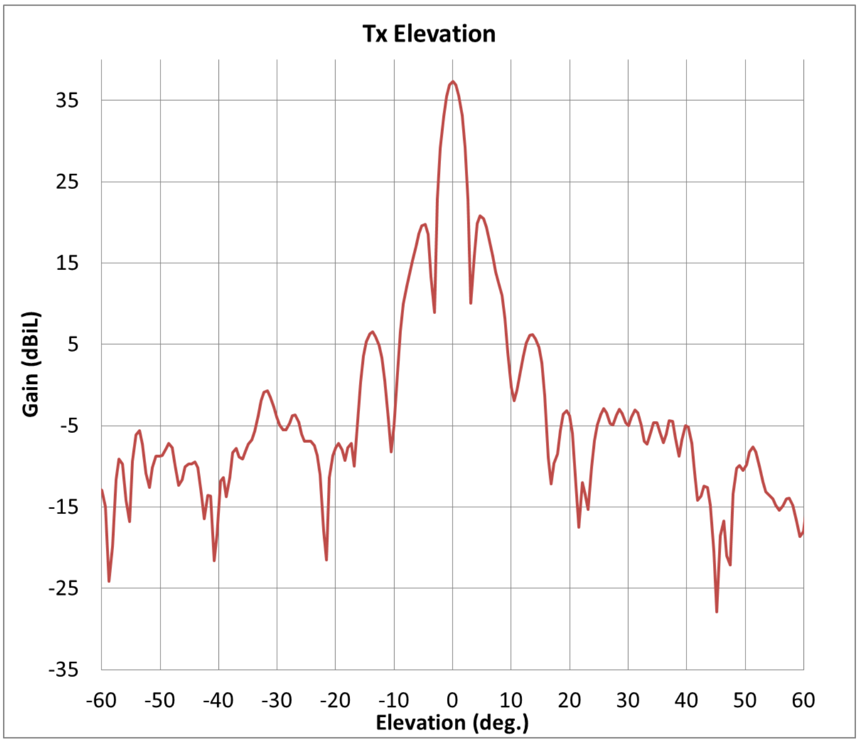


FIGURE 2.1-1B

GSO MSS user terminal antenna pattern – Tx elevation



2.2 GSO MSS satellite characteristics

The proposed GSO MSS satellite characteristics are provided in Table 2.2-1.

TABLE 2.2-1

GSO MSS satellite characteristics

GSO	Units	Forward link	Return link
Transponder Bandwidth	(MHz)	125	
Carrier parameters			
Centre frequency of uplink band	(GHz)	24	24
Uplink polarization (RHC, LHC, VL, HL or offset linear)		linear	linear
Centre frequency of downlink band	(GHz)	24	24
Downlink polarization (RHC, LHC, VL, HL or offset linear)		linear	linear
Modulation type (e.g. FM, BPSK, QPSK etc.)		QPSK	BPSK
Uplink occupied bandwidth per carrier	(MHz)	16.2	4.05
Downlink occupied bandwidth per carrier	(MHz)	16.2	4.05
Receive antenna gain	(dBi)	44.38	44.38
Transmit e.i.r.p. per carrier	(dBW)	44.21	33.28
Peak transmit antenna gain	(dBi)	43.29	43.29
Satellite G/T	(dB/K)	10	10
Antenna diameter	(m)	0.8	0.8
Antenna beamwidth	(degrees)	1	1

2.3 GSO MSS link parameters

Table 2.3-1 below presents end-to-end link parameters to be used in these studies.

TABLE 2.3-1

GSO MSS link parameters

List of parameters	Values
Additional losses	Uplink = 0.77 dB Downlink = 1.1 dB
Rain Attenuation (based on satellite at 44ºE as seen from Dubai, UAE Using P.618-10, (moderate rainfall rate) Hub availability: 99.5% UT availability: 99%	Forward (Hub to Sat) = 3.07 dB (U/L) Forward (Sat to Mobile User Terminal) = 1.14 dB (D/L) Return (Mobile User Terminal to Sat) = 1.55 dB (U/L) Return (Sat to Hub) = 2.27 dB (D/L)

3 Results of studies

Summarized data on existing allocations of frequency bands in the range 22-26 GHz are shown in Table 3-1.

TABLE 3-1

Existing spectrum allocations in the frequency range 22-26 GHz

<table>
<tr><th rowspan="2">Band (GHz)</th><th rowspan="2">Bandwidth (MHz)</th><th colspan="3">The main existing allocations</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>22-22.21</td><td>210</td><td colspan="3">FIXED
MOBILE except aeronautical mobile
5.149</td></tr>
<tr><td>22.21-22.5</td><td>290</td><td colspan="3">EARTH EXPLORATION-SATELLITE (passive)
FIXED
MOBILE except aeronautical mobile
RADIO ASTRONOMY
SPACE RESEARCH (passive)
5.149</td></tr>
<tr><td>22.5-22.55</td><td>50</td><td colspan="3">FIXED
MOBILE</td></tr>
<tr><td>22.55-23.15</td><td>600</td><td colspan="3">FIXED
INTER-SATELLITE
MOBILE
SPACE RESEARCH (Earth-to-space)
5.149</td></tr>
<tr><td>23.15–23.55</td><td>400</td><td colspan="3">FIXED
INTER-SATELLITE
MOBILE</td></tr>
<tr><td>23.55–23.6</td><td>50</td><td colspan="3">FIXED
MOBILE</td></tr>
<tr><td>23.6-24</td><td>400</td><td colspan="3">EARTH EXPLORATION-SATELLITE (passive)
RADIO ASTRONOMY
SPACE RESEARCH (passive)
5.340</td></tr>
<tr><td>24-24.05</td><td>50</td><td colspan="3">AMATEUR
AMATEUR-SATELLITE</td></tr>
<tr><td>24.05-24.25</td><td>200</td><td colspan="3">RADIOLOCATION
Amateur
Earth exploration satellite (active)</td></tr>
<tr><td>24.25–24.45</td><td>200</td><td>FIXED</td><td>RADIONAVIGATION</td><td>RADIONAVIGATION
FIXED
MOBILE</td></tr>
<tr><td>24.45–24.65</td><td>200</td><td>FIXED
INTER-SATELLITE</td><td>INTER-SATELLITE
RADIONAVIGATION</td><td>FIXED
INTER-SATELLITE
MOBILE
RADIONAVIGATION</td></tr>
</table>

<table>
<tr><th rowspan="2">Band (GHz)</th><th rowspan="2">Bandwidth (MHz)</th><th colspan="3">The main existing allocations</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>24.65–24.75</td><td>100</td><td>FIXED
FIXED-SATELLITE (Earth-to-space)
INTER-SATELLITE</td><td>INTER-SATELLITE
RADIOLOCATION-SATELLITE (Earth-to-space)</td><td>FIXED
FIXED-SATELLITE (Earth-to-space)
INTER-SATELLITE
MOBILE</td></tr>
<tr><td>24.75–25.25</td><td>500</td><td>FIXED
FIXED-SATELLITE (Earth-to-space)</td><td>FIXED-SATELLITE (Earth-to-space)</td><td>FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE</td></tr>
<tr><td>25.25–25.5</td><td>250</td><td colspan="3">FIXED
INTER-SATELLITE
MOBILE
Standard frequency and time signal-satellite (Earth-to-space)</td></tr>
<tr><td>25.5–26</td><td>500</td><td colspan="3">EARTH EXPLORATION-SATELLITE (space-to-Earth)
FIXED
INTER-SATELLITE
MOBILE
SPACE RESEARCH (space-to-Earth)
Standard frequency and time signal-satellite (Earth-to-space)</td></tr>
</table>

It is obvious that additional spectrum for MSS in the range 22-26 GHz could be allocated only on the basis of frequency sharing and compatibility with the existing services. Therefore a preliminary analysis of the frequency range 22-26 GHz was aimed at identification of the most obvious difficulties for sharing with existing radio services. The analysis was based on consideration of the following criteria:

– radioastronomy service (RAS) operations in a frequency band considered or in the adjacent bands;

– Earth exploration-satellite service (EESS) (passive) allocations in a frequency band considered;

– space research service (SRS) (passive) allocations in a frequency band considered;

– radiolocation service (RLS) allocations in a frequency band considered;

– inter-satellite service (ISS) allocations in a given frequency band when MSS uplink allocation was considered.

On the basis of the above criteria it was determined that difficult problems in sharing with existing services would be expected in the frequency bands 22-22.21 GHz, 22.21-22.5 GHz, 22.5-22.55 GHz, 23.55-23.6 GHz, 23.6-24 GHz, 24-24.05 GHz, 24.05-24.25 GHz and 24.65-24.75 GHz. It was also determined that it would be inappropriate to consider the above frequency bands as priority ones for studies associated with WRC-15 AI 1.10.

The remaining frequency bands including 22.55-23.15 GHz (downlink), 23.15-23.55 GHz (downlink), 24.25-24.45 GHz (uplink/ downlink), 24.45-24.65 GHz (uplink and downlink), 24.75-25.25 GHz (uplink), 25.25-25.5 GHz (uplink/downlink) and 25.5-26 GHz (downlink) were the primary focus for study under WRC-15 AI 1.10. Note that in the band 22.55-23.55 GHz, there are radioastronomy operations in 23.07-23.12 GHz.

It was noted that the bands adjacent to the 22.21-22.5 GHz Radio Astronomy band have very different bandwidths (210 MHz lower adjacent band, 22.0-22.22 GHz; 50 MHz upper adjacent band, 22.5-22.55 GHz).

The material in this Section includes studies addressing sharing between the MSS and incumbent services in each of the 15 bands identified in Table 3-1. Note that not all sharing scenarios have been studied for all bands. For example, no study has been conducted which examines FS interference into MSS earth stations.

3.1 The frequency band 22-22.21 GHz

Allocations for this frequency band are shown in Table 3.1-1:

TABLE 3.1-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 22-22.21 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
22-22.21	FIXED MOBILE except aeronautical mobile 5.149	

5.149 In making assignments to stations of other services to which the bands:… 22.01-22.21 GHz are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see RR Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

3.1.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.1-2.

TABLE 3.1-2

ITU-R Recommendations relevant to the sharing studies in the band 22-22.21 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
RAS (No allocation – operation under RR **5.149**)	ITU-R RA.769 supplemented by Report ITU-R RA.2131

3.1.2 Sharing studies in the frequency band 22-22.21 GHz

3.1.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented below. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

The proposed GSO MSS user terminal characteristics are contained in Table 2.1-1, which is used to perform the sharing study.

The proposed GSO MSS space-station downlink characteristics are contained in Table 2.2-1, which is used to perform the sharing study.

Figure 3.1-1 plots FS off-axis angle as a function of MSS GSO off-zenith angle for three different FS elevation angles of 0, 5 and 10 degrees.

FIGURE 3.1-1

FS off-axis angle as a function of MSS GSO off-zenith angle for 3 FS elevation angles

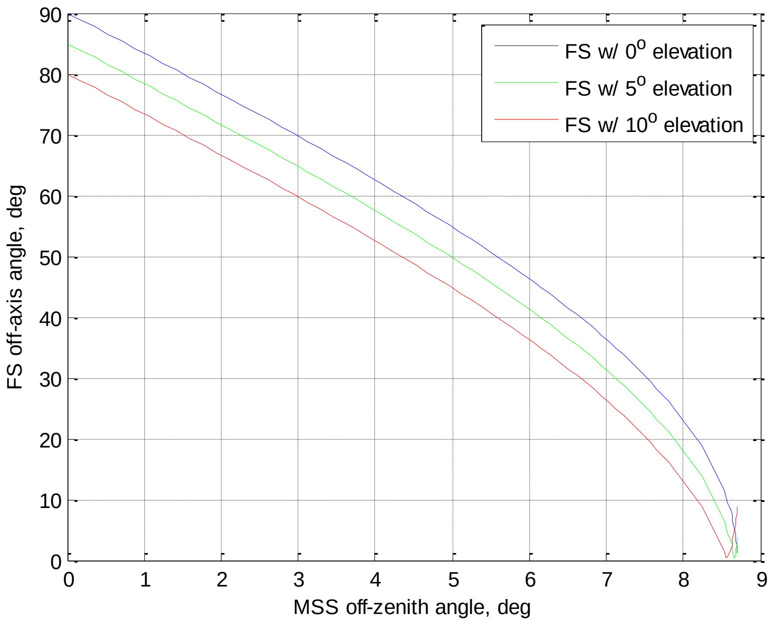
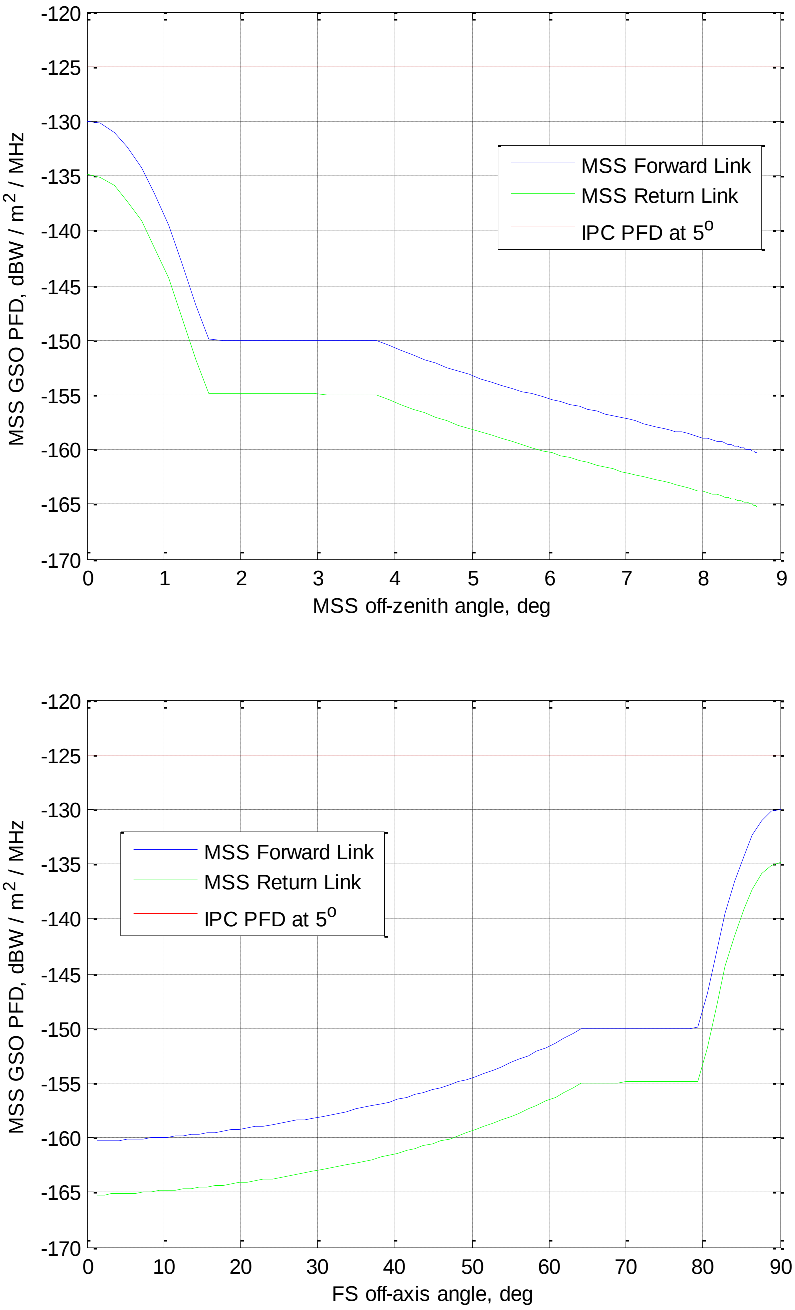


Figure 3.1-2 plots the MSS GSO PFD (dBW/m^2/MHz) as a function of MSS off-zenith angle and as a function of FS off-axis angle for MSS GSO with a maximum transmit e.i.r.p. spectral densities of –27.88 dBW/Hz for forward link and of –32.79 dBW/Hz for return link, and a peak transmit antenna gain of 43.29 dBi, as seen by a FS with a 0° elevation angle. The MSS satellite antenna gains are assumed to follow Recommendation ITU-R S.672-4. As shown in Fig. 3.1.-2, the derived MSS GSO PFD is below the PFD threshold limit to protect FS (particularly, –125.0 dBW/m^2/MHz at 5° off-axis angle).

FIGURE 3.1-2

MSS GSO PFD for FS with 0º elevation angle



3.1.2.2 MSS and MS

No studies were conducted to assess sharing between MSS and MS in the 22-22.21 GHz band.

3.1.3 Results of sharing studies in the frequency band 22-22.21 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

It was determined in initial analyses (see Section 3) that this band is inappropriate for consideration for MSS use. Therefore, no studies were done to assess sharing feasibility with the mobile service in this band. Similarly, no studies were done to assess the potential impact on radioastronomy operations called for under RR **5.149.**

3.2 The frequency band 22.21-22.5 GHz

Allocations for this frequency band are shown in Table 3.2-1:

TABLE 3.2-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 22.21-22.5 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
22.21-22.5	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) 5.149 5.532	

5.149 In making assignments to stations of other services to which the bands:… 22.01-22.21 GHz … are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see RR Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

5.532 The use of the band 22.21-22.5 GHz by the Earth exploration-satellite (passive) and space research (passive) services shall not impose constraints upon the fixed and mobile, except aeronautical mobile, services.

3.2.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.2-2.

TABLE 3.2-2

ITU-R Recommendations relevant to the sharing studies in the band 22.21-22.5 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
EESS (passive)	ITU-R RS.515, ITU-R RS.1028, ITU-R RS.1813, ITU-R RS.1861, ITU-R RS.1029
RA	ITU-R SA.509, ITU-R RA.769, ITU-R RA.1631, ITU-R RA.517, ITU-R RA.611, ITU-R RA.1031, ITU-R RA.1237, ITU-R RA.1513
SRS (passive)	ITU-R RS.515, ITU-R RS.1028, ITU-R RS.1813, ITU-R RS.1861, ITU-R RS.1029

3.2.2 Sharing studies in the frequency band 22.21-22.5 GHz

3.2.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

3.2.2.2 MSS and MS

No studies were conducted to assess sharing between MSS and MS in the 22.21-22.5 GHz band.

3.2.2.3 MSS and EESS (passive)

No studies were conducted to assess sharing between MSS and EESS (passive) in the 22.21-22.5 GHz band or the impact of unwanted emissions from MSS on the EESS (passive) in this band.

3.2.2.4 MSS and RAS

No studies were conducted to assess sharing between MSS and radio astronomy in the 22.21-22.5 GHz band or the impact of unwanted emissions from MSS on the RAS in this band.

3.2.2.5 MSS and SRS (passive)

No studies were conducted to assess sharing between MSS and SRS (passive) in the 22.21-22.5 GHz band or the impact of unwanted emissions from MSS on SRS (passive) in this band.

3.2.3 Results of sharing studies in the frequency band 22.21-22.5 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

It was determined in initial analyses (see § 3) that this band is inappropriate for consideration for MSS use. Therefore, no studies were done to assess sharing feasibility with the mobile, radio astronomy, EESS (passive) or SRS (passive) services in this band.

3.3 The frequency band 22.5-22.55 GHz

Allocations for this frequency band are shown in Table 3.3-1:

TABLE 3.3-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 22.5-22.55 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
22.5-22.55	FIXED MOBILE	

3.3.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.3-2.

TABLE 3.3-2

ITU-R Recommendations relevant to the sharing studies in the band 22.5-22.55 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7

3.3.2 Sharing studies in the frequency band 22.5-22.55 GHz

3.3.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

3.3.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.3.3 Results of sharing studies in the frequency band 22.5-22.55 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Refer to of Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.4 The frequency band 22.55-23.15 GHz

Allocations for this frequency band are shown in Table 3.4-1:

TABLE 3.4-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 22.55-23.15 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
22.55-23.15	FIXED INTER-SATELLITE 5.338A MOBILE SPACE RESEARCH (Earth-to-space) 5.532A 5.149	

5.149 In making assignments to stations of other services to which the bands:… 22.81-22.86 GHz and 23.07-23.12 GHz … are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see RR Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

5.338A In the bands 1 350-1 400 MHz, 1 427-1 452 MHz, 22.55-23.55 GHz, 30-31.3 GHz, 49.7-50.2 GHz, 50.4-50.9 GHz, 51.4-52.6 GHz, 81-86 GHz and 92-94 GHz, Resolution **750 (Rev.WRC-12)** applies. (WRC-12)

5.532A The location of earth stations in the space research service shall maintain a separation distance of at least 54 km from the respective border(s) of neighbouring countries to protect the existing and future deployment of fixed and mobile services unless a shorter distance is otherwise agreed between the corresponding administrations. Nos. **9.17** and **9.18** do not apply. (WRC-12)

Spectrum sharing between MSS and fixed and mobile services would be required in this frequency band.

Besides conditions of compatibility of the envisioned MSS with ISS and SRS (Earth-to-space) would require relevant studies.

It is to note that based on RR No. **5.149** administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference in the frequency bands 22.81-22.86 GHz and 23.07-23.12 GHz therefore feasibility of protecting RAS by envisioned MSS systems requires appropriate examination.

3.4.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.4-2.

TABLE 3.4-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 22.55-23.15 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7
Inter-satellite	ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R Report SA.2192, ITU-R SA.1743
Space research	ITU-R SA.609, ITU-R SA.509, ITU-R SA.1743, ITU-R SA.1882
RAS (No allocation – operation under RR **5.149**)	ITU-R RA.769 supplemented by Report ITU-R RA.2131

3.4.2 Sharing studies in the frequency band 22.55-23.15 GHz

3.4.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

3.4.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.4.2.3 MSS and ISS

3.4.2.3.1 ISS supporting space research systems (data relay satellite systems using GSO-NGSO links)

Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems. The two analyses in this section apply to both the 22.55-23.15 GHz and 23.15-23.55 GHz bands.

NOTE – As shown in Fig. A3-4 of Annex 3, this study assumes an MSS system with spot beams covering land masses only. It is expected that typical MSS systems would feature coverage over significant portions of the ocean areas for aeronautical and maritime users. Accordingly, the actual interference from MSS into DRS systems might exceed those shown in the study results given below in §§ 3.4.2.3.1.1.1 and 3.4.2.3.1.2.1.

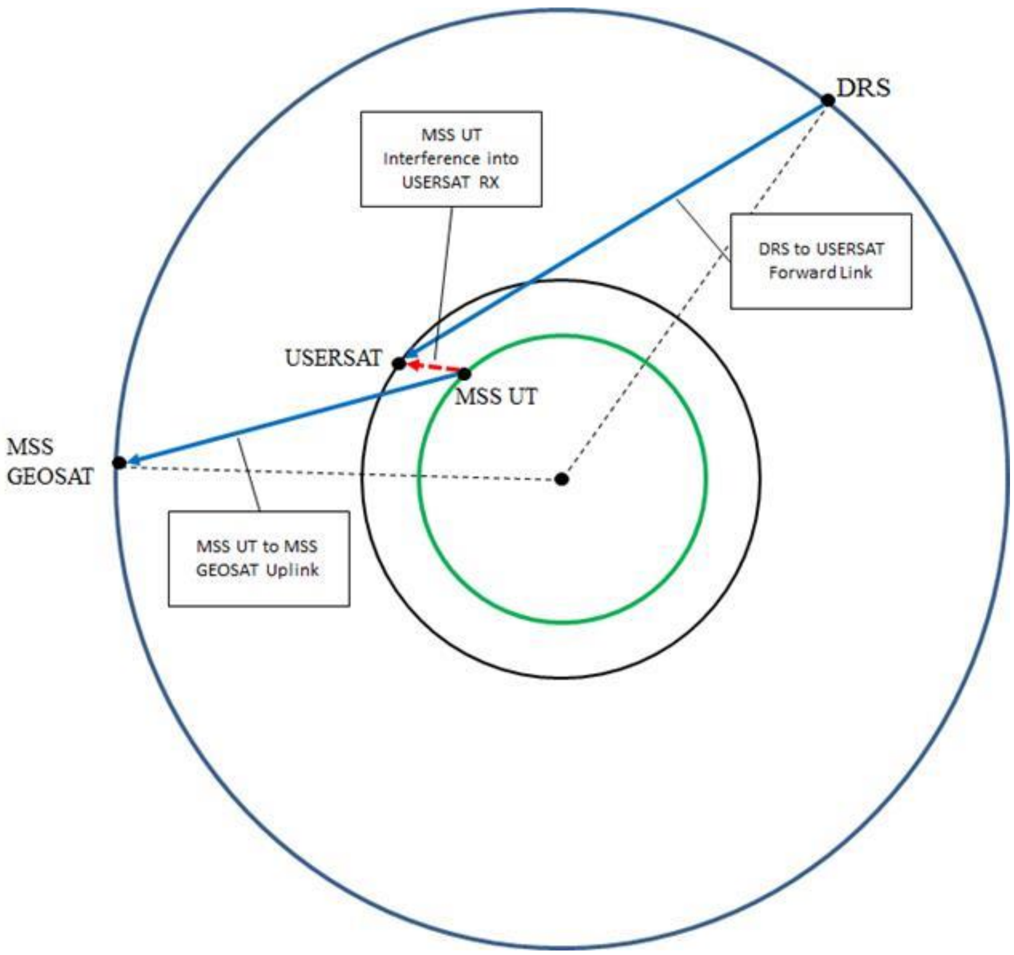
3.4.2.3.1.1 MSS user terminal uplink interference DRS forward link (SRS GEO-to-SRS LEO) (Scenario 3)

This analysis applies to both the 22.55-23.15 GHz and 23.15-23.55 GHz bands.

This scenario considers MSS user terminal (UT) uplink interference into the DRS forward link. The basic geometry is shown in Fig. 3.4-1.

FIGURE 3.4-1

MSS UT Interference into DRS Forward Link



The wanted links are shown in blue and these are the uplink from the MSS UT to the MSS GEOSAT and the forward link from the DRS (in GEO) to the USERSAT (in LEO). The victim receiver in this case is on the LEO USERSAT. The interference path from the MSS UT to the USERSAT is indicated by the dashed red line. Note that the interference geometry in this scenario is such that MSS GEOSATs at large orbital separations from the DRS generally result in the highest interference into the forward link – not the MSS GEOSATs adjacent to the DRS. This is due to the above geometry which results in the interfering MSS UT antenna having low discrimination in the direction of the USERSAT and the USERSAT receiving antenna also having low discrimination in the direction of the MSS UT. Again, this is the simplified geometry. In the analysis and simulations described in Annex 3, the aggregate interference from multiple MSS UTs in multiple uplink spot beams and from multiple GSO MSS satellites is calculated. The aggregate interference is time-varying since the USERSAT receiving beam is tracking a DRS and therefore the USERSAT receive antenna gain in the direction of the interfering MSS UTs will be time-varying as well as the transmit antenna gains of the MSS UTs in the direction of the (moving) USERSAT. The relevant USERSAT forward link receiver parameters are listed in Table A3-3 of Annex 3.

Since the Recommendation ITU-R SA.1155 interference protection criterion is in terms of an interference power spectral density (i.e. units of dBW/Hz) rather than an absolute interference level (i.e. units of dBW) and the MSS UT multiple access scheme is assumed to be FDMA, it is only necessary that a single MSS UT per uplink spot beam per GSO MSS satellite be modelled. Furthermore, since the victim receiver bandwidth in this case (50 MHz) is less than the MSS spot beam sub-band bandwidth of 125 MHz, it is assumed that only the F1 (red/green) or F2 (blue/yellow) spot beams as shown in Annex 3 are interfering. The F1 (red/green) beams were used in the analysis. Therefore, referring to Fig. 3.4-1, the analysis models a single MSS UT per uplink spot beam (located at the centre of the red and green spot beams) with an e.i.r.p. spectral density of –26.2 dBW/Hz (i.e. e.i.r.p. of 39.85 dBW per channel over 4.05 MHz channel bandwidth) with the transmit antenna gain pattern shown in Fig. A3-3 of Annex 3. Aggregate interference statistics were then generated for the (5) sample DRS locations in Table A3-3 of Annex 3 and for GSO MSS satellites at various locations and orbital spacings from the DRS.

3.4.2.3.1.1.1 Study Results for Scenario 3

Table 3.4-3 shows the results of the analysis with a separate sub-table for each of the (5) DRS locations. The values in the table correspond to a 0.1% time exceedance per the protection criterion in Recommendation ITU-R SA.1155.

TABLE 3.4-3

Interference Results for MSS UT Uplink Interference into DRS Forward Link (Values shown are for 0.1% time exceedance)

MSS UT UPLINK INTERFERENCE FOR 174°W DRS FORWARD LINK					
# MSS GEOSATs	MSS GEOSAT LOCATIONS	Io (dBW/Hz)	Io/No (dB) (for Rx SNT = 290K; No = -204 dBW/Hz)	Io/No(dB) (for Rx SNT = 1824K; No = -196 dBW/Hz)	TOP 10 Interfering MSS GEOSAT Locations
72	180W to 180E in 5 deg steps	-208.1	-4.1	-12.1	[140 125 120 -115 -105 90 115 135 -75 165]
62	180W to 180E in 5 deg steps with top 10 interfering MSS GEOSATs removed	-208.9	-4.9	-12.9	[-95 155 130 -135 70 -110 110 -70 -65 -45]
52	180W to 180E in 5 deg steps with top 20 interfering MSS GEOSATs removed	-210.2	-6.2	-14.2	

MSS UT UPLINK INTERFERENCE FOR 62°W DRS FORWARD LINK					
# MSS GEOSATs	MSS GEOSAT LOCATIONS	Io (dBW/Hz)	Io/No (dB) (for Rx SNT = 290K; No = -204 dBW/Hz)	Io/No(dB) (for Rx SNT = 1824K; No = -196 dBW/Hz)	TOP 10 Interfering MSS GEOSAT Locations
72	180W to 180E in 5 deg steps	-206.8	-2.8	-10.8	[35 -55 5 30 -65 -25 40 -10 -40 55]
62	180W to 180E in 5 deg steps with top 10 interfering MSS GEOSATs removed	-207.6	-3.6	-11.6	[-45 10 -115 20 -50 -105 15 -60 -5 -75]
52	180W to 180E in 5 deg steps with top 20 interfering MSS GEOSATs removed	-209.2	-5.2	-13.2	

MSS UT UPLINK INTERFERENCE FOR 41°W DRS FORWARD LINK					
# MSS GEOSATs	MSS GEOSAT LOCATIONS	Io (dBW/Hz)	Io/No (dB) (for Rx SNT = 290K; No = -204 dBW/Hz)	Io/No(dB) (for Rx SNT = 1824K; No = -196 dBW/Hz)	TOP 10 Interfering MSS GEOSAT Locations
72	180W to 180E in 5 deg steps	-206.7	-2.7	-10.7	[35 -55 5 55 30 -65 -25 40 -10 -40]
62	180W to 180E in 5 deg steps with top 10 interfering MSS GEOSATs removed	-207.5	-3.5	-11.5	[-45 10 25 -115 20 -50 -105 75 15 -60]
52	180W to 180E in 5 deg steps with top 20 interfering MSS GEOSATs removed	-208.4	-4.4	-12.4	

MSS UT UPLINK INTERFERENCE FOR 47°E DRS FORWARD LINK					
# MSS GEOSATs	MSS GEOSAT LOCATIONS	Io (dBW/Hz)	Io/No (dB) (for Rx SNT = 290K; No = -204 dBW/Hz)	Io/No(dB) (for Rx SNT = 1824K; No = -196 dBW/Hz)	TOP 10 Interfering MSS GEOSAT Locations
72	180W to 180E in 5 deg steps	-206.2	-2.2	-10.2	[140 35 -55 125 5 55 30 120 -25 40]
62	180W to 180E in 5 deg steps with top 10 interfering MSS GEOSATs removed	-207.3	-3.3	-11.3	[-10 -45 10 25 20 90 75 15 115 -5]
52	180W to 180E in 5 deg steps with top 20 interfering MSS GEOSATs removed	-208.2	-4.2	-12.2	

MSS UT UPLINK INTERFERENCE FOR 89°E DRS FORWARD LINK					
# MSS GEOSATs	MSS GEOSAT LOCATIONS	Io (dBW/Hz)	Io/No (dB) (for Rx SNT = 290K; No = -204 dBW/Hz)	Io/No(dB) (for Rx SNT = 1824K; No = -196 dBW/Hz)	TOP 10 Interfering MSS GEOSAT Locations
72	180W to 180E in 5 deg steps	-206.4	-2.4	-10.4	[140 35 125 5 55 30 120 40 -10 10]
62	180W to 180E in 5 deg steps with top 10 interfering MSS GEOSATs removed	-207.6	-3.6	-11.6	[25 20 90 75 15 115 -5 135 -20 165]
52	180W to 180E in 5 deg steps with top 20 interfering MSS GEOSATs removed	-208.6	-4.6	-12.6	

Note from the table that the interference is not excessive. Even with a fully populated orbit of 72 MSS satellites spaced 5° apart, the interference does not exceed the Recommendation ITU-R SA.1155 threshold by more than 2 dB. As mentioned previously and as can be observed from the last column of the tables, it is often the MSS UTs uplinking to MSS GEOSATs far away from the DRS that contribute the most interference. For example, for a DRS forward link coming from 41°W DRS, it is the MSS UTs uplinking to the MSS GEOSAT at 35°E that contributes the most interference. For a particular DRS location, the Recommendation ITU-R SA.1155 threshold can be satisfied by excluding MSS GEOSATs at 10-20 locations which could lead to a large number of exclusions when considering the 32 possible DRS locations in Recommendation ITU-R SA.1276-3. However, as noted earlier, the aggregate interference with a fully populated MSS orbit does not exceed the threshold by more than 2 dB so this does not appear to be the limiting scenario for 22.55-23.55 GHz.

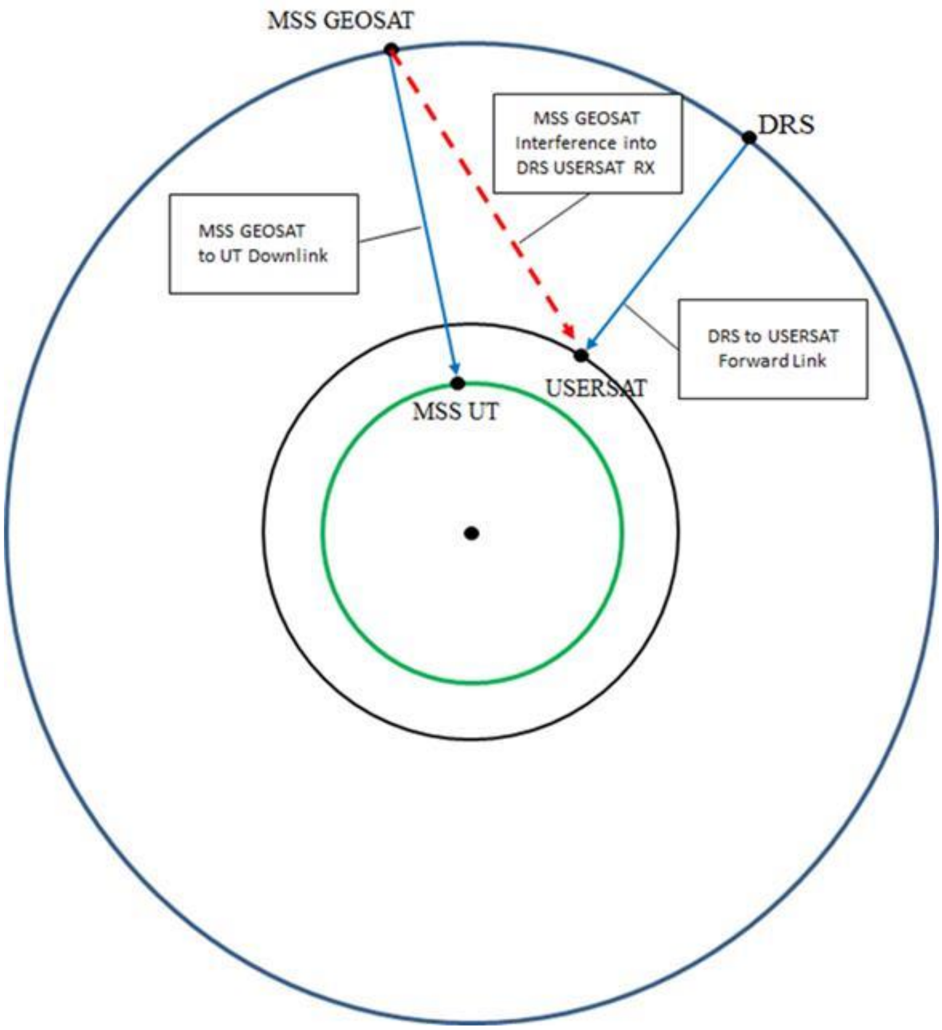
3.4.2.3.1.2 MSS GSO satellite downlink interference into DRS forward link (SRS GEO-to-SRS LEO) (Scenario 6)

This analysis applies to both the 22.55-23.15 GHz and 23.15-23.55 GHz bands.

This scenario considers MSS GEOSAT downlink interference into the DRS forward link. The basic geometry is shown in Fig. 3.4-2.

FIGURE 3.4-2

MSS GEOSAT Downlink Interference into DRS Forward Link



The wanted links are shown in blue and these are the downlink from the MSS GEOSAT to the MSS UT and the forward link from the DRS (in GEO) to the USERSAT (in LEO). The victim receiver in this case is on the LEO USERSAT. The interference path from the MSS GEOSAT to the USERSAT is indicated by the dashed red line. Note that the interference geometry in this scenario is such that MSS GEOSATs at small orbital separations from the DRS generally result in the highest interference into the forward link. For an MSS GEOSAT close to the DRS, the USERSAT receiving antenna (which is tracking the DRS in GEO) will have low discrimination in the direction of the MSS GEOSAT. Again, Fig. 3.4-2 is the simplified geometry. In the analysis and simulations described in Annex 3, the aggregate interference from multiple MSS downlink spot beams and multiple MSS satellites into the USERSAT receiver are calculated. The aggregate interference is time-varying since the USERSAT receiving beam is tracking a DRS and therefore the USERSAT receive antenna gain in the direction of the interfering MSS satellite downlink spot beams is time-varying as well as the transmit antenna gains of the MSS downlink spot beams in the direction of the (moving) USERSAT. The relevant USERSAT forward link receiver parameters are listed in Table A3-3 of Annex 3.

Since the Recommendation ITU-R SA.1155 interference protection criterion is in terms of an interference power spectral density (i.e. units of dBW/Hz) rather than an absolute interference level (i.e. units of dBW) and the MSS downlink multiple access scheme is assumed to be FDMA, it is only necessary to model each downlink spot beam with an e.i.r.p. spectral density based on the forward link channel/carrier e.i.r.p. of 44.21 dBW and the forward link channel bandwidth of 16.2 MHz per channel (see Fig. A3-1 in Annex 3). This results in a downlink spot beam e.i.r.p. spectral density of e.i.r.p.$_o$ = -27.9 dBW/Hz. Furthermore, since the victim receiver bandwidth in this case (50 MHz) is less than the MSS spot beam sub-band bandwidth of 125 MHz, it is assumed that only the F1 (red/green) or F2 (blue/yellow) spot beams from Annex 3 are interfering. The F1 (red/green) beams were used in the analysis. Each downlink spot beam is assumed to have a Recommendation ITU-R S.672-4 gain pattern. Aggregate interference statistics were then generated for the (5) sample DRS locations in Table 3.4-4 and for GSO MSS satellites at various locations and orbital spacings from the DRS.

3.4.2.3.1.2.1 Study Results for Scenario 6

Table 3.4-4 shows the results of the analysis for the (5) DRS locations. The values in the table correspond to Io/No (dB) for a 0.1% time exceedance per the protection criterion in Recommendation ITU-R SA.1155.

TABLE 3.4-4

Interference Results for MSS GEOSAT Downlink Interference into DRS Forward Link (Values shown are Io/No in dB for 0.1% time exceedance)

		DRS GEO LONGITUDE LOCATION				
# MSS GEOSATs	**MSS GEOSAT LOCATIONS**	**-174**	**-62**	**-41**	**47**	**89**
1	**Co-located with DRS**	**1.3**	**2.3**	**2.2**	**2.3**	**2.1**
2	**Adjacent to DRS with 1° spacing**	**-0.5**	**-0.4**	**-0.3**	**-0.1**	**-0.2**
2	**Adjacent to DRS with 2° spacing**	**-14.7**	**-14.9**	**-14.7**	**-14.7**	**-14.6**
2	**Adjacent to DRS with 3° spacing**	**-21.8**	**-20.8**	**-21**	**-20.9**	**-21.3**
72	**Full orbit with MSS SATs at 5° steps; min 2° separation from DRS**	**-14.3**	**-14.6**	**-14.4**	**-14.3**	**-14.2**

Note from Table 3.4-4 that the Rec. ITU-R SA.1155 protection threshold can be met as long as there is at least 2° orbital separation between the DRS and neighbouring MSS GEOSATs.

Further analysis was performed for this scenario to account for a potential increase in the MSS GEOSAT downlink spot beam e.i.r.p. to compensate for rain fades on the downlinks. Table 2.3-1 indicates that the baseline rain + atmospheric attenuation on the forward downlink from MSS GEOSAT to UT is 1.14 dB (using Rec. ITU-R P.618-10 rain model and 99% link availability), and the associated forward downlink satellite e.i.r.p. is 44.21 dBW (per spot beam carrier channel).

To account for the interference impact of increased e.i.r.p. on the DRS forward links, rain losses and atmospheric losses for each forward downlink spot beam of each MSS GEOSAT at 1° orbit increments were calculated using Rec. ITU-R P.618-10 and Rec. ITU-R P.676-10, respectively. For each spot beam, the calculated rain + atmospheric loss was then compared to the baseline attenuation value of 1.14 dB and the e.i.r.p. for that spot beam adjusted up or down relative to the baseline e.i.r.p. value of 44.21 dBW depending on the assumed link availability and rain zone of the geographical area being served by each spotbeam. Thus, for example, if the rain + atmospheric propagation loss for a particular spot beam aimed at a high precipitation region is 11.14 dB (i.e. 10 dB higher than the baseline value of 1.14 dB), then the e.i.r.p. for that spot beam is assumed to be 54.21 dBW (i.e. 10 dB higher than the baseline value of 44.21 dBW). Therefore, the downlink e.i.r.p. is assumed to vary across all the spot beams from a particular MSS GEOSAT depending on the rain and atmospheric losses of each spot beam. Annex 4 provides a detailed example describing how the MSS GSO downlink spotbeam e.i.r.p. values are adjusted from the baseline value when downlink power control is assumed to account for rain losses on a per beam basis in the analysis. For the worst case assumed link availability of 99.9 %, the individual spotbeam e.i.r.p. values in the example range from 43.51 to 75.99 dBW/16.2 MHz compared to the baseline MSS e.i.r.p. of 44.21 dBW/16.2 MHz as given in Table 2.2-1.

The results are shown in Table 3.4-5. The use of power control to overcome rain fade and provide a consistent signal on the earth's surface in fade conditions will create a varying interference environment to the inter-satellite services. In performing this study, it was recognized that the MSS parameters in this Report are the characteristics of a single possible MSS system, and may not necessarily be representative of all MSS systems which may potentially operate if a worldwide allocation to the MSS is made. In particular, for MSS systems which may be brought into operation in areas where rain losses are significant, and for purposes where levels of link availability greater than 99% are desirable, it is reasonable to expect that the downlink e.i.r.p. may be varied with time on a beam-by-beam basis in order to overcome rain fade in given geographical areas in order to maintain a constant quality of service to the MSS users.

The use of downlink power control on spacecraft to maintain a certain availability/quality of service is very common, although there are other mechanisms which could be used (such as over-designing the user terminal antenna or receiver LNA for the worst case rain situation). Alternatively, the MSS operator could choose to offer degraded or interrupted service during periods of high rain attenuation. It is recognized that the use of power control is not consistent with the fixed parameters provided in Table 2.2-1, however the parameters in Table 2.2-1 are only representative parameters for study and do not represent regulatory limitations on possible future MSS operations.

TABLE 3.4-5

Interference results for MSS GEOSAT downlink interference into DRS forward link assuming rain fade compensation on the MSS GEOSAT downlink e.i.r.p. (values shown are Io/No in dB for 0.1% time exceedance)

				DRS GEO LONGITUDE LOCATION				
# MSS GEOSATs	Link Availability Under Rain	% of spotbeams under rain	Min Orbital Separation between DRS and MSS GEOSAT	-174	-62	-41	47	89
72	99.00%	100%	2°	-11.3	-12.6	-10.4	-10.9	-10.4
72	99.50%	100%	2°	-8.1	-7	-5	-7.5	-6
72	99.50%	10%	2°	-14.2	-7.6	-6.1	-11.8	-10.2
72	99.50%	1%	2°	-14.4	-14.4	-14.4	-14.2	-14
71	99.50%	100%	5°	-14.1	-8	-9.1	-11.9	-11
71	99.50%	10%	5°	-17.5	-8.6	-10.5	-12.7	-11.3
69	99.50%	100%	10°	-17.9	-13.8	-14	-16.8	-17.7
69	99.50%	10%	10°	-19.1	-15.3	-15	-18.7	-18.6
65	99.90%	100%	20°	-0.8	-1	0.8	-1	-4.1
65	99.90%	10%	20°	-1.4	-2.3	0.1	-2.8	-4.5
65	99.90%	5%	20°	-1.7	-4.3	-1.3	-3.6	-6.1
65	99.90%	1%	20°	-7.7	-9.6	-9.7	-12.8	-10.4

Note the required orbital spacing between the DRS and nearest MSS GEOSATs depends on the link availability under rain and the number of spot beams from each MSS GEOSAT assumed to be experiencing rain fading. The top row of the table shows that for a 99% link rain availability, a 2° separation is sufficient to get DRS forward link Io/No <= –10 dB even for a fully populated MSS orbit (i.e. MSS GEOSATs spaced 5° apart) and all spot beams under rain. The values in Table 3.4-5 assume a baseline spotbeam e.i.r.p. level of 44.21 dBW per 16.2 MHz channel on the MSS forward link (i.e. 32.11 dBW/MHz) which is then adjusted for rain loss according to the methodology in Annex 4. If the baseline e.i.r.p. level is increased to 46.5 dBW/MHz as shown in the mask given in Table 3.5-10 of § 3.5.2.3.2.2.1, then for the 99% link availability case, the Annex 4 methodology yields a minimum orbit separation of approximately 50°. This methodology assumes that the baseline e.i.r.p. level increases according to downlink power control on each beam.

If the link availability is increased to 99.5%, then the required separation is between 2° and 5° depending on what percentage of the MSS GEOSAT downlink spot beams are under rain conditions. Note that a 10% or 1% value here means that for a particular MSS GEOSAT, the spot beams with the highest rain losses are considered (i.e. for each MSS GEOSAT, the spot beams are sorted in descending order according to rain loss and the top 10% or 1% of spot beams are assumed to be under rain and therefore have the highest downlink e.i.r.p. values). Based on the 32 possible DRS orbital locations in Rec. ITU-R SA.1276-3, a 5° guard spacing on each side of the 32 DRS locations leaves a total of 150.1° GEO orbital arc for placing MSS satellites (i.e. the orbital arc ranges are 7°W-5.6°E; 26.5°E-42°E; 52°E-54°E; 64°E-72°E; 100°E-108°E; 126°E-128°E; 138°E-155°E; 165°E-166°E; 155°W-144°W; 134°W-67°W; 27°W-21°W).

If the link availability is increased further to 99.9%, then an orbit separation of at least 20° is required to achieve a DRS forward link Io/No <= –10 dB. Again, based on the 32 DRS locations in Recommendation ITU-R SA.1276-3, a 20° guard spacing leaves a total of 37° GEO orbital arc for placing MSS satellites (i.e. a single orbital arc range from 119°W-82°W).

3.4.2.4 MSS and SRS (Earth-to-space)

3.4.2.4.1 SRS systems

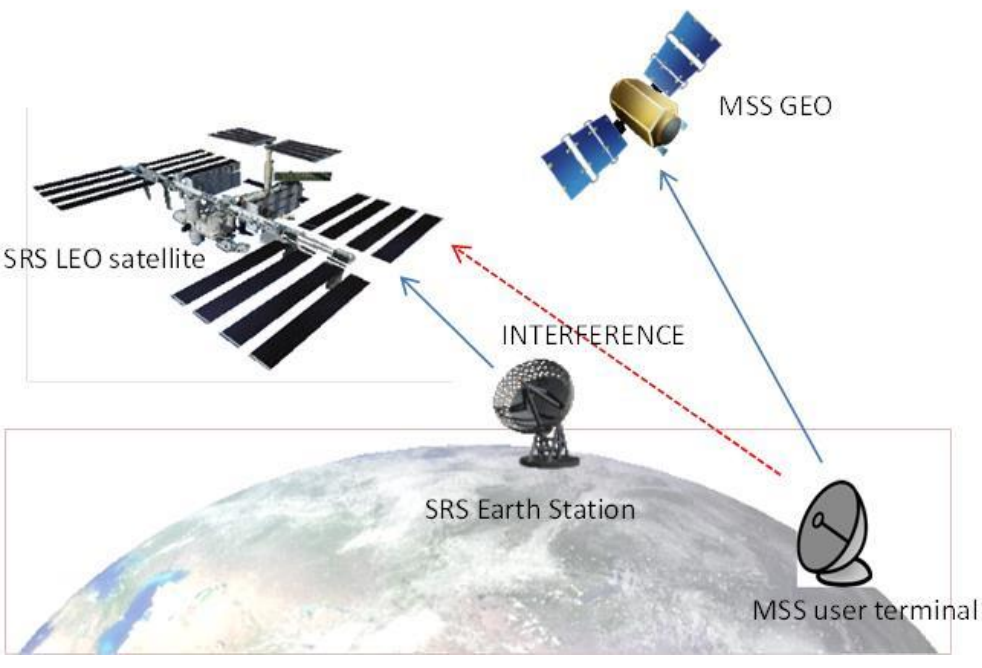
Refer to Annex 2 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems.

3.4.2.4.1.1 MSS user terminal uplink interference into non-GSO LEO receiving from earth station (Scenario 4)

As shown in Fig. 3.4-3, this analysis will consider interference from MSS user terminal transmissions into an SRS satellite in LEO receiving a transmission from SRS earth stations located at three locations throughout the United States, in the bands 22.55-23.15 GHz, taking into account the protection levels in Recommendation ITU-R SA.609.

FIGURE 3.4-3

Representative interference scenario of MSS user terminal transmissions into SRS satellite



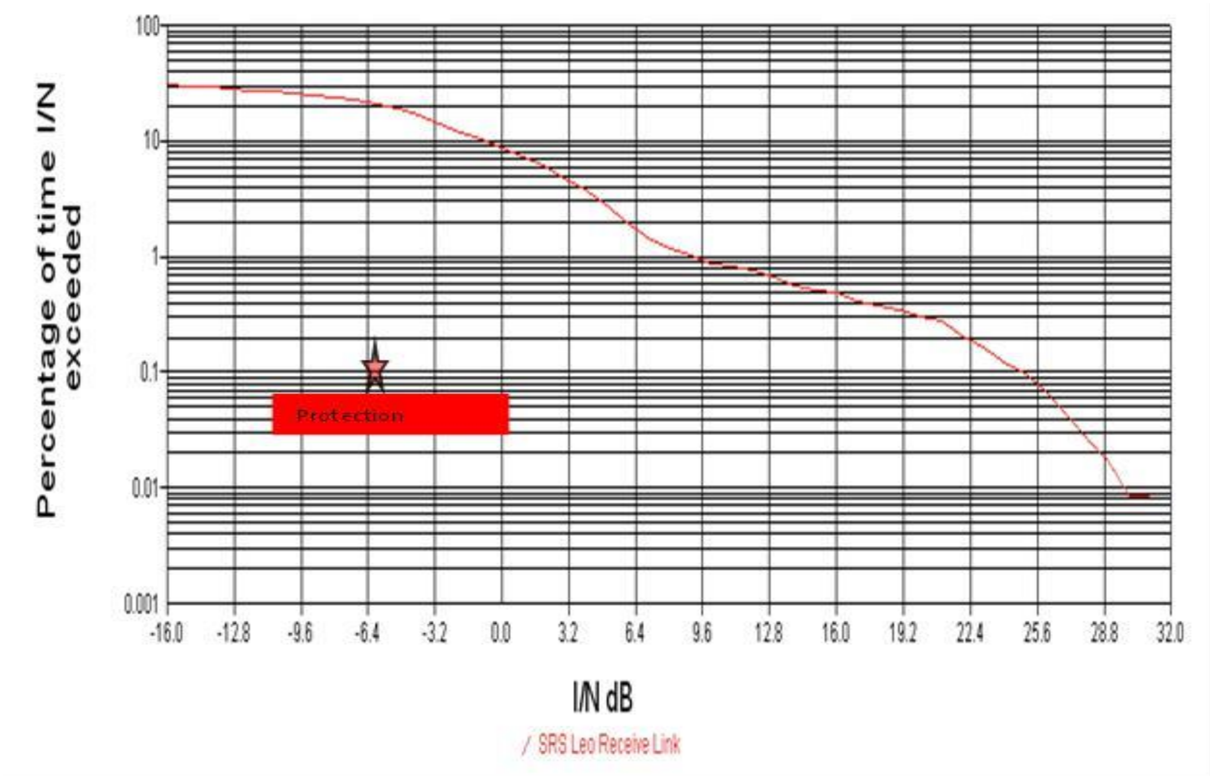
This scenario assumes a uniform distribution of MSS user terminals transmitting to an MSS GSO satellite located at 60 West. The modelled MSS GSO satellite has multiple antenna beams available for coverage within the satellite coverage area. It is assumed that each MSS user terminal selects which antenna beam to transmit based on the antenna beam with the highest gain within view of the user terminal. In this simulation, there are 10,000 MSS user terminal clusters uniformly distributed over a 26,458,207 km^2 area on the surface of the Earth. Thus, each MSS user terminal cluster is spread over an area of approximately 2,645 km^2. The aggregate power of 264 MSS user terminals is then modelled for each MSS user terminal cluster coverage area of 2,645 km^2. This corresponds to approximately 2,640,000 MSS user terminal clusters modelled over a 26,458,207 km^2 area on the surface of the Earth for a total user terminal density of 0.1 users/square km. It should be noted that this value is significantly lower than the maximum user terminal density of 8 users/square km as specified in Attachment 1 to Annex 2.

3.4.2.4.1.1.1 Study results for Scenario 4

Figure 3.4-4 shows the dynamic simulation results of this interference scenario.

FIGURE 3.4-4

***I/N* results of Interference from MSS user terminals into a SRS LEO receive link**

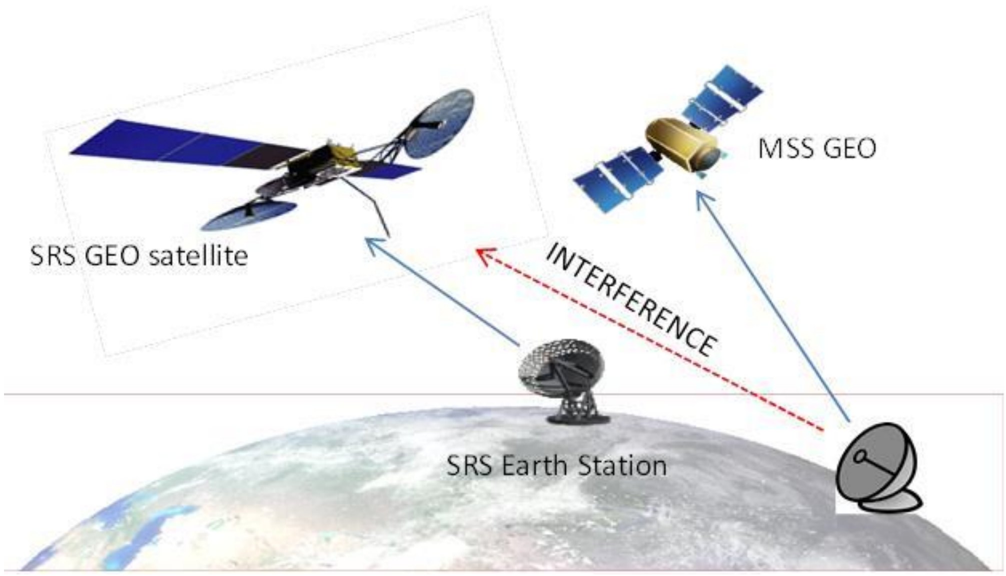


3.4.2.4.1.2 MSS user terminal uplink interference into GSO receiving from earth station (Scenario 5)

As shown in Fig. 3.4-5, this analysis will consider interference transmissions from MSS user terminals into an SRS satellite in GSO receiving a transmission from SRS earth stations located at three locations throughout the United States, in the band 22.55-23.15 GHz, taking into account the protection levels in Recommendation ITU-R SA.609.

FIGURE 3.4-5

Representative interference scenario of MSS user terminal transmissions into SRS GSO satellite



This analysis assumes 10 000 MSS user terminal clusters uniformly distributed over a 26,458,207 km^2 area on the surface of the Earth transmitting to a MSS GSO satellite. Thus, each MSS user terminal cluster is spread over an area of approximately 2,645 km^2. The aggregate power of 264 MSS user terminals is then modelled for each MSS user terminal cluster coverage area of 2,645 km^2. This corresponds to approximately 2,640,000 MSS user terminals modelled over a 26,458,207 km^2 area on the surface of the Earth for a total user terminal density of 0.1 users/square km. In this scenario, the orbital separation of the MSS GSO satellite from the SRS GSO satellite influences the amount of interference experienced by the SRS GSO satellite.

3.4.2.4.1.2.1 Study results for Scenario 5

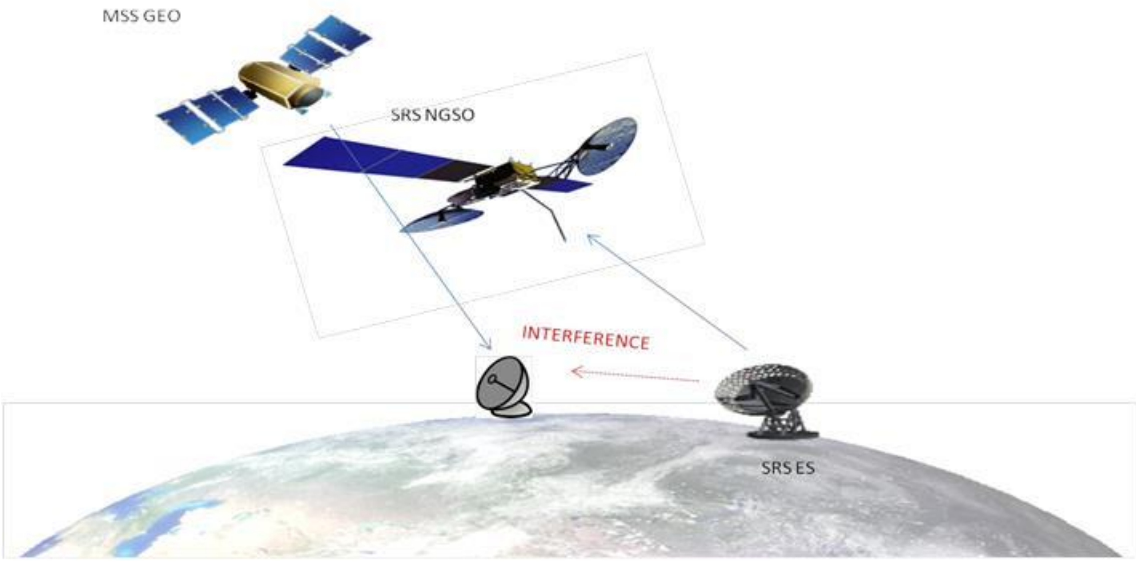
If the SRS GSO is located at 46 West and the MSS GSO is located at 48 West, than a maximum *I/N* of 22 dB is experienced by the SRS GSO. If there is proper orbital separation, in the order of 26 degrees, between the SRS GSO and the MSS GSO, exceedance of the interference criterion given in Recommendation ITU-R SA.1155 to the SRS GSO can be avoided.

3.4.2.4.1.3 SRS earth station uplink interference into MSS user terminal receiving from MSS GSO satellite (Scenario 10)

As shown in Fig. 3.4-6, this analysis will consider interference from SRS earth station transmissions into an MSS user terminal receiving a transmission from an MSS GSO located at 60 West in the band 22.55-23.15 GHz.

FIGURE 3.4-6

Representative interference scenario of SRS ES transmissions into MSS user terminal



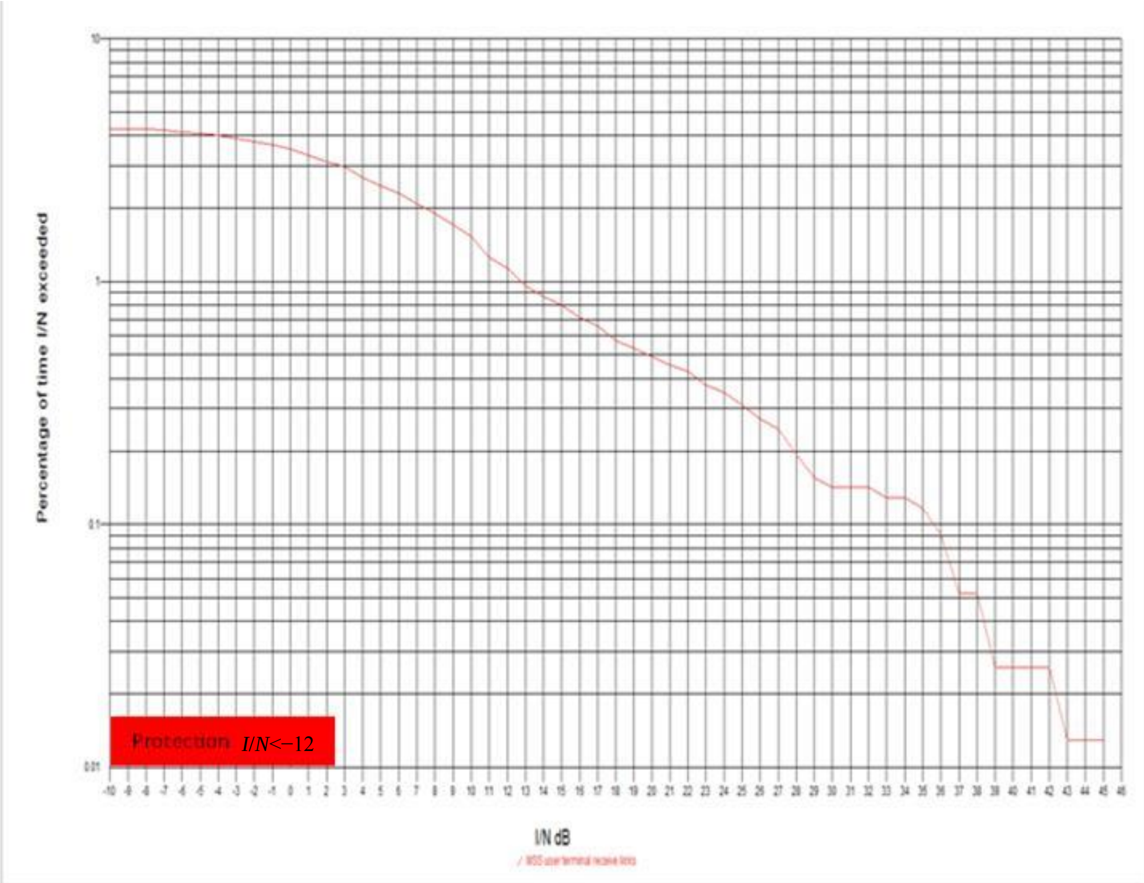
This analysis evaluates the interference from a SRS earth station transmitting to a SRS LEO into a MSS user terminal transmitting to a MSS GSO satellite located at 60 West. In this simulation, there are 10,000 MSS user terminals uniformly distributed over a 26,458,207 km^2 area on the surface of the Earth. This corresponds to total user terminal density of 0.0004 users/square km. It should be noted that this value is significantly lower than the maximum user terminal density of 8 users/square km as specified in Attachment 1 to Annex 2.

3.4.2.4.1.3.1 Study results for Scenario 10

Figure 3.4-7 shows the dynamic simulation results of this interference scenario over all the MSS user terminal links. The worst value of interference received to any one MSS user terminal is *I/N* = 45 dB.

FIGURE 3.4-7

Representative interference scenario of SRS earth station transmission into MSS user terminal receive links



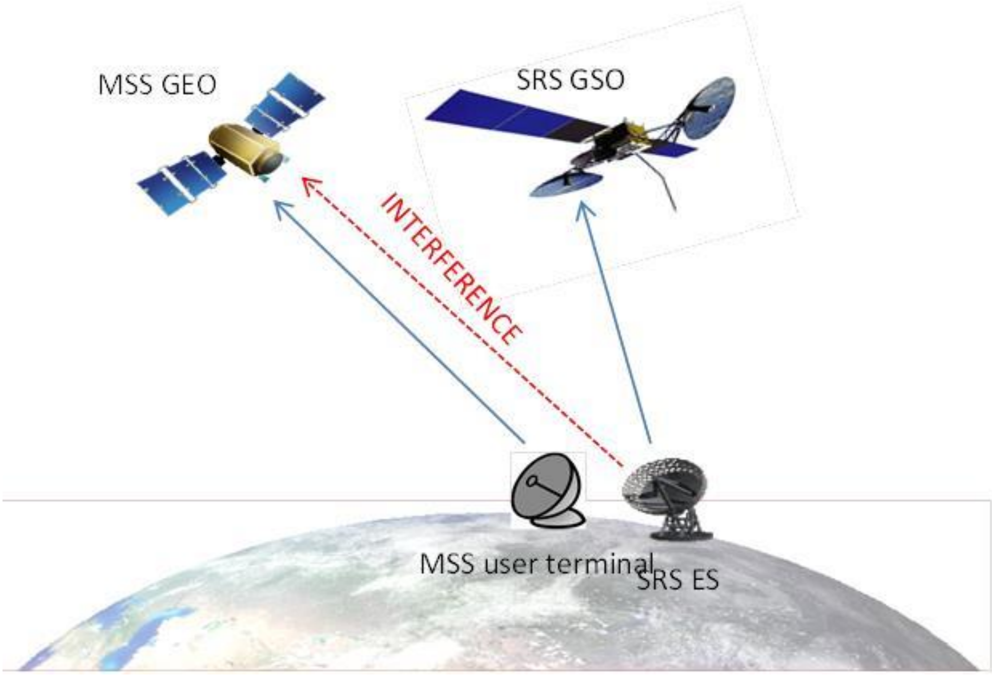
This scenario involves interference from one earth station into another. In such a case, a coordination zone can be calculated to determine the minimum required separation distance between the MSS user terminal and the SRS earth station to avoid interference. Using a generic path calculating with Recommendation ITU-R P.452-14 and assuming a maximum sidelobe gain consistent with Recommendation ITU-R S.580, a coordination distance of over 330 km would be needed to avoid interference from an SRS earth station.

3.4.2.4.1.4 SRS earth station uplink interference into MSS GSO satellite receiving from MSS user terminal (Scenario 11)

As shown in Fig. 3.4-8, this analysis will consider interference from SRS earth station transmissions into an MSS GSO satellite in the band 22.55-23.15 GHz.

FIGURE 3.4-8

Representative interference scenario of SRS ES transmissions into MSS GSO satellite



This analysis examines the interference caused by the transmission of three SRS earth stations throughout the United States to a SRS GSO satellite into a MSS GSO satellite. In this scenario, the orbital separation of the MSS GSO satellite from the SRS GSO satellite influences the amount of interference experienced by the SRS GSO satellite.

3.4.2.4.1.4.1 Study results for Scenario 11

If the SRS GSO is located at 46 West and the MSS GSO is located at 48 West, than a maximum *I/N* of 2 dB is experienced by the MSS GSO. If there is proper orbital separation, in the order of 3 degrees, between the SRS GSO and the MSS GSO, exceedance of the interference to the MSS GSO link can be avoided.

3.4.2.5 MSS and RAS

3.4.2.5.1 MSS in-band and RAS

No studies were conducted to assess sharing between MSS in the 22.55-23.15 GHz band and the radio astronomy service operations under RR No. **5.149**.

3.4.2.5.2 Potential impact of unwanted emissions from MSS (s-E) in the frequency band 23.15-23.4 GHz on RAS in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz[1]

The Radio Regulations maintains no allocations for RAS in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz. Subject to RR No. **5.149** «in making arrangements to stations of other services

[1] This study of the potential impact of MSS unwanted emissions on radioastronomy operations was incorporated into this Report without the opportunity for the ITU-R RAS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

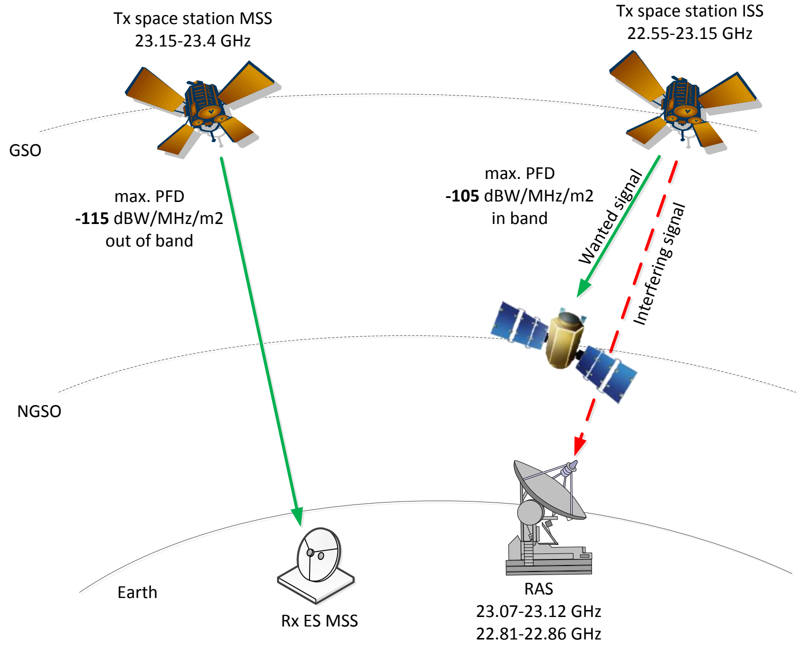
to which the bands 23.07-23.12 GHz and 22.81-22.86 MHz are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference». The provisions of RR No. **5.149** do not entitle RAS to protection from unwanted emissions from out-of-band systems operating in accordance with the existing allocations in the RR. However, some administrations are of the view that a proposed new allocation to the MSS represents a change to the sharing environment with regard to RAS operations in bands included in RR No. **5.149**, and believe that the impact to RAS from a new allocation to MSS downlinks in adjacent or near-adjacent frequency bands needs to be assessed. It should be noted that emissions from space-borne and air-borne stations would cause especially detrimental interference to RAS.

The frequency band 23.15-23.4 GHz, which has been considered as a potential candidate band for MSS (space-Earth), has no frequency overlap with the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz in which administrations are urged to take all practical steps to protect the radioastronomy service when making spectrum assignments to stations in other services.

There is no protection criteria included in Tables 1, 2, 3 in Annex 1 of Recommendation ITU-R RA.769, or any other ITU-R Recommendation, for the bands 23.07-23.12 GHz and 22.81-22.86 GHz due to the lack of an RAS allocation in these bands. However, Annex 1 of Recommendation ITU-R RA.769 also gives a methodology to derive the protection criteria for bands not explicitly listed. Report ITU-R RA.2131 supplements this information with a procedure for interpolating between bands listed in Recommendation ITU-R RA.769.

It is worth mentioning that the Intersatellite service is allocated in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz on the primary basis. According to Recommendation ITU-R SA.1019, DRS systems in the Intersatellite service operate in the GSO-NGSO direction in the frequency band 22.55-23.55 GHz in which overlaps the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz. According to Table 21-4 of RR Article **21** the maximum PFD for DRS systems in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz is –105 dBW/m^2 in 1 MHz, which exceeds the maximum PFD for the envisioned MSS in the frequency band 23.15-23.4 GHz by 10 dB (see Annex 1). See Fig. 3.4-9.

FIGURE 3.4-9



Thus the conclusion of this study is that unwanted emissions from MSS space stations operating in the frequency band 23.15-23.4 GHz will not cause detrimental interference to RAS stations in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz.

It should be noted that the inter-satellite link from a GSO data relay satellite to a low-Earth orbiting user satellite moves rapidly with respect to a given point on the ground while an MSS downlink beam would be continuously pointed at a given point on the ground. The interference to an RAS receiver resulting from an ISS link would be highly transient while that from an MSS downlink would be continuous in nature. It is worth noting that the MSS transmissions may not be continuous as the system may not be fully loaded at all times.

However some administrations of the view that since some RAS applications do not make use of integrated measurements, the continuity of MSS or DRS transmissions is not relevant for that RAS application.

3.4.3 Results of sharing studies in the frequency band 22.55-23.15 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Pfd limits will have to be applied to the proposed MSS downlink.

Based on the results presented in §§ 3.4.2.3 and 3.4.2.4, the proposed MSS operations in the band 22.55-23.15 GHz are not compatible with incumbent ISS NGSO-GSO space-to-space and SRS Earth-to-space systems. Note that this conclusion is based on studies which assumed an MSS system with coverage for land masses only. It is anticipated that actual MSS systems would provide global coverage, with spot beams covering nearly the entirety of the Earth’s surface. Accordingly the interference from MSS into ISS NGSO-GSO might be even greater than shown in these results.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

No studies were done to assess sharing feasibility between the MSS operating in this band and the radio astronomy operations under RR No. **5.149**.

One study examining the impact of unwanted emissions from MSS (s-E) operations in the band 23.15 – 23.4 GHz on RAS is presented in § 3.4.2.5.2. This study shows that MSS space stations will not cause detrimental interference to radioastronomy service in the frequency bands 23.07-23.12 GHz and 22.81-22.86 GHz. Note that this study was incorporated into this Report without the opportunity for the ITU-R RAS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

3.5 The frequency band 23.15-23.55 GHz

Allocations for this frequency band are shown in Table 3.5-1:

TABLE 3.5-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 23.15-23.55 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
23.15-23.55	FIXED INTER-SATELLITE 5.338A MOBILE	

5.338A In the bands 1 350-1 400 MHz, 1 427-1 452 MHz, 22.55-23.55 GHz, 30-31.3 GHz, 49.7-50.2 GHz, 50.4-50.9 GHz, 51.4-52.6 GHz, 81-86 GHz and 92-94 GHz, Resolution **750 (Rev.WRC-12)** applies. (WRC-12)

Spectrum sharing between MSS and fixed and mobile services would be required in this frequency band.

Besides conditions of compatibilityof the envisioned MSS with ISS of the NGSO systems would require relevant studies.

3.5.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.5-2.

TABLE 3.5-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 23.15-23.55 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	Recs ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7
Inter-satellite	Recs ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R SA.1743. Report ITU-R SA.2192.

3.5.2 Sharing studies in the frequency band 23.15-23.55 GHz

3.5.2.1 MSS (space-to-Earth) and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

3.5.2.2 MSS and MS

3.5.2.2.1 Characteristics of MS stations

Currently characteristics of land MS systems required for estimating the values of interference from MSS into MS in the frequency band 23.15-23.55 GHz are not available at WP 4C. Therefore the MS characteristics shown in Table 3.5-3 and Table 3.5-4 are proposed for usage in the compatibility studies. The characteristics of aeronautical MS are based on the data in Annex 7.

TABLE 3.5-3

Characteristics of land MS systems

Frequency range (GHz)	23.15-23.55	
Type	User Terminal	Base station
Antenna gain (dBi)	0	35 (Rec. ITU-R F.1336)
Feeder/multiplexer loss range (dB)	0…3	0…3
Receiver noise power density typical (= N_{RX}) (dBW/MHz)	−138	–138
Nominal long-term interference power density (dBW/MHz)	−138 + *I/N*	−138 + *I/N*

TABLE 3.5-4

Characteristic of aeronautical MS

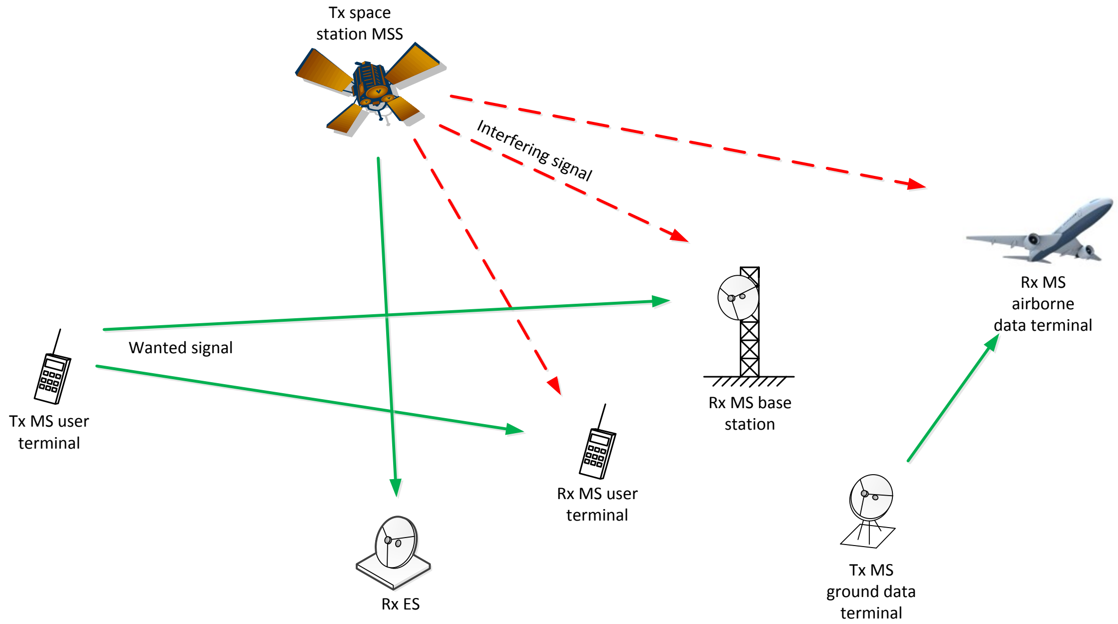
Parameter	**Units**	**System 1 Airborne**	**System 2 Airborne**
Tuning range	GHz	22.9-23.3	22.55-23.5
NF	dB	4	3.5
Antenna gain	dBi	33	33
1st Sidelobe	dBi	17	16
Antenna model		Recommendation ITU-R M.1851	Recommendation ITU-R M.1851

3.5.2.2.2 Interference Scenario

The estimation of compatibility between GSO MSS and MS in the frequency band 23.15-23.55 GHz was based on a scenario in which emissions from a transmitting MSS space station could cause interference to a receiving MS earth station. The indicated interference impact scenario is shown in Fig. 3.5-1. As described in Annex 7, the receiving stations of AMS in the considered frequency band are airborne.

FIGURE 3.5-1

Interference Impact Scenario



The propagation losses for the interfering signal were calculated on the basis of Recommendation ITU-R P.525. The feeder and polarization losses were not taken into account. The interfering signal attenuation in atmospheric gases was estimated according to Recommendation ITU-R F.1404-1 (for the frequency of 23.6 GHz with a MS station deployed at the altitude of 300 m above the sea level).

Since the protection criteria for land MS stations is not defined yet this study assumed a protection criterion for receiving MS ground stations in form of an aggregate criterion of protection from the services allocated in the considered frequency band on a primary basis. This criterion was taken as interference-to-noise ratio (I/N) equal to minus 6 dB (I/N = -6 dB). This protection criterion was assumed by analogy with that in the adjacent frequency range (Ku-band).

As explained in Annex 7, the aggregate protection criteria (I/N = -6 dB) from all operating MSS space stations was used as a protection criterion for the AMS receiving stations.

The aggregate interference caused by a set of transmitting MSS space stations was taken into account assuming a minimum spacing angle of 5 degrees. It was also assumed to consider a minimum possible satellite orbital spacing if the typical MSS characteristics described in Tables 2.1-1 and 2.2-1 were used.

The above assumptions were used for deriving the limits of power flux density (pfd) produced by GSO MSS network stations at the Earth surface. Such limits would provide protection to the MS receiving stations from emissions produced by MSS transmitting space stations.

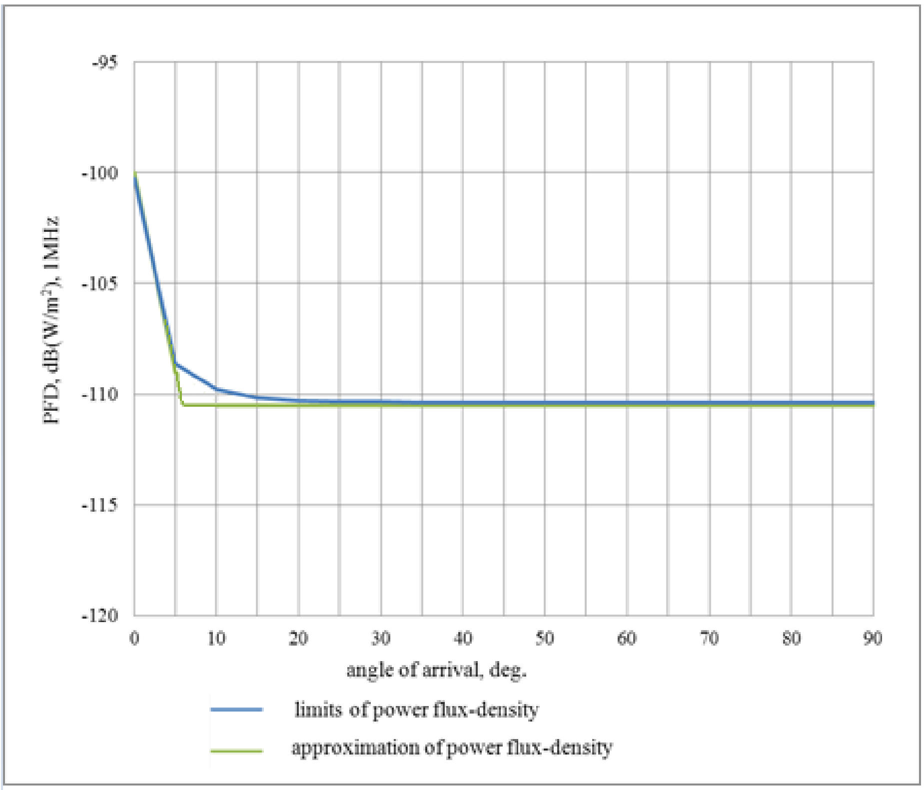
For the interference scenario from MSS into AMS the simulation of the aggregate interference impact was carried out with the characteristics given in Table 3.5-4. The duration of simulation was 1 hour 12 minutes with a step of 5 sec. The flight altitude was 8 km, the flight path was 900 km.

3.5.2.2.3 Estimation results

The estimation results based on the above assumptions and on the described interference scenario show that MS receiving stations could be protected from emissions produced by MSS transmitting space stations if the relevant pfd levels would not exceed the levels shown in Fig. 3.5-2 (a blue curve).

FIGURE 3.5-2

Masks for acceptable PFD from the envisioned MSS for user terminals



The approximation was then conducted on the basis of the derived acceptable pfd which would provide protection of the user terminal MS receiving stations from emissions produced by the MSS transmitting space stations. The results are shown in Fig. 3.5-2 (a green curve) and in Table 3.5-5.

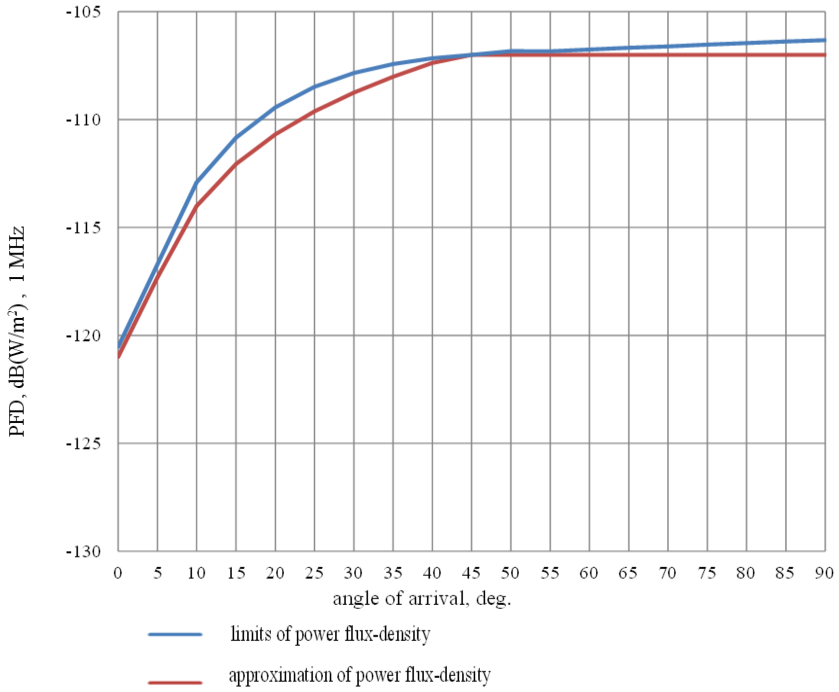
TABLE 3.5-5

Derived acceptable PFD to provide protection of the MS receiving stations

Frequency band, GHz	**Service**	**Limit in dB(W/m^2) for angles of arrival (δ) above the horizontal plane**		**Reference bandwidth**
		0°–5.84°	**5.84°–90°**	
23.15–23.55	Mobile-satellite service (space-to-Earth)	–100 – 1.8*δ	-110.5	1 MHz

FIGURE 3.5-3

Mask for acceptable PFD for base stations



In accordance with the obtained mask of the acceptable pfd the approximation (see Fig. 3.5-3 (red line) and also indicated in Table 3.5-6) was carried out for protection of the MS receiving base stations from the emissions of the transmitting space stations of MSS:

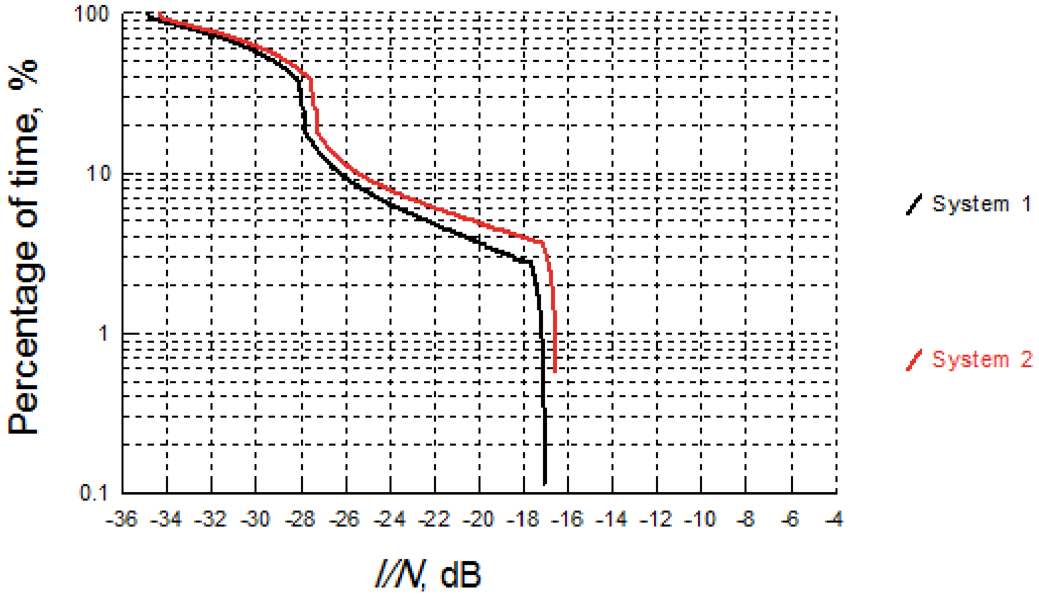
TABLE 3.5-6

Frequency band, GHz	**Service**	**Limit in dB(W/m²) for angles of arrival (δ) above the horizontal plane**			**Reference bandwidth**
		0°–5°	**5°–40°**	**40°–90°**	
23,15–23,55	Mobile satellite (space-to-Earth)	–121 + 0.8*δ	–124.7 + 11*log(δ)	–107	1 MHz

The simulation results of MSS impact to AMS are presented in Fig. 3.5-4.

FIGURE 3.5-4

Estimation results in relation to the AMS receiving stations



3.5.2.2.4 Conclusions

The conducted studies show that the protection of MS receiving stations from emissions of MSS transmitting space stations could be provided if levels of pfd would not exceed values shown in Table 3.5-5 and 3.5-6. Using the typical characteristics of MSS the protection criterion with respect to AMS stations is not exceeded (see Fig. 3.5-4).

3.5.2.3 MSS and ISS

3.5.2.3.1 ISS supporting space research systems (data relay satellite systems using GSO-NGSO links)

3.5.2.3.1.1 Study 1 of data relay satellite systems using GSO-NGSO links:

Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems. Refer to §§ 3.4.2.3.1.1 and 3.4.2.3.1.2 for sharing analyses that apply to both the 22.55-23.15 GHz and 23.15-23.55 GHz bands.

3.5.2.3.1.2 Study 2 of data relay satellite systems using GSO-NGSO links

3.5.2.3.1.2.1 Characteristics of ISS stations

In accordance with Recommendation ITU-R SA.1019, ISS stations operate in the frequency band 23.15-23.55 GHz in GSO-NGSO direction. Therefore in this case a receiving station is a station located on NGSO satellite.

The assumed relevant technical characteristics were taken from Recommendation ITU-R SA.1414 for the frequency band 23.15-23.55 GHz, and are shown in Table 3.5-7.

TABLE 3.5-7

Data relay satellite system characteristics

Transmitting DRS			
Network	type 1 Europe	type 2 Japan	type 3 USA
Orbital locations	Rec. ITU-R SA.1275 or Rec. ITU-R SA.1276		
Frequency range (GHz)	22.55-23.55		
Link description	Single Access (Ka-SA) link		
Transmission rate (bit/s)	≤ 10 Mbit/s	≤ 50 Mbit/s	≤ 25 Mbit/s
Modulation	PSK		
Polarization	Circular		
Antenna size (m)	2.8	3.6	4.9
Tx antenna gain (dBi)	53.4	57.4	58.9
Tx antenna radiation pattern	Rec. ITU-R S.672		
Necessary bandwidth (MHz)	60	≤ 150	50
Maximum power density (dB(W/Hz))	-65.1	–49.5	–64.5
Maximum e.i.r.p. density (dB(W/Hz))	–11.7	–7.9	–5.6
Receiving spacecraft			
Orbital locations	Mainly low-Earth orbit		
orbital altitude in calk (km)	700	700	700
Inclination angle, (deg)	60	60	60
Frequency range (GHz)	22.55-23.55		
Antenna size (m)	≤ 1.3		≤ 1.3
Rx antenna gain (dBi)	≤ 47	≤ 48.9	≤ 47
Rx antenna gain in calk (dBi)	47	48.9	47
Rx antenna radiation pattern	Rec. ITU-R S.672		
System noise temperature (K)	1 400	850	1400
Required Eb/N0 (dB)	9.5	10.8	9.5
Required BER	1×10^{-6}		
Link reliability (%)	99.9		99.99
Interference criterion	Rec. ITU-R SA.1155		
The aggregate interference impact from MSS stations into ISS stations is simulated			

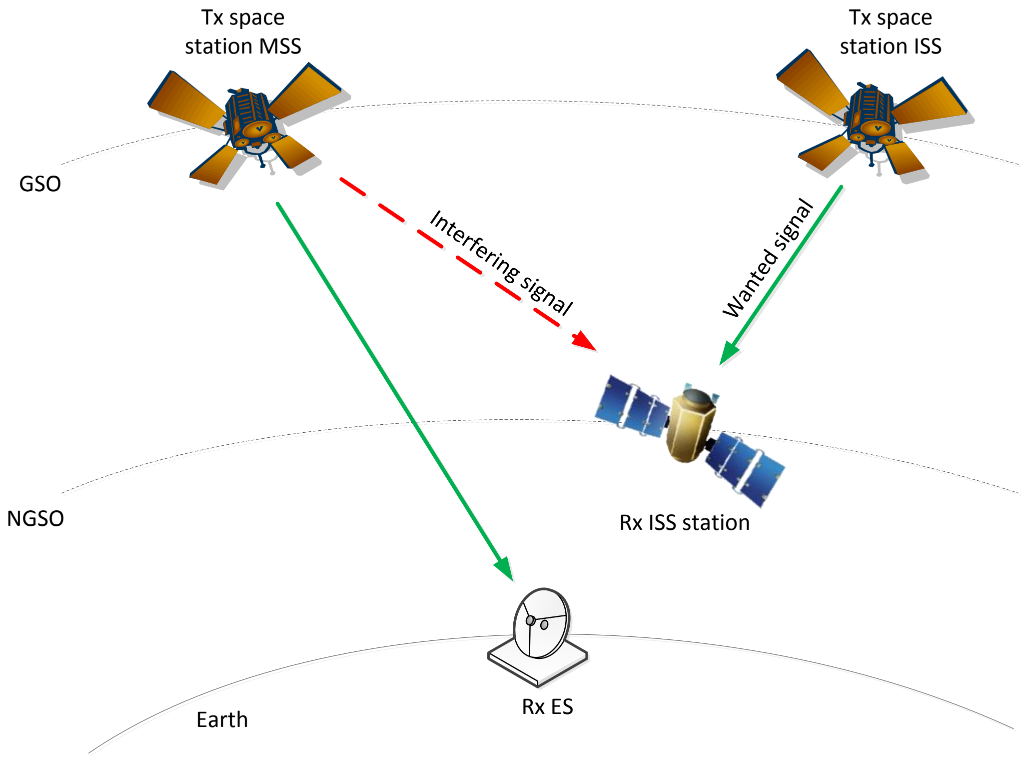
The antenna pattern shape for the ISS receiving stations in GSO-NGSO link was defined according to Recommendation ITU-R S. 672.

3.5.2.3.1.2.2 Interference impact scenario

The estimation of compatibility between the envisioned MSS and ISS (GSO-NGSO link) in the frequency band 23.15-23.55 GHz was based on an interference scenario in which emissions from GSO MSS transmitting space station could cause interference to ISS receiving space station. The interference impact scenario is shown in Fig. 3.5-5.

FIGURE 3.5-5

Interference Impact Scenario



It should be noted that the sharing between two GSO satellite systems is based on RR Article **9** provisions (see RR No. **9.7**). In addition the studies were conducted to determine orbital spacing on the basis of characteristics shown in Table 3.5-7.

Using the above interference scenario, the simulation of aggregate interference effect was conducted on the basis of characteristics contained in Table 3.5-7. The simulation included estimation of I/N values for orbital spacing of 0° and 2° between a GSO MSS transmitting space station and a GSO ISS transmitting space station. GSO MSS transmitting space station coverage area was assumed using MSS typical characteristics (Table 2.2-1).

The protection criterion for ISS receiving space stations (GSO-NGSO link) was assumed in form of an aggregate protection criterion from all operating MSS space stations. This criterion was taken as I/N equal to minus 10 dB (I/N = -10 dB) according to Recommendation ITU-R SA.1155. (The above criterion shall not be exceeded for 0.1% of the time).

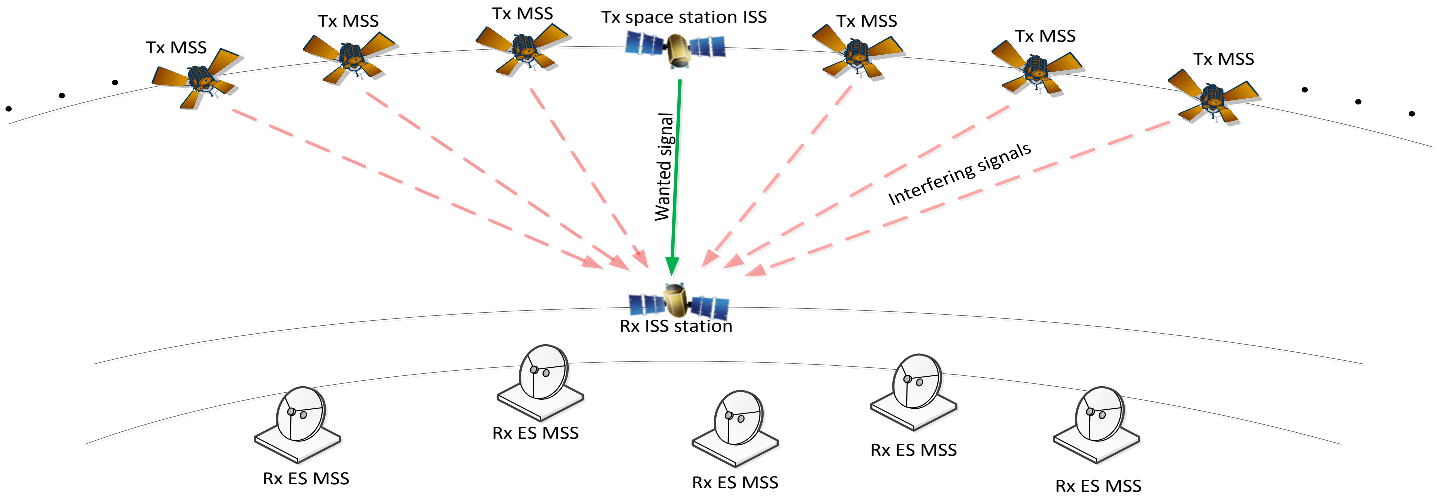
The simulation accounted for aggregate interference from a set of MSS transmitting space stations assuming a minimum spacing angle of 5 degrees. For each case the simulation duration was 30 days with a step of 30 seconds.

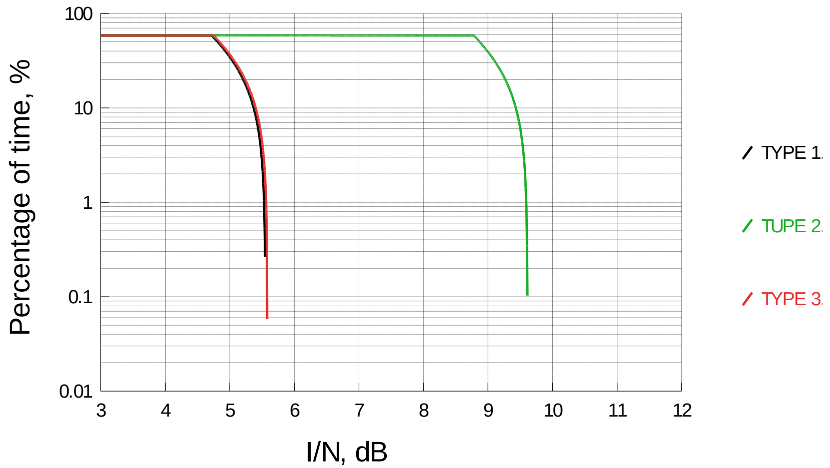
3.5.2.3.1.2.3 Estimation results

Based on the above assumptions and interference impact scenario of GSO-NGSO link the estimation was conducted and its results are shown in Fig. 3.5-6 below:

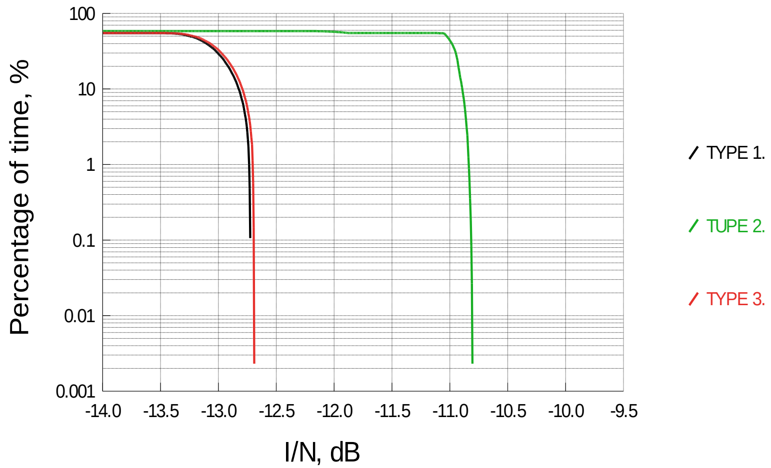
FIGURE 3.5-6

Estimation Results





Calculation results of *I/N* for orbital spacing of 0°



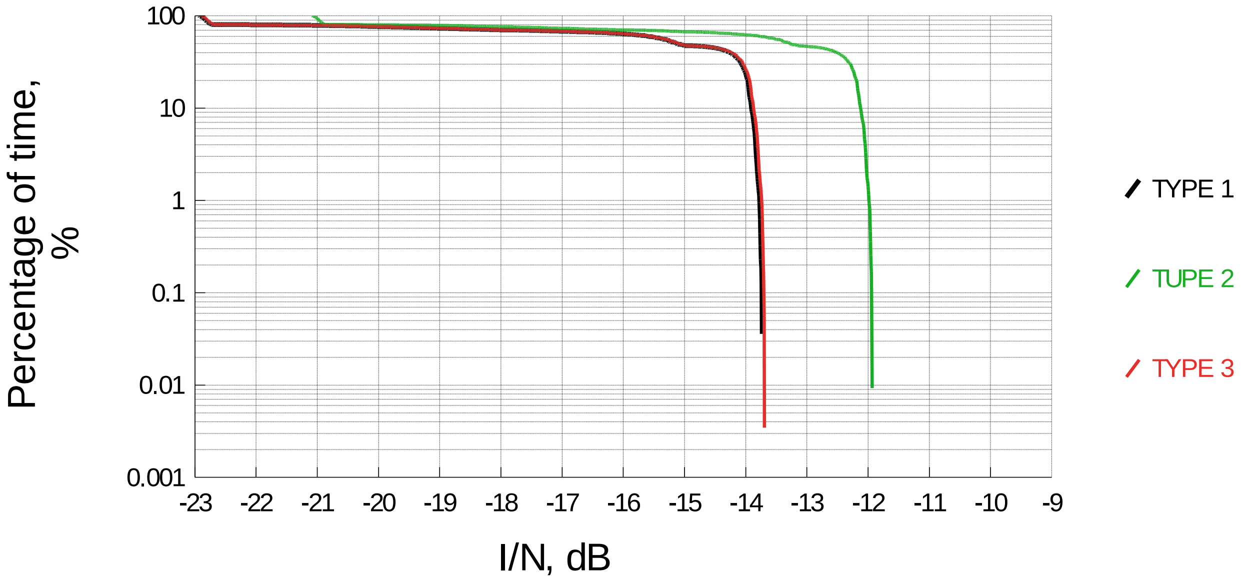
Calculation results of *I/N* for orbital spacing of 2°

The simulation results show that for orbital spacing of 2 degrees between GSO MSS transmitting space station and GSO ISS transmitting station it is not expected that protection criterion of *I/N* = –10 dB in 0.1% of time would be exceeded

To conduct comprehensive analysis of MSS effect on ISS the impact of aggregate interference was simulated using the characteristics shown in Table 3.5-12 i.e. for maximum e.i.r.p. of 42 dBW/1 MHz (the e.i.r.p. value satisfying the required *I/N* = –16 dB for HIBLEO-2 system; see § 3.5.2.3.2.2.1). The study estimated *I/N* value for orbital spacing of 8 degrees between a GSO MSS transmitting space station and a GSO ISS transmitting space station. The GSO MSS transmitting space station coverage area was assumed on the basis of MSS typical characteristics (Table 2.2-1).

The simulation accounted for aggregate interference from multiple MSS transmitting space stations assuming a minimum spacing angle of 5 degrees. In that case the simulation duration was 30 days with a step of 3 seconds. The simulation results are shown in Fig. 3.5-7.

FIGURE 3.5-7



The simulation results show that for assumed e.i.r.p. limitations shown in Table 3.5-12 it is not expected that the protection criterion of *I/N* = -10 dB for 0.1% of time would be exceeded for orbital spacing of 8 degrees between a GSO MSS transmitting space station and a GSO ISS transmitting space station.

Thus it is proposed to use the current provisions of RR Article **9** (RR No. **9.7** specifically) to provide sharing between the envisaged MSS and ISS receiving stations operating in GSO-NGSO direction. The issue of defining the threshold criteria for coordination requires further studies.

3.5.2.3.2 HIBLEO-2/-2FL use of ISS used in a non-GSO MSS system

The HIBLEO-2 non-GSO MSS satellite system has been in operation for a number of years. Its frequencies have been coordinated, notified, and recorded in the MIRF. It provides full global coverage, and is the only mobile communication satellite system that does so.

It consists of 66 satellites orbiting in six planes having 11 satellites each. These operate at an approximate orbital altitude of 780 km. These 66 satellites in the system route user traffic and command and control information using inter-satellite links on a continuous basis. This critical inter-satellite link function operates in the 23.183-23.377 GHz band. The protection criteria for these links, along with some technical characteristics, may be found in Recommendation ITU-R S.1899.

The characteristics specified in Recommendation ITU-R S.1899 and shown in Table 3.5-8 were used as technical characteristics of a NGSO satellite system operating in the ISS using NGSO-NGSO links in the frequency band 23.15-23.55 GHz in the conducted studies.

TABLE 3.5-8

Characteristics of ISS used in a non-GSO MSS system

System parameter	Value
Number of orbital planes	6
Number of satellite per plane	11
Nominal orbit altitude (km)	780
Orbit type	Polar circular (inclination = 86.5°)
Orbit period (min)	100
Frequency band (GHz)	23.183–23.377
Bandwidth required for 8 channels	8 × 19 MHz (total bandwidth is 194 MHz) Bandwidth required for 1 channel is 19 MHz Channel spacing is 25 MHz
Satellite system noise temperature (K)	877
Peak transmitter power (per 19 MHz channel) (dBW)	3
Antenna gain (one antenna per xhannel) (dBi)	36.6
e.i.r.p. (separate 19 MHz channel (dBW)	39.6

The antenna pattern shape for NGSO satellite system operating in the ISS on NGSO-NGSO link was defined according to Recommendation ITU-R S.1899, the antenna off-pointing error of 1 dB is also taken into account.

Two interference scenarios are studied:

Study 1 of HIBLEO-2/-2FL use of ISS in a non-GSO MSS system: MSS User Terminal uplink interference into non-GSO receiver in ISS band.

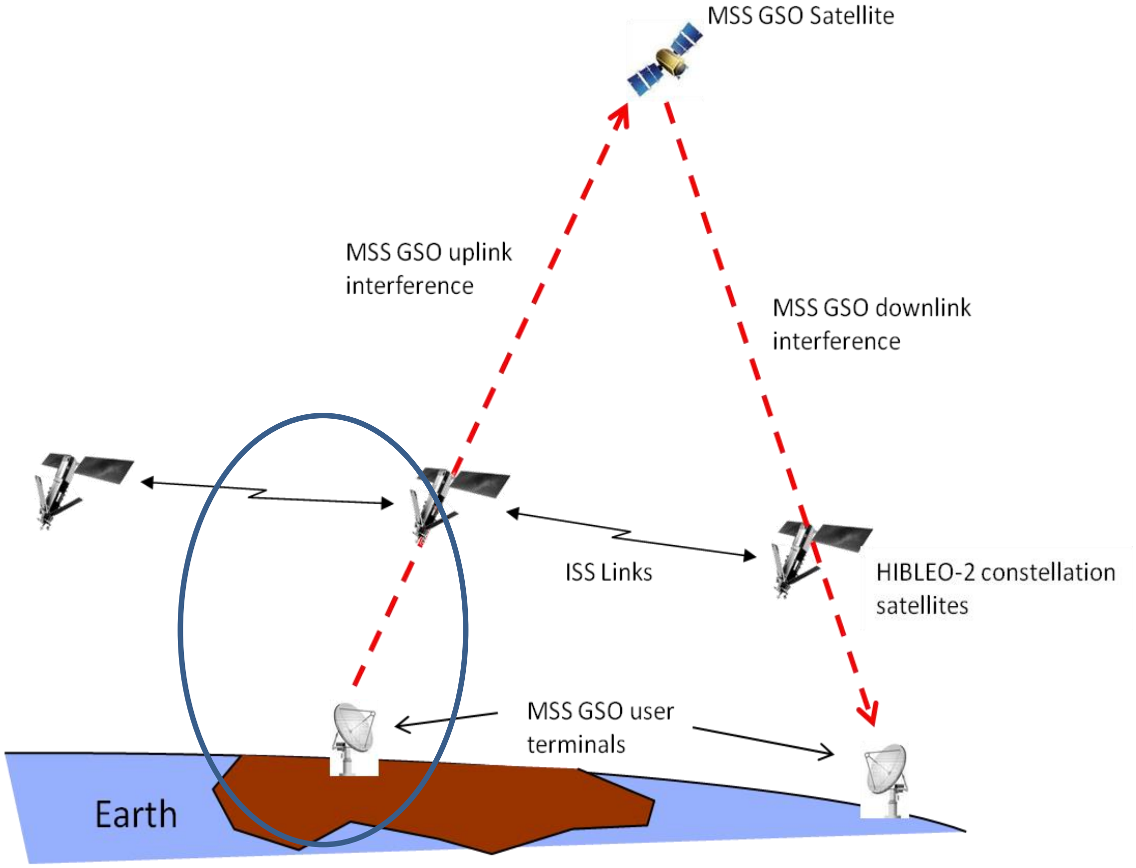
Study 2 of HIBLEO-2/-2FL use of ISS in a non-GSO MSS system: GSO MSS satellite downlink interference into non-GSO receiver in ISS band.

3.5.2.3.2.1 Scenario of interference between GSO MSS and ISS links of a non-GSO MSS system (Study 1 of HIBLEO-2/-2FL use of ISS in a non-GSO MSS system: MSS user terminal uplink interference into non-GSO receiver in ISS band)

An assessment of interference from the proposed GSO MSS network into the HIBLEO-2 ISS links must consider: interference from the GSO MSS user terminal Earth-to-space emissions into the HIBLEO-2 ISS receivers. Figure 3.5-8 depicts this scenario.

FIGURE 3.5-8

GSO MSS uplink interference scenario



High power emissions from the GSO MSS user terminals may potentially produce large levels of interference into the non-GSO satellite constellation during in-line events (i.e., when non-GSO satellite passes through the main beam of the GSO MSS user terminal), even when considering antenna angle discrimination from the non-GSO satellite antenna. Furthermore, large densities of GSO MSS terminals, in aggregate, have the potential to produce even higher levels of interference.

Table 3.5-9 provides a static interference analysis of the victim HIBLEO-2 inter-satellite link receiver, relative to the GSO MSS user terminal and satellite emissions.

TABLE 3.5-9

Static interference analysis of GSO MSS emissions into HIBLEO-2 ISS receivers

Value	**GSO MSS USER- TTERMINAL 1**
e.i.r.p. (dBW)	45.6
Emission bandwidth (MHz)	1.0
e.i.r.p. density (dBW/MHz)	45.6
Path loss (dB)	177.6
Victim antenna side lobe gain (dB)	0.0
Io (dBW/MHz)	–132.0
No(dBW/MHZ)	–139.0
I/*N* (dB)	7.0

3.5.2.3.2.1.1 Results

This study provides a generic description of potential interference scenarios between the proposed GSO MSS system and existing non-GSO MSS system inter-satellite service links operating in the 23 GHz band. These interference scenarios are then quantitatively evaluated using a static interference analysis based on a minimal set of preliminary parameters for the proposed GSO MSS user terminals and satellites. This analysis shows the potential for very large *I/N* values to occur during co-frequency interference events in which an HIBLEO-2 satellite is within the main beam of the GSO MSS user terminal transmission.

3.5.2.3.2.1.2 Additional considerations

Emissions from the proposed GSO MSS systems may include emissions from many satellites and would be expected to serve large service areas that could potentially affect HIBLEO-2/-2FL satellites in those service areas all the time.

This potential interference scenario then has the characteristics of long term interference, possibly producing lower interference levels than considered under Recommendation ITU-R S.1899, but for larger percentages of time.HIBLEO-2/-2FL inter-satellite links do not suffer degradation from propagation effects and therefore have very small link margins, on the order of 1 dB, in order to compensate for antenna pointing and satellite position errors, and thus cannot tolerate interference from other sources. These characteristics result in the need for stringent protection from external interference.

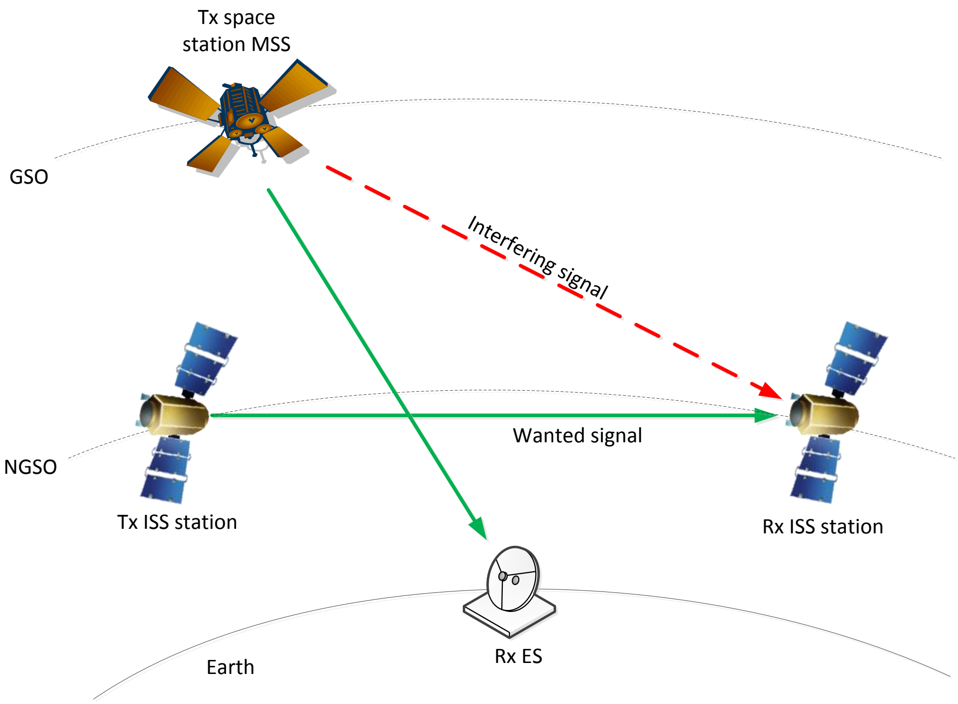
In addition, given the potential for other users of the band there is a need for proper apportionment of interference. There are not any existing Recommendations addressing performance characteristics or protection criteria for the HIBLEO-2/-2FL inter-satellite links. These considerations are under the scope of ITU-R Working Party 4A.

3.5.2.3.2.2 Interference impact scenario (Study 2 of HIBLEO-2/-2FL use of ISS in a non-GSO MSS system: GSO MSS satellite downlink interference into non-GSO receiver in ISS band)

The estimation of compatibility between the envisioned GSO MSS and ISS (NGSO-NGSO link) in the frequency band 23.15-23.55 GHz was based on an interference impact scenario in which the emissions from a MSS transmitting space station would cause interference to an ISS receiving space station. This interference impact scenario is shown in Fig. 3.5-9.

FIGURE 3.5-9

Interference Impact Scenario



The study assumed a protection criterion for the ISS receiving space stations (NGSO-NGSO link) in form of an aggregate protection criterion from the services allocated in the considered frequency band on a primary basis.. In a liaison statement from WP 4A it was indicated that Recommendation ITU-R S.1899 – Protection criteria and interference assessment methods for non-GSO inter-satellite links in the 23.183-23.377 GHz band with respect to the space research service, and Recommendation ITU-R SA.1155 – Protection criteria related to the operation of data relay satellite systems, were not applicable for protection NGSO-NGSO inter-satellite links currently in use by the HIBLEO-2/-2FL system. Unfortunately WP 4A could not suggest any existing Recommendation addressing performance characteristics or protection criteria for the HIBLEO-2/-2FL inter-satellite links.

In such a situation protection criterion of *I/N* = –10 dB in 0.1% of the time was taken from Recommendations ITU-RS.1899 and SA.1155 in this study for co-channel case. WP 4A also indicated that development of appropriate protection criteria for the HIBLEO-2 ISS receivers from the proposed MSS GSO system would require further study by WP 4A.

It was also assumed that a NGSO ISS satellite receiver antenna was pointed at associated NGSO ISS satellite.

As it was mentioned above there are 66 HIBLEO-2 satellites in the system. Each satellite can support up to four inter-satellite channels: two channels for the front satellite and behind satellite in the same orbital planes and two channels for the satellites in the adjacent planes in both sides. The considered system use inter-satellite links for transmission of signals from satellite to satellite using on-board signal processing. Therefore the potential change of *I/N* ratio for transmission from satellite to satellite is not taken into account.

The aggregate interference caused by a set of MSS transmitting space stations was taken into account assuming a minimum spacing angle of 5 degrees. The protection criterion for NGSO-NGSO link is subject to refinement.

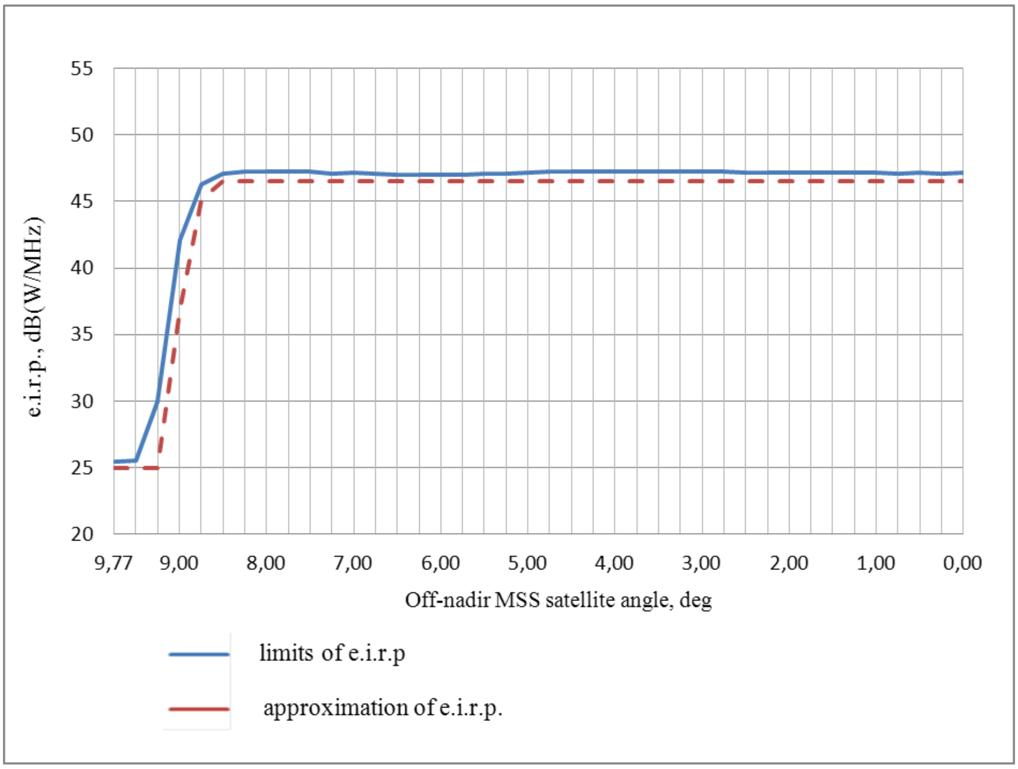
3.5.2.3.2.2.1 Estimation results

The characteristics specified in Recommendation ITU-R S.1899 and shown in Table 3.5-8 were used as technical characteristics of a NGSO satellite system operating in the ISS using NGSO-NGSO links in the frequency band 23.15-23.55 GHz in the conducted studies.

The conducted studies showed that levels of equivalent isotropic radiated power (e.i.r.p.) in 1 MHz from the envisioned MSS to meet a criterion of I/N = –10 dB for a NGSO satellite system operating in the ISS using NGSO-NGSO link in the frequency band 23.15-23.55 GHz should not exceed the levels reflected in Fig. 3.5-10 (a blue curve).

FIGURE 3.5-10

Mask of acceptable e.i.r.p. from envisioned MSS



The obtained e.i.r.p. mask was approximated to meet an I/N = –10 dB criterion for the NGSO satellite system operating in ISS using NGSO-NGSO link from emissions produced by MSS space stations. The result is shown in Fig. 3.5-10 (a red dotted curve) and in Table 3.5-10 below:

TABLE 3.5-10

Mask of acceptable e.i.r.p. from envisioned MSS

Off-nadir angle	*Max e.i.r.p. from MSS satellite*
$0° \le \varphi \le 8.7°$	46.5* dB(W/MHz)
$8.7° < \varphi < 9.25°$	46.5+62log(9.7-φ) dB(W/MHz)
$9.25° \le \varphi \le 90°$	25 dB(W/MHz)

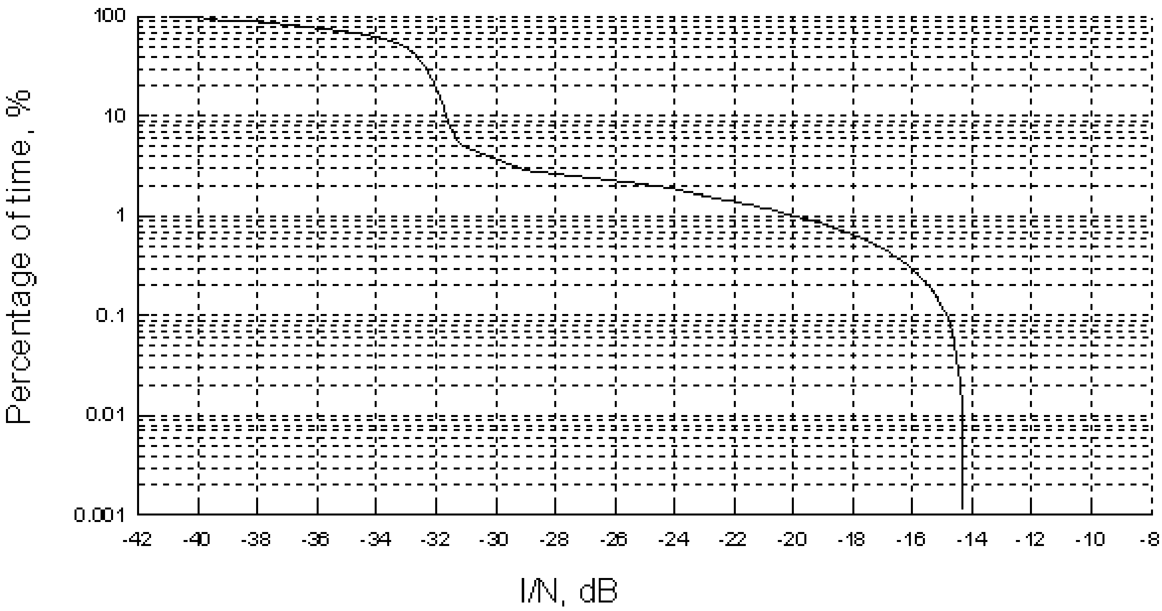
* *It is noted that this maximum e.i.r.p. value is 14.4 dB greater than the MSS satellite e.i.r.p. value given in Table 2.2-1 and used in sharing analyses with all other services*

In addition to the presented results the simulation of the aggregate interference impact was carried out with the characteristics given in Table 2.2-1 and with the assumption that the attenuation of MSS satellite transmitting antennae of 10 dB beyond the visible Earth in relation to the maximum antenna off-pointing error of NGSO-NGSO link is 1 dB. In the simulation the worst location of antenna beam is taken into account while operating in one orbital plane or in adjacent orbital plane.

In the simulation the aggregate interference caused by a set of MSS transmitting space stations into a single HIBLEO-2 ISS receiver was taken into account assuming a minimum spacing angle of 5 degrees. The simulation duration was 30 days with a step of 30 sec. the simulation results are given below in Fig. 3.5-11:

FIGURE 3.5-11

Simulation results of *I/N* with respect to MSS receiving stations



In addition, the simulation *I/N* result provided in § 3.5.2.3.2.2 provides *I/N* as a percentage of time relative to a single satellite in the HIBLEO-2 system.

In accordance to the simulation results in Fig. 3.5-10, at least 4 dB margin exists with reference to *I/N* of -10 dB, assuming the GSO MSS satellite is transmitting at the levels provided in Table 2.2-1 instead of the levels provided in Table 3.5-11. In this case, the percent of time issue is not critical because the *I/N* criterion is not exceeded. However, this percent of time issue is critical when the *I/N* criterion is exceeded since there are 66 satellites in the HIBLEO-2 system, with each satellite having the potential to receive interference. There are two aspects of the HIBLEO-2 system that need to be accounted for when considering the impact of the percentage of time of interference. The first aspect is recognition that the HIBLEO-2 satellites have onboard signal processing such that signal defects on any given inter-satellite link are not propagated (i.e. accumulated) through the rest of the inter-satellite link network. Therefore, the interference degradation impact on any given inter-satellite link does not need to be accounted for elsewhere within the system. However, the second aspect that needs to be accounted for is that potential interference resulting from the planned GSO MSS satellite would be persistent over time within a given coverage region. In this case, all 66 HIBLEO-2 satellites that pass through this interference region may be impacted at independent points in time.

Therefore, the impact of this regional interference needs to be accounted for by aggregating the percentage of time this interference occurs over all satellites in the HIBLEO-2 system. Furthermore, if multiple GSO MSS satellites are transmitting in the GSO arc, then multiple HIBLEO-2 satellites may be impacted, which should also be accounted for when analyzing the percentage of time of interference. It is noted that there is no existing ITU-R methodology to properly characterize the impact of regional interference into every satellite of the HIBLEO-2 system as it passes through the region of interference.

A different assessment of GSO MSS downlink interference into the HIBLEO-2 ISS receiver using the proposed e.i.r.p. mask in Table 3.5-10 and out of band protection criteria *I/N*=-16 in 0.01% of time from ITU-R S.1899 was performed Fig. 3.5-12 below depicts the geometry of the interference scenario between a single GSO MSS satellite and the HIBLEO-2 satellite as it is over the Earth's North Pole. In this scenario, the off-axis angle, θ, between the GSO MSS satellite and the HIBLEO-2 satellite is 9.6°. Referring to Table 3.5-10 above, the e.i.r.p. density of the GSO MSS satellite would be 25.0 dBW/MHz. Table 3.5-11 provides the interference calculations for this scenario.

FIGURE 3.5-12

GSO MSS and HIBLEO-2 Interference Geometry

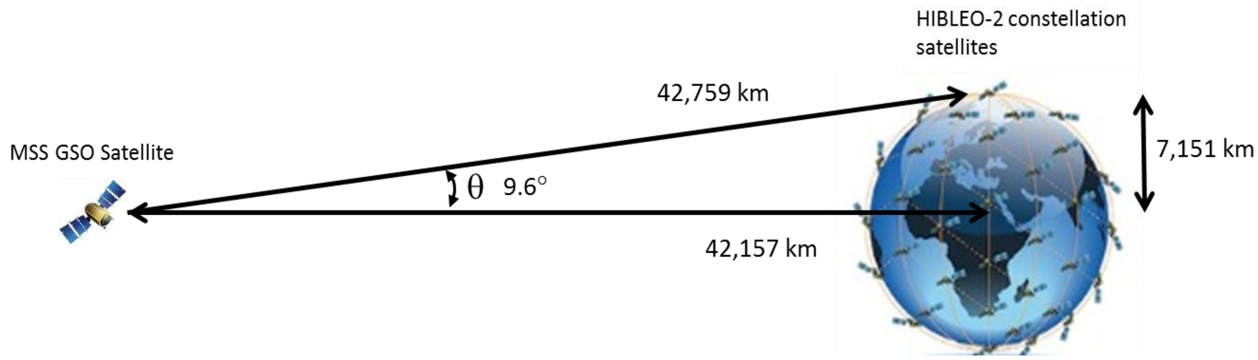


TABLE 3.5-11

GSO MSS Interference Calculations to HIBLEO-2 ISS Receiver

Frequency	23.3	GHz
GSO MSS off-axis e.i.r.p.	25.0	dB(W/MHz)
Interference path length	42759.0	Km
Interference path loss	212.4	dB
HIBLEO-2 receiver antenna gain	36.7	dBi
Interference density at HIBLEO-2 receiver antenna output	–150.7	dB(W/MHz)
HIBLEO-2 satellite receiver system noise temperature	877.0	K
HIBLEO-2 satellite receiver noise power density	–139.2	dB(W/MHz)
Io/No	–11.5	dB

Referencing the *I/N* = –16 dB criterion provided in Recommendation ITU-R S.1899, Table 3.5-11 reveals that the ensuing interference from a single GSO MSS satellite exceeds the criterion by 4.5 dB.

In a third assessment, to estimate MSS impact on HIBLEO-2 system a simulation was conducted assuming a potential protection criterion of *I/N* = –16 dB and characteristics of MSS transmitting stations shown in Table 3.5-12.

The simulation accounted for aggregate interference from multiple MSS transmitting space stations assuming a minimum spacing angle of 5 degrees. For that case the simulation duration was 30 days with a step of 3 seconds. The simulation results are shown in Fig. 3.5-13.

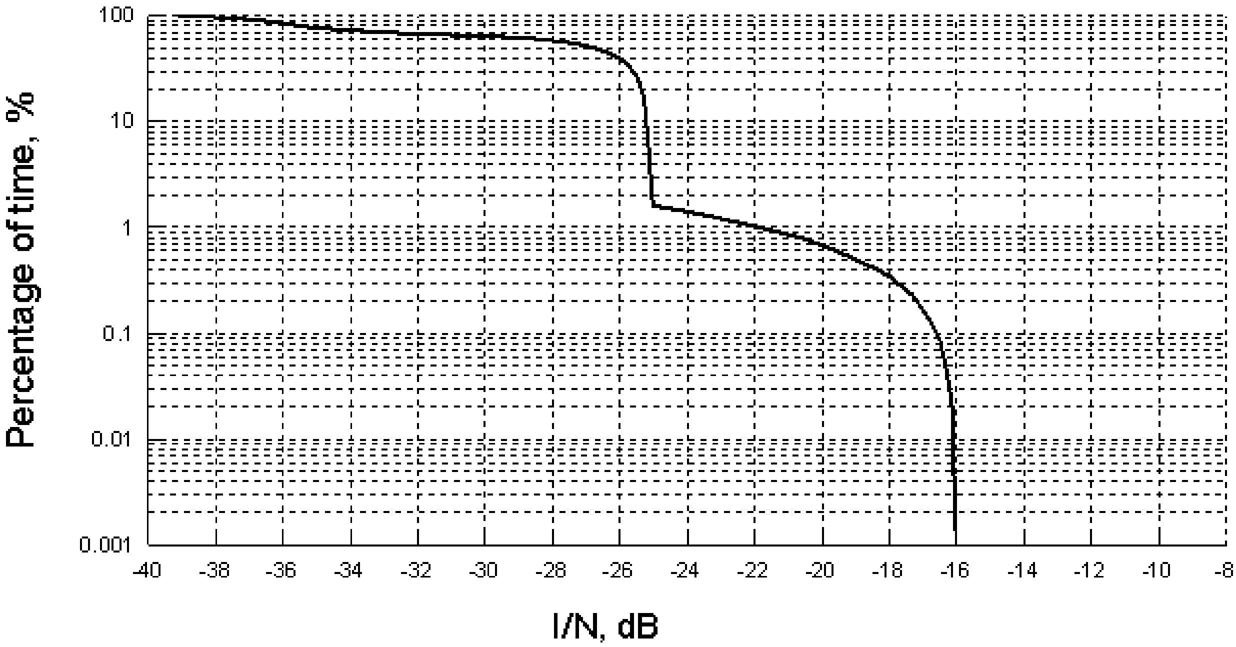
TABLE 3.5-12

Mask of acceptable e.i.r.p. from envisioned MSS for *I/N* = -16 dB

Off-nadir angle	*Max e.i.r.p. from MSS satellite*
0° ≤ φ ≤ 8.7°	42 dB(W/MHz)
8.7° < φ < 9.25°	42+62log(9.7-φ) dB(W/MHz)
9.25° ≤ φ ≤ 90°	20.5 dB(W/MHz)

* It is noted that this maximum e.i.r.p. value is 9.9 dB greater than the MSS satellite e.i.r.p. value given in Table 2.2-1 and used in sharing analyses with all other services

FIGURE 3.5-13



The simulation results show that usage of the assumed e.i.r.p. limitations shown in Table 3.5-12 would not exceed *I/N* = -16 dB for the HIBLEO-2 system, noting that there is no definitive protection criteria.

The three assessments of Study 2 of proposed GSO MSS satellite emissions into the HIBLEO-2 system yielded different results and were inconclusive with respect to adequately determining the limit on aggregate interference needed to protect the HIBLEO-2 system, due to lack of appropriate protection criteria. It is difficult to assess what the required limits on aggregate interference should be given the lack of a defined protection criteria for HIBLEO-2.

3.5.2.4 MSS and Passive Services

Studies of the potential impact of MSS (space-Earth) operating in the frequency band 23.15-23.4 GHz on passive services can be found in § 3.4.2.5.2 (for RAS operating in the bands 23.07-23.12 GHz and 22.81-22.86 GHz under RR No. **5.149**), in § 3.7.2.1.2.1 (for RAS in the band 23.6-24 GHz) and in § 3.7.2.2.2.1 (for EESS in the band 23.6 – 24 GHz).

3.5.3 Results of sharing studies in the frequency band 23.15-23.55 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Pfd limits will have to be applied to the proposed MSS downlink.

The conducted studies show that the protection of MS receiving stations from emissions of MSS transmitting space stations could be provided if levels of pfd would not exceed values shown in Tables 3.5-5 and 3.5-6. Using the typical characteristics of MSS the protection criterion with respect to AMS stations is not exceeded (see Fig. 3.5-4), and RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

Study 1 of data relay satellite systems using GSO-NGSO links: Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems. Refer to §§ 3.4.2.3.1.1 and 3.4.2.3.1.2 for sharing analyses that apply to both the 22.55-23.15 GHz and 23.15-23.55 GHz bands. Refer to § 3.4.2.3.1.1.1 and § 3.4.2.3.1.2.1 for the results of studies.

Study 2 of data relay satellite systems using GSO-NGSO links: The simulation results show that for orbital spacing of 2 degrees between GSO MSS transmitting space station and GSO ISS transmitting station it is not expected that protection criterion of $I/N = -10$ dB in 0.1% of time would be exceeded. Thus it is proposed to use the current provisions of RR Article **9** (RR No. **9.7** specifically) to provide sharing between the envisaged MSS and ISS receiving stations operating in GSO-NGSO direction. The issue of defining the threshold criteria for coordination requires further studies.

Study 1 of HIBLEO-2 use of ISS to support non-GSO MSS system: MSS User Terminal uplink interference into non-GSO receiver in ISS band: Based on the information presented in § 3.5.2.3.1, the proposed MSS operations in the band 23.15-23.55 GHz are not compatible with incumbent ISS space-to-space systems. Based on these preliminary analyses in § 3.5.2.3.2, it appears that the only way to ensure protection of the HIBLEO-2 ISS links is to avoid use of the 23.15-23.55 GHz band by the envisioned MSS satellite networks.

Study 2 of HIBLEO-2 use of ISS to support non-GSO MSS system: GSO MSS satellite downlink interference into non-GSO receiver in ISS band: The conducted studies showed, assuming GSO MSS transmission parameters in Table 2.2-1, that levels of interference into a single HIBLEO-2 ISS receiver is quantified in Fig. 3.5-10. A different assessment showed that the level of interference is quantified as shown in Table 3.5-11. Concerns about the analysis including appropriate protection criteria have been noted at the end of § 3.5.2.3.

A third assessment of Study 2 showed that with MSS usage of the assumed e.i.r.p. limitations shown in Table 3.5-12 interference would not exceed $I/N = -16$ dB for the HIBLEO-2 system, noting that there is no definitive protection criteria.

3.6 The frequency band 23.55-23.6 GHz

Allocations for this frequency band are shown in Table 3.6-1:

TABLE 3.6-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 23.55-23.6 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
23.55-23.6	FIXED MOBILE	

3.6.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.6-2.

TABLE 3.6-2

ITU-R Recommendations relevant to the sharing studies in the band 23.55-23.6 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7

3.6.2 Sharing studies in the frequency band 23.55-23.6 GHz

3.6.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS.

3.6.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.6.3 Results of sharing studies in the frequency band 23.55-23.6 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. A related study is presented in § 3.1.2.1. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.7 The frequency band 23.6-24 GHz

Allocations for this frequency band are shown in Table 3.7-1. It is noted this is a “passive band” protected by RR No. **5.340**.

TABLE 3.7-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 23.6-24 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
23.6-24	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340	

5.340 All emissions are prohibited in the following bands … 23.6-24 GHz …. (WRC-03)

3.7.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues are listed in Table 3.7-2. These are provided for the purposes of compatibility studies for out-of-band emissions.

TABLE 3.7-2

ITU-R Recommendations relevant to the band 23.6-24 GHz

Service	Relevant ITU-R Recommendations
EESS (passive)	ITU-R RS.515, ITU-R RS.1028, ITU-R RS.1813, ITU-R RS.1861, ITU-R RS.1029
RAS	ITU-R SA.509, ITU-R RA.769, ITU-R RA.1631, ITU-R RA.517, ITU-R RA.611, ITU-R RA.1031, ITU-R RA.1237, ITU-R RA.1513
SRS (passive)	ITU-R RS.515, ITU-R RS.1028, ITU-R RS.1813, ITU-R RS.1861, ITU-R RS.1029

3.7.2 Sharing and compatibility studies in the frequency band 23.6-24 GHz

3.7.2.1 MSS and RAS / SRS (passive)

No study was performed with respect to SRS (passive) due to inability to identify information on system technical characteristics and required protection levels.

3.7.2.1.1 MSS in-band and RAS

As a “passive band” protected by RR No. **5.340**, this band is not considered for allocation to the MSS under WRC-15 agenda item 1.10. Consequently, no studies of sharing between the MSS operating in this band and RAS were performed.

3.7.2.1.2 MSS unwanted emissions into RAS

3.7.2.1.2.1 Potential impact of unwanted emissions from MSS (s-E) in the 23.15-23.4 GHz band on RAS in the Frequency Band 23.6-24.0 GHz[2]

The frequency band 23.6-24.0 GHz is used by RAS for continuum observations, for spectral-line observation and for Very-Long Baseline Interferometry (VLBI) measurements.

Passive services are typically more susceptible to detrimental interference from satellite transmissions due to the fact that terrestrial sources of interference are usually deployed far in the radiotelescope side-lobes and therefore, their emissions are mitigated by surrounding terrains. In contrast, a case may occur when satellite emissions could fall into a RAS station main lobe with the result that the interfering signal would be amplified by the significant passive service station antenna gain. Therefore due to importance of protecting the passive services in the frequency band 23.6-24.0 GHz from unwanted emissions produced by envisioned new MSS (space-Earth) in the frequency band 23.15-23.4 GHz the compatibility studies have been conducted assuming the above mentioned scenario.

According to Table 1 (Recommendation ITU-R RA.769 Annex 1) the PFD level of –147 dBW/m^2 in 400 MHz band width (equivalent to PFD = –173 dBW/m^2 in 1 MHz) would be a protection level for continuum observations conducted by RAS in the frequency band 23.6-24.0 MHz.

According to Table 2 (Recommendation ITU-R RA.769 Annex 1) the PFD level of -161 dBW/m^2 in 250 kHz band width (equivalent to PFD = –155 dBW/m^2 in 1 MHz) would be a protection level for spectral-line observations conducted by RAS in the frequency band 23.6-24.0 MHz.

However, subject to Recommendation ITU-R RA.769 the level specified in Table 1 therein applies to terrestrial sources of interference and assumes that affecting emission is received through a side lobe having 0 dB gain. Interference from GSO space stations to RAS stations are of special importance because they are acquired through radiotelescope antenna side lobes having a higher gain level.

Subject to Recommendation ITU-R RA.769A the value of 5 degrees shall be assumed as a minimum required angular spacing between RAS antenna main lobe and direction to GSO. According to antenna pattern approximation described in Recommendation ITU-R SA.509 the side lobe gain level would be 15 dBi for 5 degrees offset angle from the main lobe. Thus to avoid detrimental interference to RAS radiotelescopes it would be advisable to reduce the level of GSO space station emissions by 15 dB in relation to the PFD levels specified in Table 1 of Recommendation ITU-R RA.769.

VLBI observations where signals from widely separated antennas are acquired and recorded with a post-observation processing are significantly less accessible to interference. It is reflected in the PFD threshold level for VLBI observations in the frequency band considered. The threshold PFD level of –183 dBW/m^{2}Hz (equivalent to PFD of –123 dBW/m^2 in 1 MHz) required for protecting the RAS stations operating in the VLBI observation mode is described in Table 3 of Recommendation ITU-R RA.769 Annex 1.

Recommendation ITU-R SM.1542 describes interference mitigation techniques (such as filtration for reducing unwanted peaks in spurious emission bandwidth) to be used for protecting the RAS from unwanted emissions produced by FSS systems in the Russian Federation.

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[2] This study of the potential impact of MSS unwanted emissions on radioastronomy operations was incorporated into this Report without the opportunity for the ITU-R RAS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

MSS Space Station (SS) characteristics in the frequency band 23.15-23.4 GHz were assumed on the basis of maximum limitation values estimated for the envisioned MSS. Maximum MSS SS PFD at the Earth surface would be of –115 dBW/m^2 in 1 MHz (equivalent to e.i.r.p. of 47 dBW/MHz at GSO MSS SS output; see Annex 1) to provide protection for FS.

Subject to Radio regulations the boundary between out-of-band and spurious emissions is located at frequencies spaced from a central emission frequency by the values specified in Table 1 of RR Appendix **3** Annex 1. As a general case the boundary would be offset from a central emission frequency by 250% of the required frequency bandwidth or by the value of 2.5 B_N.

FIGURE 3.7-1

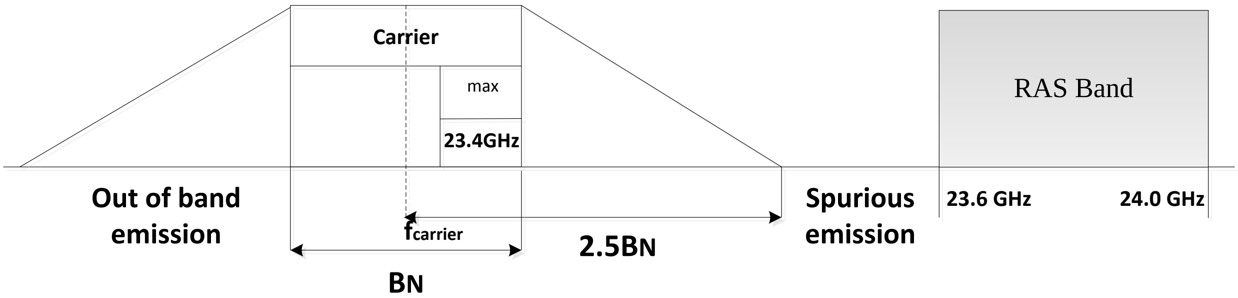
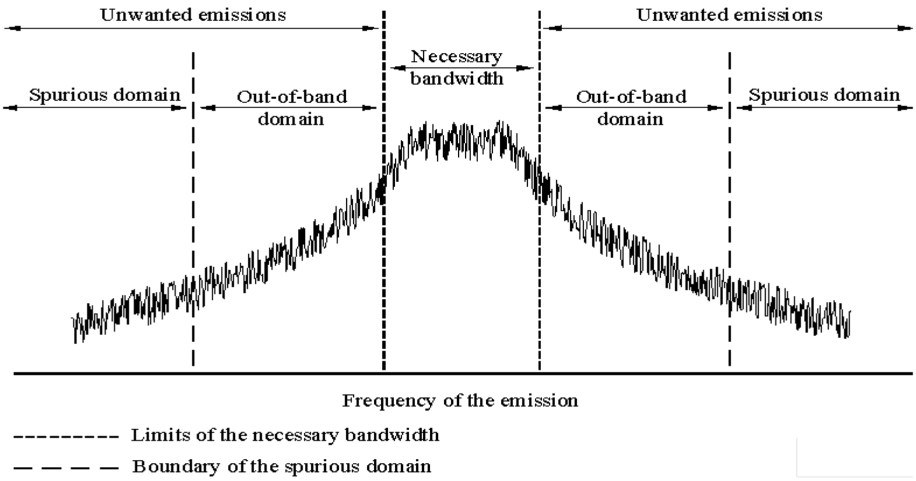


Figure 3.7-1 shows a MSS transponder with B_N bandwidth as operating in the frequency band 23.15-23.4 GHz in close vicinity to the RAS and SRS band.

Based on the typical characteristics (Table 2.2-1) the MSS required bandwidth would be of 16.2 MHz. Moreover in any case the frequency band allocated to RAS would be within a MSS transmitter out-of-band emission area as defined in the Radio Regulation (see Fig. 3.7-2).

FIGURE 3.7-2

Out-of-band and spurious domains



Therefore attenuation values employed for estimating maximum acceptable power levels within out-of-band emission area would be taken from Table 1 of RR Appendix **3** (see Table 3.7-3).

TABLE 3.7-3

Category of services according to RR Article 1 or equipment type	Attenuation (dB) in relation to power level applied at the antenna feeder
Space services (Space stations)	43 + 10 log (*P*) or 60 dBi depending on which of them refers to less stringent requirements.

Results of estimating the levels of detrimental interference caused in the RAS frequency band 23.6-24.0 GHz by MSS SS out of band emission in the frequency band 23.15-23.4 GHz are shown in Table 3.7-4.

TABLE 3.7-4

MSS e.i.r.p. (dB(W/MHz))	47*
Attenuation (dB) below the power supplied to the antenna transmission line	60
RF filter rejection (dB)	20
Minimum spreading factor (dB)	162.1
Maximum spectral pfd (dB(W/m^2·MHz))	–195.1
Continuum observations	
Assumed bandwidth (MHz)	400
Threshold pfd in assumed bandwidth for 0 dBi side-lobe level (dB(W/ m^2·400MHz))	–147
Threshold pfd for 0 dBi side-lobe level in 1 MHz (dB(W/m^2·MHz))	–173
Threshold pfd for 15 dBi side-lobe level in 1 MHz (dB(W/m^2·MHz))	–188
Threshold margin (dB)	**7.1**
Spectral-line observations	
Assumed bandwidth (MHz)	0.25
Threshold pfd in assumed bandwidth for 0 dBi side-lobe level (dB(W/ m^2·250kHz))	–161
Threshold pfd for 0 dBi side-lobe level in 1 MHz (dB(W/m^2·MHz))	–155
Threshold pfd for 15 dBi side-lobe level in 1 MHz (dB(W/m^2·MHz))	–170
Threshold margin (dB)	**25.1**
VLBI	
Reference bandwidth (Hz)	1
Threshold pfd level in reference bandwidth (dB(W/m^2·Hz))	–183
Threshold pfd level in 1 MHz (dB(W/m^2·MHz))	–123
Threshold margin (dB)	**72.1**

* maximum e.i.r.p. level was assumed on the basis of MSS limitations to provide protection for FS. Maximum e.i.r.p. for providing protection of Intersatellite stations in NGSO-NGSO links could be below the above level.

Considering an additional 20 dB filter rejection (as considered in Recommendation ITU-R SM.1542 as an example for BSS in Ka-band in downlink) on top of the 60 dB spurious attenuation from RR Appendix **3**, the results of the conducted estimations in this study show that MSS (space-Earth) unwanted emissions would not exceed the threshold levels specified for protection of RAS stations (Continuum, spectral-line and VLBI observations) in the frequency band 23.6-24.0 GHz.

Some administrations have expressed concerns regarding the lack of expertise in RAS issues available within the working party responsible for this report to assess the assumptions and methodologies used in this analysis, and are not prepared to support conclusions regarding compatibility between MSS (s-E) operations in the band 23.15-23.4 GHz and the RAS in the band 23.6-24 GHz.

3.7.2.1.2.2 Potential impact of unwanted emissions from MSS (s-E) in the band 24.25 – 24.45 GHz on RAS in the frequency band 23.6-24.0 GHz[3]

The potential impact of envisioned MSS space-Earth links in the frequency band 23.15-23.4 GHz on RAS and on passive services in the frequency band 23.6-24.0 GHz is discussed in § 3.7.2.1.2.1. For that study, the minimum frequency separation from RAS and SRS (passive) operations in the 23.6-14 GHz band is 200 MHz. For MSS operations in the 24.25-24.45 GHz band, the minimal frequency separation is 250 MHz.

Considering an additional 20 dB filter rejection (as considered in Recommendation ITU-R SM.1542 as an example for BSS in Ka-band in downlink) on top of the 60 dB spurious attenuation from RR Appendix **3**, unwanted emissions from MSS (space-Earth) in the frequency band 24.25-23.5 GHz would not exceed the threshold values for protecting RAS stations (continuum, spectral-line and VLBI measurements) in the band 23.6-24.0 GHz.

Some administrations have expressed concerns regarding the lack of expertise in RAS issues available within the working party responsible for this report to assess the assumptions and methodologies used in this analysis, and are not prepared to support conclusions regarding compatibility between MSS (s-E) operations in the band 24.25-24.45 GHz and the RAS in the band 23.6-24 GHz.

3.7.2.1.2.3 Potential Impact of unwanted emissions from MSS (E-s) in the band 24.25-24.45 GHz on RAS in the frequency band 23.6-24.0 GHz[4]

The frequency band 23.6-24.0 GHz is used by RAS and SRS services for continuum observations, for spectral-line observation and for Very-Long Baseline Interferometry (VLBI) measurements.

Considering the importance of protecting the passive services in the frequency band 23.6-24.0 GHz from unwanted emissions produced by envisioned new MSS (Earth-space) in the frequency band 24.25-24.5 GHz the compatibility studies have been conducted assuming the above mentioned scenario.

According to Table 1 in Recommendation ITU-R RA.769 Annex 1, power level of –195 dBW in 400 MHz is a protection criterion for RAS stations conducting the continuum observations in the frequency band 23.6-24.0 GHz.

According to Table 2 in Recommendation ITU-R RA.769 Annex 1, power level of –210 dBW in 250 kHz is a protection level for RAS stations conducting the spectral-line observations in the frequency band 23.6-24.0 GHz.

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[3] This study of the potential impact of MSS unwanted emissions on radioastronomy operations was incorporated into this Report without the opportunity for the ITU-R RAS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

[4] This study of the potential impact of MSS unwanted emissions on radioastronomy operations was incorporated into this Report without the opportunity for the ITU-R RAS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

The minimum basic losses required for protecting RAS stations from unwanted emissions produced by FSS Earth stations (ES) may be estimated using the following equation:

$$L_b(p\%) = P_{unwanted} + G_{MSS}(\theta_t) - (\Delta P_H - G_{RAS}(\theta_r))$$

where:

$P_{unwanted}$: power of unwanted emissions from MSS ES transmitter in the RAS frequency band, dBW

$G_{MSS}(\theta_t)$: MSS ES antenna gain in the direction of RAS station, dBi

$G_{RAS}(\theta_r)$: radiotelescope antenna side-lobe gain according to Recommendation ITU-R RA.769, dBi

ΔP_H : threshold interference level at RAS station receiver front end gain according to Recommendation ITU-R RA.769, dBW

θ_t : angle between direction of basic emission and direction to affected receiver, degrees

θ_r : angle between direction of RAS station main lobe and direction to interfering transmitter, degrees

$Lb(p\%)$: minimum required basic loss level non-exceeded for p% of time, dB.

Protection distance is estimated on the basis of basic propagation loss described with the methodology discussed in Recommendation ITU-R P.452-14, including the following assumptions:

– MSS ES antenna phase center height is 3 m above the Earth surface;

– RAS antenna phase center height is 40 m, 80 m and 120 m above the Earth surface;

– Flat earth surface was assumed;

– Zone A (land terrain which is far away from the sea) propagation model was used.

Table 3.7-5 shows results of protection distances estimation as a function of required basic propagation losses for RAS antenna heights of 40 m, 80 m and 120 m. The MSS ES characteristics were based on data in Table 2.2-1.

TABLE 3.7-5

Characteristics	MSS user terminal	Network hub terminal 2.4 m
Antenna gain, dBi	37.4	53.7
Transmit effective isotropic radiated power e.i.r.p. per carrier, dBW	39.85	57.23
Bandwidth at –3 dB, MHz	4.05	16.2
Transmit Antenna Minimum Elevation Angle, deg.	5	5
Antenna MSS phase centre altitude, m	3	3
Attenuation (dB) below the power supplied to the antenna transmission line	60	60
Unwanted emission PSD in the RAS band (dB(W/Hz))	–123.6	–128.57
MSS antenna gain in the RAS direction (dBi)	11.53	11.53
Continuum observations		
The gain for the RAS antenna side-lobe level (dBi)	0	0
Threshold level of interference detrimental to radio astronomy continuum observations (dBW/Hz)	–281	–281
Minimum required value of basic losses (dB)	–168.9	–163.9
Separation distance required for RAS (40 m). km	**35**	**32.5**
Separation distance required for RAS (80 m). km	**43.7**	**41.3**
Separation distance required for RAS (120 m). km	**50,8**	**48,4**
Spectral-line observations		
The gain for the RAS antenna side-lobe level (dBi)	0	0
Threshold interference level detrimental to radio astronomy spectral-line observations (dBW/Hz)	–264	–264
Minimum required value of basic losses (dB)	–151.93	–146.9
Separation distance required for RAS (40 m). km	**25.7**	**17**
Separation distance required for RAS (80 m). km	**25,7**	**17**
Separation distance required for RAS (120 m). km	**25,7**	**17**

It is obvious from Table 3.7-5 that geographical separation for protecting RAS stations operating in the frequency band 23,6-24.0 GHz from unwanted emissions from MSS ES in the frequency band 24.25-24.45 GHz would be from 17 km to 50.8 km depending on RAS statin type and RAS antenna height. The discussed values were obtained without taking the affecting signal propagation path terrain features into consideration. Therefore the data values may be decreased in case of considering diffraction and scattering from natural obstacles.

Some administrations have expressed concerns regarding the lack of expertise in RAS issues available within the working party responsible for this report to assess the assumptions and methodologies used in this analysis, and are not prepared to support conclusions regarding compatibility between MSS (E-s) operations in the band 24.25-24.45 GHz and the RAS in the band 23.6-24 GHz.

3.7.2.2 MSS and EESS (passive) / SRS (passive)

Here SRS passive should be understood as sensors operating on spacecraft around other planets and was therefore not studied. The following sections only address EESS (passive).

3.7.2.2.1 MSS in-band and EESS (passive)

As a “passive band” protected by RR No. **5.340**, this band is not considered for allocation to the MSS under WRC-15 agenda item 1.10. Consequently, no studies of sharing between the MSS operating in this band and EESS (passive) were performed.

3.7.2.2.2 MSS unwanted emissions in-band and EESS (passive)

3.7.2.2.2.1 Potential impact of unwanted emissions from MSS (s-E) in the frequency band 23.15-23.4 GHz on EESS in the Frequency Band 23.6-24.0 GHz[5]

The frequency band 23.6-24.0 GHz is used in EESS for measurements of water vapor and liquid water parameters based on appropriate atmosphere sensing channels in nadir and limb modes. As reflected in Recommendation ITU-R S.1861 (Table 9) the systems in EESS (passive) in the frequency band 23.6-24.0 GHz operate in non-geostationary orbits (NGSO) at the altitudes of 700-850 km with antenna pointing at a certain point on the Earth surface.

In the case of passive sensing the measurements in the frequency range 23.8 GHz (total water vapor content), 31.5 GHz (window channel) and 90 GHz (liquid water) provide auxiliary data which play the main role in the processing of temperature measurements sampling in the O_2 absorption spectrum. The auxiliary measurements should have radiometric and geometry operational characteristics and accessibility criteria corresponding to criteria of temperature measurements. A conical scan radiometer provides for measurements of horizontal water vapor distribution with other channels. Basic parameters of EESS sensors in the band 23.6-24.0 GHz according to Recommendation ITU-R RS.1861 are shown in Table 3.7-6. The antenna pattern for passive sensors operating in EESS (passive) was taken on the basis of Recommendation ITU-R RS.1813.

[5] This study of the potential impact of MSS unwanted emissions on EESS (passive) was incorporated into this Report without the opportunity for the ITU-R EESS (passive) expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

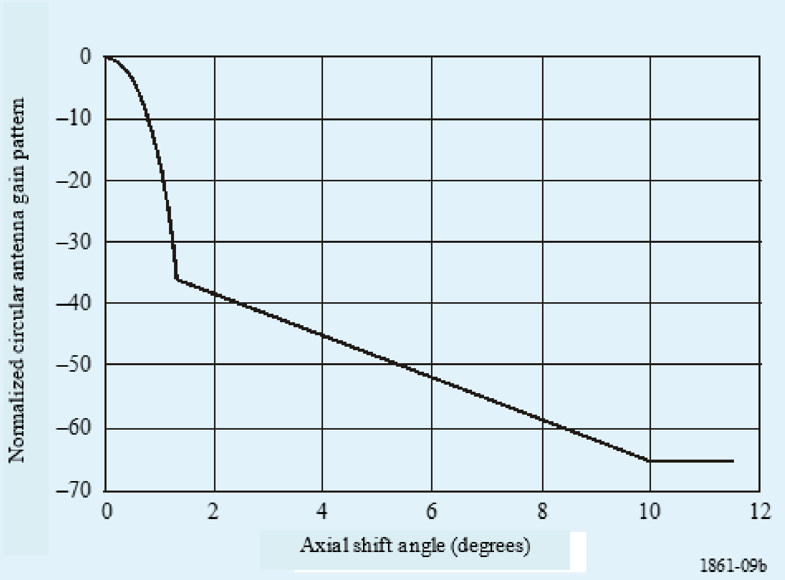
TABLE 3.7-6

EESS (passive) sensor characteristics in the 23.6-24 GHz band

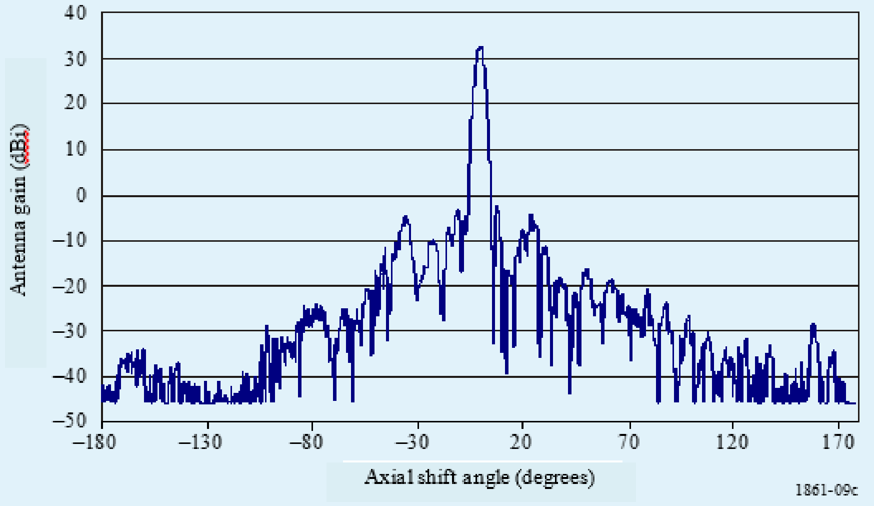
	Sensor F1	**Sensor F2**	**Sensor F3**	**Sensor F4**	**Sensor F5**	**Sensor F6**	**Sensor F7**	**Sensor F8**
Sensor type	Conical scan			Mechanical nadir scan		Conical scan	Push-broom	Conical scan
Orbit parameters								
Altitude	817 km	705 km	828 km	833 km 822 km*	824 km	835 km	850 km	699.6 km
Inclination	20°	98.2°	98.7°	98.6° 98.7°*	98.7°	98.85°	98°	98.186°
Eccentricity	0	0.0015	0	0 0.001	0			0.002
Repeat period	7 days	16 days	17 days	9 days 29 days*	9 days			16 days
Sensor antenna parameters								
Number of beams	1			30 earth fields per 8 s scan period	2	1	90	1
Reflector diameter	0.6 m	1.6 m	2.2 m	0.3 m 0.274 m*	0.203 m	0.6 m	0.9 m	48.5 dBi
Maximum beam gain	40 dBi	46.7 dBi	52 dBi	34.4 dBi	30.4 dBi	43 dBi	45 dBi	2.0 m
Polarization	H, V			V QV*	QV	H, V		H, V
−3 dB beamwidth	1. 81°	0.9°	0.64°	3.3°	5.2°	1.5°	1.1°	0.75°
Instantaneous field of view	63 km × 38 km	32 km × 18 km	18 km × 12 km	Nadir FOV: 48.5 km Outer FOV: 149.1 × 79.4 km 147 × 79 km*	Nadir FOV: 74.8 km Outer FOV: 323.1 × 141.8 km	36 km × 86 km	16 km × 2 282 km	26 km × 15 km
Main beam efficiency	96%	94.8%	95%					94%
Off-nadir pointing angle	44.5°	47.5°	46.6°	±48.33° cross-track	±52.725° cross-track	55.4°		47.5°

	Sensor F1	Sensor F2	Sensor F3	Sensor F4	Sensor F5	Sensor F6	Sensor F7	Sensor F8
Sensor antenna parameters (*cont.*)								
Beam dynamics	31.9 rpm	40 rpm	31.6 rpm	8 s scan period	8/3 s scan period cross-track; 96 earth fields per scan period	2.88 s scan period	90 resolution elements/ line	40 rpm
Incidence angle at Earth	52.3°	55°	53.63°	0° (nadir) 57.5°*		65°		55°
–3 dB beam dimensions	38.7 km (cross-track)	18 km (cross-track)	14.1 km (cross-track)	45 km 48 km*	76 km	22 km	16 km	15 km (cross-track)
Swath width	1 607 km	1 450 km	1 688 km	2 343 km 2 186 km*	2 503 km	2 000 km	2 282 km	1 450 km
Sensor antenna pattern	See Rec. ITU-R RS.1813	Fig. 3.7-3	See Rec. ITU-R RS.1813	Fig. 3.7-3	See Rec. ITU-R RS.1813		−12 dBi back lobe gain	See Rec. ITU-R RS.1813
Cold calibration ant. gain	N/A	32.1 dBi	N/A	34.4 dBi	30.4 dBi	N/A	35 dBi	32.4 dBi
Cold calibration angle (degrees re. satellite track)	N/A	115.5º	N/A	90° −90° ± 3.9°*	0	N/A	90°	115.5º
Cold calibration angle (degrees re. nadir direction)	N/A	97.0º	N/A	83°	82.175°	N/A	83°	N/A
Sensor receiver parameters								
Sensor integration time	1 ms	2.5 ms	1.2 ms	158 ms	18 ms	N/A		2.5 ms
Channel bandwidth	400 MHz	400 MHz centred at 23.8 GHz		270 MHz centred at 23.8 GHz		400 MHz centred at 23.8 GHz	N/A	400 MHz centred at 23.8 GHz
Measurement spatial resolution								
Horizontal resolution	40 km	18 km	17.6 km	45 km 48 km*	75 km	38 km	16 km	15 km
Vertical resolution	N/A	30 km	N/A	45 km 48 km*	75 km	38 km	16 km	25 km

FIGURE 3.7-3



F2 sensor antenna envelope pattern for the frequency band 23.6-24.0 GHz



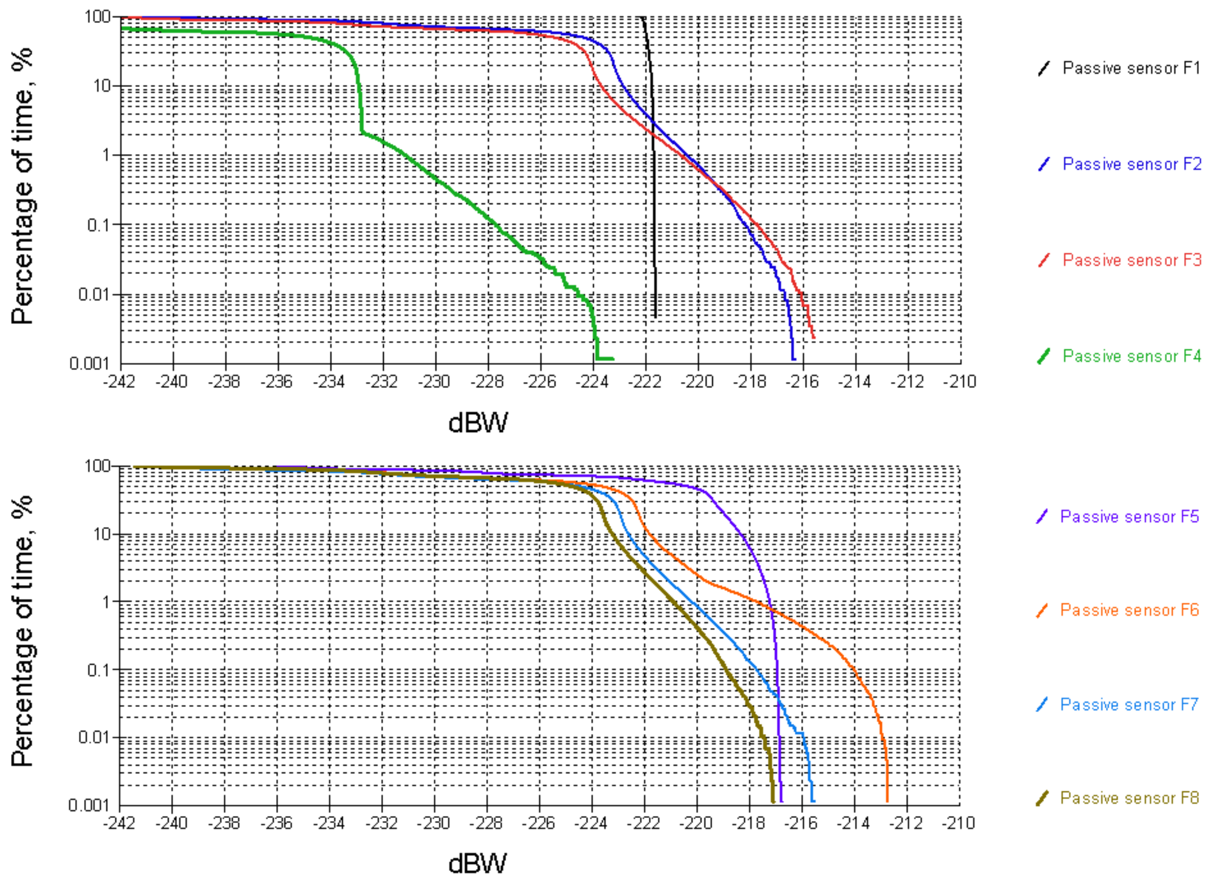
F4 sensor antenns pattern (23.8 GHz)

The impact from MSS on EESS systems operating in the frequency band 23.6-24.0 GHz was estimated using simulation with assumed 72 MSS transmitting stations on GSO with the minimum separation angle of 5 degrees, characteristics shown in Table 3.5-10 (i.e. with e.i.r.p. mask having a maximum value of 46.5 dBW/MHz), attenuation in the spurious domain 60 dB, RF filtering 20 dB.

The acceptable interference value of –166 dBW in 200 MHz reference bandwidth (the criterion shall not be exceeded for more than 0.01% of time) was assumed as EESS protection criterion as shown in Recommendation ITU-R RS.1029.

Aggregate interference caused by multiple MSS transmitting space stations was assumed considering a minimum spacing angle of 5° (72 MSS space stations). The simulation duration was 30 days with a step of 3 seconds. The simulation results are shown in Fig. 3.7-4 assuming a measurement area covering the whole world.

FIGURE 3.7-4



Since these curves were derived without taking into account the 2 million square km area of interest per Recommendation ITU-R RS.1029 , no conclusion can be drawn regarding the compatibility of MSS (s-E) operating in 23.15-23.4 GHz and EESS (passive) in 23.6-24 GHz.

3.7.2.2.2.2 Potential impact of unwanted emissions from MSS (s-E) in the frequency band 24.25-24.45 GHz on EESS (passive) in the frequency band 23.6-24.0 GHz[6]

The potential impact of envisioned MSS on space-Earth links in the frequency band 23.15-23.4 GHz on EESS (passive) in the frequency band 23.6-24.0 GHz is discussed in § 3.7.2.2.2.1. For that study, the minimum frequency separation from EESS (passive) operations in the 23.6-24 GHz band is 200 MHz. For MSS operations in the 24.25-24.45 GHz band, the minimal frequency separation 250 MHz.

Therefore, it is expected that the results for the band 24.25-24.45 GHz will be better than the results obtained for the 23.15-23.4 GHz.

3.7.2.2.2.3 Potential impact of unwanted emissions from MSS (E-s) in the frequency band 24.25-24.45 GHz on EESS (passive) in the frequency band 23.6-24.0 GHz

The frequency band 23.6-24.0 GHz is used in EESS for measurements of water vapor and liquid water parameters based on appropriate atmosphere sensing channels in nadir and limb modes. As reflected in Recommendation ITU-R S.1861 (Table 9) the systems in EESS (passive) in the frequency band 23.6-24.0 GHz operate in non-geostationary orbits (NGSO) at the altitudes of 700-850 km with antenna pointing at a certain point on the Earth surface.

The basic parameters of EESS sensors are shown in Table 3.7-6. Antenna pattern for passive sensors operating in EESS (passive) was taken on the basis of Recommendation ITU-R RS.1813-1.

MSS impact on EESS systems operating in the frequency band 23.6-24.0 GHz was estimated using simulation. The aggregate interference from many transmitting MSS Earth stations transmitting to GSO satellites separated by 5 degrees was taken into account. It was assumed that each MSS space station on GSO operates with 19 user terminal MSS Earth stations and 1 hub station which are uniformly deployed in the service area. The MSS ES characteristics were based on data in Table 2.1-1, attenuation in the spurious domain 60 dB and RF filtering 20 dB which is used only for the hubs.

The acceptable interference value of -166 dBW in 200 MHz reference bandwidth (the criterion shall not be exceeded for more than 0.01% of time) was assumed as EESS protection criterion as shown in Recommendation ITU-R RS.1029.

The simulation duration was 30 days with a step of 3 seconds. The simulation results are shown in Fig. 3.7-5.

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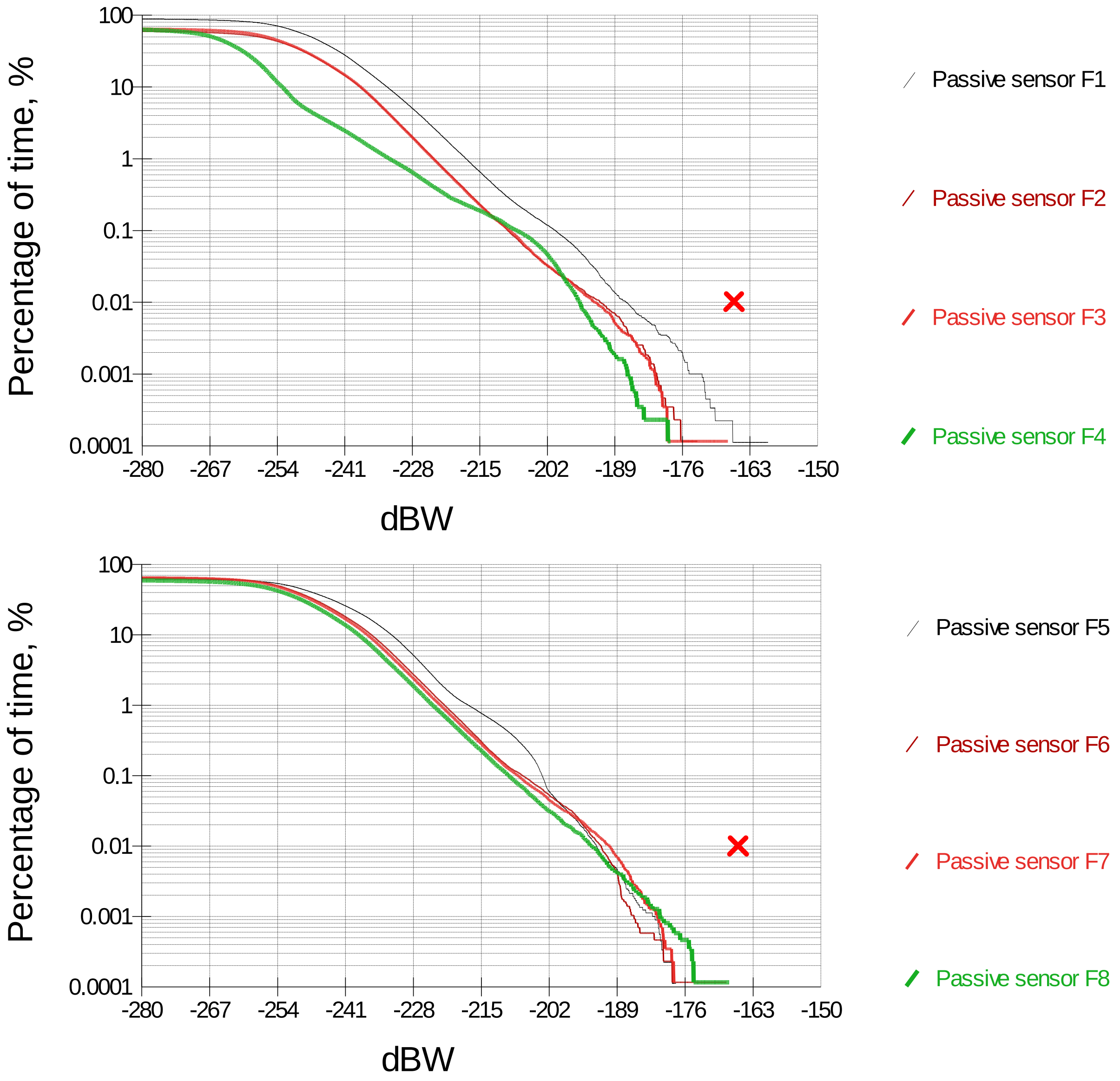
[6] This study of the potential impact of MSS unwanted emissions on EESS (passive) was incorporated into this Report without the opportunity for the ITU-R EESS (passive) expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

FIGURE 3.7-5



Since these curves were derived without taking into account the 2 million square km area of interest per Recommendation ITU-R RS.1029 , no conclusion can be drawn regarding the compatibility of MSS (E-s) operating in 24.25-24.45 GHz and EESS (passive) in 23.6-24 GHz

Also, some administrations believe that the number of MSS earth stations used in this analysis is underestimated by at least a factor of 4.

3.7.3 Results of sharing studies in the frequency band 23.6-24 GHz

A study of the impact of unwanted emissions from MSS (s-E) in the 23.15-23.4 GHz band on RAS is presented in § 3.7.2.1.2.1. The impact of unwanted emissions from MSS (s-E) in the band 24.25-24.45 GHz on RAS is studied in § 3.7.2.1.2.2. A study of the impact of unwanted emissions from MSS (E-s) in the band 24.25-24.5 GHz on RAS is given in § 3.7.2.1.2.3.

A study of the impact of unwanted emissions from MSS (s-E) in the 23.15-23.4 GHz band on EESS (passive) is presented in § 3.7.2.2.2.1. The impact of unwanted emissions from MSS (s-E) in the band 24.25-24.45 GHz on EESS (passive) is studied in § 3.7.2.2.2.2. A study of the impact of unwanted emissions from MSS (E-s) in the band 24.25-24.5 GHz on EESS (passive) is given in § 3.7.2.2.2.3.

3.8 The frequency band 24-24.05 GHz

Allocations for this frequency band are shown in Table 3.8-1:

TABLE 3.8-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24-24.05 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24-24.05	AMATEUR AMATEUR-SATELLITE 5.150	

5.150 The following bands: … 24-24.25 GHz (centre frequency 24.125 GHz) are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. **15.13**.

3.8.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.8-2.

TABLE 3.8-2

ITU-R Recommendations relevant to the sharing studies in the band 24-24.05 GHz

Service	Relevant ITU-R Recommendations
Amateur	ITU-R M.1732 (technical characteristics only)
Amateur-Satellite	ITU-R M.1732 (technical characteristics only)

3.8.2 Sharing studies in the frequency band 24-24.05 GHz

3.8.2.1 MSS and amateur

No studies were conducted to assess sharing between MSS and the amateur service in the 24-24.05 GHz band.

3.8.2.2 MSS and amateur-satellite

No studies were conducted to assess sharing between MSS and amateur-satellite service in the 24 - 24.05 GHz band.

3.8.3 Results of sharing studies in the frequency band 24-24.05 GHz

Since no protection criteria recommendations were available, no studies were done to assess sharing feasibility with the amateur and amateur-satellite services in this band. In addition, no compatibility studies were performed to assess out-of-band interference into the EESS (passive), SRS (passive) or radio astronomy services in 23.6-24 GHz.

3.9 The frequency band 24.05-24.25 GHz

Allocations for this frequency band are shown in Table 3.9-1:

TABLE 3.9-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24.05-24.25 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.05-24.25	RADIOLOCATION Amateur Earth exploration-satellite (active) 5.150	

5.150 The following bands: … 24-24.25 GHz (centre frequency 24.125 GHz) are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. **15.13**.

3.9.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.9-2.

TABLE 3.9-2

ITU-R Recommendations relevant to the sharing studies in the band 24.05-24.25 GHz

Service	Relevant ITU-R Recommendations
Radiolocation	Not available
Amateur	ITU-R M.1732
Earth exploration-satellite (active)	ITU-R RS.577, ITU-R SA.1166, ITU-R RS.1029

3.9.2 Sharing studies in the frequency band 24.05-24.55 GHz

3.9.2.1 MSS and RLS

No studies were conducted to assess sharing between MSS and the radiolocation service in the 24.05-24.55 GHz.

3.9.2.2 MSS and amateur

No studies were conducted to assess sharing between MSS and the amateur service in the 24.05-24.55 GHz band.

3.9.2.3 MSS and EESS (active)

No studies were conducted to assess sharing between MSS and EESS (active) in the 24.05-24.55 GHz band.

3.9.3 Results of sharing studies in the frequency band 24.05-24.25 GHz

Since no protection criteria recommendations were available, no studies were done to assess sharing feasibility with the radiolocation and amateur services in this band. Also, no studies were done to assess the feasibility of sharing with the EESS (active) service.

In addition, no compatibility studies were performed to assess out-of-band interference into the EESS (passive), SRS (passive) or radio astronomy services in 23.6-24 GHz.

3.10 The frequency band 24.25-24.45 GHz

Allocations for this frequency band are shown in Table 3.10-1.

TABLE 3.10-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24.25-24.45 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.25-24.45 FIXED	**24.25-24.45** RADIONAVIGATION	**24.25-24.45** RADIONAVIGATION FIXED MOBILE

Spectrum sharing between MSS and fixed service (in Regions 1 and 3) and mobile service (in Region 3) would be required in this frequency band.

Besides conditions of compatibility of the envisioned MSS with radionavigation service would require relevant studies.

3.10.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.10-2.

TABLE 3.10-2

ITU-R Recommendations relevant to the sharing studies in the band 24.25-24.45 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
Radionavigation	Not available

3.10.2 Sharing studies in the frequency band 24.25-24.45 GHz

3.10.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.10.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.10.2.3 MSS and RNS

No studies were conducted to assess sharing between MSS and the radionavigation service in the 24.25-24.45 GHz band.

3.10.2.4 MSS and Passive Services

Studies of the potential impact of MSS (s-E) operating in the frequency band 24.25-24.45 GHz on passive services can be found in § 3.7.2.1.2.2 (for RAS) operating in the band 23.6-24 GHz) and § 3.7.2.2.2.2 (for EESS (passive) in the 23.6-24 GHz band). Similarly, studies of the potential impact of MSS (E-s) on these services in 23.6-24 GHz can be found in §§ 3.7.2.1.2.3 and 3.7.2.2.2.3.

3.10.3 Results of sharing studies in the frequency band 24.25-24.45 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

Since no Recommendations providing protection criteria or technical characteristics were identified, no studies were done to assess sharing feasibility with the radionavigation service in this band.

3.11 The frequency band 24.45-24.65 GHz

Allocations for this frequency band are shown in Table 3.11-1.

TABLE 3.11-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24.45-24.65 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.45-24.65 FIXED INTER-SATELLITE	**24.45-24.65** INTER-SATELLITE RADIONAVIGATION	**24.45-24.65** FIXED INTER-SATELLITE MOBILE RADIONAVIGATION
	5.533	5.533

5.533 The inter-satellite service shall not claim protection from harmful interference from airport surface detection equipment stations of the radionavigation service.

Spectrum sharing between MSS and fixed as well as radionavigation (Regions 2 and 3) and mobile (Region 3) services would be required in this frequency band.

Besides conditions of compatibility of the envisioned MSS with ISS would require relevant studies.

3.11.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.11-2.

TABLE 3.11-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 24.45-24.65 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
Radionavigation	Not available
Inter-satellite	Recs ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R SA.1743, Report ITU-R SA.2192

3.11.2 Sharing studies in the frequency band 24.45-24.65 GHz

3.11.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.11.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.11.2.3 MSS and RNS

No studies were conducted to assess sharing between MSS and the radionavigation service in the 24.45-24.65 GHz band.

3.11.2.4 MSS and ISS

No studies were conducted to assess sharing between MSS and the inter-satellite service in the 24.45-24.65 GHz band.

3.11.3 Results of sharing studies in the frequency band 24.45-24.65 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore. Pfd limits will have to be applied to the proposed MSS downlink.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

Since no Recommendations providing technical characteristics and protection criteria could be identified, no studies were done to assess sharing feasibility with the radionavigation service. Also, no studies of sharing with the inter-satellite service waere done in this band.

3.12 The frequency band 24.65-24.75 GHz

Allocations for this frequency band are shown in Table 3.12-1:

TABLE 3.12-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24.65-24.75 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.65-24.75 FIXED FIXED-SATELLITE (Earth-to-space) 5.532B INTER-SATELLITE	24.65-24.75 INTER-SATELLITE RADIOLOCATION-SATELLITE (Earth-to-space)	**24.65-24.75** FIXED FIXED-SATELLITE (Earth-to-space) 5.532B INTER-SATELLITE MOBILE 5.533

5.532B Use of the band 24.65-25.25 GHz in Region 1 and the band 24.65-24.75 GHz in Region 3 by the fixed-satellite service (Earth-to-space) is limited to earth stations using a minimum antenna diameter of 4.5 m. (WRC-12)

5.533 The inter-satellite service shall not claim protection from harmful interference from airport surface detection equipment stations of the radionavigation service.

3.12.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.12-2.

TABLE 3.12-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 24.65-24.75 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
Fixed Satellite (Earth-to-space)	ITU-R S.465, ITU-R S.1329, ITU-R S.1323
Inter-satellite	Recs ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R SA.1743, Report ITU-R SA.2192
Radiolocation-Satellite (Earth-to-space)	Not available

3.12.2 Sharing studies in the frequency band 24.65-24.75 GHz

3.12.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.12.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.12.2.3 MSS and FSS (Earth-to-space)

No studies were conducted to assess sharing between MSS and the fixed-satellite service (Earth-to-space) in the 24.65-24.75 GHz band.

3.12.2.4 MSS and ISS

No studies were conducted to assess sharing between MSS and the inter-satellite service in the 24.65-24.75 GHz band.

3.12.2.5 MSS and radiolocation-satellite (Earth-to-space)

No studies were conducted to assess sharing between MSS and the radiolocation-satellite (Earth-to-space) service in the 24.65-24.75 GHz band.

3.12.3 Results of sharing studies in the frequency band 24.65-24.75 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

Since no Recommendations providing technical characteristics and protection criteria could be identified, no sharing studies were performed with the radiolocation-satellite service (Earth-to-space). Also, no studies were done to assess sharing feasibility with the FSS (Earth-to-space) and inter-satellite services in this band.

3.13 The frequency band 24.75-25.25 GHz

Allocations for this frequency band are shown in Table 3.13-1.

TABLE 3.13-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 24.75-25.25 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.75-25.25 FIXED FIXED-SATELLITE (Earth-to-space) 5.532B	**24.75-25.25** FIXED-SATELLITE (Earth-to-space) 5.535	**24.75-25.25** FIXED FIXED-SATELLITE (Earth-to-space) 5.535 MOBILE

5.532B Use of the band 24.65-25.25 GHz in Region 1 and the band 24.65-24.75 GHz in Region 3 by the fixed-satellite service (Earth-to-space) is limited to earth stations using a minimum antenna diameter of 4.5 m. (WRC-12)

5.535 In the band 24.75-25.25 GHz, feeder links to stations of the broadcasting-satellite service shall have priority over other uses in the fixed-satellite service (Earth-to-space). Such other uses shall protect and shall not claim protection from existing and future operating feeder-link networks to such broadcasting satellite stations.

Spectrum sharing between MSS and fixed (Regions 1 and 2) as well as mobile (Region 3) services would be required in this frequency band.

Besides conditions of compatibility of the envisioned MSS with FSS (Earth-to-space) in the frequency band 24.25-24.45 GHz would require relevant studies. It should be taken into consideration that FSS is limited to earth stations using antennas of 4.5 m minimum diameter.

3.13.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.13-2.

TABLE 3.13-2

ITU-R Recommendations relevant to the sharing studies in the band 24.75-25.25 GHz

Service	Relevant ITU-R Recommendations
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	Not available
Fixed-satellite	ITU-R S.465, ITU-R S.1329, ITU-R S.1323

3.13.2 Sharing studies in the frequency band 24.75-25.25 GHz

3.13.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.13.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.13.2.3 MSS and FSS

No studies were conducted to assess sharing between MSS and the fixed-satellite service (Earth-to-space) in the 24.75-25.25 GHz band.

3.13.3 Results of sharing studies in the frequency band 24.75-25.25 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

No studies were done to assess sharing feasibility with the FSS (Earth-to-space) service in this band.

3.14 The frequency band 25.25-25.5 GHz

Allocations for this frequency band are shown in Table 3.14-1.

TABLE 3.14-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 25.25-25.5 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
25.25-25.5	FIXED INTER-SATELLITE 5.536 MOBILE Standard frequency and time signal-satellite (Earth-to-space)	

5.536 Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space.

Spectrum sharing between MSS and fixed as well as mobile services would be required in this frequency band.

Besides conditions of compatibility of the envisioned MSS with primary ISS as well as with secondary standard frequency and time signal-satellite service (Earth-to-space) would require relevant studies.

3.14.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.14-2.

TABLE 3.14-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 25.25-25.5 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7
Inter-satellite	Recs ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R SA.1743, Report ITU-R SA.2192,
Standard frequency and time signal-satellite	ITU-R TF.1011, ITU-R TF.1153, ITU-R TF.374

3.14.2 Sharing studies in the frequency band 25.25-25.5GHz

3.14.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.14.2.2 MSS and MS

3.14.2.2.1 Characteristics of MS station

Currently the characteristics for interference estimation from the MSS to land MS in the frequency band 25.25-25.5 GHz are not available in WP 4C. Therefore the characteristics indicated in Tables 3.14-3 and 3.14-4 were proposed as MS characteristics to be used in the studies. The characteristics of AMS are based on the data in Annex 7.

TABLE 3.14-3

Characteristics of land MS systems

Frequency range (GHz)	25.25-25.5	
Type	User Terminal	Base station
Antenna gain (dBi)	0	35 (Rec. ITU -P F.1336)
Feeder/multiplexer loss range (dB)	0…3	0…3
Receiver noise power density typical (=N_{RX}) (dBW/MHz)	−136	-136
Nominal long-term interference power density (dBW/MHz)	−136 + *I/N*	-136 + *I/N*

TABLE 3.14-4

AMS receiver characteristics

Parameter	Units	System 2 Ground
Tuning range	GHz	25.25-27.5
NF	dB	4.5
Antenna gain	dBi	33
1st Sidelobe	dBi	16
Antenna model		Recommendation ITU-R M.1851

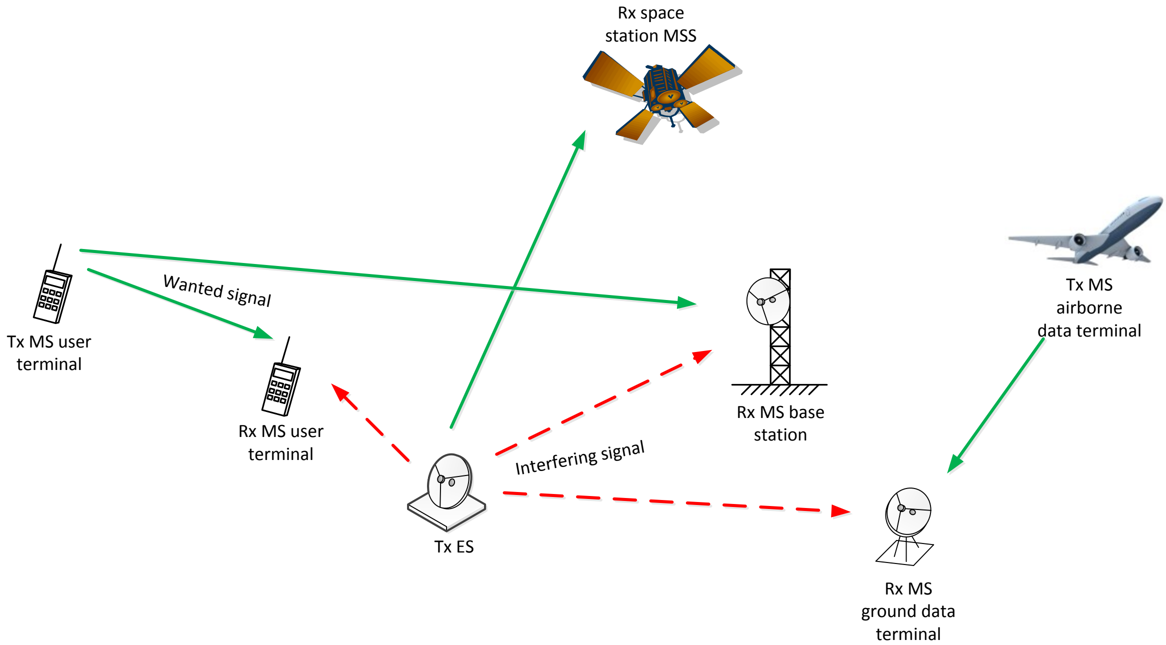
3.14.2.2.2 Interference impact scenario

In the compatibility assessment of the mobile satellite service with the mobile service in the frequency band 25.25-25.5 GHz the following interference impact scenario was considered: the transmitting MSS earth station emissions can cause interference to the receiving MS ground station.

Figure 3.14-1 presents the interference impact scenario mentioned above. As described in Annex 7, the receiving stations of AMS in the considered frequency band are earth stations.

Figure 3.14-1

Interference Impact Scenario



It should be noted that sharing between the transmitting MSS earth station and receiving MS earth station is provided under RR Article **9** (particularly RR **No. 9.17**).

It is required to define the separation distance between the receiving MS station and transmitting MSS earth station in order to provide protection for the receiving MS stations from the transmitting MSS earth station emissions.

Therefore currently the protection criteria of the land MS stations is not defined yet and the aggregate protection criteria equals to *I/N* –6 dB from the services having primary allocation in the considered frequency band was used as the protection criteria of the receiving MS ground stations. This protection criterion was assumed by analogy with that in the adjacent frequency range (Ku-band).

As explained in Annex 7, the aggregate protection criteria of *I/N* –6 dB from all operating MSS space stations was used as a protection criterion for the AMS receiving stations.

The propagation losses of the interfering signal were calculated in accordance with Recommendation ITU-R P.425-14. With this:

– antenna phase centre altitude of the MSS earth station was 3 m above the ground surface;

– antenna phase centre altitude was 3 m for MS user terminal and AMS earth station, 20 m for MS base station above the ground surface;

– the ground surface was assumed as smooth surface;

– the propagation model in A2 area (the land is far away from the sea).

3.14.2.2.3 Estimation results

Tables 3.14-5 and 3.14-6 provides the estimation results of the user MSS ES with antenna size of 0.33 m and also from the hub terminal MSS ES with antenna size of 2.4 m. Table 3.14-7 provides the estimation results of the AMS station.

TABLE 3.14-5

Estimation results for MS user terminal

Characteristics of user terminal	Units	User terminal			Network hub terminal 2.4 m		
Transmitter centre frequency	GHz	25.375					
Transmit antenna diameter	M	0.33			2.4		
Antenna gain	dBi	37.4	37.4	37.4	53.7	53.7	53.7
Transmit effective isotropic radiated power e.i.r.p. per carrier	dBW	39.85	39.85	39.85	57.23	57.23	57.23
Bandwidth at -3 dB	MHz	4.05	4.05	4.05	16.2	16.2	16.2
Transmit antenna pattern type		Rec. ITU-R S.580					
Transmit antenna minimum elevation angle	Deg	5	10	side lobe	5	10	side lobe
Antenna gain towards horizon at elevation angle	dBi	11.53	4.00	–10.00	11.53	4.00	–10.00
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW	19.74	12.21	–1.79	15.06	7.53	–6.47
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW/MHz	7.64	0.11	–13.89	2.96	–4.57	–18.57
Antenna gain	dBi	0.00	0.00	0.00	0.00	0.00	0.00
Receiver noise power density typical	dBW/MHz	–136	–136	–136	–136	–136	–136
Criteria *I/N*,	dB	–6	–6	–6	–6	–6	–6
Required attenuation to avoid interference	dB	149.90	142.38	128.38	144.96	137.43	123.43
Required separation distance to MES to avoid interference	Km	10.6	8.35	2.5	9.06	6.62	1.44

TABLE 3.14-6

Estimation results for MS base station

Characteristics of user terminal	Units	User terminal			Network hub terminal 2.4 m		
Transmitter centre frequency	GHz	25.375					
Transmit antenna diameter	m	0.33			2.4		
Antenna gain	dBi	37.4	37.4	37.4	53.7	53.7	53.7
Transmit effective isotropic radiated power e.i.r.p. per carrier	dBW	39.85	39.85	39.85	57.23	57.23	57.23

TABLE 3.14-6 *(end)*

Characteristics of user terminal	**Units**	**User terminal**			**Network hub terminal 2.4 m**		
Bandwidth at -3 dB	MHz	4.05	4.05	4.05	16.2	16.2	16.2
Transmit antenna pattern type		Rec. ITU-R S.580					
Transmit antenna minimum elevation angle	deg	5	10	Side lobe	5	10	Side lobe
Antenna gain towards horizon at elevation angle	dBi	11.53	4.00	–10.00	11.53	4.00	–10.00
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW	13.98	6.45	–7.55	15.06	7.53	–6.47
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW/MHz	7.90	0.38	–13.62	2.96	–4.57	–18.57
Antenna gain	dBi	35.00	35.00	35.00	35.00	35.00	35.00
Receiver noise power density typical	dBW/MHz	–136	–136	–136	–136	–136	–136
Criteria *I/N*,	dB	–6	–6	–6	–6	–6	–6
Required attenuation to avoid interference	dB	184.90	177.38	163.38	179.96	172.43	158.43
Required separation distance to MES to avoid interference	km	39.72	36.21	29.8	37.4	33.95	27.4

TABLE 3.14-7

Estimation results for AMS station

Characteristics of user terminal	**Units**	**User terminal**			**Network hub terminal 2.4 m**		
Transmitter centre frequency	GHz	25.375					
Transmit antenna diameter	m	0.33			2.4		
Antenna gain	dBi	37.4	37.4	37.4	53.7	53.7	53.7
Transmit effective isotropic radiated power e.i.r.p. per carrier	dBW	39.85	39.85	39.85	57.23	57.23	57.23
Bandwidth at -3 dB	MHz	4.05	4.05	4.05	16.2	16.2	16.2
Transmit antenna pattern type		Rec. ITU-R S.580					
Transmit antenna minimum elevation angle	deg	5	10	Side lobe	5	10	Side lobe
Antenna gain towards horizon at elevation angle	dBi	11.53	4.00	–10.00	11.53	4.00	-10.00
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW	13.98	6.45	–7.55	15.06	7.53	–6.47

TABLE 3.14-7 (*end*)

Characteristics of user terminal	Units	User terminal			Network hub terminal 2.4 m		
Transmit e.i.r.p. per carrier towards horizon at elevation angle	dBW/MHz	7.90	0.38	–13.62	2.96	–4.57	–18.57
Antenna gain	dBi	33.00	33.00	33.00	33.00	33.00	33.00
Receiver noise power density typical	dBW/MHz	–139.4	–139.4	–139.4	–139.4	–139.4	–139.4
Criteria *I/N*,	dB	–6	–6	–6	–6	–6	–6
Required attenuation to avoid interference	dB	186.30	178.78	164.78	181.36	173.83	159.83
Required separation distance to MES to avoid interference	km	27.1	22.95	16.35	24.3	20.4	14.35

The analysis of the estimation results show that while changing the considered characteristics of the MSS ES the required protection distance to the receiving MS station will change in the range from 39.72 to 1.44 km. It should be noted that the approach when the main antenna axis of the MS station was directed towards the transmitting MSS ES was applied in the estimation. Consequently the obtained result is the worst case of interference impact and in the dynamic simulation this distance can be reduced.

Therefore RR No**. 9.17** is proposed to apply to provide the sharing of the proposed MSS with the receiving MS stations.

3.14.2.2.4 Conclusion

The performed studies showed that RR No. **9.17** should be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.14.2.3 MSS and ISS – ISS used in space research systems (data relay satellite systems using GSO-NGSO links)

This section contains three studies of MSS and ISS. All three are ISS supporting Space Research Systems (data relay satellite systems using GSO-NGSO links). One study (named Case A) examines the specific situation of MSS GSO satellite downlink interference into GSO receiving from non-GSO LEO. The other two studies (named Cases B1 and B2) examine the specific situation of MSS user terminal uplink interference into GSO receiving from non-GSO LEO.

3.14.2.3.1 Case A: MSS GSO satellite downlink interference into DRS return link (SRS LEO-to-SRS GEO)

NOTE - As shown in Fig. A3-4 of Annex 3, this study assumes an MSS system with spot beams covering land masses only. It is expected that typical MSS system**s** would feature coverage over significant portions of the ocean areas for aeronautical and maritime users. Accordingly, the actual interference from MSS into DRS systems might exceed those shown in the study results given below in § 3.14.2.3.1.1 (Case A).

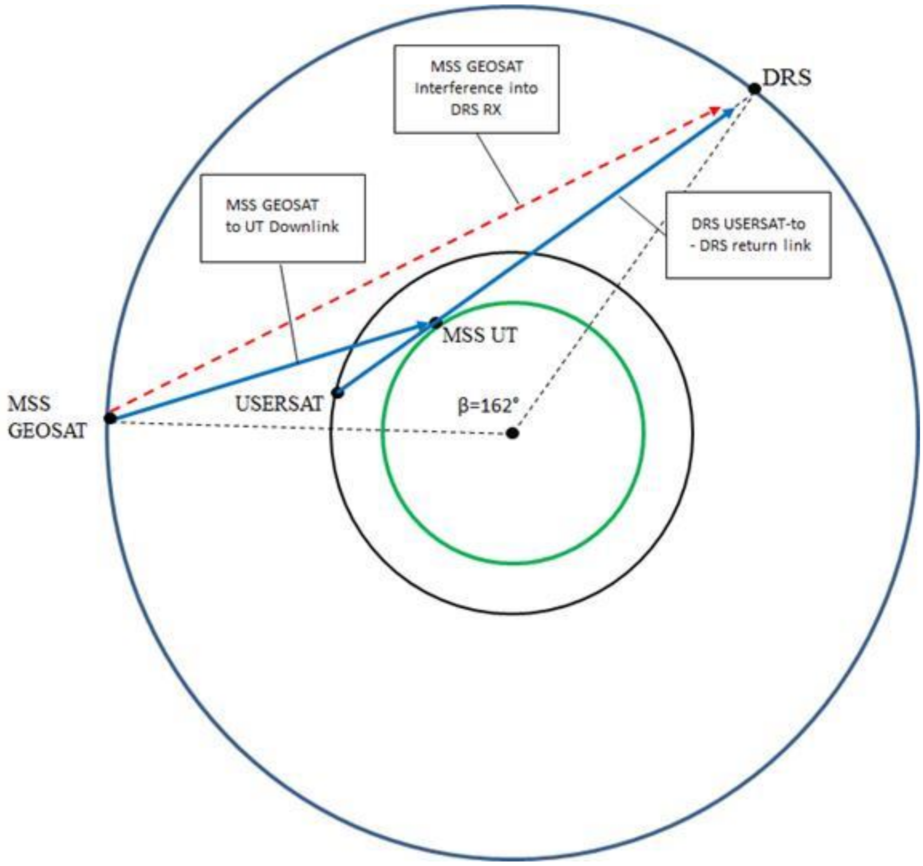
Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems.

This scenario applies to both the 25.25-25.5 GHz and 25.5-26 GHz bands.

This scenario considers MSS GEOSAT downlink interference into the DRS return link. The basic geometry is shown in Fig. 3.14-2.

FIGURE 3.14-2

MSS GEOSAT downlink interference into DRS return link

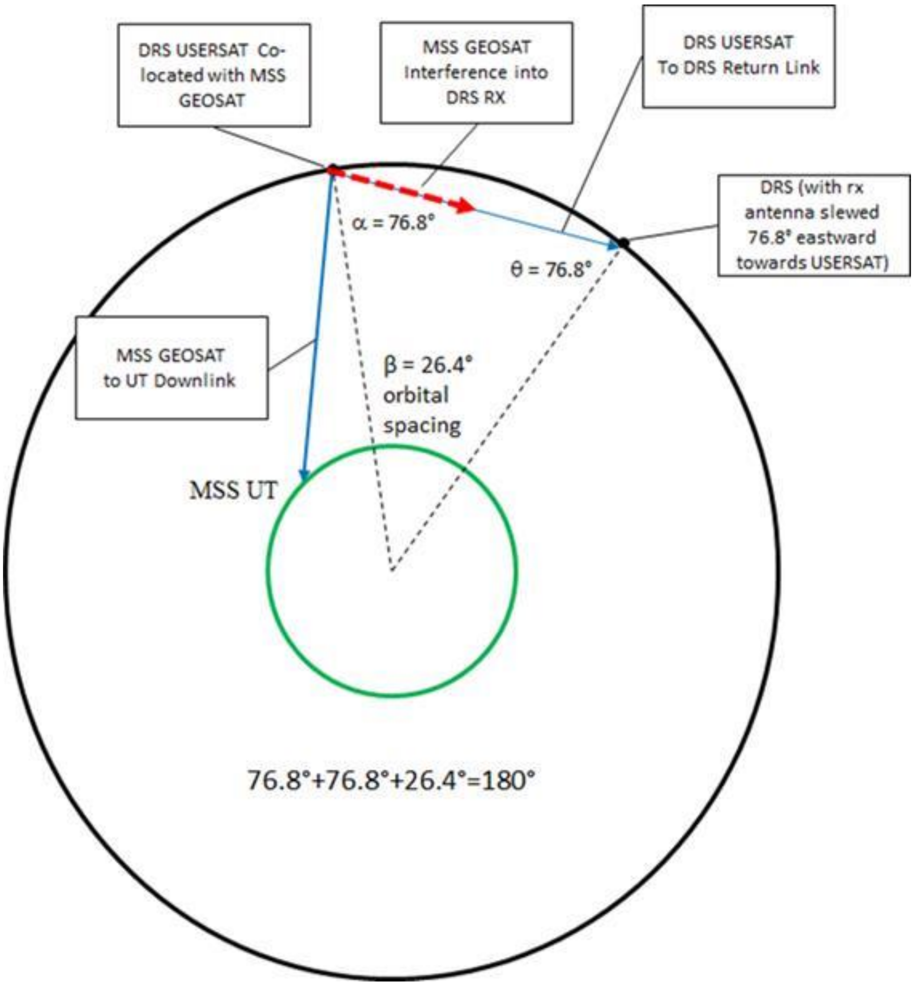


The wanted links are shown in blue and these are the downlink from the MSS GEOSAT to the MSS UT and the return link from the USERSAT (in LEO) to the DRS (in GEO). The victim receiver in this case is on the DRS (in GEO). The interference path from the MSS GEOSAT to the DRS is indicated by the dashed red line. Note that the interference geometry in Figure 3.14-2 depicts a worst case geometry for a single MSS GEOSAT and USERSAT in LEO that results in maximum interference into the DRS return link as will be shown later in the results. Again, Fig. 3.14-2 is the simplified geometry. In the analysis and simulations as described in Annex 3, the aggregate interference from multiple MSS downlinks spot beams and multiple MSS satellites into the DRS receiver are calculated. The aggregate interference is time-varying since the DRS receiving beam is tracking a LEO USERSAT and therefore the DRS receive antenna gain in the direction of the interfering MSS satellite downlink spot beams is time-varying. However, the MSS downlink spot beam gains in the direction of the DRS are constant since both the MSS GEOSAT and DRS are assumed geostationary. The relevant DRS return link receiver parameters are the same as those in Table A3-2 in Annex 3. Since the victim receive bandwidth is 300-600 MHz and the MSS downlink spot beam sub-band bandwidth is 125 MHz, all spot beams (all 4 colors) are assumed to be interfering as shown in Annex 3. Again each downlink spot beam is assumed to have an e.i.r.p. spectral density of e.i.r.p.$_0$ = -27.9 dBW/Hz (i.e. 44.21 dBW e.i.r.p. per channel over 16.2 MHz channel bandwidth) and Recommendation ITU-R S.672 gain pattern.

Interference results were first calculated for the somewhat rare case where the USERSAT is also in GEO orbit. The Ka-band single access antennas of the latest generation DRS satellites can operate in an extended elliptical FOV (EEFOV) mode with the antenna pointed outward to 76.8° in an East-West direction. This allows coverage of GEO USERSATs that are at least 26.4° separated from the DRS location. In this case, the worst interference scenario is when an MSS GEOSAT is co-located with the GEO USERSAT. This geometry is shown in Fig. 3.14-3.

FIGURE 3.14-3

MSS GEOSAT Interference into DRS Return Link for Co-located GEO USERSAT



3.14.2.3.1.1 Study Results for Case A

The results for this scenario are given in Table 3.14-8.

Table 3.14-8

Interference Results (Io/No @ 0.1% exceedance) for case of GEO USERSAT

		DRS GEO LONGITUDE LOCATION [TDRS USERSAT IN GEO ORBIT 27° West of DRS]				
# MSS GEOSATs	**MSS GEOSAT LOCATIONS**	**-174**	**-62**	**-41**	**47**	**89**
1	**Co-located with DRS USERSAT IN GEO**	**-7.4**	**-5.1**	**-4.6**	**-2.9**	**-2.9**
72	**Full orbit [180W to 180E in 5° steps - but no co-located MSS SAT]**	**-30.9**	**-28.4**	**-26.8**	**-31.6**	**-25.9**

		DRS GEO LONGITUDE LOCATION [TDRS USERSAT IN GEO ORBIT 27° East of DRS]				
# MSS GEOSATs	**MSS GEOSAT LOCATIONS**	**-174**	**-62**	**-41**	**47**	**89**
1	**Co-located with DRS USERSAT IN GEO**	**-11**	**-4.1**	**-3.2**	**-3.2**	**-4.4**
72	**Full orbit [180W to 180E in 5° steps - but no co-located MSS SAT]**	**-32.8**	**-33.3**	**-26.2**	**-26.4**	**-26.7**

Note that in the (rare) case of a DRS USERSAT co-located with an MSS GEOSAT, the interference into the DRS receiver on the return link can be significant. However, as long as there is no co-location, interference is negligible even with a fully populated MSS orbit.

In the next return link scenario, the USERSAT is assumed to be in a typical LEO. Table 3.14-9 shows the results for this case.

Table 3.14-9

Interference Results (Io/No @ 0.1% exceedance) for case of LEO USERSAT

		DRS GEO LONGITUDE LOCATION **[TDRS USERSAT IN 400km/51.6° LEO]**				
# MSS GEOSATs	**MSS GEOSAT LOCATIONS**	**-174**	**-62**	**-41**	**47***	**89**
72	**Full orbit [180W to 180E in 5° steps]**	**-24.9**	**-18.6 [Primary interference from 100°E MSS GEOSAT which is 162° away]**	**-28.3**	**-15.1 [Primary interference from 115°W MSS GEOSAT which is 162° away]**	**-27.7**

The Recommendation ITU-R SA.1155 threshold is met even with a fully populated MSS satellite orbit. Note, however, that some DRS locations (i.e. 62°W and 47°E) can have higher than usual interference when the worst case geometry of Fig. 3.14-3 occurs.

Lastly, Table 3.14-10 shows the results for the case of a MEO USERSAT in a GPS-like orbit. For this case, the interference is also negligible.

Table 3.14-10

Interference Results (Io/No @ 0.1% exceedance) for case of MEO USERSAT

		DRS GEO LONGITUDE LOCATION **[TDRS USERSAT IN 20,200km/55° MEO]**				
# MSS GEOSATs	**MSS GEOSAT LOCATIONS**	**-174**	**-62**	**-41**	**47**	**89**
72	**Full orbit [180W to 180E in 5° steps]**	**<-30**	**-26**	**-28.2**	**-24**	**-27.4**

3.14.2.3.2 Cases B1 and B2

3.14.2.3.2.1 Case B1: MSS user terminal uplink interference into DRS return link (SRS LEO-to-SRS GEO)

Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems.

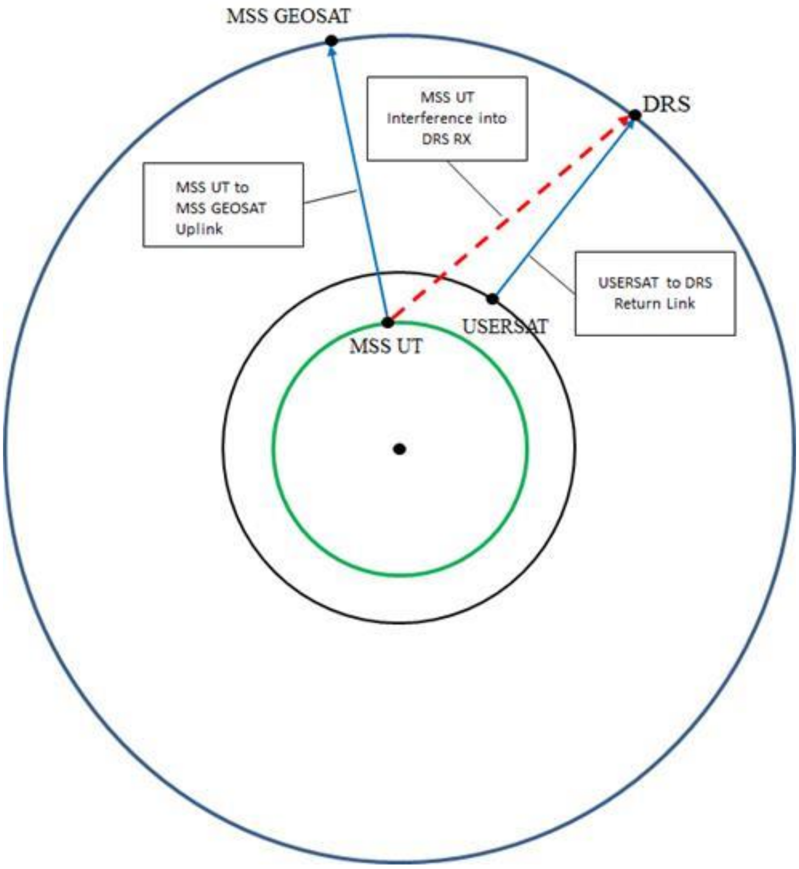
Note: As shown in Fig. A3-4 of Annex 3, this study assumes an MSS system with spot beams covering land masses only. It is expected that typical MSS systems would feature coverage over significant portions of the ocean areas for aeronautical and maritime users. Accordingly, the actual interference from MSS into DRS systems might exceed those shown in the study results given below in § 3.14.2.3.2.1.1 (Case B1).

This scenario applies to both the 25.25-25.5 GHz and 25.5-26 GHz bands.

This scenario considers MSS user terminal (UT) uplink interference into the DRS return link. The basic geometry is shown in Fig. 3.13-4.

FIGURE 3.14-4

MSS UT interference into DRS return link



The wanted links are shown in blue and these are the uplink from the MSS UT to the MSS GEOSAT and the return link from the DRS usersat (in LEO) to the DRS in GEO. The victim receiver in this case is on the GEO DRS satellite. The interference path from the MSS UT to the GEO DRS is indicated by the dashed red line. Note that this is the simplified geometry. In the analysis and simulations, the aggregate interference from multiple MSS UTs in multiple uplink spot beams and from multiple GSO MSS satellites is calculated. The aggregate interference will also be time-varying since the DRS receiving beam is tracking a USERSAT in LEO and therefore the DRS receive antenna gain in the direction of the interfering MSS UTs will be time-varying. However, the transmit gains of the MSS UTs in the direction of the DRS will be essentially constant since both the MSS UTs and the DRS (in GEO) are stationary with respect to each other. The relevant DRS return link receiver parameters are listed in Table A3-2 in Annex 3.

Since the DRS interference protection criterion is in terms of an interference power spectral density (i.e. units of dBW/Hz) rather than an absolute interference level (i.e. units of dBW) and the MSS UT multiple access scheme is assumed to be FDMA, it is only necessary that a single MSS UT per uplink spot beam per GSO MSS satellite be modelled. Furthermore, since the victim receiver bandwidth in this case exceeds the assumed MSS spot beam sub-band bandwidth of 125 MHz, it is assumed that all spot beams (of all colors) are interfering beams. Therefore, the analysis models a single MSS UT per uplink spot beam (located at the centre of the spot beam) with an e.i.r.p. spectral density of –26.2 dBW/Hz (i.e. e.i.r.p. of 39.85 dBW per channel over 4.05 MHz channel bandwidth) with the transmit antenna gain pattern shown in Fig. A3-3 in Annex 3. Aggregate interference statistics were then generated for the (5) sample DRS locations in Table A3-2 in Annex 3 and for GSO MSS satellites at various locations and orbital spacings from the DRS.

3.14.2.3.2.1.1 Study results for Case B1

Table 3.14-11 shows the results of the analysis. The values in the table are the Io/No (dB) values corresponding to a 0.1% time exceedance per the protection criterion in Recommendation ITU-R SA.1155.

Table 3.14-11

Interference results for MSS UT uplink interference into DRS return link (Values shown are 0.1% exceedance Io/No in dB)

		DRS GEO LONGITUDE LOCATION				
# MSS GEOSATs	MSS GEOSAT LOCATIONS	-174	-62	-41	47	89
1	Co-located with DRS	12.7	15.2	15.2	15.6	15.4
2	Adjacent to DRS with 5° spacing	-3.3	-1.8	-1.9	-1.8	-1.8
2	Adjacent to DRS with 6° spacing	-5.7	-5	-4.8	-4.6	-4.6
2	Adjacent to DRS with 7° spacing	-8.9	-8.9	-8.8	-8.3	-8.2
2	Adjacent to DRS with 8° spacing	-13	-13.1	-12.9	-12.5	-12.5
2	Adjacent to DRS with 9° spacing	-20	-20	-19.7	-19.6	-19.3
2	Adjacent to DRS with 10° spacing	<-20	<-20	<-20	<-20	<-20
70	Full orbit with MSS SATs at 5° steps; min 8° separation from DRS	-12.9	-12.8	-12.5	-12.1	-12

Note from Table 3.14-11 that the results are basically the same regardless of DRS longitude location. Also, observe that the two MSS GEOSATs adjacent to the DRS dominate the net interference. A minimum orbital spacing of 8° between the DRS and adjacent MSS satellites is required to satisfy the Recommendation ITU-R SA.1155 threshold for all five of the sample DRS locations. Note that Recommendation ITU-R SA.1276-3 lists 32 possible orbital locations for DRS operating in the 25.25-27.5 GHz band. Thus, accounting for an 8° guard spacing on each side of the 32 DRS locations, leaves a total of 97.1° GEO orbital arc for placing MSS satellites (i.e. the orbital arc ranges are 152°W-147°W; 131°W-70°W; 4°W-2.6°E; 29.5°E-39°E; 67°E-69°E; 103°E-105°E; 141°E-152°E).

3.14.2.3.2.2 Case B2: MSS user terminal uplink interference into GSO receiving from non-GSO LEO

3.14.2.3.2.2.1 Characteristics

In accordance with Recommendation ITU-R SA.1019 in the frequency band 25.25-25.5 GHz the ISS stations operate in the direction of NGSO-GSO and in this case the receiving station is a station located on GSO satellite.

The data from Recommendation ITU-R SA.1414 was taken as the technical characteristics for the frequency band 25.25–25.5 GHz shown in Table 3.14-12.

TABLE 3.14-12

Data relay satellite system characteristics

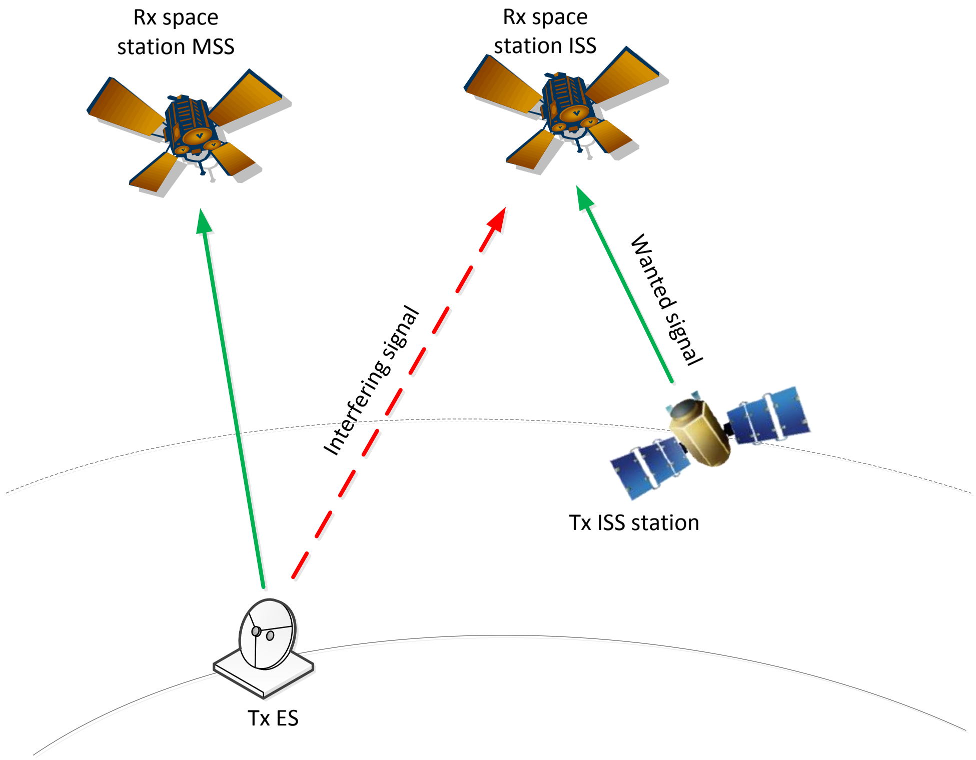
Transmitting spacecraft			
Network	type 1	type 2	type 3
	Europe	Japan	USA
Orbital locations	Mainly low-Earth orbit		
orbital altitude in calk (km)	500	500	500
Inclination angle, (deg)	60	60	60
Frequency range (GHz)	25.25–25.5		
Link description	Single Access (Ka-SA) link		
Transmission rate (bit/s)	≤ 150 Mbit/s	≤ 300 Mbit/s	≤ 800 Mbit/s
Modulation	PSK		
Polarization	Circular		
Antenna size (m)	≤ 1.5	≤ 1.9	≤ 1.5
Tx antenna gain (dBi)	≤ 47	≤ 49.7	≤ 47
Tx antenna radiation pattern	Rec. ITU-R S.672		
Necessary bandwidth (MHz)	≤ 300	≤ 300	≤ 300
Maximum power density (dB(W/Hz))	-65.1	–58.8	
Maximum e.i.r.p. density (dB(W/Hz))	-23	-9.1	
Receiving DRS			
Orbital locations	Recommendations ITU-R SA.1275 or ITU-R SA.1276		
Frequency range (GHz)	25.25–25.5		
Antenna size (m)	2.8	3.6	4.9
Rx antenna gain (dBi)	53.4	58.8	58
Rx antenna radiation pattern	Rec. ITU-R S.672		
System noise temperature (K)	1305	475	800
Link reliability (%)	99.9		99.99
Interference criterion	Rec. ITU-R SA.1155		
The aggregate interference impact from MSS stations into ISS stations is simulated.			

The receiving ISS station antenna pattern in the GSO-NGSO link was taken in accordance with Recommendation ITU-R S.672.

In the compatibility assessment of the mobile satellite service with the ISS (NGSO- GSO link) in the frequency band 25.25–25.5 GHz the following interference impact scenario was considered: the transmitting MSS ground stations can cause interference to the receiving ISS space station. Figure 3.14-5 presents the interference impact scenario mentioned above.

FIGURE 3.14-5

Interference impact scenario



It should be noted that sharing between two satellite systems on GSO is ensured under provisions of RR Article **9** (in particular RR No. **9.7**). In addition based on the characteristics presented in Table 2.1-1 the orbital separation distances were studied.

The simulation of the aggregate interference impact based on the characteristics presented in Table 3.14-12 was made for the considered interference scenario. In the studies the *I/N* ratio for the orbital separation of 0 and 7 degrees between the receiving GSO MSS space station and receiving GSO ISS space station was estimated.

In accordance with Recommendation ITU-R SA.1155 the aggregate protection criteria *I/N* minus 10 dB (this criterion shall not be exceeded at more than 0.1% time) from all operating MSS Earth stations was used as the protection criterion of the receiving ISS space stations (NGSO-GSO link).

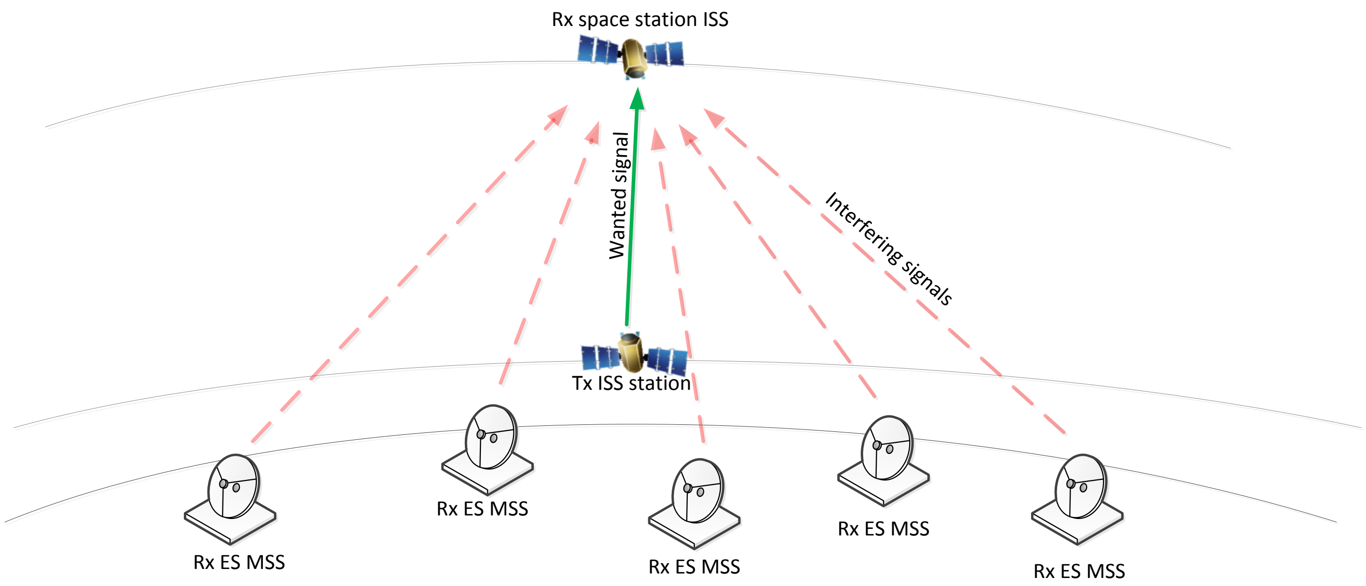
In the simulation the aggregate interference from many transmitting MSS Earth stations was taken into account in case when the set of the MSS transmitting earth stations operate with the MSS stations on GSO with the minimum separation angle of 5 degrees. It was assumed that each MSS space station on GSO operates with 20 user terminals MSS ES and 1 hub station which are equally deployed in the service area. As a result the number of simultaneously transmitting MSS ES was estimated as 1512. The typical characteristics of the MSS transmitting earth station were taken from Table 2.1-1. The duration of simulation for each case was 30 days with a step of 30 sec.

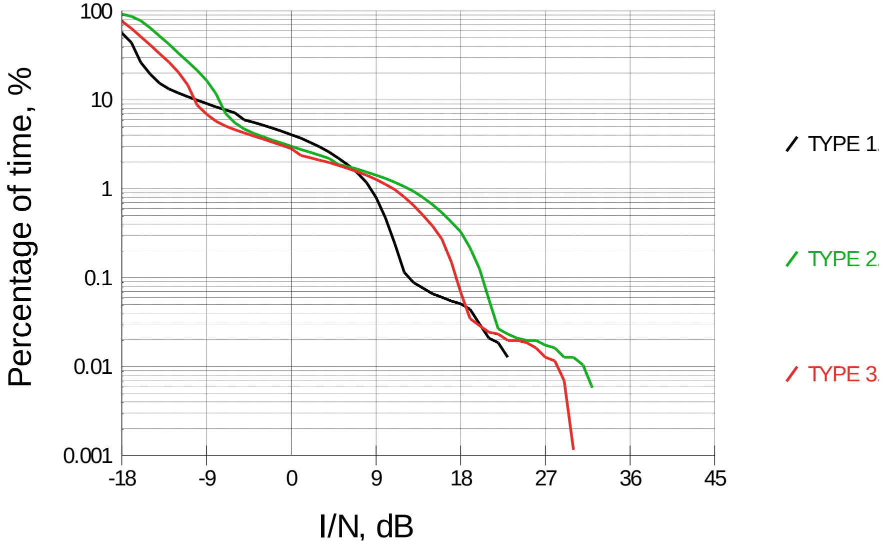
3.14.2.3.2.2.2 Estimation results

Based on the indicated initial data and interference impact scenario of GSO-NGSO the estimation was carried out. The obtained results are presented in Fig. 3.14-6 below.

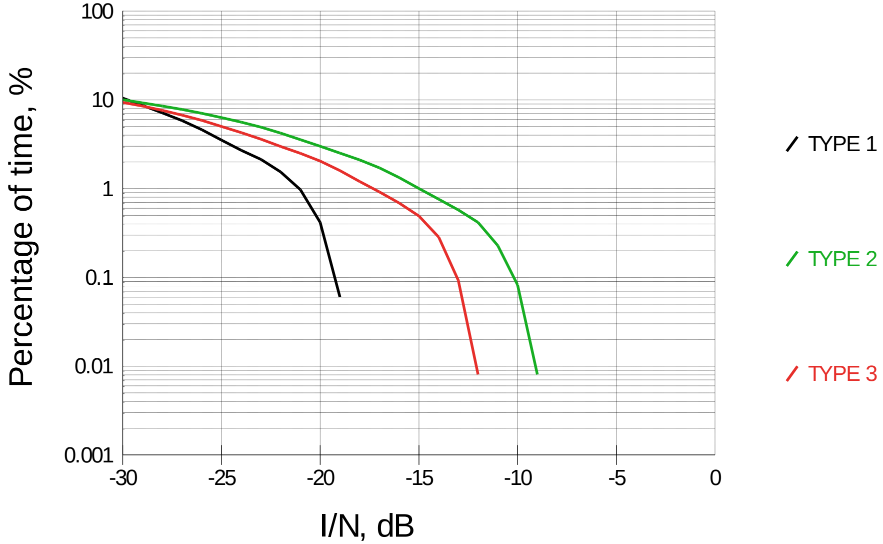
FIGURE 3.14-6

Estimation Results





Calculation results of *I/N* for orbital separation of 0 degree



Calculation results of *I/N* for orbital separation of 7 degrees

The simulation results show that at orbital separation of 7 degrees between the GSO receiving MSS station and GSO receiving ISS station the protection criterion I/N = −10 dB at 0.1% time is not exceeded.

Therefore the current provisions of RR Article **9** (RR No. **9.7**) are proposed to use for providing sharing of the proposed MSS with the receiving ISS stations operating in the direction of NSCO-GSO. The issue of the threshold level for coordination requires further examination.

3.14.2.4 MSS and standard frequency and time signal-satellite service (Earth-to-space)

In the frequency band 25.25-25.5 GHz the standard frequency and time signal-satellite service is allocated on a secondary basis.

Currently the stations of standard frequency and time signal-satellite service are not notified in the frequency band 25.25-25.5 GHz.

Recommendation ITU does not contain the technical characteristics of stations in the standard frequency and time signal-satellite service in the frequency band 25.25-25.5 GHz.

Therefore, since there are no systems in the standard frequency and time signal-satellite service in the frequency band 25.25-5 GHz, no compatibility issue exists at this time; however, it may not be the case if in the future new standard frequency and time signal-satellite systems operate in this frequency band.

3.14.3 Results of sharing studies in the frequency band 25.25-25.5 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore. Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Radio Regulations No. **9.17** is proposed to apply to provide the sharing of the proposed MSS with the receiving MS stations.

For the three cases of ISS supporting Space Research Systems (data relay satellite systems using GSO-NGSO links):

– Case A: For the case of MSS GSO satellite downlink interference into DRS return link (SRS LEO-to-SRSGSO) in 25.25-25.5 GHz and 25.5-26 GHz, the interference into the DRS receiver on the return link is negligible even with a fully populated MSS orbit. Co-location of the MSS satellite with a DRS satellite in geostationary orbit, however, must be avoided.

– Case B1: For the case of MSS user terminal uplink interference into DRS return link (SRS LEO-to-SRSGSO) in 25.25-25.5 GHz and 25.5-26 GHz, a minimum orbital spacing of 8° between the DRS and adjacent MSS satellites is required to satisfy the Recommendation ITU-R SA.1155 protection criteria.

Note that these conclusions are based on studies which assumed an MSS system with coverage for land masses only. It is anticipated that actual MSS systems would provide global coverage, with spot beams covering nearly the entirety of the Earth’s surface. Accordingly the interference from MSS into ISS NGSO-GSO might be even greater than shown in these results.

– Case B2: MSS user terminal uplink interference into GSO receiving from non-GSO LEO: The simulation results show that at orbital separation of 7 degrees between the GSO receiving MSS station and GSO receiving ISS station the protection criterion $I/N = -10$ dB at 0.1% time is not exceeded. Therefore the current provisions of RR Article **9** (No. **9.7**) are proposed to use for providing sharing of the proposed MSS with the receiving ISS stations operating in the direction of NSCO-GSO. The issue of the threshold level for coordination requires further examination.

3.15 The frequency band 25.5-26 GHz

Allocations for this frequency band are shown in Table 3.15-1:

TABLE 3.15-1

Extract from Radio Regulations Article 5 Table of Frequency Allocations in the frequency band 25.5-26 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
25.5-26	EARTH EXPLORATION-SATELLITE (space-to-Earth) 5.536B FIXED INTER-SATELLITE 5.536 MOBILE SPACE RESEARCH (space-to-Earth) 5.536C Standard frequency and time signal-satellite (Earth-to-space) 5.536A	

5.536 Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space.

5.536A Administrations operating earth stations in the Earth exploration-satellite service or the space research service shall not claim protection from stations in the fixed and mobile services operated by other administrations. In addition, earth stations in the Earth exploration-satellite service or in the space research service should be operated taking into account the most recent version of Recommendation ITU-R SA.1862. (WRC-12)

5.536B In Saudi Arabia, Austria, Belgium, Brazil, Bulgaria, China, Korea (Rep. of), Denmark, Egypt, United Arab Emirates, Estonia, Finland, Hungary, India, Iran (Islamic Republic of), Ireland, Israel, Italy, Jordan, Kenya, Kuwait, Lebanon, Libya, Liechtenstein, Lithuania, Moldova, Norway, Oman, Uganda, Pakistan, the Philippines, Poland, Portugal, the Syrian Arab Republic, Dem. People's Rep. of Korea, Slovakia, the Czech Rep., Romania, the United Kingdom, Singapore, Sweden, Switzerland, Tanzania, Turkey, Viet Nam and Zimbabwe, earth stations operating in the Earth exploration-satellite service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (WRC-12)

5.536C In Algeria, Saudi Arabia, Bahrain, Botswana, Brazil, Cameroon, Comoros, Cuba, Djibouti, Egypt, United Arab Emirates, Estonia, Finland, Iran (Islamic Republic of), Israel, Jordan, Kenya, Kuwait, Lithuania, Malaysia, Morocco, Nigeria, Oman, Qatar, Syrian Arab Republic, Somalia, Sudan, South Sudan, Tanzania, Tunisia, Uruguay, Zambia and Zimbabwe, earth stations operating in the space research service in the band 25.5-27 GHz shall not claim protection from, or constrain the use and deployment of, stations of the fixed and mobile services. (WRC-12)

3.15.1 Review of Recommendations

ITU-R Recommendations which may be relevant to the analysed issues and may be useful for the sharing studies are listed in Table 3.15-2.

TABLE 3.15-2

ITU-R Recommendations and Reports relevant to the sharing studies in the band 25.5-26 GHz

Service	Relevant ITU-R Recommendations and Reports
Fixed	ITU-R F.758, ITU-R F.1245, ITU-R F.699
Mobile	See Annex 7
Earth Exploration Satellite (space-to-Earth)	ITU-R SA.1026, ITU-R SA.1027, ITU-R RS.1166
Inter-satellite	Recs ITU-R SA.1155, ITU-R SA.509, ITU-R S.1899, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1276, ITU-R SA.1414, ITU-R SA.1882, ITU-R SM.1633 Annex 13, ITU-R SA.1743, Report ITU-R SA.2192
Space Research (space-to-Earth)	ITU-R SA.609, ITU-R SA.509 ITU-R SA.1862, ITU-R SA.1743
Standard frequency and time signal-satellite	ITU-R TF.1011, ITU-R TF.1153, ITU-R TF.374

3.15.2 Sharing studies in the frequency band 25.5-26 GHz

3.15.2.1 MSS and FS

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

3.15.2.2 MSS and MS

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

3.15.2.3 MSS and EESS (space-to-Earth)

No studies were conducted to assess sharing between MSS and the Earth exploration-satellite service (space-to-Earth) in the 25.5-26 GHz band, however the results should be similar to those for SRS (space-to-Earth) as given in § 3.15.2.5.

3.15.2.4 MSS and ISS

3.15.2.4.1 ISS supporting space research systems (data relay satellite systems using GSO-NGSO links)

Refer to Annex 3 of this Report for background information on sharing studies between the proposed MSS and ISS allocations used to support space research systems. Refer to § 3.14.2.3.1 (Case A) and § 3.14.2.3.2.1 (Case B1) for two sharing analyses that apply to both the 25.25-25.5 GHz and 25.5-26 GHz bands.

3.15.2.5 MSS and SRS (space-to-Earth)

3.15.2.5.1 SRS systems

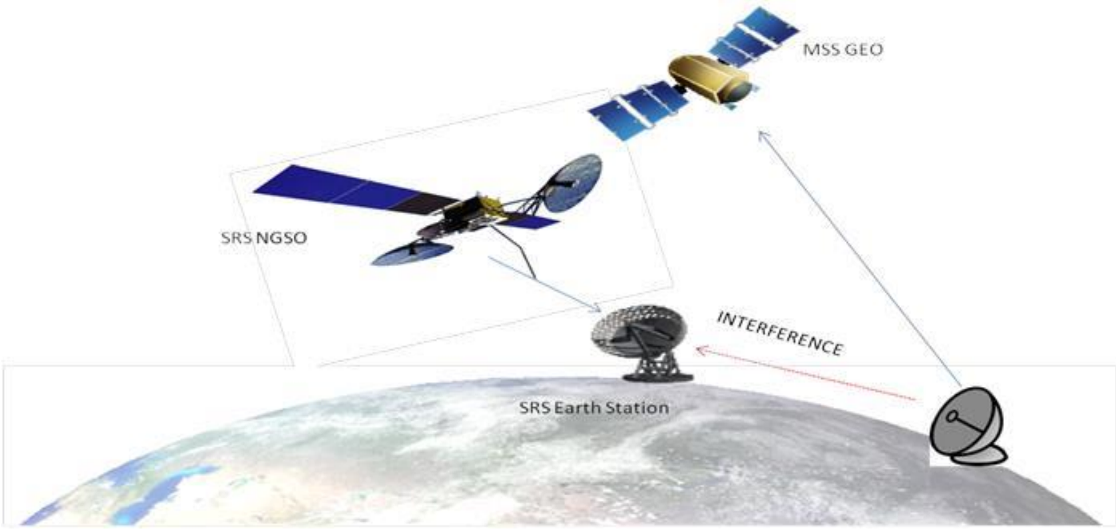
Refer to Annex 2 of this Report for background information on sharing studies between the proposed MSS and space research service (space-to-Earth) systems.

3.15.2.5.1.1 MSS user terminal uplink interference into SRS earth station (Scenario 2)

As shown in Fig. 3.15-1, this analysis will consider interference from MSS user terminals transmission into a receiving SRS Earth station in the 25.5-26 GHz band, taking into account the protection levels identified in Recommendation ITU-R SA.609 of *I/N* > –6 dB for 0.1% of the time.

FIGURE 3.15-1

Representative interference scenario of MSS transmissions into SRS earth stations



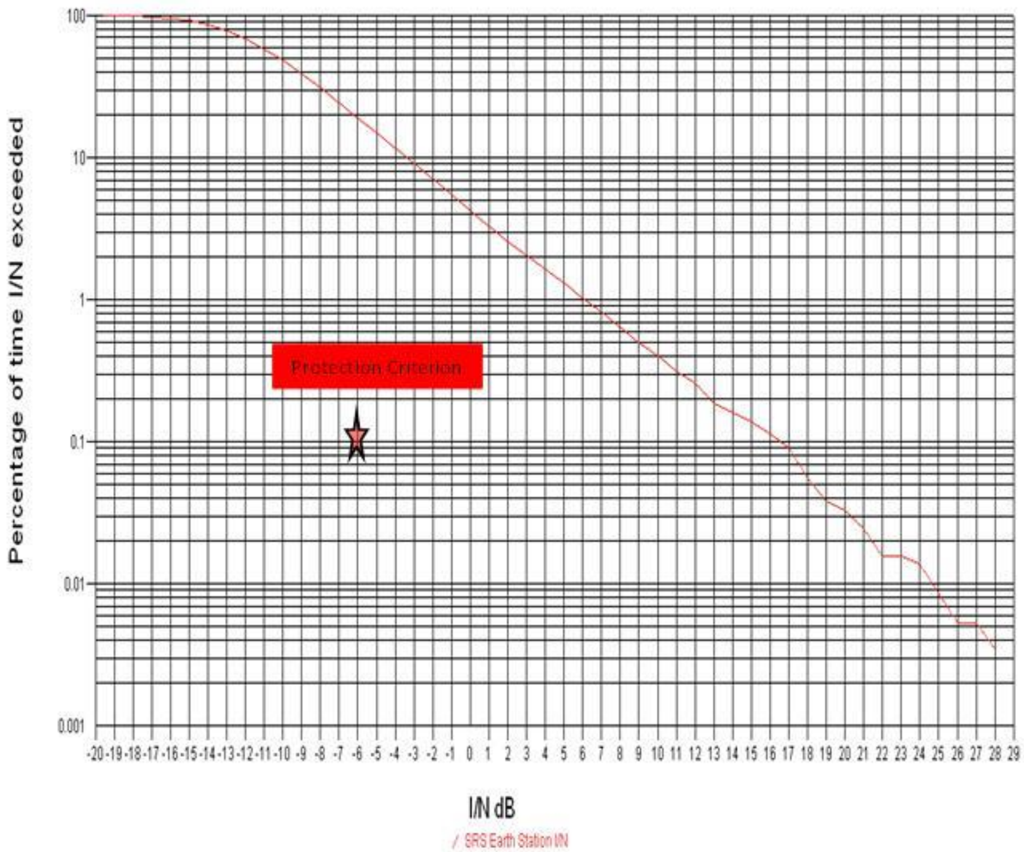
This scenario assumes a random distribution of 8 MSS user terminals transmitting to an MSS GSO satellite located at 48 West. The modelled MSS GSO satellite has multiple antenna beams available for use within the satellite coverage area. It is assumed that each MSS user terminal selects which antenna beam to transmit based on the antenna beam with the highest gain within view of the user terminal. In order to reduce computational complexity in this scenario, there are 8 MSS user terminals randomly distributed over a 64 km^2 area around the WSGT SRS earth station. This corresponds to an average density of 0.1 users/square km around the SRS earth station. It should be noted that this value is significantly lower than the maximum user terminal density of 8 users/square km as specified in Attachment 1 to Annex 2.

3.15.2.5.1.1.1 Study results for Scenario 2

Figure 3.15-2 shows the dynamic simulation results of this interference scenario.

FIGURE 3.15-2

***I/N* results of Interference from MSS user terminals into a SRS earth station**



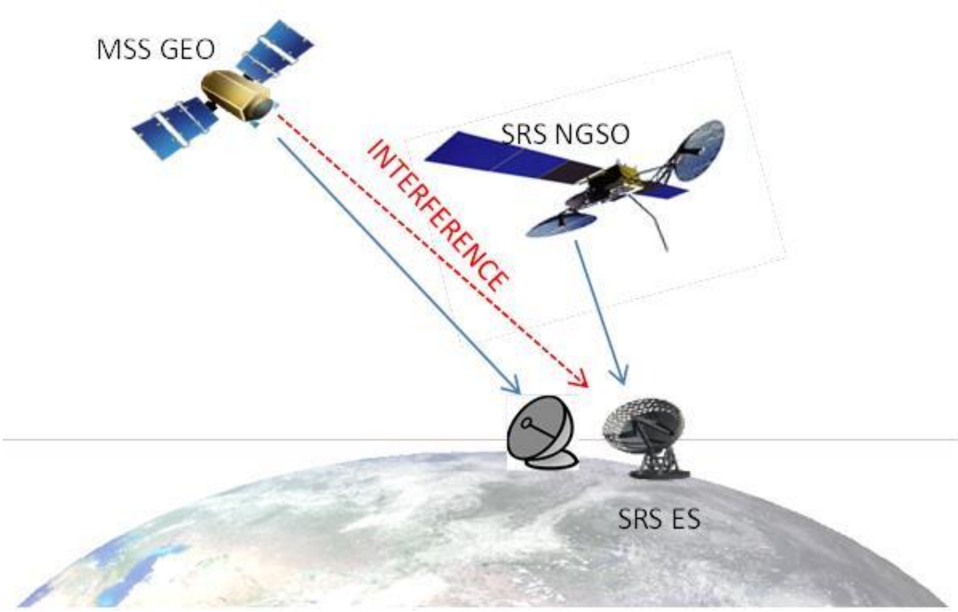
This scenario involves interference from one earth station into another. In such a case, a coordination zone can be calculated to determine the minimum required separation distance between the MSS user terminal and the SRS earth station to avoid interference. Using a generic path calculating with Recommendation ITU-R P.452-14 and assuming a maximum sidelobe gain consistent with Recommendation ITU-R S.580 and an orbital separation of two degrees, a coordination distance of over 330 km would be needed to avoid interference from a MSS user terminal communicating with an SRS earth station.

3.15.2.5.1.2 MSS GEO downlink interference into SRS earth station receiving from non–GSO LEO (Scenario 8)

As shown in Fig. 3.15-3, this analysis will consider interference from MSS GSO satellite transmissions into an SRS earth station receiving from an SRS LEO satellite in the band 25.5-26.0 GHz, taking into account the protection levels identified in Recommendation ITU-R SA.609.

FIGURE 3.15-3

Representative interference scenario of MSS GSO transmissions into SRS earth station receiving from SRS LEO



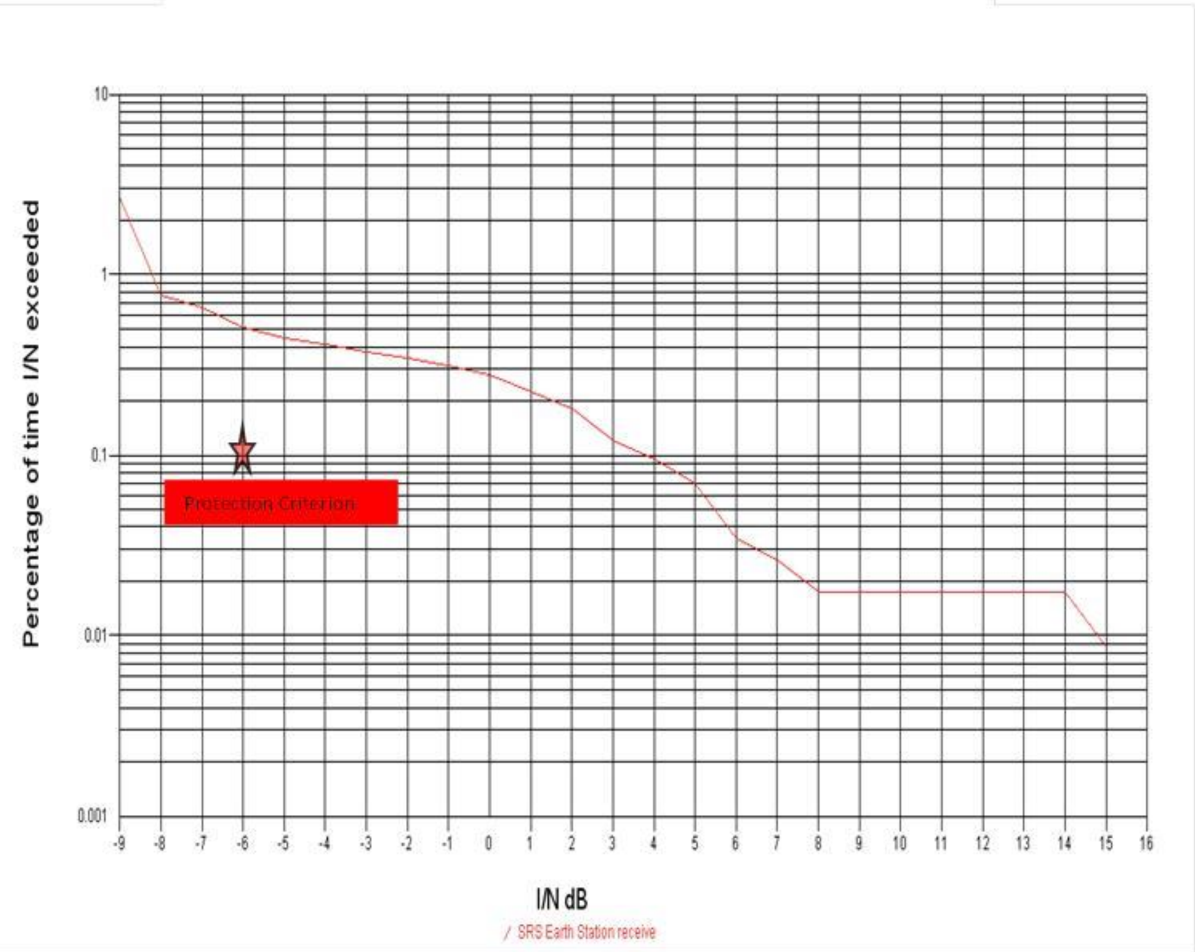
This analysis examines the interference between a MSS GSO satellite located at 60 West transmitting to a uniform distribution of MSS user terminals to a SRS earth station receiving a transmission from a SRS LEO satellite. To reduce computational complexity in this simulation, there are 10,000 MSS user terminals uniformly distributed over a 26,458,207 km^2 area on the surface of the Earth. This corresponds to total user terminal density of 0.0004 users/square km. It should be noted that this value is significantly lower than the maximum user terminal density of 8 users/square km as specified in Attachment 1 to Annex 2.

3.15.2.5.1.2.1 Study results for Scenario 8

Figure 3.15-4 shows the dynamic simulation results of this interference scenario.

FIGURE 3.15-4

Representative interference scenario of MSS transmissions into SRS earth station receiving a transmission from an SRS LEO satellite

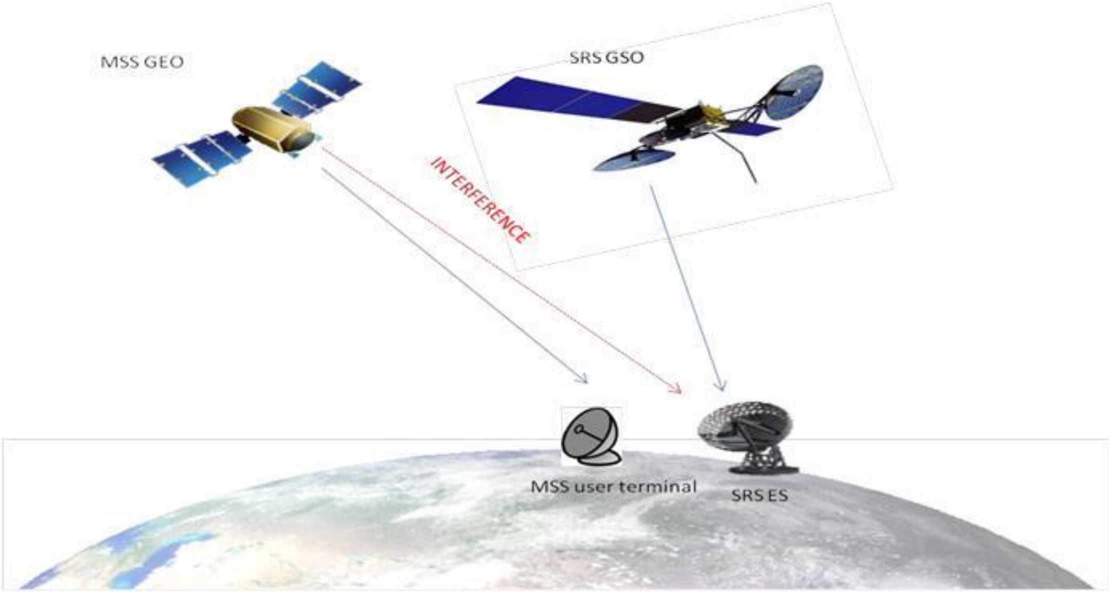


3.15.2.5.1.3 MSS GEO downlink interference into SRS earth station receiving from GSO (Scenario 9)

As shown in Fig. 3.15-5, this analysis will consider interference from MSS GSO satellite transmissions into an SRS earth station receiving from an SRS GSO in the bands 25.5-26.0 GHz, taking into account the protection levels identified in Recommendation ITU-R SA.609.

FIGURE 3.15-5

Representative interference scenario of MSS GSO transmissions into SRS earth station receiving from SRS GSO



This analysis assumes a MSS GSO satellite transmitting to 10000 user terminals uniformly distributed over a 26,458,207 km^2 area on the surface of the Earth. This corresponds to a density of 0.0004 users/square km. In this scenario, the orbital separation of the MSS GSO satellite from the SRS GSO satellite influences the amount of interference experienced by the SRS GSO satellite.

3.15.2.5.1.3.1 Study results for Scenario 9

If the SRS GSO is located at 46 West and the MSS GSO is located at 48 West, than a maximum *I/N* of 24 dB is experienced by the SRS GSO. If there is proper orbital separation, in the order of 31 degrees, between the SRS GSO and the MSS GSO, exceedance of the interference protection criterion given in Recommendation ITU-R SA.609 to the SRS earth station can be avoided.

3.15.2.6 MSS and standard frequency and time signal-satellite service (Earth-to-space)

No sharing studies could be performed with respect to the standard frequency and time signal-satellite service. Currently the stations of the standard frequency and time signal-satellite service are not notified in the frequency band 25.5-26 GHz. No ITU-R Recommendation contains the technical characteristics of stations in the standard frequency and time signal-satellite service in the frequency band 25.5-26 GHz. Therefore, since there are no systems in the standard frequency and time signal-satellite service in the frequency band 25.5-26 GHz, no compatibility issue exists at this time; however, it may not be the case if in the future new standard frequency and time signal-satellite systems operate in this frequency band.

3.15.3 Results of sharing studies in the frequency band 25.5-26 GHz

Section 4.1 of Annex 1 presents an analysis of potential interference from MSS (s-E) into the FS. Sections 4.2 and 4.3 of Annex 1 present analyses of interference from land-based MSS (E-s) earth stations into the FS. Annex 6 presents an analysis of interference from MSS stations on vessels into FS stations located near the shore.

Pfd limits will have to be applied to the proposed MSS downlink. Exclusion zones will be required to protect FS from the proposed MSS uplink.

Based on the results presented in § 3.15.2.5, the proposed MSS operations in the band 25.5-26 GHz are not compatible with incumbent SRS space-to-Earth systems.

Refer to Annex 5 of this Report for these studies which conclude that RR No. **9.17** could be applied to provide protection of the receiving MS stations from the transmitting MSS earth stations.

No studies were conducted to assess feasibility of sharing between MSS and the frequency and time signal-satellite service in the 25.5-26 GHz band.

Annex 1

Sharing study of proposed MSS and incumbent fixed service

1 Introduction

A compatibility analysis between a hypothetical geostationary-satellite MSS network and existing fixed stations was performed for both transmission links of the satellite network: space-to-Earth and Earth-to-space in the frequency bands between 22 GHz and 26 GHz allocated to the fixed service under RR Article **5** (see Table A1-1).

TABLE A1-1

Frequency bands between 22 and 26 GHz, allocated to the FS

Frequency (GHz)	ITU Region(s)	Allocations
22.0-22.21	All	FIXED 5.149
22.21-22.5	All	FIXED 5.149
22.5-22.55	All	FIXED
22.55-23.55	All	FIXED 5.149
23.55-23.6	All	FIXED
24.25-24.45	1.3	FIXED
24.45-24.65	1.3	FIXED
24.65-24.75	1.3	FIXED
24.75-25.25	1.3	FIXED
25.25-25.5	All	FIXED
25.5-27.0	All	FIXED

Interference was assessed only from the MSS satellite network towards existing FS stations; assessment of possible interference in the opposite direction was not performed.

Calculation of interference towards existing FS stations from the hypothetical MSS satellite network for space-to-Earth link was performed for the purpose to define hard pfd limits providing protection to the FS.

Calculation of interference towards existing FS stations from the hypothetical MSS satellite network for Earth-to-space link was performed for the purpose to define protective separation distances providing protection to the FS.

2 Technical parameters

2.1 Technical characteristics of hypothetical MSS systems

Technical characteristics of the hypothetical MSS system are found in § 2 of this Report.

It should be noted that a detailed analysis of sharing between existing radio-relay stations and hypothetical MSS GSO system is possible only when the above tables are filled with realistic parameters that would provide operation of the hypothetical MSS system with required QoS.

2.2 Technical characteristics of radio-relay systems (point-to-point)

Table A1-2 gives technical characteristics of point-to-point FS systems defined by Recommendation ITU-R F.758-5.

TABLE A1-2

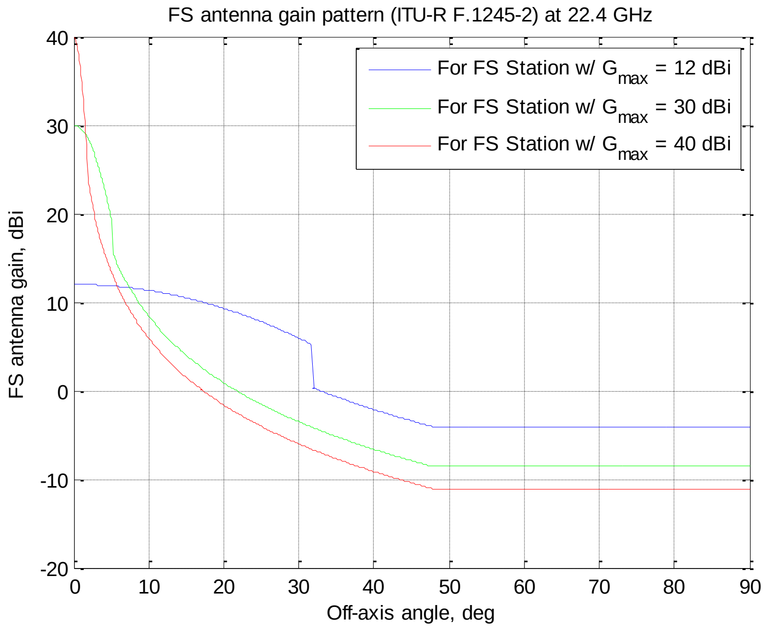
Technical characteristics of FS systems (point-to-point)

Frequency range (GHz)	**21.2-23.6**		**24.25-29.50**	
Reference ITU-R Recommendation	F.637		F.748	
Modulation	FSK	128-QAM	16-QAM	……..
Channel spacing and receiver noise bandwidth (MHz)	2.5, 3.5, 7, 14, **25**, 28, 50, 56, 112	2.5, 3.5, 7, 14, 28, **30**, 50, 56, 112	2.5, 3.5, 7, 14, 28, 40, 56, **60**, 112	2.5, 3.5, 7, 14, 28, 40, 56, 60, 112
Tx output power range (dBW)	−10	−13	−39…−19	
Tx output power density range (dBW/MHz)	−24.0	−27.8	−53.8… −33.8	
Feeder/multiplexer loss range (dB)	0…3	…	0.0	
Antenna gain (dBi)	34.8	…	31.5	
e.i.r.p. range (dBW)	21.8… 24.8	…	−7.5… 12.5	
e.i.r.p. density range (dBW/MHz)	7.8…10.8		−21.3… −2.3	
Receiver noise figure typical	11	6	8	
Receiver noise power density typical (dBW/MHz)	−133	−138	−136	
Normalized Rx input level for 1×10^{-6} BER (dBW/MHz)	−119.6	−108.5	−115.5	
Nominal long-term interference power density (dBW/MHz)	$-133 + I/N$	$-138 + I/N$	$-136 + I/N$	$N_{RX} + I/N$

The FS antenna gain pattern is assumed to follow the Recommendation ITU-R F.1245-2. Figure A1-1 shows the antenna gains at 22.4 GHz as a function of off-axis angles for three FS antennas with antenna peak gains of 12.0, 30.0 and 40.0 dBi.

FIGURE A1-1

FS antenna gain pattern (Recommendation ITU-R F.1245-2)



2.2.1 Technical characteristics of radio-relay stations registered in the ITU-R

According to BR IFIC 2735 (Terrestrial services) of 08.01.2013, there are 57 447 registered in ITU-R FS stations in the frequency bands between 22 and 26 GHz. Most of them have 0° elevation angle, but some stations have higher elevations reaching up to 33° (see Attachment 1 to this Annex).

It should be noted that in most cases administrations register in the ITU-R mostly border terrestrial stations and, consequently, the number of actually operating stations exceeds registered one.

Technical parameters of some registered radio-relay stations differ from those given in Recommendation ITU-R F.758-5.

Table A1-3 shows technical parameters of the radio-relay stations registered in the ITU-R and currently used. The radio-relay stations having these parameters will be more sensitive to interference from hypothetical MSS GSO system as shown in § 4 of this Annex.

TABLE A1-3

Technical characteristics of radio-relay stations registered in the ITU-R

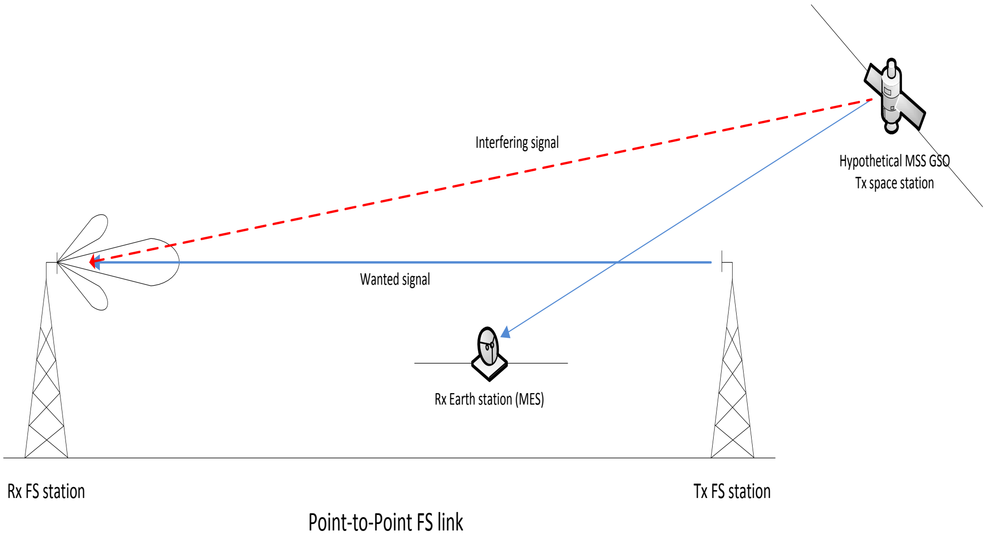
Frequency range (GHz)	**21.2-23.6**	**24.25-29.50**
Reference ITU-R Recommendation	F.637	F.748
Feeder/multiplexer loss range (dB)	0	
Max antenna gain (dBi)	47.8	46.9
Receiver noise power density typical (dBW/MHz)	–136	
Nominal long-term interference power density (dBW/MHz)	−136+ *I/N*	

3 Possible interference scenarios

There are two possible scenarios of interference caused by hypothetical MSS GSO system to FS radio-relay station receivers. Interference towards hypothetical MSS GSO system is not a subject of the contribution.

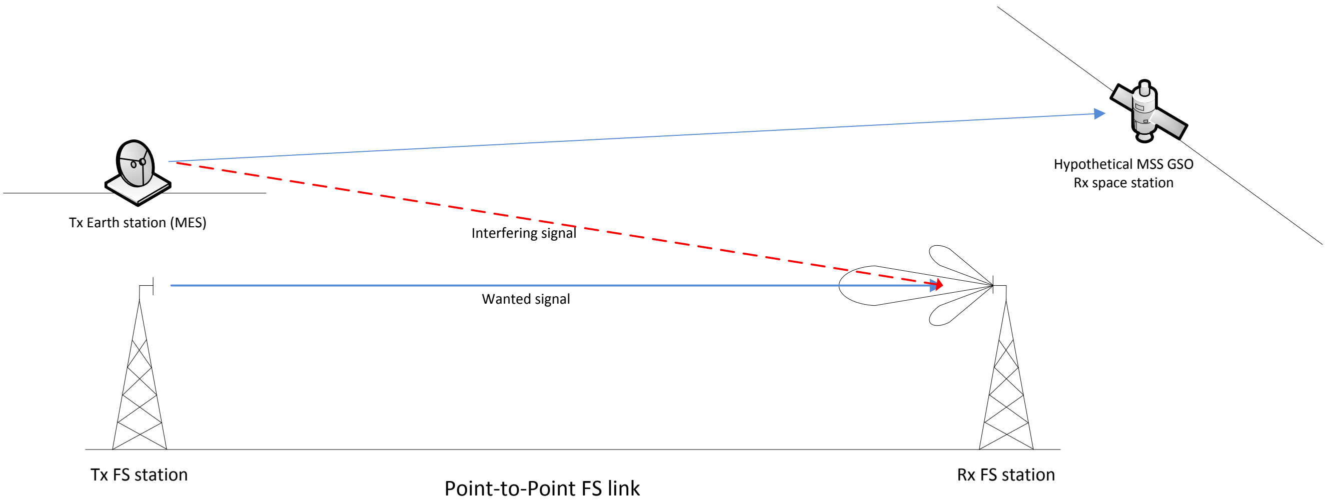
Scenario 1

Emissions from hypothetical MSS GSO space station (space-to-Earth) may cause interference to FS radio-relay station receivers:



Scenario 2

Emissions from hypothetical MSS GSO Earth station (Earth-to-space) may cause interference to FS station receivers:



4 Possible constraints on hypothetic MSS GSO system to ensure protection of existing radio-relay stations

4.1 Calculation of interference towards existing FS stations from the hypothetical MSS satellite network for space-to-Earth direction (Scenario 1).

The calculation was performed using two approaches (scenarios):

– worst case;

– probability analysis (assessment of the mean probability of interference to FS terrestrial station, exceeding the acceptable criterion).

Technical characteristics of stations described in Recommendation ITU-R F.758-5 and in the BR Circular IFIC 2735 (Terrestrial Services) of 8 January 2013 were used to calculate hard limits of PFD created by the MSS geostationary space station at the Earth's surface, ensuring protection of existing FS stations. It should be noted that technical characteristics of fixed stations, frequency assignments of which are included into the BR IFIC, differ from those specified in Recommendation ITU-R F.758-5.

4.1.1 Worst case

To ensure protection of radio-relay stations from emission of MSS GSO space station, it is required to determine allowable power flux density, produced by the space station at the Earth surface.

To ensure protection of FS, the worst case of potential interference is considered when determining allowable power flux density at the Earth surface, produced by the hypothetic MSS GSO space station, i.e. when antennas of space station and of FS station are co-axis. This is possible for both radio-relay stations operating at the mostly used 0° elevation angle (when MSS system provide service to northern latitudes), and for radio-relay stations operating at higher elevation angles. Thus, the calculated power flux density (shown below) should be considered as a limit (in the worst case) for space stations operated at elevation angles from 0 degree to, as minimum, 33 degrees, to ensure protection of all existing radio-relay stations.

According to the Recommendation ITU-R F.758-5 long-term protection criterion (20% of time) for fixed service stations from aggregated interference from radio services to which the band is allocated on the equal primary basis – I/N should not exceed –10 dB ($I/N \leq -10$ dB).

In absence of single interference protection criterion for FS in sharing studies between receive radio-relay station and transmit space station we will use the above-mentioned criterion, i.e. $I/N \leq -10$ dB.

Assumed input data and results of calculation are shown in Tables A1-4 and A1-5.

TABLE A1-4

Input data (Rec. ITU-R F.758-5) and calculated data

Frequency range (GHz)	22.0-23.6		24.25-26.0
Receiver centre frequency (GHz)	22.8		25.125
Antenna gain (dBi)	34.8		31.5
Feeder/multiplexer loss (dB)	0		0
Receiver noise power density typical (dBW/MHz)	−133	−138	−136
Criteria, *I/N* (dB)	–10	–10	–10
p.f.d. ($dBW/MHz/m^2$)	–129.2	–134.2	–128.0

TABLE A1-5

Input data (IFIC terrestrial services) and calculated data

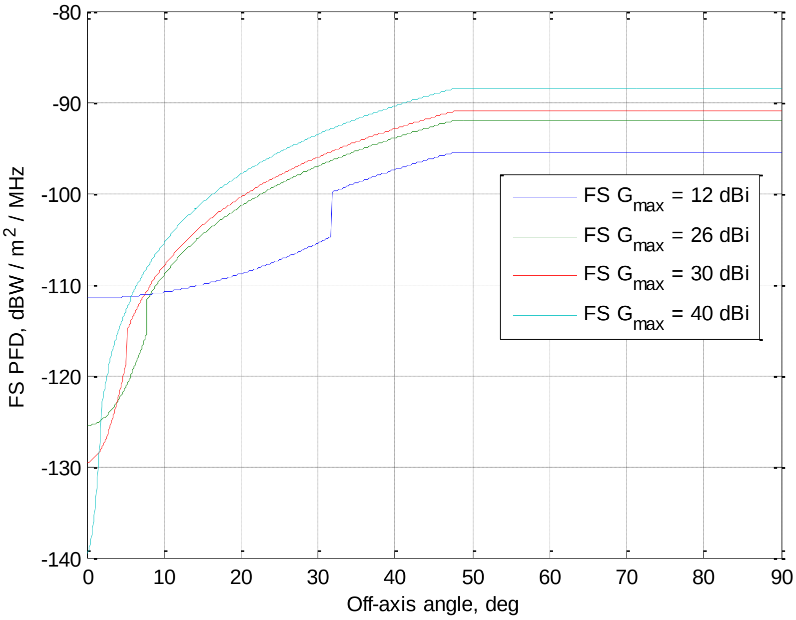
Frequency range (GHz)	22.0-26.0	
Receiver centre frequency (GHz)	22.800	25.125
Max antenna gain (dBi)	47.8	46.9
Feeder/multiplexer loss (dB)	0	
Receiver noise power density typical (dBW/MHz)	–136	
Criteria, *I/N* (dB)	–10	
p. f. d. ($dBW/MHz/m^2$)	–145.2	–143.4

It should be noted that calculated pfd levels are the allowable aggregate levels of emission from all MSS GSO space stations, as well as from other services, to which this frequency band is allocated on the equal primary basis, and which are operating in the same area. Hence, allowable pfd from one MSS GSO space station will be lower than it is shown in the Tables A1-4 and A1-5.

For FS systems operating in 21.2-23.6 GHz, the interference protection threshold required to protect the FS systems, in ($dBW/m^2/MHz$), as function of off-axis arrival angles from 0º to 90º, is shown in Fig. A1-2. This calculation is based on the nominal long-term interference power density for 128-QAM FS systems (see Table A1-2, taken from Recommendation ITU-R F.758-5), the representative FS antenna gains of 12, 26, 30, and 40 dBi (at a carrier frequency of 22.4 GHz), and the FS interference protection criteria *I/N* of –10 dB (Recommendation ITU-R F.758-5).

FIGURE A1-2

FS interference protection threshold - (dBW/m²/MHz)



In order to determine to what extent the pfd levels, obtained during worst case scenario calculation (Tables A1-4 and A1-5), can be reduced, assessment of the mean interference probability exceeding the acceptable criterion of the FS terrestrial station taking into account the allocation of notified FS stations by different parameters is given further. In case of adopting a decision on the allocation to the MSS in the space-to-Earth direction of any frequency band in the range 22-26 GHz which has already been allocated to the FS, the pfd levels specified below in § 4.1.3, Table 21-4 should be included into RR Article **21**.

4.1.2 Probability analysis

Estimation of mean interference probability exceeding the acceptable criterion for FS terrestrial station located at any point of the Earth's surface was performed based on data (number of registered FS stations, elevation angles in the locations of the receiving antennas of the specified stations and their gain) published in BR IFIC 2745 (Terrestrial Services) of 28 May 2013.

According to the data published in the BR IFIC 2745 (Terrestrial Services) there are 66376 registered stations in the frequency bands allocated to the FS on the primary basis (see Table A1-1).

4.1.2.1 The initial data and the main assumptions for the calculation.

Interference was taken into account from the four nearest satellites located at the geostationary orbit with the angular separation of 4 degrees. Altitude of the FS station was not considered and taken to be equal to the sea level. Technical characteristics of FS terrestrial stations used in the calculations are defined in Recommendation ITU-R F.758-5. Gain values of the receiving terrestrial stations were determined from the BR IFIC database. Off-point of the FS stations receiving antenna from the direction towards the geostationary orbit was not taken into account. The location of FS stations on the globe was assumed to be uniform.

Azimuthal distribution of receiving beams of FS stations was assumed to be equiprobable. This assumption was made based on Fig. AA1-2, which shows the distribution of existing terrestrial fixed service stations by their antenna azimuth, based on information published in BR IFIC 2735

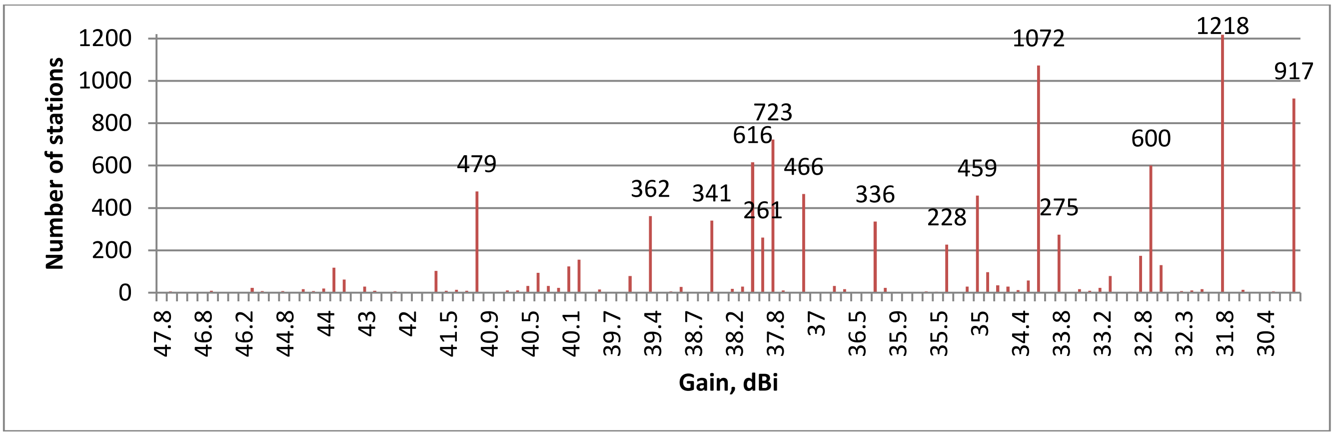
(Terrestrial Services) of 8 January 2013. The Figure shows that azimuthal distribution of the station antennas is quasi equiprobable.

Calculation of the minimum signal attenuation in atmospheric gases was performed according to Recommendation ITU-R F.1404-1 and taken into account in determining hard pfd limits for geostationary MSS networks.

Distribution of registered FS stations by gain and elevation angle is given below.

TABLE A1-6

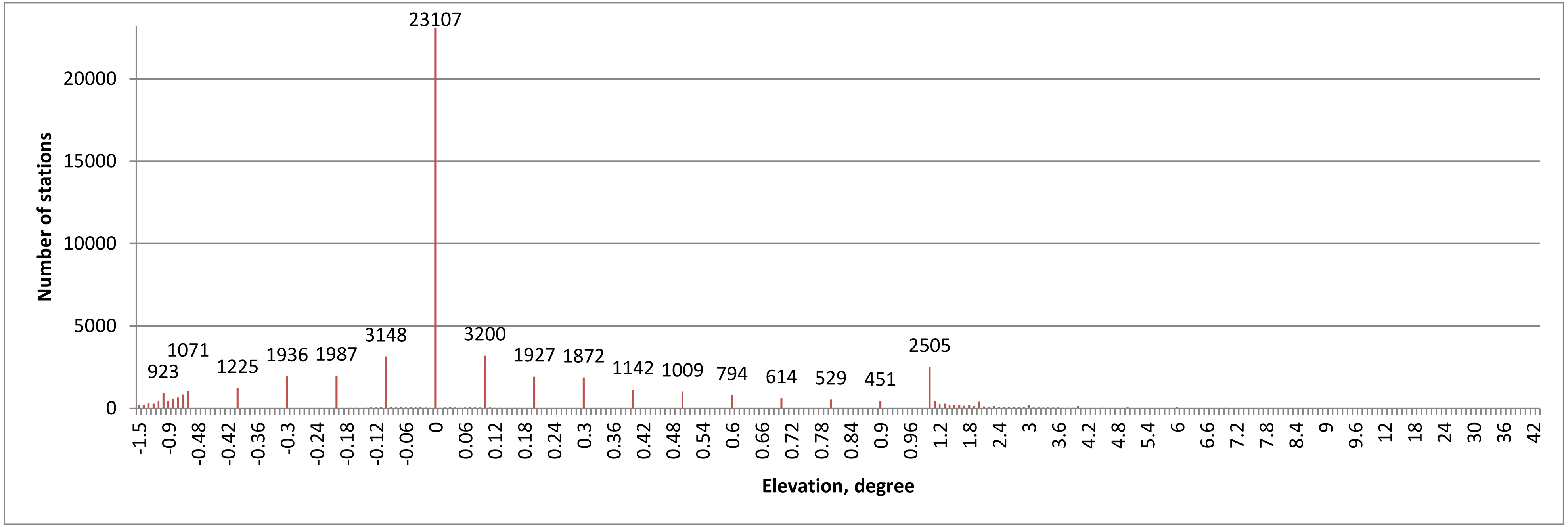
Distribution of antenna gains



More than 90 % of FS stations registered in MIFR had gain between 47.8…29 dBi.

TABLE A1-7

Distribution by station elevations



93.3% of FS stations registered in MIFR had elevation angle between –1.5 degrees and 1.5 degrees.

4.1.2.2 Results of calculation

Tables A1-8A through A1-8F below shows calculation results of average possibility of interference to FS ground station, exceeding the allowable criterion with various levels of power flux density at the Earth's surface in the 22-26 GHz frequency range.

TABLE A1-8A

Pfd = -130 dBW/MHz/m²

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	0	0	0	$3,485*10^{-3}$	0,02	0,024	0,029	0,046
Number of damaged stations	0	0	0	1	2	2	1	3

TABLE A1-8B

Pfd = -125 dBW/MHz/m²

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	0,081	0,1	0,108	0,11	0,123	0,122	0,198	0,215
Number of damaged stations	10	5	9	6	12	9	9	13

TABLE A1-8C

Pfd = -120 dBW/MHz/m^2

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	0,324	0,338	0,469	0,633	0,659	0,641	0,57	0,43
Number of damaged stations	40	18	40	35	62	47	26	26

TABLE A1-8D

Pfd = -115 dBW/MHz/m^2

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	1,73	1,655	1,561	1,444	1,322	1,268	1,091	0,737
Number of damaged stations	216	90	134	79	125	93	49	45

TABLE A1-8E

Pfd = -110 dBW/MHz/m²

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	2,902	2,797	2,645	2,43	2,02	1,95	1,807	1,527
Number of damaged stations	362	152	226	133	191	143	82	93

TABLE A1-8F

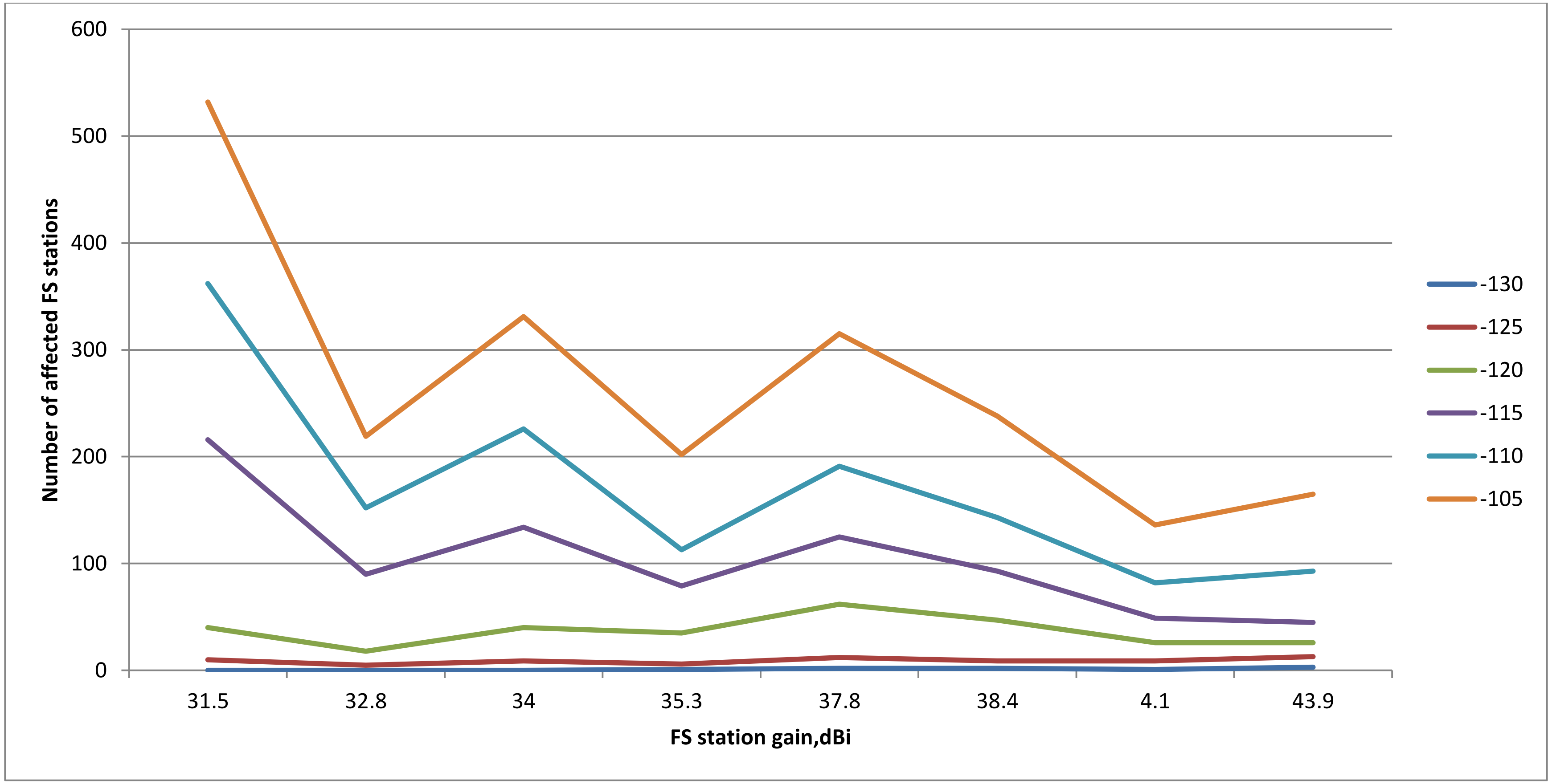
Pfd = -105 dBW/MHz/m²

FS receive antenna gain, dBi	31,5	32,8	34	35,3	37,8	38,4	40,1	43,9
FS antenna pattern	Rec. ITU-R F.1245-1							
Number of registered FS stations with elevation angle 0..5 degrees.	12311	5371	8443	5405	9319	7231	4466	6013
Number of registered FS stations with elevation angle 5..25 degrees	174	76	119	76	132	102	63	85
Number of registered FS stations with elevation angle more than 25 degrees	0	0	0	0	0	0	0	0
Total number of registered FS stations	12485	5446	8562	5481	9451	7333	4529	6098
Criterion for aggregate interference, *I/N*, dB	-10							
Percentage of damaged stations, %	4,259	4,028	3,861	3,683	3,328	3,243	3,009	2,698
Number of damaged stations	532	219	331	202	315	238	136	165

The diagram shows generalized results for the number of damaged stations with various levels of power flux density at the Earth's surface and various gains of FS.

FIGURE A1-3

Number of damaged FS systems



4.1.3 Refined results of probability analysis

Refined estimation of the average probability of interference exceeding permissible criterion for the FS terrestrial station located anywhere at the Earth's surface has been carried out using the same methodology as in the previous estimation.

Unlike the previous version however, the refined calculation has been carried out taking into account division of the 22-26 GHz frequency band into sub-bands (see Table A1-9) and taking into consideration differences in attenuation due to atmospheric propagation and refraction for each sub-band.

TABLE A1-9

<table>
<tr><th>Frequency band (GHz)</th><th>Antenna gain of the FS station (dBi)</th><th>Radiation pattern of the FS station antenna</th><th>Feeder losses (dB)</th><th>Noise power density (dBW/MHz)</th></tr>
<tr><td>22.00-22.55</td><td rowspan="6">31.8
32.8
34.0
35.3
37.8
38.4
40.1
43.9</td><td rowspan="6">Rec. ITU-R F.1245-1</td><td rowspan="6">0</td><td>–133
–138</td></tr>
<tr><td>22.55-23.15</td><td>–133
–138</td></tr>
<tr><td>23.15-23.60</td><td>–133
–138</td></tr>
<tr><td>24.45-24.65</td><td>–136</td></tr>
<tr><td>24.65-25.25</td><td>–136</td></tr>
<tr><td>25.25-26.00</td><td>–136</td></tr>
</table>

The minimum signal attenuation in atmospheric gases has been calculated according to Recommendation ITU-R F.1404-1.For frequency bands which are not shown in the Recommendation ITU-R F.1404-1, characteristics were chosen as for the nearest band. Interference signal losses due to the refraction have been calculated according to Recommendation ITU-R P.834-6.

Two power flux density masks from the Report have been considered in this analysis (see Table A1-10).

TABLE A1-10

<table>
<tr><th rowspan="2">Name</th><th rowspan="2">Service</th><th colspan="3">Power flux density (dBW/MHz/m^2)</th></tr>
<tr><th>0°–5°</th><th>5°–25°</th><th>25°–90°</th></tr>
<tr><td>Mask1</td><td rowspan="2">Mobile satellite service(space-to-Earth)</td><td>–115</td><td>$-115 + 0.5(\delta - 5)$</td><td>–105</td></tr>
<tr><td>Mask2</td><td>–125</td><td>$-125 + 0.5(\delta - 5)$</td><td>–115</td></tr>
</table>

4.1.3.1 Results of calculation

Refined calculation of average probability of interference exceeding permissible criterion for the FS terrestrial station with two pfd masks is given in Table A1-11 below.

TABLE A1-11A

Frequency band: 22-22.55 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40.1	43.9	Total
Total number of registered FS stations		5312	2317	3643	2331	4021	3121	1927	2595	**25267**
Aggregate interference criterion *I/N*, dBW		-10								
Noise power density, dBW/MHz		-138								
Mask 1	Damaged stations, %	3.305	3.054	2.792	2.551	2.161	2.082	1.886	1.51	**-**
	Number of damaged stations	176	71	102	60	87	65	37	40	**638**
Mask 2	Damaged stations, %	0.149	0.149	0.237	0.315	0.346	0.341	0.303	0.226	**-**
	Number of damaged stations	8	4	9	8	14	11	6	6	**66**
Noise power density, dBW/MHz		-133								
Mask 1	Damaged stations, %	1.724	1.646	1.513	1.352	1	0.927	0.735	0.476	**-**
	Number of damaged stations	92	39	56	32	41	29	15	13	**317**
Mask 2	Damaged stations, %	0	0	0.007	0.018	0.035	0.037	0.038	0.076	**-**
	Number of damaged stations	0	0	1	1	2	2	1	2	**9**

TABLE A1-11B

Frequency band: 22.55-23.15 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40.1	43.9	**Total**
Total number of registered FS stations		2886	1259	1980	1267	2185	1695	1047	1410	**13729**
Aggregate interference criterion *I/N*, dBW		-10								
Noise power density, dBW/MHz		-138								
Mask 1	Damaged stations, %	3.26	3.005	2.739	2.482	2.089	2.012	1.82	1.443	
	Number of damaged stations	95	38	55	32	46	35	20	21	**342**
Mask 2	Damaged stations, %	0.141	0.143	0.191	0.282	0.322	0.323	0.29	0.218	
	Number of damaged stations	5	2	4	4	8	6	4	4	**37**
Noise power density, dBW/MHz		-133								
Mask 1	Damaged stations, %	1.804	1.712	1.572	1.389	1.034	0.956	0.754	0.495	
	Number of damaged stations	53	22	32	18	23	17	8	7	**180**
Mask 2	Damaged stations, %	0	0	0.01	0.021	0.037	0.039	0.04	0.082	
	Number of damaged stations	0	0	1	1	1	1	1	2	**7**

TABLE A1-11C

Frequency band: 23.15-23.6 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40.1	43.9	**Total**
Total number of registered FS stations		3472	1514	2381	1524	2627	2039	1260	1696	**16513**
Aggregate interference criterion *I/N*, dBW		-10								
Noise power density, dBW/MHz		-138								
Mask 1	Damaged stations, %	3.655	3.33	3.018	2.747	2.306	2.221	2.008	1.634	
	Number of damaged stations	127	51	72	42	61	46	26	28	**453**
Mask 2	Damaged stations, %	0.157	0.177	0.305	0.373	0.389	0.376	0.355	0.256	
	Number of damaged stations	6	3	8	6	11	8	5	5	**52**
Noise power density, dBW/MHz		-133								
Mask 1	Damaged stations, %	2.043	1.893	1.729	1.542	1.125	1.041	0.835	0.538	
	Number of damaged stations	71	29	42	24	30	22	11	10	**239**
Mask 2	Damaged stations, %	0	0	0,009	0,022	0,04	0,042	0,042	0,094	
	Number of damaged stations	0	0	1	1	2	1	1	2	**8**

TABLE A1-11D
Frequency band: 24.25-24.65 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40.1	43.9	**Total**
Total number of registered FS stations		75	32	52	33	57	45	27	38	**359**
Aggregate interference criterion *I*/*N*, dBW		-10								
Noise power density, dBW/MHz		-136								
Mask 1	Damaged stations, %	2.897	2.658	2.341	2.038	1.589	1.501	1.245	0.885	
	Number of damaged stations	3	1	2	1	1	1	0	0	**9**
Mask 2	Damaged stations, %	0.059	0.075	0.083	0.086	0.145	0.166	0.191	0.17	
	Number of damaged stations	0	0	0	0	0	0	1	0	**1**

TABLE A1-11E
Frequency band:24.65-25.25 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40,1	43,9	**Total**
Total number of registered FS stations		835	364	573	366	631	491	303	409	**3972**
Aggregate interference criterion *I*/*N*, dBW		-10								
Noise power density, dBW/MHz		-136								
Mask 1	Damaged stations, %	3.837	3.473	3.09	2.697	2.133	2.035	1.789	1.33	
	Number of damaged stations	33	13	18	10	14	10	6	6	**110**
Mask 2	Damaged stations, %	0.092	0.109	0.119	0.175	0.293	0.322	0.323	0.265	
	Number of damaged stations	1	1	1	1	2	2	1	2	**11**

TABLE A1-11F

Frequency band: 25.25-26 GHz

FS receiving antenna gain, dBi		31.8	32.8	34	35.3	37.8	38.4	40.1	43.9	**Total**
Total number of registered FS stations		835	364	572	367	632	490	303	407	**3970**
Aggregate interference criterion *I/N*, dBW		-10								
Noise power density, dBW/MHz		-136								
Mask 1	Damaged stations, %	3.78	3.429	3.052	2.655	2.083	1.985	1.731	1.28	
	Number of damaged stations	32	13	18	10	14	10	6	6	**109**
Mask 2	Damaged stations, %	0.085	0.101	0.113	0.15	0.268	0.3	0.311	0.259	
	Number of damaged stations	1	1	1	1	2	2	1	2	**11**

The calculation results show that when GSO MSS space station uses Mask 1 in the 22-26 GHz frequency bands, the number of damaged FS stations (interference exceeds permissible criterion) is nearly 10 times greater than in case of Mask 2 (see Table A1-12) in the same frequency sub-band.

TABLE A1-12

Frequency band (GHz)	**Mask 1 (-105/-115 dBW/MHz/m^2)**		**Mask 2 (-115/-125 dBW/MHz/m^2)**	
	Damaged stations (%)	**Number of damaged stations**	**Damaged stations (%)**	**Number of damaged stations**
22.00-22.55	2.525	638	0.261	66
22.55-23.15	2.491	342	0.269	37
23.15-23.60	2.743	453	0.314	52
24.25-24.65	2.507	9	0.191	1
24.65-25.25	2.769	110	0.277	11
25.25-26.00	2.745	109	0.276	11

Note that only small part of operating FS stations is registered (by administrations) in MIFR that is mainly stations located in frontier areas. Thus according to ECC Report 173 (see Table A1-13) the number of FS stations in 22.0-23.6 GHz and 24.5-26 GHz frequency bands in Europe alone considerably exceeds (more than 10 times) the number of FS stations registered in the MIFR worldwide. Hence, taking into account this information, the real number of damaged stations would be 10 times more than in Table A1-12. Besides if one station is damaged, the whole radio link may become damaged.

TABLE A1-13

Frequency band (GHz)	**Number of stations in Europe (point-to-point)**	**Number of base stations in Europe (point-to-multipoint)**
22.0-23.6	230000	-
24.25-24.50	200	
24.5-26.0	74000	2259

4.1.3 Views on section 4.1:

Results of calculation show that with the power flux density mask given in Table A1-14 (–115 /–125) dBW/MHz, created by geostationary space station of MSS at the Earth's surface in frequency bands, which are shown in the Table A1-9 the number of FS damaged stations (interference exceeds the tolerable criterion) will be 0,191% - 0,314 % from general number of stations that will amount to 1 - 66 stations registered (by administrations) in MIFR in absolute figures. With the power flux density mask given in Table A1-15 (–105 /–115) dBW/MHz, created by geostationary space station of MSS at the Earth's surface in frequency bands, which are shown in the Table A1-9, the number of FS damaged stations (interference exceeds the tolerable criterion) will be 2,491% - 2,769 % from general number of stations that will amount to 9 - 638 stations registered (by administrations) in MIFR in absolute figures. The concept of a pfd mask can be taken as hard limit for these frequency bands. It should be noted that only small part of operating FS stations is registered (by administrations) in MIFR that is mainly stations located in frontier areas, and besides, when one station in the chain is damaged, all the chain can fail.

The real number of damaged stations only in Europe would be 10 times more than number of damaged stations registered in MIFR.

TABLE A1-14

Mask 2: TABLE 21-4 (cONT-D) (REV. WRC-15)

Frequency band	**Service** *	**Limit in dB(W/m2) for angles of arrival (δ) above the horizontal plane ти**			**Reference bandwidth**
		0°–5°	**5°–25°**	**25°–90°**	
Relevant bands in the frequency band 22-26 GHz (if allocated)	Mobile-satellite service(space-to-Earth)	–125	–125 + 0,5(δ – 5)	–115	1 MHz

Table A1-15

Mask 1: TABLE 21-4 (cONT-D) (REV. WRC-15)

Frequency band	**Service**	**Limit in dB(W/m^2) for angles of arrival () above the horizontal plane**			**Reference bandwidth**
		0°-5°	**5°-25°**	**25°-90°**	
Relevant bands in the frequency band 22-26 GHz (if allocated)	Mobile-satellite service	–115	–115 + 0.5(δ -5) [13A]	–105	1 MHz

4.2 Calculation of interference impact to existing FS stations from hypothetical MSS satellite network for Earth-to-space direction (Scenario 2).

To ensure protection of radio-relay station from emission of MSS GSO earth station (MES), it is necessary to determine required separation distance between radio-relay station and MES.

It should be noted that calculation of separation distance is made using various initial data sets for two MES antenna diameters 1.8 m and 0.33 m (see Table 2.1-1 in section 2 of this Report). Calculated separation distances could be further corrected after renewal of input data, and also could be complemented with relevant separation distances after the availability of input data for other station types.

Signal propagation attenuation path was calculated according to Recommendation ITU-R P.452-14 for the following conditions:

– A propagation model (1) is used in area A2 (all of the land territory is far away from the sea).

– Height of the MES antenna centre is 3 m above the smooth surface of the Earth.

– Height of the radio-relay station antenna centre is 30 m above the smooth surface of the Earth.

– Axes of MES antenna and radio-relay station antenna are coplanar.

– No obstacles along the signal propagation path (smooth surface).

– Radio-relay station and MES are located in mid-latitudes.

Input data used and result of calculations are shown in Tables A1-16, A1-17, and A1-18.

TABLE A1-16

Input data (MES) and calculated data

Characteristics of user terminal	**Units**	**User terminal 1.8m**		**User terminal 0.33 m**	
Transmitter centre frequency	(GHz)	22.8	25.125	22.8	25.125
Transmit antenna diameter	(m)	1.8		0.33	
Antenna gain	(dBi)	50.78	51.64	36.96	37.81
Transmit effective isotropic radiated power e.i.r.p. per carrier	(dBW)	45.14	46.00	45.17	46.02
Transmit output power per carrier	(dBW)	-5.64		8.21	
Bandwidth at -3 dB	(MHz)	4.05		4.05	
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot		App. 8 RR		App. 8 RR	
Transmit antenna minimum elevation angle	(deg.)	5		5	
Antenna gain towards horizon at elevation angle 5º	(dBi)	14.52		20.31	
Transmit effective isotropic radiated power e.i.r.p. per carrier (towards horizon at elevation angle 5º)	(dBW)	8.88		28.52	
Transmit effective isotropic radiated power e.i.r.p. per carrier (towards horizon at elevation angle 5º)	(dBW/MHz)	2.81		22.45	

TABLE A1-17

Input data (Recommendation ITU-R F.758-5) and calculated data

User terminal antenna diameter (m)	**1.8**			**0.33**		
Frequency range (GHz)	22.0-23.6		24.25-26.0	22.0-23.6		24.25-26.0
Receiver centre frequency (GHz)	22.8		25.125	22.8		25.125
Antenna gain (dBi)	34.8		31.5	34.8		31.5
Receive antenna minimum elevation angle (deg)	0		0	0		0
Feeder/multiplexer loss (dB)	0		0	0		0
Receiver noise power density typical (dBW/MHz)	−133	−138	−136	−133	−138	−136
Criteria, $\frac{I}{N}$ (dB)	–10			–10		
Allowable interference at the input of radio-relay station antenna (dBW/MHz)	–177.8	–182.8	–177.5	–177.8	–182.8	–177.5
Required attenuation to avoid interference effect to radio-relay station (dB)	180.61	185.61	180.31	200.25	205.25	199.95
Required separation distance to MES to avoid interference to existing radio-relay stations (km)	40	42.6	40.2	50.9	55	51.8

TABLE A1-18

Input data (IFIC terrestrial services) and calculated data

User terminal antenna diameter (m)	**1.8**		**0.33**	
Frequency range (GHz)	22.0-23.6	24.25-26.0	22.0-23.6	24.25-26.0
Receiver centre frequency (GHz)	22.8	25.125	22.8	25.125
Antenna gain (dBi)	47.8	46.9	47.8	46.9
Feeder/multiplexer loss (dB)	0		0	
Receiver noise power density typical (dBW/MHz)	–136		–136	
Criteria, $\frac{I}{N}$ (dB)	–10		–10	
Allowable interference at the input of radio-relay station antenna, (dBW/MHz)	–193.8	–192.9	–193.8	–192.9
Required attenuation to avoid interference effect to radio-relay station (dB)	190.61	189.71	216.25	215.35
Required separation distance to MSS Earth station to avoid interference to existing radio-relay stations (km)	48.8	48.9	89.0	89.0

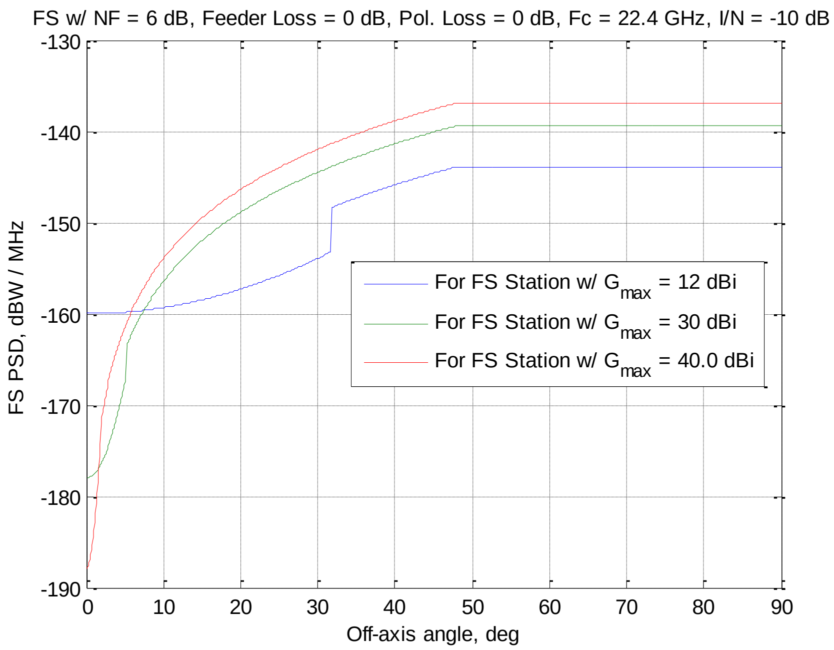
Furthermore it should be noted that there are radio-relay stations registered in the ITU-R, with elevation angles below 0 degree, and this may lead to beam coaxiality between MES antenna and radio-relay station antenna and hence increase in interference towards radio-relay station. In this case allowed distance between location of radio-relay station and MSS Earth station will be increased.

Moreover similarly to the Scenario 1, allowable distances are calculated based on aggregate interference criterion from other (primary) services, and calculation of the separation distance using single interference criterion will show longer distances.

Based on the FS characteristics and using an interference level of *I/N* = –10 dB (Recommendation ITU-R F.758-5), the maximum aggregate power spectral density (PSD) (dBW/MHz) mask, required to protect the FS systems, is shown in Fig. A1-4. This calculation assumes feeder/multiplexer loss of 0 dB, 0 dB polarization loss, a 6 dB FS receiver noise figure, and the FS antenna gains (at a carrier frequency of 22.4 GHz) for off-axis arrival angles from 0° to 90°.

FIGURE A1-4

FS interference protection threshold - Power spectral density (dBW/MHz)



Radio Regulations Appendix **7** should be used to determine the coordination area, such that the maximum aggregate interference power density (dBW/MHz) from all MSS earth stations to a FS station is below all FS PSD protection masks shown in Figure A1-4 apportioned to per-service.

4.2.1 Conclusions for section 4.2

The analysis based on the worst case scenario showed that to ensure guaranteed protection of radio-relay stations (line-of-sight) from interference caused by hypothetic MSS GSO satellite system (Earth-to-space), it is required to suppress operation of MSS transmitting stations within distances of several tens km from receiving stations.

Therefore, to protect existing FS stations which are used to transmit data between base stations in existing 2G and 3G networks, from emissions of transmitting MSS ground stations, it is suggested to use existing provisions of RR Article **9** (particularly RR No. **9.17**).

4.3 Probabilistic analysis for sharing between FS stations and MSS satellite network for Earth-to-space

The following parameters have been considered as common parameters for all calculations:

– Signal propagation attenuation is calculated according to Recommendation ITU-R P.452-14 for the following conditions:

– A propagation model (1) is used in area A2 (all of the land territory is far away from the sea).

– Receiver height above the sea level is 300 m.

– Height of the MES antenna centre is random value from 2 m to 4 m above the surface of the Earth.

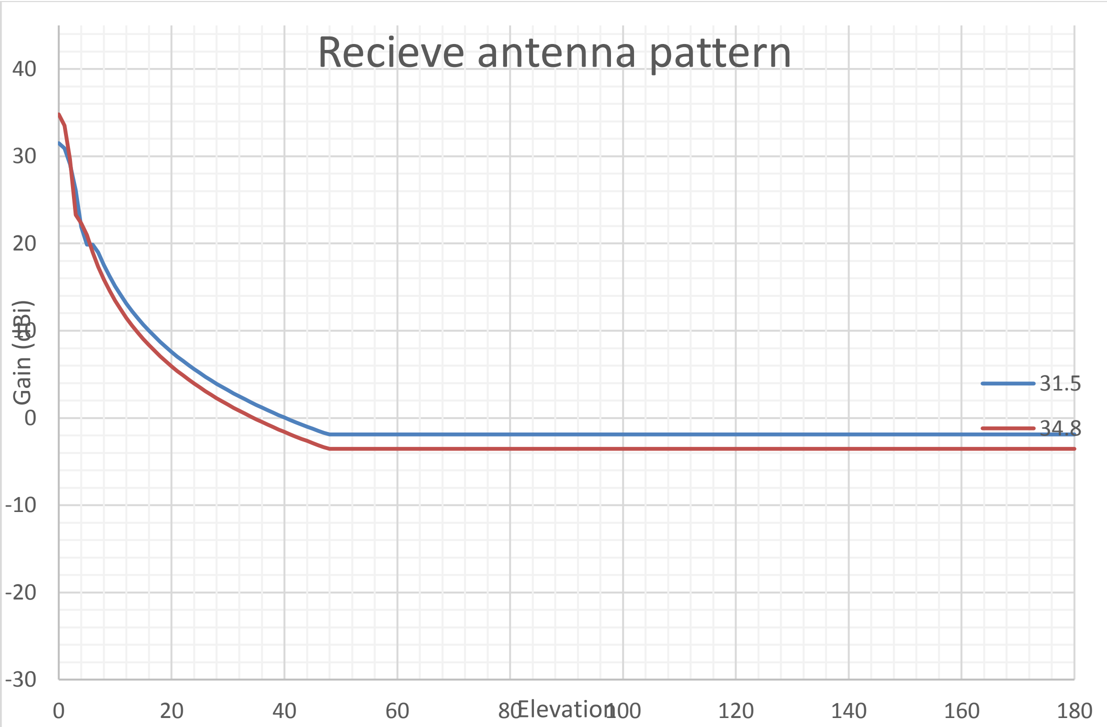
– Height of the radio-relay station antenna centre is random value form 20 m to 30 m above the surface of the Earth.

– MES antenna and radio-relay antenna both are with linear polarization and the polarization difference between the interfering signal and the receiver is any random value between 0 and 90 degrees.
– A random object is generated every 1 km, of a random height from 0 m to 10 m.
– Variation of the earth surface terrain due to natural topography of the earth surface is random value -5 m to 5 m each one 1 km.
– The elevation of the MES is random value from 5 degrees to 31 degrees (31 is the maximum elevation to the GEO orbit and 5 is the minimum allowed elevation angle).
– The transmitter can transmit in any direction (not necessarily in direction of the victim).
– The off axis angle is random value.
– Required time percentage(s) for which the calculated basic transmission loss is not exceeded (p) equal to 20%, which is used for long term conditions.
– Longitude and latitude is selected for a location inside Europe.
– The average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere (ΔN) =46 per km from the long term ΔN chart.
– The sea-level surface refractivity (N0) =328.
– All the interfering transmitters are at equal distance from the victim receiver.
– No of MES is random from 1 to 4.
– The MES radiation pattern is Recommendation ITU-R S-580.
– The FS receive antenna pattern is Recommendation ITU-R F.699.
– No. of Simulations 2000.
– Any protection distance less than 3 km will be considered as 3 km.

The following graph in Fig. A1-5 show the receive antenna pattern using Recommendation ITU-R F.699 for the different antenna gain used in the sharing study.

FIGURE A1-5

Receive Antenna Pattern



4.3.1 Effect of the hub terminal (2.4m) over the FS system

4.3.1.1 In the band from 22 to 23.6 GHz

Two different FS systems exists in this band, one uses FSK modulation and the other one uses 128-QAM.

4.3.1.1.1 For the FSK modulated system

The following parameters in Table A1-19 are used as input to simulation.

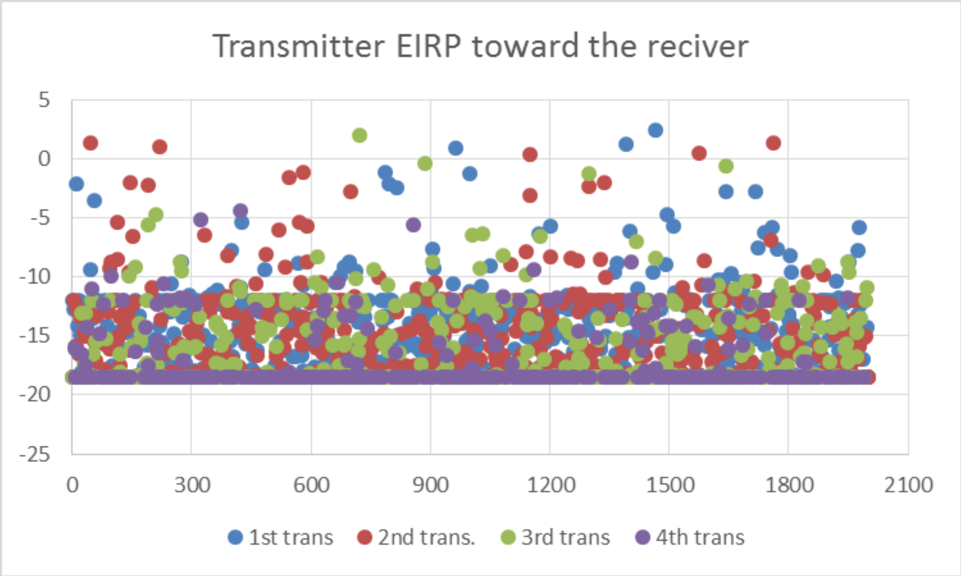
TABLE A1-19

Simulation parameters

Feeder loss (dB)	0-3
Freq. (GHz)	22.8
Max receive antenna gain (dBI)	34.8
Receiver noise power density (dBW/MHz)	-133
I/N (dB)	-10
Transmit Antenna Diameter (m)	2.4
Transmit e.i.r.p. (dBW)	57.23
Bandwidth at -3 dB	16.2

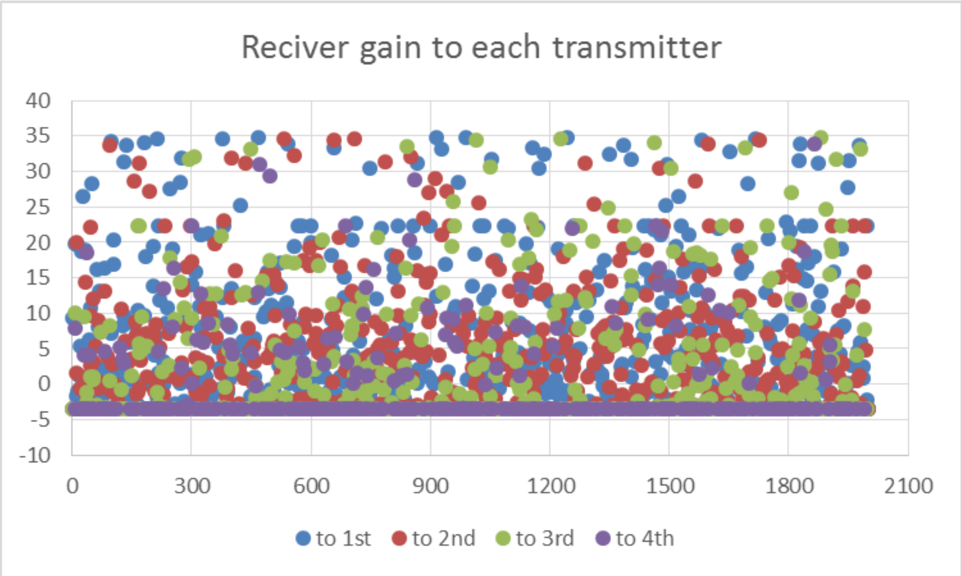
The transmitters e.i.r.p. toward the receiver is shown in the next graph in Fig. A1-6.

FIGURE A1-6



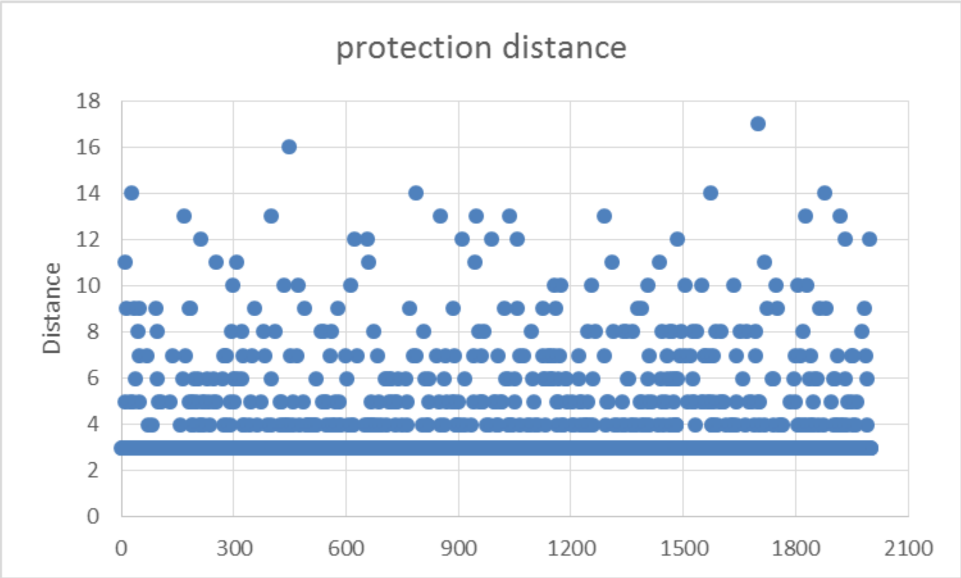
The value of receiver gain to each transmitter is shown in Fig. A1-7.

FIGURE A1-7



The required protection distance is shown in Fig. A1-8.

FIGURE A1-8



The percentage where the protection distance is less than or equal to 3 km is 77.6% of the fixed stations.

The protection distance to protect 99.3% of the receivers is 12 km.

4.3.1.1.2 For 128-QAM modulated system

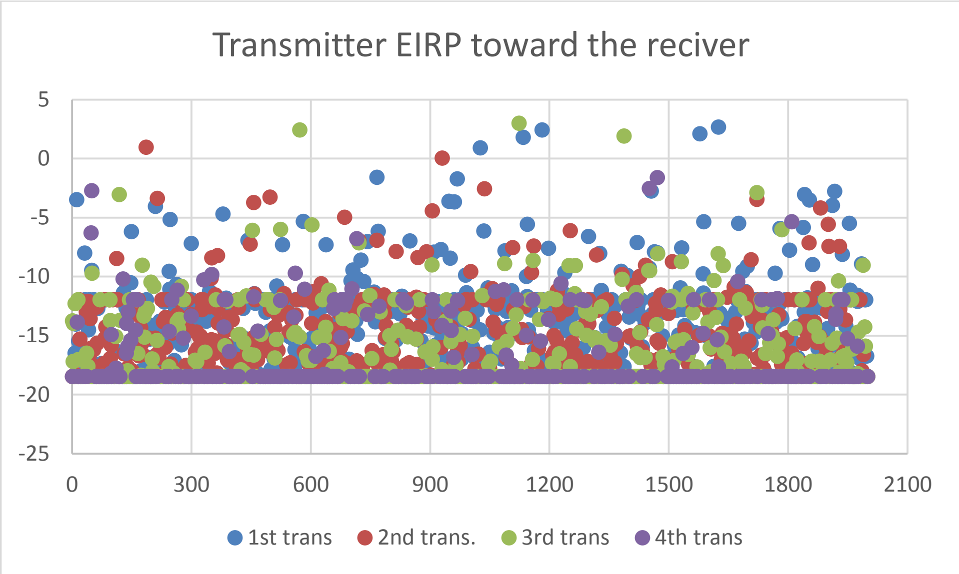
The following parameters shown in Table A1-20 are used as input for the simulation.

TABLE A1-20

Feeder loss (dB)	0-3
Freq. (GHz)	22.8
Max receive antenna gain (dBI)	34.8
Receiver noise power density (dBW/MHz)	–138
I/N (dB)	–10
Transmit Antenna Diameter (m)	2.4
Transmit e.i.r.p. (dBW)	57.23
Bandwidth at -3 dB	16.2

The transmitter's e.i.r.p. toward the receiver is shown in the following graph in Fig. A1-9.

FIGURE A1-9



The value of receiver gain to each transmitter is shown in Fig. A1-10.

FIGURE A1-10

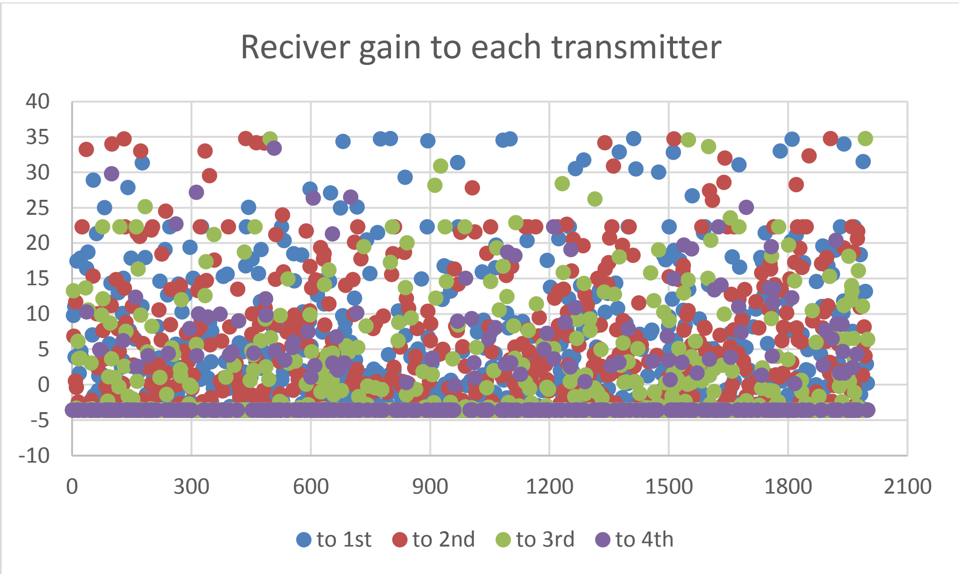
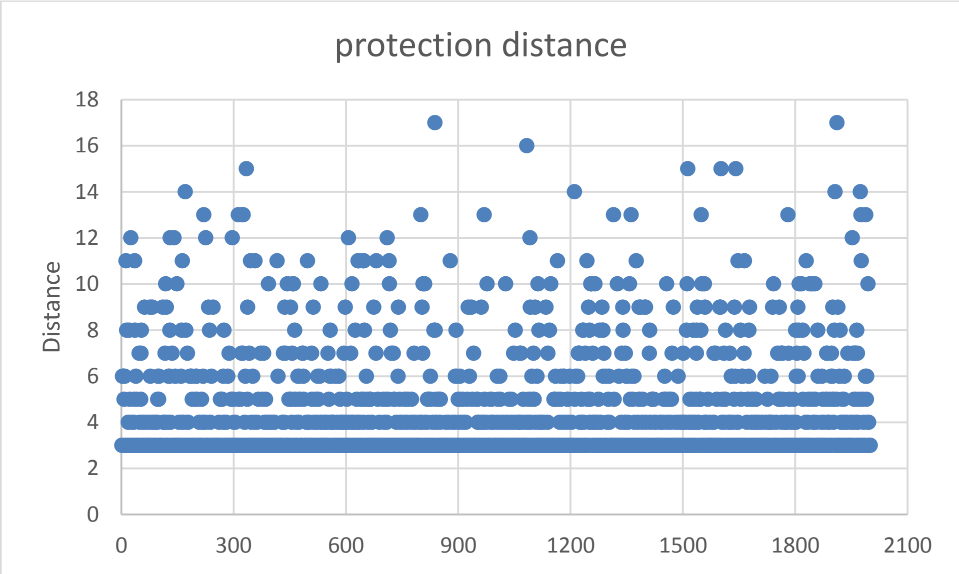


FIGURE A1-11



4.3.1.1.3 The protection distance

The percentage where the protection distance (shown in Fig. A1-11) is less than or equal to 3 km is 63.05% of the fixed stations.

The protection distance to protect 99.45% of the receivers is 13 km.

4.3.1.2 In the band from 24.25 to 26

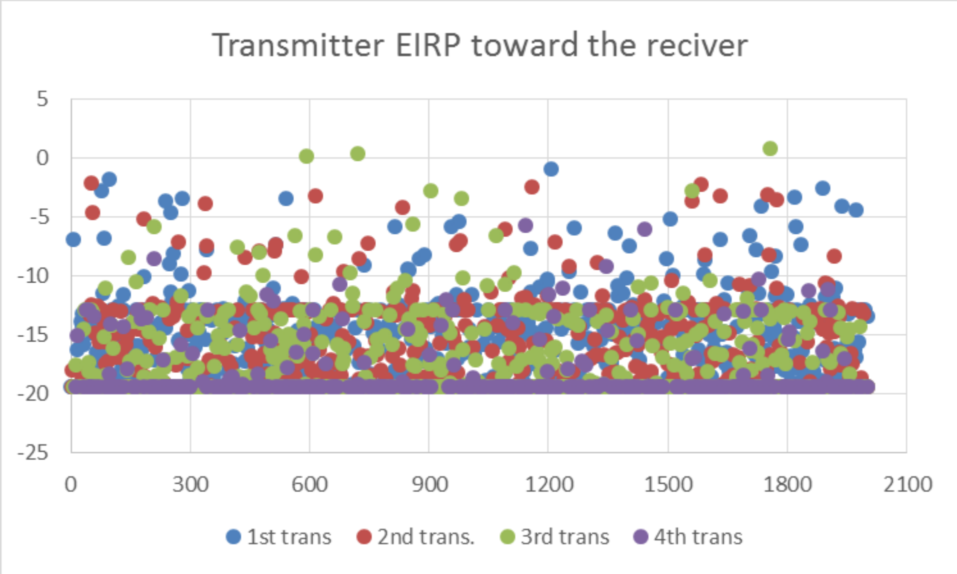
The input parameters for the simulator are shown in Table A1-21.

TABLE A1-21

Feeder loss (dB)	0
Frequency (GHz)	25.13
Max receive antenna gain (dBI)	31.5
Receiver noise power density (dBW/MHz)	–136
I/N (dB)	–10
Transmit antenna diameter (m)	2.4
Transmit e.i.r.p. (dBW)	57.23
Bandwidth at -3 dB	16.2

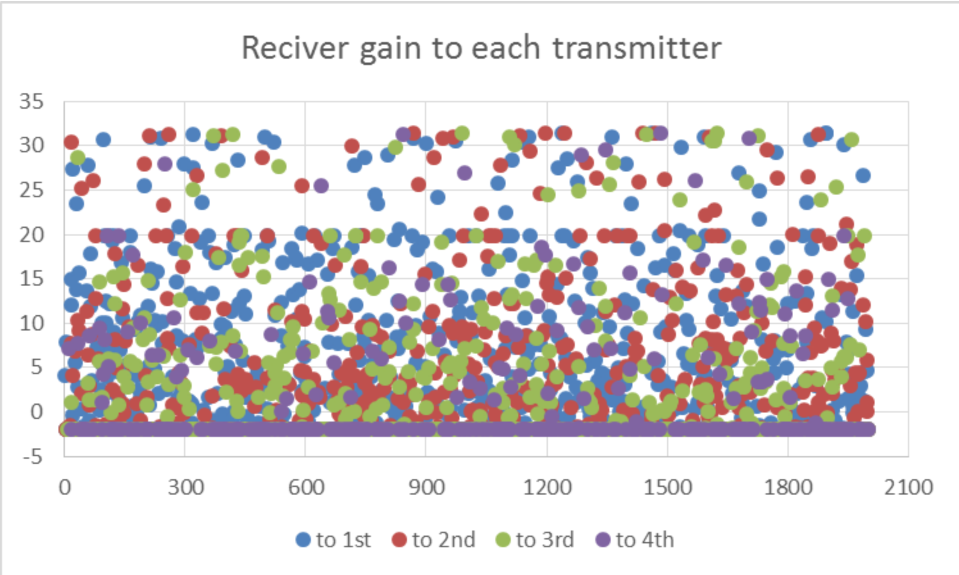
The transmitters e.i.r.p. towards the receiver is shown in the following graph in Fig. A1-12.

FIGURE A1-12



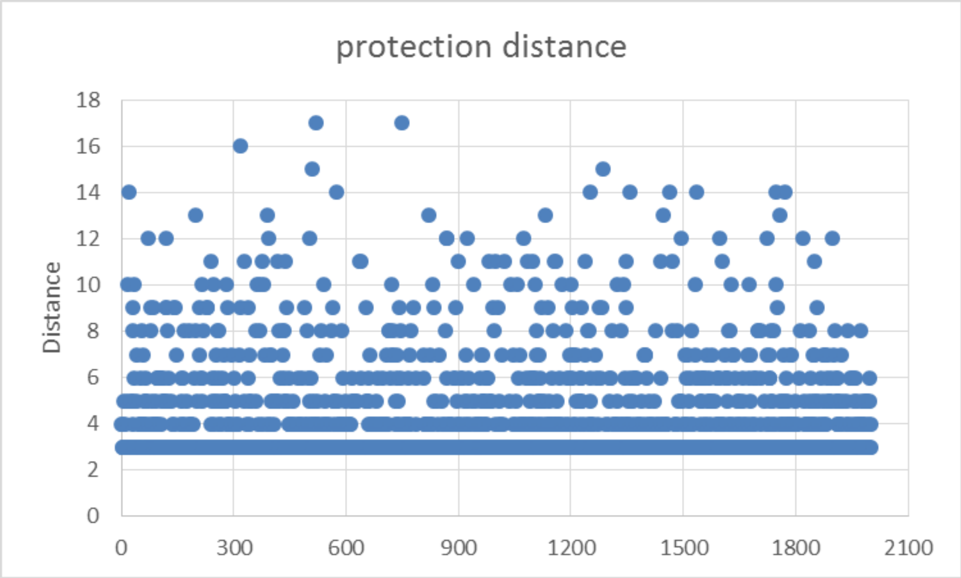
The value of receiver gain to each transmitter is shown in Fig. A1-13.

FIGURE A1-13



And the protection distance is shown in Fig. A1-14.

FIGURE A1-14



The percentage where the protection distance is less than or equal to 3 km is 62.05% of the fixed stations.

The protection distance to protect 99.35% of the receivers is 13 km.

4.3.2 Effect of the user terminal over the FS system

4.3.2.1 In the band from 22 to 23.6

Two different FS systems exist, one uses FSK modulation and the other one using 128-QAM.

4.3.2.1.1 For the FSK modulated P-P system

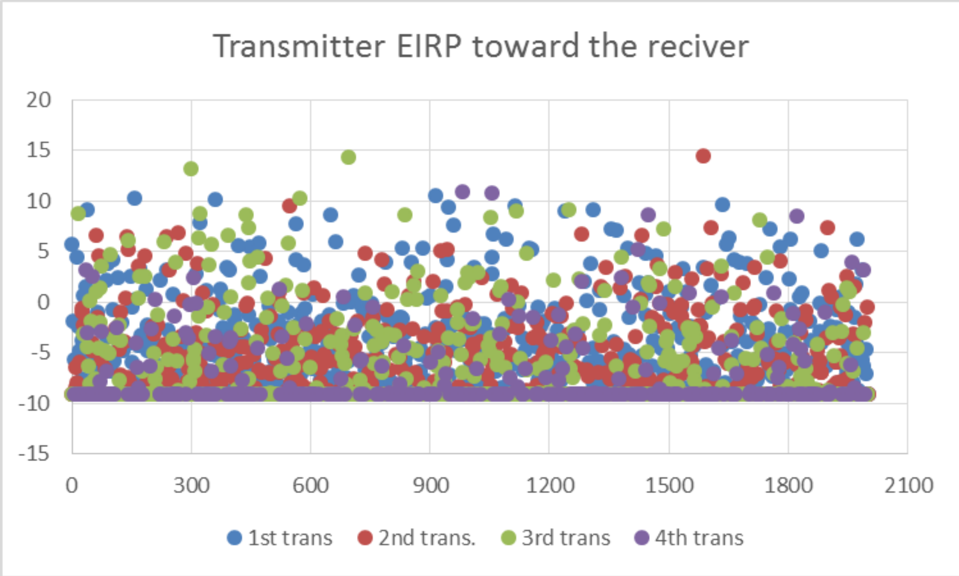
The following parameters in Table A1-22 are used as input to simulator.

TABLE A1-22

Feeder loss (dB)	0-3
Frequency (GHz)	22.8
Max receive antenna gain (dBI)	34.8
Receiver noise power density (dBW/MHz)	–133
I/N (dB)	–10
Transmit Antenna Diameter (m)	0.33
Transmit e.i.r.p. (dBW)	37.4
Bandwidth at -3 dB	4.05

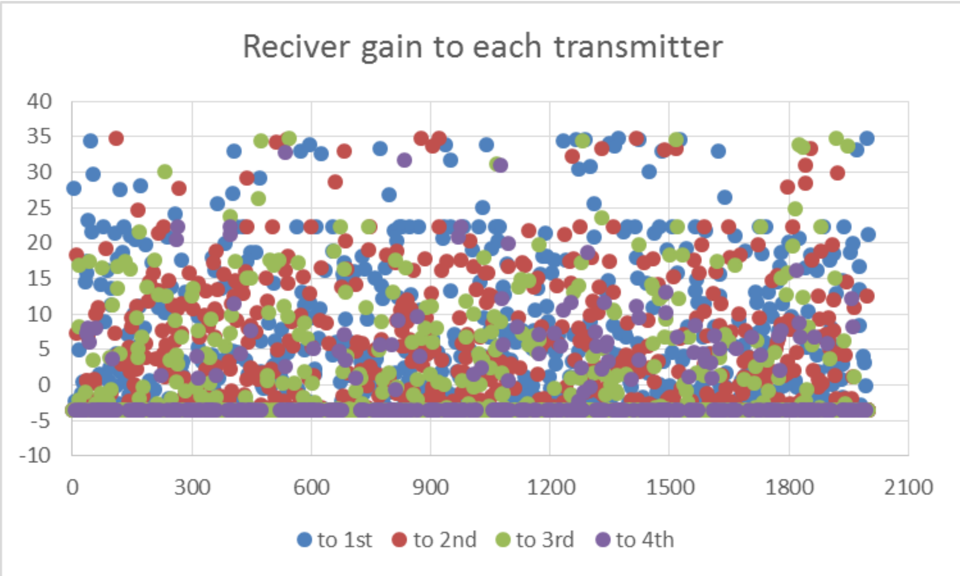
The transmitter e.i.r.p. toward the receiver is shown in the following graph in Fig. A1-15.

FIGURE A1-15



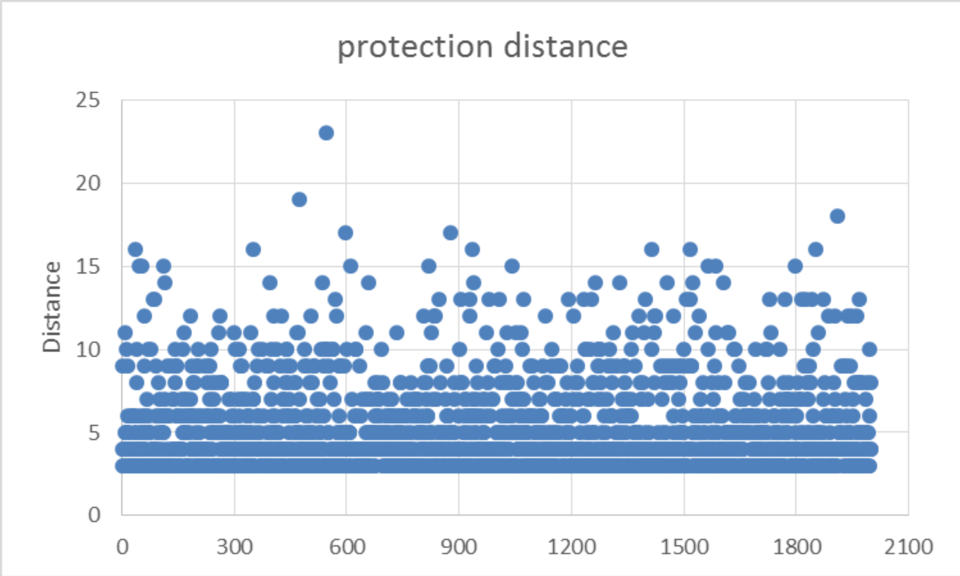
The value of receiver gain to each transmitter is shown in Fig. A1-16.

FIGURE A1-16



And the protection distance is shown in Fig. A1-17.

FIGURE A1-17



The percentage where the protection distance less than or equal to 5 km is 70.1% of the fixed stations. The protection distance to protect 99.45% of the receivers is 15 km.

4.3.2.1.2 For the128-QAM P-P system

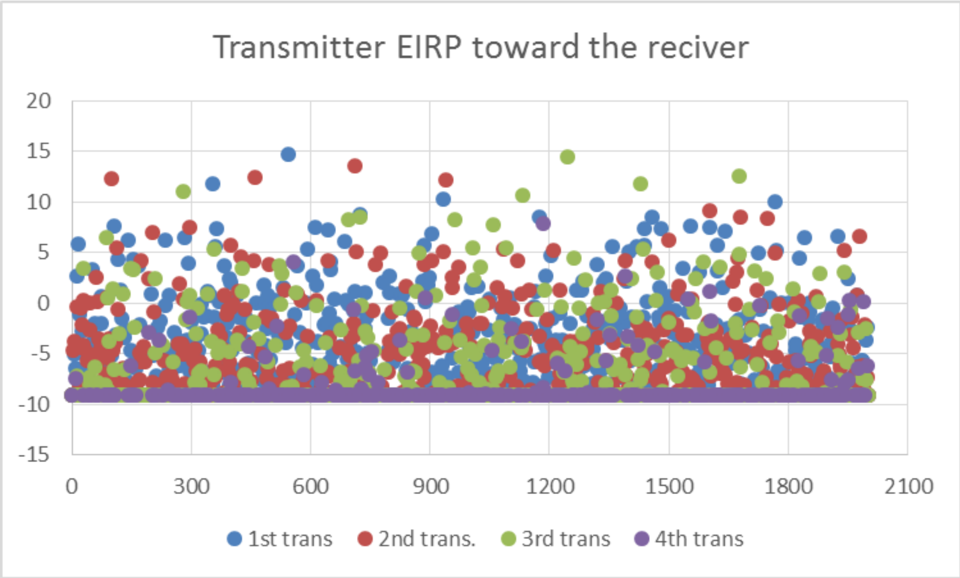
The following parameters shown in Table A1-23 are used as input to simulator.

TABLE A1-23

Feeder loss (dB)	0-3
Frequency (GHz)	22.8
Max receive antenna gain (dBI)	34.8
Receiver noise power density (dBW/MHz)	–138
I/N (dB)	–10
Transmit Antenna Diameter (m)	0.33
Transmit e.i.r.p. (dBW)	37.4
Bandwidth at -3 dB	4.05

The transmitters e.i.r.p. toward the receiver is shown in the following graph in Fig. A1-18.

FIGURE A1-18



The value of receiver gain to each transmitter is shown in Fig. A1-19.

FIGURE A1-19

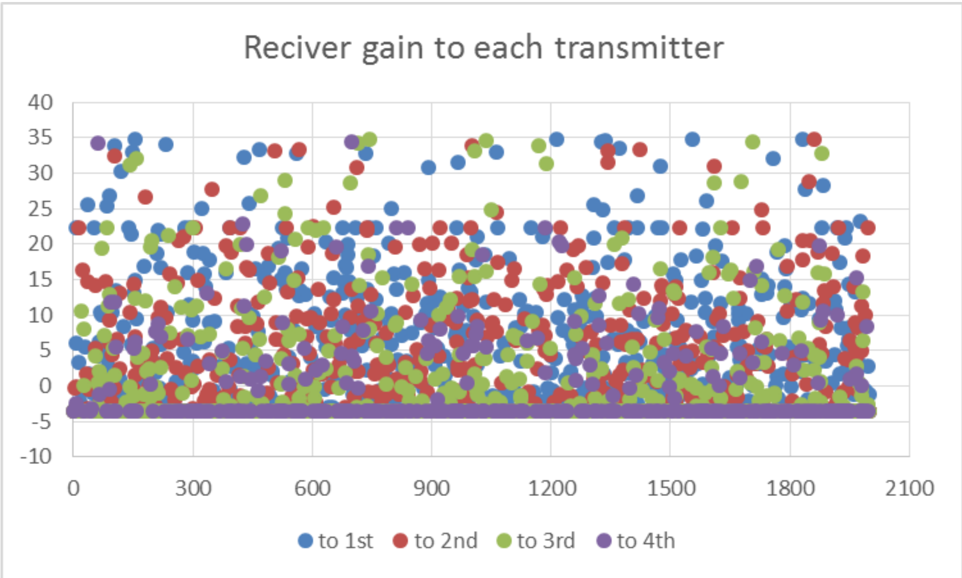
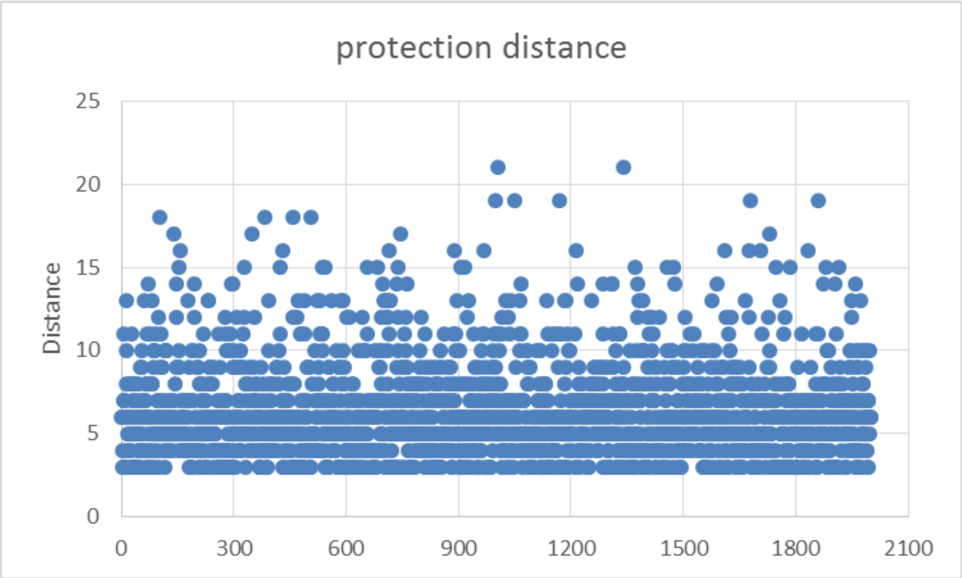


FIGURE A1-20



The percentage where the protection distance shown in Fig. A1-20 is less than or equal to 6 km is 62.8 % of the fixed stations

The protection distance to protect 99.25% of the receivers is 16 km. However, larger distances are required to reduce the percentage of affected fixed stations.

4.3.2.2 In the band from 24.25 to 26

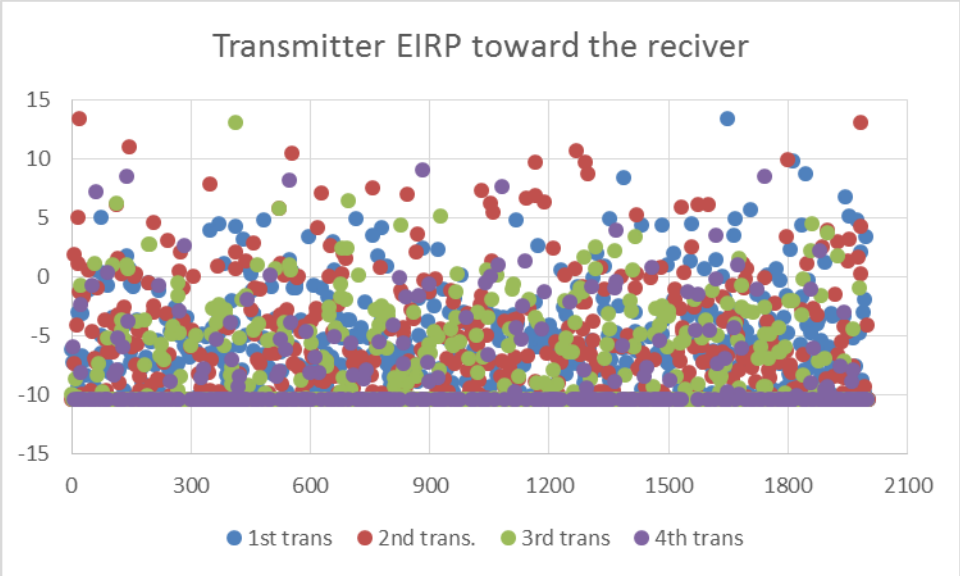
Simulation parameters are given in Table A1-24.

TABLE A1-24

Feeder loss (dB)	0
Freq. (GHz)	25.13
Max receive antenna gain (dBI)	31.5
Receiver noise power density (dBW/MHz)	–136
I/N (dB)	–10
Transmit Antenna Diameter (m)	0.33
Transmit e.i.r.p. (dBW)	37.4
Bandwidth at -3 dB	4.05

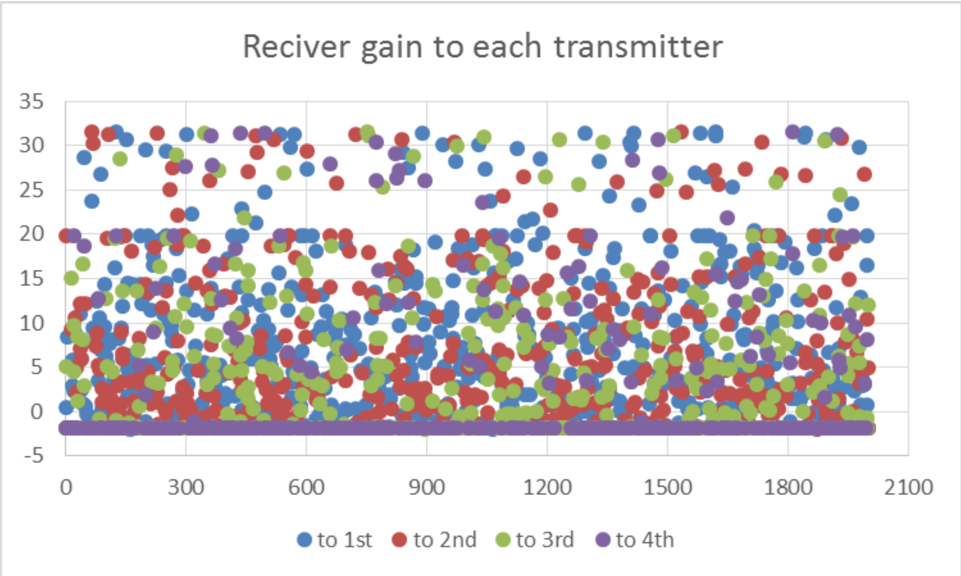
The transmitters e.i.r.p. toward the receiver is shown in the following graph in Fig. A1-21.

FIGURE A1-21



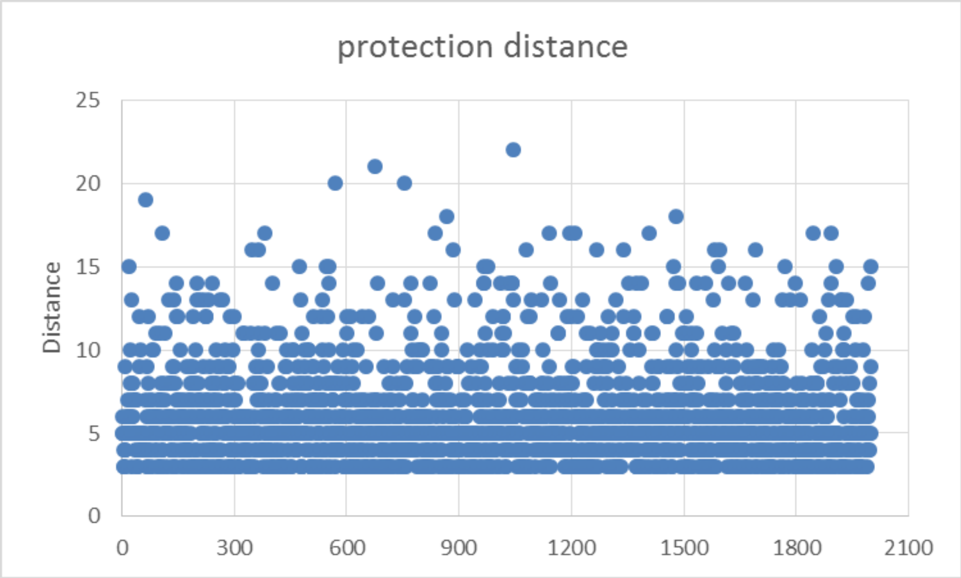
The value of receiver gain to each transmitter is shown in Fig. A1-22.

FIGURE A1-22



And the protection distance is shown in Fig. A1-23.

FIGURE A1-23



The protection distance of 16 km is required to protect 99.2% of the receivers, and at percentage of 68.9% of the receivers, protection distance of 6 km is required.

4.3.3 Conclusions and Recommendations of section 4.3

Under worst case scenario in order to ensure protection of FS systems, a protection distance of 52 km is required, however this worst case scenario only represent less than 1% of the FS stations with specific parameters. Under few practical assumptions considering the actual operations of FS stations in various countries in order to simulate real case scenario the required separation distance to protect more than 99 percent of the receivers is 16 km, while for more than 60 percent of the receivers the required protection distance is only 6 km.

These results show that the separation distance between the proposed MSS system and the existing FS systems can largely be reduced when we consider the actual implementation of FS systems around the world.

The exclusion areas that results from these separation distances can be put into effect by using the geo-location facility which already exists in most MESs. This might consist of, for example, a GPS receiver in the MES so that its location can be determined and signalled to the MSS control facility. If the MES is located in an exclusion area, it could be prohibited from transmitting on the necessary frequencies. Alternatively, the exclusion could be applied to any MES within a particular satellite beam which overlaps with the excluded area.

Attachment 1
to Annex 1

Distribution of antenna azimuths and elevations of registered FS stations

This Annex showed distribution of antenna azimuths and elevation angles for existing FS stations on the basis of data published in BR IFIC (Terrestrial services) 2735 of 08.01.2013 (see Figs AA1-1 and AA1-2). As Table cells with elevation and azimuth are not mandatory for registration terrestrial stations, so the number of considered in this Annex FS stations is less than the total number of registered stations, mentioned in § 2 of Annex 1.

FIGURE AA1-1

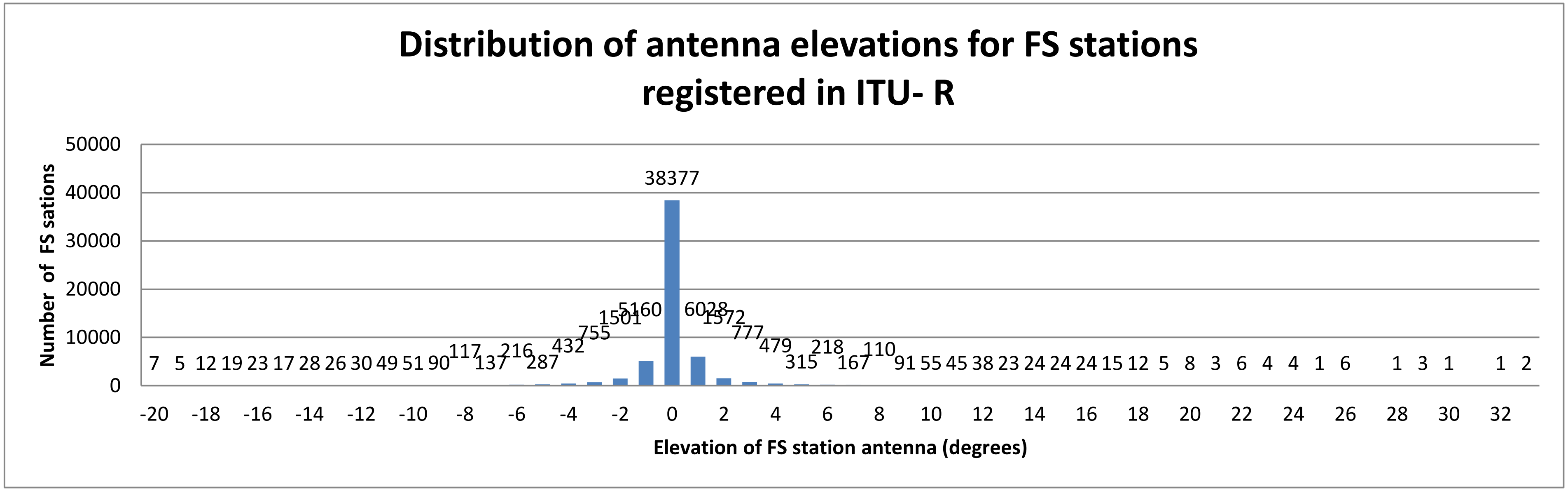
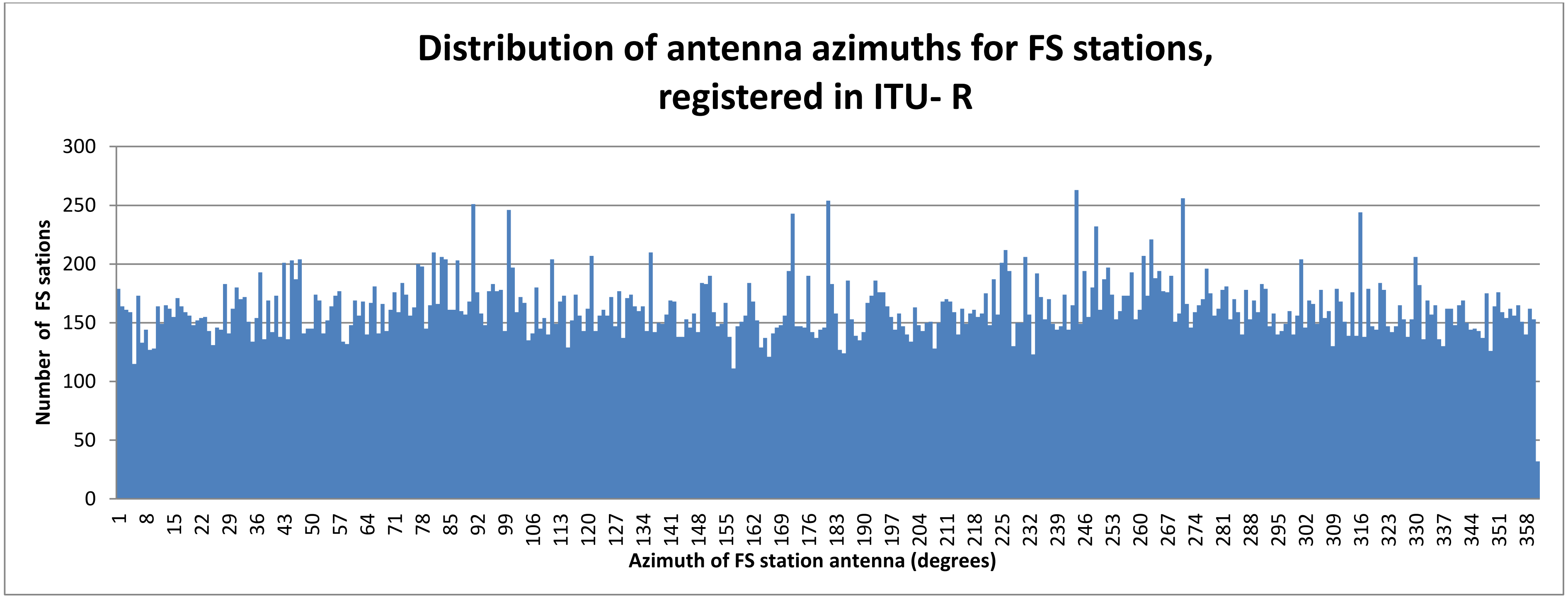

Distribution of antenna elevations for FS stations registered in ITU- R
Number of FS sations
Elevation of FS station antenna (degrees)
50000
40000
30000
20000
10000
0
38377
5160
1501
755
432
287
216
137
117
6028
1572
777
479
315
218
167
110
7 5 12 19 23 17 28 26 30 49 51 90
91 55 45 38 23 24 24 24 15 12 5 8 3 6 4 4 1 6 1 3 1 1 2
-20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32

FIGURE AA1-2


Distribution of antenna azimuths for FS stations, registered in ITU- R
Number of FS sations
Azimuth of FS station antenna (degrees)
300
250
200
150
100
50
0
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
148
155
162
169
176
183
190
197
204
211
218
225
232
239
246
253
260
267
274
281
288
295
302
309
316
323
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337
344
351
358

Annex 2

Sharing study of proposed MSS and incumbent space research and earth exploration-satellite services

Introduction

This Annex 2 describes the space research and Earth exploration-satellite services within the 22-26 GHz frequency bands, and discusses sharing feasibility from the proposed new MSS allocations in the 22-26 GHz range with these incumbent services. This contribution introduces the system characteristics of both SRS and MSS systems, interference study parameters, and study results of potential MSS allocations interference into SRS services.

For the purposes of this preliminary sharing analysis with space research and Earth exploration-satellite systems described in § 3, the technical parameters for MSS systems have been gathered from Attachment 1 to this Annex, although the information was incomplete, Recommendation ITU-R S.1328 and Report ITU-R M.2221. Table A2-1 provides an overview of the technical characteristics for MSS system user terminals and Table A2-2 provides an overview of MSS satellite parameters as used in this sharing analysis, as well as the source of the information.

TABLE A2-1

MSS user terminal technical characteristics used in SRS sharing studies in section 3

Environment type	Estimated user terminal distribution density (user/square km)	Source
Land – All types	8	Attachment 1 to this Annex
	User terminal 1	
Transmit centre frequency	22-26 GHz	Attachment 1 to this Annex
Transmit antenna diameter	1.8 m	Attachment 1 to this Annex
Transmit e.i.r.p. per carrier	45 dBW	Attachment 1 to this Annex
Transmit antenna pattern	Rec. ITU-R S.580	Rec. ITU-R S.1328
Transmit antenna minimum elevation angle	5-10 deg	Attachment 1 to this Annex
Receiver noise temperature	650 K	Attachment 1 to this Annex
Interference threshold	I/N > –12.2 dB	Report ITU-R M.2221

TABLE A2-2

MSS GSO satellite technical characteristics used in SRS sharing studies in section 3

Environment type	Estimated user terminal distribution density (user/square km)	Source
Transmit centre frequency	22-26 GHz	Attachment 1 to this Annex
Modulation type	QPSK	Attachment 1 to this Annex
Uplink occupied bandwidth per carrier	4.05 MHz	Attachment 1 to this Annex
Downlink occupied bandwidth per carrier	16.2 MHz	Attachment 1 to this Annex
Transmit antenna pattern	Rec. ITU-R S.672	Rec. ITU-R S.1328
Antenna coverage area	The coverage area of the satellite is divided into about 200 spot beams generated on demand.	Report ITU-R M.2221
Transmit e.i.r.p. per carrier	42.05 dBW	Attachment 1 to this Annex

1 SRS satellite system characteristics

The SRS technical system characteristics used in this analysis are indicated in Table A2-3 below.

TABLE A2-3

SRS technical characteristics

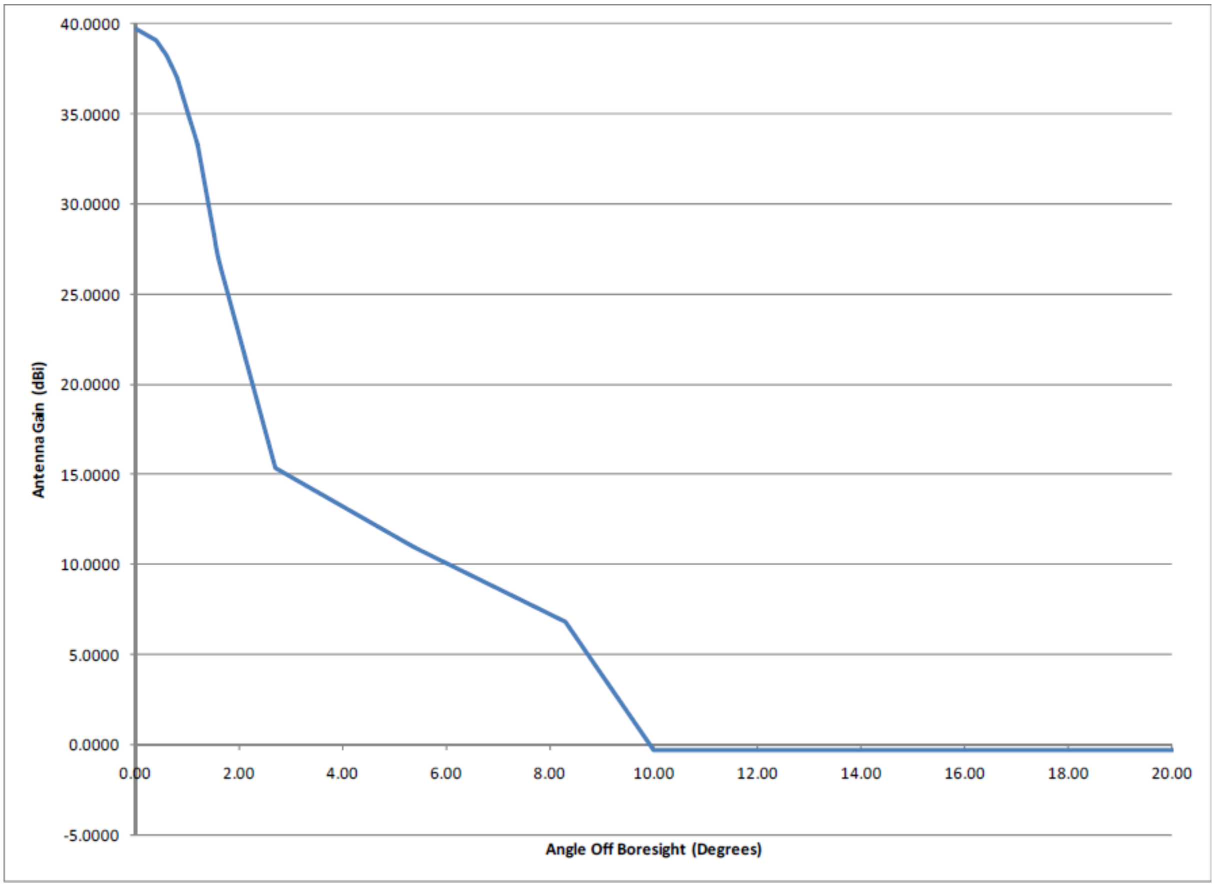
Interference threshold (Earth-space and space-Earth)	***I/N* > –6 dB for 0.1 % of the time (Rec. ITU-R SA.609)**
SRS GSO parameters	
Parameter	**Value**
Orbit type	GSO
Longitude	46 West
RF receive parameters	
Antenna pattern	ITU-R S.672-4
Antenna gain	57.9 dBi
Reference bandwidth	25 MHz
Noise temperature	572 K

SRS NGSO parameters	
Orbit type	NGSO
Height	350 km
Inclination	51.6 deg
RF receive parameters	
Antenna pattern	See Figure A2-1
Antenna gain	39.7 dBi
Reference bandwidth	25 MHz
Noise temperature (space-to-Earth, Earth-to-space)	570 k
Interference threshold	$I/N >$ –6 dB (Recommendation ITU-R SA.609)

SRS earth station parameters	
Goldstone SRS earth station	
Latitude	35.34
Longitude	–116.89
WSGT SRS earth station	
Latitude	35.51
Longitude	–106.61
Wallops SRS earth station	
Latitude	37.93
Longitude	–75.48
RF receive parameters	
Antenna pattern	Rec. ITU-R S.465
Antenna gain	49.7
Reference bandwidth	25 MHz
Noise temperature	190

FIGURE A2-1

SRS NGSO antenna pattern



2 Protection of space research service links from proposed MSS Earth-to-space and space-to-Earth links

For a complete set of sharing studies and compatibility between the MSS and the SRS services within the 22-26 GHz frequency band, several sharing scenarios including interference assessments of MSS GSO transmissions and high density MSS user terminal transmissions into SRS space-to-Earth, space-to-space, and Earth-to-space need to be studied. (See Annex 3 for SRS (space-to-space.)) Table A2-4 presents a listing of sharing scenarios to be considered. The specific scenarios are detailed in the appropriate sub-sections of § 3 of this Report. All sharing scenarios are assumed to be co-frequency and were conducted using a commercially available software.

TABLE A2-4

Sharing analysis considered for protection of space research service links from proposed MSS operations in 22-26 GHz

Scenario number	Description of sharing analysis	Protection Criteria used	Cross-reference to section 3 of this Report
Scenario 1	MSS ground station uplink into SRS GEO receiver (space-to-space) from SRS LEO transmitter in 25.25-26 GHz	I/N > –10 dB	Sections 3.14.2.3 and 3.15.2.4 (see also Annex 3)
Scenario 2	MSS ground station uplink into SRS ground station receiver (space-to-Earth) from SRS LEO transmitter in 25.5-26 GHz	I/N > –6 dB	Section 3.15.5
Scenario 3	MSS ground station uplink into SRS LEO receiver (space-to-space) from SRS GEO transmitter in 22.55-23.55 GHz	I/N > –10 dB	Sections 3.4.2.3 and 3.5.2.3 (see also Annex 3)
Scenario 4	MSS ground station uplink into SRS LEO receiver (Earth-to-space) from SRS earth station transmitter in 22.55-23.15 GHz	I/N > –6 dB	Section 3.4.2.4
Scenario 5	MSS ground station uplink into SRS GEO receiver (Earth-to-space) from SRS earth station transmitter in 22.55-23.15 GHz	I/N > –6 dB	Section 3.4.2.4
Scenario 6	MSS GEO satellite downlink into SRS LEO receiver (space-to-space) from SRS GEO transmitter in 22.55-23.55 GHz	I/N > –10 dB	Sections 3.4.2.3 and 3.5.2.3 (see also Annex 3)
Scenario 7	MSS GEO satellite downlink into SRS GEO receiver (space-to-space) from an SRS LEO transmitter in 25.25-26 GHz	I/N > –10 dB	Sections 3.14.2.3 and 3.15.2.4 (see also Annex 3)
Scenario 8	MSS GEO satellite downlink into SRS earth station (space-to-Earth) from SRS LEO transmitter in 25.5-26 GHz	I/N > –6 dB	Section 3.15.2.5
Scenario 9	MSS GEO satellite downlink into SRS earth station (space-to-Earth) from SRS GEO transmitter in 25.5-26 GHz	I/N > –6 dB	Section 3.15.2.5

3 Sharing considerations with the proposed MSS links with incumbent SRS links

To examine the feasibility of proposed MSS operations in the bands 22-26 GHz, interference assessments from incumbent SRS systems and the proposed MSS allocations should be considered. Table A2-5 presents a listing of sharing scenarios concerning interference between operations of incumbent SRS operations and proposed MSS Earth-to-space and space-to-Earth links. The specific scenarios are detailed in the appropriate sub-sections of § 3 of this Report. All sharing scenarios are assumed to be co-frequency and were conducted using a commercially available software.

TABLE A2-5

Sharing analysis considered for protection of proposed MSS operations from incumbent SRS operations in 22-26 GHz

Scenario number	Description of sharing analysis	Protection Criteria used	Cross-reference to section 3 of this Report
Scenario 10	SRS ground station uplink to SRS NGSO satellite into MSS user terminal receiver at 22.55-23.15 GHz	I/N > –12.2 dB	Section 3.4.2.4
Scenario 11	SRS ground station uplink to SRS GSO into MSS GEO satellite at 22.55-23.15 GHz	I/N > –12.2 dB	Section 3.4.2.4

4 Conclusions

This Annex 2 presents preliminary study results of sharing between SRS operations in the 22-26 GHz range with available characteristics of proposed MSS operations. Several interference scenarios were considered between proposed MSS user terminal Earth-to-space links and MSS GSO space-to-Earth links and incumbent space research service (SRS) space-Earth and Earth-space links used in space research operations in the bands 22-26 GHz. The assumptions and parameters used for proposed MSS operations in the bands 22-26 GHz considered in these sharing scenarios are conservative. If the full deployment scenario of 8 MSS user terminals per square km was considered in these sharing analyses, the resulting interference to the incumbent SRS service would be increased drastically compared to the results presented in this Report. For example, in the majority of sharing scenarios considered in this Report, where the distribution was modelled as 0.1 users per square kilometre, an approximation of total interference if 8 users/km^2 was modelled would be an additional 19 dB of interference.
For sharing scenarios with an even lower user terminal density, the interference levels would be higher than an additional 19 dB.

However, even with the conservative assumptions used in these analyses, the aggregate criterion given for protection of SRS services is exceeded by as much as 30 dB for Earth-space and space-Earth incumbent operational links of the space research service in 22-26 GHz. Further, the interference criterion for protection of MSS user terminals of I/N of –12.2 dB can be exceeded by over 40 dB by interference from the space research service.

Table A2-6 presents a summary of the aggregate interference found in each of the sharing scenarios considered in this Report and the results obtained from the analysis. In order to reduce computational complexity, the modelled scenarios were extremely conservative with respect to the MSS terminal distributions. If the scenarios were considered with a larger deployment of MSS terminals, the results presented below would be drastically increased. Further scenarios considering different MSS terminal deployments may be considered in further revisions of this Report.

TABLE A2-6

Sharing analysis considered for protection of space research service links from proposed MSS operations in 22-26 GHz

Scenario number	Description of sharing analysis	Aggregate *I*/*N* criteria	*I*/*N* value found in analysis	Aggregate *I*/*N* exceedance amount	MSS Distribution considered in analysis**
Scenario 1	MSS ground station uplink into SRS GEO receiver (space-to-space) from SRS LEO transmitter in 25.25-26 GHz	See Annex 3	See Annex 3	See Annex 3	See Annex 3
Scenario 2	MSS ground station uplink into SRS ground station receiver (space-to-Earth) from SRS LEO transmitter in 25.5-26 GHz	Io/No not to exceed -6 dB more than 0.1% time	17 dB	23 dB	0.1 users/km^2
Scenario 3	MSS ground station uplink into SRS LEO receiver (space-to-space) from SRS GEO transmitter in 22.55-23.55 GHz	See Annex 3	See Annex 3	See Annex 3	See Annex 3
Scenario 4	MSS ground station uplink into SRS LEO receiver (Earth-to-space) from SRS earth station transmitter in 22.55-23.15 GHz	Io/No not to exceed -6 dB more than 0.1% time	25.6 dB	31.6 dB	0.1 users/km^2
Scenario 5	MSS ground station uplink into SRS GEO receiver (Earth-to-space) from SRS earth station transmitter in 22.55-23.15 GHz	Io/No not to exceed -6 dB more than 0.1% time	22 dB*	28 dB	0.1 users/km^2
Scenario 6	MSS GEO satellite downlink into SRS LEO receiver (space-to-space) from SRS GEO transmitter in 22.55-23.55 GHz	See Annex 3	See Annex 3	See Annex 3	See Annex 3

TABLE A2-6 (*end*)

Scenario number	**Description of sharing analysis**	**Aggregate *I*/*N* criteria**	***I*/*N* value found in analysis**	**Aggregate *I*/*N* exceedance amount**	**MSS Distribution considered in analysis****
Scenario 7	MSS GEO satellite downlink into SRS GEO receiver (space-to-space) from an SRS LEO transmitter in 25.25-26 GHz	See Annex 3	See Annex 3	See Annex 3	See Annex 3
Scenario 8	MSS GEO satellite downlink into SRS earth station (space-to-Earth) from SRS LEO transmitter in 25.5-26 GHz	Io/No not to exceed -6 dB more than 0.1% time	4 dB	10 dB	0.0004 users/km^2
Scenario 9	MSS GEO satellite downlink into SRS earth station (space-to-Earth) from SRS GEO transmitter in 25.5-26 GHz	Io/No not to exceed -6 dB more than 0.1% time	24 dB*	30 dB	0.0004 users/km^2
Scenario 10	SRS ground station uplink to SRS NGSO satellite into MSS user terminal receiver at 22.55-23.15 GHz	Io/No not to exceed -12.2 dB	36 dB	48.2 dB	0.0004 users/km^2
Scenario 11	SRS ground station uplink to SRS GSO into MSS GEO satellite at 22.55-23.15 GHz	Io/No not to exceed -12.2 dB	2 dB*	14.4 dB	N/A

* Interference mitigation techniques could be considered in these scenarios.

** Attachment 1 to this Annex identifies the maximum MSS user terminal distribution as 8 users/km^2.

Based on the results presented in Table A2-6, the proposed MSS operations in the band 22-26 GHz are not compatible with incumbent SRS Earth-to-space, and SRS space-to-Earth systems.

Attachment 1
to Annex 2

Mobile-satellite service (MSS) technical characteristics

This Attachment contains technical parameter values for the proposed MSS system provided for ITU-R studies used in the studies addressed in Annex 2. The MSS system is composed of satellite network and earth stations user terminals. The technical parameters of each of these components are required to conduct studies to demonstrate compatibility with existing services. The following tables show the minimum required parameters needed to conduct the compatibility studies.

NOTE − Additional characteristics can be added as more information becomes available.

User terminal characteristics

The number of user terminal subscribers and user terminal densities are necessary to conduct the aggregate interference analysis and show the impact on incumbent services. Table AA2-1 shows the estimated numbers of users and user density for each environment type. The table may be expanded to add any other types as needed.

TABLE AA2-1

Summary of user terminal requirements

Environment type	Estimated worldwide number of user terminals	Estimated user terminal distribution density (users/square km)
Land – All types		8 (See note)
Land – Urban		
Land – SubUrban		
Land – Rural		
Maritime		
Aeronautical		
Add any other types as needed		
Add any other types as needed		

Note: This is the maximum user terminal density in the coverage area of the satellite.

Several types of terminals are foreseen with technical characteristics as shown in Table AA2-2. Additional types should be added as extra columns.

TABLE AA2-2

Terminal characteristics

Characteristics of user terminal	Units	User terminal type 1	User terminal type 2	Network Hub Terminal
Density of User Terminal - Land	Units/km^2			
Density of User Terminal - Maritime	Units/km^2			
Density of User Terminal - Aeronautical	Units/km^2			
Transmitter Center Frequency	(GHz)	24		24
Transmit Output Power per Carrier	(Watts)			
Transmit Antenna Diameter	(m)	1.8		9
Transmit Antenna Peak Gain	(dBi)			
Transmit effective isotropic radiated power e.i.r.p. per carrier	(dBW)	45.61		
Transmit Antenna Pattern Type (ITU-R Recommendation, Data (Angle versus Gain) or Plot)				
Transmit Antenna Minimum Elevation Angle	(degree)	5-10		5-10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)				
Transmit Losses	(dB)			
Transmit Emission Bandwidth at -3 dB	(MHz)	*		*
Transmit Emission Bandwidth at -20 dB	(MHz)	*		*
Transmit Emission Bandwidth at -40 dB	(MHz)	*		*
Transmit Emission Bandwidth at -60 dB	(MHz)	*		*
Receiver Center Frequency	(GHz)	24		24
Receive Antenna Diameter (If different from Transmit)	(m)	1.8		9
Receive Antenna Peak Gain (If different from Transmit)	(dBi)			
Receive Antenna Pattern Type (ITU-R Recommendation, Data (Angle versus Gain) or Plot) (If different from Transmit)				
Receive antenna polarization (RHC, LHC, VL, HL or offset linear)				
Receiver Noise Figure	(dB)			
Receiver Noise Temperature	(K)	650		450
Receiver IF Bandwidth at -3 dB	(MHz)	16.2		16.2
Receiver IF Bandwidth at -20 dB	(MHz)			
Receiver IF Bandwidth at -40 dB	(MHz)			
Receiver IF Bandwidth at -60 dB	(MHz)			
Receiver Losses	(dB)			
G/T	(dB/K)	9.27		27.23

***** Value to be calculated using Recommendation ITU-R SM.1541.

Satellite system characteristics

The MSS satellite system is based on a constellation of satellites and the use of either single or multiple spot beams to provide global coverage. The satellite system is a constellation of geostationary satellites with a multi-spot beam payload. The coverage area of the satellite is divided into about N-spot beams that could be generated on demand.

The modulation is assumed to be (Modulation Type), with channel bandwidth of (Bandwidth). Multiple access technique is assumed to be (TDMA/FDMA, etc.).

The required parameters, to carry out compatibility studies, are shown in the tables below for geostationary satellite systems.

TABLE AA2-3

GSO satellite system design characteristics (partially derived from Rec. ITU-R S.1328)

GSO	**UNITS**	**Forward Link**	**Return Link**
SATELLITE PARAMETERS			
Orbital position	(deg. East)		
CARRIER PARAMETERS			
Centre frequency of uplink band	(GHz)	24	24
Uplink polarization (RHC, LHC, VL, HL or offset linear)			
Centre frequency of downlink band	(GHz)		
Downlink polarization (RHC, LHC, VL, HL or offset linear)			
Modulation type (e.g. FM, BPSK, QPSK etc.)		QPSK	BPSK
Uplink occupied bandwidth per carrier	(MHz)	16.2	4.05
Downlink occupied bandwidth per carrier	(MHz)	16.2	4.05
SPACE STATION PARAMETERS			
Peak receive antenna gain	(dBi)		
Receive antenna gain in the direction of the transmit earth station	(dBi)		
Receive antenna gain pattern (e.g. Rec. ITU-R S.672, CR/58 data file, etc.)			
Satellite receive noise temperature	(K)		
Receiver IF -3 dB Bandwidth	(MHz)		
Transmit e.i.r.p. per carrier	(dBW)	42.05	40.75
Peak transmit antenna gain	(dBi)		
Transmit antenna gain in the direction of the receive earth station	(dBi)		
Transmit antenna gain pattern (e.g. Rec. ITU-R S.672, CR/58 data file, etc.)			
Satellite G/T	(dB/K)	4	4

Annex 3

System characteristics used in interference analyses between MSS GSO systems and Data Relay Satellite (DRS) space-to-space links in the inter-satellite service in the 22.55-23.55 GHz and 25.25-26 GHz bands

NOTE – As shown in Fig. A3-4, this study assumes an MSS system with spot beams covering land masses only. It is expected that typical MSS system would feature coverage over significant portions of the ocean areas for aeronautical and maritime users.

1 Introduction

This Annex contains the MSS system characteristics and DRS system characteristics used in the analyses for the space-to-space link scenarios in the Report in the 22.55-23.55 GHz (Scenarios 3 and 6) and 25.25-26 GHz bands (i.e. Scenarios 1 and 7), as shown in Table A3-1.

TABLE A3-1

MSS sharing analysis scenarios for Inter-Satellite Service DRS space-to-space operations in 22.55-23.55 GHz and 25.25-26 GHz bands

Scenario number	Description of sharing analysis	Protection Criteria used	Cross-reference to section 3 of this Report
Scenario 1	MSS user terminal uplink interference into DRS return link (SRS LEO-to-SRS GEO) in 25.25-26 GHz	Io/No not to exceed –10 dB more than 0.1% time	Section 3.14.2.3 and section 3.15.2.4
Scenario 3	MSS user terminal uplink interference into DRS forward link (SRS GEO-to-SRS LEO) in 22.55-23.55 GHz	Io/No not to exceed –10 dB more than 0.1% time	Section 3.4.2.3 and section 3.5.2.3
Scenario 6	MSS GEO satellite downlink interference into DRS forward link (SRS GEO-to-SRS LEO) in 22.55-23.55 GHz	Io/No not to exceed –10 dB more than 0.1% time	Section 3.4.2.3 and section 3.5.2.3
Scenario 7	MSS GEOSAT downlink interference into DRS return link (SRS LEO-to-SRS GEO) in 25.25-26 GHz	Io/No not to exceed –10 dB more than 0.1% time	Section 3.14.2.3 and section 3.15.2.4

2 MSS system characteristics

The GSO MSS system characteristics assumed in the study are those found in § 2 of this Report. Specifically, the GSO MSS user terminal characteristics are taken from Table 2.1-1 of this Report and GSO MSS satellite characteristics are taken from Table 2.2-1. Pictorials of the relevant MSS system parameters used in the interference analysis are shown in Figs A3-1 and A3-2.

FIGURE A3-1

MSS forward link parameters

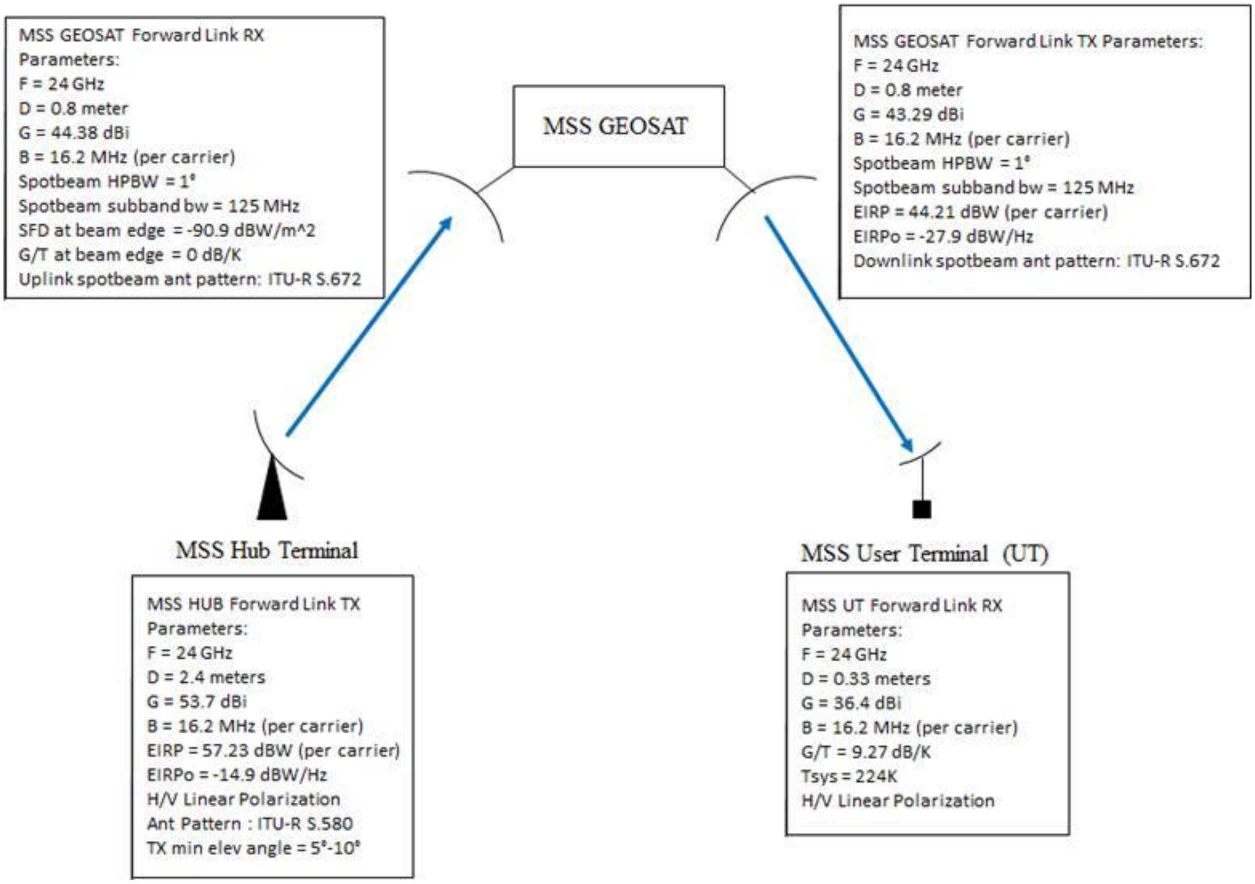
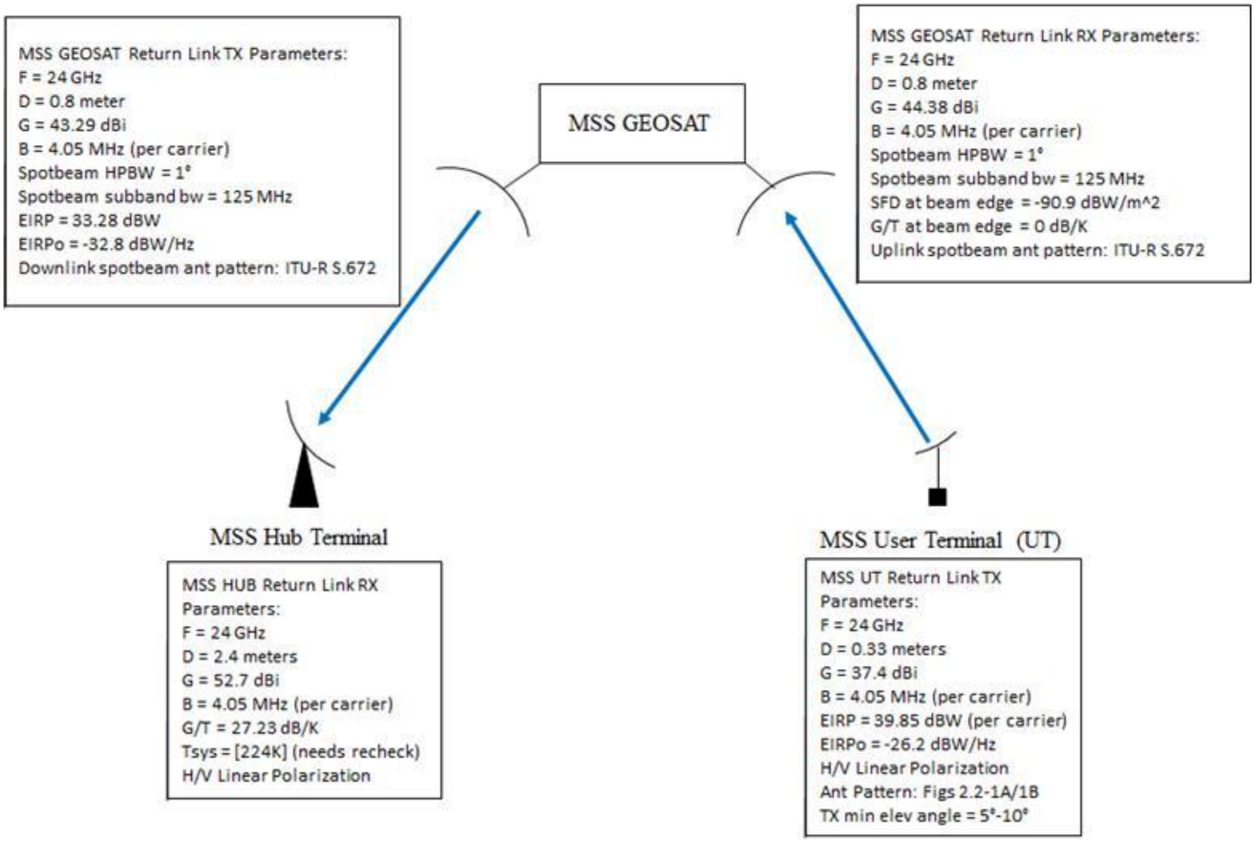


FIGURE A3-2

MSS return link parameters

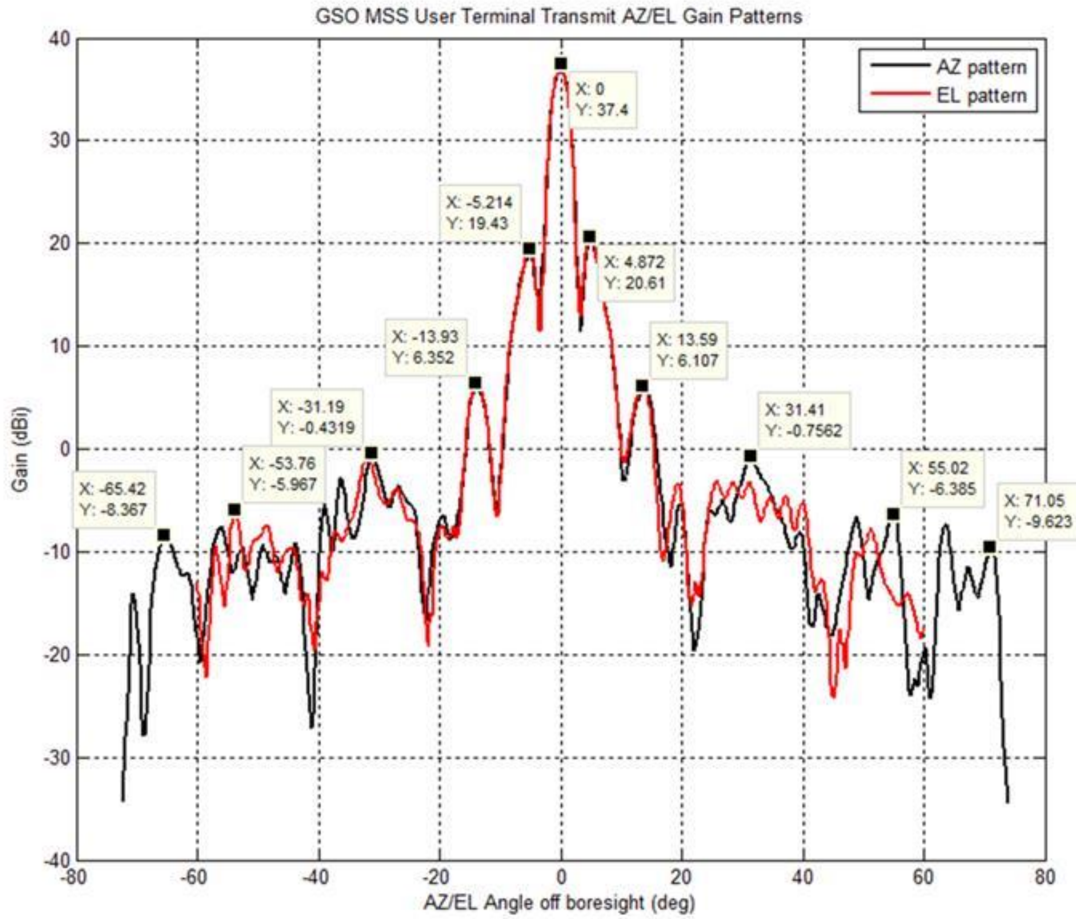


It should also be noted that to simplify the analyses, a frequency of 24 GHz is assumed for both the forward and return links. Obviously, they would not be the same in a real system, but the analysis results will not be significantly dependent on the specific MSS uplink/downlink frequencies over the 22-26 GHz range.

The GSO MSS user terminal transmit azimuth and elevation patterns are given in Figs 2.1-1A and 2.1-1B of this Report, respectively. These patterns are for a 33 cm diameter antenna with peak gain of 37.4 dBi. Figure A3-3 shows the two patterns overlaid on each other. Since the two patterns are very similar, this analysis assumes the antenna beam is circularly symmetric with gain calculated using the azimuth pattern (black curve) since it is defined over a wider range (about ±72°) than the elevation pattern (red curve) which is defined over a narrower range (about ±60°). For off-axis angles greater than 72°, the user terminal antenna gain is assumed to be a constant –35 dBi.

FIGURE A3-3

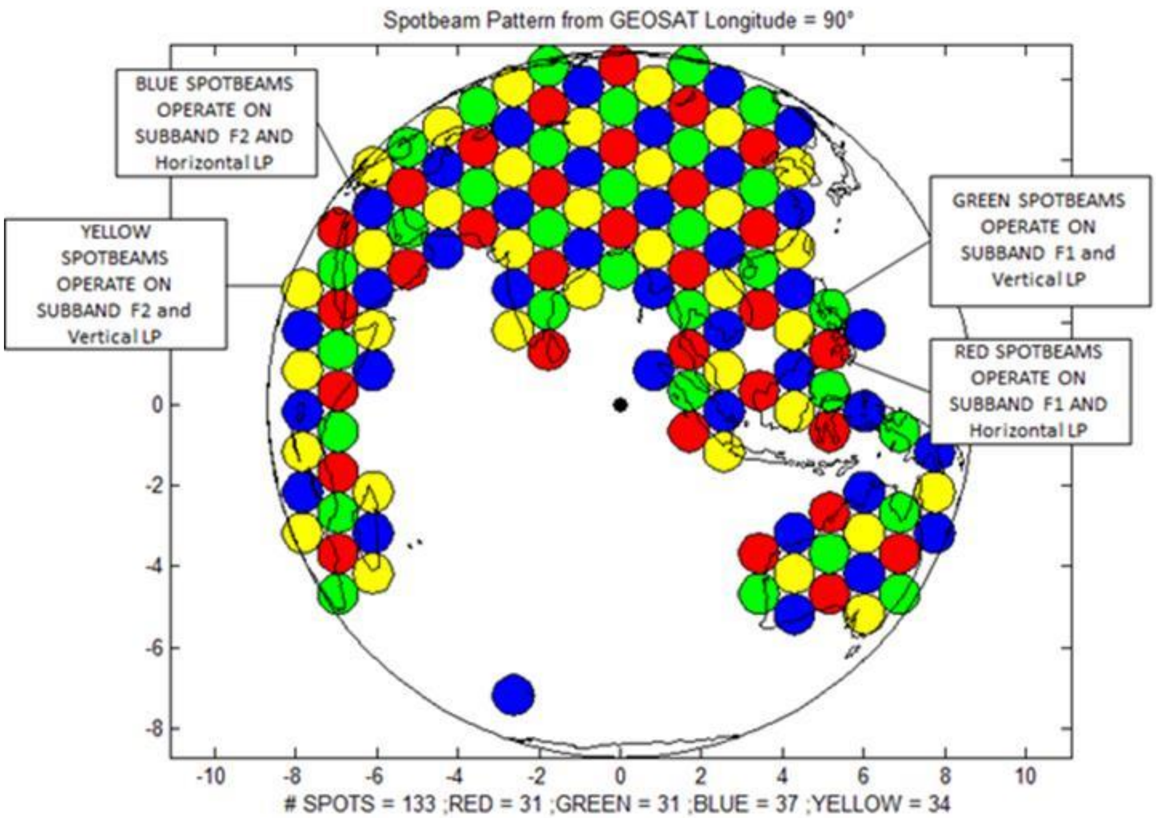
GSO MSS user terminal transmit azimuth/elevation gain patterns



It should be noted that § 2 of this Report does not specify a GSO MSS spot beam antenna pattern or frequency re-use scheme. (Table 2.2-1 of this Report only specifies a spot beam beamwidth of 1 degree on the forward link.) In order to calculate the aggregate interference from a GSO MSS satellite generating a large number of downlink/uplink spot beams, it is necessary to make assumptions on the number of spot beams and the frequency reuse plan of the spot beam pattern. Based on a representative MSS system in Report ITU-R M.2221 - Feasibility of MSS operations in certain frequency bands (see § 3.2.1 of Report ITU-R M.2221), this study assumes a "four-color" frequency/polarization reuse scheme with 1 degree spot beams as illustrated in Fig. A3-4 for both the uplink and downlink coverage.

FIGURE A3-4

Four-colour frequency/polarization reuse scheme for GSO MSS satellites



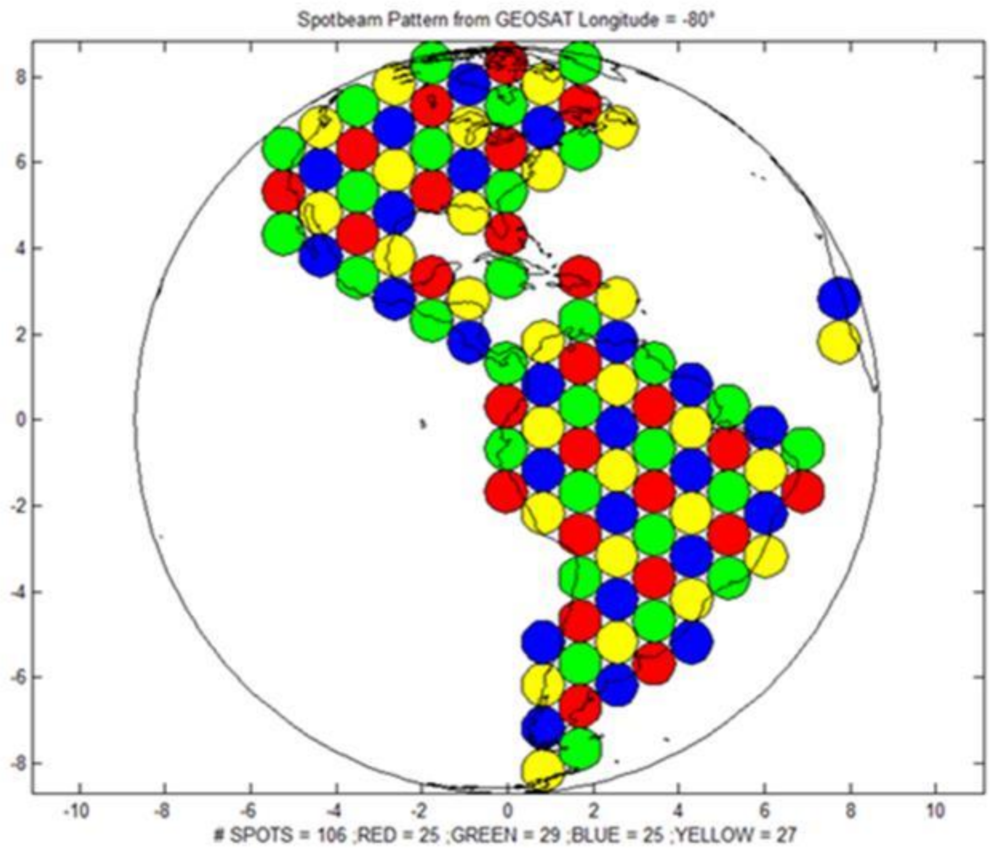
The F1 and F2 spot beam sub-bands are each assumed to be 125 MHz wide based on total uplink/downlink band allocation of 250 MHz per MSS satellite. This 125 MHz sub-band bandwidth along with the victim receiver bandwidth will determine which "colour" spot beams are interfering spot beams in the particular scenario. For example, a victim receiver bandwidth less than 125 MHz wide will receive interference only from the F1 (red/green) beams or the F2 (blue/yellow) beams. Within a particular 125 MHz spot beam, the uplink/downlink multiple access scheme is assumed to be FDMA. The example spot beam pattern in Fig. A3-4 is for an MSS satellite located at 90°E longitude consisting of a total of 133 (1 degree diameter HPBW) spot beams. In the study, the number of spot beams is assumed to vary with the GSO MSS satellite longitude location and is the number of 1° beams needed to cover all visible land mass above a 10 degrees elevation angle as viewed from the particular MSS satellite longitude. For example, Fig. A3-5 shows a different spot beam pattern for an MSS satellite located at 80°W longitude.

For use in the simulations, spot beam patterns with the 4-color scheme illustrated above were pre-calculated for MSS satellite longitudes over the entire 360° of orbital arc in 1 degrees increments.

Also, it is assumed that MSS satellites require a minimum of 5 degrees orbit spacing between them to avoid mutual interference between overlapping spot beams.

FIGURE A3-5

Four-colour spot beam pattern for GSO MSS satellite at 80°W longitude



3 DRS system characteristics for Scenarios 1 and 7 (25.25-26 GHz)

Scenarios 1 and 7 involve interference from the MSS to the DRS return link which is the link from the user satellite to the DRS satellite in GSO. Therefore, for these two scenarios the victim receiver is onboard the GSO DRS. The relevant DRS return link receiver parameters are listed in Table A3-2. Simulations for these scenarios assumed a 10-day simulation period and 1-second time step.

TABLE A3-2

DRS return link receiver parameters used in Scenarios 1 and 7

DRS Parameter	Value(s)	Comment
DRS Satellite Longitude Locations (in GEO)	174°W (TDRS J) ; 62°W ; 41°W (TDRS I) ; 47°E ; 89°E (TDRS H)	These locations are from ITU-R Rec SA.1276-3 which lists a total of 32 DRS GEO orbital locations for DRS operating in 25.25-27.5 GHz
Receive Antenna Gain	57.8 dBi	4.6 meter parabolic mesh
Receive Antenna HPBW	0.2°	
Receive Antenna Gain Pattern	ITU-R Rec S.672-4 with first sidelobe level at -25 dB	
Receive System Noise Temp	871 K	No = -199.2 dBW/Hz
Receive Antenna Tracking	Antenna assumed to be tracking a LEO in a 400 km altitude/51.6° inclined orbit	
Receive passband bandwidth	300-600 MHz	Note since the spotbeam subband bandwidth is 125 MHz, this means spotbeams of all 4 colors are interfering beams
Interference Protection Criterion	ITU-R SA.1155: aggregate interference at rx antenna output not to exceed -178 dBW/kHz (-208 dBW/Hz) more than 0.1% of the time	Equivalent Io/No threshold for DRS rx (SNT = 871K) is -8.8 dB

4 DRS system characteristics for Scenarios 3 and 6 (22.55-23.55 GHz)

Scenarios 3 and 6 involve interference from the MSS to the DRS forward link which is the link from the DRS satellite in GSO to the user satellite. Therefore, for these two scenarios, the victim receiver is onboard the user satellite. The relevant DRS forward link receiver parameters are listed in Table A3-3. Simulations for these scenarios assumed a 10-day simulation period and 1-second time step.

TABLE A3-3

DRS forward link receiver parameters used in Scenarios 3 and 6

USERSAT Parameter	Value(s)	Comment
Orbit	Circular 400 km altitude; 51.6° inclination	
DRS Satellite Longitude Locations (in GEO)	174°W (TDRS J) ; 62°W ; 41°W (TDRS I) ; 47°E ; 89°E (TDRS H)	These locations are from ITU-R Rec SA.1276-3 which lists a total of 32 DRS GEO orbital locations for DRS operating in 25.25-27.5 GHz
Receive Antenna Gain	39.8 dBi	0.5 meter parabolic
Receive Antenna HPBW	1.75°	
Receive Antenna Gain Pattern	ITU-R Rec S.672-4 with first sidelobe level at -25 dB	
Receive System Noise Temp	RX1: 290 K RX2: 1824 K (NASA SCaN Testbed)	RX1: No = -204 dBW/Hz RX2: No = -196 dBW/Hz
Receive Antenna Tracking	Antenna is on LEOSAT assumed to be tracking a DRS (in GEO) at one of the above (5) DRS longitude locations	
Receive passband bandwidth	50 MHz	Note since the spotbeam subband bandwidth is 125 MHz, this means only the F1 (red/green) or F2 (blue/yellow) beams are interfering. Here we assume the F1 beams.
Interference Protection Criterion	ITU-R SA.1155: aggregate interference at rx antenna output not to exceed -178 dBW/kHz (-208 dBW/Hz) more than 0.1% of the time	Equivalent Io/No threshold for USERSAT rx: RX1 : Io/No = -4 dB RX2 : Io/No = -12 dB

Annex 4

Calculation of MSS GSO satellite spot beam e.i.r.p. values under rain loss conditions in the analysis of MSS GSO satellite downlink interference into DRS forward links in 22.55-23.55 GHz band (Scenario 6)

Note: As shown in Figure A3-4, this study assumes an MSS system with spot beams covering land masses only. It is expected that typical MSS system would feature coverage over significant portions of the ocean areas for aeronautical and maritime users.

Section 3.4.2.3.1.2 of the main report considers analysis of MSS GSO satellite downlink interference into the data relay satellite (DRS) forward link in the 22.55-23.55 GHz band (Scenario 6). As noted in § 3.4.2.3.1.2.1, additional analysis was performed for this scenario to examine the potential impact to the DRS forward link of higher MSS GEOSAT downlink spotbeam e.i.r.p. when used to compensate for downlink rain fades. There could be other methods used to deal with rain attenuation such as over-designing the user terminal antenna or receiver LNA to account for worst case rain attenuation, or perhaps just allowing the service to be degraded or interrupted during periods of heavy rain. This analysis, however, assumes that traditional downlink power control is used to maintain a certain link availability. Maintaining a link availability of 99.9% during periods of rain for an MSS system operating in this frequency range may be atypical, but the analysis is intended to be a parametric analysis which is why results are also given for lower link availabilities of 99% and 99.5% so as not to presume the performance objectives of potential MSS operators. The results in Table 3.4-5 for the 99.5% and 99.9% link availabilities are shown in order to provide estimates of the required orbital separation if an MSS system were to operate at these higher availabilities.

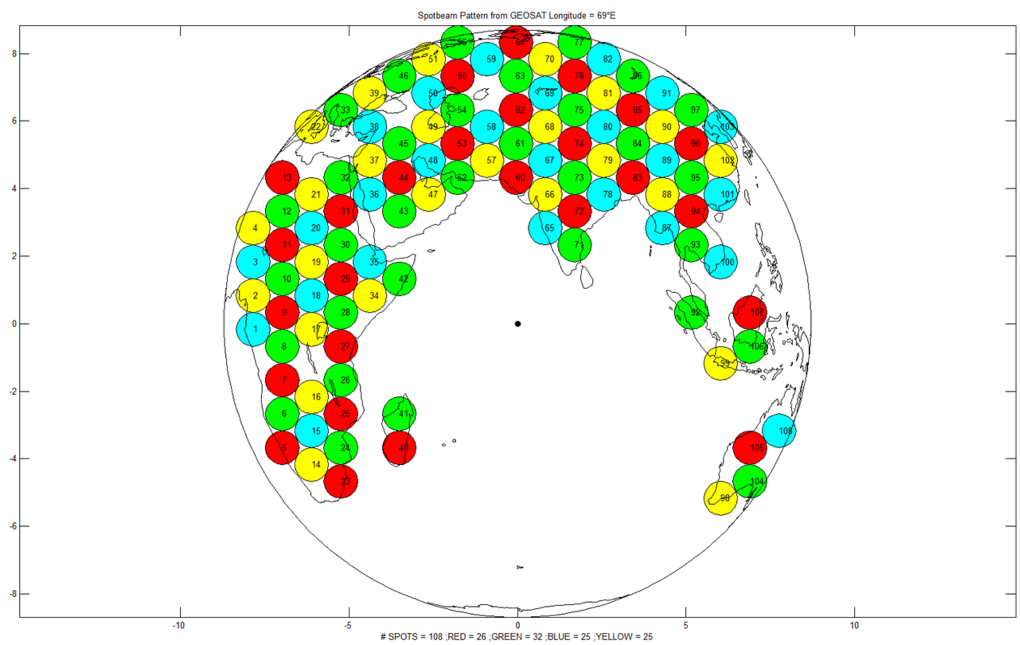
The purpose of this Annex is to describe how the MSS GSO downlink spotbeam e.i.r.p. values are adjusted from the baseline value when downlink rain losses are assumed in the analysis. The baseline spotbeam e.i.r.p. spectral density on the MSS forward downlink (MSS GEOSAT-to-MSS user terminal) is taken to be -27.9 dBW/Hz based on a downlink channel e.i.r.p. of 44.21 dBW and channel bandwidth of 16.2 MHz (from Table 2.2-1). The associated baseline rain + atmospheric propagation loss on the MSS forward downlink is 1.14 dB as shown in Table 2.5-1. This value is based on the Recommendation ITU-R P.618-10 rain model and a 99% link availability.

To calculate the adjusted spotbeam e.i.r.p.s for different link availabilities, rain losses (at 99%, 99.5%, and 99.9% availabily) and atmospheric losses were first calculated for each forward downlink spotbeam of each MSS GEOSAT at 1° orbit increments over the entire 360° orbital arc using ITU-R Recommendations P.618-10 (for rain loss) and P.676-10 (for clear air atmospheric loss). As described in Annex 3, each MSS GEOSAT has its own spotbeam pattern based on its longitude location (i.e. the number of beams and beam pattern is such as to cover visible land mass above a 10° elevation angle as viewed from the particular satellite longitude). Knowing the aimpoint latitude and longitude of each spotbeam, the elevation angle and rain region of each spotbeam aimpoint can be determined and then used in ITU-R Recommendations P.618-10 and P.676-10 to compute the corresponding rain and atmospheric losses. For each spotbeam of each MSS GEOSAT, the rain + atmospheric loss was then compared to the baseline value of 1.14 dB and the difference used to adjust the beam e.i.r.p.o relative to the baseline e.i.r.p.o of –27.9 dBW/Hz.

As an example, Fig. A4-1 shows the spotbeam pattern for an MSS GEOSAT at 69°E longitude. The pattern consists of 108 beams (each 1° HPBW diameter) using the 4-color frequency/polarization reuse scheme as described in Annex 3. The pattern consists of 26 red beams; 32 green beams; 25 blue beams; and 25 yellow beams. In this scenario, the victim receiver bandwidth (victim receiver is on the DRS user satellite) is less than the MSS spotbeam subband bandwidth (assumed to be 125 MHz), so that only the subband F1 (red/green) or F2 (blue/yellow) beams are interfering. The F1 (red/green) beams were assumed to be the interfering beams in the analysis.

FIGURE A4-1

Spotbeam Pattern for MSS GEOSAT at 69°E (total of 108 beams)



Keeping with this example, Table A4-1 shows the aimpoint latitude/longitude, atmospheric loss, and rain loss (99.9% availability) for each of the spotbeams in Fig. A4-1.

TABLE A4-1

Spotbeam aimpoints and rain/atmospheric losses for the Figure A4-1 pattern

BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)	BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)	BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)
1	-1.05	12.52	0.95	25.66	41	-15.58	47.71	0.48	20.95	81	45.98	91.52	0.76	2.60
2	5.12	12.06	0.97	20.96	42	7.65	48.45	0.45	11.91	82	58.45	100.68	1.31	6.56
3	11.43	10.03	1.08	19.95	43	19.67	47.11	0.49	4.71	83	26.18	91.66	0.53	18.50
4	18.10	5.45	1.42	18.12	44	26.20	45.76	0.53	5.58	84	33.37	93.76	0.60	1.58
5	-23.23	15.24	0.97	9.81	45	33.40	43.59	0.61	5.16	85	41.69	97.44	0.74	2.38
6	-16.46	19.25	0.80	18.66	46	52.53	30.99	1.17	9.07	86	52.42	105.82	1.14	7.11
7	-10.13	21.42	0.72	20.46	47	22.72	52.39	0.49	5.32	87	16.69	95.78	0.51	24.91
8	-4.03	22.46	0.69	21.96	48	29.47	51.20	0.53	6.40	88	23.06	97.21	0.55	13.95
9	1.98	22.60	0.69	22.86	49	37.02	49.27	0.61	5.41	89	29.99	99.50	0.61	3.60
10	8.04	21.88	0.71	16.57	50	46.02	45.70	0.77	5.59	90	37.84	103.42	0.74	3.78
11	14.27	20.14	0.77	10.28	51	58.57	36.04	1.35	9.29	91	47.56	111.72	1.11	7.55
12	20.86	16.89	0.89	1.86	52	25.89	57.65	0.49	7.82	92	1.92	100.32	0.51	26.74
13	28.15	10.62	1.24	4.17	53	32.92	56.69	0.54	2.49	93	13.78	101.55	0.54	23.65
14	-26.18	23.61	0.78	13.71	54	40.97	55.09	0.63	3.60	94	20.05	103.06	0.58	16.18
15	-19.34	26.99	0.67	14.64	55	50.97	51.87	0.83	5.75	95	26.79	105.54	0.65	10.28
16	-13.00	28.96	0.61	17.50	56	67.39	38.75	2.17	8.43	96	34.32	109.78	0.79	9.79
17	-1.00	30.45	0.58	18.00	57	29.22	63.03	0.50	2.41	97	43.42	118.60	1.20	10.11
18	4.91	30.25	0.58	18.44	58	36.65	62.43	0.56	3.59	98	-33.81	119.48	1.01	9.03
19	10.91	29.41	0.60	13.69	59	57.03	58.86	0.99	8.36	99	-6.92	107.30	0.58	23.77
20	17.15	27.78	0.65	10.02	60	25.78	68.75	0.47	12.79	100	10.90	107.91	0.59	25.03
21	23.78	24.97	0.73	0.18	61	32.77	68.73	0.52	5.75	101	23.74	112.20	0.72	18.75
22	40.04	8.68	1.71	14.22	62	40.74	68.69	0.60	5.81	102	31.06	116.97	0.89	16.40
23	-29.28	30.52	0.70	10.96	63	50.54	68.63	0.77	5.43	103	39.85	127.43	1.55	17.26
24	-22.31	33.56	0.61	16.10	64	65.64	68.40	1.48	7.27	104	-30.79	129.36	1.41	12.98
25	-15.89	35.40	0.56	17.13	65	16.34	73.87	0.44	21.73	105	-23.17	121.65	0.93	14.49
26	-9.81	36.49	0.53	19.75	66	22.54	74.10	0.46	15.86	106	-4.02	114.75	0.68	30.99
27	-3.91	37.03	0.52	16.63	67	29.21	74.44	0.50	15.86	107	1.98	114.61	0.67	26.66
28	1.92	37.11	0.51	12.16	68	36.64	74.99	0.56	0.49	108	-20.43	133.31	1.52	31.40
29	7.79	36.73	0.52	13.10	69	45.38	75.96	0.68	4.11					
30	13.79	35.84	0.55	10.58	70	57.01	78.23	0.98	7.55					
31	20.08	34.29	0.59	1.84	71	13.39	78.88	0.43	20.55					
32	26.83	31.74	0.66	0.14	72	19.44	79.25	0.45	16.24					
33	43.55	18.03	1.26	11.29	73	25.88	79.83	0.49	18.92					
34	4.80	43.01	0.48	18.73	74	32.91	80.74	0.54	1.24					
35	10.65	42.54	0.49	16.97	75	40.95	82.27	0.63	2.24					
36	23.09	40.19	0.55	5.35	76	50.93	85.31	0.83	5.61					
37	30.02	37.83	0.62	2.91	77	67.20	97.47	2.07	7.07					
38	37.89	33.77	0.75	5.33	78	22.70	85.09	0.48	19.20					
39	47.68	25.06	1.15	9.27	79	29.45	86.23	0.53	3.48					
40	-21.83	46.72	0.51	15.58	80	36.99	88.10	0.60	0.76					

The next step is to sort the beams in descending order according to the rain loss so that the beams with the highest rain loss appear at the top of the list. This is shown in Table A4-2.

TABLE A4-2

Spotbeams sorted according to rain loss

BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)	BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)	BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)
108	-20.43	133.31	1.52	31.40	15	-19.34	26.99	0.67	14.64	63	50.54	68.63	0.77	5.43
106	-4.02	114.75	0.68	30.99	105	-23.17	121.65	0.93	14.49	49	37.02	49.27	0.61	5.41
92	1.92	100.32	0.51	26.74	22	40.04	8.68	1.71	14.22	36	23.09	40.19	0.55	5.35
107	1.98	114.61	0.67	26.66	88	23.06	97.21	0.55	13.95	38	37.89	33.77	0.75	5.33
1	-1.05	12.52	0.95	25.66	14	-26.18	23.61	0.78	13.71	47	22.72	52.39	0.49	5.32
100	10.90	107.91	0.59	25.03	19	10.91	29.41	0.60	13.69	45	33.40	43.59	0.61	5.16
87	16.69	95.78	0.51	24.91	29	7.79	36.73	0.52	13.10	43	19.67	47.11	0.49	4.71
99	-6.92	107.30	0.58	23.77	104	-30.79	129.36	1.41	12.98	13	28.15	10.62	1.24	4.17
93	13.78	101.55	0.54	23.65	60	25.78	68.75	0.47	12.79	69	45.38	75.96	0.68	4.11
9	1.98	22.60	0.69	22.86	28	1.92	37.11	0.51	12.16	90	37.84	103.42	0.74	3.78
8	-4.03	22.46	0.69	21.96	42	7.65	48.45	0.45	11.91	54	40.97	55.09	0.63	3.60
65	16.34	73.87	0.44	21.73	33	43.55	18.03	1.26	11.29	89	29.99	99.50	0.61	3.60
2	5.12	12.06	0.97	20.96	23	-29.28	30.52	0.70	10.96	58	36.65	62.43	0.56	3.59
41	-15.58	47.71	0.48	20.95	30	13.79	35.84	0.55	10.58	79	29.45	86.23	0.53	3.48
71	13.39	78.88	0.43	20.55	95	26.79	105.54	0.65	10.28	37	30.02	37.83	0.62	2.91
7	-10.13	21.42	0.72	20.46	11	14.27	20.14	0.77	10.28	81	45.98	91.52	0.76	2.60
3	11.43	10.03	1.08	19.95	97	43.42	118.60	1.20	10.11	53	32.92	56.69	0.54	2.49
26	-9.81	36.49	0.53	19.75	20	17.15	27.78	0.65	10.02	57	29.22	63.03	0.50	2.41
78	22.70	85.09	0.48	19.20	5	-23.23	15.24	0.97	9.81	85	41.69	97.44	0.74	2.38
73	25.88	79.83	0.49	18.92	96	34.32	109.78	0.79	9.79	75	40.95	82.27	0.63	2.24
101	23.74	112.20	0.72	18.75	51	58.57	36.04	1.35	9.29	12	20.86	16.89	0.89	1.86
34	4.80	43.01	0.48	18.73	39	47.68	25.06	1.15	9.27	31	20.08	34.29	0.59	1.84
6	-16.46	19.25	0.80	18.66	46	52.53	30.99	1.17	9.07	84	33.37	93.76	0.60	1.58
83	26.18	91.66	0.53	18.50	98	-33.81	119.48	1.01	9.03	74	32.91	80.74	0.54	1.24
18	4.91	30.25	0.58	18.44	56	67.39	38.75	2.17	8.43	80	36.99	88.10	0.60	0.76
4	18.10	5.45	1.42	18.12	59	57.03	58.86	0.99	8.36	68	36.64	74.99	0.56	0.49
17	-1.00	30.45	0.58	18.00	52	25.89	57.65	0.49	7.82	21	23.78	24.97	0.73	0.18
16	-13.00	28.96	0.61	17.50	70	57.01	78.23	0.98	7.55	32	26.83	31.74	0.66	0.14
103	39.85	127.43	1.55	17.26	91	47.56	111.72	1.11	7.55					
25	-15.89	35.40	0.56	17.13	64	65.64	68.40	1.48	7.27					
35	10.65	42.54	0.49	16.97	86	52.42	105.82	1.14	7.11					
27	-3.91	37.03	0.52	16.63	77	67.20	97.47	2.07	7.07					
10	8.04	21.88	0.71	16.57	82	58.45	100.68	1.31	6.56					
102	31.06	116.97	0.89	16.40	48	29.47	51.20	0.53	6.40					
72	19.44	79.25	0.45	16.24	62	40.74	68.69	0.60	5.81					
94	20.05	103.06	0.58	16.18	55	50.97	51.87	0.83	5.75					
24	-22.31	33.56	0.61	16.10	61	32.77	68.73	0.52	5.75					
66	22.54	74.10	0.46	15.86	76	50.93	85.31	0.83	5.61					
67	29.21	74.44	0.50	15.86	50	46.02	45.70	0.77	5.59					
40	-21.83	46.72	0.51	15.58	44	26.20	45.76	0.53	5.58					

The next step is to specify the percentage of spotbeams assumed to be under rain and for those spotbeams not under rain, reset the rain loss back to zero. For example, if it is assumed that 10% of the spotbeams are under rain, then for this spotbeam pattern of 108 beams, this results in 11 beams under rain (after rounding to nearest integer) and the remaining 97 beams under clear sky (i.e. just atmospheric loss with zero rain loss). For the 11 beams under rain, we choose the beams which have the highest rain loss (i.e. the first 11 beams in Table A4-2). As noted above, however, in this case where the DRS victim receive bandwidth is less than the beam subband bandwidth, only the F1 subband (red/green) beams are considered to be interfering beams so that of the 11 beams under rain, only the red/green beams are considered to be under rain for this MSS GEOSAT (i.e. beams 106, 92, 107, 93, 9, and 8). The next step is to calculate the total rain + atmospheric loss for each beam and the delta/difference with respect to the baseline loss of 1.14 dB. Then apply the delta to the baseline e.i.r.p. o of –27.9 dBW/Hz to get the adjusted beam e.i.r.p.o. The result is shown in Table A4-3. Only the red/green beams in Table A4-3 are interfering.

TABLE A4-3

Adjusted spotbeam e.i.r.p. Values (for MSS GEOSAT pattern at 69°E)

BEAM #	LAT	LON	ATMO LOSS (dB)	RAIN LOSS (dB) (99.9%)	TOTAL PROP LOSS (dB)	DELTA wrt baseline loss of 1.14 dB)	EIRPo (dBW/Hz) [Baseline EIRPo + DELTA]
1	-1.05	12.52	0.95	25.66	26.61	25.47	-2.43
2	5.12	12.06	0.97	0.00	0.97	-0.17	-28.07
3	11.43	10.03	1.08	0.00	1.08	-0.06	-27.96
4	18.10	5.45	1.42	0.00	1.42	0.28	-27.62
5	-23.23	15.24	0.97	0.00	0.97	-0.17	-28.07
6	-16.46	19.25	0.80	0.00	0.80	-0.34	-28.24
7	-10.13	21.42	0.72	0.00	0.72	-0.42	-28.32
8	-4.03	22.46	0.69	21.96	22.65	21.51	-6.39
9	1.98	22.60	0.69	22.86	23.55	22.41	-5.49
10	8.04	21.88	0.71	0.00	0.71	-0.43	-28.33
11	14.27	20.14	0.77	0.00	0.77	-0.37	-28.27
12	20.86	16.89	0.89	0.00	0.89	-0.25	-28.15
13	28.15	10.62	1.24	0.00	1.24	0.10	-27.80
14	-26.18	23.61	0.78	0.00	0.78	-0.36	-28.26
15	-19.34	26.99	0.67	0.00	0.67	-0.47	-28.37
16	-13.00	28.96	0.61	0.00	0.61	-0.53	-28.43
17	-1.00	30.45	0.58	0.00	0.58	-0.56	-28.46
18	4.91	30.25	0.58	0.00	0.58	-0.56	-28.46
19	10.91	29.41	0.60	0.00	0.60	-0.54	-28.44
20	17.15	27.78	0.65	0.00	0.65	-0.49	-28.39
21	23.78	24.97	0.73	0.00	0.73	-0.41	-28.31
22	40.04	8.68	1.71	0.00	1.71	0.57	-27.33
23	-29.28	30.52	0.70	0.00	0.70	-0.44	-28.34
24	-22.31	33.56	0.61	0.00	0.61	-0.53	-28.43
25	-15.89	35.40	0.56	0.00	0.56	-0.58	-28.48
26	-9.81	36.49	0.53	0.00	0.53	-0.61	-28.51
27	-3.91	37.03	0.52	0.00	0.52	-0.62	-28.52
28	1.92	37.11	0.51	0.00	0.51	-0.63	-28.53
29	7.79	36.73	0.52	0.00	0.52	-0.62	-28.52
30	13.79	35.84	0.55	0.00	0.55	-0.59	-28.49
31	20.08	34.29	0.59	0.00	0.59	-0.55	-28.45
32	26.83	31.74	0.66	0.00	0.66	-0.48	-28.38
33	43.55	18.03	1.26	0.00	1.26	0.12	-27.78
34	4.80	43.01	0.48	0.00	0.48	-0.66	-28.56
35	10.65	42.54	0.49	0.00	0.49	-0.65	-28.55
36	23.09	40.19	0.55	0.00	0.55	-0.59	-28.49
37	30.02	37.83	0.62	0.00	0.62	-0.52	-28.42
38	37.89	33.77	0.75	0.00	0.75	-0.39	-28.29
39	47.68	25.06	1.15	0.00	1.15	0.01	-27.89
40	-21.83	46.72	0.51	0.00	0.51	-0.63	-28.53
41	-15.58	47.71	0.48	0.00	0.48	-0.66	-28.56
42	7.65	48.45	0.45	0.00	0.45	-0.69	-28.59
43	19.67	47.11	0.49	0.00	0.49	-0.65	-28.55
44	26.20	45.76	0.53	0.00	0.53	-0.61	-28.51
45	33.40	43.59	0.61	0.00	0.61	-0.53	-28.43
46	52.53	30.99	1.17	0.00	1.17	0.03	-27.87
47	22.72	52.39	0.49	0.00	0.49	-0.65	-28.55
48	29.47	51.20	0.53	0.00	0.53	-0.61	-28.51
49	37.02	49.27	0.61	0.00	0.61	-0.53	-28.43
50	46.02	45.70	0.77	0.00	0.77	-0.37	-28.27
51	58.57	36.04	1.35	0.00	1.35	0.21	-27.69
52	25.89	57.65	0.49	0.00	0.49	-0.65	-28.55
53	32.92	56.69	0.54	0.00	0.54	-0.60	-28.50
54	40.97	55.09	0.63	0.00	0.63	-0.51	-28.41
55	50.97	51.87	0.83	0.00	0.83	-0.31	-28.21
56	67.39	38.75	2.17	0.00	2.17	1.03	-26.87
57	29.22	63.03	0.50	0.00	0.50	-0.64	-28.54
58	36.65	62.43	0.56	0.00	0.56	-0.58	-28.48
59	57.03	58.86	0.99	0.00	0.99	-0.15	-28.05
60	25.78	68.75	0.47	0.00	0.47	-0.67	-28.57
61	32.77	68.73	0.52	0.00	0.52	-0.62	-28.52
62	40.74	68.69	0.60	0.00	0.60	-0.54	-28.44
63	50.54	68.63	0.77	0.00	0.77	-0.37	-28.27
64	65.64	68.40	1.48	0.00	1.48	0.34	-27.56
65	16.34	73.87	0.44	0.00	0.44	-0.70	-28.60
66	22.54	74.10	0.46	0.00	0.46	-0.68	-28.58
67	29.21	74.44	0.50	0.00	0.50	-0.64	-28.54
68	36.64	74.99	0.56	0.00	0.56	-0.58	-28.48
69	45.38	75.96	0.68	0.00	0.68	-0.46	-28.36
70	57.01	78.23	0.98	0.00	0.98	-0.16	-28.06
71	13.39	78.88	0.43	0.00	0.43	-0.71	-28.61
72	19.44	79.25	0.45	0.00	0.45	-0.69	-28.59
73	25.88	79.83	0.49	0.00	0.49	-0.65	-28.55
74	32.91	80.74	0.54	0.00	0.54	-0.60	-28.50
75	40.95	82.27	0.63	0.00	0.63	-0.51	-28.41
76	50.93	85.31	0.83	0.00	0.83	-0.31	-28.21
77	67.20	97.47	2.07	0.00	2.07	0.93	-26.97
78	22.70	85.09	0.48	0.00	0.48	-0.66	-28.56
79	29.45	86.23	0.53	0.00	0.53	-0.61	-28.51
80	36.99	88.10	0.60	0.00	0.60	-0.54	-28.44
81	45.98	91.52	0.76	0.00	0.76	-0.38	-28.28
82	58.45	100.68	1.31	0.00	1.31	0.17	-27.73
83	26.18	91.66	0.53	0.00	0.53	-0.61	-28.51
84	33.37	93.76	0.60	0.00	0.60	-0.54	-28.44
85	41.69	97.44	0.74	0.00	0.74	-0.40	-28.30
86	52.42	105.82	1.14	0.00	1.14	0.00	-27.90
87	16.69	95.78	0.51	24.91	25.42	24.28	-3.62
88	23.06	97.21	0.55	0.00	0.55	-0.59	-28.49
89	29.99	99.50	0.61	0.00	0.61	-0.53	-28.43
90	37.84	103.42	0.74	0.00	0.74	-0.40	-28.30
91	47.56	111.72	1.11	0.00	1.11	-0.03	-27.93
92	1.92	100.32	0.51	26.74	27.25	26.11	-1.79
93	13.78	101.55	0.54	23.65	24.19	23.05	-4.85
94	20.05	103.06	0.58	0.00	0.58	-0.56	-28.46
95	26.79	105.54	0.65	0.00	0.65	-0.49	-28.39
96	34.32	109.78	0.79	0.00	0.79	-0.35	-28.25
97	43.42	118.60	1.20	0.00	1.20	0.06	-27.84
98	-33.81	119.48	1.01	0.00	1.01	-0.13	-28.03
99	-6.92	107.30	0.58	23.77	24.35	23.21	-4.69
100	10.90	107.91	0.59	25.03	25.62	24.48	-3.42
101	23.74	112.20	0.72	0.00	0.72	-0.42	-28.32
102	31.06	116.97	0.89	0.00	0.89	-0.25	-28.15
103	39.85	127.43	1.55	0.00	1.55	0.41	-27.49
104	-30.79	129.36	1.41	0.00	1.41	0.27	-27.63
105	-23.17	121.65	0.93	0.00	0.93	-0.21	-28.11
106	-4.02	114.75	0.68	30.99	31.67	30.53	2.63
107	1.98	114.61	0.67	26.66	27.34	26.20	-1.70
108	-20.43	133.31	1.52	31.40	32.92	31.78	3.88

This procedure is repeated for the spotbeam pattern of each MSS GEOSAT in the simulation before calculating aggregate interference into the DRS forward link. For each iteration of the simulation, a minimum orbital separation value between the DRS and neighboring MSS GEOSATs is specified. The aggregate interference is then calculated and if it exceeds the threshold value, additional iterations are performed with successively larger orbital DRS-MSS GEOSAT separations until the interference protection threshold is met. Increasing the DRS-(neighboring) MSS satellite orbital separation removes more and more MSS satellites from the orbital arc since the spacing between neighboring MSS satellites is always assumed to be fixed at 5° (with the exception of the spacing between the two MSS satellites nearest to the DRS). The assumed percentage of beams under rain will also affect the results as shown in Table 3.4-5 of the main report. The large separations for 99.9% link availability (i.e. 20°) are due to the very large rain losses at this link availability compared to the smaller losses at 99% and 99.5% availabilities where the required spacing is only 2°-5°. To illustrate, Table 4 shows the rain loss values for these different availabilities for the example beam pattern in Fig. A4-1 (MSS GEOSAT at 69°E). Note that the rain loss as calculated using Recommendation ITU-R P.618-10 is a function of several variables including the frequency, link availability percentage, satellite elevation angle, and latitude/longitude location of the beam aimpoint. The beam aimpoint location, in turn, determines other parameters in the rain loss model such as the rain zone (0.01% rain rate) and specific attenuation. These parameters are also shown in Table A4-4.

TABLE A4-4

Comparison of rain loss values for 99%, 99.5%, and 99.9% link availabilities

BEAM #	LAT	LON	RAIN LOSS (dB)			SPECIFIC ATTENUATION (dB/km)			Rain Rate (Ro) exceeded 0.01% of year (mm/hr)	RAIN ZONE (A,B,C)	SATELLITE ELEVATION ANGLE (deg)
			99%	99.50%	99.90%	99%	99.50%	99.90%			
1	-1.05	12.52	6.17	10.88	25.66	1.02	1.79	4.23	68.64	N	25.67
2	5.12	12.06	5.06	8.79	20.96	0.81	1.40	3.34	56.16	L	25.03
3	11.43	10.03	4.26	8.23	19.95	0.57	1.11	2.68	40.89	K	22.30
4	18.10	5.45	3.24	7.29	18.12	0.31	0.69	1.71	22.70	F	16.72
5	-23.23	15.24	2.41	3.95	9.81	0.31	0.51	1.27	24.35	F	25.03
6	-16.46	19.25	4.62	7.80	18.66	1.02	1.72	4.12	72.33	N	30.83
7	-10.13	21.42	4.85	8.55	20.46	1.11	1.96	4.69	78.40	N	34.45
8	-4.03	22.46	4.99	9.17	21.96	1.02	1.88	4.51	71.84	N	36.33
9	1.98	22.60	5.13	9.56	22.86	1.04	1.95	4.65	72.90	N	36.59
10	8.04	21.88	3.78	6.82	16.57	0.72	1.30	3.16	52.68	L	35.27
11	14.27	20.14	2.36	4.12	10.28	0.33	0.57	1.41	25.46	F	32.27
12	20.86	16.89	0.38	0.67	1.86	0.04	0.08	0.21	4.59	A	27.30
13	28.15	10.62	0.73	1.54	4.17	0.06	0.14	0.37	5.95	A	19.33
14	-26.18	23.61	3.48	5.65	13.71	0.77	1.25	3.03	57.18	L	31.68
15	-19.34	26.99	3.53	6.02	14.64	0.75	1.28	3.12	55.85	L	37.64
16	-13.00	28.96	4.05	7.23	17.50	1.03	1.83	4.44	74.66	N	41.77
17	-1.00	30.45	3.75	7.36	18.00	0.95	1.86	4.54	69.57	N	45.33
18	4.91	30.25	3.98	7.58	18.44	0.88	1.68	4.09	64.16	N	44.83
19	10.91	29.41	3.04	5.56	13.69	0.57	1.04	2.56	42.91	L	42.81
20	17.15	27.78	2.29	4.01	10.02	0.35	0.62	1.55	27.99	G	39.23
21	23.78	24.97	0.03	0.06	0.18	0.00	0.01	0.02	0.49	A	33.94
22	40.04	8.68	3.84	5.91	14.22	0.67	1.03	2.47	48.54	L	13.84
23	-29.28	30.52	2.76	4.46	10.96	0.57	0.93	2.28	44.20	L	36.05
24	-22.31	33.56	3.96	6.67	16.10	0.81	1.37	3.30	59.03	L	42.53
25	-15.89	35.40	3.98	7.07	17.13	0.98	1.74	4.22	71.46	N	47.36
26	-9.81	36.49	4.37	8.18	19.75	1.09	2.03	4.91	77.98	N	50.70
27	-3.91	37.03	3.42	6.76	16.63	0.79	1.57	3.86	59.04	L	52.54
28	1.92	37.11	2.38	4.84	12.16	0.46	0.94	2.37	36.51	K	52.81
29	7.79	36.73	2.73	5.27	13.10	0.83	1.59	3.96	64.06	N	51.50
30	13.79	35.84	2.30	4.22	10.58	0.40	0.73	1.83	31.47	H	48.66
31	20.08	34.29	0.36	0.66	1.84	0.04	0.08	0.21	4.42	A	44.34
32	26.83	31.74	0.02	0.04	0.14	0.00	0.00	0.02	0.42	A	38.46
33	43.55	18.03	2.99	4.62	11.29	0.69	1.06	2.60	52.26	L	18.95
34	4.80	43.01	3.83	7.66	18.73	0.79	1.59	3.88	58.08	L	59.15
35	10.65	42.54	3.66	6.95	16.97	0.89	1.68	4.10	65.37	N	56.88
36	23.09	40.19	1.18	2.06	5.35	0.21	0.36	0.94	18.14	D	47.90
37	30.02	37.83	0.65	1.09	2.91	0.11	0.18	0.49	10.45	B	41.29
38	37.89	33.77	1.31	2.08	5.33	0.34	0.55	1.40	29.94	G	32.85
39	47.68	25.06	2.41	3.75	9.27	0.56	0.87	2.16	44.20	L	20.90
40	-21.83	46.72	3.73	6.42	15.58	1.01	1.75	4.24	74.80	N	54.13
41	-15.58	47.71	4.81	8.74	20.95	1.12	2.03	4.87	78.98	N	59.43
42	7.65	48.45	2.37	4.74	11.91	0.41	0.82	2.07	32.37	J	64.38
43	19.67	47.11	0.98	1.79	4.71	0.16	0.29	0.75	14.21	C	56.07
44	26.20	45.76	1.27	2.16	5.58	0.24	0.40	1.04	20.54	E	49.96
45	33.40	43.59	1.24	2.00	5.16	0.23	0.37	0.96	20.10	E	42.57
46	52.53	30.99	2.35	3.66	9.07	0.43	0.66	1.65	33.56	J	20.52
47	22.72	52.39	1.15	2.04	5.32	0.17	0.31	0.80	15.17	D	57.47
48	29.47	51.20	1.52	2.51	6.40	0.32	0.53	1.36	27.16	F	50.49
49	37.02	49.27	1.34	2.11	5.41	0.28	0.44	1.14	24.26	F	42.33
50	46.02	45.70	1.38	2.19	5.59	0.22	0.36	0.91	19.22	E	32.31
51	58.57	36.04	2.41	3.76	9.29	0.40	0.62	1.54	31.27	H	17.68
52	25.89	57.65	1.81	3.09	7.82	0.34	0.58	1.47	27.92	E	57.22
53	32.92	56.69	0.56	0.92	2.49	0.12	0.19	0.53	11.64	B	49.48
54	40.97	55.09	0.86	1.37	3.60	0.12	0.20	0.52	11.28	B	40.56
55	50.97	51.87	1.43	2.25	5.75	0.24	0.38	0.96	20.33	E	29.46
56	67.39	38.75	2.17	3.39	8.43	0.23	0.36	0.90	18.38	D	10.88
57	29.22	63.03	0.52	0.88	2.41	0.11	0.19	0.52	11.21	B	55.32
58	36.65	62.43	0.85	1.36	3.59	0.15	0.23	0.61	13.45	C	46.95
59	57.03	58.86	2.15	3.35	8.36	0.40	0.63	1.56	32.10	J	24.50
60	25.78	68.75	3.09	5.22	12.79	0.55	0.92	2.26	41.28	K	59.89

TABLE A4-4 (*continued*)

Comparison of rain loss values for 99%, 99.5% and 99.9% link availabilities

BEAM #	LAT	LON	RAIN LOSS (dB)			SPECIFIC ATTENUATION (dB/km)			Rain Rate (Ro) exceeded 0.01% of year (mm/hr)	RAIN ZONE (A,B,C)	SATELLITE ELEVATION ANGLE (deg)
			99%	99.50%	99.90%	99%	99.50%	99.90%			
62	40.74	68.69	1.44	2.28	5.81	0.27	0.42	1.08	22.83	F	42.93
63	50.54	68.63	1.34	2.12	5.43	0.23	0.36	0.93	19.75	E	32.13
64	65.64	68.40	1.84	2.89	7.27	0.22	0.35	0.88	18.14	D	16.03
65	16.34	73.87	4.96	9.07	21.73	1.13	2.07	4.97	79.62	N	70.02
66	22.54	74.10	3.78	6.54	15.86	0.74	1.29	3.12	54.40	L	63.00
67	29.21	74.44	4.06	6.59	15.86	0.84	1.36	3.27	60.61	M	55.43
68	36.64	74.99	0.10	0.16	0.49	0.06	0.11	0.33	8.60	B	47.06
69	45.38	75.96	0.99	1.57	4.11	0.15	0.25	0.64	13.86	C	37.33
70	57.01	78.23	1.92	3.01	7.55	0.33	0.52	1.31	27.00	F	24.64
71	13.39	78.88	4.51	8.52	20.55	1.02	1.92	4.63	72.52	N	70.53
72	19.44	79.25	3.75	6.68	16.24	0.74	1.31	3.19	53.90	L	64.38
73	25.88	79.83	4.77	7.93	18.92	1.03	1.72	4.11	73.13	N	57.45
74	32.91	80.74	0.26	0.44	1.24	0.11	0.18	0.51	12.01	C	49.69
75	40.95	82.27	0.51	0.83	2.24	0.07	0.11	0.31	7.04	A	40.77
76	50.93	85.31	1.39	2.20	5.61	0.38	0.59	1.52	32.41	J	29.70
77	67.20	97.47	1.79	2.81	7.07	0.20	0.31	0.78	16.13	D	11.42
78	22.70	85.09	4.70	8.02	19.20	1.08	1.84	4.40	76.29	N	57.82
79	29.45	86.23	0.78	1.31	3.48	0.28	0.47	1.25	26.50	F	50.81
80	36.99	88.10	0.16	0.26	0.76	0.05	0.08	0.23	5.72	A	42.64
81	45.98	91.52	0.60	0.97	2.60	0.09	0.15	0.40	8.89	B	32.65
82	58.45	100.68	1.65	2.59	6.56	0.24	0.38	0.97	20.24	E	18.21
83	26.18	91.66	4.70	7.75	18.50	1.08	1.78	4.24	76.42	N	50.39
84	33.37	93.76	0.34	0.57	1.58	0.15	0.24	0.68	15.91	D	42.99
85	41.69	97.44	0.54	0.88	2.38	0.08	0.12	0.33	7.42	A	33.85
86	52.42	105.82	1.80	2.82	7.11	0.26	0.41	1.03	21.35	E	21.14
87	16.69	95.78	5.95	10.53	24.91	1.45	2.57	6.08	99.26	P	53.63
88	23.06	97.21	3.37	5.72	13.95	0.80	1.35	3.30	59.64	L	48.43
89	29.99	99.50	0.82	1.36	3.60	0.29	0.48	1.28	27.29	F	41.82
90	37.84	103.42	0.90	1.44	3.78	0.17	0.27	0.71	15.61	D	33.42
91	47.56	111.72	1.92	3.01	7.55	0.32	0.49	1.24	25.57	F	21.66
92	1.92	100.32	5.62	11.19	26.74	1.26	2.51	5.99	86.69	N	53.46
93	13.78	101.55	5.54	9.95	23.65	1.30	2.33	5.54	89.58	N	49.29
94	20.05	103.06	3.90	6.69	16.18	0.91	1.55	3.76	66.11	N	44.96
95	26.79	105.54	2.52	4.15	10.28	0.52	0.85	2.10	40.23	K	39.10
96	34.32	109.78	2.53	3.96	9.79	0.44	0.68	1.69	33.86	J	31.30
97	43.42	118.60	2.65	4.11	10.11	0.39	0.61	1.49	30.13	H	19.93
98	-33.81	119.48	2.16	3.61	9.03	0.38	0.63	1.58	30.23	H	23.99
99	-6.92	107.30	5.34	9.96	23.77	1.40	2.60	6.22	97.21	P	45.04
100	10.90	107.91	5.86	10.56	25.03	1.32	2.38	5.64	90.40	N	43.54
101	23.74	112.20	4.80	7.86	18.75	0.95	1.55	3.69	66.60	N	34.72
102	31.06	116.97	4.38	6.86	16.40	0.71	1.11	2.66	50.57	L	27.28
103	39.85	127.43	4.75	7.27	17.26	0.68	1.05	2.49	48.06	L	15.32
104	-30.79	129.36	2.35	5.13	12.98	0.26	0.57	1.44	20.40	E	16.83
105	-23.17	121.65	3.68	5.99	14.49	0.58	0.94	2.29	42.48	L	26.10
106	-4.02	114.75	7.24	13.23	30.99	1.61	2.95	6.91	106.80	P	37.19
107	1.98	114.61	6.04	11.25	26.66	1.47	2.74	6.49	100.38	P	37.46
108	-20.43	133.31	5.84	13.08	31.40	0.70	1.56	3.74	47.09	L	15.59

ANNEX 5

Sharing study of proposed MSS and incumbent MS service MSS uplink interference into MS in the bands 22.5-23.6 GHz and 24.25-26 GHz

1 Proposed MS system characteristics

The MS is allocated in the sub bands 22.5-23.6, 24.25-25.25 GHz (Region 3) and 25.25-26 GHz within the band. Currently, the characteristics for interference estimation from the MSS to land MS in the frequency band 22-26 GHz are not available in WP 4C. Therefore, the characteristics indicated in Tables 1 and 2 were proposed as MS characteristics for sharing between MS and MSS in other bands for uplink direction.

1.1 Proposed system characteristics for land MS in the band 22.5-23.6 GHz

TABLE A5-1

Frequency range (GHz)	22.5-23.6		
Type	User Terminal	Base station	
Antenna gain (dBi)	0	35 (Rec. ITU-R F.1336)	45 (Rec. ITU-R F.1336)
Feeder/multiplexer loss range (dB)	0…3	0…3	0…3
Receiver noise power density typical (=NRX) (dBW/MHz)	−138	−138	−138
Nominal long-term interference power density (dBW/MHz)	−138 + *I*/*N*	−138 + *I*/*N*	−138 + *I*/*N*

1.2 Proposed system characteristics for land MS in the band 24.25-26 GHz

TABLE A5-2

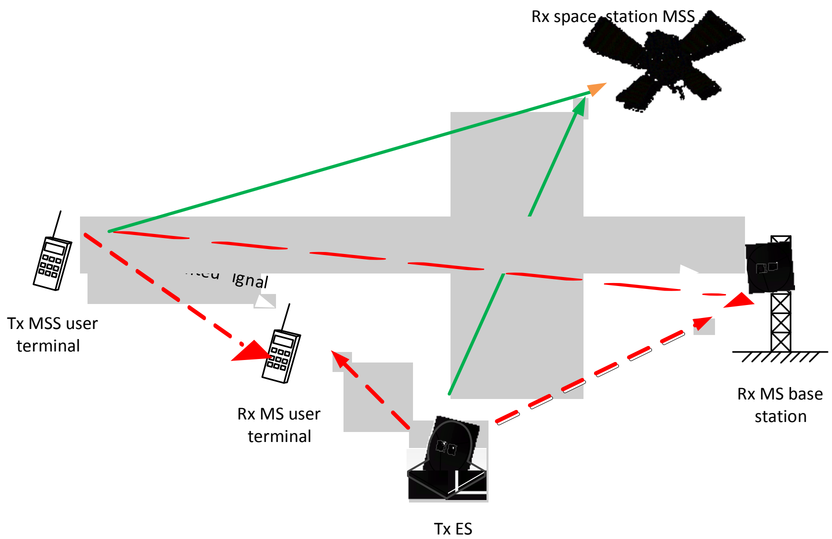
Frequency range (GHz)	24.25-26	
Type	User Terminal	Base station
Antenna gain (dBi)	0	35 (Rec. ITU -P F.1336)
Feeder/multiplexer loss range (dB)	0…3	0…3
Receiver noise power density typical (=N_{RX}) (dBW/MHz)	−136	−136
Nominal long-term interference power density (dBW/MHz)	−136 + *I*/*N*	−136 + *I*/*N*

2 Interference scenario

Interference from MSS user terminal and hub station transmitters into both MS user terminal and MS base station is shown in Fig. A5-1 below.

FIGURE A5-1

Interference Scenarios



3 Analysis of interference impact on the MS system from the proposed MSS

The analysis was performed using different transmitter elevation angles under short term conditions.

The following parameters were used during the analysis:

– A propagation model (1) is used in area A2 (all of the land territory is far away from the sea).

– Height of the MES antenna is 3 m above the smooth surface of the Earth.

– Height of the MS station antenna centre is 20 m above the smooth surface of the Earth.

– Height of the MS terminal centre is 2 m above the smooth surface of the Earth.

– MES antenna and radio-relay station antenna always have the same polarization (to get maximum interference from the transmitter).

– No obstacles along the signal propagation path (no buildings or objects along the path between transmitter and receiver to increase probability of interference).

– No variation of the terrain due to natural topography over the earth surface is taken into account.
– The elevation of the MES is taken as 5 degree, 10 degree and side lobe.
– Required time percentage(s) for which the calculated basic transmission loss is not exceeded (p) equal to 20%.
– The average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere (ΔN) =53 per km (from the map for short term analysis).
– The sea-level surface refractivity (N0) =328.

3.1 Interference analysis for the band 22.5-23.6 GHz

The following Table A5-3 summarizes the interference analysis and required protection distance for the band 22.5-23.6 GHz.

TABLE A5-3

MSS antenna	**2.4**			**0.33**						**2.4**						**0.33**		
Center Frequency (GHz)	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05	23.05
Transmit Antenna Diameter (m)	2.4	2.4	2.4	0.33	0.33	0.33	0.33	0.33	0.33	2.4	2.4	2.4	2.4	2.4	2.4	0.33	0.33	0.33
Antenna gain (dBi)	53.709	53.7	53.709	36.47	36.475	36.475	36.48	36.475	36.48	53.71	53.71	53.70	53.71	53.71	53.71	36.475	36.475	36.475
e.i.r.p. per carrier	57.239	57.239	57.239	38.925	38.925	38.925	38.925	38.925	38.9	57.24	57.239	57.24	57.239	57.24	57.239	38.925	38.925	38.925
Power	3.53	3.53	3.53	2.45	2.45	2.45	2.45	2.45	2.45	3.53	3.53	3.53	3.53	3.53	3.53	2.45	2.45	2.45
Bandwidth at -3 dB	16.2	16.2	16.2	4.05	4.05	4.5	4.05	4.05	4.5	16.2	16.2	16.2	16.2	16.2	16.2	4.05	4.05	40.5
Transmit Antenna Pattern	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6
Antenna Elevation Angle(degee)	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe
Antenna gain towards horizon	11.526	4	–10	20.485	12.959	–4.415	20.485	12.959	–4.415	11.526	4	–10	11.526	4	–10	20.485	12.959	–4.415

TABLE A5-3 (*end*)

e.i.r.p. per carrier (towards horizon)	15.056	7.53	–6.47	22.935	15.409	–1.965	22.935	15.409	–1.965	15.056	7.53	–6.47	15.056	7.53	–6.47	22.935	15.409	–1.965
e.i.r.p. per Mega (towards horizon)	2.960	–4.565	–18.56	16.860	9.33	–8.497	16.86	9.33	–8.49	2.96	–4.56	–18.56	2.96	–4.56	–18.56	16.86	9.33	–18.04
Land Ms	User terminal			Base station						Base station						User terminal		
Antenna gain	0	0	0	35	35	35	45	45	45	35	35	35	45	45	45	0	0	0
Receive Antenna Minimum Elevation Angle (deg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feeder/multiplexer loss	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Receiver noise power density typical	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138	–138
Criteria,	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6
Allowable interference at the input of radio-relay station antenna	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144	–144
Required attenuation to avoid interference	–146.9	–139.4	–125.43	–195.8	–188.3	–170.50	–205.8	–198.3	–180.50	–181.9	–174.4	–160.4	–191.9	–184.4	–170.4	–160.86	–153.3	–125.95
Separation distance Km	17.7	9	2	54.4	45.2	33.2	68.4	57.6	38.4	39	33.8	26.2	49.6	41.2	31.8	28.4	24	6

3.2 Interference analysis for the band 24.25-26 GHz

The following Table A5-4 summarizes the interference analysis and required protection distance for the band 24.25-26 GHz.

TABLE A5-4

MSS antenna	**2.4**			**0.33**			**2.4**			**0.33**		
Center Frequency (GHz)	25.125	25.125	25.125	25.125	25.125	25.125	25.125	25.125	25.125	25.125	25.125	25.125
Transmit Antenna Diameter (m)	2.4	2.4	2.4	0.33	0.33	0.33	2.4	2.4	2.4	0.33	0.33	0.33
Antenna gain (dBi)	54.458	54.458	54.458	37.224	37.224	37.224	54.458	54.458	54.458	37.224	37.224	37.224
e.i.r.p. per carrier	57.988	57.988	57.988	39.674	39.674	39.674	57.988	57.988	57.988	39.674	39.674	39.674
Power	3.53	3.53	3.53	2.45	2.45	2.45	3.53	3.53	3.53	2.45	2.45	2.45
Bandwidth at –3 dB	16.2	16.2	16.2	4.05	4.05	40.5	16.2	16.2	16.2	4.05	4.05	40.5
Transmit Antenna Pattern	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6	580-6
Antenna Elevation Angle(degee)	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe	5	10	Side lobe
Antenna gain towards horizon	11.526	4	–10	20.111	12.585	–4.41499	11.526	4	–10	20.111	12.585	–4.41499
e.i.r.p. per carrier (towards horizon)	15.056	7.53	–6.47	22.561	15.035	–1.96585	15.056	7.53	–6.47	22.561	15.035	–1.96585
e.i.r.p. per Mega (towards horizon)	2.961	–4.565	–18.565	16.486	8.96	–8.04	2.961	–4.565	–18.565	16.486	8.96	–8.04
Land Ms	User terminal			Base station			Base station			User terminal		

TABLE A5-4 (*end*)

Antenna gain	0	0	0	35	35	35	35	35	35	0	0	0
Receive Antenna Minimum Elevation Angle (deg)	0	0	0	0	0	0	0	0	0	0	0	0
Feeder/multiplexer loss	0	0	0	0	0	0	0	0	0	0	0	0
Receiver noise power density typical	–136	–136	–136	–136	–136	–136	–136	–136	–136	–136	–136	–136
Criteria,	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6	–6
Allowable interference at the input of radio-relay station antenna	–142	–142	–142	–142	–142	–142	–142	–142	–142	–142	–142	–142
Required attenuation to avoid interference	–144.961	–137.435	–123.435	–193.486	–185.96	–168.96	–179.961	–172.435	–158.435	–158.486	–150.96	–133.96
Separation distance km	14	7	1.5	53	44	33	38	34	28	28	22	4.8

4 Conclusion

In order to protect the MS systems from the proposed MSS system protection distance is required from 1.5-68 km and RR No. **9.17** should be applied to ensure protection of MS system from the MSS up link.

ANNEX 6

Frequency sharing study between MSS systems featuring earth stations on vessels and fixed services in the Ka band frequency range of 22-26 GHz[7]

1 Introduction

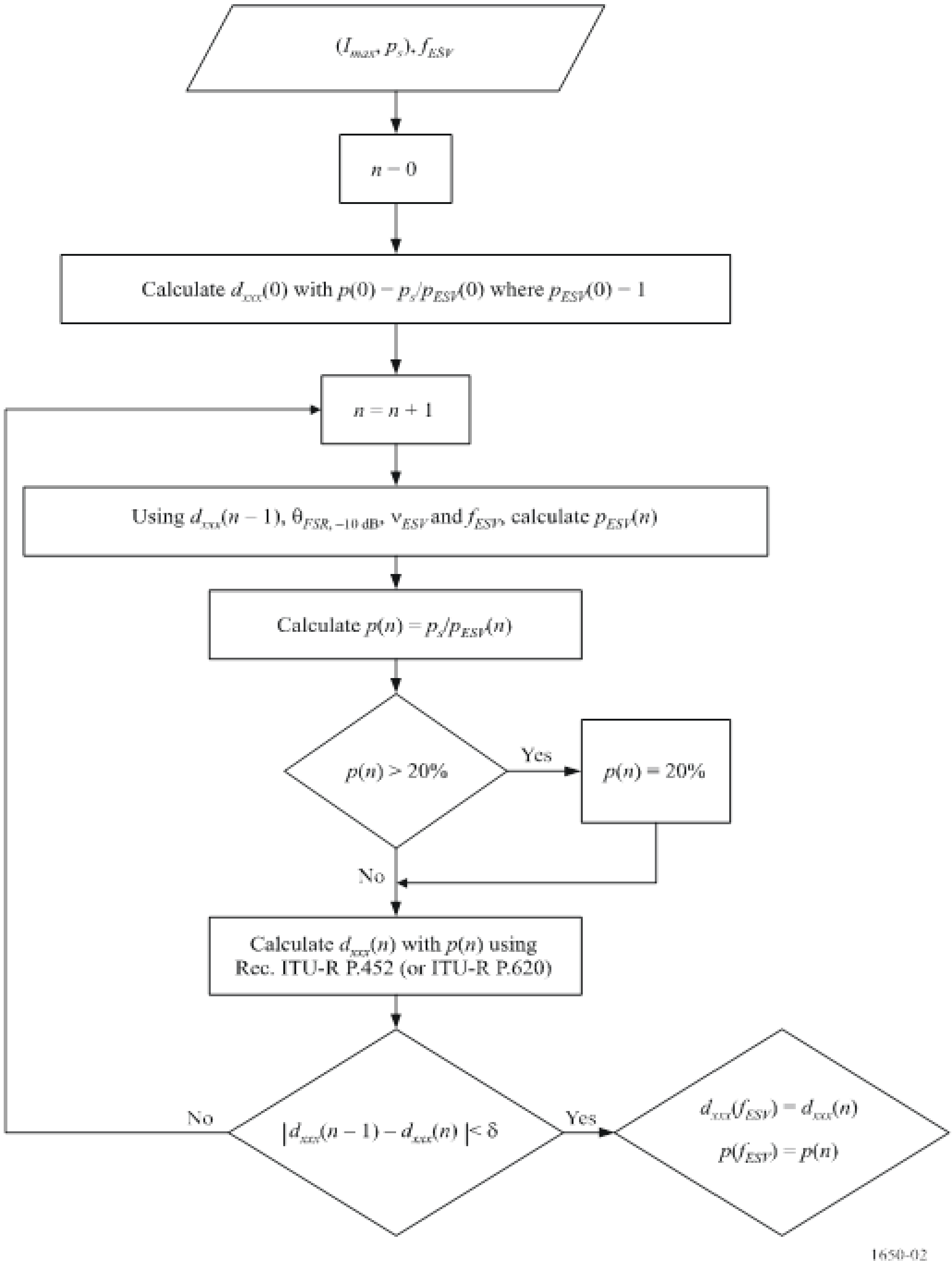
WRC-15 agenda item 1.10 calls for conducting sharing and compatibility studies for mobile-satellite service (MSS) in the Earth-to-space and Space-to-Earth directions, within portions of the bands between 22 GHz to 26 GHz, while ensuring protection of existing services within these bands. This study provides sharing analysis performed between the proposed MSS when the MSS earth station is used on board vessels and FS terrestrial stations for bandwidth of 250 to 300 MHz within the band 24.25-26 GHz.

2 Method to determine the separation/protection distance

To determine the required protection distance, the method in Recommendation ITU-R SF.1650-1 along with the propagation model as described in Recommendation ITU-R P.452-15 has been used. The methodology to determine the distance as described in Recommendation ITU-R SF.1650-1 can be summarized in the following flow chart and more details can be found in Recommendation ITU-R SF.1650-1.

[7] NOTE – This study addressing sharing between the MSS and the fixed service was incorporated into the Report without the opportunity for the ITU-R FS expert working party to review and comment on the contents or conclusions of this study prior to WRC-15.

Flow chart of iterative process



n: stage of the iteration, $n = 0, 1, 2, ...$

I_{max}: maximum permissible interference power (dBW)

P_s: time percentage (annual) for which I_{max} be exceeded (%)

P_{ESV}: time percentage (annual) for which *ESV*s are present (%)

ν_{ESV}: ship's speed (km/h)

p: time percentage (annual) for which minimum required transmission loss is not exceeded (%)

δ: 3 km is recommended (distances < 3 km are not recommended due to the interaction between the iterations of the propagation model and the iterations of this method)

3 Technical parameters for MSS and FS systems

3.1 MSS system characteristics

Characteristics of user terminal	Units	User terminal
Transmitter bandwidth	MHz	4.05
Transmit antenna diameter	(m)	0.33
Transmit antenna peak gain	(dBi)	37.4
Transmit effective isotropic radiated power e.i.r.p. per carrier	(dBW)	39.85
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		Recommendation ITU-R S.580
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		linear
Transmit losses	(dB)	0.77
Ship's speed	Km/h	18.3
Transmitter height	m	40

3.2 FS system characteristics

FSR parameters		
Frequency of operation, f (MHz)	25 000	
Antenna height above ground, h_{rg} (m)	30	
Ground height above mean sea level, h_g (m)	50	
Antenna height above mean sea level, $h_{rs} = h_g + h_{rg}$ (m)	80	Sum of values above
Maximum boresight antenna gain, $G_r = G_{FSR}(0)$ (dBi)	42	For typical 0.6 m antenna
–10 dB beamwidth, $\theta_{FSR,\,-10\ \mathrm{dB}}$ (degrees)	2.53	Calculated from Recommendation ITU-R F.1245
Average antenna gain in –10 dB beamwidth, $G_{r,\,AVE}$ (dBi)	39.5	Calculated
Feeder loss, F (dB)	0	
Data rate (Mbit/s)	34	
Receiver bandwidth, B_{FSR} (MHz)	14	For 34 Mbit/s link
Net fade margin referenced to the 1×10^{-3} BER level (dB)	20	

I/N applicable to ES criterion (I/N_{th})	15	fade margin 20 dB typical was assumed can be given to interference: for Point to Point (P-P) systems: – for ES (G.828): I/N = 15 dB not to be exceeded for more than 0.0016% of the time – for ES (G.826): I/N = 15 dB not to be exceeded for more than 0.006% of the time – for SES: I/N = 19 dB not to be exceeded for more than 0.00016 % of the time see ECC Report 023 As the value for ES (G.828) gives is the most strict it will be used in calculation (I/N =15 for 0.0016% of time)
Noise figure, NF (dB)	5	
Short-term interference objective		
Parameter	**Value**	**Comment**
Permissible interference power level, I_{max} (dBW)	–112.5387	$= 10 \log(k\ T\ B_{FSR}) + NF + I/N_{th}$
Time percentage for which I_{max} may be exceeded, p_s (%)	0.0016	
Calculation (dB) of minimum permissible transmission losses		
Loss, $L_{b,\ min}(p_s)$ (dB)	Calculated	

Calculation of applicable time percentage for which minimum propagation loss is not exceeded considering that ESVs are not always present		
Sample range of ESV from FSR, d_{xxx} (km)	Calculated	
Distance travelled by ESV through –10 dB beamwidth, $d_{ESV\ in\ beam}$ (km)	Calculated	$= 2d_{xxx} \tan(\theta_{FSR,\ -10\ \mathrm{dB}}/2)$
Time spent by ESV in –10 dB beamwidth, $t_{ESV\ in\ beam}$ (h)	Calculated	$= d_{ESV\ in\ beam} / \nu_{ESV}$
ESV interference percentage, p_{ESV} (%)	Calculated	$= (f_{ESV}\, t_{ESV\ in\ beam} / 8\,760) \times 100\%$
Time percentage for which $L_{b,\ min}(p_s)$ is not exceeded, p (%)	Calculated	$= (p_s / p_{ESV}) \times 100\%$

4 Assumptions and parameter values

The propagation model used is Recommendation ITU-R P.452. The calculation has been done for discrimination angles 20 and 36 (see Recommendation ITU-R SF.1650-1, section 3.2) at two example latitudes, 45° and 20°. The calculations are presented for two locations of the FSR (0 km and 15 km). A typical fade margin value of 20 dB was assumed for Point to Point (P-P) systems. For ES (G.828): I/N = 15 dB not to be exceeded for more than 0.0016% of the time, and for ES (G.826): I/N = 15 dB not to be exceeded for more than 0.006% of the time and for SES: I/N = 19 dB not to be exceeded for more than 0.00016% of the time, see ECC Report 023 in the calculation. The value for ES (G.828):

I/N = 15 dB not to be exceeded for more than 0.0016% of the time is selected as it gives more conservative limits.

Assuming 12 000 vessels/ships arrival using the band of 300 MHz within the range 24.25 to 26 GHz, equals 33 ships arrival per day for ships using equipment operating in this band which leads to 66 passes per day for the number of vessels passes overlap FSR is 66 * 22/300 4.84 and if the same number of vessels uses will operate within 250 MHz the number of passes becomes 66 * 22/250 = 5.8. The calculations is also presented for three vessel passes per day and six vessels passes per day.

5 Calculations results

The protection distance in the 25 GHz band using Recommendation ITU-R P.452, latitude = 20º, 45º (ΔN = 70, 50) for the 0.33 m antenna.

		FSR at 0 km from the coast		**FSR at 15 km from the coast(1)**	
Antenna discrimination angle (degrees)		20	36	20	36
L_b (dB)		159.944	153.615	159.944	153.615
3 vessels every day	Distance (km)	**67**	**45**	**52**	**30**
	p (%)	0.079	0.11	0.079	0.11
6 vessels every day	Distance (km)	**70**	**47**	**55**	**32**
	p (%)	0.038	0.055	0.038	0.055

6 Conclusion

A separation distance of 70 km between the FSR and the MSS shipborne earth station is required.

Annex 7

Technical characteristics and protection criteria for aeronautical mobile service systems in the frequency bands 22.5-23.6 and 25.25-27.5 GHz

1 Introduction

Systems and networks operating in the AMS are used for broadband, airborne data links to support scientific research, remote sensing, fire-fighting, land and crop surveying, pipeline monitoring, and emergency management applications. The research/remote sensing/monitoring equipment may be on-board either manned aircraft or unmanned aeronautical systems (UAS). In the case of a manned aircraft, the broadband data links may be used to transmit data collected from one or multiple research/remote sensing/monitoring equipment on the aircraft. In the case where the remote sensing equipment is on-board a UAS, systems and networks operating in the AMS may be used for narrow-band, airborne command and control data links. These narrow-band data links may be used to command and control either or both the remote sensing equipment and the UAS.

2 Operational deployment

In the frequency band 22.5-23.6 GHz and 25.25-27.5 GHz, the mobile service is allocated on a primary basis in all three ITU-R regions. The AMS is a mobile service between aeronautical stations and aircraft stations, or between aircraft stations. Platforms equipped with AMS data links (ADL) can be deployed anywhere within a country whose administration has authorized their use in accordance with the authorization.

An ADL may exist between an airborne data terminal (ADT), which is an aircraft station, and a ground data terminal (GDT), which is an aeronautical station, or between two ADTs. ADLs are bi-directional by design and may operate in either a narrow-band or wide-band mode in one or both directions depending upon operational requirements.

The GDT may be at a single permanent location or they may be transportable. Transportable GDTs can be moved to meet operational needs. The duration that a transportable GDT remains at a particular location is dependent upon operational requirements.

The link distance for the ADL is generally limited by the radio-line-of-sight (RLOS) horizon which is a function of the terrain in the vicinity of the GDT and the altitude of the ADT. The operational altitude of airborne platforms equipped with these ADLs depends on specific operational requirements and can be up to approximately 20 km. Although some of the link lengths may be relatively short, many of the link distances approach RLOS horizon distance. For an air-to-ground link, the link distance may be approximately 450 km.

The link between two ADTs operates in similar manner as the link between a GDT and an ADT with the exception that the link distance is a function of the operating altitude of the two ADTs. In the case of a direct air-to-air link, this link distance may be up to 900 km. Other factors to consider, such as atmospheric losses (rain attenuation, gases, etc.) and clutter losses, as described in the ITU-R Recommendations P-Series, could reduce the maximum distance of the link between two aircraft. Depending on the environmental conditions and locations of the aircraft, the crosslink distance might be shorter than 900 km.

A single GDT may support several ADT via different links. If the ADLs are operating in a narrow-band mode, multiple data links may be supported through frequency separation. If the data links are operating in a wide band mode, multiple data links may be supported through geographic separation using multiple high-gain, narrow-beam antennas.

An ADT may serve as a node within a larger network or as a repeater to extend the range between the data-collection ADT and the data-receiving GDT. In this case, the ADT may have two or more ADLs between either two ADTs or between one ADT and one GDT.

The temporal duration of the link can span the entire flight duration, i.e. take off/landing, transit to/from the operational area, and the time used for data collection in the operational area. Thus, the time duration during which an ADL can be active may extend for many hours.

3 Technical characteristics of aeronautical mobile systems

Representative technical characteristics for airborne data links in the AMS for the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz are provided in Table 1.

3.1 Transmitter characteristics

The aeronautical mobile systems operating or planned to operate in the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz typically use digital modulations. A given transmitter may be capable of radiating more than one waveform. Solid-state power amplifier output devices are typically used in the transmitters. The trend towards use of solid-state transmitters in new mobile systems will continue for the foreseeable future due to the wide bandwidth, low level of generated spurious emissions, low power consumption, and reliability of these devices.

Typical transmitter RF emission (3 dB) bandwidths of mobile systems operating or planned to operate in the frequency band 22.5-23.6 GHz and 25.25-27.5 GHz range from about 143 to 865 MHz. Transmitter peak output powers range from 0.1 W (20 dBm) to 60 W (48 dBm). However, the maximum power level at the input to the antenna is limited to 10 watts in the 25.25-27.5 GHz frequency range by RR Article **21.5**, and the equivalent isotropically radiated power is limited to 24 dBW (in any 1 MHz band) in the 25.25-27.5 GHz frequency range when the direction of maximum radiation of the antenna is within 1.5 degrees of the geostationary-satellite orbit by RR Article **21.2**.

3.2 Receiver characteristics

The aeronautical mobile systems in the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz use digital signal processing to enhance system performance.

The signal processing in the newer generation of aeronautical mobile systems may use direct sequence spread spectrum or other advanced techniques to produce a processing gain for the desired signal and may also provide suppression of undesired signals.

3.3 Antenna characteristics

A variety of different types of antennas may be used by systems in the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz. The antennas gain is typically in the range 28-45 dBi. Horizontal, vertical, and circular polarizations are used.

If antenna characteristics provided in Table 1 are sufficient, these characteristics should be used in sharing analyses. If additional characteristics are required, the first source of the data should be measured antenna characteristics. Otherwise the antenna data in Table 1 in conjunction with Recommendation ITU-R M.1851 should be used.

4 Protection criteria for the aeronautical mobile service in the frequency bands 22.5-23.6 GHz and 25.25-27.5 GHz

When operating near the maximum radio line-of-sight distance separation between the transmitter and receiver, the performance of the communication link is often noise limited. An increase in receiver effective noise of 1 dB would constitute significant degradation communication range, equivalent to a reduction in communication range of approximately 10% in a free-space propagation environment.

Such an increase in effective receiver noise corresponds to an (I + N)/N ratio of 1.26, or an *I/N* ratio of about –6 dB. This represents the required protection criterion for the AMS from interference due to another radiocommunication service. If multiple potential interference sources are present, protection of the AMS requires that this criterion is not exceeded due to the aggregate interference from the multiple sources.

TABLE 1

Representative technical characteristics of the aeronautical mobile service systems in the frequency bands 22.5-23.6 and 25.25-27.5 GHz

Parameter		Units	System 1 Airborne	System 1 Ground	System 2 Airborne	System 2 Ground
Transmitter						
Tuning range		GHz	25.75-27.15	22.9-23.3	25.25-27.5	22.55-23.5
Power output[1]		dBm	27 to 48	30 to 48	20 to 47	20 to 47
Bandwidth	3 dB	MHz	865	580	746	143
	20 dB	MHz	930	850	1 009	196
	60 dB	MHz	4 100	3 250	5 270	1 010
Harmonic attenuation		dB	65	65	62	62
Spurious attenuation		dB	60	60	60	60
Modulation			Digital	Digital	Digital	Digital
Receiver						
Tuning range		GHz	22.9-23.3	25.75-27.15	22.55-23.5	25.25-27.5
RF Selectivity	3 dB	MHz	1 410	2 410	3 299	3 299
	20 dB	MHz	1 540	2 620	3 510	3 510
	60 dB	MHz	1 850	3 300	3 940	3 940
IF Selectivity	3 dB	MHz	1 290	1 290	1 548	1 548
	20 dB	MHz	1 700	1 700	2 040	2 040
	60 dB	MHz	3 540	3 540	4 248	4 248
NF		dB	4	4	3.5	4.5
Sensitivity		dBm	–67	–56 to –62	–64	–63
Image rejection		dB	80	80	Not Available	Not Available
Spurious rejection		dB	65	65	75	75

TABLE 1 (*end*)

Parameter	Units	System 1 Airborne	System 1 Ground	System 2 Airborne	System 2 Ground
Antenna					
Antenna gain	dBi	33	36	33	33
1st Sidelobe	dBi	17	18	16	16
Polarization		RHCP[2]	RHCP[2]	RHCP[2]	RHCP[2]
Antenna pattern/Type		Parabolic Reflector	Parabolic Reflector	Parabolic Reflector	Parabolic Reflector
Horizontal BW	degrees	3.0	2.7	7.2	7.2
Vertical BW	degrees	3.0	2.7	7.2	7.2
Antenna model		Recommendation ITU-R M.1851[3] (Uniform distribution)	Recommendation ITU-R M.1851[3] (Uniform distribution)	Recommendation ITU-R M.1851[3] (Uniform distribution)	Recommendation ITU-R M.1851[3] (Uniform distribution)

Notes:

(1) In the frequency range 25.25 -27.5 GHz, RR Article **21** (§**21.2** and **21.5**) apply.

(2) RHCP – Right Hand Circularly Polarized.

(3) Recommendation ITU-R M.1851 provides several patterns based on the field distribution across the aperture of the antenna. The suggested distribution for modelling the antennas is shown in the parenthetical text based on guidance in Recommendation ITU-R M.1851.