International Telecommunication Union

ITU-R
Radiocommunication Sector of ITU

Report ITU-R M.2358-0
(06/2015)

Possible allocations to the maritime mobile-satellite service in the 7/8 GHz range

M Series
Mobile, radiodetermination, amateur and related satellite services

150
1865-2015

International Telecommunication Union

Foreword

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

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at http://www.itu.int/publ/R-REP/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	**Mobile, radiodetermination, amateur and related satellite services**
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

***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.2358-0

Possible allocations to the maritime mobile-satellite service in the 7/8 GHz range

(2015)

TABLE OF CONTENTS

Page

1 Introduction

Under WRC-15 agenda item 1.9.2 and Resolution **758 (WRC-12)**, studies are required to determine the feasibility of additional allocations to the maritime mobile-satellite service (MMSS) in the bands 7 375-7 750 MHz (space-to-Earth) and 8 025-8 400 MHz (Earth-to-space).

This Report provides sharing studies in the bands 7 375-7 750 MHz and 8 025-8 400 MHz.

Throughout this Report, references to the Radio Regulations reflect the situation as per the 2012 Edition.

2 MMSS satellite system characteristics

2.1 Earth station characteristics

Two types of MMSS earth stations are foreseen. The transmit technical characteristics are shown in Table 1.

TABLE 1

Earth station transmit characteristics

Characteristics of earth station	**Units**	**Small**	**Large**
Transmitter center frequency	(GHz)	8.2125	8.2125
Maximum transmit output power	(Watts)	100	2 000
Transmit antenna diameter	(m)	0.4	2.6
Transmit antenna peak gain	(dBi)	29	45
Transmit Antenna –3 dB beamwidth	(deg.)	6.2	0.8
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		Rec. ITU-R S.580-6 or Appendix **8** of the RR	
Transmit antenna minimum elevation angle towards the satellite	(deg.)	10	10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		RHC	RHC
Uplink occupied bandwidth per carrier	(MHz)	0.004 to 4	
Transmit losses	(dB)	2	2
Transmit effective isotropic radiated power e.i.r.p.[1]	(dBW)	47	76
Transmit e.i.r.p. spectral density	(dBW/Hz)	–10	10
Transmit e.i.r.p. spectral density limit in a 10 MHz bandwidth[2]	(dBW/10 MHz)	47	76

The receive technical characteristics are shown in Table 2.

[1] Transmit effective isotropic radiated power e.i.r.p. = 10 * Log (maximum transmit output power) – Transmit losses + Transmit antenna peak gain.

[2] (dBW/10 MHz).

TABLE 2

Earth station receive characteristics

Receiver center frequency	(GHz)	7.5	7.5
Receive antenna diameter (if different from transmit)	(m)	–	–
Receive antenna peak gain (if different from transmit)	(dBi)	27	44
Transmit antenna –3 dB beamwidth	(deg.)	7.2	1
Receive antenna pattern type (ITU Recommendation, data (angle versus gain) or plot) (if different from transmit)		Rec. ITU-R S.580-6	Rec. ITU-R S.580-6
Receive antenna minimum elevation angle towards the satellite	(deg.)	10	10
Receive antenna polarization (RHC, LHC, VL, HL or offset linear)		LHC	LHC
Receiver Noise Temperature	(K)	468	200
Downlink occupied bandwidth per carrier	(MHz)	0.004 to 100	
Receiver losses	(dB)	0	0
Earth station G/T	(dB/K)	0.3	21

2.2 Space station characteristics

The required MMSS space station parameters, to carry out compatibility studies, are shown in the tables below for geostationary satellite systems. Table 3 shows the MMSS space station receive characteristics. Table 4 shows the MMSS space station transmit characteristics.

TABLE 3

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

GSO	Units	Value	Value	Value	Value
Carrier parameters					
Type		Minimum	Maximum	Minimum	Maximum
Centre frequency of uplink band	(GHz)	8.15	8.15	8.15	8.15
Uplink polarization (RHC, LHC, VL, HL or offset linear)		RHC	RHC	RHC	RHC
Space station parameters					
Receiver noise temperature	K	900	900	900	900
Peak receive antenna gain	(dBi)	20	20	33	33

TABLE 4

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

GSO	Units	Value	Value	Value	Value
Carrier parameters					
Type		Minimum	Maximum	Minimum	Maximum
Centre frequency of downlink band	(GHz)	7.5	7.5	7.5	7.5
Downlink polarization (RHC, LHC, VL, HL or offset linear)		LHC	LHC	LHC	LHC
Modulation type (e.g. FM, BPSK, QPSK, etc.)		BPSK, Q-PSK, 8-PSK			
Downlink occupied bandwidth per carrier	(MHz)	0.004	100	0.004	100
Space station parameters					
Maximum satellite power	(W)	100	100	100	100
Peak transmit antenna gain	(dBi)	20	20	33	33
Minimum transmit antenna gain for passive antenna :	(dBi)	16	16	29	29
Transmit antenna gain pattern (e.g. Rec. ITU R S.672, CR/58 data file, etc.)		Rec. ITU-R S.672	Rec. ITU-R S.672	Rec. ITU-R S.672	Rec. ITU-R S.672
Maximum transmit e.i.r.p. spectral density	(dBW/Hz)	–26	–26	–26	–26

3 Analysis of the 7/8 GHz bands

3.1 Frequency band 7 375-7 750 MHz

The allocation of this band in Article **5** of the Radio Regulations is indicated below.

Allocation to services		
Region 1	**Region 2**	**Region 3**
7 300-7 450	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.461	
7 450-7 550	FIXED FIXED-SATELLITE (space-to-Earth) METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.461A	
7 550-7 750	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile	

5.461 *Additional allocation:* the bands 7 250-7 375 MHz (space-to-Earth) and 7 900-8 025 MHz (Earth-to-space) are also allocated to the mobile-satellite service on a primary basis, subject to agreement obtained under No. **9.21**.

5.461A The use of the band 7 450-7 550 MHz by the meteorological-satellite service (space-to-Earth) is limited to geostationary-satellite systems. Non-geostationary meteorological-satellite systems in this band notified before 30 November 1997 may continue to operate on a primary basis until the end of their lifetime. (WRC-97)

This section addresses sharing between the MMSS and incumbent services in the 7 375-7 750 MHz band. It should be noted that no analyses of interference from incumbent services into the MMSS receiver have been performed.

3.1.1 Sharing with the fixed service in the 7 375-7 750 MHz band

This section addresses the feasibility of sharing between MMSS uplinks in the 7 GHz band and stations operating in the fixed service. Three separate studies are included in §§ 3.1.1.1, 3.1.1.2 and 3.1.1.3.

3.1.1.1 7 GHz FS sharing study 1

In the United States, fixed service systems operate in the 7 125-8 500 MHz band. This contribution provides information for sharing studies between the fixed service and the proposed MMSS in the 7 375-7 750 MHz (s-E) band.

3.1.1.1.1 Study 1 Fixed service systems characteristics

There is a wide variety of fixed service systems equipment in use. The characteristics of several widely-used fixed service receivers, operating in the 7 125-8 500 MHz frequency band, are provided in Table 5.

TABLE 5

Fixed service system receivers – Specifications

Characteristics	FR8	MDR-6508	MDR-6708
Frequency Range (MHz)	7 125-8 400	7 125-8 500	7 125-8 500
Max Antenna gain (dBi) – typical	30 – 40, peak gain		
IF passband (MHz): –3 dB –20 dB	44 56	1.25 to 7.5	0.8 to 5

For the purpose of establishing the sharing criteria between the fixed service systems and the proposed MMSS service, the FS system antenna patterns are assumed to follow the antenna pattern in Recommendation ITU-R F.1245-2. The fixed service systems characteristics and protection criteria are assumed to follow the systems characteristics and protection criteria in Recommendation ITU-R F.758-5.

Figure 1 shows the FS antenna patterns (Rec. ITU-R F.1245-2) at a carrier frequency of 7 375 MHz to be used in sharing studies between FS and proposed MMSS (s-E), for representative antenna gains of 12 dBi and 30 dBi.

FIGURE 1

FS antenna patterns (Recommendation ITU-R F.1245-2) at 7 375 MHz

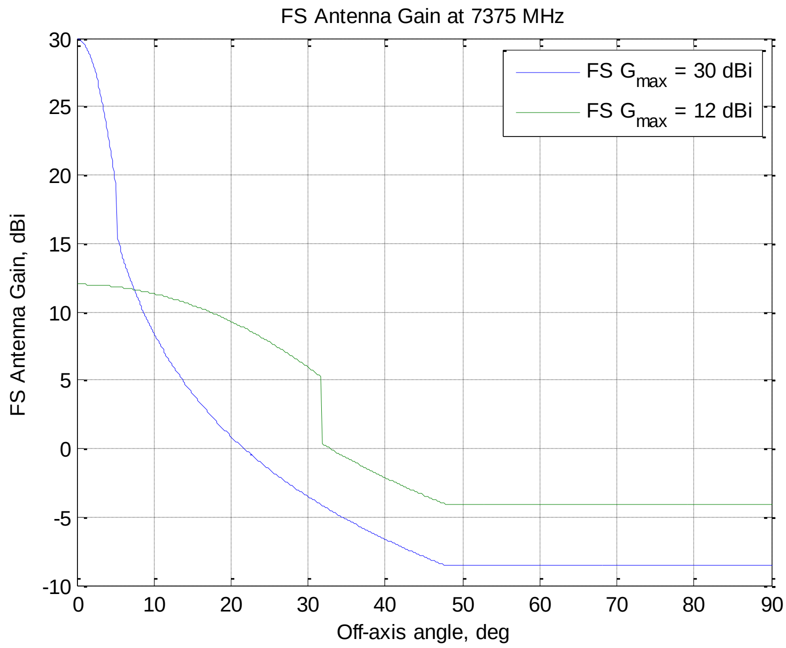


Table 6 shows the system parameters for Point-Point FS systems in allocated bands between 7.1 and 8.5 GHz frequency band (Table 7 of Recommendation ITU-R F.758-5) that are similar to the FR8 receiver characteristics in Table 5. The FS systems parameters in Table 6 are to be used in the sharing studies between the FS systems and the proposed MMSS systems in the bands between 7.1 and 8.5 GHz.

TABLE 6

System parameters for PP FS systems in allocated bands between 7.1 and 8.5 GHz

Frequency range (GHz)	**7.110-7.900**		**7.725-8.500**	
Reference ITU-R Recommendation	F.385		F.386	
Modulation	16-QAM	128-QAM	16-QAM	128-QAM
Channel spacing and receiver noise bandwidth (MHz)	3.5, 5, 7, **10**, 14, **20**, **28**, **30**(3), **40**(3), **60**(3), **80**(3)	3.5, 5, 7, **10**, 14, **20**, **28**, **30**(3),**40**(3), **60**(3), **80**(3)	1.25, 2.5, 5, 7, **10**, 11.662, 14, **20**, **28**, 29.65, **30**, **40**, **60**(3), **80**(3)	1.25, 2.5, 5, 7, **10**, 11.662, 14, **20**, **28**, 29.65, **30**, **40**, **60**(3), **80**(3)
Tx output power range (dBW)	−6.5…20.0	−6.5…20.0	−6.5…20.0	−6.5…20.0
Tx output power density range (dBW/MHz)(1)	−25.5…10.0	−25.5…10.0	−25.5…10.0	−25.5…10.0
Feeder/multiplexer loss range (dB)	0…3.0	0…3.0	0…3.0	0…3.0
Antenna gain range (dBi)	12…48.6	12…48.6	12…48.6	12…48.6
e.i.r.p. range (dBW)	5.5…65.5	5.5…65.5	5.5…65.5	5.5…65.5
e.i.r.p. density range (dBW/MHz)(1)	−13.5…55.5	−13.5…55.5	−13.5…55.5	−13.5…55.5
Receiver noise figure typical (dB)	2.5…6	2.5…6	2.5…6	2.5…8
Receiver noise power density typical (=N_{RX}) (dBW/MHz)	−141.5… −138.0	−141.5… −138.0	−141.5…−138 .0	−141.5…−136
Normalized Rx input level for 1 × 10^{-6} BER (dBW/MHz)	−121.0… −117.5	−112.5… −115.0	−121.0…−117 .5	−111.3…−106.5
Nominal long-term interference power density (dBW/MHz)(2)	−141.5… −138.0 + *I/N*	−141.5… −138.0 + *I/N*	−141.5… −138.0 + *I/N*	−141.5… −136+ *I/N*

NOTE (Rec. ITU-R F.758-5) – The intended set of parameters for two reference systems for sharing/coexistence studies are presently not or only partially available; administrations are invited to contribute. On a provisional basis, the parameters reported in Annex 3 for the same bands may be used.

1) To calculate the values for the Tx/ e.i.r.p. densities, channel spacing/bandwidth needs to be identified. In these tables, the channel spacing indicated in the bold letter is used. Where a modal value (Mode) is provided, it is to be taken as indicative within the range specified and further sensitivity analysis may be required on a case-by-case basis to assess a given interference potential due to the variations within the range specified.

2) Nominal long-term interference power density is defined by "Receiver noise power density + (required *I/N*)" as described in § 4.13 in Annex 2 (see also § 4.1 in Annex 1).

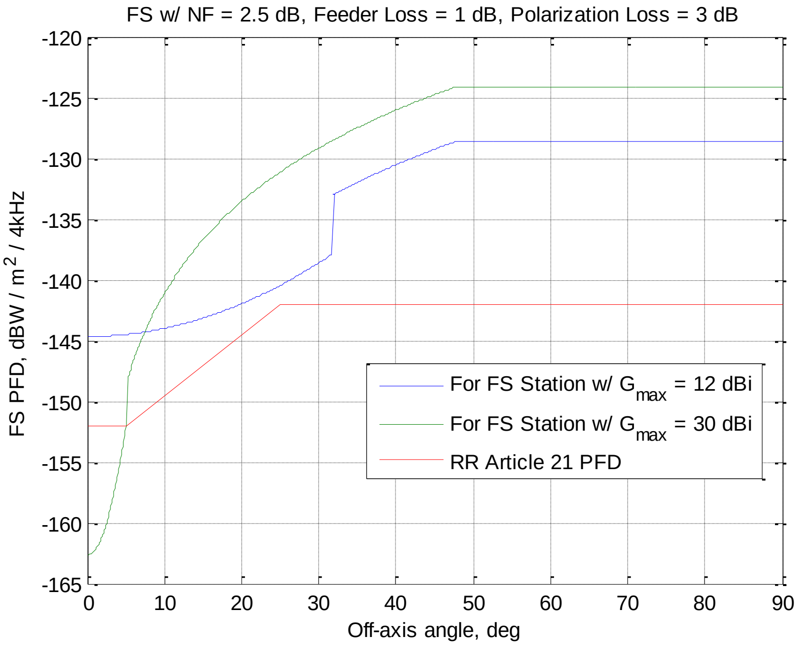
3) This channel spacing value is not specified in the reference Recommendation.

3.1.1.1.2 Study 1 Interference assessment

Based on the FS characteristics and using an interference level of $I/N = -10$ dB (Rec. ITU-R F.758-5), the derived interference assessment in PFD for the FS is shown in Fig. 2 in agreement with Radio Regulation Article 21 PFD limits. This calculation assumes a feeder / multiplexer loss of 1 dB, a 3 dB polarization loss, a 2.5 dB FS receiver noise figure, and the FS antenna gain (at a carrier frequency of 7 375 MHz) for off-axis arrival angles from 0° to 90°.

FIGURE 2

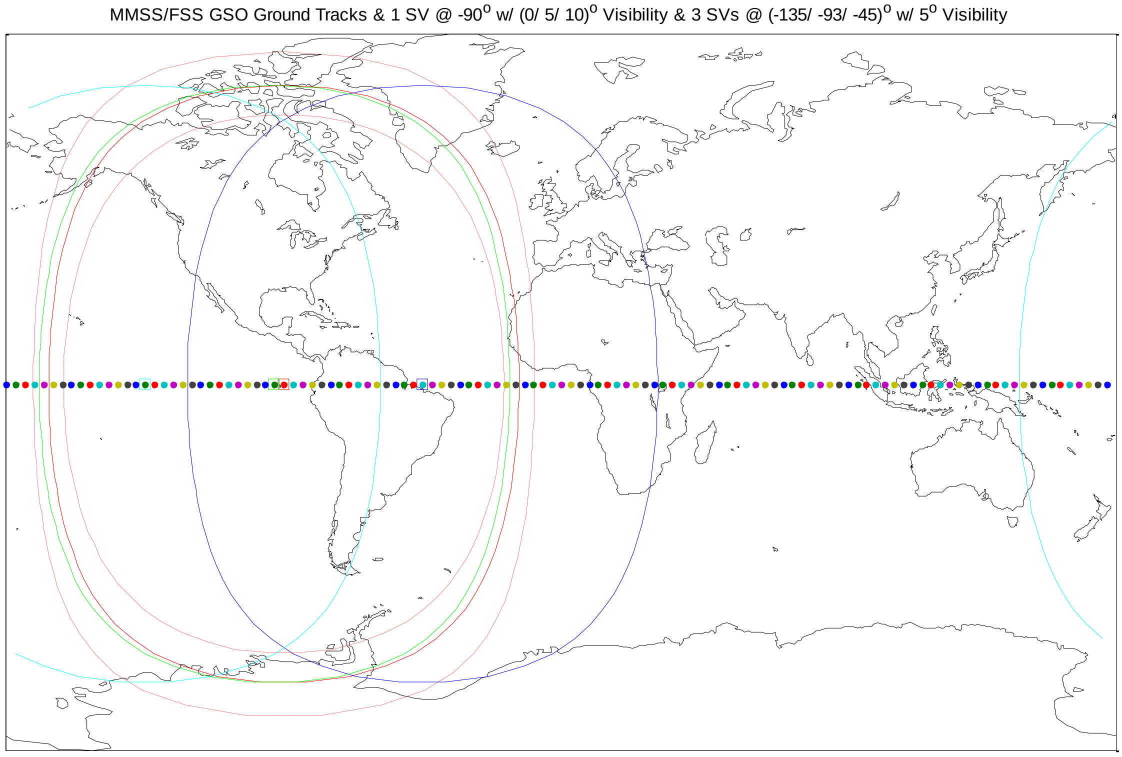
Interference assessment in PFD for the FS



For the purpose of sharing study, 120 GSO FSS+MMSS satellites with 3° spacing are used to calculate the MMSS power flux density on the surface of the earth, even if in some portions of the orbital arc more or less than 3 degrees spacing can happen. Figure 3 shows the 24 hours ground tracks of the 120 GSO satellites (along the equator), where satellite ground track points stay fixed as expected. The figure also shows 1 SV at –90° longitude with 0, 5, and 10 degrees visibility regions (red curves), and 3 SVs at –135°, –93°, and –45° longitudes with 5° visibility regions. As shown by the cyan circle, an MMSS ship-station would point through the land to communicate with that GSO satellite with elevation angles as low as 5°. Since the minimum pointing elevation of the ship-stations are specified as 10°, it is reasonable in this simulation to use this 10° elevation angle to do the sharing study.

FIGURE 3

MMSS/FSS GSO ground tracks and examples of satellite visibility



The MMSS satellite antenna gains are assumed to follow the Recommendation ITU-R S.672-4. Figure 4 plots the antenna gains at 7.5 GHz as a function of off-boresight angles for two MMSS antennas with maximum antenna gains of 20 dBi and 33 dBi.

FIGURE 4

MMSS satellite antenna gain (Rec. ITU-R S.672-4)

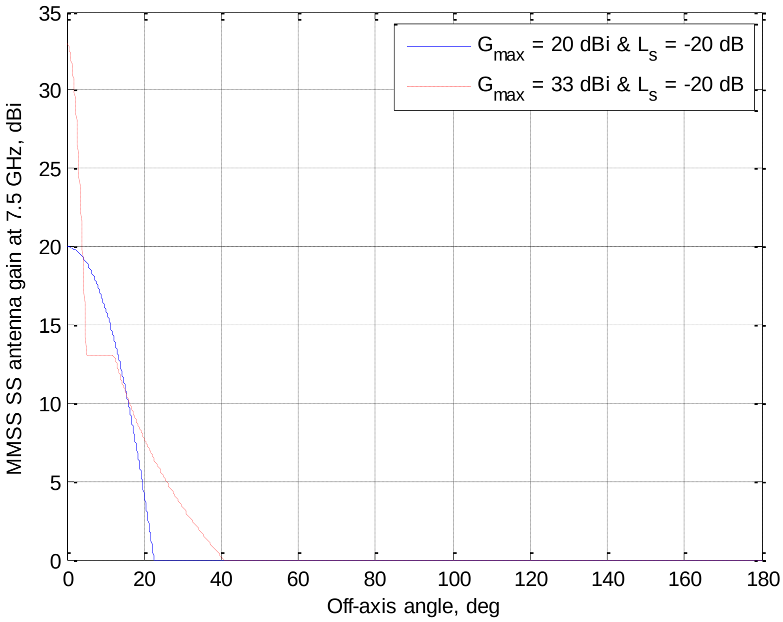
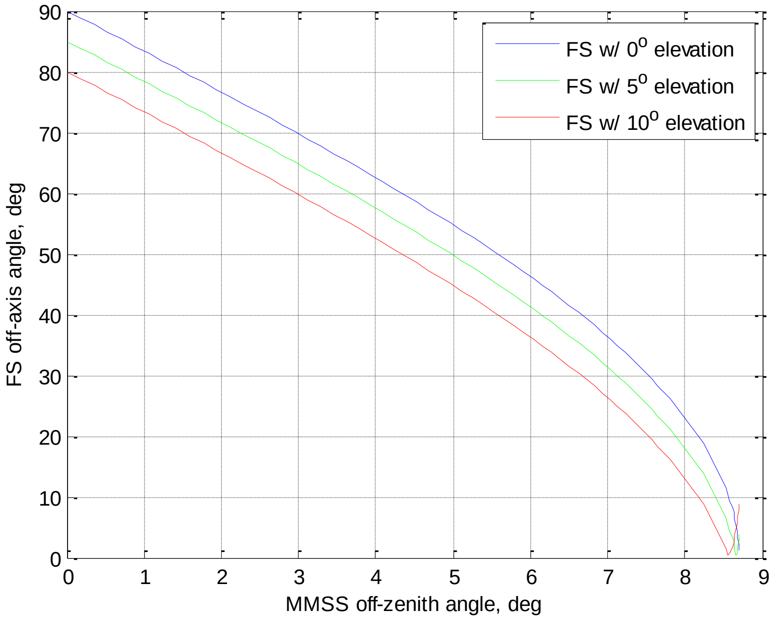


Figure 5 plots FS off-axis angle as a function of MMSS GSO off-zenith angle for three different FS elevation angles of 0, 5, and 10 degrees.

FIGURE 5

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



Figures 6A and 6B plot the MMSS GSO PFD (dBW/m^2/4 kHz) as a function of MMSS off-zenith angle and as a function of FS off-axis angle for MMSS GSO with a maximum transmit e.i.r.p. spectral density of –26 dBW/Hz and peak transmit antenna gains of 20 dBi and 33 dBi, as seen by a FS with a 0^o elevation angle. The MMSS satellite antenna gains are assumed to follow Recommendation ITU-R S.672-4, shown in Fig. 4. As shown in Fig. 6, the derived MMSS GSO PFD meets the RR Article **21** PFD limits (particularly, –152.0 dBW/m^2/4 kHz at 5^o off-axis angle).

FIGURE 6A

MMSS GSO PFD vs MMSS off-zenith angle for FS with 0° elevation angle

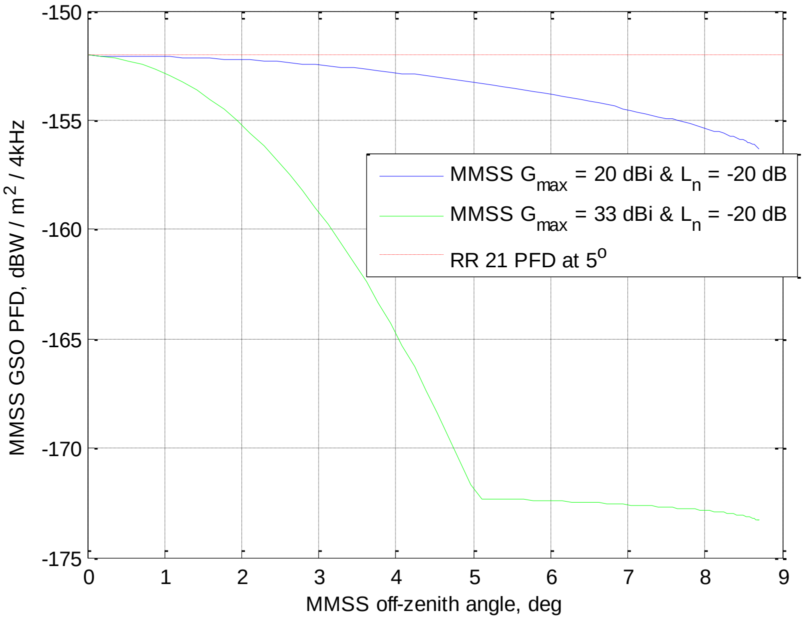
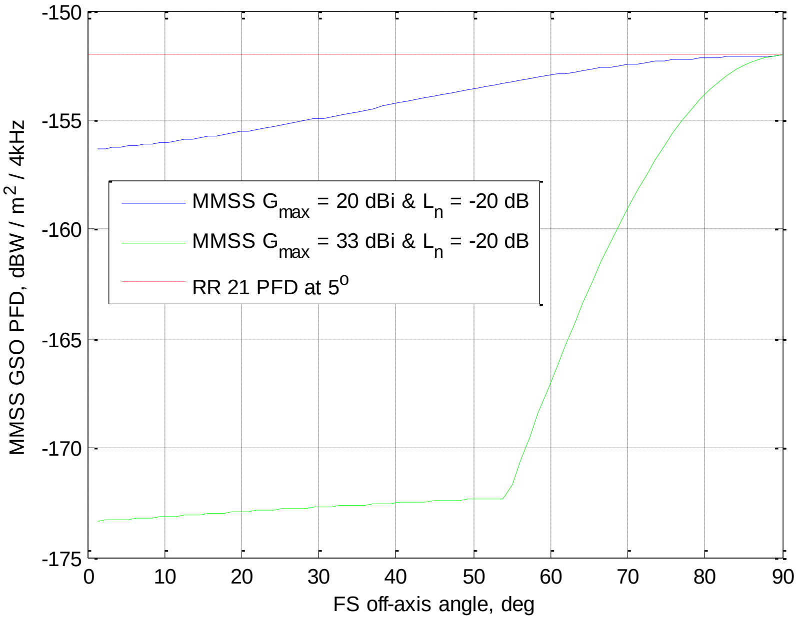


FIGURE 6B

MMSS GSO PFD vs FS-off-axis angle for FS with 0° elevation angle



3.1.1.1.3 Study 1 Sharing feasibility and regulatory methods / results

Considering the assumptions used in this analysis, the MMSS downlink power flux density is expected to meet the RR Article **21** limits for protection of the FS and sharing between FS and MMSS downlinks in the 7 GHz band may be feasible.

3.1.1.2 7 GHz FS sharing study 2

This study examines the impact of MMSS (space-to-Earth) space station into the fixed service and proposes a pfd mask which ensures the protection of the FS.

3.1.1.2.1 Study 2 Methodology

Interferences from GSO satellite are constant and long-term. In the most cases interference from GSO satellites come through the side lobes and back lobes of FS station antenna pattern. It was proposed to evaluate interference from single spacecraft. The equivalent power density of interference at the FS station input is defined as the sum of the power densities produced at the FS receive station on the Earth's surface by all the transmit stations within a geostationary-satellite system, operating co-frequency taking into account the off-axis discrimination of a reference FS receiving antenna. The equivalent power density is calculated using the following formula (see RR Nos. **22** and **22.5C.1**):

$$I_\Sigma = 10 \cdot log_{10}\left[\sum_{i=1}^{N} 10^{\frac{P_i}{10}} \cdot \frac{g_t(\varphi_i) \cdot g_{rx}(\theta_i)}{l_i}\right] \quad (1)$$

where:

- N: number of transmit stations in the GSO system that are visible from the FS receive station on the Earth's surface
- I: index of the transmit station considered in the GSO satellite system
- P_i: RF power at the input of the antenna of the transmit station, considered in the GSO satellite system (dBW) in the reference bandwidth of 1 MHz, dBW/MHz
- φ_i: off-axis angle between the bore-sight of the transmit station considered in the GSO satellite system and the direction of the FS receive station
- $g_t(\varphi_i)$: transmit antenna gain of the station considered in the GSO satellite system in the direction of the FS receive station
- θ_i: off-axis angle between the bore-sight of the antenna of the FS receive station and the direction of the *i*-th transmit station considered in the GSO system
- $g_{rx}(\theta_i)$: receive antenna gain of the FS receive station in the direction of the *i*-th transmit station considered in the GSO satellite system
- l_i: free space losses of the *i*-th interfering signal
- I_Σ: equivalent power density of the aggregate interference.

In case when interference is caused by single source, equation (1) is the following:

$$I = 10 \cdot log_{10}\left[10^{\frac{P_t}{10}} \cdot \frac{g_t(\varphi) \cdot g_{rx}(\theta)}{l}\right] \quad (2)$$

or coming from absolute to relative values:

$$I = P_t + G_t(\varphi) + G_{RX}(\theta) - L \quad (3)$$

where:

- P_t: maximum power density at the antenna input of the considered transmit station in GSO in the referenced bandwidth 1 MHz, dB (W/MHz)

$G_t(\varphi)$: transmit antenna gain of the station considered in the GSO satellite system in the direction of the FS receive station, dBi

$G_{RX}(\theta)$: receive antenna gain of the FS station in the direction of the transmit station considered in the GSO satellite system, dBi

L: free space losses in the interfering signal distribution.

The study proposed to determine a pfd mask which respect the pfd limits defined in the RR Article **21** (Table **21-4**).

The losses of the interfering signal were calculated in accordance with Recommendation ITU-R P.525. The antenna-feeder path losses, polarization losses and also fading of interfering signal in the atmosphere and hydrometeors were not taken into account.

3.1.1.2.2 Study 2 MMSS characteristics

The MMSS characteristics are defined in § 2 in Tables 1, 2, 3 and 4.

3.1.1.2.3 Study 2 Fixed service characteristics

FS station characteristics in the considered frequency band are given in Recommendation ITU-R F.758-5 and presented in Table 6 above.

The indicated characteristics were recommended to use in the sharing studies of the FS with MMSS in the frequency bands 7 375-7 750 MHz (space-to-Earth) and 8 025-8 400 MHz (Earth-to-space) in the liaison statement from ITU-R WP 5C to WP 4C "Fixed service characteristics, protection criteria and modeling for WRC-15 agenda item 1.9.2" (Document 4C/41). The LS 4C/108 also proposes to use the criterion I/N = –10 dB (for aggregate interference). It is proposed to take the FS antenna parameters from Recommendations ITU-R F.699, ITU-R F.1245 and ITU-R F.1336.

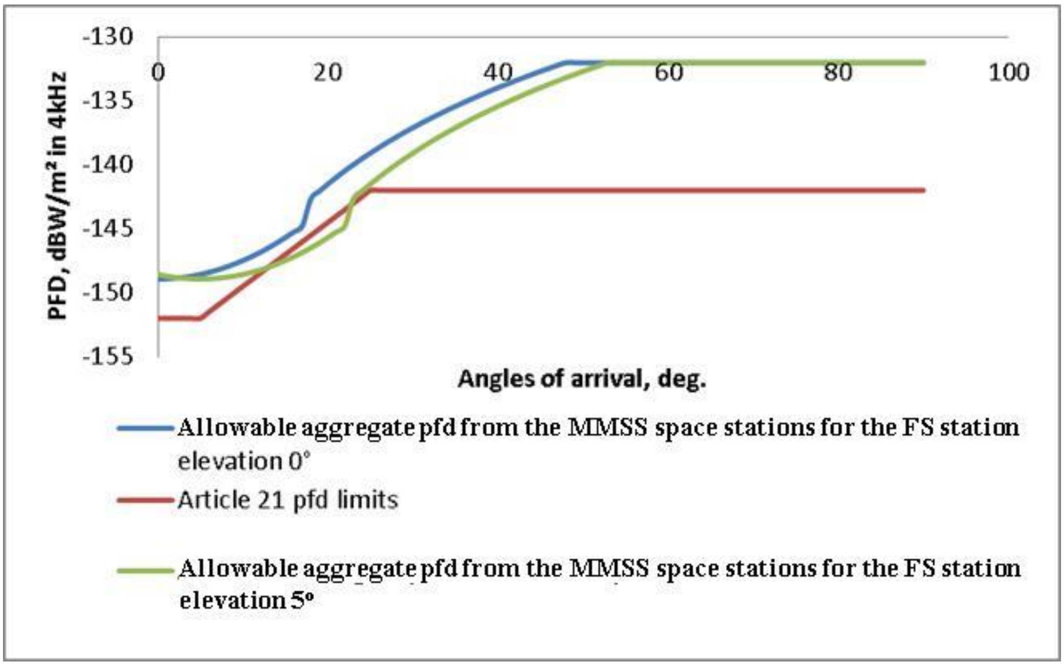
Therefore the value of the maximum allowable power density of the long-term interference at the FS station input is $(-141.5 \ldots -138.0)+I/N$ *dB(W/MHz)*. Taking into account the worst case (power density of the receiver noise, N_{RX} = –141.5 dB(W/MHz)) and the set criterion I/N = −10 dB, the maximum allowable power density of the long-term aggregate interference at the FS station input is −151.5 dB(W/MHz).

3.1.1.2.4 Study 2 Results

Figure 7 below shows the pfd masks which ensure a protection for a FS station with an elevation equal to 0° and 5°

FIGURE 7

PFD Mask to ensure protection of FS stations



3.1.1.2.5 Study 2 Sharing feasibility and regulatory methods / results

Working Party 5C draws to the attention of WP 4C to consideration being given to meet the RR Article **21** pfd limits (Table 21-4) for space services sharing with fixed service currently applied to adjacent bands where applications used in the respective services are of similar nature. This can be applied to WRC-15 agenda item 1.9.2 if the MMSS satellite is geo-stationary.

Regarding the results from the simulation, the allowable aggregate pfd masks defined are very similar to the pfd mask defined in RR Article **21**. One administration has invited WP 4C to use the following pfd mask defined in RR Article **21** (Table **21-4**) to ensure the protection of the FS service.

3.1.1.3 7 GHz FS sharing study 3

In the Radio Regulations, the band 7 375-7 750 MHz is already allocated to the fixed-satellite service (space-to-Earth) on a primary basis. In order to share with terrestrial services such as the fixed and mobile services, the provisions of RR No. **21.16** shall be applied to a space station in the fixed-satellite service in this band. Therefore, the power flux-density at the Earth’s surface produced by emissions from a space station in the fixed-satellite service in this band shall not exceed the limits in Table **21-4** of Article **21** of the Radio Regulations as shown in the following Table 7.

TABLE 7

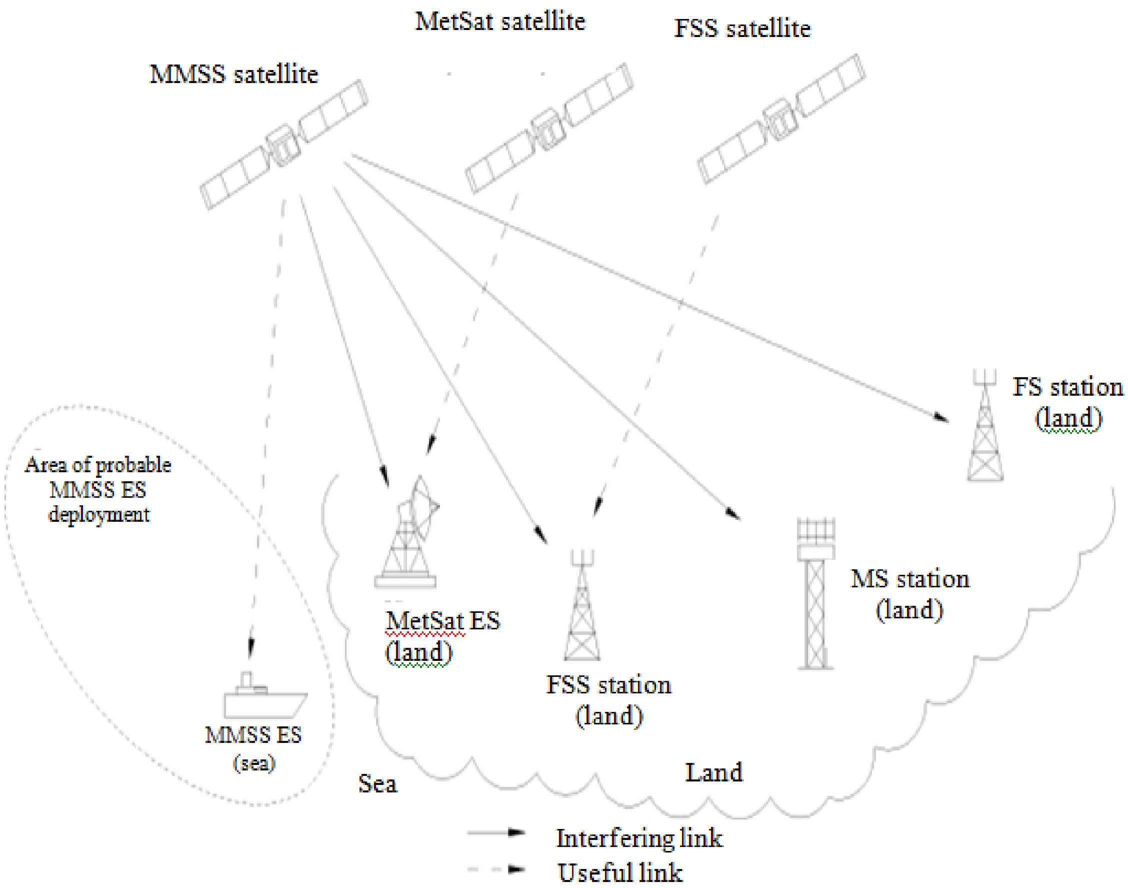
Extract from Radio Regulations Article 21 Table 21-4 specifying limits for power flux-density produced by emissions from space stations at the Earth surface

Frequency band	Service*	Limit in dB(W/m²) for angles of arrival (δ) above the horizontal plane			Reference bandwidth
		0°-5°	5°-25°	25°-90°	
4 500-4 800 MHz 5 670-5 725 MHz (Nos. **5.453** and **5.455**) 7 250-7 900 MHz	Fixed-satellite (space-to-Earth) Meteorological-satellite (space-to-Earth) Mobile-satellite Space research	−152	−152 + 0.5(δ − 5)	−142	4 kHz

Scenario of interference between envisioned MMSS (space-to-Earth) and radio services allocated in the frequency band 7 375-7 750 MHz is shown in Fig. 8.

FIGURE 8

Scenario of interference between planned MMSS (space-to-Earth) and other services allocated in the band 7 375-7 750 MHz



The conducted analysis shows that the scenarios of interference between the envisioned MMSS (space-to-Earth) and other services in the frequency band 7 375-7 750 MHz would be similar to those for FSS (space-to-Earth) and these services in the discussed frequency band. The only difference consists in additional scenario of interference between MMSS (space-to-Earth) and FSS (space-to-Earth) which is actually similar to interference scenario for different networks operating in FSS (space-to-Earth).

Since the interference characteristics from a space station in the fixed-satellite service into a station in terrestrial services are equal to those from a space station in the maritime mobile-satellite service into a terrestrial station, any additional sharing condition would not be required providing that the power flux-density limit shown above apply to a space station in the maritime mobile-satellite service in the band 7 375-7 750 MHz. Taking into account the provisions of RR No. **9.6.3**[3], in order to protect terrestrial services, the application of the provisions of RR No. **9.21** specified in RR No. **5.461** would not be required to a space station in the maritime mobile-satellite service in the band 7 375-7 750 MHz.

3.1.1.4 Study 3 Sharing feasibility and regulatory methods / results

Sharing between MMSS (space-to-Earth) and fixed service (FS) in the frequency band 7 375-7 750 MHz could be provided if the limits specified in RR Article **21** for the frequency band 7 250-7 850 MHz would be applied to MMSS.

3.1.1.5 Summary of FS sharing in the 7 375-7 750 MHz band

Multiple studies noted that the interference characteristics from a space station in the proposed MMSS into the FS are identical to the interference characteristics from a space station in the existing FSS into the FS. The FS is protected from the FSS by a pfd limit applicable to the FSS, which is given in RR No. **21.16** (Table **21-4**). It is further noted that the same pfd limit also already applies to the MSS, and thus it would also apply to the proposed MMSS.

3.1.2 Sharing with the fixed-satellite service in the 7 375-7 750 MHz band

This section addresses sharing between fixed satellite service and the maritime mobile satellite service in the 7 375-7 750 MHz band.

3.1.2.1 7 GHz FSS sharing study 1

3.1.2.1.1 Study 1 Sharing feasibility and regulatory methods / results

Since the interference characteristics between the fixed-satellite service networks are equal to those between the fixed-satellite service network and the maritime mobile-satellite service network in the down link in the band 7 375-7 750 MHz, in order to protect a station in the fixed-satellite service network, no additional sharing condition for the maritime mobile-satellite service network in this band would be required. However, taking into account the provisions of RR No. **5.461**, in order to protect the fixed-satellite service, the application of the provisions of RR No. **9.21** to the maritime mobile-satellite service in the band 7 375-7 750 MHz would be considered.

---

[3] **9.6.3** Unless otherwise specified, coordination under any of the particular sharing situations defined in Nos. **9.7** to **9.21** is not applicable when limits for that sharing situation are specified elsewhere in these Regulations. (WRC-03)

3.1.2.2 7 GHz FSS sharing study 2

3.1.2.2.1 Study 2 Sharing feasibility and regulatory methods / results

Sharing between MMSS (space-to-Earth) and FSS (space-to-Earth) in the frequency band 7 375-7 750 MHz could be provided by application of RR Article **9** (No. **9.7** specifically).

3.1.2.3 Summary of FSS sharing in the 7 375-7 750 MHz band

No technical studies regarding sharing between the MMSS and the FSS in the 7 375-7 750 MHz band have been performed. However, if MMSS operations in the band would be limited to GSO systems and the interference characteristics between MMSS and FSS would therefore be the same as between two FSS systems, sharing can be accomplished through coordination under RR Article **9**.

3.1.3 Sharing with the mobile service except aeronautical mobile in the 7 375-7 750 MHz band

This section addresses sharing between the mobile service (except aeronautical mobile) and the maritime mobile satellite service in the 7 375-7 750 MHz band.

3.1.3.1 Mobile service (except aeronautical mobile) sharing study 1

3.1.3.1.1 Study 1 Sharing feasibility and regulatory methods / results

The band 7375-7750 MHz is also allocated to the fixed-satellite service (space-to-Earth) on a primary basis. In order to share with terrestrial services such as the fixed and mobile services, the provisions of RR No. **21.16** shall be applied to a space station in the fixed-satellite service in this band. Therefore, the power flux-density at the Earth's surface produced by emissions from a space station in the fixed-satellite service in this band shall not exceed the limits in Table **21-4** of Article **21** of the Radio Regulations as shown in Table 7 of § 3.1.1.3.

Since the interference characteristics from a space station in the fixed-satellite service into a station in terrestrial services are equal to those from a space station in the maritime mobile-satellite service into a terrestrial station, any additional sharing condition would not be required providing that the power flux-density limit shown above apply to a space station in the maritime mobile-satellite service in the band 7375-7750 MHz. Taking into account the provisions of RR No. **9.6.3**[4], in order to protect terrestrial services, the application of the provisions of RR No. **9.21** specified in RR No. **5.461** would not be required to a space station in the maritime mobile-satellite service in the band 7375-7750 MHz.

3.1.3.2 Summary of mobile service (except aeronautical mobile) sharing in the 7 375-7 750 MHz band

Multiple studies noted that the interference characteristics from a space station in the proposed MMSS into the MS (except aeronautical mobile) are identical to the interference characteristics from a space station in the existing FSS into the MS (except aeronautical mobile). The existing MS (except aeronautical mobile) is protected from the FSS by a pfd limit applicable to the FSS, which is given in RR No. **21.16** (Table **21-4**). It is further noted that the same pfd limit also already applies to the MSS, and thus it would also apply to the proposed MMSS.

---

[4] **9.6.3** Unless otherwise specified, coordination under any of the particular sharing situations defined in Nos. **9.7** to **9.21** is not applicable when limits for that sharing situation are specified elsewhere in these Regulations. (WRC-03)

3.1.4 Sharing with the meteorological-satellite service (space-to-Earth) in the band 7 375-7 750 MHz

3.1.4.1 7 GHz MetSat sharing Study 1

3.1.4.1.1 Study 1 Sharing feasibility and regulatory methods / results

Since the interference characteristics between fixed-satellite service network and the meteorological-satellite service network are equal to those between maritime mobile-satellite service network and the meteorological-satellite service network in the down link in the band 7 450-7 550 MHz, in order to protect a station in the meteorological-satellite service network, no additional sharing condition for the maritime mobile-satellite service network in this band would be required. However, taking into account the provisions of RR No. **5.461**, in order to protect the meteorological-satellite service, the application of the provisions of RR No. **9.21** to maritime mobile-satellite service in the band 7 450-7 550 MHz would be considered

3.1.4.2 7 GHz Metsat sharing Study 2

3.1.4.2.1 Study 2– Sharing feasibility and regulatory methods / results

Sharing between MMSS (space-to-Earth) and meteorological-satellite service (space-to-Earth) in the frequency band 7 375-7 750 MHz could be provided by application of RR Article **9** (No. **9.7** specifically).

3.1.4.3 Summary of meteorological-satellite service sharing in the 7 375-7 750 MHz band

No technical studies regarding sharing between the MMSS and MetSats in the 7 375-7 750 MHz band have been performed. However, since MMSS operations in the band would be limited to GSO systems and the interference characteristics between MMSS and systems in the Meteorological Satellite service would be the same as between FSS and MetSat systems, it is expected that sharing could be accomplished through coordination under RR Article **9**.

3.1.5 Summary for all affected services in the 7 375-7 750 MHz band

Technical sharing studies for this band have only been performed for the fixed service. However, since the interference characteristics in the band 7 375-7 750 MHz between a space station in the fixed-satellite service and a station in the primary allocated services are equal to those between a space station in the maritime mobile-satellite service and a station in the primary allocated services, no additional sharing condition for the maritime mobile-satellite service in this band would be required except the conditions which apply to a space station in the fixed-satellite service in the band 7 375-7 750 MHz and a space station in the mobile-satellite service in the band 7 250-7 375 MHz, as specified in the provisions of RR Nos. **21.16** and **5.461**, respectively.

Therefore, existing pfd limits in Table 21-4 of RR Article **21** and the coordination requirement under No. **9.21** of the Radio Regulations to the maritime mobile-satellite service are sufficient to protect the primary allocated services in the band 7 375-7 750 MHz.

3.2 Frequency band 8 025-8 400 MHz

The allocation of this band in RR Article **5** is indicated below.

Allocation to services		
Region 1	**Region 2**	**Region 3**
8 025-8 175	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A	
8 175-8 215	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) METEOROLOGICAL-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A	
8 215-8 400	EARTH EXPLORATION-SATELLITE (space-to-Earth) FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.463 5.462A	

5.462A In Regions 1 and 3 (except for Japan), in the band 8 025-8 400 MHz, the Earth exploration-satellite service using geostationary satellites shall not produce a power flux-density in excess of the following provisional values for angles of arrival (θ), without the consent of the affected administration:

–135 dB(W/m^2) in a 1 MHz band for $0° \leq \theta < 5°$

–135 + 0.5 (θ – 5) dB(W/m^2) in a 1 MHz band for $5° \leq \theta < 25°$

–125 dB(W/m^2) in a 1 MHz band for $25° \leq \theta \leq 90°$ (WRC-12)

5.463 Aircraft stations are not permitted to transmit in the band 8 025-8 400 MHz. (WRC-97)

3.2.1 Sharing with the fixed service in the band 8 025-8 400 MHz

3.2.1.1 8 GHz FS sharing study 1

This study provides information for sharing studies between the fixed service and the proposed MMSS (E-s) in the band 8 025-8 400 MHz.

3.2.1.1.1 Study 1 – Fixed service system characteristics

There is a wide variety of fixed service systems equipment in use. The characteristics of several widely-used fixed service receivers, operating in the 7 125-8 500 MHz frequency band, are provided in Table 8.

TABLE 8

Fixed service system receivers – Specifications

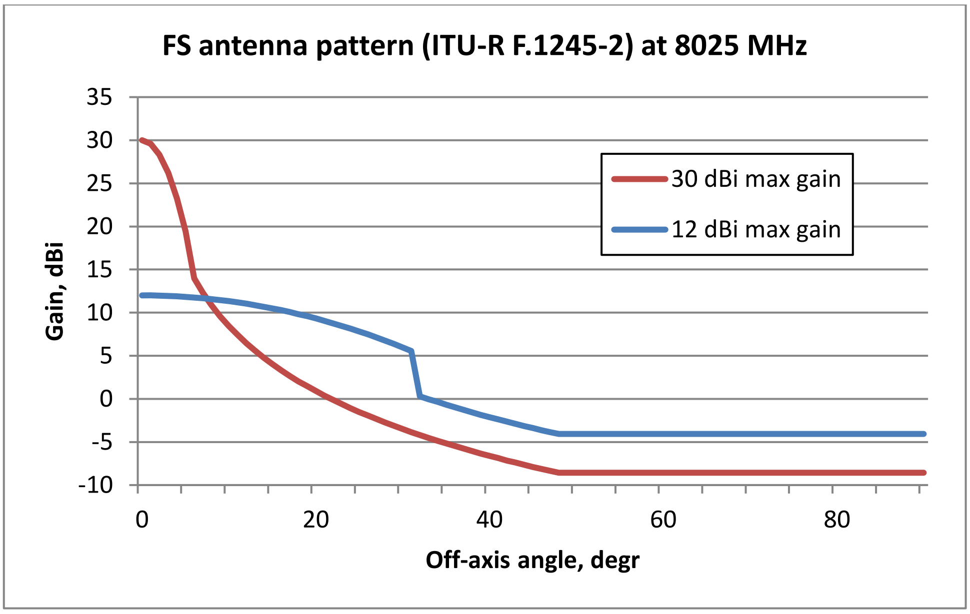
Characteristics	FR8	MDR-6508	MDR-6708
Frequency range (MHz)	7 125-8 400	7 125-8 500	7 125-8 500
Max antenna gain (dBi) – typical	30 – 40, peak gain		
IF passband (MHz): –3 dB –20 dB	44 56	1.25 to 7.5	0.8 to 5

For the purpose of establishing the sharing criteria between the fixed service systems and the proposed MMSS service, the FS system antenna patterns are assumed to follow the antenna pattern in Recommendation ITU-R F.1245-2. The fixed service systems characteristics and protection criteria are assumed to follow the systems characteristics and protection criteria in Recommendation ITU-R F.758-5.

Figure 9 shows the FS antenna patterns (Recommendation ITU-R F.1245-2) at a carrier frequency of 8 025 MHz to be used in sharing studies between FS and proposed MMSS E-s, where the peak antenna gains of 30 dBi and 12 dBi are achieved.

FIGURE 9

FS antenna patterns (Rec. ITU-R F.1245-2) at 8 025 MHz



3.2.1.1.2 Study 1 – Interference assessment

The antenna gains of the MMSS ship-born earth stations (max antenna gains of 29 dBi and 45 dBi), shown in Fig. 10, are assumed to be RR Appendix **8**, Annex III.

FIGURE 10

MMSS ES antenna gains at 8.2 GHz (RR Appendix 8, Annex III)

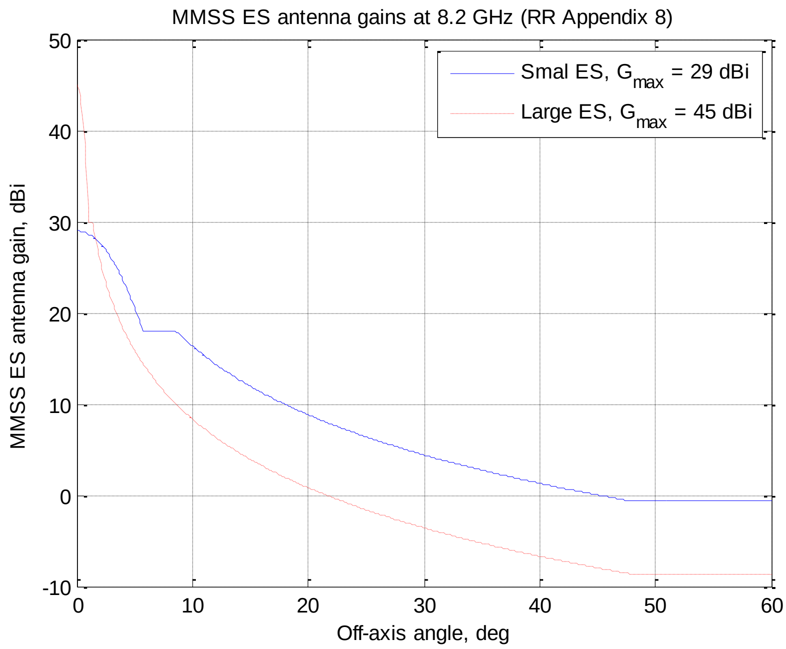
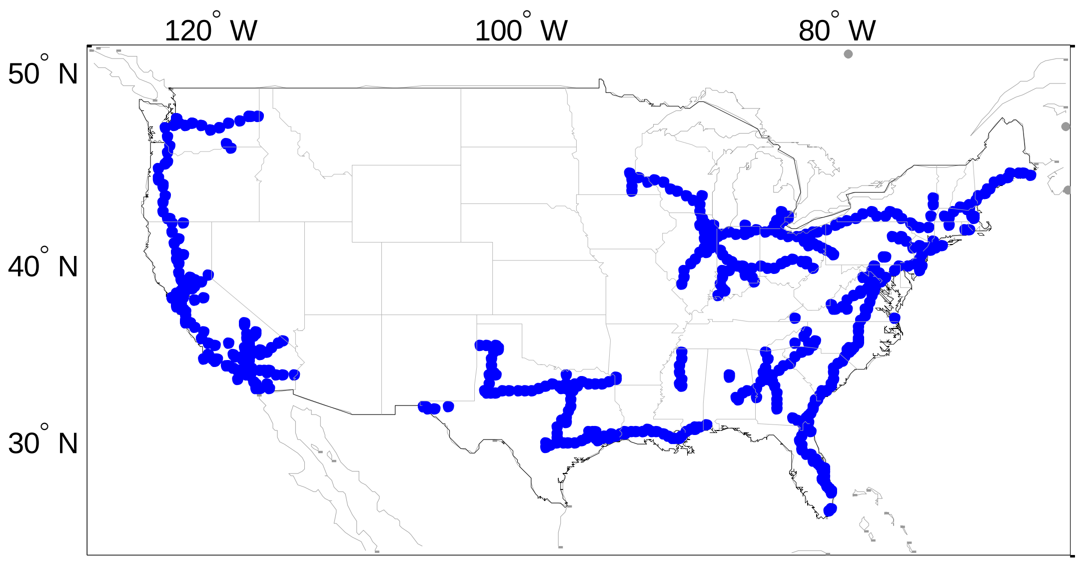


Figure 11 shows just some of the FS systems employed by one administration along the east, west, and gulf coasts of the United States as well as along the Great lakes.

FIGURE 11

Some FS systems along East/ West/ Gulf coasts and the great lakes of US



For the purpose of sharing study, the minimum pointing elevation of the ship-stations is specified as 10°.

Using the FS system parameters in Table 7b of RR Appendix **7** and the Recommendation ITU-R P.452-14 radio propagation model with p = 0.0025% to assess interference from the proposed MMSS into existing FS ground stations, the simulations are done for each FS station along the east coast and west coast of the U.S., covering the azimuths from –60 to +60 degrees towards the sea-side. Figure 12 shows the required coordination distances from the East coast of the US, equal to 313 km for MMSS ES of 20 dBW power and max antenna gain of 29 dBi into FS stations of 46 dBi max antenna gain. The 'blue' dots along the east coast and west coast are some of the representative FS stations and the 'blue' line emanating from each station is the maximum coordination distance in the 'blue' line radial direction for that station along the range of azimuths considered. The 'red' contour line for each station is the coordination distance contour between MMSS ES and each particular FS station to avoid interference. The outer bounds of all these 'red' contours will create the coordination boundary along the east coast of U.S.

FIGURE 12

MMSS ES and FS coordination distances – US East Coast

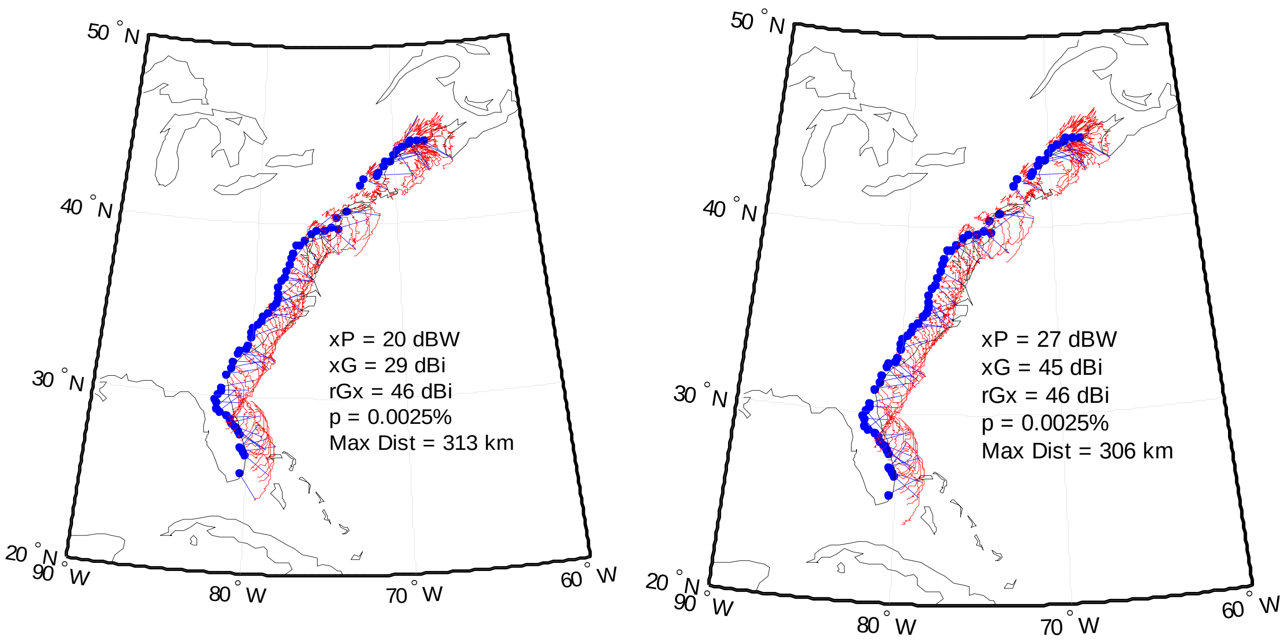


Figure 13 shows the required coordination distances from the west coast of the U.S., equal to 328 km for MMSS ES of 27 dBW power and max antenna gain of 45 dBi into to FS stations of 46 dBi max antenna gain. The outer bounds of all these 'red' contours will create the coordination boundary along the west coast of U.S.

FIGURE 13

MMSS ES and FS coordination distances – U.S. West Coast

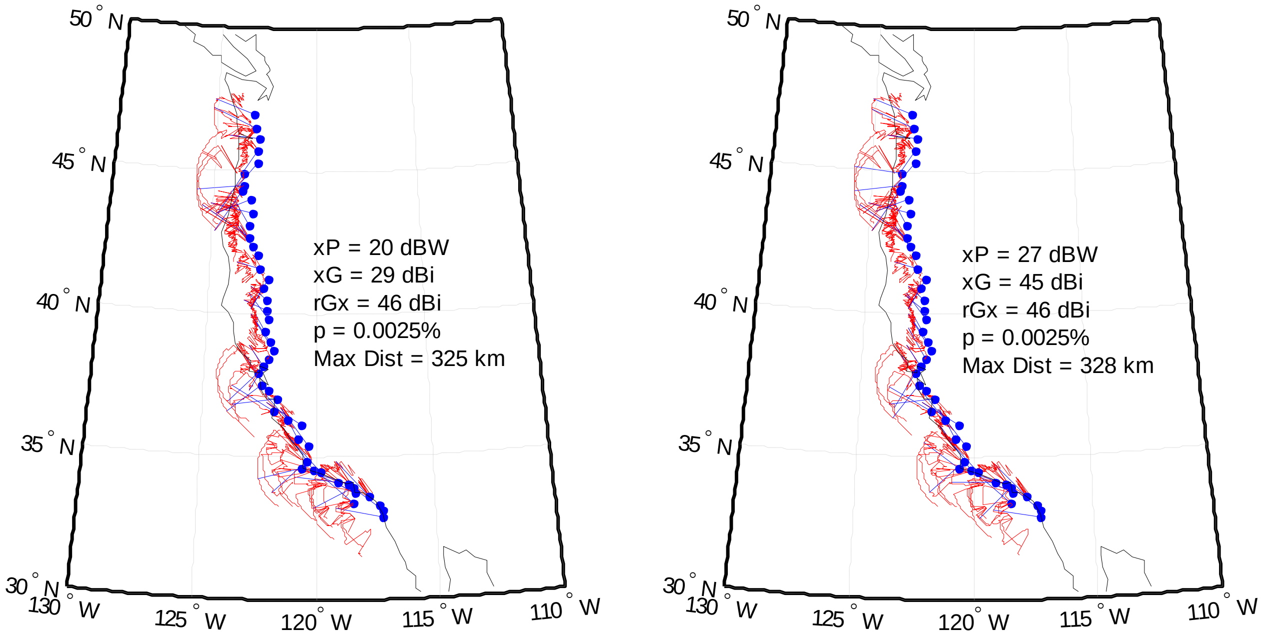
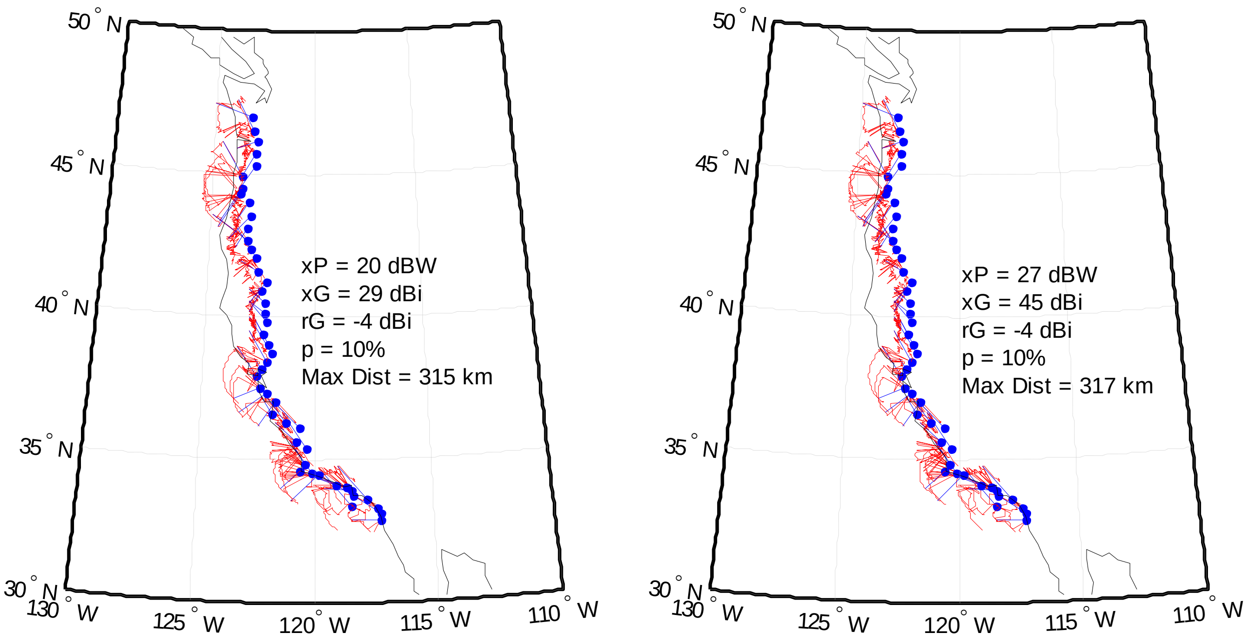


Figure 14 shows the required coordination distance from the west coast of the U.S., equal to 317 km for MMSS ES of 27 dBW power and max antenna gain of 45 dBi into FS stations with –4 dBi backlobe antenna gain, considering the long-term FS protection criteria specified in the Recommendation ITU-R F.758-5. The outer bounds of all these 'red' contours will create the coordination boundary along the west coast of U.S.

FIGURE 14

MMSS ES and FS separation distances – U.S. West Coast



3.2.1.1.3 Study 1 Sharing feasibility and regulatory methods / conclusion

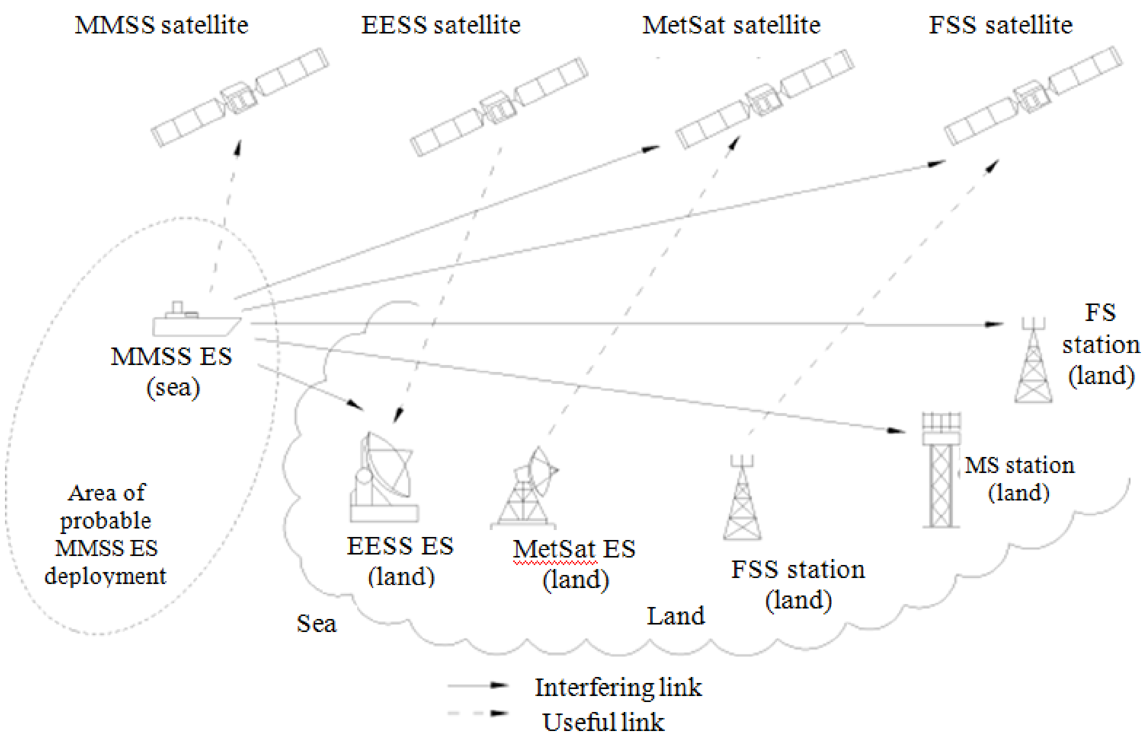
Based on the results in the study 1 above, the calculated coordination distance of 317 km from the coasts of the U.S. is required to protect FS stations from one MMSS ES. It is noted that there are 4 primary services sharing the 8 025-8 400 MHz frequency band, namely, EESS (s-E), FS, FSS (E-s), and MS. Some of systems in these services could potentially interfere with a FS system in addition to multiple MMSS earth stations. Hence, the separation distance is larger than the separation distance due to a single MMSS ES alone. These results should be taken into account, should a primary MMSS allocation in the Earth-to-space direction be considered in this frequency band.

3.2.1.2 8 GHz FS sharing study 2

Scenario of interference between envisioned MMSS (Earth-to-space) and radio services allocated in the frequency band 8 025-8 400 MHz is shown in Fig. 15.

FIGURE 15

Scenario of interference between envisioned MMSS (Earth-to-space) and other services allocated in the band 8 025-8 400 MHz



The conducted analysis shows that the scenario of interference between the envisioned MMSS (Earth-to-space) and other services in the frequency band 8 025-8 400 MHz would be similar in many aspects to those for FSS (Earth-to-space) and the same services in the discussed frequency band.

The only difference consists in the fact that MMSS (Earth-to-space) mobile earth station which can move within a certain service area should be considered instead of a fixed or typical station operating in FSS.

3.2.1.2.1 Study 2 Sharing feasibility and regulatory methods / conclusion

Protection of Fixed service from interference caused by envisioned MMSS (Earth-to-space) in the frequency band 8 025-8 400 MHz could be provided on the basis of applying the existing regulatory provisions of RR Article **9** (No. **9.17** in particular) and by using alternative mechanism of protection distances specified for MMSS earth stations. In this case it would require determining appropriate performances of MMSS and FS for incorporation into RR Appendix **7** or for calculation of predetermined coordination distances.

3.2.1.3 Summary of fixed service sharing in the 8 025-8 400 MHz band

Sharing between FS and MMSS uplinks in the 8 025-8 400 MHz band requires a minimum separation distance to protect the FS receiver. The distances calculated using the approach contained in RR Appendix **7** can be large and for the systems of one administration have been determined to be on the order of 306-328 km from the coasts, considering potential interference from a single MMSS earth station. It is noted that an FS station could receive interference from multiple MMSS stations transmitting simultaneously, and that in this circumstance, the required distance required to protect the FS station could be even greater. These results should be taken into account, should a primary MMSS allocation in the Earth-to-space direction be considered in this frequency band.

3.2.2 Sharing with the fixed-satellite service (Earth-space) in the 8 025-8 400 MHz band

This section addresses MMSS sharing with the FSS in the 8 GHz band.

3.2.2.1 8 GHz FSS sharing study 1

3.2.2.1.1 Study 1 Sharing feasibility and regulatory methods / conclusion

Sharing between MMSS (Earth-to-space) and FSS (Earth-to-space) in the frequency band 8 025-8 400 MHz could be provided by application of RR Article **9** (No. **9.7** specifically).

3.2.2.2 Summary of fixed satellite service sharing in the 8 025-8 400 MHz band

No technical studies have been conducted to examine MMSS sharing with the FSS in the 8 025-8 400 MHz band. However, since MMSS operations in the band would be limited to GSO systems and the interference characteristics between MMSS and FSS would therefore be the same as between two FSS systems, it is expected that sharing could be accomplished through coordination under RR Article **9**.

3.2.3 Sharing with the mobile (except aeronautical mobile) service in the 8 025-8 400 MHz band

This section addresses MMSS sharing with the mobile service.

3.2.3.1 8 GHz Mobile service (except aeronautical mobile) sharing study 1

This study examines the suitability of using the regulatory provisions of RR article **9** to protect systems in the MS from interference originating from the MMSS.

3.2.3.1.1 Study 1 Sharing feasibility and regulatory methods / conclusion

Protection of Mobile service from interference caused by envisioned MMSS (Earth-to-space) in the frequency band 8 025-8 400 MHz could be provided on the basis of applying the effective regulatory provisions of RR Article **9** (No. **9.17** in particular) and by using alternative mechanism of protection distances specified for MMSS earth stations. In this case it would require determining appropriate performances of MMSS and MS for incorporation into RR Appendix **7** or for calculation of predetermined coordination distances.

3.2.3.2 Summary of mobile (except aeronautical mobile) service sharing in the 8 025-8 400 MHz band

No technical studies have been conducted regarding the feasibility of sharing between the proposed MMSS (E-s) and the mobile (except aeronautical mobile) service in the band 8 025-8 400 MHz.

3.2.4 Sharing with the meteorological-satellite service in the 8 025-8 400 MHz band

This section presents the results of one study into mechanisms for sharing between MMSS and MetSat in the band.

3.2.4.1 8 GHz Metsat Sharing Study 1

This study considers sharing between MMSS and MetSat systems in the 8 GHz band.

3.2.4.1.1 Study 1 Sharing feasibility and regulatory methods / conclusion

Sharing between MMSS (Earth-to-space) and MetSat (Earth-to-space) in the frequency band 8 025-8 400 MHz could be provided by application of RR Article **9** (No. **9.7** specifically).

3.2.4.2 Summary of meteorological satellite service sharing in the 8 025-8 400 MHz band

No technical studies have been conducted to examine MMSS sharing with the meteorological satellite service the 8 025-8 400 MHz band. However, since MMSS operations in the band would be limited to GSO systems and the interference characteristics between MMSS and MetSats would therefore be the same as between FSS and MetSat systems, it is expected that sharing between the MMSS and the meteorological satellite service could be accomplished through coordination under RR Article **9**.

3.2.5 Sharing with the Earth exploration-satellite service (space-to-Earth) in the 8 025-8 400 MHz band

This section addresses the potential for interference from MMSS uplinks in the 8 025-8 400 MHz band into EESS earth stations. Two separate studies are presented. EESS 8 GHz Sharing Study 1 in section 3.2.5.1 calculates the minimum required separation distances between an MMSS transmitter and a number of existing EESS earth stations needed to protect against harmful interference. EESS 8 GHz Sharing Study 2 in section 3.2.5.2 demonstrates the application of calculation methods in RR Appendix **7** for determination of coordination contours for an MMSS transmitter operating in a defined region or for a particular EESS earth station.

3.2.5.1 8 GHz EESS Sharing Study 1

A number of independent analyses have been performed to investigate the potential for sharing between MMSS uplinks and EESS downlinks in the band 8 025-8 400 MHz. For the most part, these analyses have employed similar modeling approaches and assumptions regarding system characteristics in determining the required separation between the MMSS transmitter and the EESS earth station in order to prevent harmful interference. The multiple analyses have determined the required distances for a large number of EESS earth stations located globally and produced consistent results which are documented in summary form in this section.

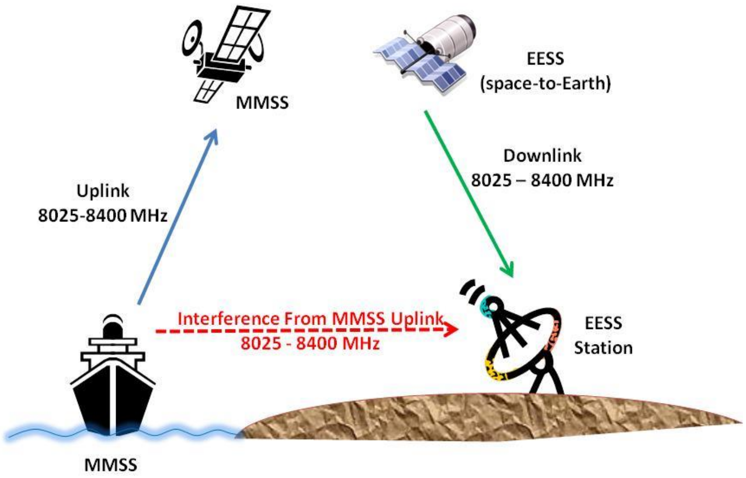
For each of the analyses performed, a detailed description of the approach and any unique parameter value assumptions are provided in an associated section of Annex 2. These sections also contain detailed results including figures depicting locations of EESS earth stations and the corresponding areas in which an MMSS transmitter would cause harmful interference to the EESS station. Interference scenarios involving both NGSO and GSO MMSS systems are considered. It should be noted that no parameters and no characteristics of NGSO MMSS systems that might operate in the considered frequency band have been provided. As a consequence the characteristics used in the study are derived from the GSO MMSS systems.

3.2.5.1.1 Analysis Methods

Figure 16 shows the potential interference scenario to an EESS earth station.

FIGURE 16

Interference scenarios from proposed MMSS allocations to EESS



For all the EESS earth stations studied, the same basic approach defined in Rec. ITU-R SA.1277 was used to calculate the required separation distance between the EESS and the MMSS earth stations in order to satisfy the EESS protection criteria. For each EESS station, a simulation was performed in which the MMSS station was randomly located within some area around the victim EESS station and a calculation of the interference power from the MMSS station received by the EESS station was performed. This level was a function of transmit e.i.r.p. (see discussion of e.i.r.p. density levels below), EESS and MMSS antenna pointing (see discussion of GSO vs NGSO cases below) and terrain-dependent propagation losses determined using Rec. ITU-R P.452.

In the case of the Maspalomas, Kourou, and Santa Maria stations, an additional analysis was performed using a slightly different approach which provided statistical information of the portion of MMSS station locations from which harmful interference levels were realized in the simulations.

As described in the Annex, two separate cases, defined by the assumed MMSS earth station transmit power density, are studied. In Case 1, the transmit power density is calculated from the typical MMSS system parameters provided in section 2 of this document. In Case 2, the MMSS earth station transmit power density is calculated from the ITU RR No. **21.8** constraint on the maximum e.i.r.p. density towards the horizon. The power density for Case 1 is considerably lower than that for Case 2 and is reflected in the minimum separation distances reported below.

As described above, analyses are performed for NGSO and GSO MMSS networks. For NGSO MMSS networks, the MMSS antenna is assumed to be pointed at its minimum allowed elevation angle and at the azimuth towards the EESS station. For GSO MMSS networks, the MMSS antenna is assumed to be pointed to a satellite on the GSO arc. For most stations studied, the precise location (longitude) of the GSO MMSS satellite which results in the largest amount of interference is used in the simulations. For the additional results provided for the Maspalomas, Kourou, and Santa Maria stations, the MMSS station antenna was assumed to be pointed to a specific FSS satellite.

3.2.5.1.2 EESS earth station characteristics

The EESS earth station parameters used in the simulations are given in Table 9.

TABLE 9

Parameters used for all EESS earth stations

ESS Parameter	Values	Units	Notes
Frequency(1)	8.2	GHz	Assumed receive frequency for all stations and transmit frequency for MMSS
Min. tracking angle(2)	5	deg	Antenna minimum tracking angle
Antenna diameter	4.2 / 7.3 5.4 15	m	HaiNan station Prudhoe Bay station All other stations
Antenna Height	5 6.7 20	m	From dish antenna center to ground HaiNan, station Prudhoe Bay station All other stations
Antenna gain pattern	ITU-R S.465 ITU RR AP **8-10** Annex III		The antenna gain is estimated at 5 degrees elevation angle HaiNan, station All other stations
Antenna gain towards MMSS	38 −9.61 14.53	dBi	Fixed value HaiNan station Korean station All other stations
Permissible interference level((3,4,5)	–133	dBW/10 MHz	Rec. ITU-R SA.1027
Probability of exceedence (*p*)(3,4,5)	0.005	%	Rec. ITU-R SA.1027

(1) Frequency used for HaiNan and US Worldview system analyses are in band 8 025-8 400 MHz.

(2) Korean EESS system includes a GSO satellite, earth station elevation = 46.17 deg.

(3) Rec. ITU-R SA.1027 criteria is for the terrestrial interference path and the short term (p = .005%) level was used as it is the driving case.

(4) The analysis performed for HaiNan and Korean stations used ITU-R SA.514 with a permissible interference level of –214 dB(W/Hz) to be exceeded no more than 1% of the time.

(5) US Worldview system analysis calculated separation distances based on both short term (p = .005% of time corresponding to I/N = –0.8 dB) and long term criteria (p = 20% of time corresponding to I/N =-10 dB) criteria (from Recommendation ITU-R SA.1022-1) due to criticality of reliable data transmission over satellite links to high latitude earth stations.

The band 8 025-8 400 MHz is heavily used by all space agencies, including government and private companies, to download data obtained by EESS satellites. Future EESS missions will continue to use this band. The Space Frequency Coordination Group (SFCG) maintains a database on a best effort basis to provide an overview of all EESS missions operating in the 8 025-8 400 MHz range. This database includes mainly Administration-sponsored scientific missions, and cover commercial missions to a limited extent. The SFCG database currently includes 100 operational missions, plus dozens of missions in development phase.

There are two types of EESS users of that band, one requiring wideband communications (100 to 1 200 megabits/second) and the other requiring moderate data rates (15-20 megabits/s). A list of EESS earth stations is provided in Annex 1.

While inland EESS earth stations may not be impacted by the MMSS, coastal sites – of which there are many – are vulnerable. Depending upon the topography of the terrain surrounding an earth station and the elevation of the earth station, areas of concern may include EESS earth stations located several hundred kilometers inland from the coast itself.

The elements provided in the sections below take into account the EESS earth stations known at the time this report was drafted. It should be pointed out that the locations of other earth stations are not known, because they are not registered, and do not require a license if they are receive-only.

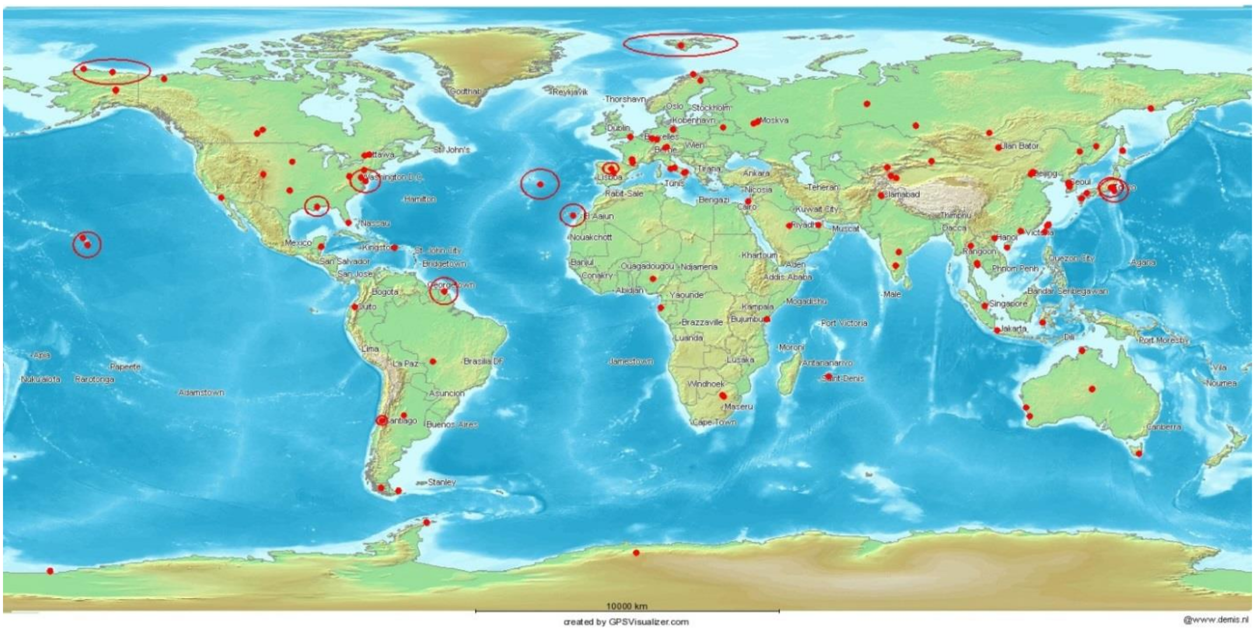
3.2.5.1.2.1 Wideband, high data-rate science data downlinks

The wideband data links are crucial to the Earth observing community as they are used to transmit the data collected and stored on-board EESS satellites to the ground, where it can be processed and analyzed. The stored data are transmitted at rates up to 1 200 megabits/second. As the data include error-correcting coding, bandwidths of up to 375 MHz may be required. Some instruments (e.g., the Enhanced Thematic Mapper on Landsat-7) have data rates that require wideband data links to send their real-time data to the ground. Earth stations with wideband capability typically require antennas at least 10 meters in diameter and have both receive and transmit capabilities, although the commanding is usually done using S-band. These stations are the primary data downlink stations for the EESS satellites that they service. Their locations are known, and they are expected to remain a permanent part of the EESS communications infrastructure.

Many of these stations are located at a high latitudes to maximize the number of daily passes from low-Earth, polar-orbiting satellites. Most of the EESS satellites using X-band are in sun-synchronous orbits which require such near-polar orbits. Over 100 earth stations have this capability. The locations of these stations are shown on Fig. 17 and are listed in Table A1-1 of Annex 1. Note that several stations may be near each other and may appear as one location in the figure. Calculated zones of exclusion are included for a small sample of those stations.

FIGURE 17

High data-rate X-band EESS earth stations (s-E) and calculated exclusion zones for some stations



The receiving earth stations are spread worldwide. There are many stations located in coastal areas which would be susceptible to interference from nearby MMSS Earth-to-space transmissions as shown in the interference studies.

As an example, ESA owns X-band stations in Maspalomas, Canary Islands, 2 km from the coast; Kourou, French Guyana, less than 6 km from the coast; Perth, Australia, less than 8 km from the coast; and Santa Maria, Azores, 500 m from the coast. In addition, EESS missions are supported by earth stations located in Norway, Hawaii, northern Alaska, and Antarctica. All are located close to the sea and need to be protected from harmful interference from transmitting MMSS earth stations that might operate in the band, should an allocation be accepted by WRC-15.

Globally, there are many earth stations that may be employed for tracking EESS satellites, with each station possibly having multiple antennae (see Annex 1 for a list of such stations). Table 10 lists a small sample of stations which have been analyzed.

TABLE 10

Sample EESS stations capable of operating in the 8 025 to 8 400 MHz band

Ground station name	Country	Ground station Lat (deg N)	Ground station Long (deg E)
Santiago	Chile	–33.15	–70.67
Beijing	China	40.45	116.90
Hatoyama	Japan	36.02	139.33
Katsuura	Japan	35.21	140.30
Svalbard	Norway	78.23	15.40
Valladolid	Spain	41.65	–4.72
Prudhoe Bay	USA	70.22	–148.40
South Point	USA	19.00	–155.66
Stennis Space Center	USA	30.37	–89.45
Wallops	USA	37.93	–75.48
Maspalomas	Spain	27.76	–15.63
Kourou	France	5.25	–52.81
Santa Maria	Portugal	37.00	–25.14
HaiNan	China	18.3	109.4
Daejon	Korea	36.38	127.35
Worldview System	US	70.22	148.40

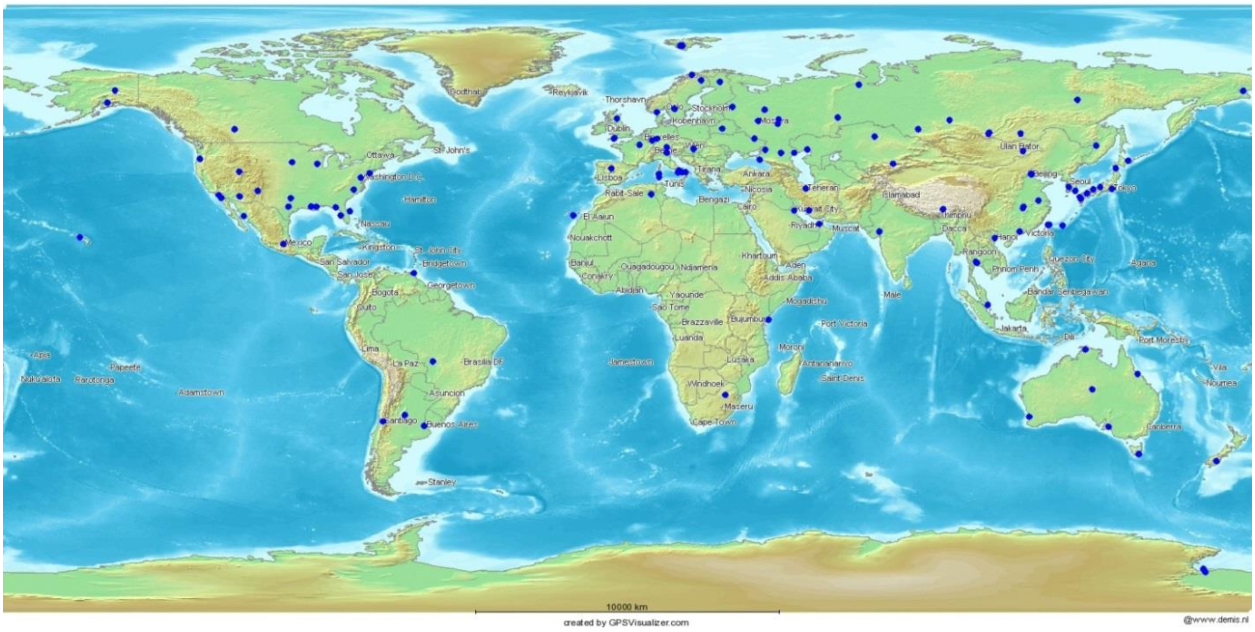
3.2.5.1.2.2 Narrow-band, moderate data-rate science data downlinks

These links provide real-time data transmitted directly from the satellite to any earth station with a direct line-of-sight to the satellite. These real-time data systems are called “direct readout” (DRO) or “direct broadcast” (DB) systems (see: http://directreadout.sci.gsfc.nasa.gov/). Their data-rates are 13 to 15 megabits/second, and the required antenna is typically 3 meters in diameter. Such EESS earth station systems are commercially available, and they include everything from the antenna system through the data processing equipment (both hardware and software). Over 130 direct readout earth stations are known to be in use today.

These systems provide immediate observations of the local environment and are used for tasks ranging from forecasting weather to monitoring plant health to directing fire fighters battling wildland fires. As these are receive-only stations, they need not be licensed and hence all of their locations may not be known. The known stations are shown on Fig. 18 and listed in Table A1-2 of Annex 1.

FIGURE 18

Direct readout-direct broadcast X-band EESS earth stations (s-E)



3.2.5.1.3 Study 1 Sharing feasibility and regulatory methods / conclusion

These studies, detailed in Annex 2, show that an allocation to the maritime mobile satellite service in the band 8 025-8 400 MHz can create a potential for harmful interference to a certain number of receiving EESS earth stations located in proximity to coasts worldwide. In such cases MMSS earth stations would operate within the exclusion zone identified to protect these EESS earth stations. From a list of over 100 known EESS earth stations, a small subset of EESS earth stations was examined. Most EESS earth stations that were within 100 km of the coast would require significant separation distance to prevent interference from MMSS operations.

For NGSO MMSS systems operating under Case 1 assumptions (where the MMSS station transmit power is based on the system characteristics given in section 2 of this document), the required separation distances for the sample EESS earth stations considered in this document are in the range of between 148 km and 544 km depending upon the geographical characteristics surrounding the EESS earth station. Similarly for GSO MMSS systems operating under Case 1 assumptions, the range is from 78 km to 484 km. These results are shown in Table 11 below.

TABLE 11

Required separation distance results for Case 1 transmitter power density

Ground station name	Country	Relevant Annex 2 section	EESS station approx distance to shore (km)	Required separation distance determined using typical MMSS e.i.r.p. values for NGSO MMSS systems (Table 2.1-1)		Required separation distance determined using typical MMSS e.i.r.p. values for GSO MMSS systems (Table 2-1-1)	
				Distance from ES (km)(1)	**Distance from Shore (km)(2)**	**Distance from ES (km)(1)**	**Distance from Shore (km)(2)**
Maspalomas	Spain	A2.2	< 5	495		360	
Kourou	France	A2.2	< 10	540		440	
Santa Maria	Portugal	A2.2	< 10	484		484	
Santiago	Chile	A2.2	85	148(3)	0	122(3)	0
Beijing	China	A2.2	165	207(3)	0	78(3)	0
Hatoyoma	Japan	A2.2	110	422	312	314	207
Valladolid	Spain	A2.2	195	246(3)	0	191(3)	0
South Point	USA	A2.2	5	478	478	417	417
Stennis Space Center	USA	A2.2	5	446	418	327	294
Wallops	USA	A2.2	10	469	485	379	374
Katsuura	Japan	A2.2	5	456	439	374	308
Prudhoe Bay	USA	A2.2	< 5	414	336	256	241
Svalbard	Norway	A2.2	< 5	544	509	368	319
HaiNan	China	A2.3	100	410			
Worldview station(4)	US	A2.5				Long Term d 20%: 278 Short Term d .005%: 545	

(1) Required separation distance between the MMSS transmitter and the EESS station in the direction of the nearest shoreline.

(2) Required separation distance between the MMSS transmitter and the nearest point on the shoreline. This can be greater or lesser than the distance to the EESS station depending on the location of the EESS station and the shape of the shoreline.

(3) For these stations, the EESS antenna is sufficiently inland that the separation distance does not reach the shoreline. The distances shown are over land.

(4) Results are for the worst case month. Separation distance requirement driven by short term criteria due to criticality of link.

For Case 1, an additional analysis based on a Monte Carlo methodology was performed for three of the earth stations. Results are shown in Table 12.

TABLE 12

Statistical distribution of required separation distance results for Case 1 transmitter power density

Station	Country	Relevant Annex 2 section	Percent of MMSS station locations causing harmful interference (%)	Separation Distance (km)
Maspalomas	Spain	A2.6	0.95	200
			0.43	300
			0	440
Kourou	France		0.77	200
			0.41	300
			0	450
Santa Maria	Portugal		1.41	200
			0.82	300
			0	500

It should be noted that the Monte-Carlo methodology used in this study determines the geometric probability of harmful interference to an EESS earth station based on a single randomly positioned MMSS earth station in a defined area around the EESS station. This differs from the other 8 GHz sharing studies which calculate a maximum separation distance between the EESS and MMSS earth stations needed to satisfy the Recommendation ITU-R SA.1027 sharing criteria defined for a percentage of time, assuming a single MMSS earth station and using the methodology defined in Recommendation ITU-R SA.1277. The geometric probability of harmful interference cases is not the same as the percent of time the EESS earth station sharing criteria is exceeded. Nevertheless the results highlight that MMSS earth stations located within the exclusion area defined by the maximum separation distance do not necessarily create harmful interference into the receiving EESS earth station all the time.

In the same fashion, Table 13 provides the maximum required separation distances when the MMSS transmitters operate using Case 2 assumptions (with the maximum allowed e.i.r.p. density determined by ITU RR No. **21.8** towards the horizon). Maximum required separation distances range from 198 km to 892 km for NGSO MMSS systems and from 237 km to 850 km for GSO MMSS systems.

Similar distances might be expected for the other EESS earth stations located within one hundred km or more from the coast worldwide. These separation distances have been computed using Recommendation ITU-R SA.1277 which is close to a Time Invariant Gain (TIG) methodology, and gives a relatively larger distance than what would be determined using a Time Variable Gain (TVG) methodology developed to cover non-GSO satellite victim systems, noting that the protection criteria from Recommendation ITU-R SA.1027 cover only non-GSO satellites.

TABLE 13

Required separation distance results for Case 2 transmitter power density

Ground station name	Country	Relevant Annex 2 section	EESS station approx distance to shore (km)	Required separation distance determined using max allowable e.i.r.p. values as determined by ITU RR No. 21.8 for NGSO MMSS systems		Required separation distance determined using max allowable e.i.r.p. values as determined by ITU RR No. 21.8 for GSO MMSS systems	
				Distance from ES (km)(1)	Distance from Shore (km)(2)	Distance from ES (km)(1)	Distance from Shore (km)(2)
Maspalomas	Spain	A2.2	< 5	850		850	
Kourou	France	A2.2	< 10	850		830	
Santa Maria	Portugal	A2.2	< 10	860		830	
Santiago	Chile	A2.2	85	385	264	237	60
Beijing	China	A2.2	165	300	66	266	0
Hatoyoma	Japan	A2.2	110	576	509	530	415
Valladolid	Spain	A2.2	195	525	262	318	126
South Point	USA	A2.2	5	653	653	616	616
Stennis Space Center	USA	A2.2	5	609	584	541	492
Wallops	USA	A2.2	10	609	657	558	572
Katsuura	Japan	A2.2	5	627	634	579	553
Prudhoe Bay	USA	A2.2	< 5	523	535	461	487
Svalbard	Norway	A2.2	< 5	892	834	718	670
Daejon	Korea	A2.4		198			

(1) Required separation distance between the MMSS transmitter and the EESS station in the direction of the nearest shoreline.

(2) Required separation distance between the MMSS transmitter and the nearest point on the shoreline. This can be greater or lesser than the distance to the EESS station depending on the location of the EESS station and the shape of the shoreline.

This study shows that even when transmitting at the lower Case 1 power density, an MMSS station at a distance from a receiving EESS earth station of less than 544 km (when transmitting to an NGSO MMSS satellite) or 417 km (when transmitting to a GSO MMSS satellite) can cause harmful interference into the EESS system.

The inputs received stated that a minimum seaborne transmitting antenna elevation was 10 degrees above the horizon. This minimum antenna elevation limits MMSS service to below 71.4 degrees of latitude when looking due South (Arctic) or North (Antarctic). However, EESS earth stations track satellites down to 5 degrees above the horizon, not 10 degrees. Communications using MMSS antenna elevation angles less than 10 degrees are possible, although not as robust, and such communications pose a much higher risk of interference to the high latitude EESS earth stations.

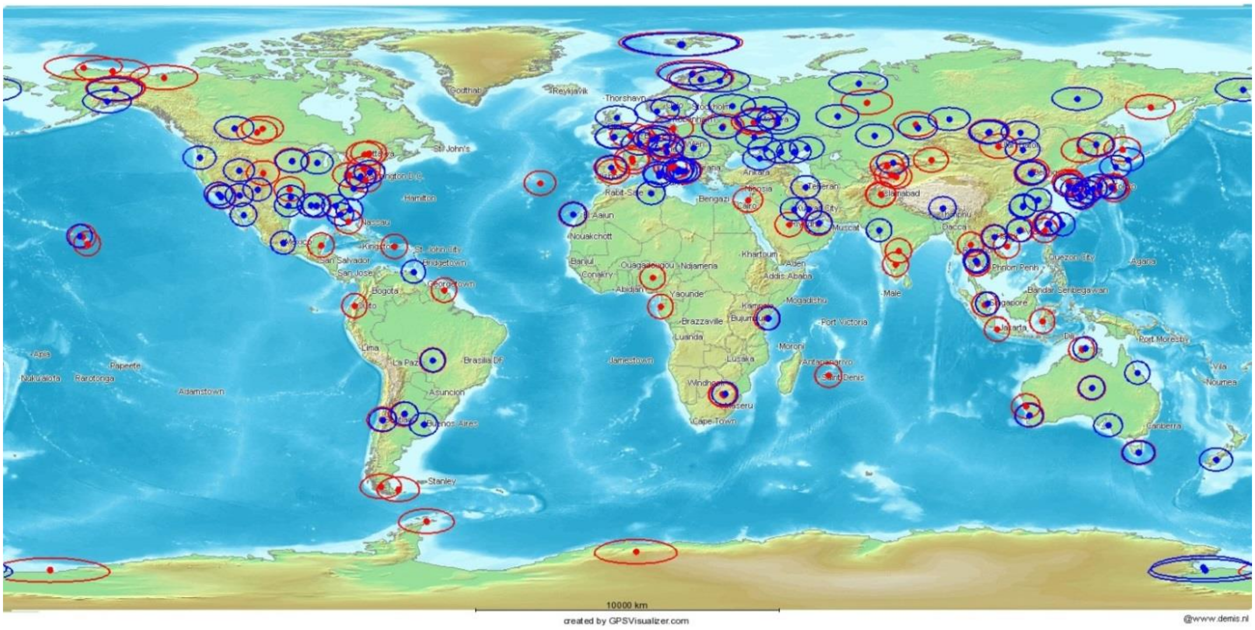
GSO MMSS communication links may pose a near main-beam to main-beam coupling situation to EESS stations at Barrow and Prudhoe Bay, Alaska; Svalbard, Norway; some Antarctic EESS station locations; and possibly Tromso, Norway. While the Svalbard and McMurdo stations are at high enough latitudes that the elevation limitation should rule out any use of the MMSS, the EESS earth stations in northern Alaska, the station in Tromso, Norway, and the remaining Antarctic stations are at risk as they are located below the 71.4 degree limit and potentially between a ship and its GSO space station. It is however recognized that such cases would be very limited in practice, and the duration of such events limited in time.

Note that this analysis is based on the presence in the area of a single MMS terminal operating on a single channel. In case of multiple MMS terminals operating on multiple channels, the required exclusion zone may grow accordingly, also depending on the respective width of EESS and MMSS channels. It should however be noted that more and more EESS systems need the entire allocated band to download a larger amount of data.

Figure 19 illustrates areas of concern that may require exclusion zones around the known EESS earth stations in Annex 1. Some of the inland stations shown in this picture would not lead to exclusion zones while others could be affected by maritime traffic on rivers and lakes. The exclusion zone of 400 km was based on calculated zones using the least intrusive MMSS parameters (Case 1 GSO parameters), although some EESS earth stations may require a larger exclusion zone. The worst case exclusion zones (Case 2 NGSO parameters) could be larger by as much as a factor of 2.

FIGURE 19

400 km exclusion zones around receiving X-band EESS earth stations
(High data rate stations in red, direct readout / direct broadcast stations in blue)



In addition, such MMSS allocation could also be envisaged for global maritime distress and safety service (GMDSS) operations. This usage would lead to a very large number of ships potentially transmitting close to the coasts, therefore substantially increasing the risk of harmful interference or even damage to receiving EESS earth stations. . Since the International Maritime Organization has liaised that it is not interested in pursuing this allocation at this time, the likelihood of GMDSS operations in the band is small at present.

3.2.5.2 8 GHz EESS Sharing Study 2

In accordance with RR No. **9.17A**, the coordination requirement is defined for any typical mobile earth station in respect of specific earth stations or for any specific earth station, in respect of other earth stations operating in the opposite direction of transmission operating in the opposite direction of transmission, in frequency bands allocated with equal rights to space radiocommunication services in both directions of transmission.

To implement this procedure it is required to determine the predetermined coordination distances or coordination distances for MMSS transmitting earth stations and EESS receiving earth stations operating bidirectionally in frequency band 8 025-8 400 MHz.

One of the possible methods for determination of coordination distances for protection of EESS receiving earth stations is the method described in RR Appendix **7**.

RR Appendix **7** Annex 3 describes the methods for determination of the coordination area between the earth stations sharing a bi-directionally allocated band.

It should be noted that RR Appendix **7** Table 2 describes the coordination contours and also the methods to determine the contours required for each bidirectional scenario. The Table relating to transmitting ES operating with GSO space station is shown below.

TABLE 14

Coordination contours required for each bidirectional scenario

Coordinating earth station operating to a space station in the	**Unknown receiving earth station operating with a space station in the**	**Section containing the method to determine GtandGr**	**Contours required**	
			No.	**Details**
Geostationary orbit	Geostationary orbit	§ 3.1	1	A coordination contour comprising both propagation mode (1) and propagation mode (2) contours
	Non-geostationary orbit	§ 3.2.1	1	A propagation mode (1) coordination contour
	Geostationary or non-geostationary orbits[1]	§§ 3.1.1 and 3.2.1	2	Two separate coordination contours, one for the geostationary orbit (propagation mode (1) and mode (2) contours) and one for the non-geostationary orbit (propagation mode (1) contour)
...	…	…	…	…

In addition the determination of the coordination area for the mobile earth station is based on RR Appendix **7** item 1.4.6: "For a mobile (except aeronautical mobile) earth station, the coordination area is determined by extending the periphery of the specified service area, within which the mobile (except aeronautical mobile) earth stations are operating, by the coordination distance…".

The parameters required for protection of EESS receiving earth stations in the bidirectionally allocated frequency band 8 025-8 400 MHz are given in RR Appendix **7** Table 9a.

Taking into account the above mentioned it can concluded that the current provisions of RR Appendix **7** can be applied for sharing of the transmitting MMSS with the EESS receiving stations in the frequency band 8 025-8 400 MHz.

As an example of application of the current provisions of RR Appendix **7**, in this study the coordination area for a transmitting mobile earth station of GSO MMSS operating in the specific service are (see Fig. 20) is determined in relation to the NGSO EESS receiving earth stations. In addition the coordination area for a certain coast earth station of GSO MMSS is determined in relation to NGSO EESS receiving earth stations in the frequency band 8 025-8 400 MHz.

The coordination area for protection of the EESS receiving earth stations is based in the characteristics given in Table 15.

TABLE 15

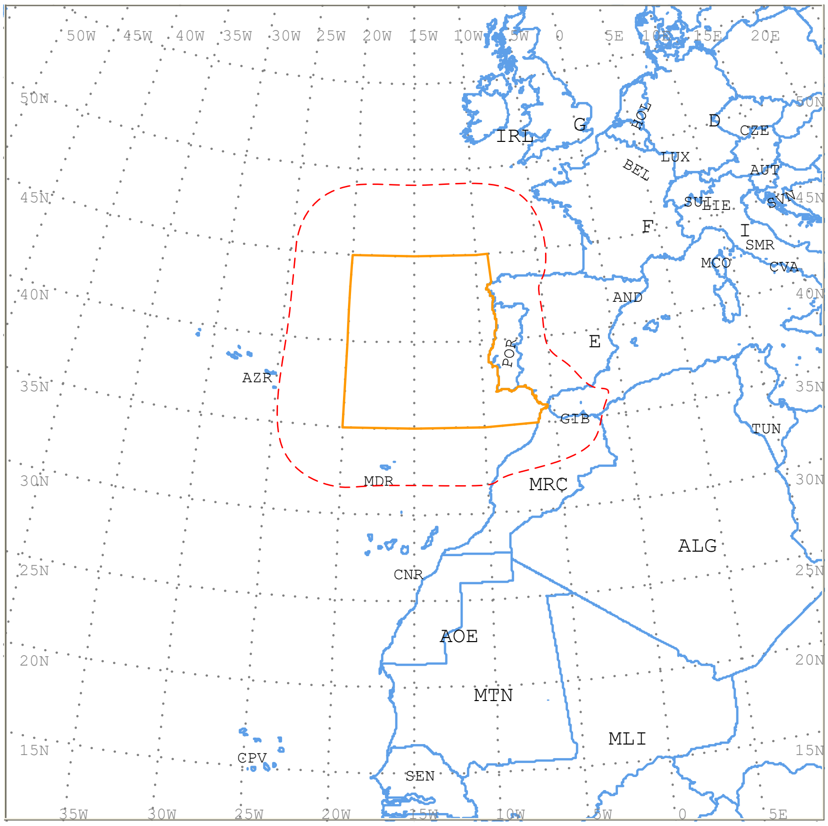
GSO MMSS Earth station transmit characteristics

Characteristics of earth station	**Units**	MMSS Small ES	MMSS Large ES
Transmitter center frequency	(GHz)	8.2125	8.2125
Transmit antenna diameter	(m)	0.4	2.6
Transmit antenna peak gain	(dBi)	29	45
Transmit Antenna –3 dB beamwidth	(deg.)	6.2	0.8
Transmit antenna pattern type		Rec. ITU-R S.580-6	
Transmit antenna minimum elevation angle towards the satellite	(deg.)	10	10
Uplink occupied bandwidth per carrier	(MHz)	10	
Transmit e.i.r.p. spectral density	(dBW/Hz)	–10	10
Nominal orbital long GSO station	(deg.)	20E	
Antenna height	(m)	10	
Allowable time percentage of short term interference	%	.0055	

The coordination areas for the GSO MMSS transmitting earth stations (see Characteristics in Table 15) obtained in accordance with RR Appendix **7** are shown in Figs. 20 and 21 below.

FIGURE 20

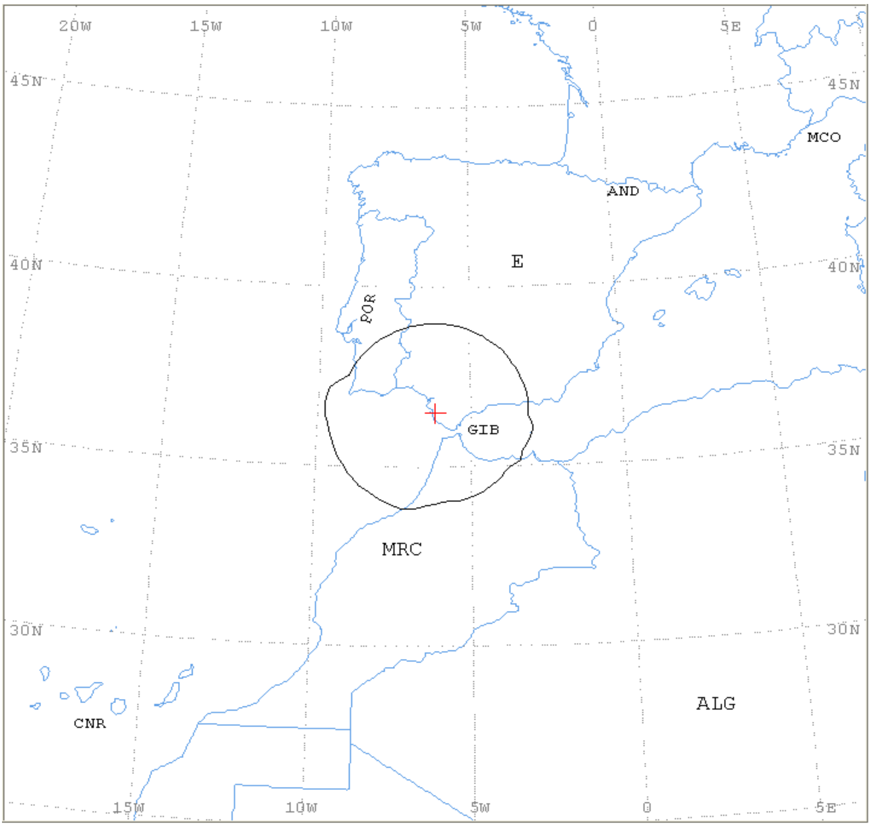
Coordination area for GSO MMSS transmitting mobile earth station



In this Figure the service area of MMSS is shown by yellow colour and the obtained coordination area for protection of EESS from the GSO MMSS mobile earth station is shown by red colour. In accordance with Fig. 20 the maximum coordination distance providing protection for the EESS receiving earth stations is up to 363 km.

FIGURE 21

Coordination area for GSO MMSS transmitting coast earth station



In accordance with Fig. 21 the maximum coordination distance providing protection for the EESS receiving earth station is up to 324 km.

3.2.5.3 Summary of EESS sharing in the 8 025-8 400 MHz band

See Summary of sharing for all services in § 3.2.7.

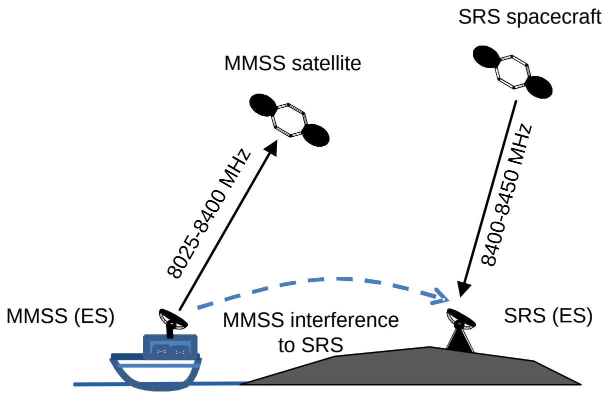
3.2.6 Compatibility of MMSS and SRS (deep-space) bands around 8 GHz

3.2.6.1 8 GHz SRS compatibility Study 1

The potential for out-of-band interference from MMSS earth stations to SRS (deep-space) earth stations is of great concern due to the high sensitivity of SRS deep-space receivers, and due to the importance of critical events in SRS deep-space missions. The potential for interference from the proposed MMSS exists because the 8 400-8 450 MHz deep space band and the 8 025-8 400 MHz EESS band are adjacent to each other. Figure 22 below shows the potential interference scenario to SRS (deep-space) space-to-Earth link.

FIGURE 22

Interference scenario from proposed MMSS allocation SRS deep-space earth station



Two separate analyses have been performed specific to a number of existing SRS (deep space) to investigate the compatibility of a potential MMSS (E-s) allocation in the 8 025-8 400 MHz band with SRS (deep space) operations in the adjacent 8 400-8 450 MHz band. These analyses have similar assumptions regarding system characteristics but have used different methods leading to different results.

3.2.6.1.1 MMSS system characteristics

The analyses documented in this section consider the parameters for a typical system proposed by MMSS (with characteristics described in § 2 of this R) that will use the potential new 8 025-8 400 MHz band, which will have the highest e.i.r.p. towards the SRS earth station. There are two types of MMSS earth stations: small and large. Since the large MMSS earth station with 2.6 m antenna diameter yields the highest e.i.r.p. towards horizon, it is used in these analyses. Note, however, that maximum e.i.r.p. spectral density towards the horizon allowed by ITU Radio Regulations (RR) No. **21.8** is much higher than the e.i.r.p. of this proposed MMSS system. Using the proposed MMSS e.i.r.p. spectral density, the required separation distances around the SRS earth stations will also be determined in order to protect the SRS deep-space earth stations.

3.2.6.1.2 Analysis approaches

The first analysis documented in this section has been performed using the approach defined in Recommendation ITU-R SA.1277 which is close to a Time Invariant Gain (TIG) methodology, and gives a relatively larger distance than what would be determined using a Time Variable Gain (TVG) methodology developed to cover non-GSO satellite victim systems. In these studies, the location of the MMSS station was selected within some area around the victim SRS station and the interference power received was calculated using certain worst case assumptions (e.g. worst case MMSS and SRS antennas are pointing subject to minimum elevation angles and requirement to track GSO MMSS satellites). Using the protection criteria level given in Recommendation ITU-R SA.1157, these results have been used to define zones within which MMSS station transmissions could be expected to cause harmful interference.

Since every location at which an MMSS station can be placed such that it can cause harmful interference to SRS (deep space) operations in the adjacent band is considered to be part of the exclusion zone, this analysis is characterized as deterministic. These exclusion zone results are presented in § 3.2.6.1.4 below.

As part of this analysis and using these results, for the MMSS transmitters, the limit of the e.i.r.p. spectral density towards horizon at the 8 400 MHz band-edge frequency has been determined so that the required separation distances would be confined to the over-the-land distances, and not extend to the sea. It should be checked if the planned MMSS systems would meet this power spectral density limit at the 8 400 MHz band-edge frequency, using the actual boresight e.i.r.p. spectral density, the spectral roll-off, and off-boresight angle towards the horizon of the MMSS transmit antenna. These band separation results are presented in § 3.2.6.1.5 below.

It should be noted that MMSS systems can also reduce the out-of-band emission levels by using well-designed filters. For example, a poorly filtered 14-W (8 212.5 MHz, 13.125 Mbit/s data rate) Direct Broadcast-Direct Readout system on a sun-synchronous satellite at an altitude of 705 km can produce substantial interference to an SRS deep-space earth station; whereas, a well-designed 25-W (8 160 MHz, 15 Mbit/s data rate) Direct Broadcast-Direct Readout system on a similar-sun synchronous satellite can operate without producing any harmful interference. Since the MMSS will operate substantially closer to the SRS deep-space earth stations and with higher power, well-designed filters to reduce the out-of-band emissions into the SRS band should be considered. A second, similar analysis has also been performed in which the MMSS station position, velocity, duration of transmission, and propagation model weather statistic (p), as well as the SRS antenna pointing were also randomized in a Monte Carlo fashion. The objective of this analyses is to document a statistical distribution of interference levels for different values of MMSS station separation distance. Central to the approach used in this analysis are the concept of developing a time distribution of interference levels based on geo-spatial and weather statistic randomization, and the existence and value of an associated percent of time exceedance for SRS deep space protection levels. The results of this statistical distribution analysis are presented as separation distances in § 3.2.6.1.6 below.

3.2.6.1.3 SRS (deep-space) earth station characteristics

There are 13 SRS deep-space earth stations that are listed in Recommendation ITU-R SA.1014-2. The locations of these stations are shown in Fig. 23, and they are given in Table A1-2 of Annex 1. Calculated exclusion zones are shown for many of these stations.

FIGURE 23

SRS deep-space earth stations and some calculated exclusion zones

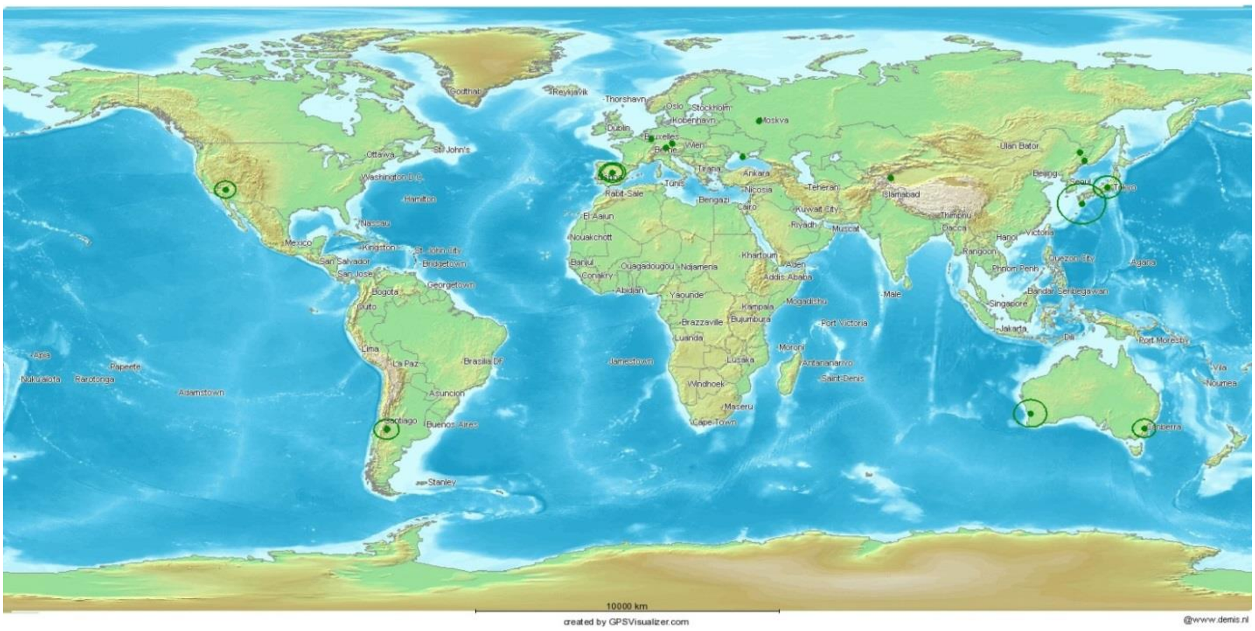


Table 16 below gives a list of parameters for the SRS earth station receiver used in the interference analysis.

TABLE 16

SRS earth station parameters used in interference analysis

SRS earth station (receive, 8 400-8 450 MHz)				
Parameter		**Value**		**Note**
Min. tracking angle	θ_r	10	deg	
Antenna diameter Antenna height	D h	70 39	m m	Goldstone, Robledo, Canberra
Antenna diameter Antenna height	D h	35 21	m m	Cebreros, Malargüe Sur, New Norcia
Antenna diameter Antenna height	D h	34, 64 20, 35	m m	Uchinoura, Usuda
Antenna gain pattern	G_R	ITU RR AP **8**-Annex III		
Terrain elevation angle	ε_r	Variable	deg	Varies depending on the azimuth direction
Antenna gain towards MMSS earth station	G_r	$G_R(\theta_r\text{-}\varepsilon_r)$	dBi	Varies depending on the difference between terrain elevation and min. tracking angle
Permissible interference level	P_{0r}	–221	dBW/Hz	SRS deep-space protection (Rec. ITU-R SA.1157)
Probability of exceedance (due to weather statistics)[(1)]	p	0.001	%	For trans-horizon interference sources (Rec. ITU-R SA.1157)

(1) Note that in the calculation of interference power in the analysis designed to determine a statistical distribution of interference power levels, the exceedance level used to determine propagation loss varies randomly from p = .0001% to p = 50%

In this document, the required separation distances between MMSS and SRS earth stations are calculated for the following sites listed in Table 17 below.

TABLE 17

SRS (deep-space) earth station locations

Station name	Location	Latitude (deg)	Longitude (deg)
Goldstone	USA	35.43	–116.89
Robledo	Spain	40.43	–4.25
Canberra	Australia	–35.40	148.98
Cebreros	Spain	40.4542	–4.3669
Malargüe Sur	Argentina	–35.7758	–69.3983
New Norcia	Australia	–31.0482	116.1915
Uchinoura	Japan	31.2	131.0
Usuda	Japan	36.1	138.3

3.2.6.1.4 Deterministic study results of calculation of separation distances

Studies of separation distances between MMSS and SRS earth stations are provided in Annex 3.

Table 18 below shows the maximum required separation distances between the MMSS earth stations and the SRS deep-space earth stations to meet the SRS protection levels for the case considered in this study for NGSO MMSS and GSO MMSS systems. It also gives the maximum required separation distances when the MMSS transmitters operate per ITU RR No. **21.8** and transmit maximum allowed e.i.r.p. density towards the horizon.

TABLE 18

Maximum separation distances required for the MMSS earth station to meet the SRS protection criterion in the 8 400-8 450 MHz band 8 400-8 450 MHz band SRS deep-space station location	**Case 1: Using MMSS proposed parameters (as per § 2 of this document)**		**Case 2: Using max allowed e.i.r.p density by RR No. 21.8**	
	NGSO MMSS (km)	**GSO MMSS (km)**	**NGSO MMSS (km)**	**GSO MMSS (km)**
Goldstone, USA	300 (2)	275 (2)	710 (1)	620 (1)
Canberra, Australia	400 (2)	300 (2)	600 (1)	410 (1)
Robledo, Spain	400 (2)	320 (2)	750 (1)	540 (1)
Cebreros, Spain	280 (2)	264 (2)	580 (1)	423 (2)
Malargüe Sur, Argentina	450 (2)	325 (2)	570 (1)	465 (1)
New Norcia, Australia	517 (1)	449 (1)	650 (1)	632 (1)
Uchinoura, Japan	660 (1)	660 (1)	830 (1)	820 (1)
Usuda, Japan	380 (1)	360 (1)	750 (1)	740 (1)

(1) Extends to the sea.

(2) Over land, it does not extend to the sea.

3.2.6.1.5 Band separation study between MMSS and SRS (deep-space) earth stations

This study evaluates the interference from the transmissions of MMSS earth stations into the SRS deep-space earth station receivers. Since the study in the previous section indicated that MMSS carrier cannot be located at the upper edge of the proposed the 8 025-8 400 MHz band, required band separation should be studied.

3.2.6.1.5.1 Characteristics of MMSS networks in the proposed 8 025-8 400 MHz band

The characteristics of MMSS networks used in the analysis are documented in Table 19 and in Table A3-1 in Annex 3.

TABLE 19

Assumed characteristics of MMSS earth stations in the proposed 8 025-8 400 MHz band

MMSS unwanted emission levels	Rec. ITU-R M.1541-4 for unwanted emissions, Appendix **3** of the Radio Regulations for spurious emissions
MMSS max. transmit e.i.r.p. density towards horizon (0-deg elevation)	–31 dBW/Hz
MMSS max. allowed transmit e.i.r.p. density	40 dBW/4 kHz (Note 1) 4 dBW/Hz

NOTE – ITU RR No. 21.8 specifies the equivalent isotropically radiated power (e.i.r.p.) transmitted in any direction towards the horizon by an earth station shall not exceed +40 + 3 θ dBW in any 4 kHz band for 0° < θ ≤ 5°, where θ is the angle of elevation of the horizon.

3.2.6.1.5.2 Characteristics of SRS deep-space earth stations in the 8 400-8 450 MHz band

The characteristics of SRS earth stations are documented in Table A3-2 in Annex 3.

3.2.6.1.5.3 Required out-of-band attenuation levels

The required attenuation levels to ensure the protection level of –221 dB (W/Hz) at deep-space earth stations can be taken from Recommendation ITU-R SA.1157 is calculated.

As the initial assessment, the propagation losses are calculated based on the free space loss. Antenna gain of deep-space earth station towards MMSS earth stations is assumed to be 0 dBi as the averaged value over all the off-axis directions since the emission from MMSS earth stations can be in any directions towards deep-space earth stations.

Though the appropriate separation distance between MMSS earth stations and deep-space earth station may require further investigation, the distances of 10 km, 20 km, 50 km and 100 km are checked as the initial assessment.

As shown in Table 20, even if 100 km separation distance is taken into account, the required attenuation level is greater than 60 dBc specified in Appendix **3** of the Radio Regulations, which is the maximum expected attenuation level in the existing regulatory provisions. Taking into account that above analysis showed even the 60 dBc specified in Appendix **3** of the Radio Regulations will not be enough to protect the deep-space earth station, this initial assessment showed that even the maximum effective frequency separation from 8 400 MHz may not work to protect the deep-space earth station in the band 8 400-8 450 MHz.

TABLE 20

Calculation results for required attenuation levels to protect deep-space earth stations using e.i.r.p. density value in RR No. 21.8 for MMSS earth station transmission

MMSS earth station maximum transmitting e.i.r.p. density (dBW/4 kHz)	40	40	40	40
Protection level at deep-space earth stations (dBW/Hz)	–221	–221	–221	–221
Frequency (MHz)	8 400	8 400	8 400	8 400
Assumed minimum separation distance (km)	10	20	50	100
Free space loss (dB)	130.9	136.9	144.9	150.9
Required e.i.r.p. density to ensure the protection level at deep-space earth stations (dBW/4 kHz)	–54.0	–48.0	–40.0	–34.0
Required attenuation levels (dB)	94.0	88.0	80.0	74.0

TABLE 21

Calculation results for required attenuation levels to protect deep-space earth stations using e.i.r.p. density value of –31 dBW/Hz for MMSS earth station transmission

MMSS earth station transmitting e.i.r.p. density (dBW/Hz)	–31	–31	–31	–31
Protection level at deep-space earth stations (dBW/Hz)	–221	–221	–221	–221
Frequency (MHz)	8 400	8 400	8 400	8 400
Assumed minimum separation distance (km)	10	20	50	100
Free space loss (dB)	130.93	136.95	144.91	150.93
Required e.i.r.p. density to ensure the protection level at deep-space earth stations (dBW/Hz)	–90.06	–84.04	–76.08	–70.06
Required attenuation levels (dB)	59.06	53.04	45.08	39.07

Since the proposed MMSS earth station has an e.i.r.p. spectral density of –31 dBW/Hz, which is 35 dB lower than the maximum allowed e.i.r.p. spectral density, the maximum required out-of-band attenuation requirement is lower than 59 dB for the cases considered above. Thus, 60 dB attenuation requirement given in Appendix **3** of Radio Regulations would be enough to protect the SRS deep-space earth stations operating in the 8 400-8 450 MHz band.

3.2.6.1.6 Statistical analysis separation distance results

For the statistical analysis of MMSS interference levels, a series of 5 000 snap shots were taken for each simulation. At each Snapshot, the MMSS has a different localization and the SRS antenna has a different pointing. At each snapshot, the following parameters are chosen randomly and uniformly:

p the percentage of time is randomly chosen between 0.0001 and 50.

A communication time is randomly chosen between 1 and 60 min.

MMSS earth station can be moving or fixed. If moving, a random direction and speed is also allocated to the station.

The results of simulation are provided in the following Table 22:

TABLE 22

Calculation results for percent of time exceedance for MMSS Interference

Station name	Location	Percentage of time of interference	Percentage of time of interference with 250 km exclusion area
Goldstone	USA	< 0.001	< 0.001
Robledo	Spain	< 0.001	< 0.001
Canberra	Australia	< 0.001	< 0.001
Cebreros	Spain	< 0.001	< 0.001
Malargüe Sur	Argentina	< 0.001	< 0.001
New Norcia	Australia	0.0064	< 0.001
Uchinoura	Japan	0.0409	< 0.001
Usuda	Japan	0.0062	< 0.001

The simulation results show that the MMSS terminal can create interference into the SRS receivers. Nevertheless a 250 km exclusion area around the SRS station will be enough to ensure the protection of the SRS station.

It should be noted that the Monte-Carlo methodology used in this analysis determines the probability of harmful interference to an SRS earth station based on a number of randomly determined factors including geo-spatial (position and velocity of MMSS station), programmatic (MMSS contact duration, SRS antenna pointing), weather dependent propagation elements. This differs from the other 8 GHz sharing studies using a deterministic methodology which calculated a maximum separation distance between the SRS and MMSS earth stations needed to satisfy the Recommendation ITU-R SA.1157 sharing criteria defined for a percentage of time, assuming a single MMSS earth station. Over a period of time, each of these factors is certainly variable in time.

Moreover, it should be emphasized that 0.001% exceedance level used for this study is an assumed value as Rec. ITU-R SA.1157 does not explicitly define an allowable non-zero exceedance time. Recommendation ITU-R SA.1157 does explicitly indicate that the weather dependent propagation used in assessing interference into the SRS earth stations should be based on a p = .001% exceedance, rather than a variable exceedance assumed in this approach.

Nevertheless the results of this analysis highlight that MMSS earth stations located within the exclusion area defined by the maximum separation distance do not necessarily create harmful interference into the receiving SRS earth station all the time.

3.2.6.1.7 Conclusion of SRS (deep-space) studies

The exclusion zone for NGSO MMSS and GSO MMSS earth stations under the proposed 8 025-8 400 MHz allocation by WRC-15 agenda item 1.9.2 were computed for the three NASA deep-space stations in Goldstone-USA, Canberra-Australia, and Robledo-Spain, the three ESA deep-space stations in Cebreros-Spain, Malargüe Sur – Argentina and New Norcia – Australia, and the JAXA deep-space stations in Uchinoura and Usuda. The exclusions zones were computed based on the Recommendation ITU-R SA.1157 SRS protection criterion and assuming the transmit e.i.r.p. spectral density contained in section 2 and in RR Article **21.8** towards the horizon for the MMSS transmitter at the 8 400 MHz band-edge frequency.

Table 23 below shows the maximum required separation distances between the MMSS earth stations and the SRS deep-space earth stations to meet the SRS protection levels for the cases considered in this study for NGSO MMSS and GSO (the satellite is located on the GSO arc) MMSS systems. It also gives the maximum required separation distances when the MMSS transmitters operate per ITU RR No. **21.8** and transmit maximum allowed e.i.r.p. density towards the horizon.

TABLE 23

Maximum separation distances required for the MMSS earth station to meet the SRS protection criterion in the 8 400-8 450 MHz band

8 400-8 450 MHz band SRS deep-space station location	Case 1: Using MMSS proposed parameters (as per § 2 of this document)		Case 2: Using max allowed e.i.r.p density by RR No. 21.8	
	NGSO MMSS (km)	GSO MMSS (km)	NGSO MMSS (km)	GSO MMSS (km)
Goldstone, USA	300 (2)	275 (2)	710 (1)	620 (1)
Canberra, Australia	400 (2)	300 (2)	600 (1)	410 (1)
Robledo, Spain	400 (2)	320 (2)	750 (1)	540 (1)
Cebreros, Spain	280 (2)	264 (2)	580 (1)	423 (2)
Malargüe Sur, Argentina	450 (2)	325 (2)	570 (1)	465 (1)
New Norcia, Australia	517 (1)	449 (1)	650 (1)	632 (1)
Uchinoura, Japan	660 (1)	660 (1)	830 (1)	820 (1)
Usuda, Japan	380 (1)	360 (1)	750 (1)	740 (1)

(1) Extends to the sea.

(2) Over land, it does not extend to the sea.

For the e.i.r.p. spectral density case considered, large exclusion zones around the stations would need to be established in order to protect the SRS deep-space earth stations. It is to be noted that this analysis is based on the presence in the area of a single MMSS terminal operating on a single channel. In case of multiple MMSS terminals operating on multiple channels, the required exclusion zone may grow accordingly.

For the planned MMSS Earth-to-space transmitters, since the e.i.r.p. spectral density towards the horizon at 8 400 MHz band-edge frequency is less than the maximum allowed by the ITU Radio Regulations, the required separation distances are reduced accordingly and are confined to the over-the-land distances, not extending to the sea, as in the case of Goldstone, Canberra, and Robledo SRS deep-space earth stations. This is however not the case for the stations located in New Norcia, Uchinoura and Usuda.

However, as shown in Table 23 above, if higher e.i.r.p. levels are used as given in ITU RR No. **21.8**, then the required separation distances are large and extend to the sea. Therefore, it is important to limit the e.i.r.p. levels that the new MMSS earth stations in the 8 025-8 400 MHz band to the proposed e.i.r.p. values only.

For the SRS earth stations in Goldstone, Canberra, and Robledo, Table 24 below gives the maximum MMSS transmit e.i.r.p. spectral densities towards the horizon at the 8 400 MHz band-edge frequency to keep the exclusion zones around the SRS stations within land-mass.

If the planned MMSS systems satisfy these limits, then the out-of-band emissions from MMSS into the SRS earth stations in the 8 400-8 450 MHz band would satisfy the SRS protection.

TABLE 24

Maximum MMSS transmit e.i.r.p. spectral densities at the 8 400 MHz band-edge frequency to keep exclusion zones around SRS stations within land-mass

SRS deep-space station location	Maximum MMSS e.i.r.p. spectral density (dBW/Hz)
Goldstone, USA	–29
Canberra, Australia	–28
Robledo, Spain	–30

As part of an additional analysis, the required separation distances from the SRS earth stations were examined assuming a uniform statistical distribution of several key factors impacting the magnitude of the MMSS interference. These factors included location, direction, and velocity of the MMSS station, duration of MMSS station transmission, pointing of the SRS antenna, and weather dependent propagation losses. A Monte Carlo analysis was performed using these random variables to estimate the time distribution of the MMSS interference levels seen by the SRS station. The results of that analysis are depicted in Table 25 below.

TABLE 25

Calculation results for percent of time exceedance for MMSS Interference

Station name	Location	Percentage of time of interference	Percentage of time of interference with 250 km exclusion area
Goldstone	USA	< 0.001	< 0.001
Robledo	Spain	< 0.001	< 0.001
Canberra	Australia	< 0.001	< 0.001
Cebreros	Spain	< 0.001	< 0.001
Malargüe Sur	Argentina	< 0.001	< 0.001
New Norcia	Australia	0.0064	< 0.001
Uchinoura	Japan	0.0409	< 0.001
Usuda	Japan	0.0062	< 0.001

3.2.6.2 Summary for SRS (deep-space) compatibility in the bands around 8 GHz

See Summary of sharing for all services in § 3.2.7.

3.2.7 Summary for all affected services in the 8 025-8 400 MHz band

Sharing between FS and MMSS uplinks in the 8 025-8 400 MHz band requires a minimum separation distance to protect the FS receiver. The distances calculated using the methodology contained in RR Appendix 7 can be large and for the systems of one administration have been determined to be on the order of 306-328 km from the coasts, considering potential interference from a single MMSS earth station. It is noted that an FS station could receive interference from multiple MMSS stations transmitting simultaneously, and that in this circumstance, the required distance required to protect the FS station could be even greater. These results should be taken into account, should a primary MMSS allocation in the Earth-to-space direction be considered in this frequency band. Although no technical studies have been provided, it is expected that sharing between the MMSS and the FSS, MetSat and Mobile (except aeronautical mobile) service could be accomplished through coordination under RR Article **9**.

For the EESS and SRS, studies have been performed to examine the potential for unacceptable interference into earth station receivers from the Earth-to-space transmissions of MMSS systems potentially operating in the 8 GHz band. These studies considered both NGSO (although no information has been provided for this kind of system) and GSO MMSS systems and incorporated two potential MMSS system transmit power spectral density levels: a lower level (Case 1) based on the characteristics of typical GSO MMSS systems provided to ITU, and a higher level based on the RR No. **21.8** limit on radiated e.i.r.p. density towards the horizon.

These studies examined 13 EESS earth stations and 8 SRS earth stations distributed globally. It is worth noting that the EESS stations used in this study represent a small subset of the worldwide deployment of EESS earth stations, many of which are located in coastal areas.

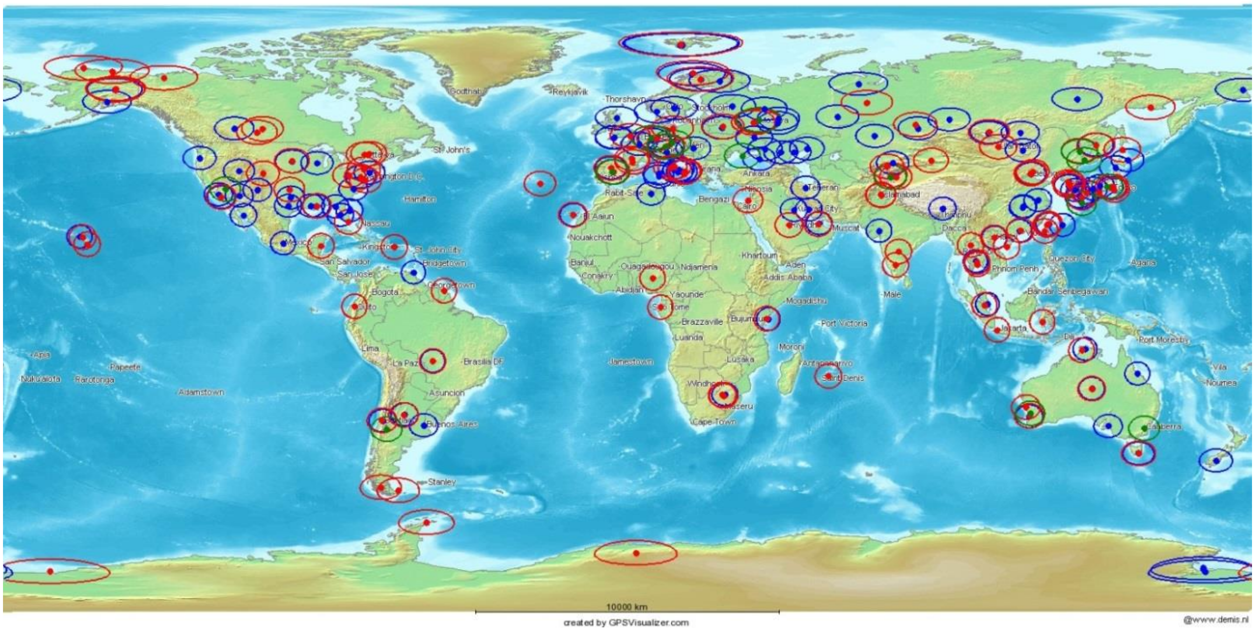
For each station, analyses defined a region around the station within which an MMSS system could potentially cause unacceptable interference. Key factors affecting the size of these zones and their impact on the potential for MMSS sharing with SRS / EESS were the local terrain features around each station and the proximity to the coast. These separation distances have been computed using Recommendation ITU-R SA.1277 which is close to a Time Invariant Gain (TIG) methodology, and for the EESS case may lead to a relatively larger distance than what would be determined using a Time Variable Gain (TVG) methodology developed to cover non-GSO satellite victim systems. Using an alternative methodology based on a Monte Carlo scenario, the results highlight that MMSS earth stations located within the exclusion area defined by the maximum separation distance do not necessarily create harmful interference into the receiving SRS/EESS earth station all the time. On the other hand, these analyses were based on the presence in the area of a single MMS terminal operating on a single channel. Considering multiple terminals may lead to increased separation distances.

Even at the lower (Case 1) MMSS power spectral density level and making the optimistic assumption of GSO MMSS networks only, the zone within which some SRS or EESS stations can experience interference from a seaborne MMSS transmitting station extends up to several hundred kilometers into the sea, in particular when those EESS and SRS stations are closed to the coast. For example, MMSS transmitters on ships located hundreds of kilometers offshore can cause interference into stations in Wallops Island, South Point, Stennis Space Center, and Prudhoe Bay in the US, as well as stations in Katsuura and Hatoyama in Japan and Svalbard, Norway.

Figure 24 illustrates areas of concern wherein an exclusion zone must be defined and used. These areas include all known high data rate EESS (red), direct readout/direct broadcast EESS (blue), and deep space SRS (green) receiving earth stations. A single radius of 400 km for all EESS and SRS stations was used based on the results obtained for a subset of EESS and SRS stations that were analyzed using the lower power spectral density of Case 1 and a GSO MMSS space station. Note that a much larger separation distance would be needed for several of the earth stations analyzed.

FIGURE 24

EESS (red, blue) and SRS (green) earth stations and 400 km exclusion zones



Typically tens of thousands of ships (http://www.sailwx.info/shiptrack/shiplocations.phtml or http://www.marinetraffic.com/) use the Gulf of Mexico and Atlantic coast regions of the United States of America, the Atlantic and Mediterranean regions surrounding Europe, and Pacific coast regions of Asia – all regions with EESS earth stations vulnerable to interference from the MMSS in the 8 025-8 400 MHz band. The IMO has liaised that it has no interest in using this band at present; however, should the band be allocated and its use become widespread, the impact would be severe.

It has been suggested that the protection of the EESS receiving stations from interference caused by the envisioned allocation of the frequency band 8 025-8 400 MHz to MMSS (Earth-to-space) could be ensured by application of RR No. **9.17A** with method for determination of protection distances in accordance with RR Appendix **7**.

However, coordination would be significantly complicated by a number of factors. These factors include the difficulty in real time communications with potentially thousands of shipboard operators, the multiplicity of administrations potentially involved, the potential for automated or remotely controlled EESS / SRS stations, the lack of predictability in ground station scheduling, and the existence of un-notified receive-only EESS stations at unspecified locations. In recognition of this situation, the regions defined in these analyses are exclusion zones, and any sharing approach must prohibit MMSS operations in these regions in order to protect critical EESS and SRS systems.

4 Summary of results

Section 3.1.5 provides the results of studies examining the feasibility of sharing between MMSS (s-E) and incumbent services in the 7 375-7 750 MHz band. Similarly, § 3.2.7 provides the results of studies for sharing between the MMSS (E-s) and incumbent services in the 8 025-8 400 MHz band as well as analysis of compatibility with SRS operations in the adjacent 8 400-8 450 MHz band.

Annex 1

Known EESS and SRS X-band earth stations

Table A1-1 lists the known EESS earth stations using the 8 025-8 400 MHz band. The data illustrated on Figs 3.2.5.1.2.1-1 and 3.2.5.1.2.2-1 are contained in this table. This list was primarily derived from the SFCG X-Band earth station List, the USGS International Co-operator list, and the direct broadcast-direct readout station list maintained by the GSFC direct readout laboratory.

Note that an asterisk, "*", indicates that an earth station includes multiple antennas and probably services many satellites. The location listed is approximately the center of the site, and an individual antenna many be as far as a kilometer or two away.

There are two types of EESS users of that band, the satellite operator requiring high data rate, wideband communications (100's of megabits/second) and the direct broadcast-direct readout user requiring moderate data rates (15-20 megabits/s).

Column 6, HDR, indicates high data rate downlink stations for the EESS satellites.

Column 7, DRO, indicates direct broadcast-direct data readout stations.

TABLE A1-1

EESS X-band (8 025-8 400 MHz) earth stations

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Antarctica	McMurdo Station(USA)	NASA and NSF	–77.833	–166.400	X	X*
Antarctica	O'Higgins(Chile/DLR)	GARC +SSC/USN	–63.321	–57.899	X	
Antarctica	TrollSat(Norway) *	Kongsberg Sat. Services	–72.329	2.495	X*	
Argentina	Castelar	INTA	–34.608	–58.670		X
Argentina	Cordoba	CONAE	–31.524	–64.464	X	X
Australia	Alice Springs	Geoscience Australia-NEO	–23.760	133.880	X	X
Australia	Darwin	Australian Bur. Met.	–12.000	132.000		X
Australia	Darwin		–12.359	130.982	X	
Australia	Dongara	West Aust. Sat. Sta.-SSC/USN	–29.200	114.900	X	
Australia	Hobart, Tasmania	CSIRO; GA-NEO	–42.924	147.422	X	X
Australia	Hobart, Tasmania	TERSS Consortium	–42.930	147.400	X	X
Australia	Mawson Lakes	U. South Australia	–34.816	138.616		X
Australia	Perth	Australian Bur. Met.	–31.933	115.833		X
Australia	Perth	ESA via Inmarsat	–31.803	115.885	X	
Australia	Townsville, Queensland	Australian Bur. Marine Sci.	–19.270	147.050		X
Azores	Santa Maria	ESA	36.997	–25.136	X	
Belarus	Minsk	Forest Inventory Ent.	53.900	27.560	X	X
Belarus	Minsk		53.520	27.300		X
Brazil	Cuiaba *	INPE	–15.552	–56.073	X*	X
Canada	Canada	CRSS	49.290	–117.240	X	

TABLE A1-1 (*continued*)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Canada	Cantley, Quebec	Gatineau Sat. Sta., CCRS	45.540	–75.760	X	
Canada	Edmonton	Environment Canada	53.321	–113.250		X
Canada	Inuvik	SSC/USN Inuvik Sat Sta	68.318	–133.539	X	
Canada	Prince Albert *, Sask.	Prince Albert Sat. Sta., CCRS	53.210	–105.124	X*	
Canada	Saskatoon	CSA	52.170	–106.680	X	
Canada	St. Hubert	CSA	45.520	–73.400	X	
Chile	Puntas Arenas	CEE/UdC (NASA)	–53.000	–71.000	X	
Chile	Santiago	Dir. Met. De Chile	–33.280	–70.450		X
Chile	Santiago	Santiago Sat Sta, SSC Chile	–33.130	–70.667	X	X
China	Beijing	DOT, CMA; CEODE	40.050	116.275		X
China	Beijing	Inst. R S for Applic.	39.950	116.317		X
China	Beijing, Chauyang Dist.	Chinese Acad of Sci.	40.451	116.858	X	X
China	Beijing, Huazhong U.	Huazhong U.	30.310	114.160		X
China	Chiang Mai		18.782	96.983	X	
China	Chung-Li		24.784	121.001	X	
China	Guangzhou, Guangdong	DOT, CMA	23.159	113.340	X	X
China	Guangzhou, Guangdong	Satellite Station	23.000	113.000		X
China	Jiamusi		46.756	130.380	X	
China	KaShi	CEODE	39.505	75.929	X	
China	Laza, Tibet	DeptObs & Telecom, CMA	29.600	90.900		X
China	Nanjing	Nanjing U.	32.120	118.420		X
China	Sanya		18.283	109.367	X	
China	Urumqi, Xinjiang	DOT, CMA	43.860	87.570		X
China	Wuhan	Sch. of Info Eng. On R. S.	30.000	114.000		X
Ecuador	Cotopaxi	CLIRSEN	0.622	–78.579	X	
England	Bordon, Surrey		51.108	0.866	X	
England	Exeter, Devon	Met. Office	50.726	–3.746		X
England	Yelverton, Devon	Dartcom	50.570	–3.940		X
Finland	Sodankyla	Finnish Met. Inst.	67.368	26.633		X
France	LannionCedex	METEO-France	48.733	3.467		X
France	Ruche		44.440	1.340	X	
French Guiana	Kourou	ESA + CNES	5.251	–52.805	X	
Gabon	Libreville		0.387	9.597	X	
Germany	Gelsdorf		50.569	7.036	X	

TABLE A1-1 (*continued*)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Germany	Marburg, Hessen	U. Marburg	50.490	8.470		X
Germany	Neustrelitz *	DLR	53.330	13.073	X*	
Germany	Oberpfaffenhofen	ESA, DLR	48.067	11.267	X	X
Germany	Traben-Trarbach	BGIO	49.970	7.120		X
Germany	Usingen *	EUMETSAT	50.333	8.480	X*	
Germany	Weilheim	SSC/USN	47.870	11.000	X	
Hungary	Budapest	EotvosLorand U.	47.475	19.062		X
India	Ahmedabad	Space App. Centre	23.033	72.617	X	X
India	Bangalore (Byalalu)	ISRO +SSC/USN	12.902	77.369	X	
India?	Shadnagar	IRS series	16.900	78.200	X	
Indonesia	Parepare	LAPAN	–3.978	119.650	X	
Indonesia	Rumpin		-6.371	106.631	X	
Iran	Shiraz	Iran Met. Org.	29.320	52.350		X
Iran	Tehran	Iran Space Agency	35.781	51.377		X
Israel	Tel Aviv	Israel IAI/MBT2	32.000	34.800	X	
Italy	Benevento *	MARSec	41.117	14.797		X
Italy	Caglari, Sardinia	U. of Cagliari	39.130	9.100		X
Italy	Fucino	SSC/USN	41.979	13.603	X	
Italy	Matera	ESA	40.390	16.420	X	X
Italy	Matera*	MTI, ESA	40.650	16.704	X*	
Italy	Renon (Bolzano)	EURAC Research	46.369	11.276		X
Italy	Salerno	Salerno U.	40.460	14.470		X
Italy	Sardinia Island	Informatica per il Territorio	40.000	9.000		X
Italy	South Tyrol	EURAC	46.360	11.270		X
Italy	Tito Scalo	IMAA-CNR	40.601	15.724		X
Japan	Abashiri	Tokyo U. in Hokkaido	43.968	144.233		X
Japan	Hakodate	Hokkaido U.	41.809	140.718		X
Japan	Hatoyama *	RESTEC	36. 004	139.348	X*	
Japan	Hiroshima	Hiroshima Inst. Tech.	34.400	132.450		X
Japan	Hiroshima *	Hiroshima Inst. Tech.	34.365	132.384	X*	
Japan	Kumamoto	U. Japan	32.836	130.869	X	X
Japan	Miyakojima *	Tokyo U. in Miyakojima	24.765	125.396		X
Japan	Okinawa	DLR	26.140	127.660	X	
Japan	Tokyo	Inst. Of Ind Sci., U. Tokyo	35.660	139.680		X
Japan	Tottori	ALRC-Tottori U.	35.501	134.235		X

TABLE A1-1 (*continued*)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Japan	Tsukuba	MAFFIN	36.117	140.050	X	X
Kazakhstan	Alma-Ata	Space Research Inst.	43.130	76.550		X
Kazakhstan	Astana	Space Monitoring Center	51.100	71.280		X
Kazakhstan	Atyrau	JSC Kazgeocosmos	47.360	51.790		X
Kenya	Malindi	U. Rome, Italy	–2.996	40.195	X	X
Korea, Rep. of		KAIST	37.000	127.500	X	
Korea, Rep. of	Busan	Fisheries Res & Dev Inst.	35.110	129.130		X
Korea, Rep. of	Daejeon	Kor. Aerospace Res. Inst.	36.380	127.370	X	
Korea, Rep. of	Daejeon	Kor. Aerospace Res. Inst.	36.220	127.210		X
Korea, Rep. of	Seoul		37.460	127.100	X	
Kuwait	Kuwait	ROPME	29.195	48.024		X
Kyrgystan	Bishkek		42.080	74.875	X	
Mauritius	Mauritius	SSC/USN	–20.000	58.000	X	
Mexico	Chetumal	Conabio + DLR(Germany)	18.545	–88.264	X	
Mexico	Guaymas, Sonora	ITG	27.590	–110.590		X
Mexico	Mexico City	Conabio	19.300	–99.186		X
Mexico	Mexico D.F.	UNAM Geography Inst.	19.328	–99.177		X
Mongolia	Ulan Bator		47.925	106.959	X	
Morocco	Rabat	CRERS	34.020	6.830		X
New Zealand	Lauder	NIWA	–45.038	169.681		X
Nigeria	Abuja		8.989	7.376	X	
Norway	Grimstad	Kongsberg Sat. Services	58.350	8.540		X
Norway	Longyearbyen, Svalbard *	Kongsberg Sat. Services	78.223	15.401	X*	X*
Norway	Tromso *	Kongsberg Sat. Services	69.765	18.920	X*	X
Pakistan	Islamabad		33.518	73.176	X	
Pakistan	Rawat near Islamabad	SUPARCO	33.717	73.067	X	
Russia	Anadyr	Dept. of Extraord. Situations	64.750	177.483		X
Russia	Astrakhan	Research Geo-Info Center	46.349	48.049		X
Russia	Barnaul, Altai Reg.	Altai State U.	53.367	83.750		X
Russia	Belgorod	Belgorod State U.	50.613	36.587		X
Russia	Chita	Chita Regional Info	52.020	113.300		X
Russia	Ekaterinburg	Ural Inf. & Computing Cntr	56.850	60.600		X
Russia	Elista	Cntr for Integrated Monitor	46.308	44.256		X
Russia	Gelendzhik	Yuzhmorgeo Enterprise	44.332	38.036		X

TABLE A1-1 (*continued*)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Russia	Irkutsk	Baikal IRK	52.267	104.333		X
Russia	Irkutsk	SCANEX	52.283	104.300	X	X
Russia	Khabarovsk	RFSA	48.330	135.100	X	X
Russia	Khanu-Mansiisk	RASA	60.970	69.070	X	
Russia	Krasnoyarsk	Siberian Reg. Center	56.010	92.792		X
Russia	Magadan	SCANEX	57.557	150.828	X	
Russia	Moscow	Ministry of Natural	55.510	37.380	X	X
Russia	Moscow *	Inst. Of Geodesy; SCANEX	55.736	37.584	X*	X*
Russia	Nizhny Novgorod	Nizhny Novgorod State U.	56.190	43.590		X
Russia	Novosibirsk	RFSA Satellites	54.470	83.070	X	
Russia	Rostov on Don	Info & Analytical Center	47.220	39.720		X
Russia	Russia 1	RFSA Satellites	55.077	36.370	X	
Russia	Salekhard	Ecology of Yamal Enterprise	66.550	66.667		X
Russia	Sarov	Inst. of Exp. Physics	54.932	43.329		X
Russia	South-Sakhalinsk	RFSA Satellites	47.020	142.720	X	
Russia	St. Petersburg	Arctic/Antarctic Res. Inst.	59.940	30.230		X
Russia	Vologda	EMERCOM	59.120	39.520		X
Russia	Yakutsk	Min. of Natural Resources	62.000	129.667		X
Saudi Arabia	Riyadh		24.720	46.633	X	
Scotland	Dundee	U. of Dundee	56.480	–3.031		X
Singapore	Singapore	Kongsberg Sat. Services	1.000	103.000	X	
Singapore	Singapore	U. of Singapore	1.293	103.856		X
South Africa	Hartebeesthoek	CSIR-MerakaInst.+SSC+KSS	–25.530	27.420	X	X
South Africa	Hartebeesthoek		–25.887	27.708	X	
South Africa	Johannesburg	SANSA	–25.890	27. 700	X	
South Africa	Pretoria	CSIR-Meraka Inst.	–25.450	28.160		X
Spain	Maspalomas *	ESA; MPS	27.761	–15.634	X*	X
Spain	Valladolid	U. of Valladolid	41.650	–4.717		X
Spain	Villafranca		40.443	–3.952	X	
Sweden	Karlstad	U. of Karlstad	59.367	13.500		X
Sweden	Kiruna-Esrange *	Swed. Space Co./USN; ESA	67.890	21.063	X*	X
Tainan	Tainan		22.939	120.276	X	
Taiwan (CHN)	Chung-Li *	National Central U.	24.968	121.186		X*

TABLE A1-1 (continued)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
Taiwan (CHN)	Hsin-Chu		24.784	121.001	X	
Taiwan (CHN)	Taipei		25.090	121.400	X	
Taiwan (CHN)	Taipei	Central Weather Bureau	25.030	121.520		X
Thailand	Bangkok	GISTDA	13.731	100.790	X	X
Thailand	Chaing Mai		18.783	98.983	X	
Thailand	Pathumthani	Asian Inst. of Tech.	14.045	100.365		X
Thailand	Si Racha		13.101	100.928	X	
Trinidad&Tob.	Chaguaramas	Inst. Of Marine Affairs	10.689	–61.616		X
UAE	Dubai	Global Scan Tech.	27.650	55.310		X
UAE	Dubai	Kongsberg Sat. Services	25.000	55.000	X	
USA	Albuquerque, NM	U. of New Mexico	35.100	–106.600		X
USA	Anchorage, AK	US weather Service	61.218	–149.900		X
USA	Austin, TX	U. Texas	30.395	–97.735		X
USA	Barrow, AK *	DigitalGlobe	71.272	–156.772	X*	
USA	Baton Rouge, LA	U. Louisiana	30.451	91.154		X
USA	Chatanika, AK-Poker Flat*	SSC/USN (NASA)	65.108	–147.425	X*	
USA	Corvallis, OR	Oregon State U.	44.550	–123.250		X
USA	Dulles, VA	Orbview	38.960	–77.420	X	
USA	Fairbanks-Gilmore Creek*	NOAA FCDA	64.976	–147.521	X*	X
USA	Fairbanks, AK-U.Alaska *	Alaska Sat. Facility	64.860	–147.473	X*	X
USA	Fairmont, WV *	NOAA	39.445	–80.193	X*	
USA	Greenbelt, MD	NASA GSFC	39.000	–76.840	X	X
USA	Lillington, NC	Ocean View Comm.	35.391	–78.940		X
USA	Irvine, TX	Orbital systems	32.878	96.998		X
USA	Madison, WI	U. Wisconsin	43.073	–89.401		X
USA	Manoa, HA	U. of Hawaii	21.300	–157.850		X
USA	Maui, HA		21.100	–157.000	X	
USA	Mesa, AZ	Global Imaging	33.422	–111.822		X
USA	Miami, FL		25.614	–80.385	X	
USA	Missoula, MT	USDA Forest Service	46.872	–113.993		X
USA	New Brunswick, NJ	Rutgers U.	40.290	–74.290		X
USA	North Pole, AK	SSC/USN (GSFC)	64.4800	–147.500	X	
USA	Orange, CA		33.797	–117.850		X
USA	Poway, CA	SeaSpace Corp.	32.980	–117.010	X	X

TABLE A1-1 (continued)

Country	Station Location	Institution	Latitude	Longitude	HDR	DRO
USA	Prudhoe Bay, AK	DigitalGlobe	70.250	–148.480	X	
USA	Mayaguez, Puerto Rico	U. of P.R.	18.211	–67.137	X	
USA	Salt Lake City, UT	USDA RS App. Center	40.761	–111.980		X
USA	Samsula, FL	Private	29.070	–80.060		X
USA	Sioux Falls, SD	USGS, EROS Data Cntr	43.736	–96.623	X	X
USA	South Point, HA *	SSC/USN (NASA)	19.014	–155.663	X*	
USA	St. Petersburg, FL	U. of South Florida	27.760	–82.630		X*
USA	Stennis Space Cntr, MS	NASA	30.370	–89.450	X	X
USA	Tallahassee, FL	Florida Emerg. Ops Cntr	30.230	–84.140		X
USA	Thornton, CO	GeoEye	39.980	–104.950	X	
USA	Wallops Island, VA *	NASA WFF	37.935	–75.469	X*	
USA	Wallops Island, VA *	NOAA WCDA	37.946	–75.462	X*	
USA	West Lafayette, IN	Purdue U.	40.416	–86.942		X
USA	Wilkes Barre, PA		41.250	–75.900	X	
Viet Nam	Hanoi	Inst. of Physics	21.033	105.85		X
Viet Nam	Viet Nam		21.05	105.75	X	

The SRS deep-space earth stations shown in Fig. 5 are listed in Table A1-2 (Annex 1 Study 5 Part 1) and were found in Recommendation ITU-R SA.1014-2.

TABLE A1-2

SRS deep-space earth stations

Country	Station location	Institution	Latitude	Longitude
Argentina	Malargüe Sur	DSA-3, ESA	–35.767	–69.367
Australia	Canberra	NASA	–35.467	148.983
Australia	New Norcia	DSA-1, ESA	–31.048	116.192
China	Jiamusi	China	46.467	130.433
China	KaShi	CEODE	38.917	75.867
Germany	Effelsberg	DLR	50.517	6.883
Germany	Weilheim	SSC/USN	47.883	11.067
Germany	Wettzell	DLR	49.167	12.833
Japan	Usuda, Nagano	JAXA	36.133	138.367
Japan	Uchinoura	JAXA	31.200	131.000
Russia	Medvezhoozera	RSA	55.867	37.950
Russia	Ussuriisk	RSA	44.017	131.750
Spain	Cebreros	DSA-2, ESA	40.453	–4.367
Spain	Robedo (Madrid)	NASA	40.433	–4.283
Ukraine	Evpatoriya	Ukraine	45.183	33.183
USA	Goldstone, CA	NASA	35.367	–115.850

Annex 2

Sharing between MMSS and EESS

Recommendation ITU-R SA.1027 provides sharing criteria for the band 8 025-8 400 MHz to be used in sharing studies, which are reproduced in Table A2-1.

TABLE A2-1

Sharing criteria for Earth exploration-satellite and meteorological-satellite earth stations using spacecraft in low-Earth orbit

Frequency band (MHz)	Type of earth station	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time		Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than p% of the time	
		Interfering signal path		Interfering signal path	
		space-to-Earth	Terrestrial	space-to-Earth	Terrestrial
8 025-8 400	54.8 dBic antenna gain Recorded data playback	–165 dBW per 10 MHz	–148 dBW per 10 MHz	–133 dBW per 10 MHz $p = 0.0025$	–133 dBW per 10 MHz $p = 0.0050$
	41.7 dBic antenna gain Direct data readout	–155 dBW per 10 MHz	–138 dBW per 10 MHz	–128 dBW per 10 MHz $p = 0.0025$	–127 dBW per 10 MHz $p = 0.0050$
	42.5 dBic antenna gain Direct data readout	–159 dBW per 10 MHz	–142 dBW per 10 MHz	–129 dBW per 10 MHz $p = 0.0013$	–129 dBW per 10 MHz $p = 0.0056$

The criteria for terrestrial path should apply in this study.

Several different analyses are provided, applied to different examples of earth stations.

A2.1 Analysis 1

A2.1.1 Methodology applied

Recommendation ITU-R SA.1277 provides in its Annex 2, § 3 the methodology to be used to calculate separation distances that would be required with FSS in order to protect the EESS earth stations from harmful interference, which was used in the study for MMSS. This methodology is close to a Time Invariant Gain (TIG) methodology, and gives a relatively larger distance than what would be determined using a Time Variable Gain (TVG) methodology developed to cover non-GSO satellite victim systems.

The minimum permissible basic transmission loss to protect the earth station can be stated as:

$$L_b(p\%) = P_t + G_t(\theta_t) - (P_i - G_r(\theta_r))$$

where:

P_t: MMSS transmitter power (dBW)

$G_t(\theta_t)$: MMSS antenna gain in the direction of the EESS earth station (dBi)

$G_r(\theta_r)$: gain of the EESS earth station antenna in the direction of the MMSS station (dBi)

P_i: maximum permissible interference at the EESS earth station receiver input (dBW)

θ_t: angle between the MMSS antenna axis and the interference path (degrees)

θ_r: angle between the EESS antenna axis and the interference path (degrees)

$L_b(p\%)$: the value of minimum acceptable basic transmission loss to be exceeded for all but p% of the time along the interference path between the terrestrial transmitter and the earth station receiver (dB).

The value θ_r is given by:

$$\theta_r = 5 - \varepsilon_r$$

where:

ε_r: the elevation of the earth station physical horizon in the direction of the MMSS earth station.

The minimum angular separation between the antenna's axis and the interference path is given by:

$$\theta_t = \alpha - \varepsilon_t$$

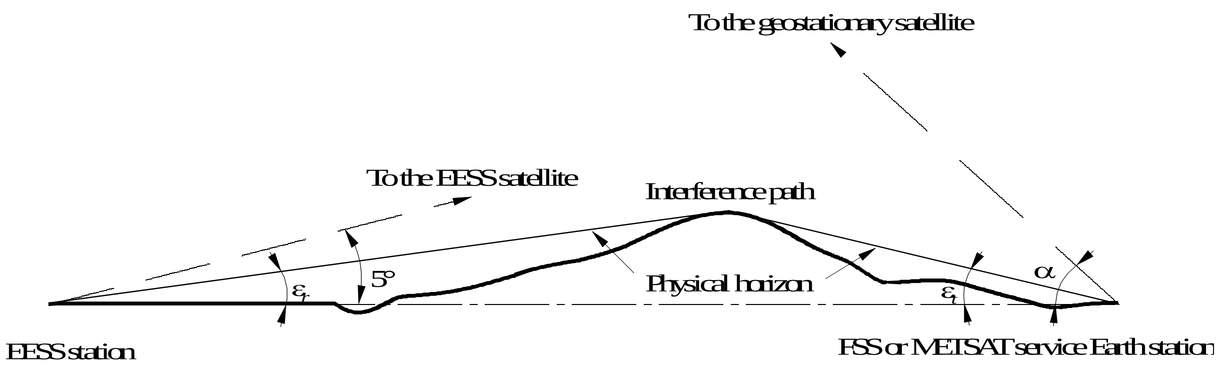
where:

α: elevation angle of the geostationary satellite relative to the MMSS earth station

ε_t: the elevation of the MMSS earth station (see Fig. 3).

FIGURE A2-1

Representation of the worst case of interference from a satellite earth station to an EESS earth station



The separation distances are then derived from the propagation loss required using the clear air version of Recommendation ITU-R P.452-14, taking into account the proportion of path over land or water.

A2.1.2 Application to existing earth stations

For the GSO case, the calculation takes into account that the MMSS earth station points towards the GSO arc and based on this assumption determines the worst case antenna gain towards the horizon for each MMSS earth station location. It should be noted that if the MMSS satellite has an orbital inclination with regard to the equatorial plan (e.g. a geo synchronous satellite), then the antenna gain towards the horizon may be higher, and thus the separation distance increase accordingly.

A2.1.2.1 Maspalomas

Figures A2-2 and A2-3 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Maspalomas EESS earth station, when considering typical MMSS characteristics.

FIGURE A2-2

Interference exceedance for the Maspalomas ESA earth station vs NGSO MMSS earth stations

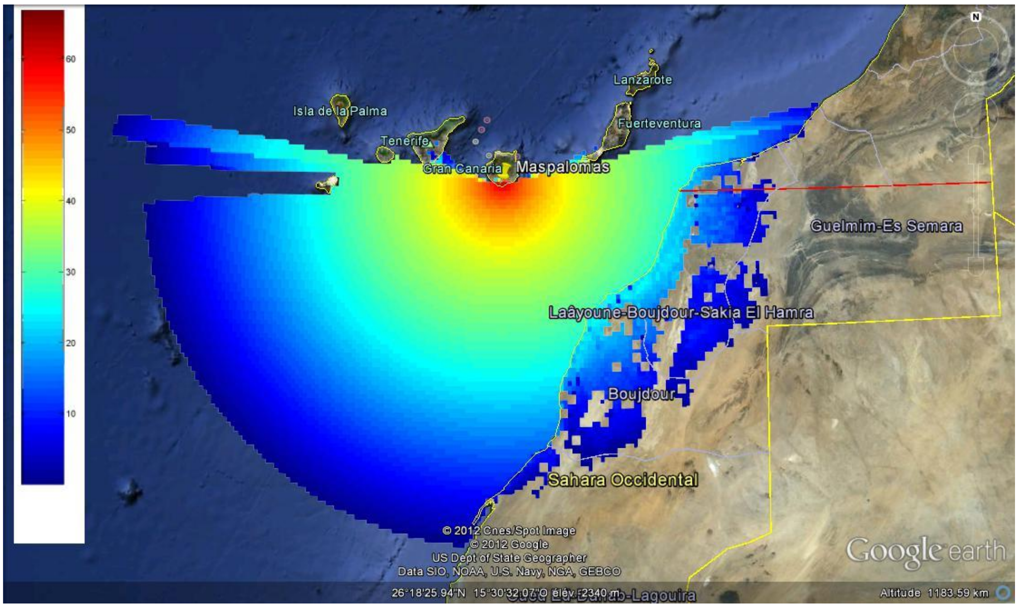
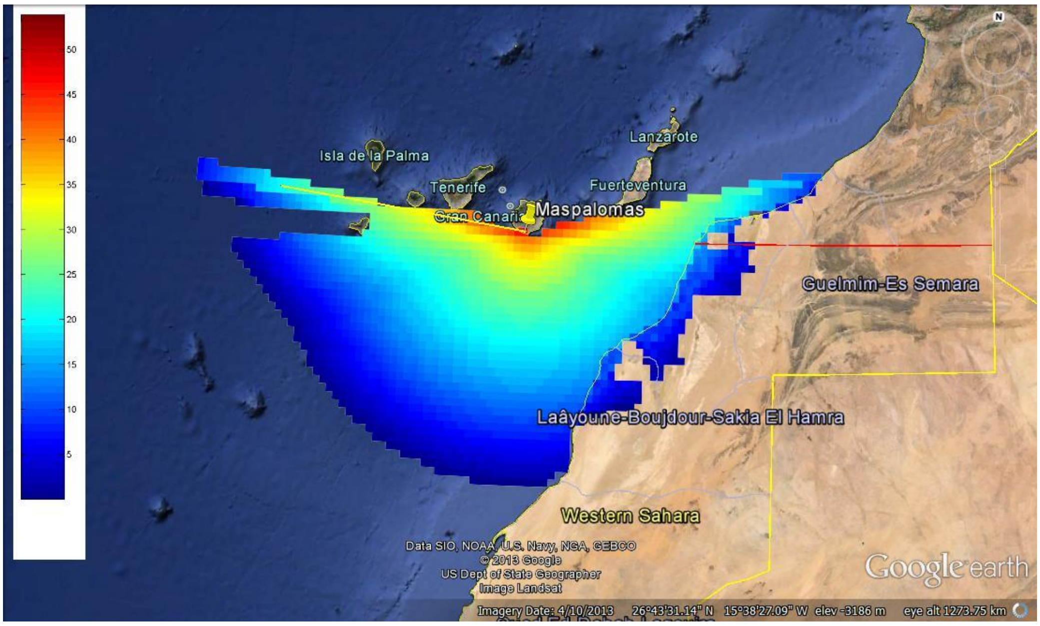


FIGURE A2-3

Interference exceedance for the Maspalomas ESA earth station vs GSO MMSS earth stations



Figures A2-4 and A2-5 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Maspalomas EESS earth station, when considering RR Art. **21-8** e.i.r.p. limits.

FIGURE A2-4

Interference exceedance for the Maspalomas ESA earth station vs NGSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)

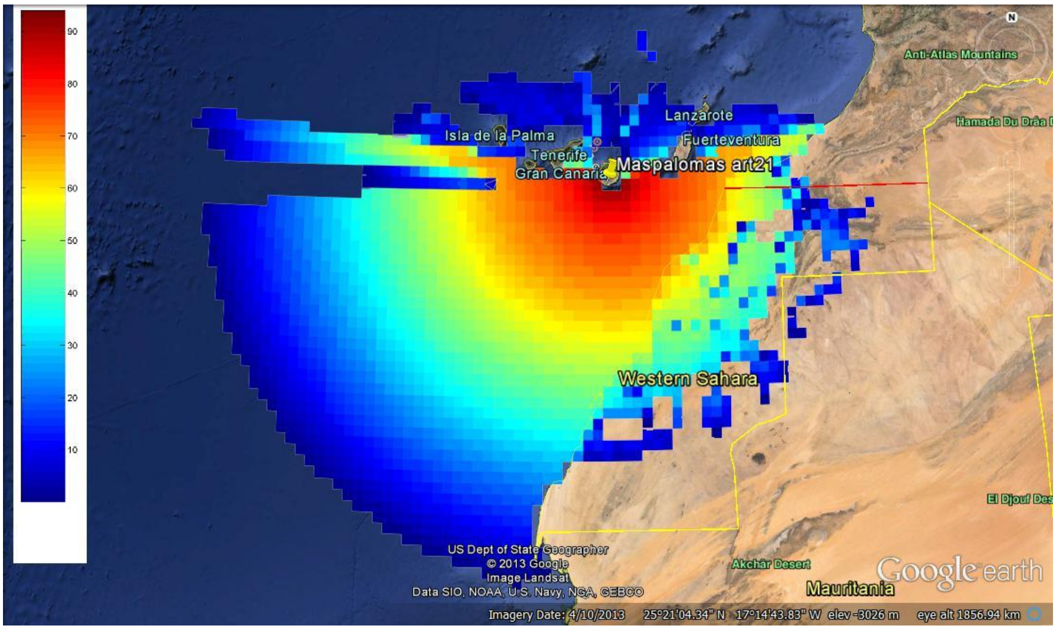
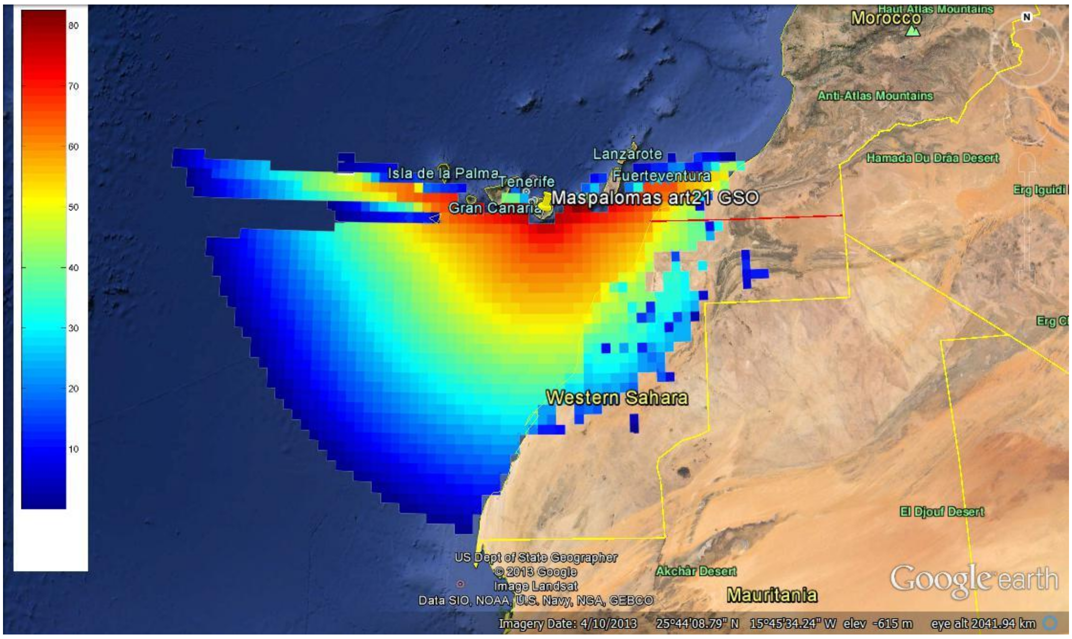


FIGURE A2-5

Interference exceedance for the Maspalomas ESA earth station vs GSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)



A2.1.2.2 Kourou

Figures A2-6 and A2-7 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Kourou earth station for typical MMSS characteristics.

FIGURE A2-6

Interference exceedance for the Kourou ESA earth station vs NGSO MMSS earth stations

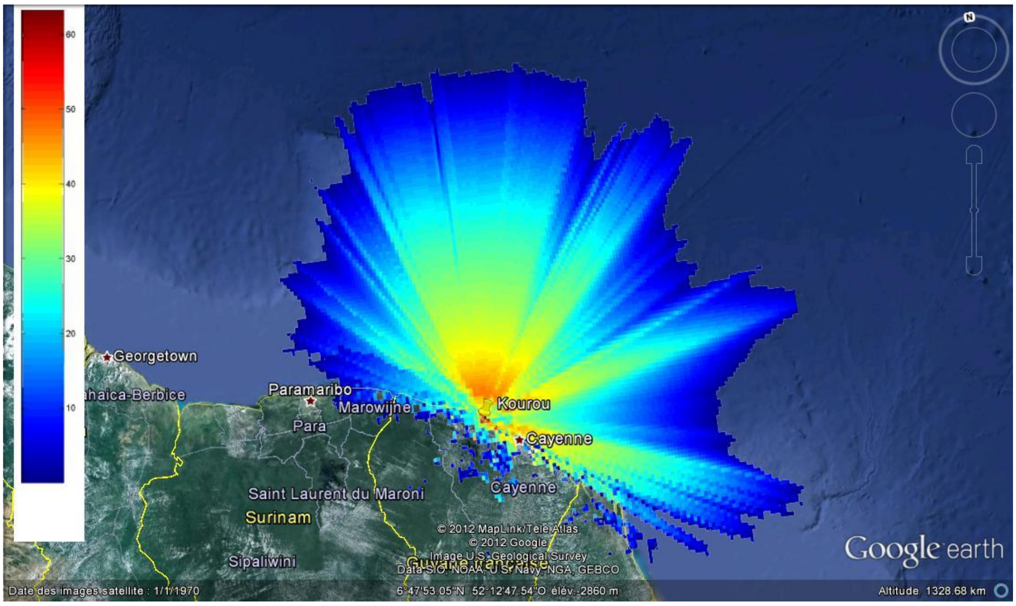
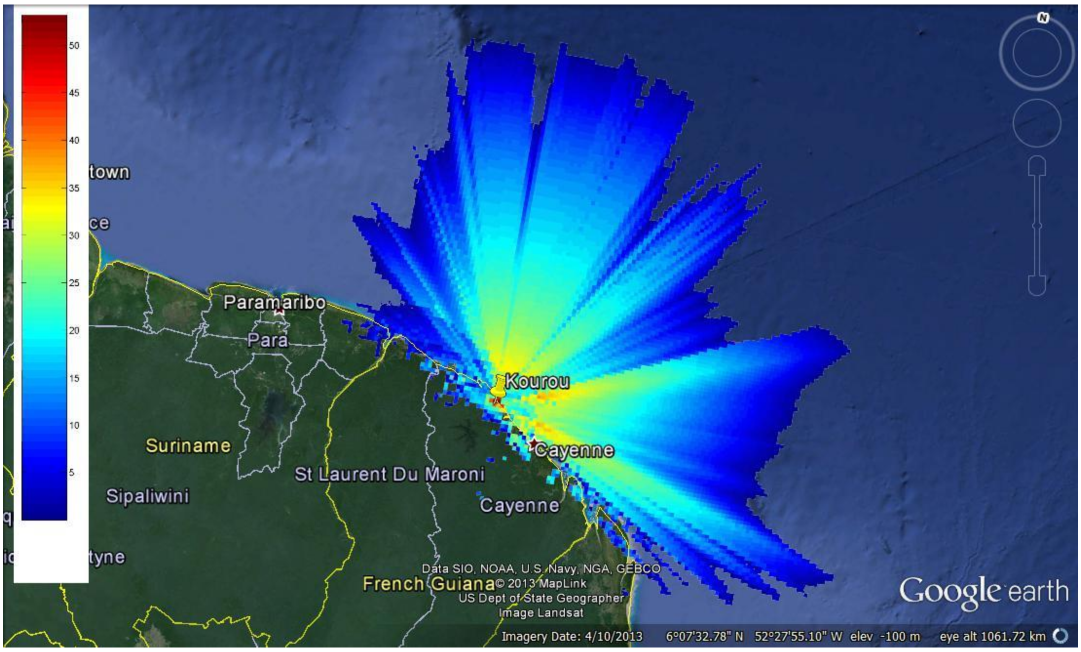


FIGURE A2-7

Interference exceedance for the Kourou ESA earth station vs GSO MMSS earth stations



Figures A2-8 and A2-9 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Kourou earth station for RR Art. **21-8** e.i.r.p. limits.

FIGURE A2-8

Interference exceedance for the Kourou ESA earth station vs NGSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)

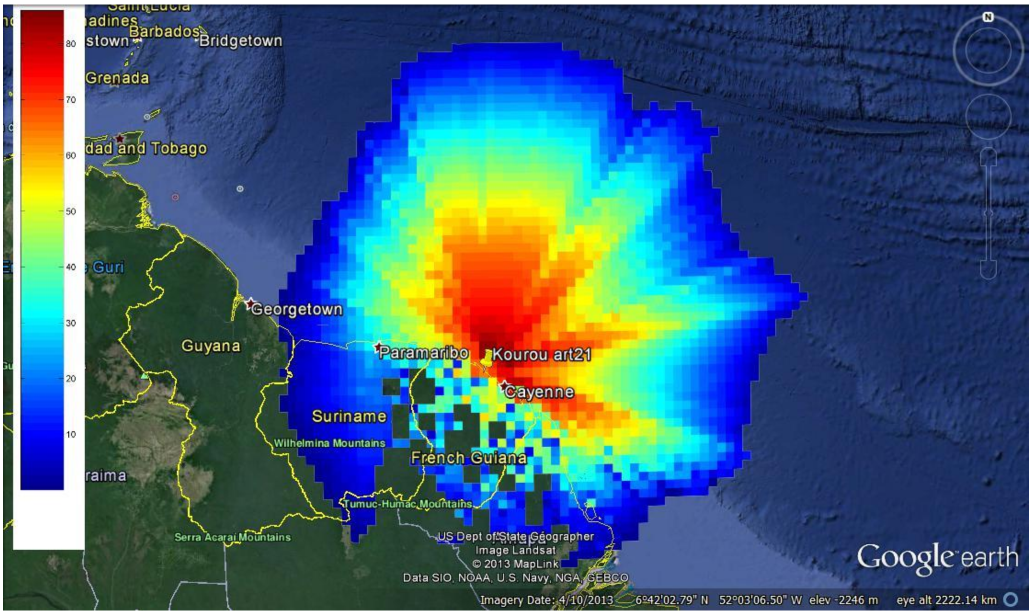
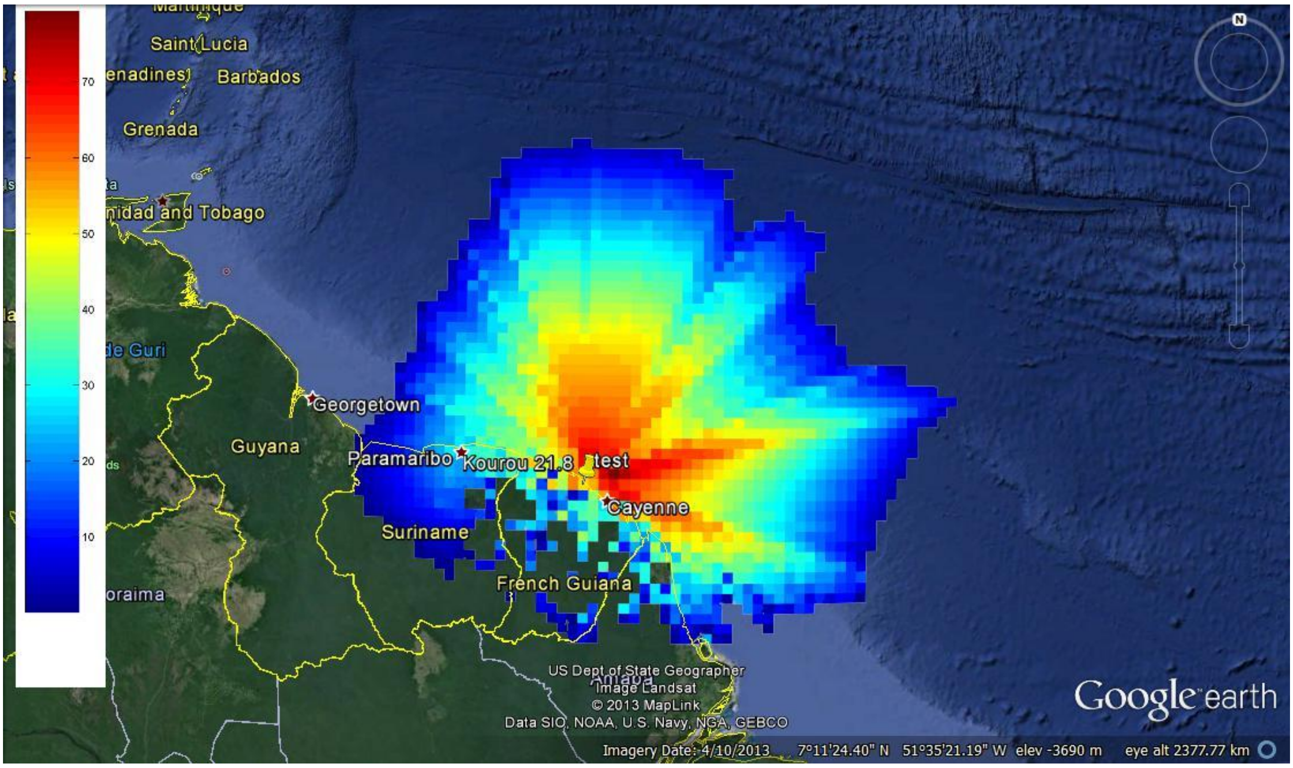


FIGURE A2-9

Interference exceedance for the Kourou ESA earth station vs GSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)



A2.1.2.3 Santa Maria

Figures A2-10 and A2-11 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Santa Maria earth station in Azores, when considering typical MMSS characteristics.

FIGURE A2-10

Interference exceedance for the Santa Maria ESA earth station vs NGSO MMSS earth stations

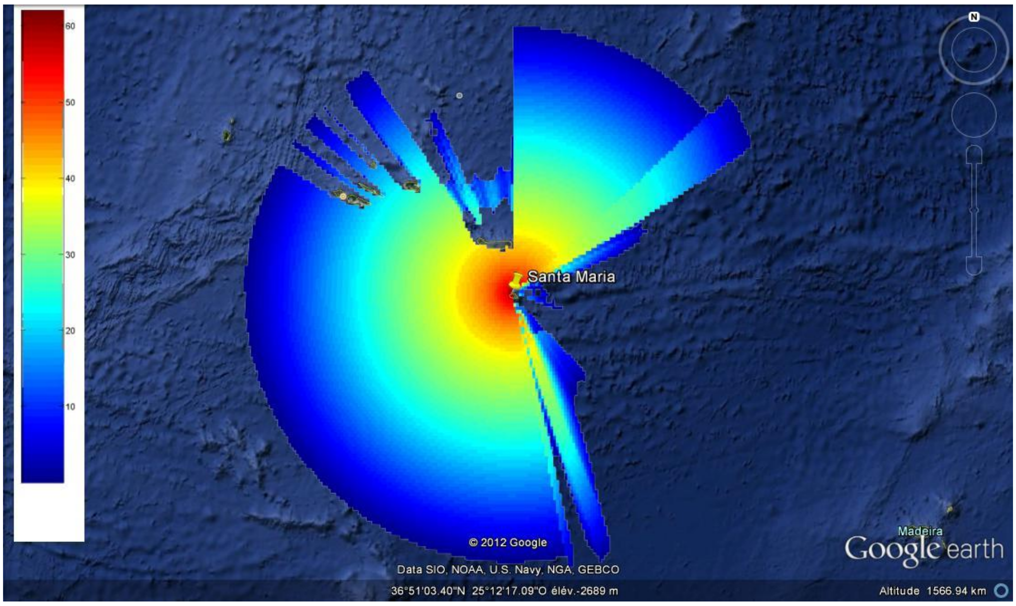
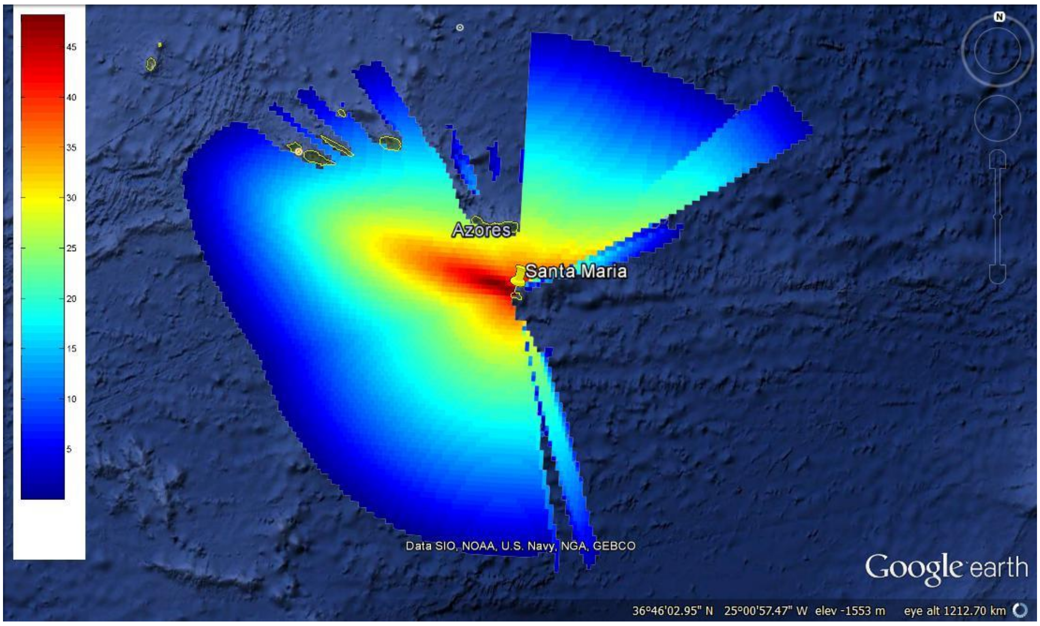


FIGURE A2-11

Interference exceedance for the Santa Maria ESA earth station vs GSO MMSS earth stations



Figures A2-12 and A2-13 give in colour the level by which the short-term EESS sharing criterion is exceeded at the ESA Santa Maria EESS earth station, when considering RR Art. **21-8** e.i.r.p. limits.

FIGURE A2-12

Interference exceedance for the Santa Maria ESA earth station vs NGSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)

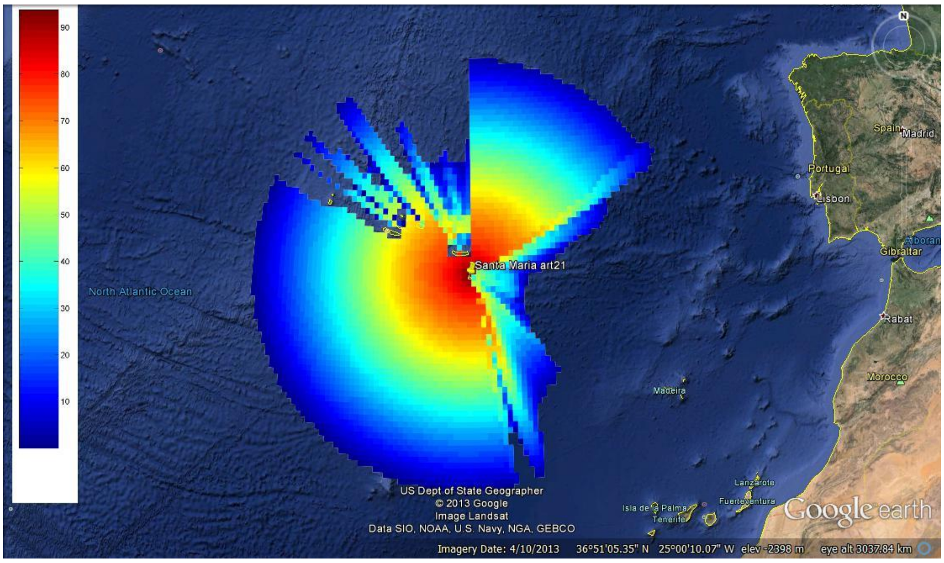
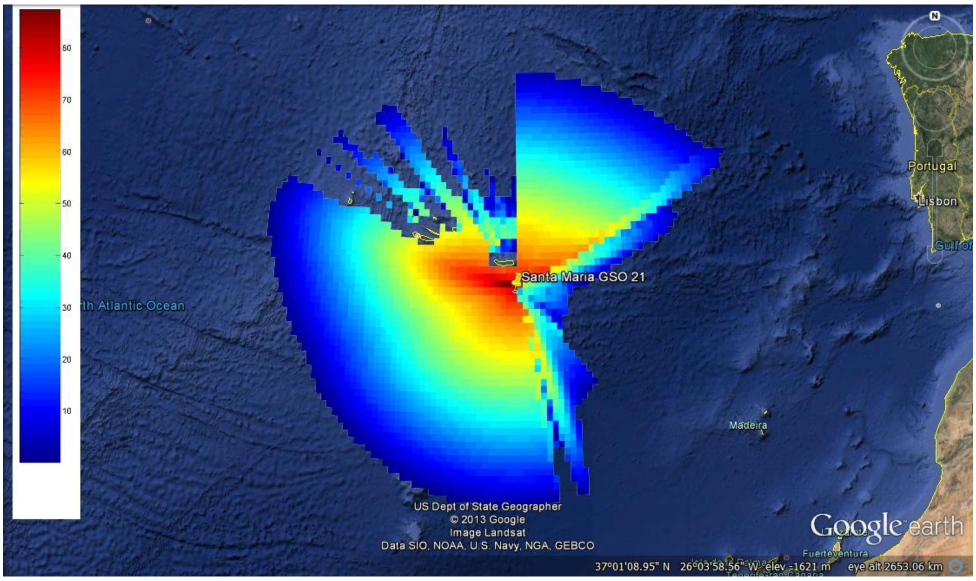


FIGURE A2-13

Interference exceedance for the Santa Maria ESA earth station vs GSO MMSS earth stations (RR Art. 21-8 e.i.r.p. limits)



A2.2 Analysis 2

A2.2.1 Parameters used in Analysis 2

The EESS ground station parameters used in the simulations are given in Table A2-2.

TABLE A2-2

Parameters used for all EESS stations

EESS Parameter	Value	Units	Notes
Frequency	8.2	GHz	Assumed receive frequency for all stations and transmit frequency for MMSS
Min. tracking angle	5	deg	Antenna minimum tracking angle
Antenna diameter Antenna height	15 (5.4) 20 (6.7)	m m	From dish antenna center to ground. Values in parentheses are for Prudhoe Bay station
Antenna gain pattern	ITU RR AP **8-10** Annex III		The antenna gain is estimated at 5 degrees elevation angle
Antenna gain towards MMSS	14.53	dBi	Fixed value
Permissible interference level	–133	dBW/10 MHz	Rec. ITU-R SA.1027
Probability of exceedence (*p*)	0.005	%	Rec. ITU-R SA.1027

The refractive index, ΔN and surface refractivity, N_0 used with Recommendation ITU-R P.452 are provided in Table A2-3.

TABLE A2-3

Refractive index, ΔN and surface refractivity, N_0 used with Recommendation ITU-R P.452

Ground station name	Country	Refractive index, ΔN	Surface refractivity, N_0
Santiago	Chile	60	335
Beijing	China	50	340
Hatoyoma	Japan	47	340
Katsuura	Japan	47	340
Svalbard	Norway	36	313
Valladolid	Spain	47	330
Prudhoe Bay	USA	40	317
South Point	USA	50	360
Stennis Space Center	USA	55	355
Wallops	USA	47	325

The MMSS system parameters assumed for this analysis are provided in Table A2-4.

TABLE A2-4

MMSS earth station parameters used in interference analysis Parameter		**Value**		**Note**
MMSS earth station (transmit, 8 025-8 400 MHz)				
Frequency		8.2	GHz	Section 2 above
Antenna min. elevation angle	θ_t	10	deg	Section 2 above
Antenna diameter		2.6	m	Section 2 above
Antenna height		15	m	Ship height + antenna
Antenna gain pattern	G_T	Rec. ITU-R S.580-6		Section 2 above
Antenna peak gain	$G0_t$	45	dB	Section 2 above
Terrain elevation angle	ε_t	Variable	deg	Varies depending on azimuth direction
Off-boresight angle	γ_t	Variable	deg	Depends on the FSS antenna pointing direction and the horizon direction towards SRS earth station For NGSO, $\gamma_t = \theta_t - \varepsilon_t$ For GSO, calculate using az-el. See Note 1
Antenna gain towards EESS earth station (at γ_t = 10 deg)	G_t	$G_T(\gamma_t)$) 4	dB dB	Varies depending on the off-boresight angle. For NGSO, terrain elevation angle ε_t approximated as $\varepsilon_t = 0$. Using side-lobe gain pattern: 29–25*Log(θ_t-ε_t) = 29-25*Log(10)
Max. transmit e.i.r.p. density at boresight	$P0_t$	76	dBW/10 MHz	Section 2 above
Transmitter power density	P_T	31	dBW/10 MHz	Case 1: Calculated = $P0_t - G0_t$
Max allowed transmitter power density per RR **21.8**	P_T	70	dBW/10 MHz	Case 2: Calculated = 4 dBW/Hz – 4 dB

TABLE A2-4 (*end*)

MMSS earth station parameters used in interference analysis Parameter		**Value**		**Note**
Max. transmit e.i.r.p. density towards horizon (at γ_t = 10 deg)		P_T+G_t 35	dBW/10 MHz	
Max. allowed transmit e.i.r.p. density towards horizon	P_t	40 4	dBW/4 kHz dBW/Hz	ITU RR No. **21.8** 40+3E (dBW/4 kHz), 0<E<5 deg

NOTE 1 – For GSO MMSS systems, the separation angle between the direction of the EESS earth station location and the boresight of the MMSS earth station antenna pointed to a GSO satellite is minimized by varying the GSO satellite location on the visible geostationary arc as described in RR Appendix **7**-Annex 5.

The minimum propagation loss, L_{min} in dB, required from the MMSS transmitter to EESS ground station receiver is given by:

$$L_{min} = e.i.r.p._{Tx} - Protection\_Criteria_{Rx} + G_{Rx}$$

e.i.r.p.$_{Tx}$ is the maximum transmit spectral density of 35.0 dBW in 10 MHz reference bandwidth (-31 dB(W/Hz)) transmitted in any direction towards the horizon by the interfering MMSS station based on the parameters of the 2.6 m MMSS system provided in section 2 of this document.

In order to check the applicability of existing provisions of the Radio Regulations (RR), the maximum transmit e.i.r.p. spectral density of 40.0 dBW in 4 kHz reference bandwidth (4.0 dB(W/Hz)) transmitted in any direction towards the horizon by the MMSS (RR No. **21.8**) is also used.

The protection criteria for the EESS earth station is –133 dB (W/10 MHz), and the EESS receive off-boresight antenna gain, G_{Rx}, is taken to be approximately 14.53 dBi. Using these parameters, the minimum propagation loss to meet the protection of the EESS earth station against MMSS with the characteristics in Table 3 (Study 5 Part 1) and maximum e.i.r.p. density in RR No. **21.8** is 182.53 and 232.5 dB, respectively.

In general, the off-boresight gain of the receive EESS ground station antenna depends on the horizon elevation and the minimum tracking angle of the EESS ground station antenna. This gain can vary considerably depending on the terrain elevation around the EESS ground station.

The simulation assumptions are as follows:

1) Used the ITU sharing criteria from Recommendation ITU-R SA.1027 as given in Table A2-1.

2) The EESS station characteristics are shown in Table A2-2.

3) EESS and MMSS satellite tracking are not considered. MMSS satellite networks are not restricted to GSO only.

4) Only one interfering MMSS earth station is used. Multiple MMSS stations can generate aggregate interference that can potentially be much higher than what is calculated in this contribution depending upon the actual MMSS density and geographical distribution.

5) The antenna height of the MMSS is 15 meters above sea level.

6) Area of analysis is approximately 700 × 700 km sampled at 5 × 5 km.

7) Employed Recommendation ITU-R P.452 with 90 meter resolution global terrain data, and ITU Digitized World Map (IDWM).

Areas where the interference value is greater than the recommended threshold are coloured in red and areas where the interference is below the required threshold are not coloured.

A2.2.2 Separation distances required to protect EESS stations

The simulation results for Case 1 (with the lower transmit power density based on Annex 5 to Document 4C/91 MMSS station parameters) are shown in Figs A2-14 through A2-33. These Figures include results for both GSO and NGSO MMSS systems. They show that for some EESS stations, particularly those close to the shore, significant separation distances are required between one interfering MMSS station and the victim EESS earth stations in order to satisfy the sharing criteria in Recommendation ITU-R SA.1027-4. However, with the lower interference power level used with Case 1, the separation distance in the direction of the ocean may not reach the coastline for other stations. The required separation distances are in the range of between of between 148 km and 544 km for NGSO MMSS systems, and between 78 km and 379 km for GSO MMSS systems depending upon the geographical characteristics surrounding the EESS earth station.

FIGURE A2-14

Santiago, Chile (Lat = -33.151°, Lon = -70.671°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 148 km,
Separation distance over water = 0 km, distance from shore = 0 km

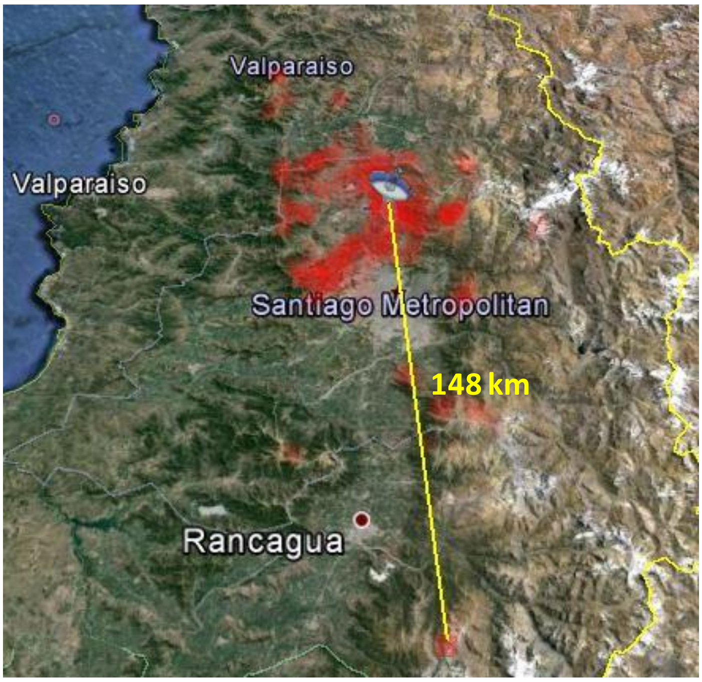


FIGURE A2-15

Santiago, Chile (Lat = -33.151°, Lon = -70.671°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 122 km,
Separation distance over water = 0 km, distance from shore = 0 km

FIGURE A2-16

Beijing, China (Lat = 40.45°, Lon = 116.90°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 207 km,
Separation distance over water = 0 km, distance from shore = 0 km

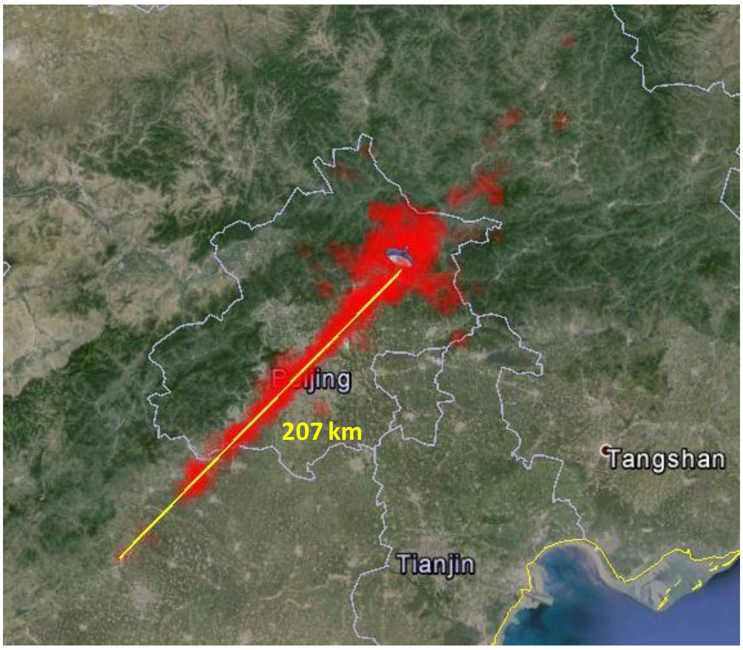


FIGURE A2-17

Beijing, China (Lat = 40.45°, Lon = 116.90°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 78 km,
Separation distance over water = 0 km, distance from shore = 0 km

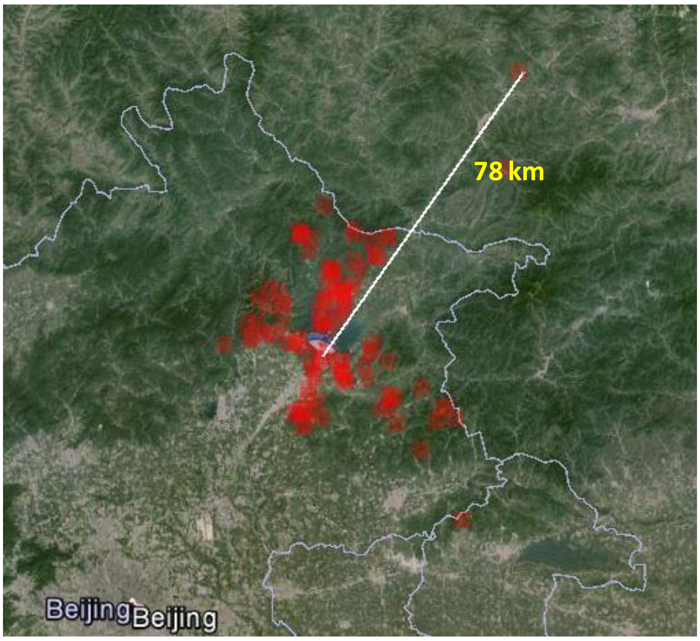


FIGURE A2-18

Hatoyama, Japan (Lat = 36.02°, Lon = 139.33°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 422 km,
Separation distance over water = 422 km, distance from shore = 312 km

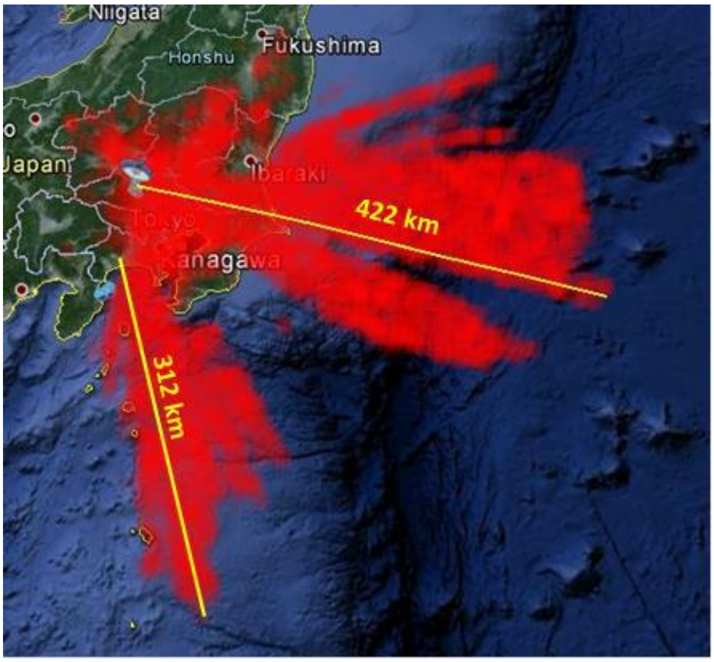


FIGURE A2-19

Hatoyama, Japan (Lat = 36.02°, Lon = 139.33°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 314 km,
Separation distance over water = 314 km, distance from shore = 207 km

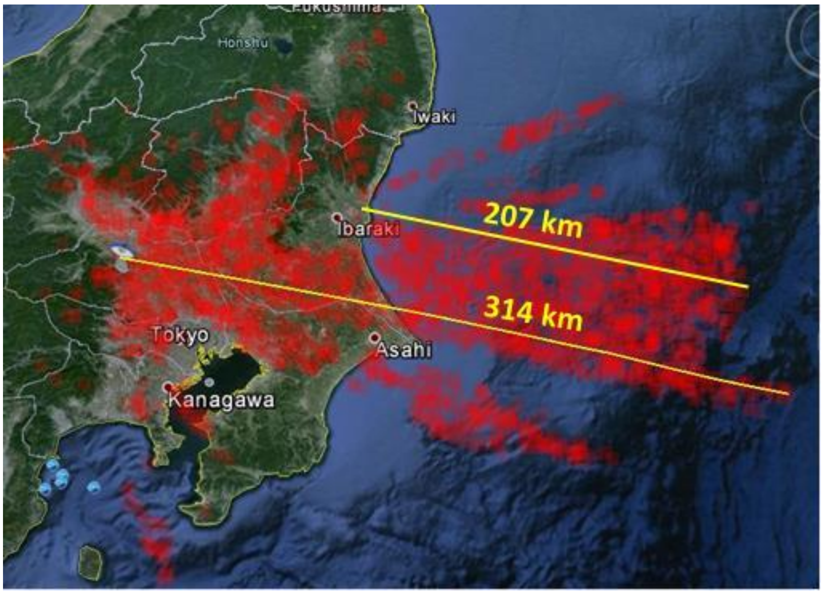


FIGURE A2-20

Valladolid, Spain (Lat = 41.65°, Lon = -4.717°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 246 km,
Separation distance over water = 0 km, distance from shore = 0 km

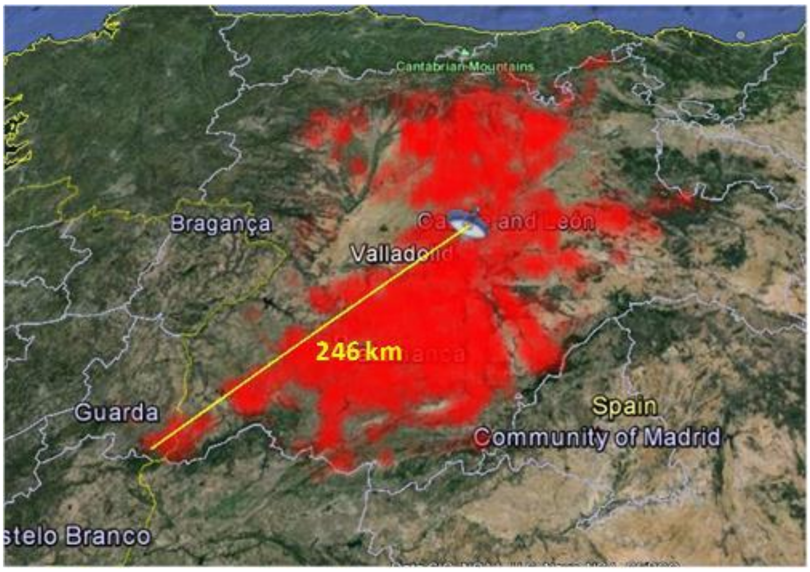


FIGURE A2-21

Valladolid, Spain (Lat = 41.65°, Lon = -4.717°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 191 km,
Separation distance over water = 0 km, distance from shore = 0 km

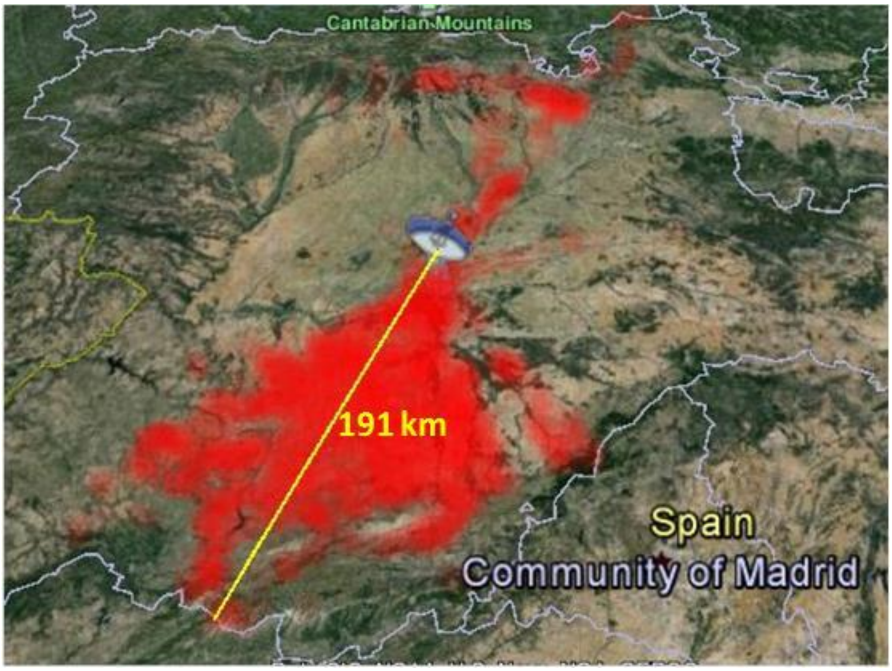


FIGURE A2-22

South Point, USA (Lat = 19.001°, Lon = -155.663°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 478 km,
Separation distance over water = 478 km, distance from shore = 478 km

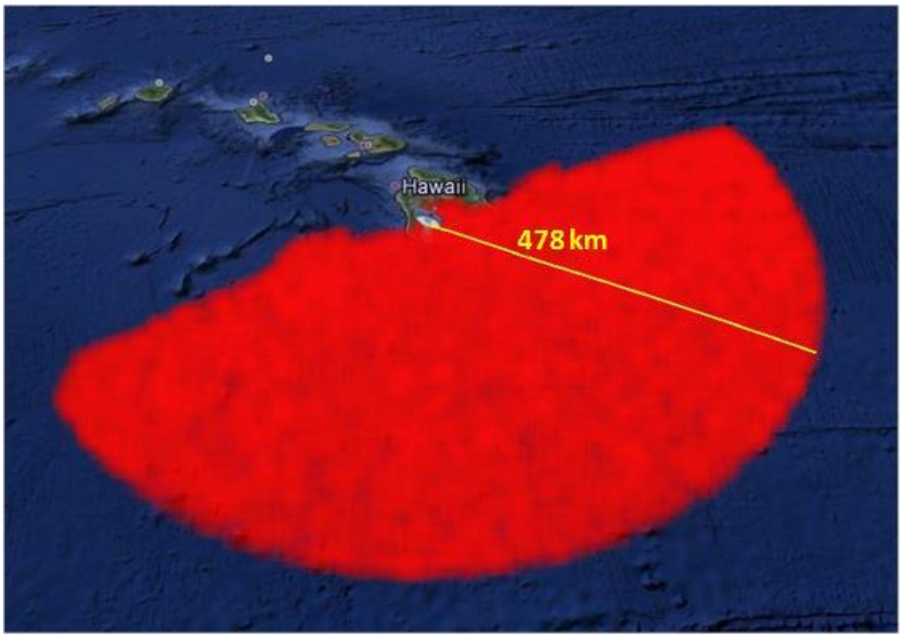


FIGURE A2-23

South Point, USA (Lat = 19.001°, Lon = -155.663°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 417 km,
Separation distance over water = 417 km, distance from shore = 417 km

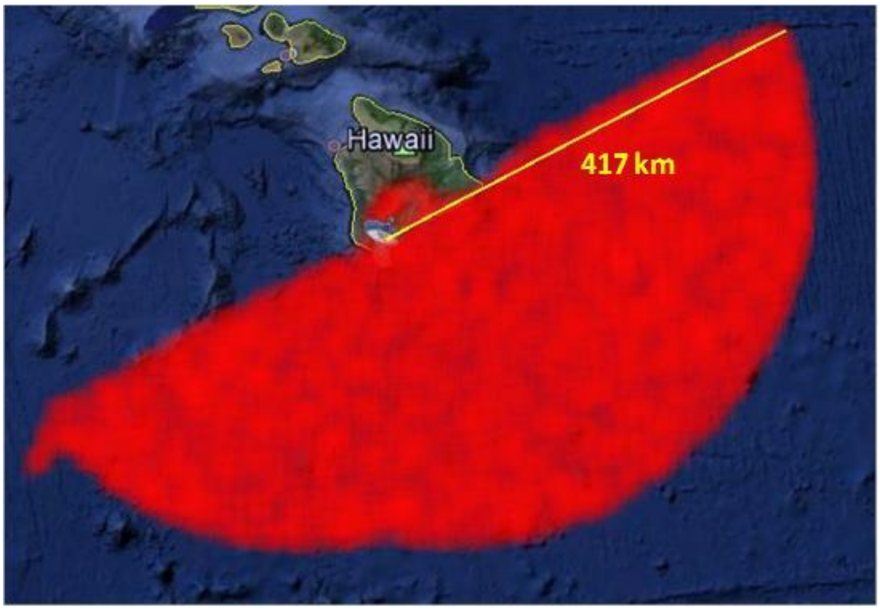


FIGURE A2-24

Stennis Space Center, USA (Lat = 30.37°, Lon = -89.45°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 446 km,
Separation distance over water = 446 km, distance from shore = 418 km

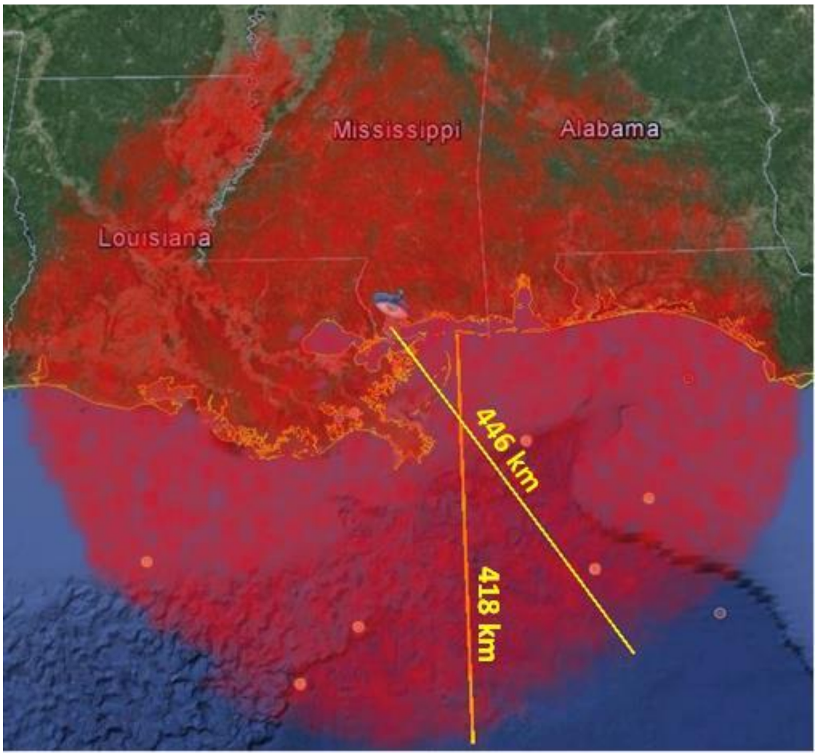


FIGURE A2-25

Stennis Space Center, USA (Lat = 30.37°, Lon = -89.45°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 327 km,
Separation distance over water = 327 km, distance from shore = 294 km

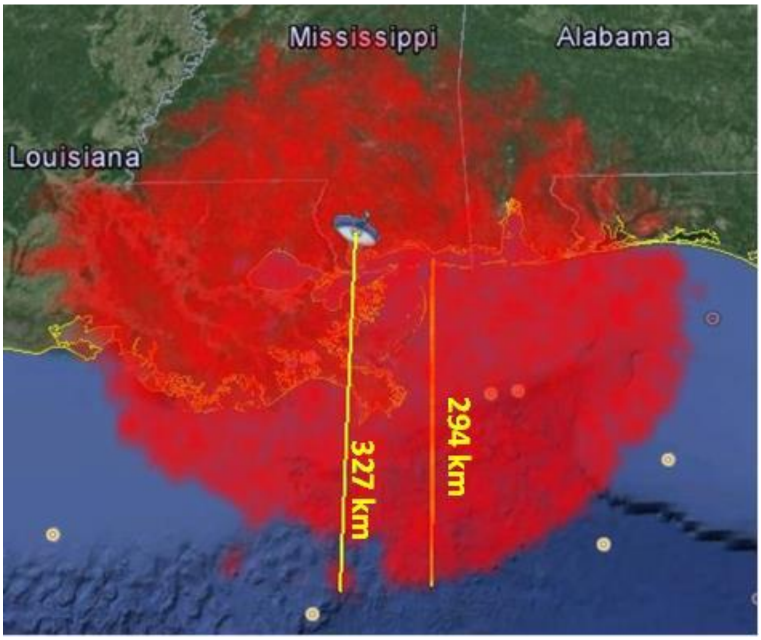


FIGURE A2-26

Wallops, USA (Lat = 37.925°, Lon = -75.476°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 469 km,
Separation distance over water = 469 km, distance from shore = 485 km

FIGURE A2-27

Wallops, USA (Lat = 37.925°, Lon = -75.476°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 379 km,
Separation distance over water = 379 km, distance from shore = 374 km

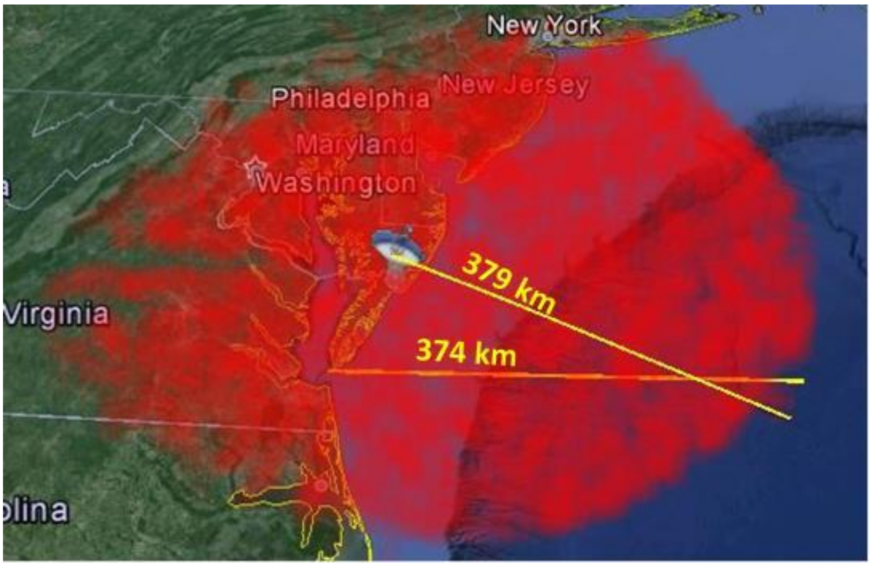


FIGURE A2-28

Katsuura, Japan (Lat = 35.21055°, Lon = 140.31055°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 456 km,
Separation distance over water = 456 km, distance from shore = 439 km

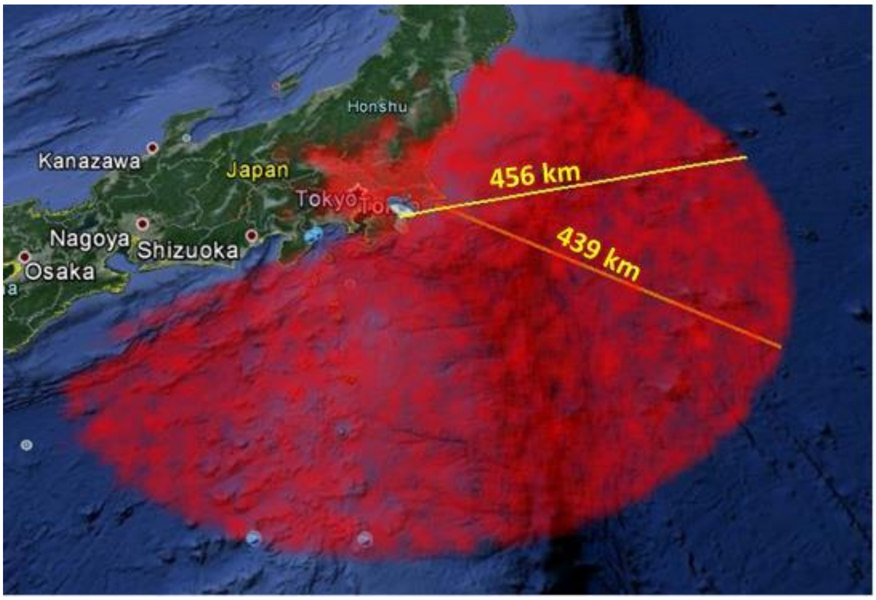


FIGURE A2-29

Katsuura, Japan (Lat = 35.21055°, Lon = 140.31055°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 374 km,
Separation distance over water = 374 km, distance from shore = 308 km

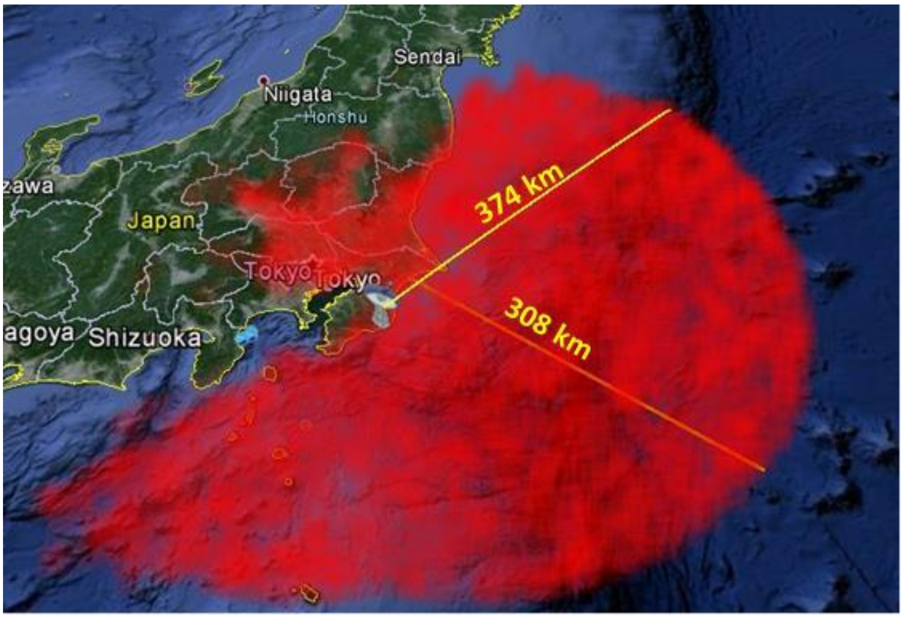


FIGURE A2-30

Prudhoe Bay, USA (Lat = 70.22045°, Lon = -148.3998°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 414 km,
Separation distance over water = 414 km, distance from shore = 366 km

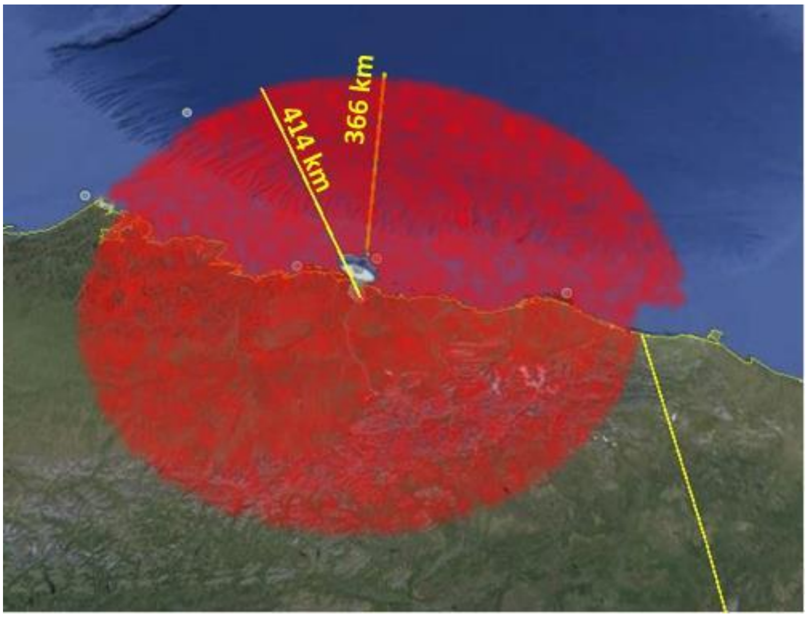


FIGURE A2-31

Prudhoe Bay, USA (Lat = 70.22045°, Lon = -148.3998°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 256 km,
Separation distance over water = 256 km, distance from shore = 241 km

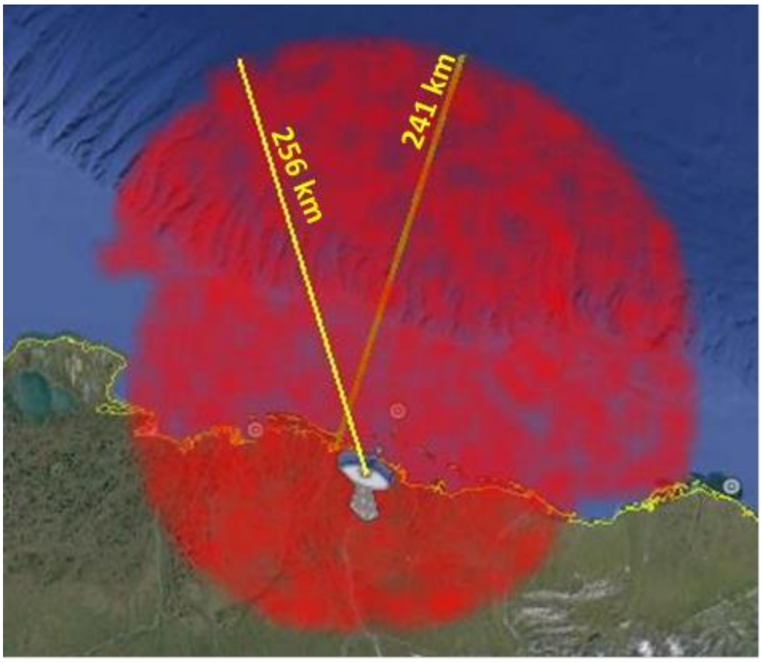


FIGURE A2-32

Svalbard, Norway (Lat = 78.23°, Lon = 15.396°)
NGSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 544 km,
Separation distance over water = 544 km, distance from shore = 509 km

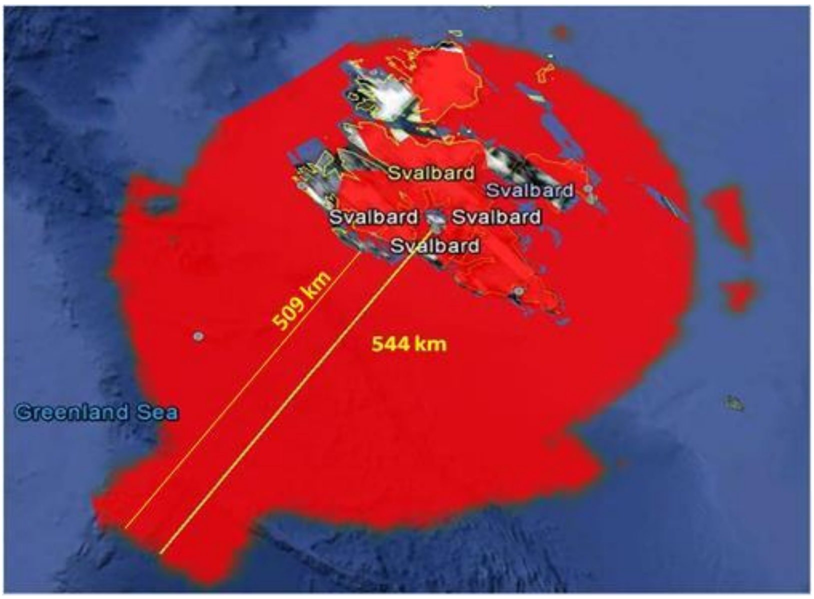
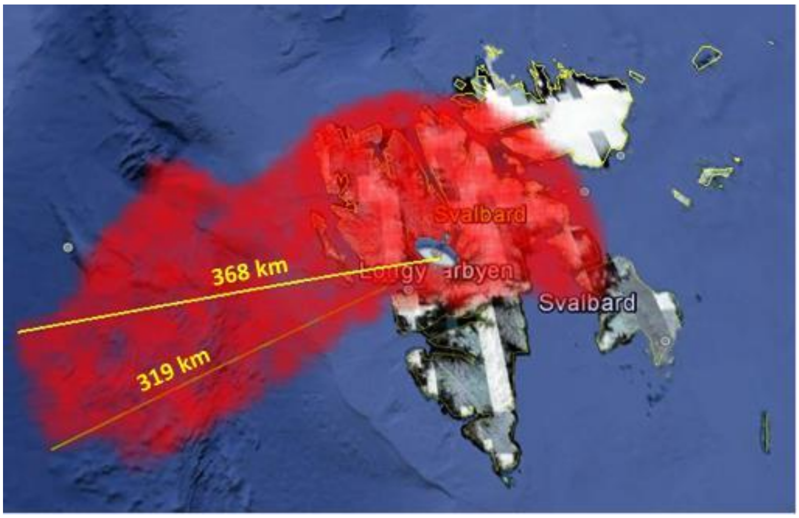


FIGURE A2-33

Svalbard, Norway (Lat = 78.23°, Lon = 15.396°)
GSO MMSS System Case 1 (P_T = 31 dBW/10 MHz) Separation distance = 368 km,
Separation distance over water = 368 km, distance from shore = 319 km



A2.2.3 Separation distances required to protect EESS stations for Case 2: transmitter power density based on ITU-R RR No. 21.8

The simulation results for Case 2 (with the higher MMSS transmit power density based on ITU-R RR **21.8** constraints) are shown in Figs A2-34 through A2-53. These figures include results for both GSO and NGSO MMSS systems. As with the Case 1 results, they show that for some EESS stations, particularly those close to the shore, significant separation distances are required between one interfering MMSS station and the victim EESS earth stations in order to satisfy the sharing criteria in Recommendation ITU-R SA.1027-4.

FIGURE A2-34

Santiago, Chile (Lat = -33.151°, Lon = -70.671°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 385 km,
Separation distance over water = 385 km, distance from shore = 264 km

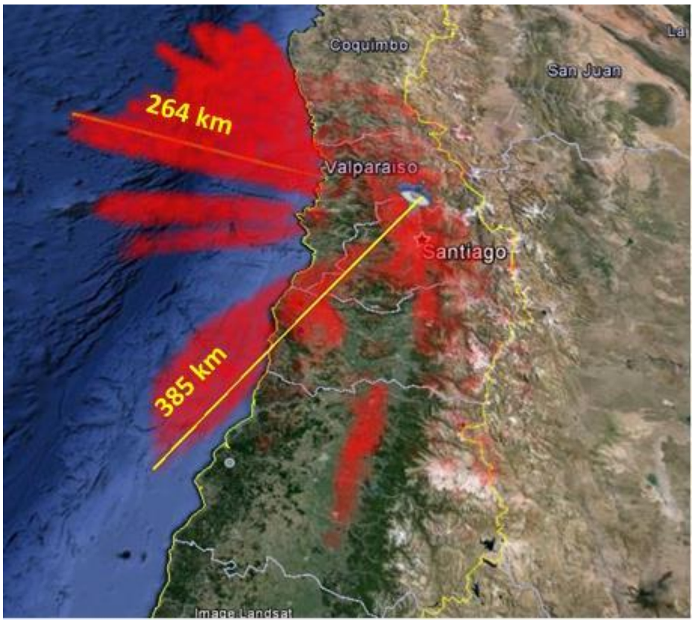


FIGURE A2-35

Santiago, Chile (Lat = -33.151°, Lon = -70.671°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 290 km,
Separation distance over water = 237 km, distance from shore = 60 km

FIGURE A2-36

Beijing, China (Lat = 40.45°, Lon = 116.90°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 357 km,
Separation distance over water = 300 km, distance from shore = 66 km

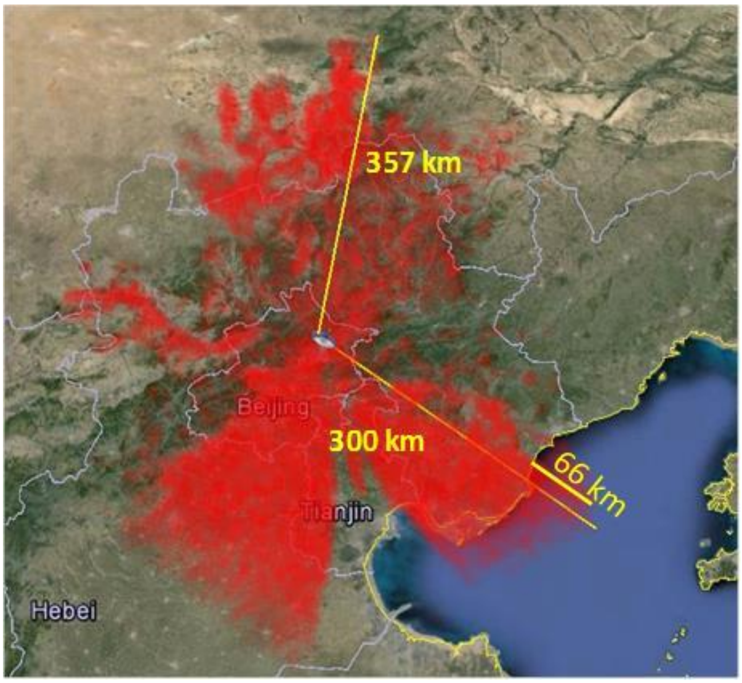


FIGURE A2-37

Beijing, China (Lat = 40.45°, Lon = 116.90°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 266 km,
Separation distance over water = 0 km, distance from shore =0 km

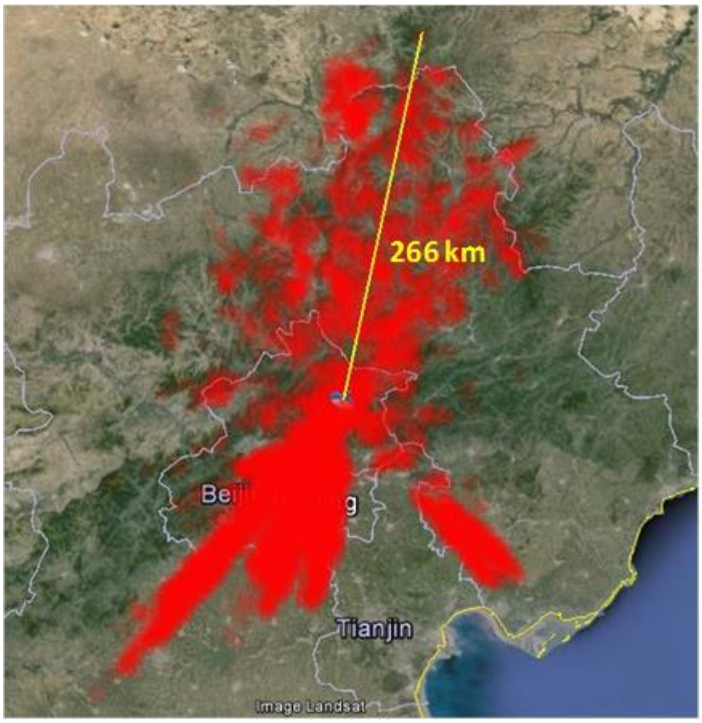


FIGURE A2-38

Hatoyama, Japan (Lat = 36.02°, Lon = 139.33°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 576 km,
Separation distance over water = 576 km, distance from shore =509 km

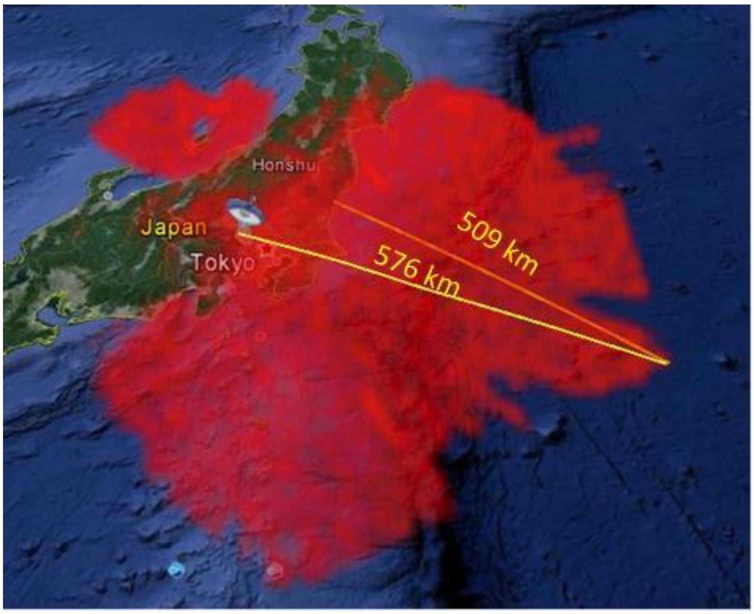


FIGURE A2-39

Hatoyama, Japan (Lat = 36.02°, Lon = 139.33°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 530 km,
Separation distance over water = 530 km, distance from shore =415 km

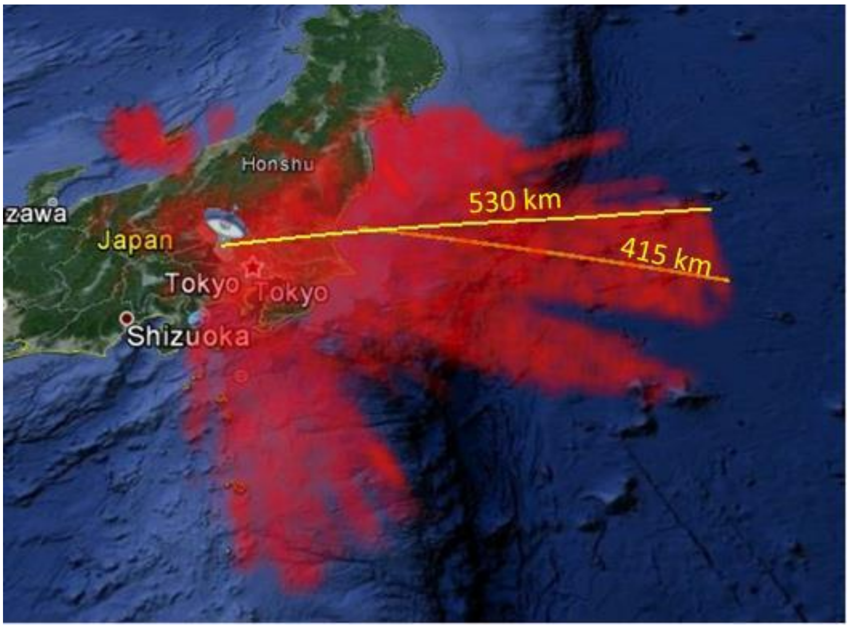


FIGURE A2-40

Valladolid, Spain (Lat = 41.65°, Lon = -4.717°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 525 km,
Separation distance over water = 525 km, distance from shore =262 km

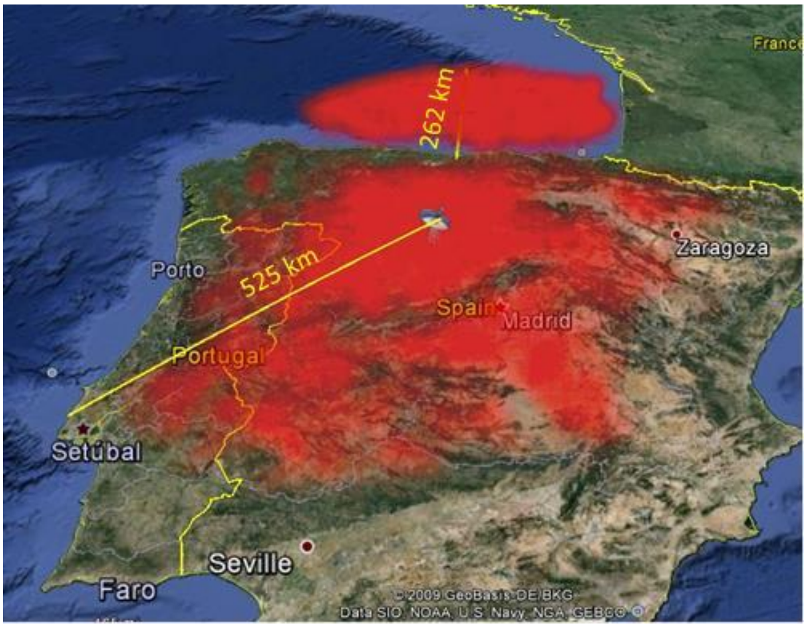


FIGURE A2-41

Valladolid, Spain (Lat = 41.65°, Lon = -4.717°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 318 km,
Separation distance over water = 318 km, distance from shore = 126 km

FIGURE A2-42

South Point, USA (Lat = 19.001°, Lon = -155.663°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 653 km,
Separation distance over water = 653 km, distance from shore =653 km

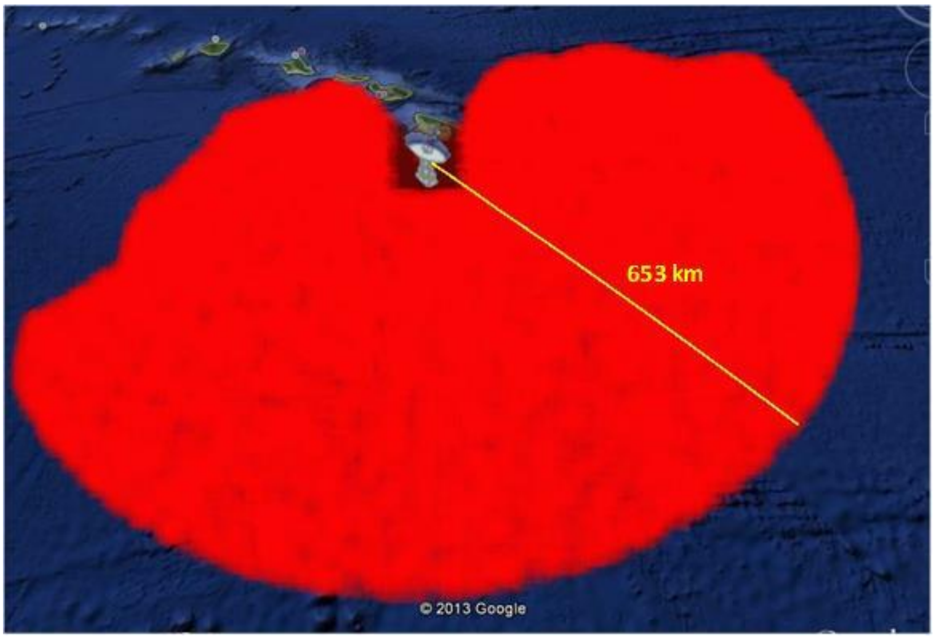


FIGURE A2-43

South Point, USA (Lat = 19.001°, Lon = -155.663°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 616 km,
Separation distance over water = 616 km, distance from shore =616 km

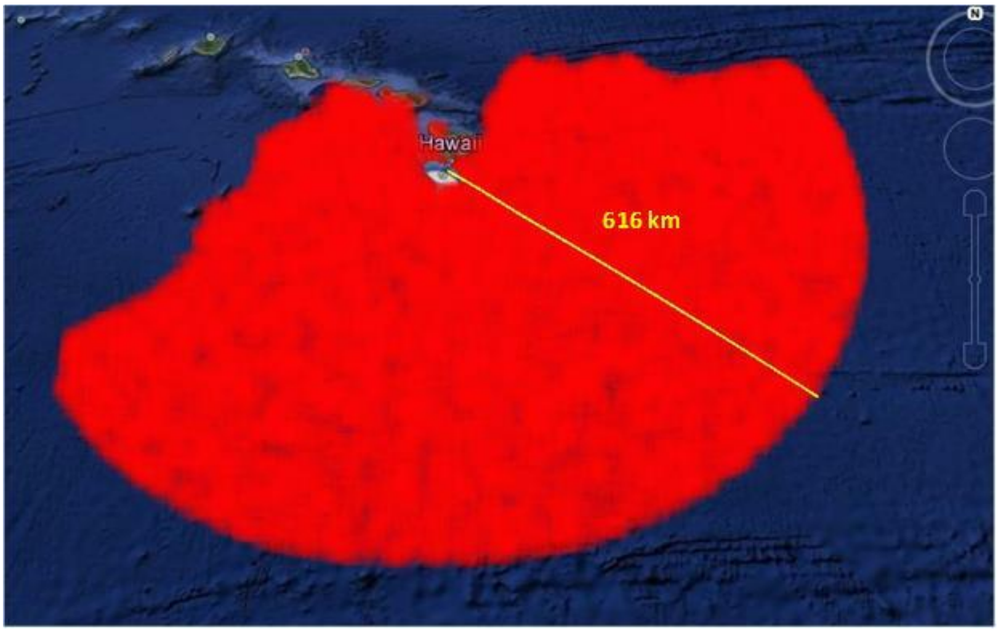


FIGURE A2-44

Stennis Space Center, USA (Lat = 30.37°, Lon = -89.45°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 609 km,
Separation distance over water = 609 km, distance from shore =584 km

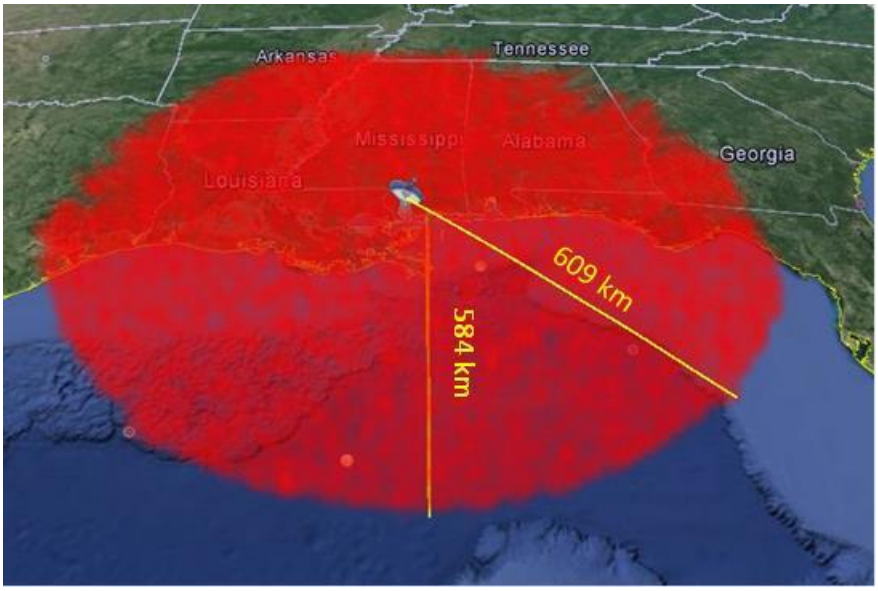


FIGURE A2-45

Stennis Space Center, USA (Lat = 30.37°, Lon = -89.45°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 541 km,
Separation distance over water = 541 km, distance from shore =492 km

FIGURE A2-46

Wallops, USA (Lat = 37.925°, Lon = -75.476°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 609 km,
Separation distance over water = 609 km, distance from shore =657 km

FIGURE A2-47

Wallops, USA (Lat = 37.925°, Lon = -75.476°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 558 km, Separation distance over water = 558 km, distance from shore =572 km

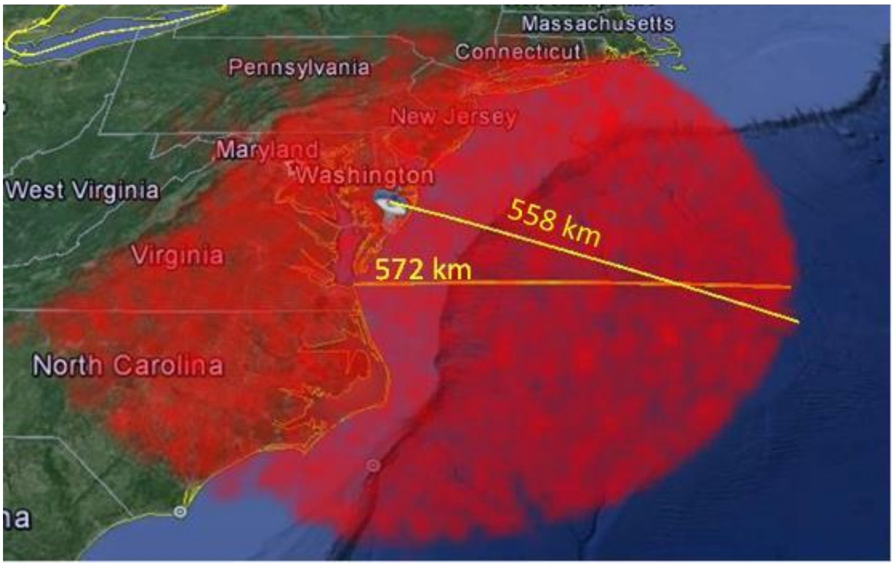


FIGURE A2-48

Katsuura, Japan (Lat = 35.21055°, Lon = 140.31055°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 627 km, Separation distance over water = 627 km, distance from shore =634 km

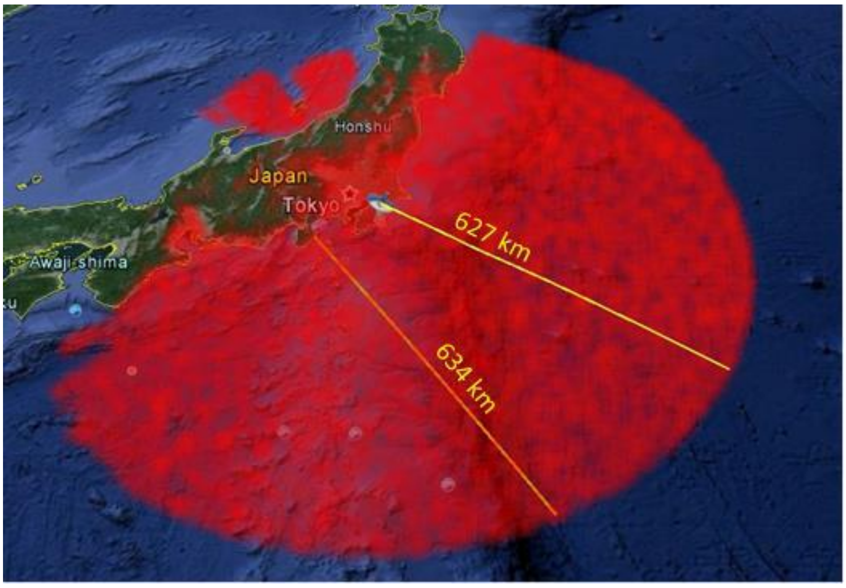


FIGURE A2-49

Katsuura, Japan (Lat = 35.21055°, Lon = 140.31055°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 579 km,
Separation distance over water = 579 km, distance from shore =553 km

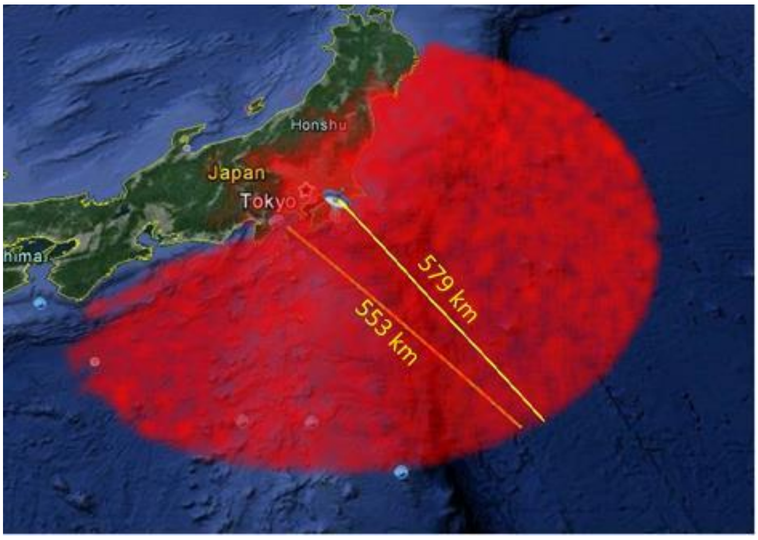


FIGURE A2-50

Prudhoe Bay, USA (Lat = 70.22045°, Lon = -148.3998°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 523 km,
Separation distance over water = 523 km, distance from shore =535 km

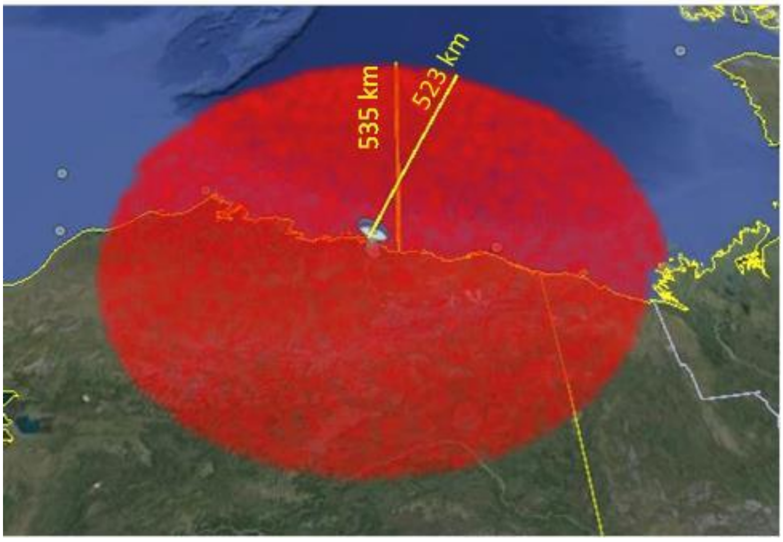


FIGURE A2-51

Prudhoe Bay, USA (Lat = 70.22045°, Lon = -148.3998°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 461 km,
Separation distance over water = 461 km, distance from shore =487 km

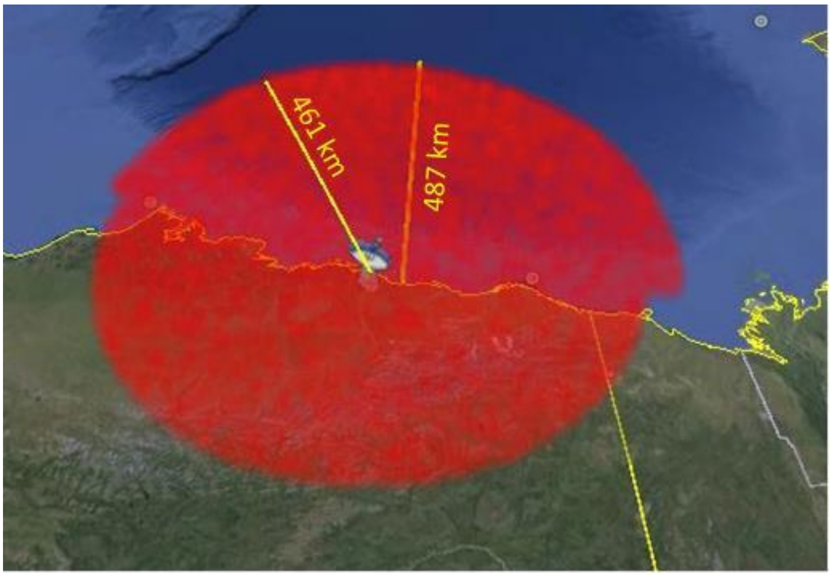


FIGURE A2-52

Svalbard, Norway (Lat = 78.23°, Lon = 15.396°)
NGSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 892 km,
Separation distance over water = 892 km, distance from shore =834 km

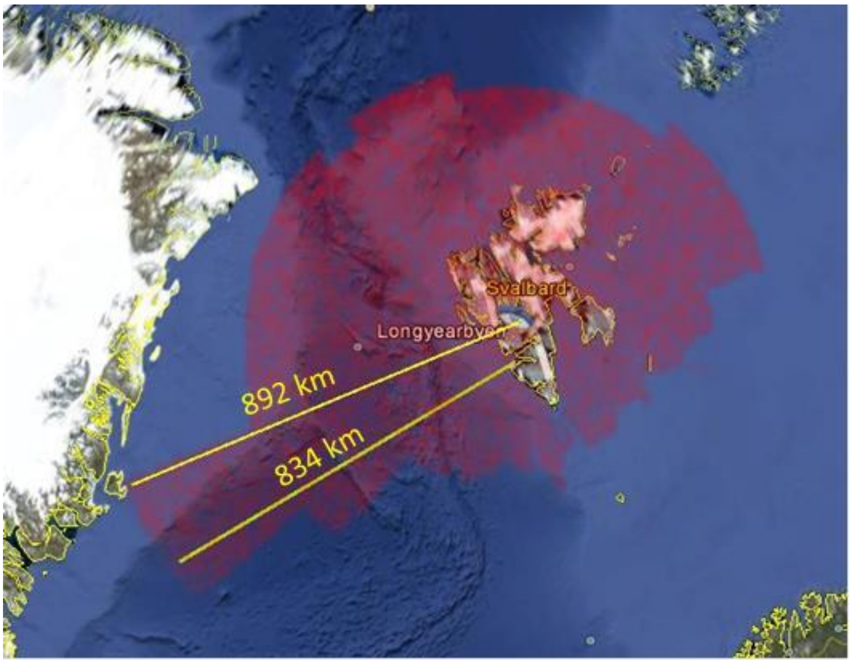
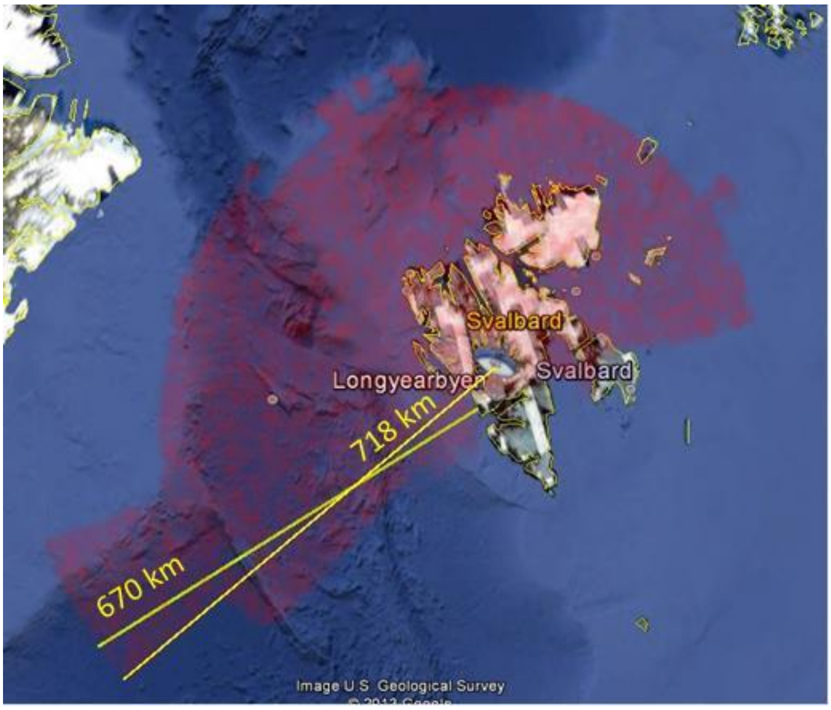


FIGURE A2-53

Svalbard, Norway (Lat = 78.23°, Lon = 15.396°)
GSO MMSS System Case 2 (P_T = 70 dBW/10 MHz) Separation distance = 718 km,
Separation distance over water = 718 km, distance from shore =670 km



A2.3 Analysis 3

A2.3.1 Introduction

Under Resolution **758 (WRC-12)**, WRC-15 agenda item 1.9.2 calls for consideration of feasibility of allocating the bands 7 375-7 750 MHz (s-E) and 8 025-8 400 MHz (E-s) to the maritime mobile-satellite service (MMSS), depending on the results of appropriate studies with other services.

The frequency band 8 025-8 400 MHz is currently allocated to Earth exploration-satellite service (EESS), fixed (FS), mobile (MS, except aeronautical mobile) and fixed-satellite (FSS, E-s) services while the band 8 175-8 215 MHz is also allocated meteorological-satellite service (E-s). The possibility of allocating the band 8 025-8 400 MHz (E-s) to the maritime mobile-satellite service should first consider the result of the sharing study with these radio services.

China has the same frequency allocations in band 8 025-8 400 MHz. Several Earth exploration-satellite service systems were deployed and more are planned in future. The receivers of these systems require protection to ensure the necessary quality of the product.

This document provides the sharing study of the impact of MMSS (E-s) earth stations into the EESS (s-E) earth station in China in the band 8 025-8 400 MHz.

A2.3.2 EESS (space-to-Earth) earth station characteristics

The band 8 025-8 400 MHz is used to download data obtained by EESS satellites. Some of these stations are located close to the sea. As an example, EESS earth station pertains to HY-1 satellite were just 100 km from the coast in Hainan province; some of the receiving only earth stations of FY satellite were deployed widely in the southeast coastal areas of China.

The characteristics of EESS system receivers pertaining to the HY-1 satellite operating in the 8 025-8 400 MHz frequency band are provided in Table A2-5.

TABLE A2-5

Some EESS system receivers' characteristics

Characteristics	**Units**	**Earth station Beijing**	**Earth station** HaiNan	**Earth station** Haerbing
Frequency range (MHz)	(GHz)	8 025-8 400 MHz	8 025-8 400 MHz	8 025-8 400 MHz
Location		116.3/39.9	109.40/18.3	129.5/44.6
Altitude	(m)	48.85	178	350
Antenna height	(m)	5	5	5
Antenna diameter	(m)	4.2/7.3	4.2/7.3	7.3/12
Antenna peak gain	(dBi)	48/53	48/53	53/58
Antenna pattern type		REC-465	REC-465	REC-465
Receive antenna minimum elevation angle	(deg.)	5	5	5
Receiver noise temperature	(K)	468	468	496
Receiver losses	(dB)	1	1	1
Receive antenna polarization		LHC	LHC	LHC

A2.3.3 Sharing criteria for EESS receiver

In Recommendation ITU-R SA.1027 "Sharing criteria for Earth exploration-satellite and meteorological-satellite earth stations using spacecraft in low-Earth orbit" provides sharing criteria for the band 8 025-8 400 MHz to be used in sharing studies, for 8 025-8 400 MHz band, the interfering signal path from terrestrial to typical 54.8 dBic antenna gain recorded data playback receiver is –148 dB (W/10 MHz) (equivalent to –218 dB (W/Hz)). This criterion in the reference bandwidth is to be exceeded no more than 20% of the time.

Also in Recommendation ITU-R SA.514 "Interference criteria for command and data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services", the 8 GHz downlink band, the Recommendation specifies a power spectral density of –154 dB (W/MHz) (equivalent to –214 dB (W/Hz)) at the input terminals of the receiver in order to protect the ground station receivers from interference. This level may be exceeded no more than 1.0% of the time. Since it is very similar for the criteria in the above mentioned Recommendation, the criterion of –154 dB (W/MHz) could be applied in this study.

A2.3.4 MMSS (E-s) earth station characteristics

The transmit technical characteristics of MMSS (E-s) are shown in Table A2-6.

TABLE A2-6

Earth station transmit characteristics

Characteristics of earth station	Units	Small	Large
Transmitter center frequency	(GHz)	8.2125	8.2125
Maximum transmit output power	(Watts)	100	2 000
Transmit antenna diameter	(m)	0.4	2.6
Transmit antenna peak gain	(dBi)	29	45
Transmit antenna –3 dB beamwidth	(deg.)	6.2	0.8
Transmit antenna height	(m)	15	
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		Rec. ITU-R S.580-6 or Appendix **8** of the RR	
Transmit antenna minimum elevation angle towards the satellite	(deg.)	10	10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		RHC	RHC
Uplink occupied bandwidth per carrier	(MHz)	0.004 to 4	
Transmit losses	(dB)	2	2
Transmit effective isotropic radiated power e.i.r.p.	(dBW)	47	76
Transmit e.i.r.p. spectral density	(dBW/Hz)	–10	10
Transmit e.i.r.p. spectral density limit in a 10 MHz bandwidth	(dBW/ 10 MHz)	47	76

A2.3.5 Sharing study

Sharing of 8 GHz band by MMSS with EESS was evaluated by computing the exclusion zones using the Recommendation ITU-R P.452 propagation loss model.

The minimum propagation loss, L_{min} in dB, required from the MMSS transmitter to EESS ground station receiver is given by:

$$L_{min} = EIRP_{Tx} - Protection_{Criteria_{Rx}} + G_{Rx}$$

$EIRP_{Tx}$ is the maximum transmit spectral density of 40.0 dBW in 4 kHz reference bandwidth (4.0 dB(W/Hz)) transmitted in any direction towards the horizon by the MMSS (RR No. **21.8**), the $Protection_{Criteria_{Rx}}$ for the EESS ground station is –214 dB(W/Hz), and the EESS receive off-boresight antenna gain, G_{Rx}, is taken to be approximately 38 dBi. Using these parameters, the minimum propagation loss to meet the protection of the EESS ground station is 252 dBw/Hz (equivalent to–162 dBm/MHz).

In general, the off-boresight gain of the receive EESS ground station antenna depends on the horizon elevation and the minimum tracking angle of the EESS ground station antenna. This gain can vary considerably depending on the terrain elevation around the EESS ground station.

A2.3.6 Result

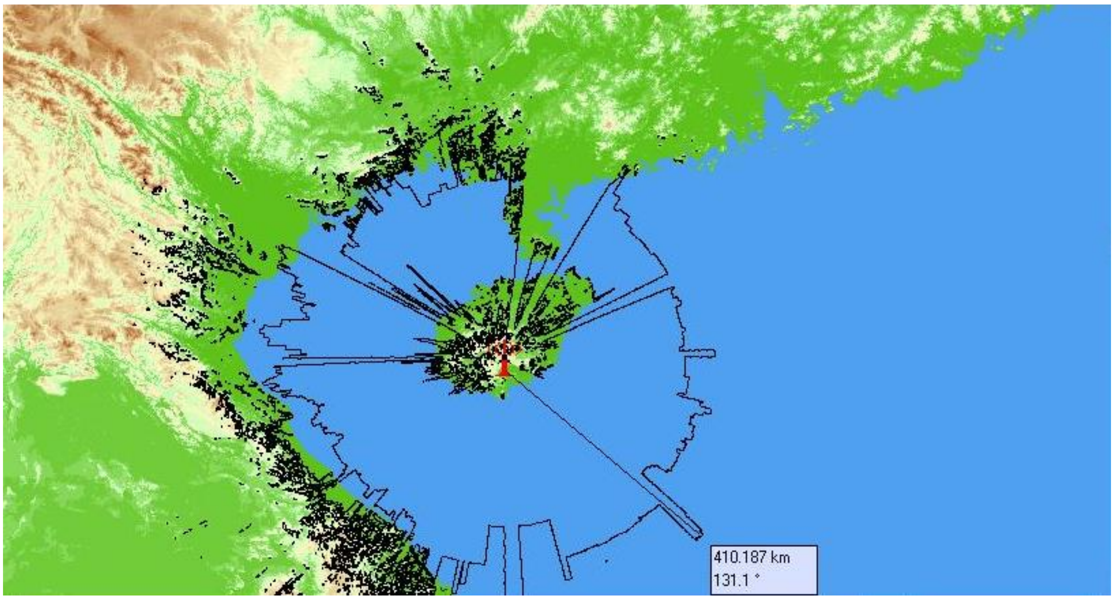
The simulation calculates the separation distances where the interference level from MMSS station into EESS station is not much than the permissible interference level –214 dBW/Hz around EESS earth station.

Figure A2-54 indicates the exclusion zones around EESS earth station HaiNan determined by the minimum propagation loss.

The large separation distances between one interfering MMSS station and the victim EESS earth stations is 410 km.

FIGURE A2-54

Exclusion zones around HaiNan EESS earth station from MMSS interfering station



To be noted, only one interfering MMSS earth station is used. Multiple MMSS stations can generate aggregate interference that can potentially be much higher than what is calculated in this contribution depending upon the actual MMSS density and geographical distribution.

A2.4 Analysis 4

A2.4.1 Introduction

This contribution provides estimated separation distance between MMSS (E-s) earth station and EESS (s-E) earth station under non-line-of-sight environment in the same frequency band in the Republic of Korea for considering the compatibility between the two services.

A2.4.2 Background

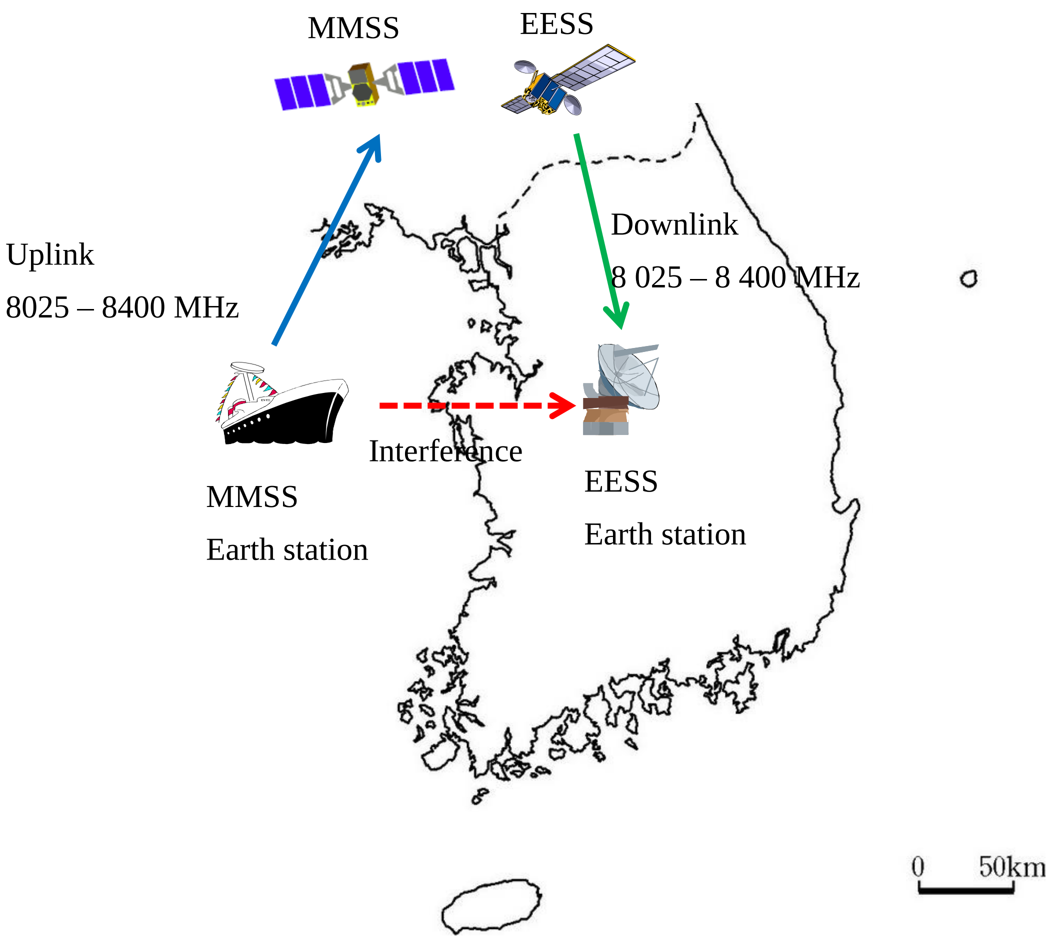
The frequency band 8 025-8 400 MHz is currently allocated for Earth exploration-satellite service (s-E), fixed-satellite service, fixed and mobile (except aeronautical mobile) services. In the current frequency allocation, the additional allocation of MMSS (E-s) can produce the potential for interference from MMSS earth station into EESS earth station in the 8 025-8 400 MHz band.

The Republic of Korea has a plan to launch the geostationary satellite (GK2-116.2E) around 2017 and EESS system will be operated in the 8 025-8 400 MHz frequency band. The EESS earth station will be located within the Korean Territory but the exact location of the station has not determined yet. Therefore, it is expected that the interference from MMSS earth station operating in the sea into the EESS earth station will be occurred, so protection criteria should be developed to operate both services in the same frequency band.

Figure A2-55 shows the interference situation between MMSS and EESS systems in the 8 025-8 400 MHz frequency band.

FIGURE A2-55

Interference situation from MMSS allocations to EESS in 8 025-8 400 MHz



A2.4.3 System parameters

The compatibility study between MMSS and EESS is conducted using computer simulation. In order to consider protection criteria, the separation distance is calculated based on permissible interference level of received EESS earth station. The computer simulation is conducted taking into account geographical data of the Korean Territory which influence the path loss heavily between two earth stations.

For the simulation, there are several assumptions of the system parameters as follows. E.i.r.p. towards the horizon direction by the transmitting MMSS earth station is 40.0 dBW in 4 kHz reference bandwidth, and the antenna height of the MMSS is 15 meters above sea level. The received EESS earth station's off-axis antenna gain towards MMSS earth station is taken to be 14.53 dBi. Recommendation ITU-R P.452 is adopted for calculating the path loss and geographical data is also used for the calculation. According to Recommendation ITU-R SA.514 "Interference criteria for command and data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services", the acceptable interference level is –214 dBW/Hz which is the value to determine the separation distance.

The EESS earth station parameters in the calculation are given in Table A2-7.

TABLE A2-7

Parameters for EESS earth stations

EESS Parameter	Value	Units	Notes
Location	Lat. 36.38N Long. 127.35E	degree	Daejon city, Korea (Rep. of)
Frequency	8 200	MHz	
elevation angle	46.17	deg	
Antenna diameter	15	m	
Antenna height	20	m	
Antenna gain pattern	RR. AP8-10 ANNEX III		
Antenna gain towards MMSS	–9.61	dBi	
Permissible interference level	–214	dBW/Hz	Derived from Rec. ITU-SA.514
Probability of exceedance (p) due to weather statistics	1.0	%	Rec. ITU-R SA.514

The refractive index, N and surface refractivity, N_0 used with Recommendation ITU-R P.452 are 40 and 330, respectively.

A2.4.4 Results

The simulation calculates the separation distances where the interference level from MMSS station into EESS station is not much than the permissible interference level –214 dBW/around EESS earth station.

Figure A2-56 shows the distribution of line of sight path around the EESS earth station. Because the EESS earth station is located in the interior of the Korean Territory and the EESS station's antenna height is relatively lower than topographic height around EESS earth station, the length of line-of-sight around EESS earth station is short. Therefore there is no line-of-sight path between EESS earth station and MMSS station which is operated in the sea in this simulation. The areas having line-of-sight path from EESS earth station are coloured in brown in Fig. A2-56.

The interference strength depending on the position of transmitting station is presented in Fig. A2-57. This figure explains that the each point of distribution is the transmitting stations position and the colour means the interference strength into the received EESS station located at latitude 36.38N, longitude 127.35E. Because there are a lot of hills and mountains in the simulation area, the interference strength appears irregular distribution. The interference from transmitting station is delivered by diffraction and reflection mainly due to the non-line-of-sight path characteristics.

Figure A2-58 shows the areas where the interference level from MMSS station into EESS station is much than the permissible interference level of EESS earth station. In other words, if the transmitting station is located in the red area, the EESS earth station received harmful interference much than permissible level.

The longest separation distance of this simulation is approximately 198 km in the land. Taking into account the MMSS station in the sea, the separation distance is approximately 138 km towards the sea. This distance is relatively shorter than that of line-of-sight situation shown in Document 4C/70 submitted at the last ITU-R WP 4C meeting. It implies that the geographical characteristics in the path give large influence in separation distance. By the way, there is one interfering MMSS earth station in this simulation.

If multiple interfering MMSS stations are operating in the sea, the potential interference will be increased and the separation distance will be also increased depending on the MMSS stations locations and geographical characteristics. When protection criteria are developed, sufficient separation distance should be considered for compatibility of both services.

FIGURE A2-56

Distribution line-of-sight around EESS earth station

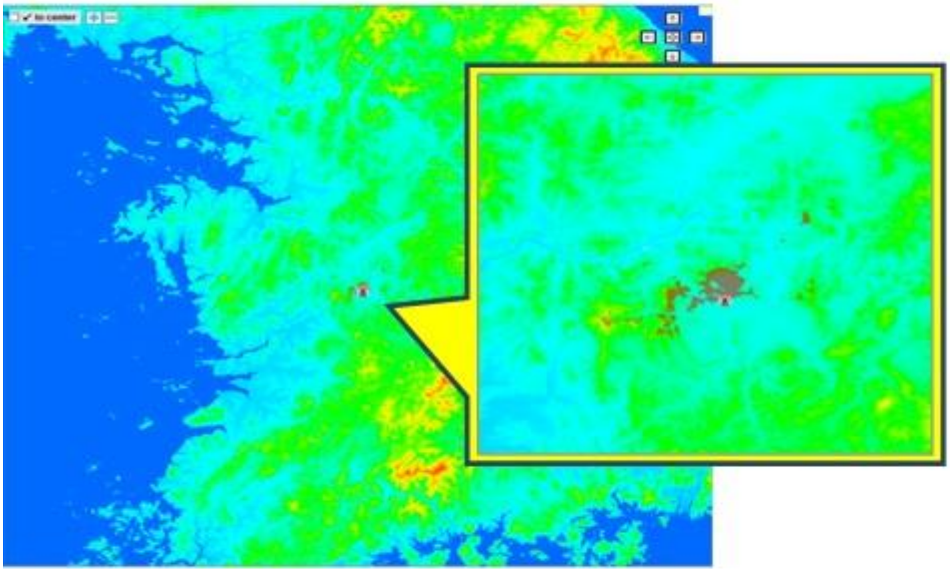
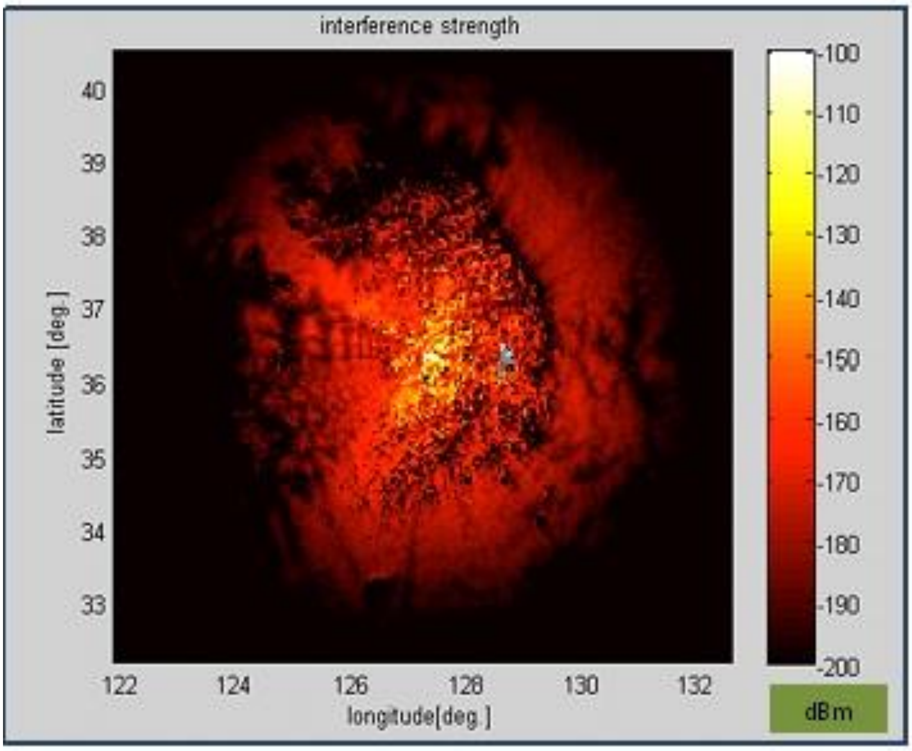


FIGURE A2-57

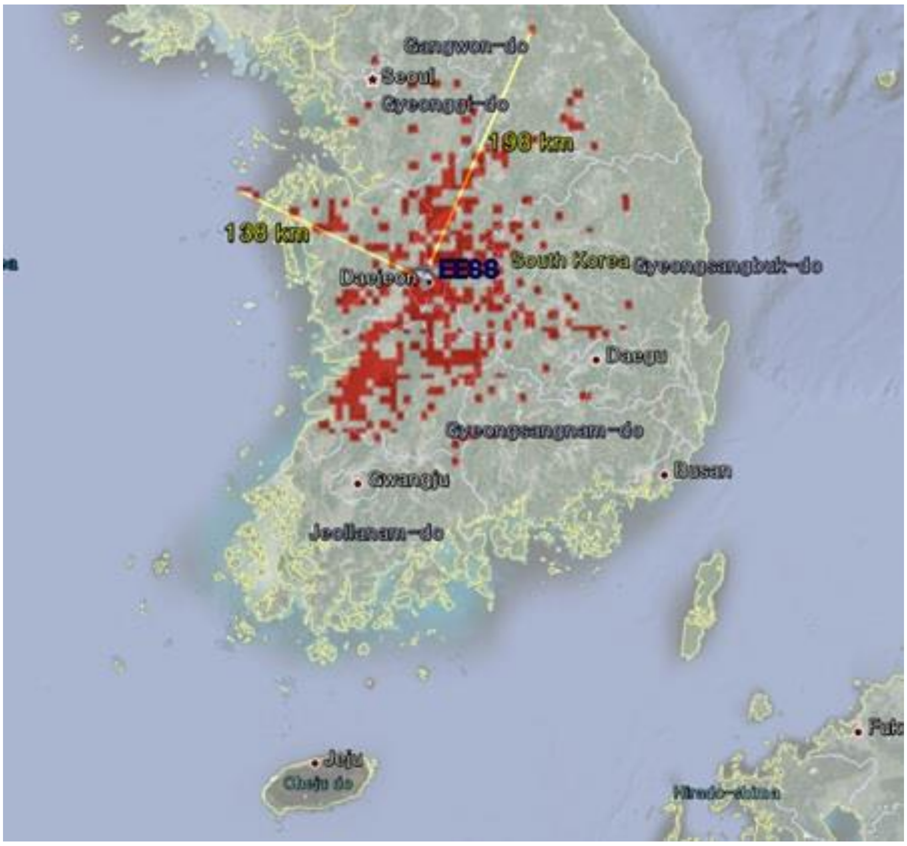
Distribution of the interference around EESS earth station



Permissible level –214 dB/Hz can be converted to –148 dBm at 4 kHz bandwidth

FIGURE A2-58

Simulation result for interference between MMSS and EESS system



A2.5 Analysis 5

A2.5.1 Introduction

WRC-15 agenda item 1.9.2 is to consider the possibility of allocating the band 8 025-8 400 MHz (E-s) to the maritime mobile-satellite service (MMSS). In the United States, this band is in part used by the Earth exploration-satellite service (EESS). One EESS system has been operating in this band for some years. It has several receive stations and is planning more on a global basis. Some of these stations are at locations that could be susceptible to interference from stations in the proposed maritime mobile-satellite service. The protection of these stations is critical for the delivery of a high-resolution product. Under WRC-15 agenda item 1.9.2 and Resolution **758 (WRC-12)**, studies are required to determine the feasibility of an additional allocation to the MMSS. This contribution provides information on the indicated EESS system and provides an outline for the interference analysis required to establish protection of the EESS receiving stations operating in the 8 025-8 400 MHz (s-E) from the proposed MMSS.

A2.5.2 EESS System Characteristics

The characteristics of certain EESS system receivers, operating in the 8025-8 400 MHz frequency band, are provided in Table A2-8.

TABLE A2-8

EESS system receivers – Specifications

Characteristics	WorldView 1,2	WorldView 3	
Frequency range (MHz)	8 025-8 400 MHz	8 025-8 400 MHz	
Max E.S. antenna gain (dBi) – typical	51.3		
Earth station receiver noise figure (°K)	75	75	The EESS antenna pattern is assumed to be 0.27 deg hpbw

A2.5.3 Interference analysis – EESS protection requirements

The computation of the receiver noise density of –147.3 dBW/MHz is shown in Table A2-9. The I/N protection level of –10 dB in Table A2-9 is derived using Recommendation ITU-R SA.1022-1 assuming a percentage of interference-free margin devoted to interference of 23%.

TABLE A2-9

EESS system in 8 025-8 400 MHz band – Interference protection requirements

	WorldView 1,2,3
Receiver noise density (dBW/MHz) (see Annex 1)	–147.3
I/N protection level (dB) from all services	–10
Nominal long-term interference power density (dBW/MHz)	–157.3

Table A2-10 shows the calculation of the receiver noise density value found in Table A2-9:

TABLE A2-10

EESS system in 8 025-8 400 MHz band – Interference protection requirements

Parameter	Units	Inputs	Results	Notes
Background noise (external to ant.)	K	59		from link and environmental analysis, 99% availability
Receiver noise figure	dB	1		LNA+transmission line to feed
Receiver noise temperature	K		75	
System noise temperature	K		134	
Boltzmann constant	dBW/Hz-K	–228.6		
System noise density	dBW/Hz		–207.3	kT
Receiver noise density	dBW/MHz		–147.3	

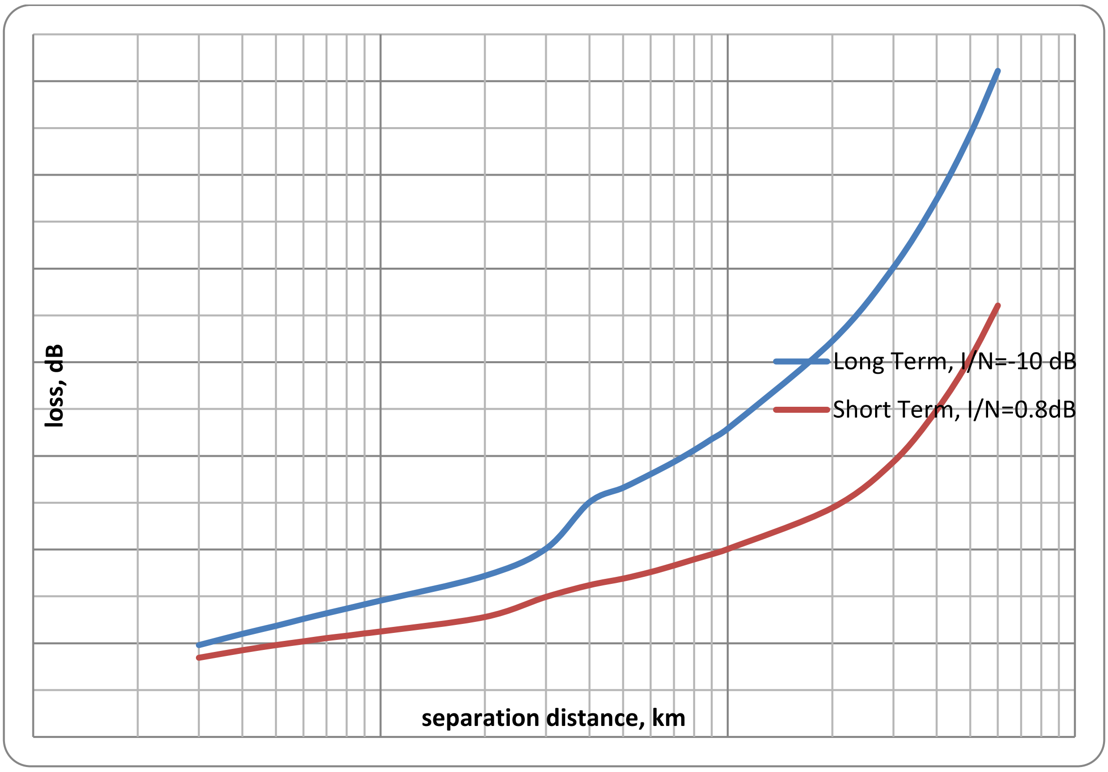
A2.5.4 MMSS earth station uplink signal to EESS systems

In this analysis, the separation distance between an MMSS uplink station and an existing EESS station at a high latitude (approximately 70 degrees north) station will be calculated. The high latitude EESS station is assumed to be as described in Tables A2-8 and A2-11. The location of the EESS station is 70.22 degrees north and 148.40 degrees west. The MMSS station is assumed to be located on the same longitude line as the EESS station, and is located north of the EESS station, pointing due south at a geosynchronous satellite. The EESS station is assumed to be pointing due north toward the MMSS station. The elevation angle of the MMSS uplink station pointing toward a geosynchronous satellite at the same latitude is approximately 10 degrees, and the elevation angle of the EESS downlink station is assumed to be 5 degrees.

Figure A2-59 gives the propagation loss for respectively 20% and 0.005% using Recommendation ITU-R P.452-14 for the worst month and assuming the EESS earth station is located 10 km from the coast. The I/N = –10 dB value is chosen in this analysis for the 20% exceedance probability, and the I/N=0.8 dB value is chosen for the 0.005% exceedance probability. The parameters used in the application of this Recommendation for this location are N_0=317, ΔN=45.5 for worst month, ΔN=40 for average year. The long term I/N value of –10 dB is calculated from Recommendation ITU-R SA.1022-1, using a fraction of interference-free margin allocated to interference of 23%. The short term I/N value of 0.8 dB is derived from sharing criteria found in ITU-R SA.1027, Table 1(c), with interference protection levels adjusted for the 51.3 dBic antenna gain of the EESS station 5.4 meter antenna. For reference, all of the interference-free margin for the 5.4 m antenna is used by interference when I/N = –2.8 dB. The system margin for this antenna is 1.8 dB.

FIGURE A2-59

Propagation loss given by Recommendation ITU-R P.452-14



Using the technique presented in paragraph A2.1, Annex 7 to Working Party 4C Chairman's Report, 3 May 2013, separation distances are calculated for several MMSS elevation angles with EESS elevation angle of 5 degrees. The separation distance required for the worst month is found to be 545 km for the short term case, and 278 km for the long term case. These results are shown in Table A2-11. The results of Table A2-11 were computed using the method of Recommendation ITU-R P.452-14.

TABLE A2-11

Derivation of the required path loss for a 51.3 dBic EESS antenna

								Worst Month		Average Year	
MMSS el angle deg	**Pt-LF dBW**	**Gt dBi**	**Gr dBi**	**I/N=-10 dB Pi(20%) dBW/10 MHz**	**I/N=0.8 dB Pi(0.005%) dBW/10 MHz**	**I/N=-10 dB Lb(20%) dB**	**I/N=0.8 dB Lb(0.005%) dB**	**I/N=-10 dB d(20%) km**	**I/N=0.8 dB d(0.005%) km**	**I/N=-10 dB d(20%) km**	**I/N=0.8 dB d(0.005%) km**
10	31	4	14.5	–147.3	–136.5	197	186	278	545	275	544
20	31	–3.5	14.5	–147.3	–136.5	189	179	230	478	228	477
30	31	–7.9	14.5	–147.3	–136.5	185	174	203	439	201	438
36	31	–10	14.5	–147.3	–136.5	183	172	190	420	188	419

Use of EESS elevation angles of 5 degrees or less for downlinking payload data are common at high latitude sites because of the need to downlink as much data as possible in a satellite pass, in order to meet timeliness requirements for the data. Also, obscuration at high latitude sites is minimal in many cases, thus permitting operation at low elevation angles of 5 degrees or less. It is thus important for high latitude EESS stations to be free from harmful interference.

A2.6 Analysis 6

A2.6.1 Introduction

WRC-15 agenda item 1.9.2 deals with the possibility of allocating the bands 7 375-7 750 MHz and 8 025-8 400 MHz to the maritime mobile-satellite service and additional regulatory measures, depending on the results of appropriate studies. This document examines the impact of MMSS earth stations into the EESS (space-to-Earth) which is allocated in the band 8 025-8 400 MHz.

A2.6.1.1 EESS (space-to-Earth) earth station characteristics

The band 8 025-8 400 MHz is used to download data obtained by EESS satellites. The receiving earth stations are spread worldwide. Some of these stations are located close to the sea. As an example, ESA owns X-band stations in Maspalomas, in Canarias, 2 km from the coast, Kourou, in French Guyana, less than 6 km from the coast, Perth in Australia, less than 8 km from the coast, Santa Maria, Azores, 500 m from the coast. The different EESS stations need to be protected from harmful interference from transmitting MMSS earth station that might operate in the band, should an allocation be accepted by WRC-15.

Recommendation ITU-R SA.1027 provides sharing criteria for the band 8 025-8 400 MHz to be used in sharing studies, which are reproduced in Table A2-12.

TABLE A2-12

Sharing criteria for Earth exploration-satellite and meteorological-satellite earth stations using spacecraft in low-Earth orbit

Frequency band (MHz)	Type of earth station	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time		Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than *p*% of the time	
		Interfering signal path		Interfering signal path	
		space-to-Earth	Terrestrial	space-to-Earth	Terrestrial
8 025-8 400	54.8 dBic antenna gain Recorded data playback	–165 dBW per 10 MHz	–148 dBW per 10 MHz	–133 dBW per 10 MHz $p = 0.0025$	–133 dBW per 10 MHz $p = 0.0050$
	41.7 dBic antenna gain Direct data readout	–155 dBW per 10 MHz	–138 dBW per 10 MHz	–128 dBW per 10 MHz $p = 0.0025$	–127 dBW per 10 MHz $p = 0.0050$
	42.5 dBic antenna gain Direct data readout	–159 dBW per 10 MHz	–142 dBW per 10 MHz	–129 dBW per 10 MHz $p = 0.0013$	–129 dBW per 10 MHz $p = 0.0056$

The criteria for terrestrial path should apply in this study.

A2.6.1.2 Characteristics of MMSS earth stations

The characteristics of the MMSS earth station are reproduced in Table A2-13.

TABLE A2-13

Earth station characteristics

Characteristics of earth station	Units	Small	Large
Transmitter center frequency	(GHz)	8.15	8.15
Maximum transmit output power	(Watts)	100	2 000
Transmit antenna diameter	(m)	0.4	2.6
Transmit antenna peak gain	(dBi)	29	45
Transmit antenna –3 dB beamwidth	(deg.)	6.2	0.8
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		Rec. ITU-R S.580-6	Rec. ITU-R S.580-6
Transmit antenna minimum elevation angle towards the satellite	(deg.)	10	10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		RHC	RHC
Uplink occupied bandwidth per carrier	(MHz)	0.004 to 4	
Transmit losses	(dB)	2	2

TABLE A2-13 (*end*)

Characteristics of earth station	Units	Small	Large
Transmit effective isotropic radiated power e.i.r.p.[5]	(dBW)	47	76
Transmit e.i.r.p spectral density	(dBW/Hz)	–10	10
Transmit e.i.r.p spectral density limit in a 10 MHz bandwidth[6]	(dBW/ 10 MHz)	47	76
Receiver center frequency	(GHz)	7.5	7.5
Receive antenna diameter (if different from transmit)	(m)	–	–
Receive antenna peak gain (if different from transmit)	(dBi)	27	44
Transmit antenna –3 dB beamwidth	(deg.)	7.2	1
Receive antenna pattern type (ITU Recommendation, data (angle versus gain) or plot) (if different from transmit)		Rec. ITU-R S.580-6	Rec. ITU-R S.580-6
Receive antenna minimum elevation angle towards the satellite	(deg.)	10	10
Receive antenna polarization (RHC, LHC, VL, HL or offset linear)		LHC	LHC
Receiver noise temperature	(K)	468	200
Downlink occupied bandwidth per carrier	(MHz)	0.004 to 100	
Receiver losses	(dB)	0	0
Earth station G/T	(dB/K)	0.3	21

A2.6.1.3 Methodology applied

This section presents the methodology of statistical simulations to analyze potential interference to EESS stations from the operation of MMSS.

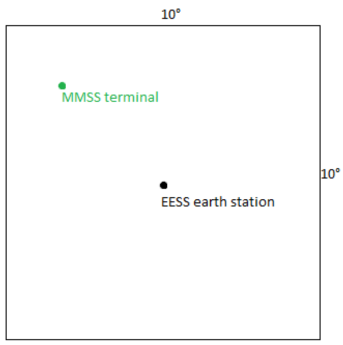
Parameters of EESS earth station were established in accordance with the main parameters set out in Table A2-12 and the parameters of the MMSS in accordance to Table A2-13.

This scenario describes the possibility that MMSS terminals are interfering into victim EESS receivers. The physical outline of this scenario was derived by randomly positioning 1 MMSS terminal within an area 10° × 10° from the EESS earth station. A snapshot taken from the status window of a statistical simulation is shown below in Fig. A2-60. The green dots indicate the location of the MMSS Terminal, while the black dot indicates the location of the EESS earth station. If the MMSS terminal does not interfere the EESS earth station the colour is green and in case of interference, the dot is red.

[5] Transmit effective isotropic radiated power e.i.r.p. = 10 * Log (maximum transmit output power) – Transmit losses + transmit antenna peak gain.

[6] (dBW/10 MHz).

FIGURE A2-60



At each Snapshot, the MMSS has a different localization and the EESS antenna has a different pointing and also, the elevation of EESS earth station is determined randomly (In this case 10 000 snapshots are done for each simulation). The permissible basic transmission losses are calculated at each snapshot and can be stated as:

$$P_t + G_t(\theta_t) - Pi - G_r(\theta_r) - L_b(p\%)$$

where:

P_t :	MMSS transmitter power (dBW)
$G_t(\theta_t)$:	MMSS antenna gain in the direction of the EESS earth station (dBi)
G_r :	gain of the EESS earth station antenna (dBi)
Pi:	maximum permissible interference at the EESS earth station receiver input (dBW)
θ_t :	angle between the MMSS antenna axis and the interference path (degrees)
$L_b(p\%)$:	the value of minimum acceptable basic transmission loss to be exceeded for all but p% of the time along the interference path between the terrestrial transmitter and the earth station receiver (dB).

The values of *p* are given in Table A2-12.

The minimum angular separation between the antenna's axis and the interference path is given by:

$$\theta_t = \alpha - \varepsilon_t$$

where:

α:	elevation angle of the geostationary satellite relative to the MMSS earth station
ε_t :	the elevation of the MMSS earth station.

The separation distances are then derived from the propagation loss required using the Recommendation ITU-R P.452 (*p*=0.005), taking into account the proportion of path over land or water.

This was calculated assuming terrain elevation.

A2.6.1.4 Application to actual earth stations

Additional terrain elevation needs to be accounted for and this may have a positive aspect by reducing the required separation distance in some directions where natural shielding such as mountains exist, but also a negative one as the altitude of the EESS earth station will increase the horizon distance, and decrease the propagation loss for a given distance.

It should be noted that all calculations below have been made assuming an elevation angle for the MMSS earth station. The MMSS earth station is pointing towards the FSS satellite Syracuse 3B. And all the simulations have been done with a large MMSS station.

A2.6.1.4.1 Maspalomas

Figure A2-61 indicates for each snapshot the possibility of the MMSS terminal located near the Maspalomas earth station to exceed or not the EESS sharing criteria. The MMSS earth station is pointing at 57° elevation.

FIGURE A2-61

Statistical study for the Maspalomas ESA earth station

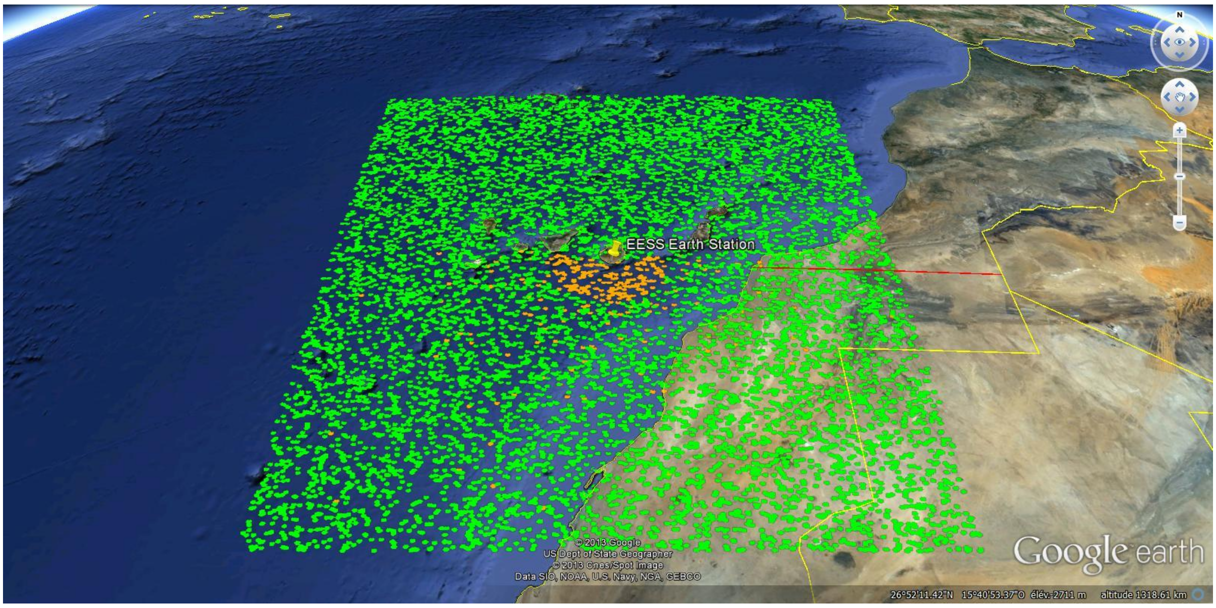


FIGURE A2-62

Interfering signal power at the EESS receiver level with no separation distance

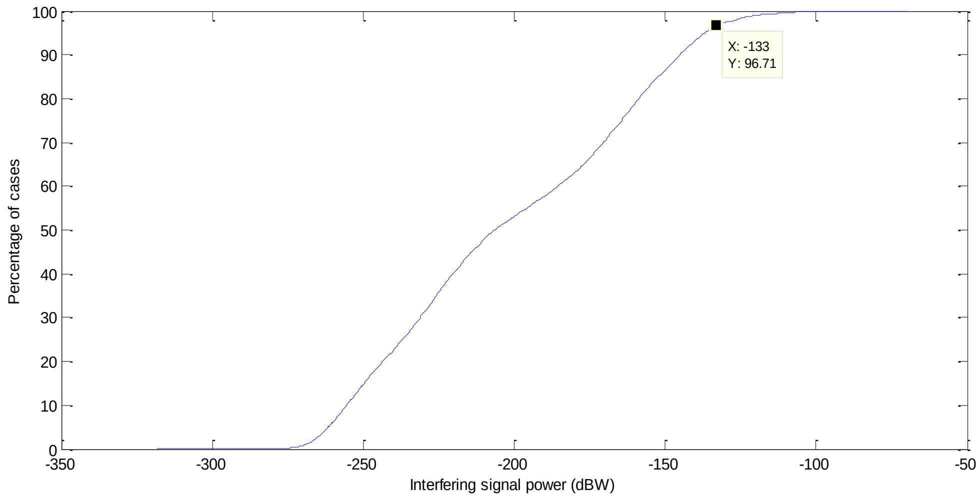


FIGURE A2-63

Interfering signal power at the EESS receiver level with 200 km separation distance

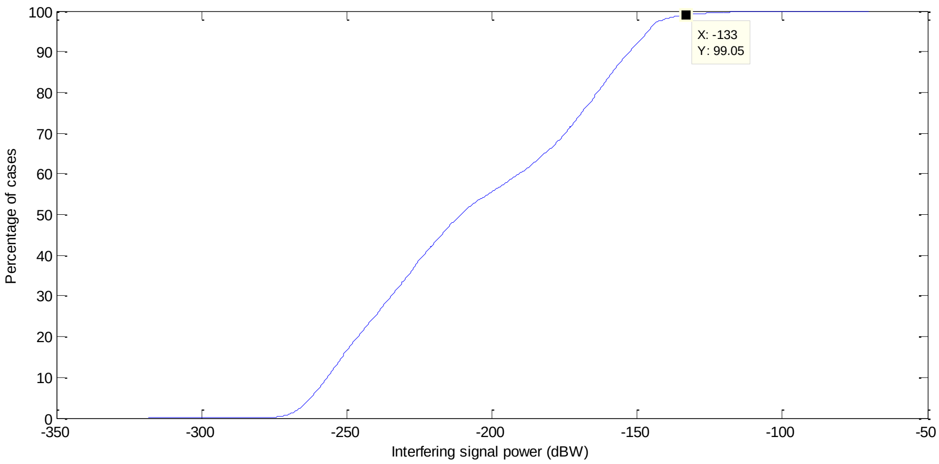
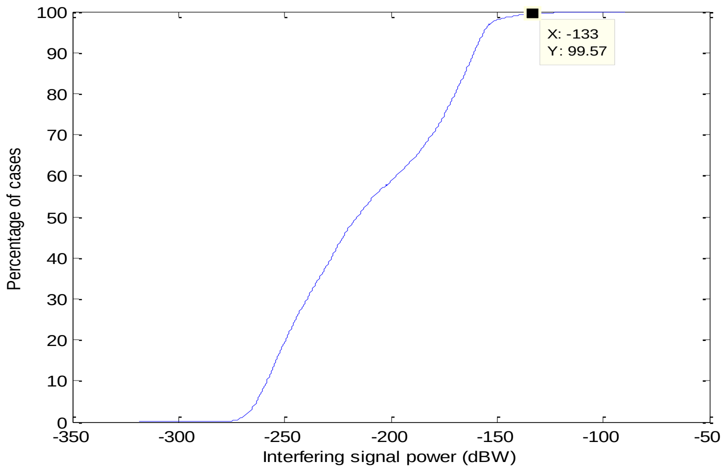


FIGURE A2-64

Interfering signal power at the EESS receiver level with 300 km separation distance



Only 3.29% of the snapshots show interference to the receiving EESS earth station. The worst-case is located at 440 km from the EESS earth station. Nevertheless main of interference cases are located in an area of 200 km radius around the EESS earth station. In case of a distance separation of 200 km, only 0.95 (Fig. A2-63) of the snapshots show interference to the receiving EESS station and this value decrease to 0.43% when a 300 km separation distance is taking into account (Fig. A2-64).

A2.6.1.4.2 Kourou

Figure A2-65 indicates for each snapshot the possibility of the MMSS terminal located near the Kourou to exceed or not the EESS sharing criteria. The MMSS earth station is pointing at 58° elevation.

FIGURE A2-65

Statistical study for the Kourou ESA earth station

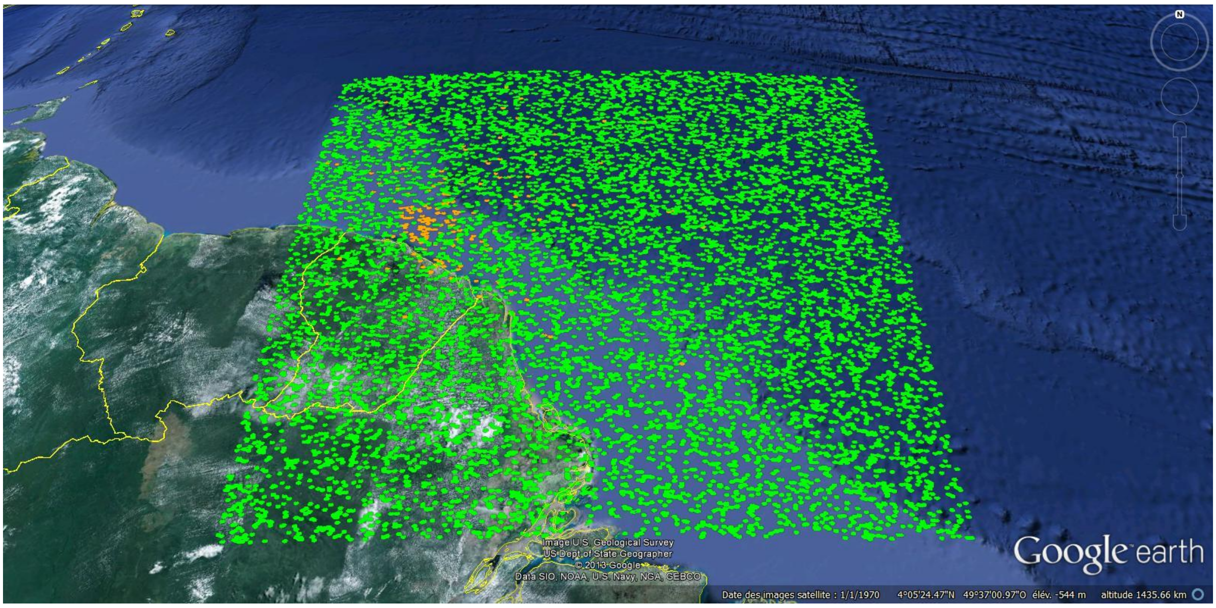


FIGURE A2-66

Interfering signal power at the EESS receiver level with no separation distance

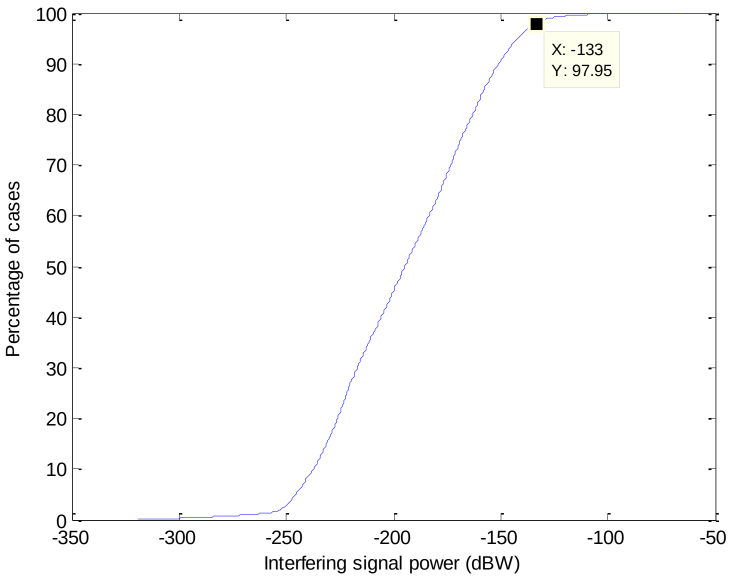


FIGURE A2-67

Interfering signal power at the EESS receiver level with 200 km separation distance

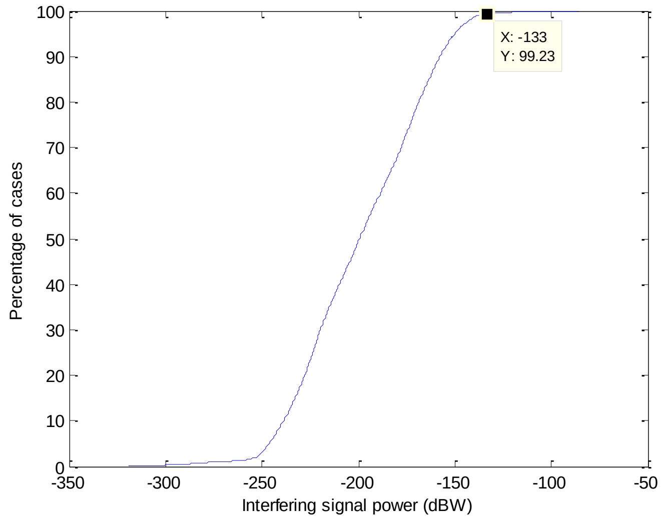
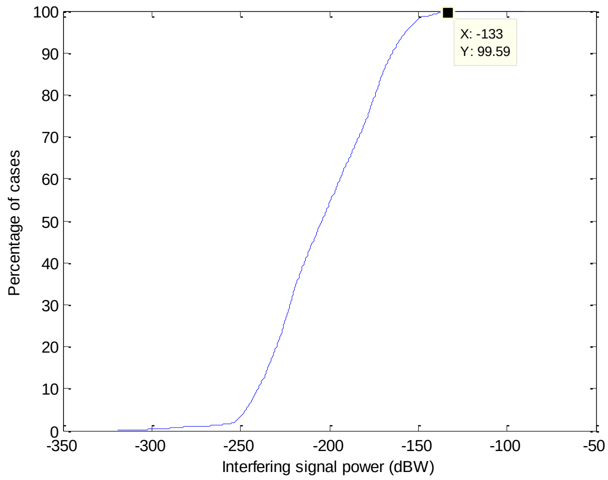


FIGURE A2-68

Interfering signal power at the EESS receiver level with 300 km separation distance



Only 2.05% of the snapshots show interference to the receiving EESS earth station. The worst-case is located at 450 km from the EESS earth station. Nevertheless main of interference cases are located in an area of 200 km radius around the EESS earth station. In case of a distance separation of 200 km, only 0.77 (Fig. A2-67) of the snapshots show interference to the receiving EESS station and this value decrease to 0.41% when a 300 km separation distance is taking into account (Fig. A2-68).

A2.6.1.4.3 Santa Maria

Figure A2-69 indicates for each snapshot the possibility of the MMSS terminal located near the Santa Maria to exceed or not the EESS sharing criteria. The MMSS earth station is pointing at 50° elevation.

FIGURE A2-69

Statistical study for the Santa Maria ESA earth station

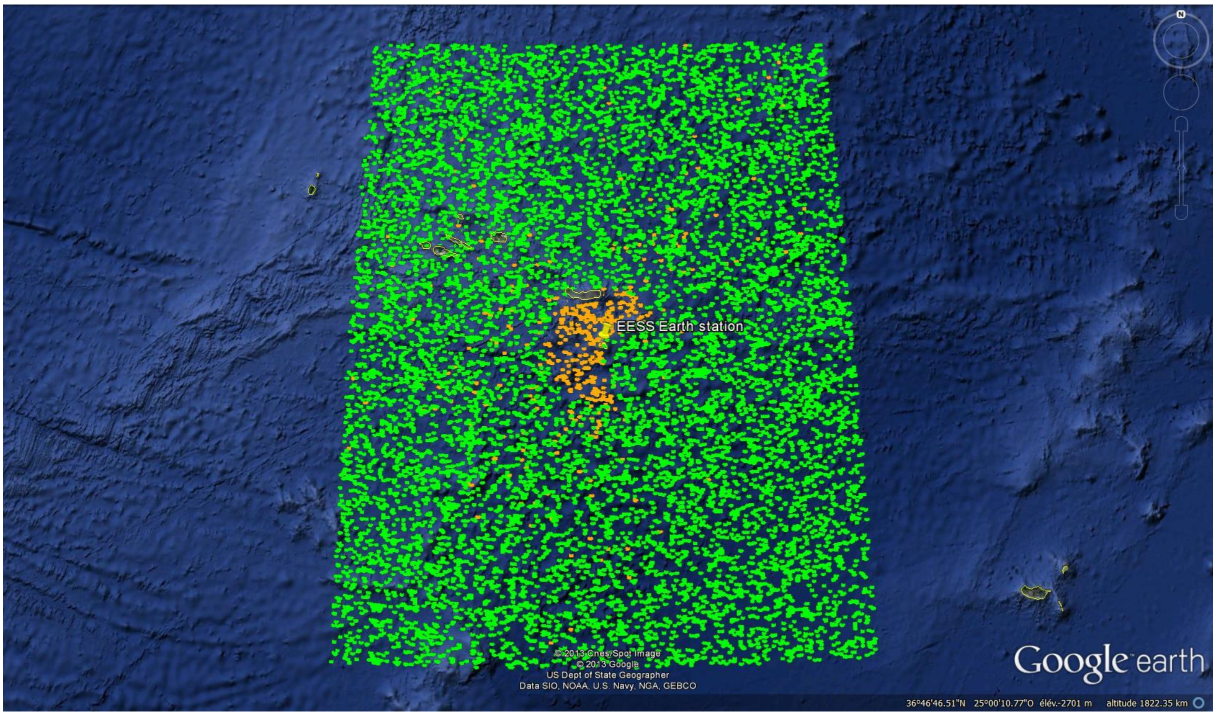


FIGURE A2-70

Interfering signal power at the EESS receiver level with no separation distance

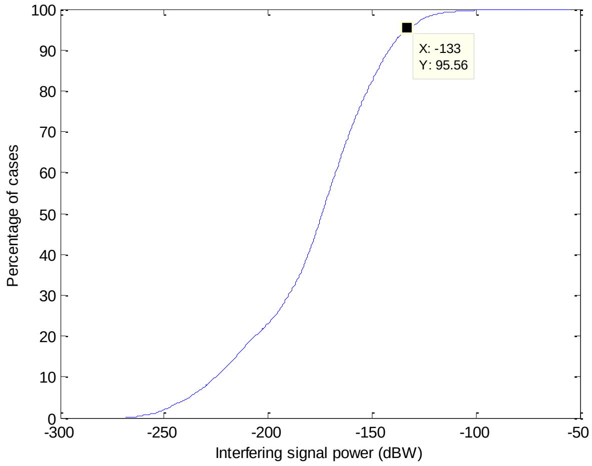


FIGURE A2-71

Interfering signal power at the EESS receiver level with 200 km separation distance

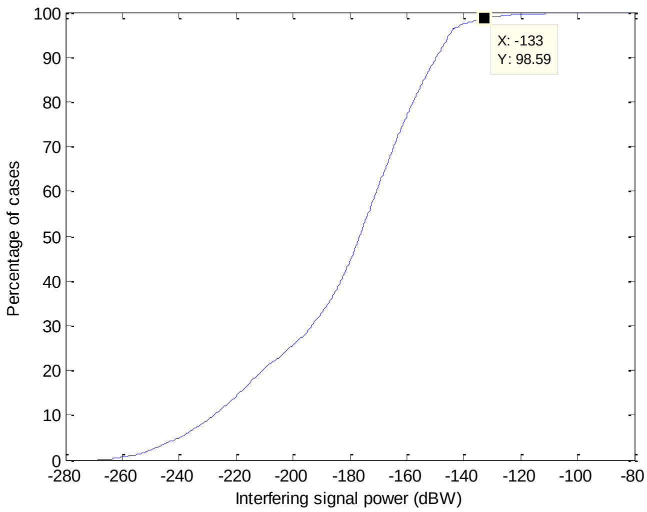
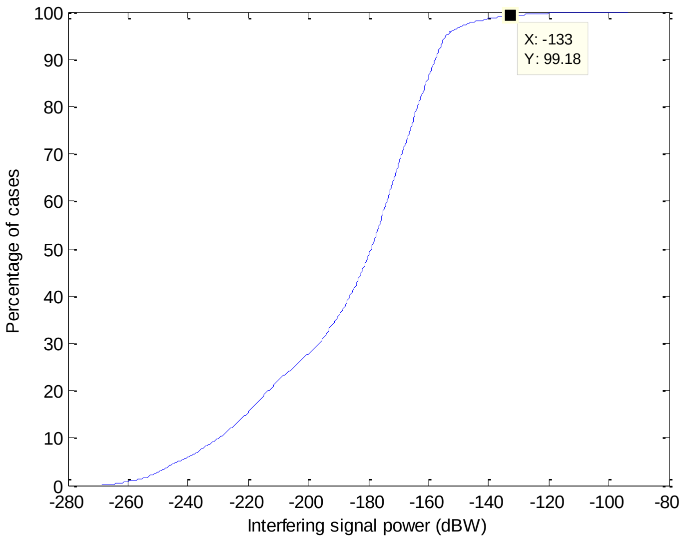


FIGURE A2-72

Interfering signal power at the EESS receiver level with 300 km separation distance



Only 4.49% of the snapshots show interference to the receiving EESS earth station. The worst case is located at 500 km from the EESS earth station. Nevertheless main of interference cases are located in an area of 200 km radius around the EESS earth station. In case of a distance separation of 200 km, only 1.41% (Fig. A2-71) of the snapshots show interference to the receiving EESS station and this value decrease to 0.82% when a 300 km separation distance is taking into account (Fig. A2-72).

A2.6.1.5 Sharing feasibility and regulatory methods / conclusion

This study shows that an allocation to the maritime mobile-satellite service in the band 8 025-8 400 MHz will create a potential for interference to the receiving EESS earth stations located close to the coast worldwide.

The simulations results show that below 200 km radius around the EESS earth station the probability of interference from MMSS earth stations into EESS receiving earth stations would be high. Interference may still be received up to 450 km although with a lower probability. Taking into account a 300 km separation distance, the percentage of snapshots interfering with the EESS station is less than 1%, based on a 10°-by-10° scenario area.

The Monte-Carlo methodology used in this study determines the geometric probability of harmful interference to an EESS earth station based on a single randomly positioned MMSS earth station in a defined area around the EESS station. This differs from the other 8 GHz sharing studies which calculate a maximum separation distance between the EESS and MMSS earth stations needed to satisfy the Recommendation ITU-R SA.1027 sharing criteria defined for a percentage of time, assuming a single MMSS earth station and using the methodology defined in Recommendation ITU-R SA.1277. The geometric probability of harmful interference cases is not the same as the percent of time the EESS earth station sharing criteria is exceeded. Nevertheless the results highlight that MMSS earth stations located within the exclusion area defined by the maximum separation distance do not necessarily create harmful interference into the receiving EESS earth station all the time.

It is to be noted that this analysis is based on the presence in the area of a single MMSS terminal operating on a single channel.

Annex 3

Compatibility between MMSS and SRS in adjacent band

A3.1 Analysis 1

A3.1.1 MMSS and SRS (deep-space) system parameters

An out-of-band interference analysis was performed to determine the MMSS uplink exclusion zone in the 8 025-8 400 MHz band needed to meet the SRS protection criterion given in Recommendation ITU-R SA.1157 for the 8 400-8 450 MHz SRS deep-space band. Table A3-1 below gives the parameters for MMSS earth station transmitter used in the interference analysis (Annex 5 to Doc. 4C/91). These parameters are assumed to be same for NGSO MMSS and GSO MMSS systems. Note that the MMSS antenna height was assumed to be 15 meters, which would typically imply a large ship or a tall antenna mast.

Only one MMSS station is assumed to be active at a time in the coordination area of the SRS station.

TABLE A3-1

MMSS earth station parameters used in interference analysis

NGSO/GSO MMSS earth station (transmit, 8 025-8 400 MHz)				
Parameter		**Value**		**Note**
Frequency	f	8 400	MHz	Band-edge frequency
Antenna min. elevation angle	θ_t	10	deg	For NGSO MMSS, it is assumed to be pointing in the direction of the SRS earth station. For GSO MMSS, see Note 1.
Antenna diameter	D	2.6	m	
Antenna height	h	15	m	Ship height + antenna
Antenna gain pattern	G_T	Rec. ITU-R S.580-6		
Antenna peak gain	G_{0t}	45	dB	
Terrain elevation angle	ε_t	Variable	deg	Varies depending on azimuth direction
Off-boresight angle	γ_t	Variable	deg	Depends on MMSS antenna pointing direction and horizon direction towards SRS earth station. For NGSO MMSS, $\gamma_t = 10 - \varepsilon_t$ For GSO MMSS, see Note 1.
Antenna gain towards SRS earth station (at γ_t = 10 deg)	G_t	$G_T(\gamma_t)$ 4	dB dB	Varies depending on the difference between antenna min. elevation angle and terrain elevation angle Using side-lobe gain pattern: 29-25*Log(10)
Max. transmit e.i.r.p. density at boresight	P_{0t}	10	dBW/Hz	
Parameter		**Value**		**Note**
Transmitter power density	P_T	-35	dBW/Hz	Case 1: $P_T = P_{0t} - G_{0t}$ = 10-45
Max. transmitter power density allowed per RR 21.8	P_T	0	dBW/Hz	Case 2: PT = 4 dBW/Hz – 4 dB (see Note 2)
Max. transmit e.i.r.p. density towards horizon (at γ_t = 10 deg)		$P_T + G_t$ = $-35+G_t$ -31	dBW/Hz dBW/Hz	Varies depending on G_t For NGSO MMSS

NOTE 1 – For GSO MMSS systems, the separation angle between the direction of the SRS earth station location and the boresight of the MMSS earth station antenna pointed to a GSO satellite is minimized by varying the GSO satellite location on the visible geostationary arc as described in RR Appendix **7**-Annex 5.

NOTE 2 –Max. transmit e.i.r.p. density towards horizon allowed per RR 21.8 is 40+3ε (dBW/4 kHz), $0<\varepsilon<5$deg. For 0-deg horizon elevation, it is 40 dBW/4kHz, or 4 dBW/Hz.

For this analysis, the uplink e.i.r.p. spectral density for the MMSS earth station at the 8 400 MHz band-edge frequency was derived using the parameters given in Table A3-1 for a typical system that will use the potential 8 025-8 400 MHz band as proposed by MMSS. Note that the calculated e.i.r.p. density towards 0-deg horizon is about –31 dBW/Hz, which is well below the maximum e.i.r.p. density allowed by ITU RR No. **21.8**, which is 4 dBW/Hz.

Table A3-2 below gives a list of parameters for the SRS earth station receiver used in the interference analysis.

TABLE A3-2

SRS earth station parameters used in interference analysis
SRS earth station (receive, 8 400-8 450 MHz)

Parameter		Value		Note
Min. tracking angle	θ_r	10	deg	
Antenna diameter Antenna height	D h	70 39	m m	Goldstone, Robledo, Canberra
Antenna diameter Antenna height	D h	35 21	m m	Cebreros, Malargüe Sur, New Norcia
Antenna diameter Antenna height	D h	34, 64 20, 35	m m	Uchinoura, Usuda
Antenna gain pattern	G_R	ITU RR **AP8**-Annex III		
Terrain elevation angle	ε_r	Variable	deg	Varies depending on the azimuth direction
Antenna gain towards MMSS earth station	G_r	$G_R(\theta_r\text{-}\varepsilon_r)$	dBi	Varies depending on the difference between terrain elevation and min. tracking angle
Permissible interference level	P_{0r}	–221	dBW/Hz	SRS deep-space protection (Rec. ITU-R SA.1157)
Probability of exceedance (due to weather statistics)	p	0.001	%	For trans-horizon interference sources (Rec. ITU-R SA.1157)

The minimum required separation distances and exclusion zones surrounding each of the SRS deep-space earth stations were computed as follows:

1) the terrain map surrounding each of the three SRS deep-space earth stations was generated for all azimuth directions;

2) the propagation loss maps around each SRS earth station were computed as a function of radial distance and azimuth angle, based on the terrain map and the ITU transhorizon propagation models given in Recommendation ITU-R P.452 for p=0.001%;

3) the minimum required propagation loss is calculated to satisfy the SRS protection criteria as given in Recommendation ITU-R SA.115, using the transmitter and receiver parameters given in Tables A3-1 and A3-2 as follows:

$$L_{req} = P_T + G_t + G_r - P_{0r}$$

$$L_{req} = -35 + G_t + G_r - (-221) = 186 + G_t + G_r \text{ (dB) (Case 1)}$$

$$L_{req} = +0 + G_t + G_r - (-221) = 221 + G_t + G_r \text{ (dB) (Case 2)}$$

Note that antenna gain Gt depends on the local terrain seen by the transmitter and the antenna gain Gr depends on the local terrain seen by the receiver. They both change as the azimuth angle and the location of the transmitter change;

4) for each azimuth direction, the minimum required separation distances from the SRS deep-space earth stations were determined, above which the required propagation losses are satisfied for all points.

A3.1.2 Separation distances required to protect SRS earth stations from MMSS (E-s) interference

Figures A3-1A and A3-1B show the minimum separation distance for MMSS earth stations needed to satisfy Recommendation ITU-R SA.1157 protection criterion around the Goldstone deep-space 70-meter antenna when considering the e.i.r.p. values in Table A3-1. Note that separation distances are computed for all azimuth directions even though there may not be water (indicated in blue) in some azimuth directions depending on the terrain. The maximum required separation distance between the Goldstone deep-space station and the MMSS maritime platform is 300 km. However, there may be isolated bodies of water including lakes and large rivers that lie within the areas denoted as land mass and may contain MMSS vessels, so the MMSS uplink exclusion zone is shown for all cases.

In order to keep the exclusion zone around the Goldstone, USA within the land-mass, the MMSS transmit e.i.r.p. spectral density towards the horizon at the 8 400 MHz band-edge frequency should be below –29 dBW/Hz. It is clear from the map of the required separation distances around Goldstone deep-space station as shown in Fig. A3-1A that the exclusion zone does not extend to the sea, since the MMSS transmit e.i.r.p. towards the horizon is about –31 dBW/Hz, which below the limit given above.

FIGURE A3-1A

Required separation distances between NGSO MMSS and SRS earth stations at Goldstone DSN site (Case 1)

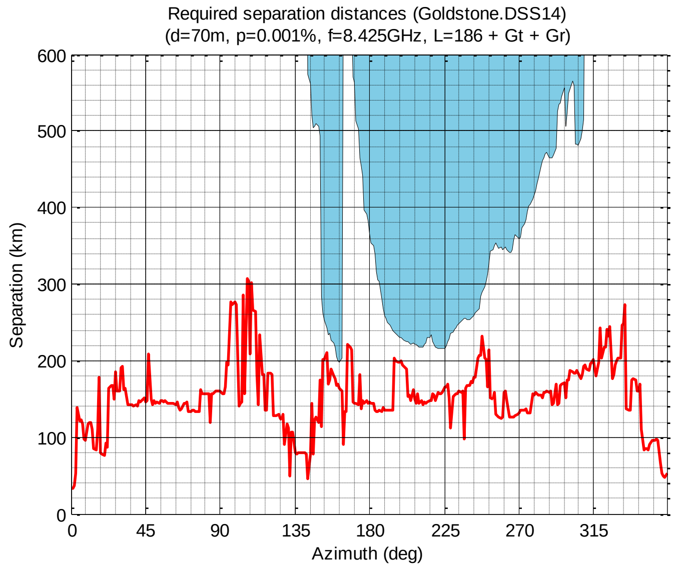


FIGURE A3-1B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Goldstone DSN site (Case 1)

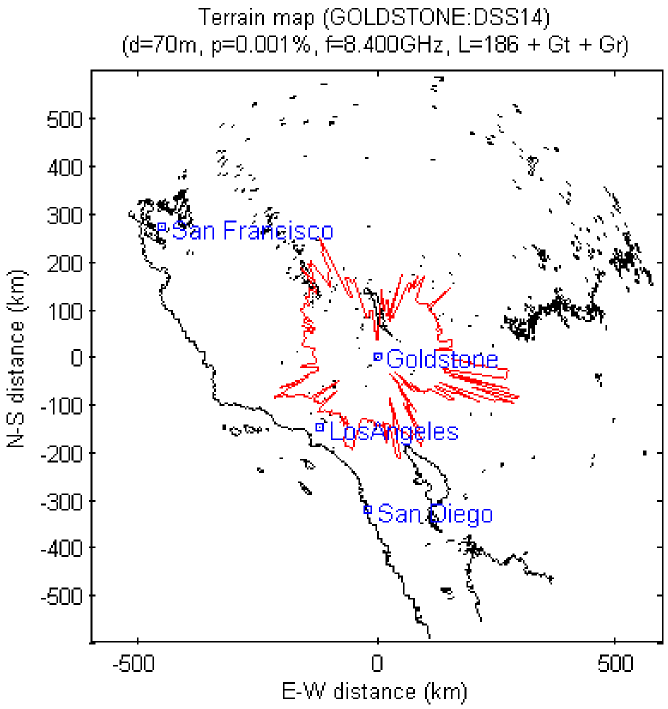


FIGURE A3-1C

Required separation distances between GSO MMSS and SRS earth stations at Goldstone DSN site (Case 1)

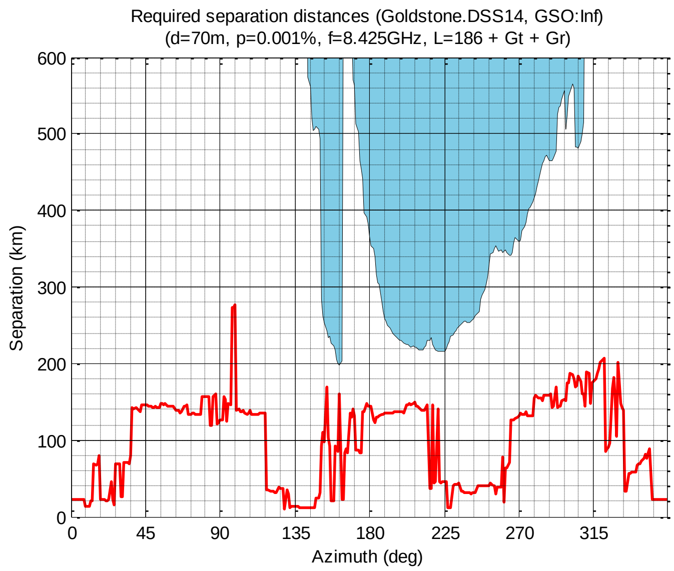
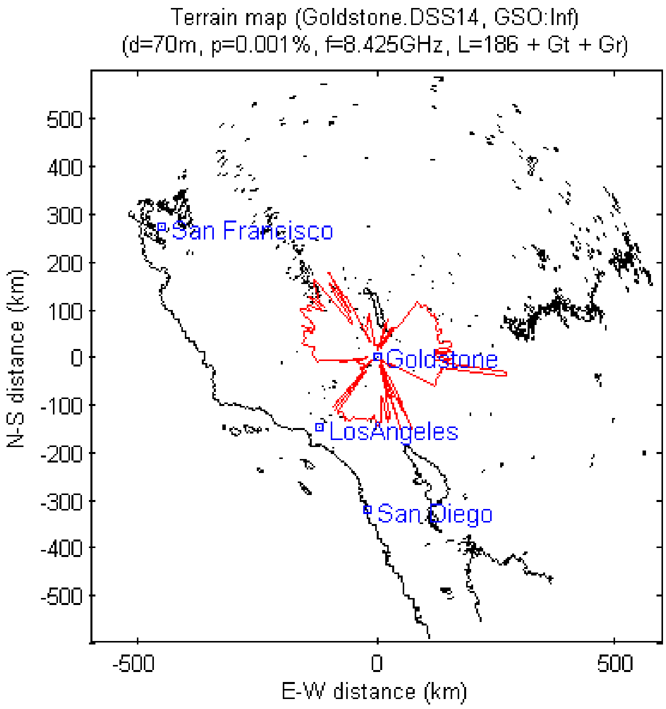


FIGURE A3-1D

Map of the required separation distances between GSO MMSS and SRS earth stations at Goldstone DSN site (Case 1)



Figures A3-2A and A3-2B provide the same information when considering e.i.r.p. values contained in RR No. **21.8**. In this case, the required separation distances extend up to 710 km around the Goldstone site.

FIGURE A3-2A

Required separation distances between NGSO MMSS and SRS earth station at Goldstone DSN site (Case 2)

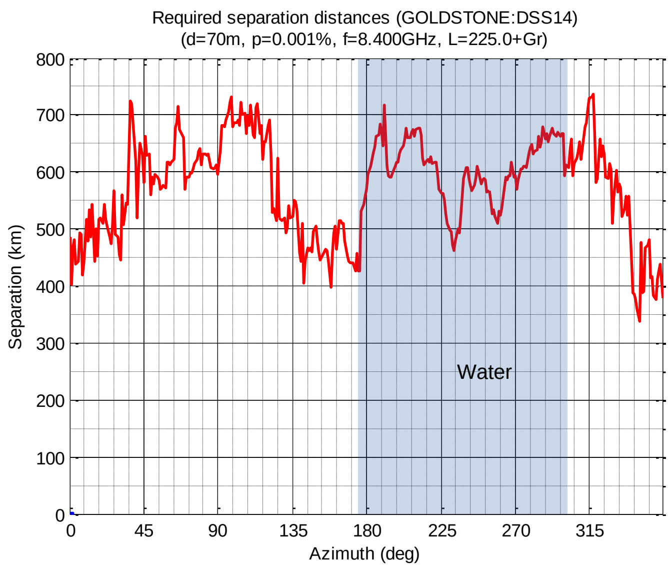


FIGURE A3-2B

Map of the required separation distances between NGSO MMSS and SRS earth station at Goldstone DSN site (Case 2)

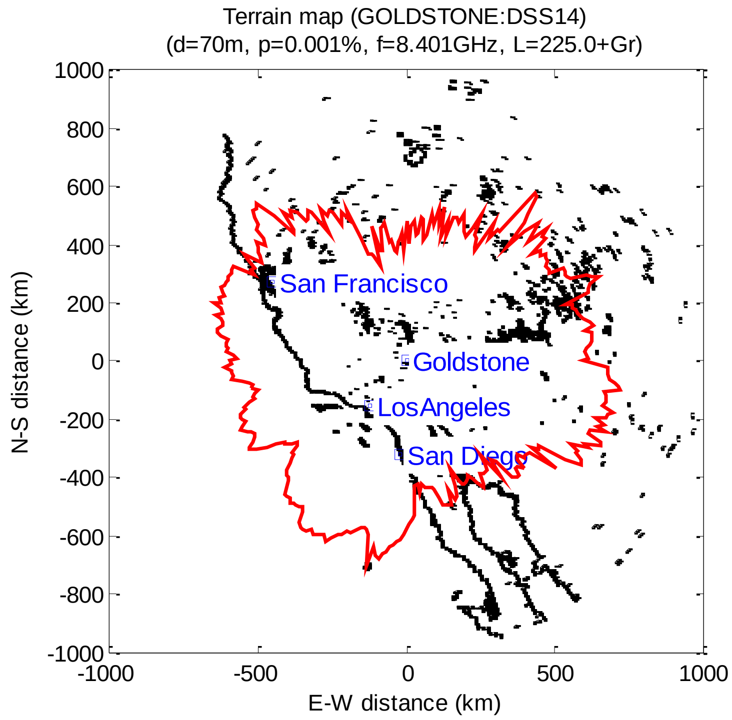


FIGURE A3-2C

Required separation distances between GSO MMSS and SRS earth station at Goldstone DSN site (Case 2)

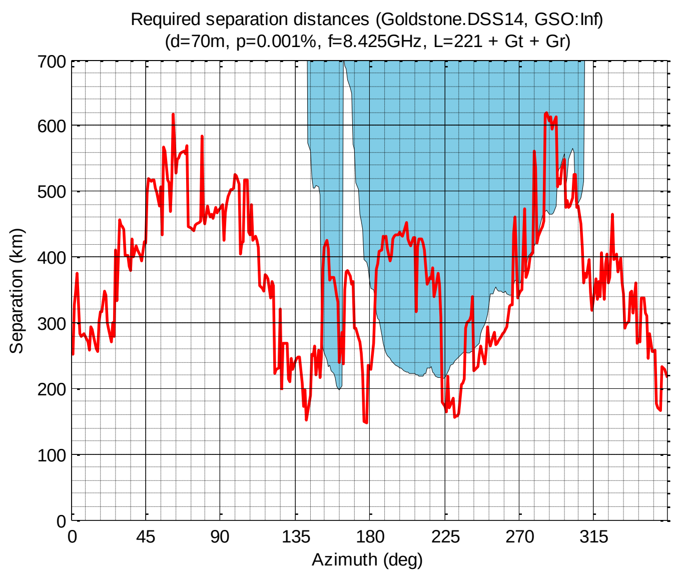
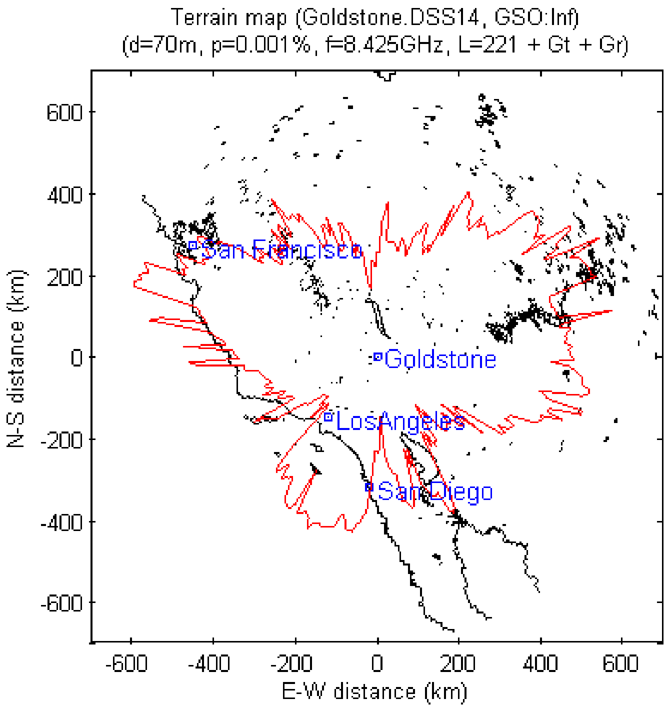


FIGURE A3-2D

Map of the required separation distances between GSO MMSS and SRS earth station at Goldstone DSN site (Case 2)



Similarly, the required MMSS separation distances are shown in Fig. A3-3A for the 70-m antenna at Canberra, Australia. The maximum separation distance required is 400 km. In Fig. A3-3B, the MMSS uplink exclusion zone is plotted on the map.

In order to keep the exclusion zone around the Canberra, Australia within the land-mass, the MMSS transmit e.i.r.p. spectral density towards the horizon at the 8 400 MHz band-edge frequency should be below –28 dBW/Hz. It is clear from the map of the required separation distances around Canberra deep-space station as shown in Fig. A3-3B that the exclusion zone does not extend to sea, since the MMSS transmit e.i.r.p. towards the horizon is about –31 dBW/Hz, which is below the limit given above.

FIGURE A3-3A

Required separation distances between NGSO MMSS and SRS earth station at Canberra DSN site (Case 1)

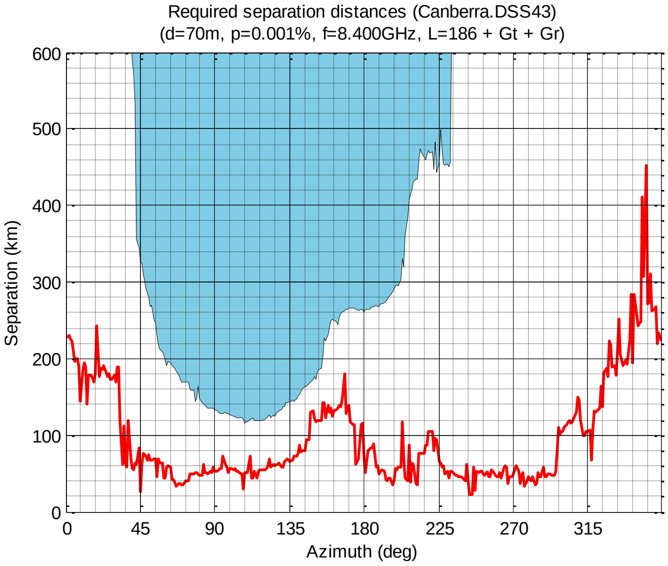


FIGURE A3-3B

Map of the required separation distances between NGSO MMSS and SRS earth station at Canberra DSN site (Case 1)

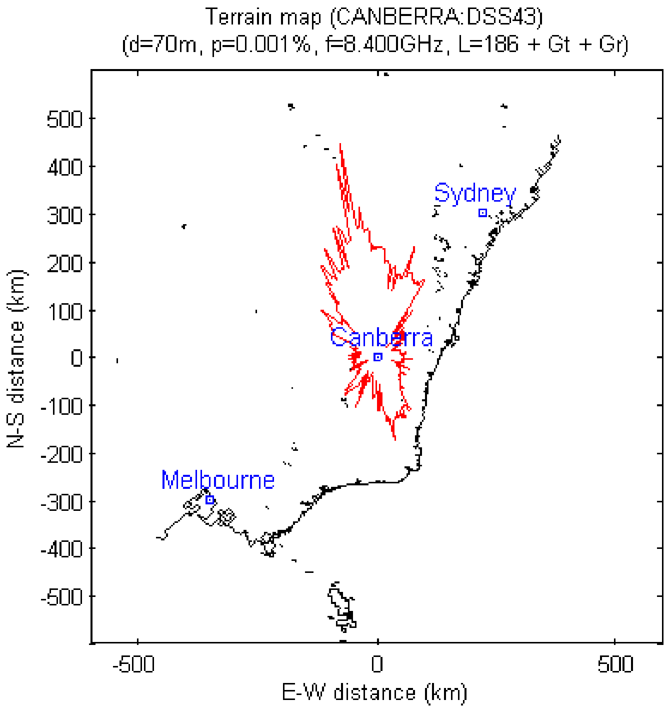


FIGURE A3-3C

Required separation distances between GSO MMSS and SRS earth station at Canberra DSN site (Case 1)

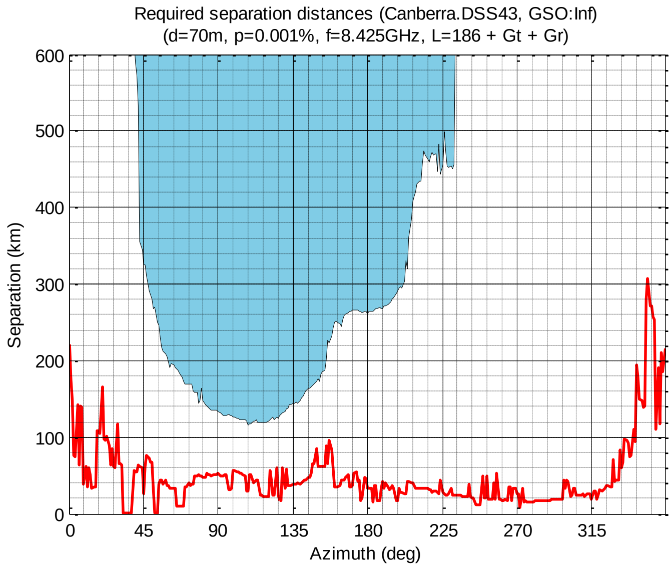
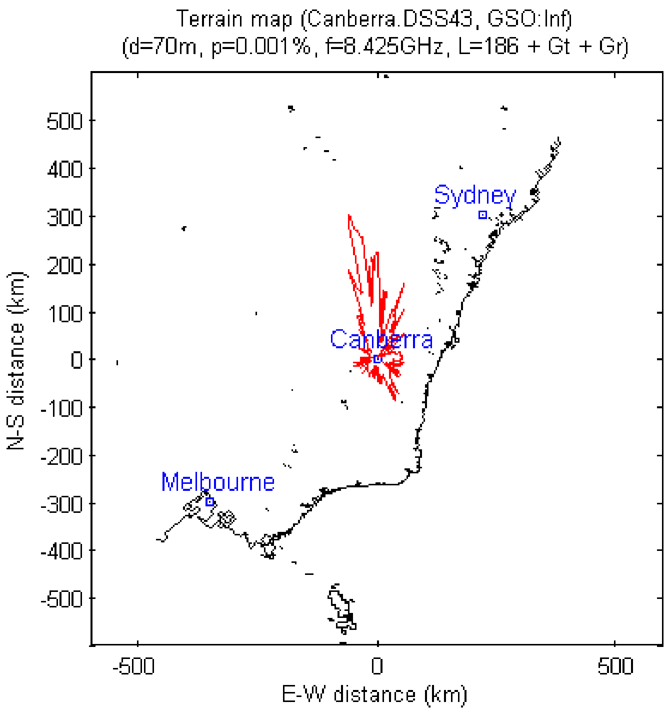


FIGURE A3-3D

Map of the required separation distances between GSO MMSS and SRS earth station at Canberra DSN site (Case 1)



Figures A3-4A and A3-4B provide the same information when considering e.i.r.p. values contained in RR No. **21.8**. In this case, the required separation distances extend up to 600 km around the Canberra site.

FIGURE A3-4A

Required separation distances between NGSO MMSS and SRS earth station at Canberra DSN site (Case 2)

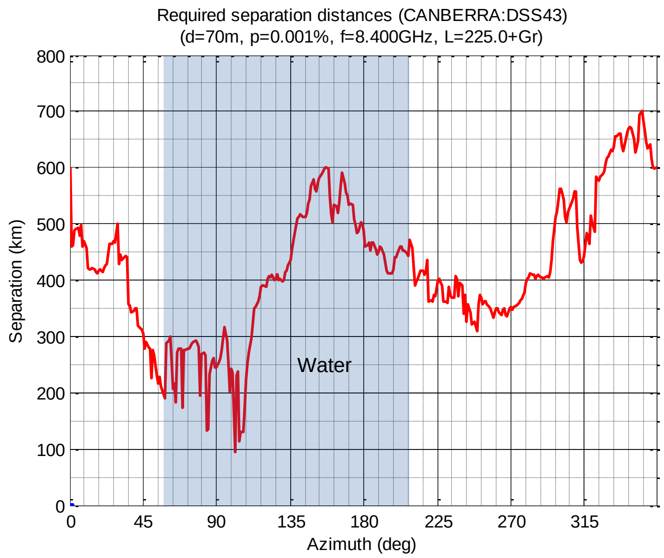


FIGURE A3-4B

Map of the required separation distances between NGSO MMSS and SRS earth station at Canberra DSN site (Case 2)

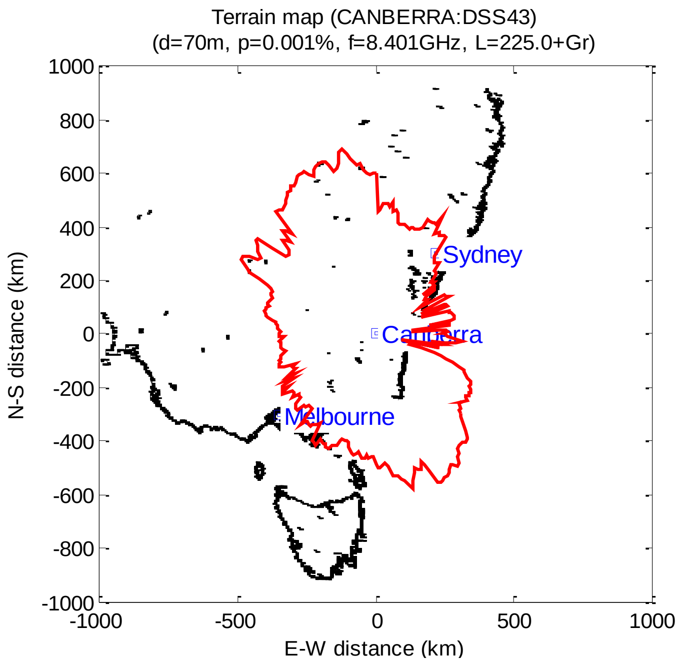


FIGURE A3-4C

Required separation distances between GSO MMSS and SRS earth station at Canberra DSN site (Case 2)

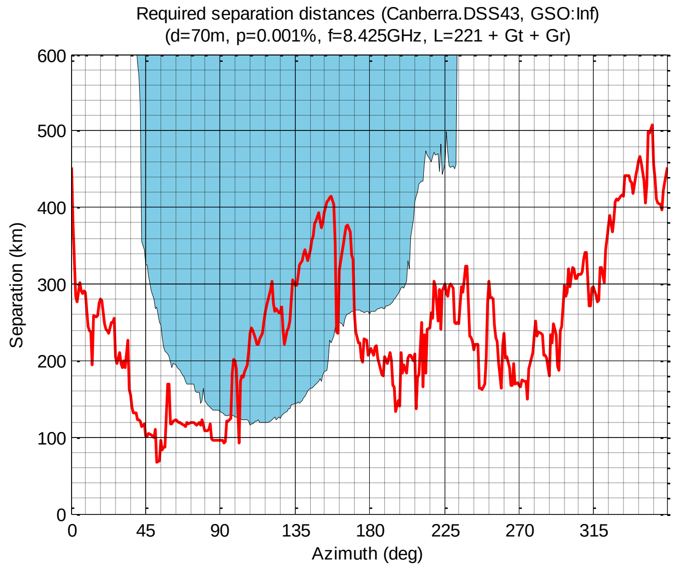


FIGURE A3-4D

Map of the required separation distances between GSO MMSS and SRS earth station at Canberra DSN site (Case 2)

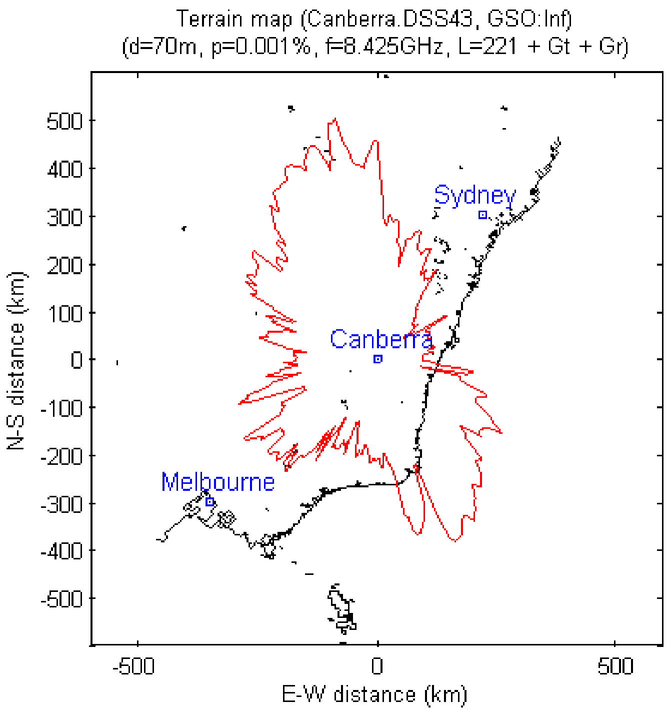


Figure A3-5A below shows the required separation distance for the MMSS uplink around the Robledo, Spain SRS (deep-space) earth station. The maximum required separation distance is roughly 400 km from the Robledo deep-space station. Figure A3-5B shows a plot of the exclusion zone superimposed on the map.

In order to keep the exclusion zone around the Robledo, Spain within the land-mass, the MMSS transmit e.i.r.p. spectral density towards the horizon at the 8 400 MHz band-edge frequency should be below –30 dBW/Hz. It is clear from the map of the required separation distances around Robledo deep-space station as shown in Fig. A3-5B that the exclusion zone does not extend to sea, since the MMSS transmit e.i.r.p. towards the horizon is about –31 dBW/Hz, which is below the limit given above.

FIGURE A3-5A

Required separation distances between NGSO MMSS and SRS earth station at Robledo DSN site (Case 1)

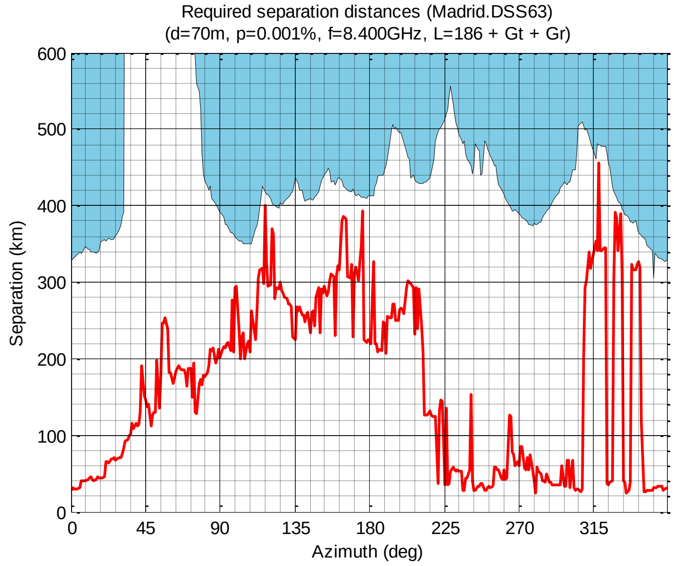


FIGURE A3-5B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Robledo DSN site (Case 1)

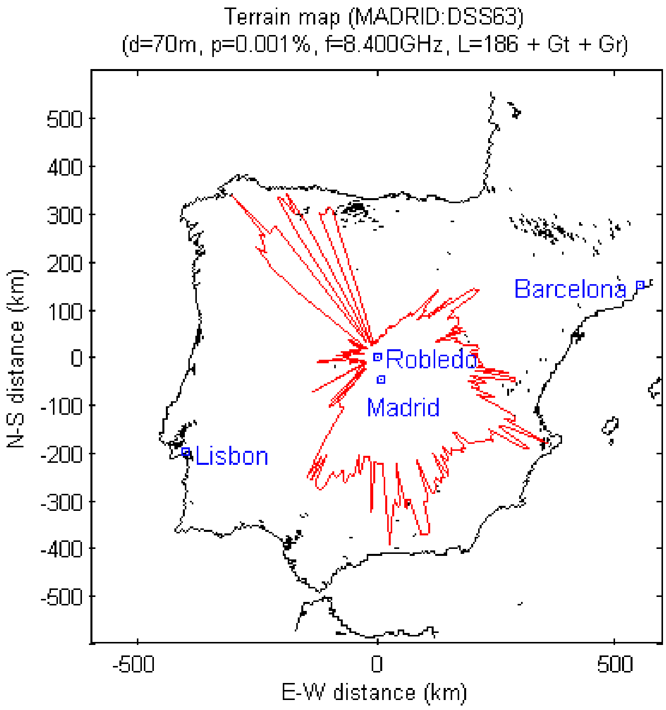


FIGURE A3-5C

Required separation distances between GSO MMSS and SRS earth station at Robledo DSN site (Case 1)

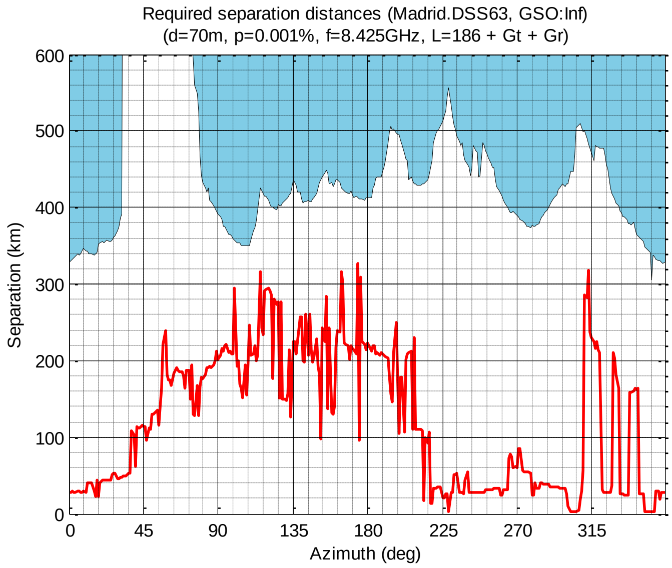
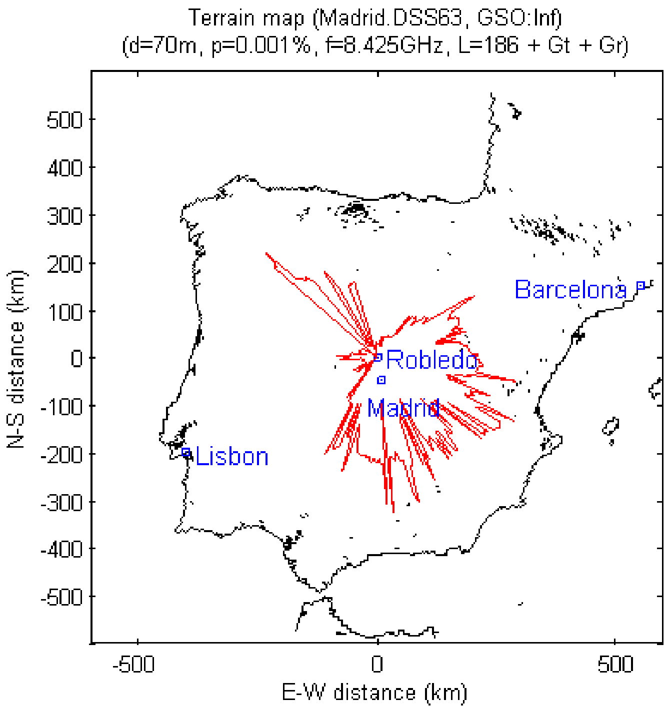


FIGURE A3-5D

Map of the required separation distances between GSO MMSS and SRS earth stations at Robledo DSN site (Case 1)



Figures A3-6A and A3-6B provide the same information when considering e.i.r.p. values contained in RR No. **21.8**. In this case, the required separation distances extend up to 750 km around the Robledo site.

FIGURE A3-6A

Required separation distances between NGSO MMSS and SRS earth stations at Robledo DSN site (Case 2)

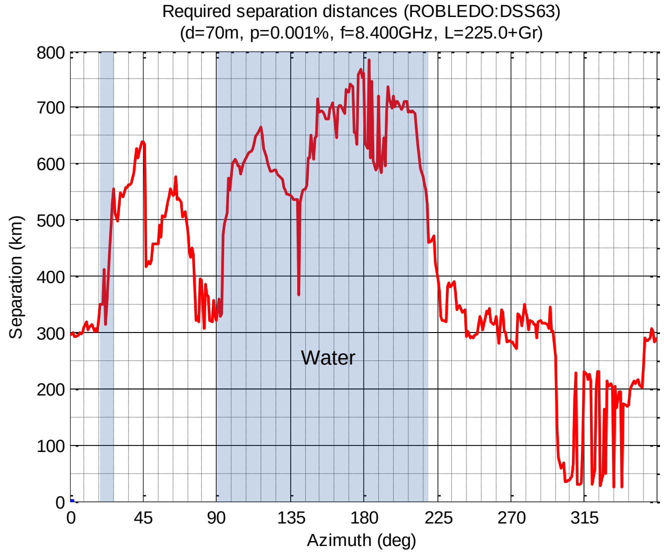


FIGURE A3-6B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Robledo DSN site (Case 2)

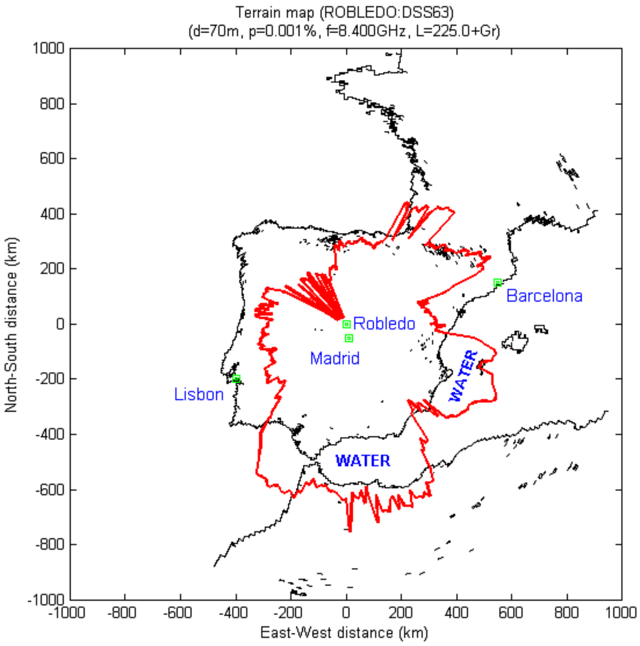


FIGURE A3-6C

Required separation distances between GSO MMSS and SRS earth stations at Robledo DSN site (Case 2)

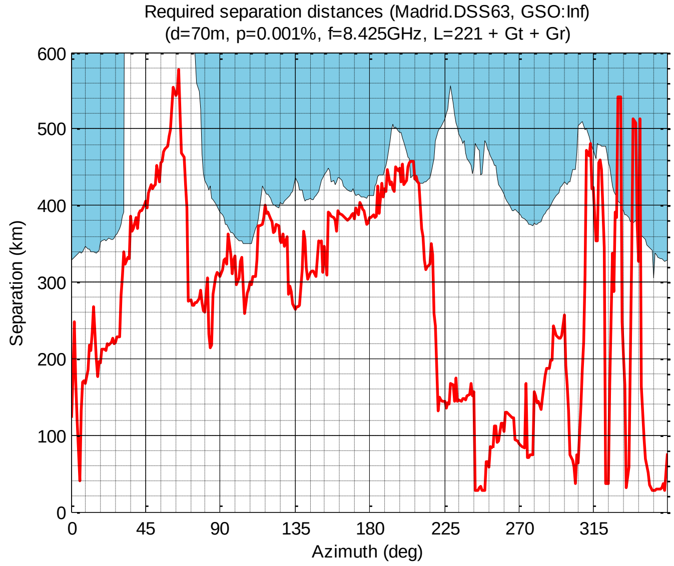
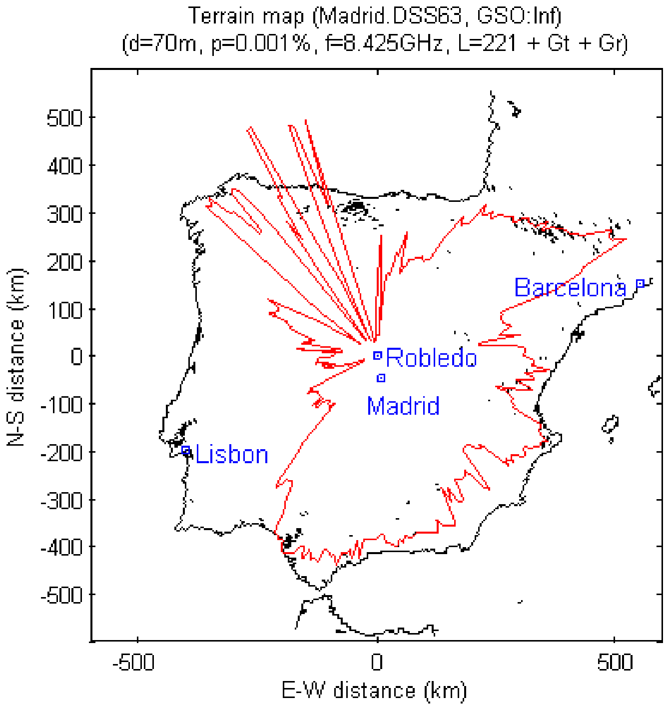


FIGURE A3-6D

Map of the required separation distances between GSO MMSS and SRS earth stations at Robledo DSN site (Case 2)



Given that it is very difficult to coordinate with mobile systems, the coordination contours and zones identified in this section are de facto exclusion contours and zones.

Figures A3-7A, A3-9A and A3-11A show diagrams of the required separation distances as a function of the azimuthal angle for the ESA's deep space stations at Cebreros, Malargüe Sur and New Norcia respectively, when considering the e.i.r.p. values given in Table A3.1-1. White and blue colours are used to roughly distinguish between land and water masses respectively.

Note that separation distances are computed for all azimuth directions even though there may not be water in some azimuth directions. For Cebreros and Malargüe Sur the separation distance from the SRS station does not reach the water line assuming only one active MMSS station at a time. At New Norcia, instead, it can be observed that the minimum separation distance for one active MMSS station ranges from 120 to 517 km.

The same information is given in Figs A3-8A, A3-10A and A3-12A when considering the e.i.r.p. values in RR No. **21.8**.

In Figures A3-7B to A3-12B the coordination contour (red line) is superimposed on a geographical map of the Earth and the main populated areas around the site are indicated.

FIGURE A3-7A

Required separation distances between NGSO MMSS and SRS earth station at Cebreros site (Case 1)

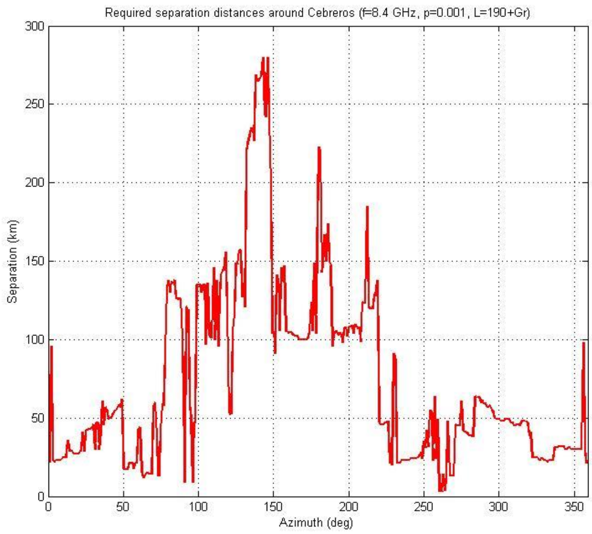


FIGURE A3-7B

Map of the required separation distances between NGSO MMSS and SRS earth station at Cebreros site (Case 1)

FIGURE A3-7C

Required separation distances between GSO MMSS and SRS earth station at Cebreros site (Case 1)

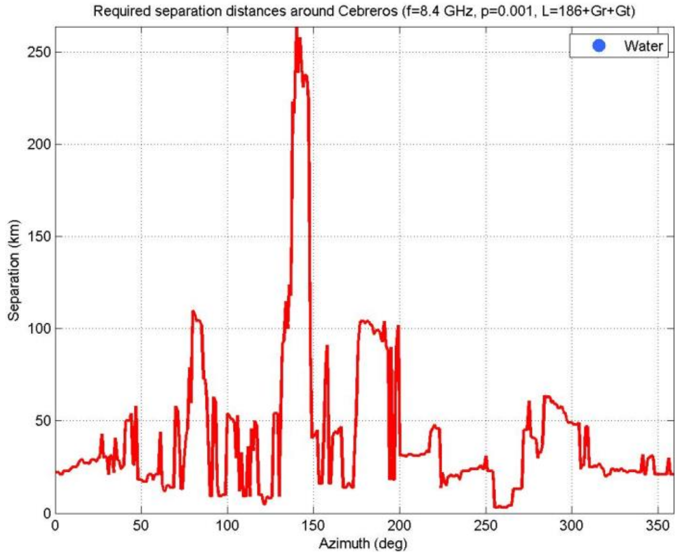


FIGURE A3-7D

Map of the required separation distances between GSO MMSS and SRS earth station at Cebreros site (Case 1)

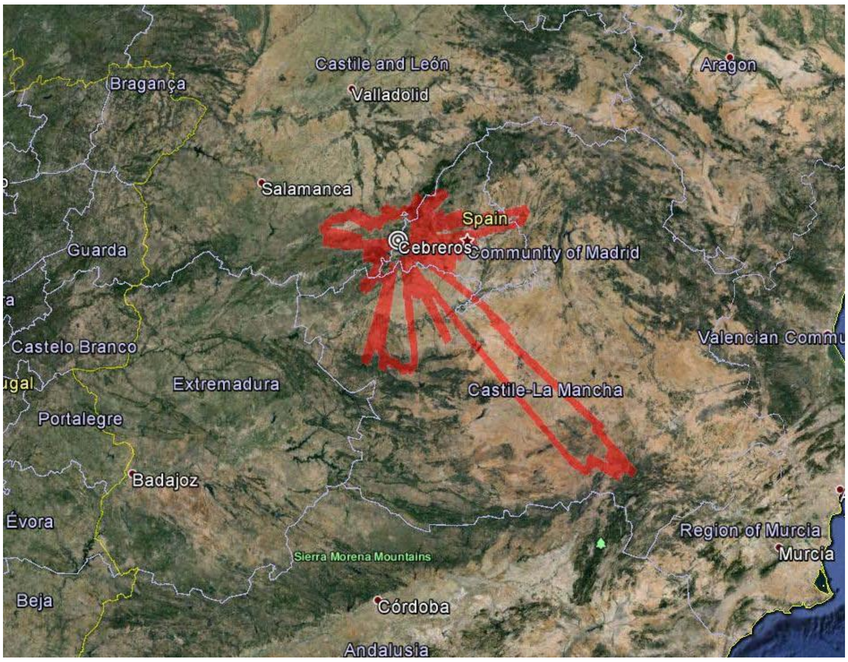


FIGURE A3-8A

Required separation distances between NGSO MMSS and SRS earth stations at Cebreros (Case 2)

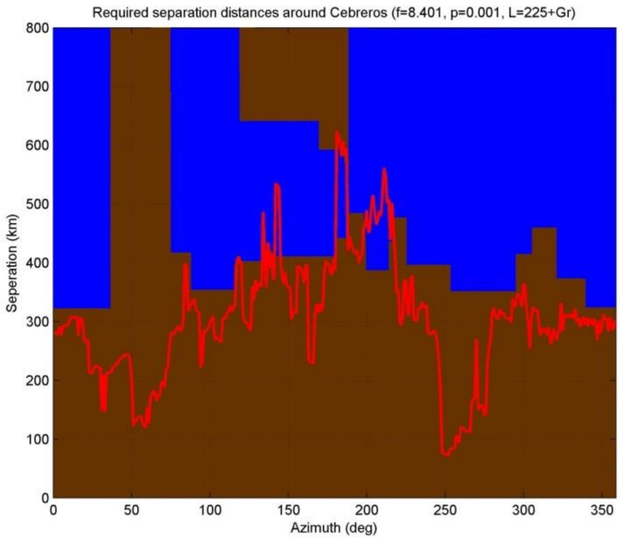


FIGURE A3-8B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Cebreros (Case 2)

FIGURE A3-8C

Required separation distances between GSO MMSS and SRS earth stations at Cebreros (Case 2)

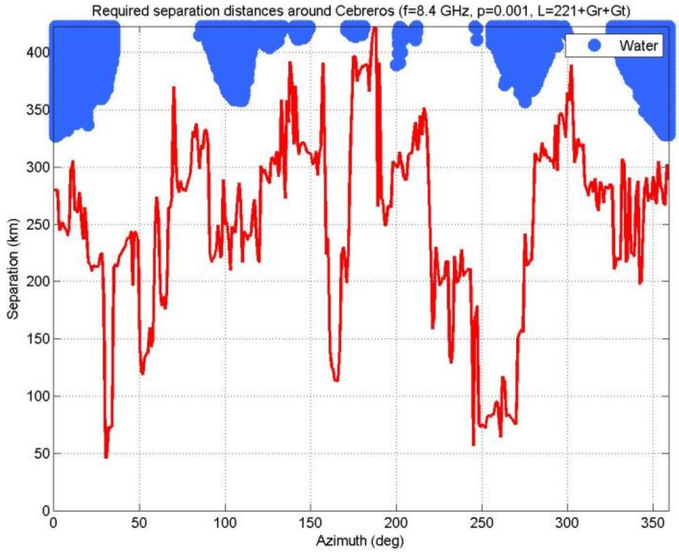


FIGURE A3-8D

Map of the required separation distances between GSO MMSS and SRS earth stations at Cebreros (Case 2)

FIGURE A3-9A

Required separation distances between NGSO MMSS and SRS earth stations at Malargüe Sur site (Case 1)

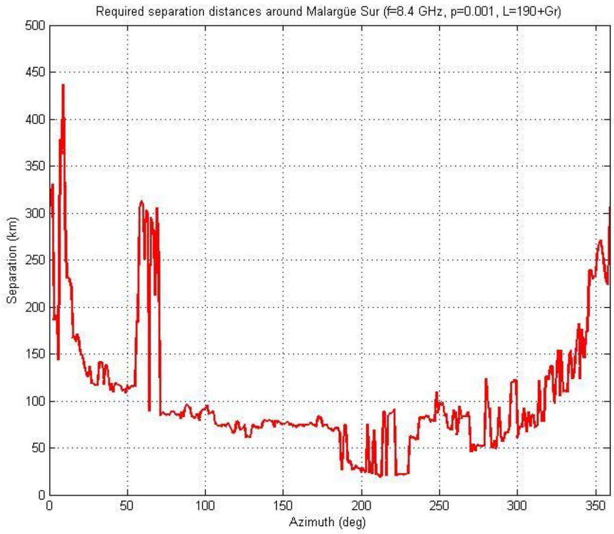


FIGURE A3-9B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Malargüe Sur site (Case 1)

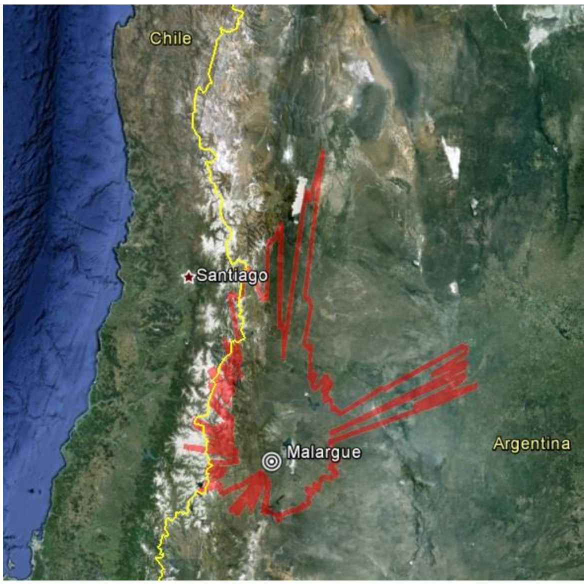


FIGURE A3-9C

Required separation distances between GSO MMSS and SRS earth stations at Malargüe Sur site (Case 1)

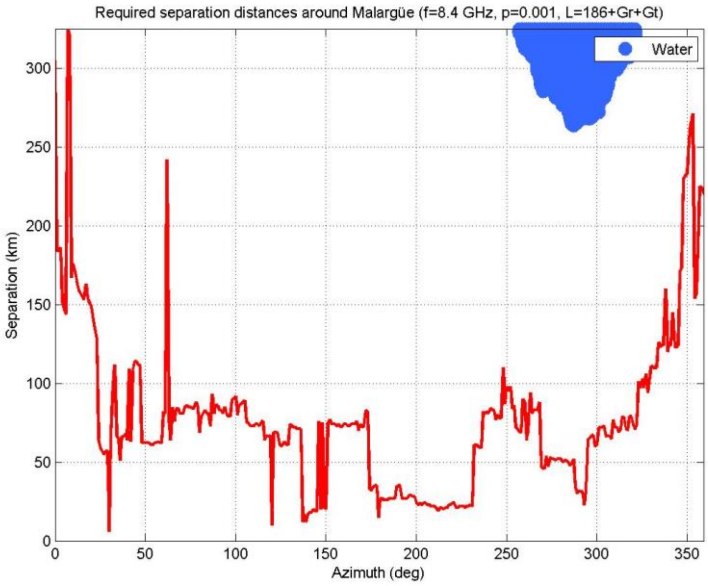


FIGURE A3-9D

Map of the required separation distances between GSO MMSS and SRS earth stations at Malargüe Sur site (Case 1)

FIGURE A3-10A

Required separation distances between NGSO MMSS and SRS earth stations at Malargüe Sur (Case 2)

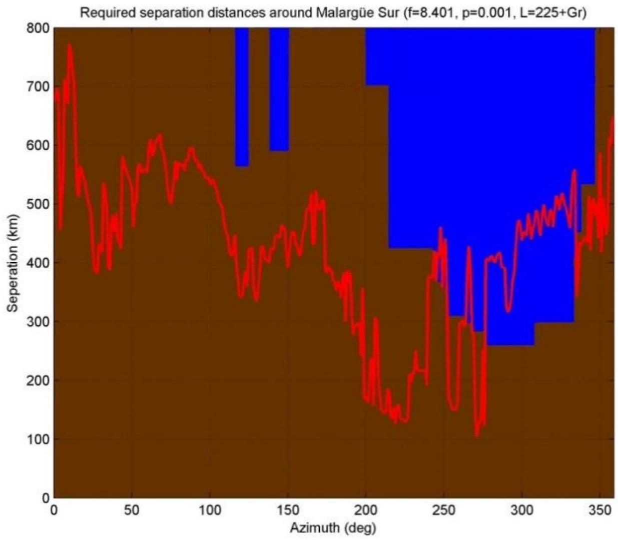


FIGURE A3-10B

Map of the required separation distances between NGSO MMSS and SRS earth stations at Malargüe Sur (Case 2)

FIGURE A3-10C

Required separation distances between GSO MMSS and SRS earth stations at Malargüe Sur (Case 2)

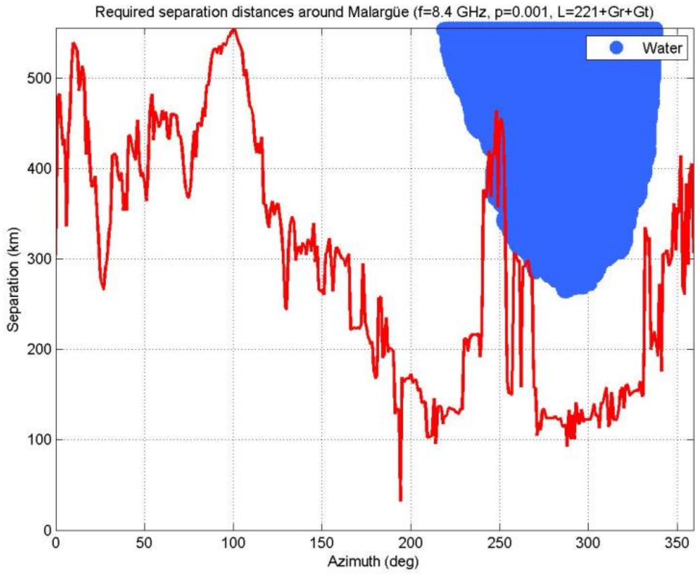


FIGURE A3-10D

Map of the required separation distances between GSO MMSS and SRS earth stations at Malargüe Sur (Case 2)

FIGURE A3-11A

Required separation distances between NGSO MMSS and SRS earth stations at New Norcia site (Case 1)

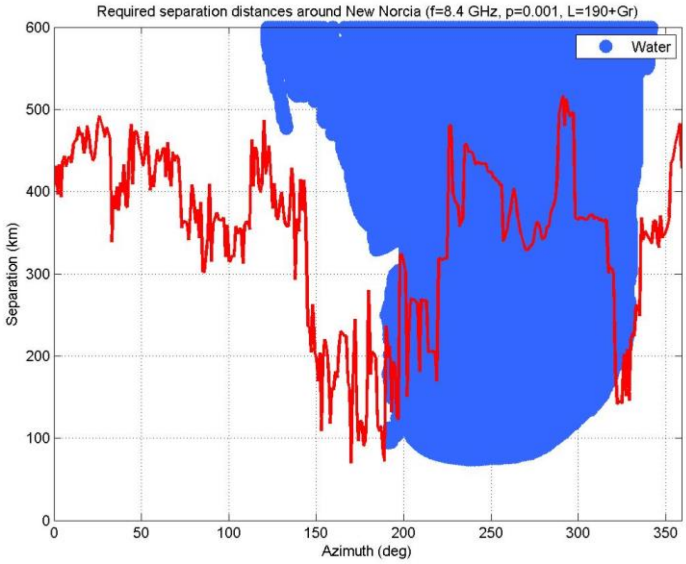


FIGURE A3-11B

Map of the required separation distances between NGSO MMSS and SRS earth stations at New Norcia Site (Case 1)

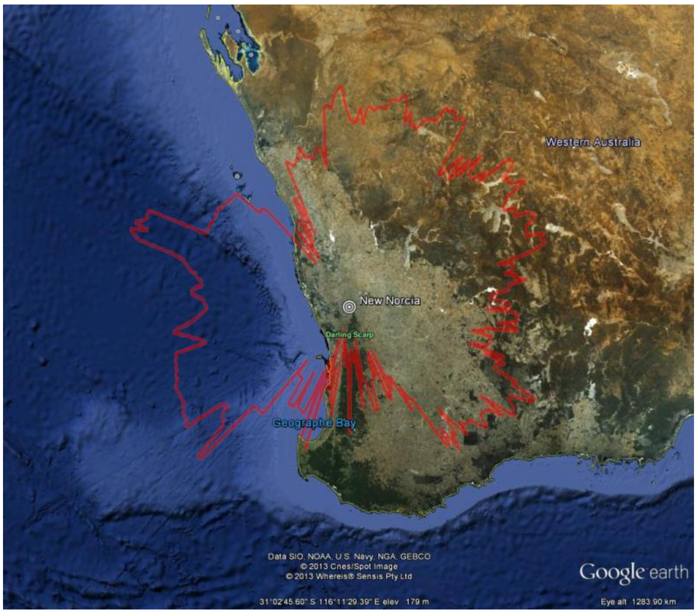


FIGURE A3-11C

Required separation distances between GSO MMSS and SRS earth stations at New Norcia site (Case 1)

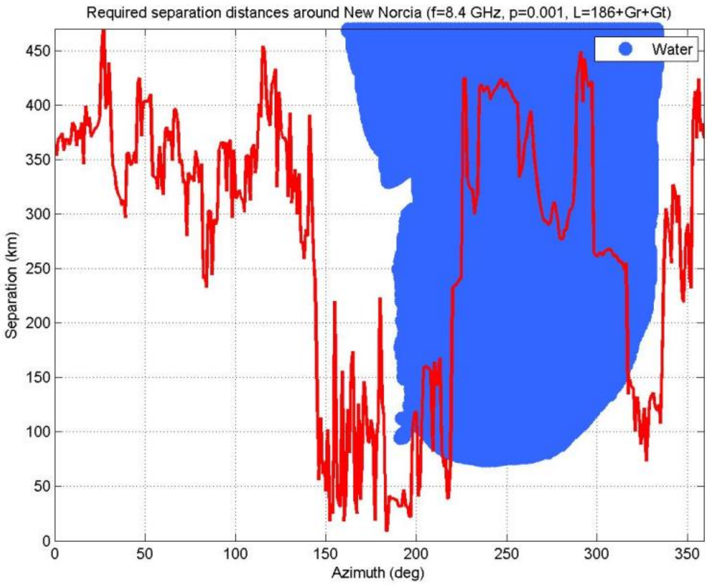


FIGURE A3-11D

Map of the required separation distances between GSO MMSS and SRS earth stations at New Norcia site (Case 1)

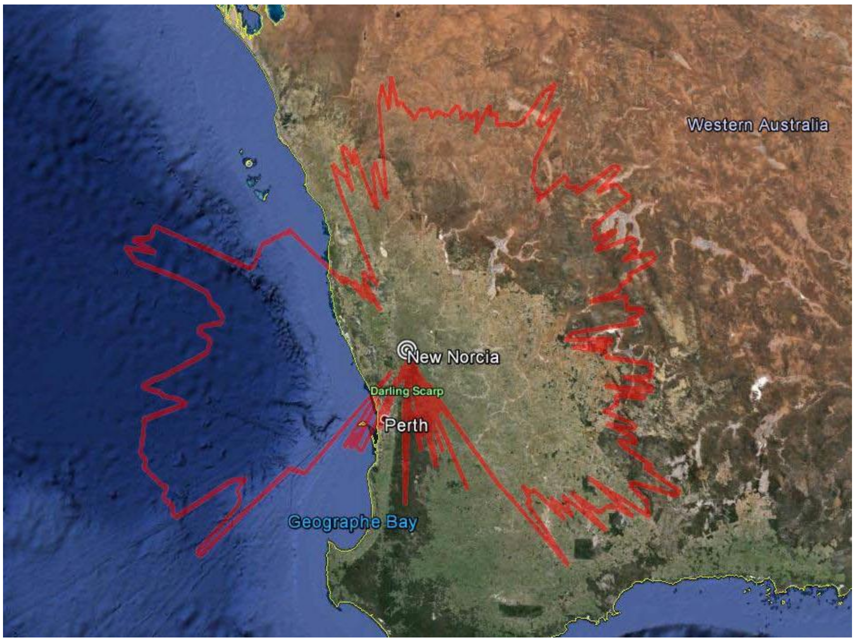


FIGURE A3-12A

Required separation distances between NGSO MMSS and SRS earth stations at New Norcia (Case 2)

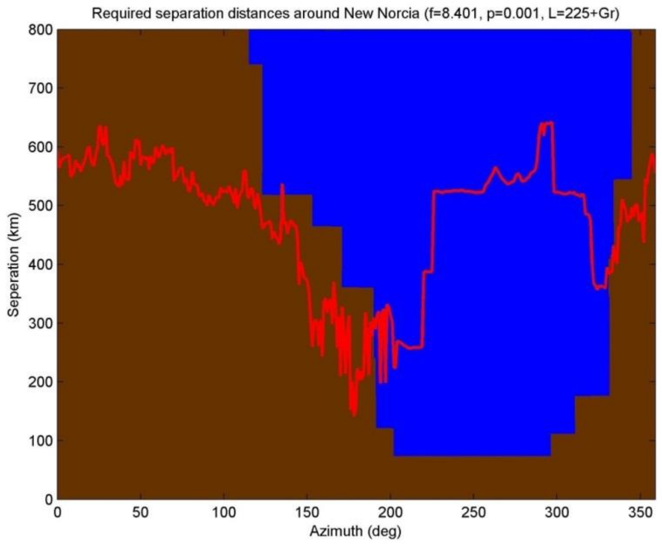


FIGURE A3-12B

Map of the required separation distances between NGSO MMSS and SRS earth stations at New Norcia (Case 2)

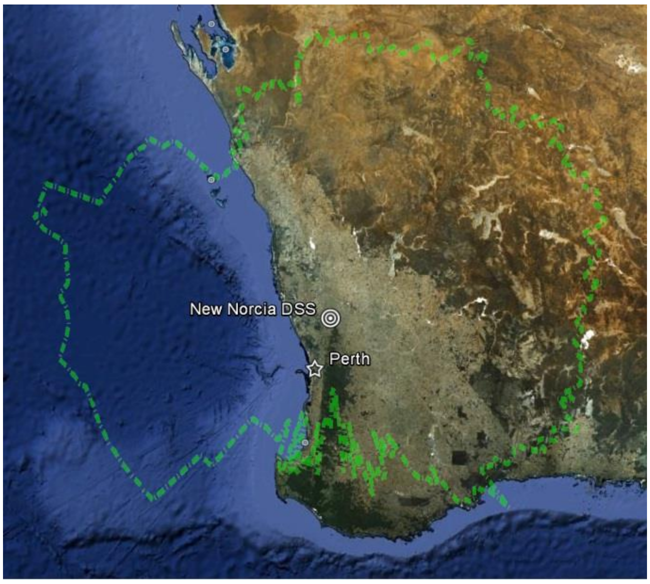


FIGURE A3-12C

Required separation distances between GSO MMSS and SRS earth stations at New Norcia (Case 2)

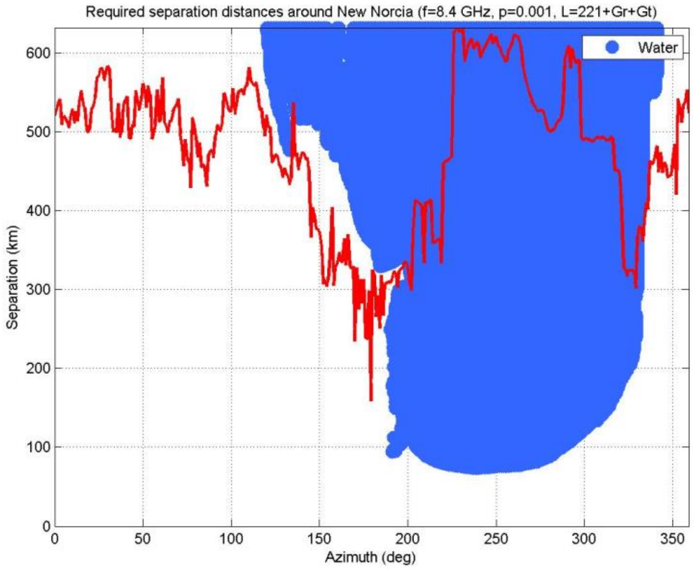
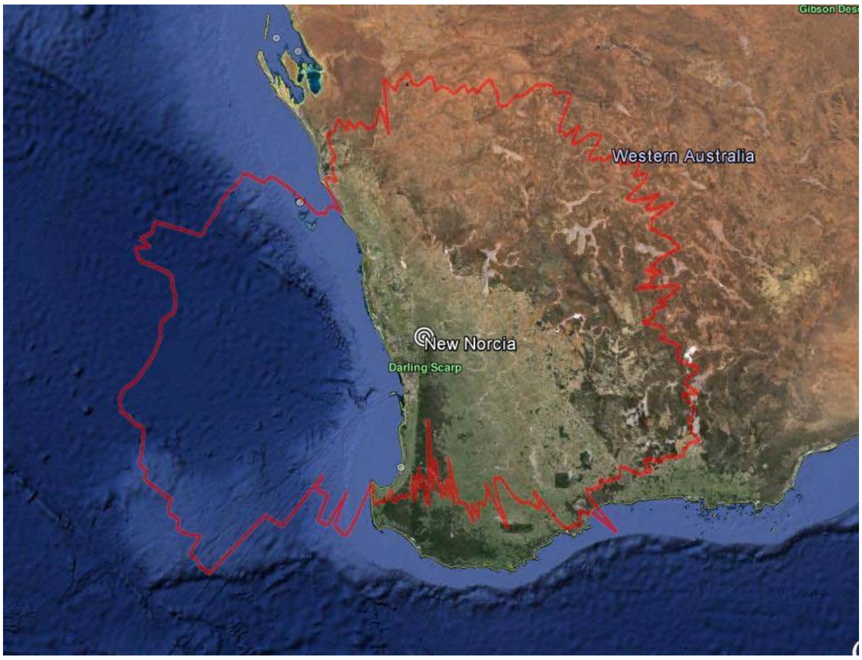


FIGURE A3-12D

Map of the required separation distances between GSO MMSS and SRS earth stations at New Norcia (Case 2)



Figures A3-13A, A3-13B, A3-13C and A3-13D show the separation distance analysis results about Uchinoura earth station against MMSS earth station's characteristics in Table A3-1.

FIGURE A3-13A

Required separation distances for the Uchinoura earth station vs NGSO MMSS earth station (Case 1)

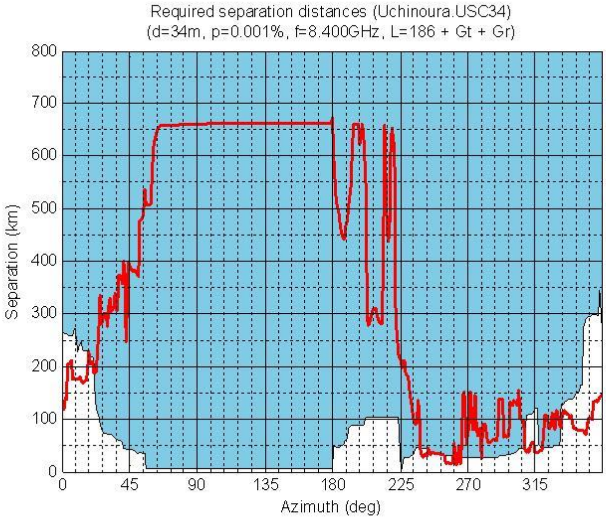


FIGURE A3-13B

Map of the required separation distances for the Uchinoura earth station vs NGSO MMSS earth station (Case 1)

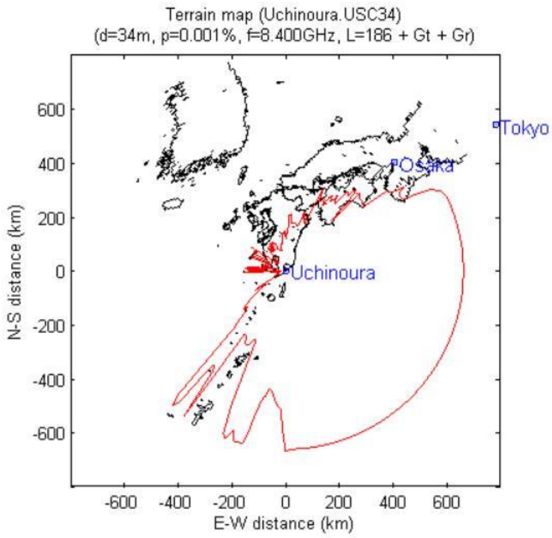


FIGURE A3-13C

Required separation distances for the Uchinoura earth station vs GSO MMSS earth station (Case 1)

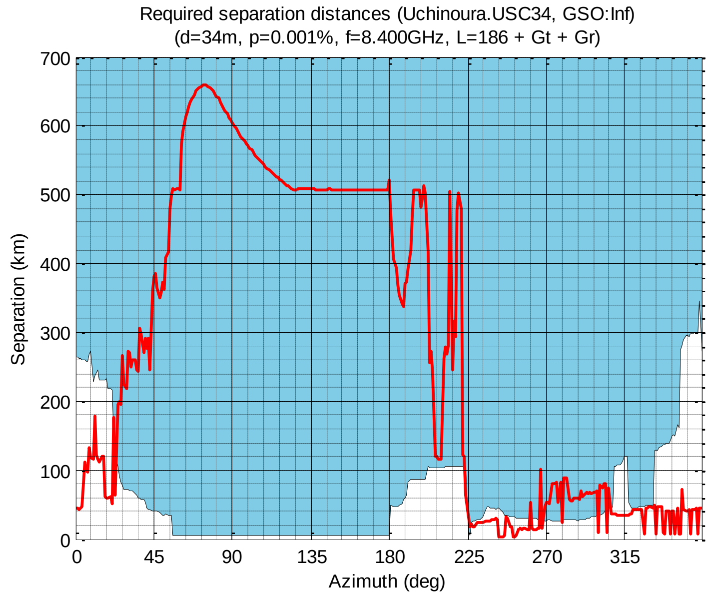
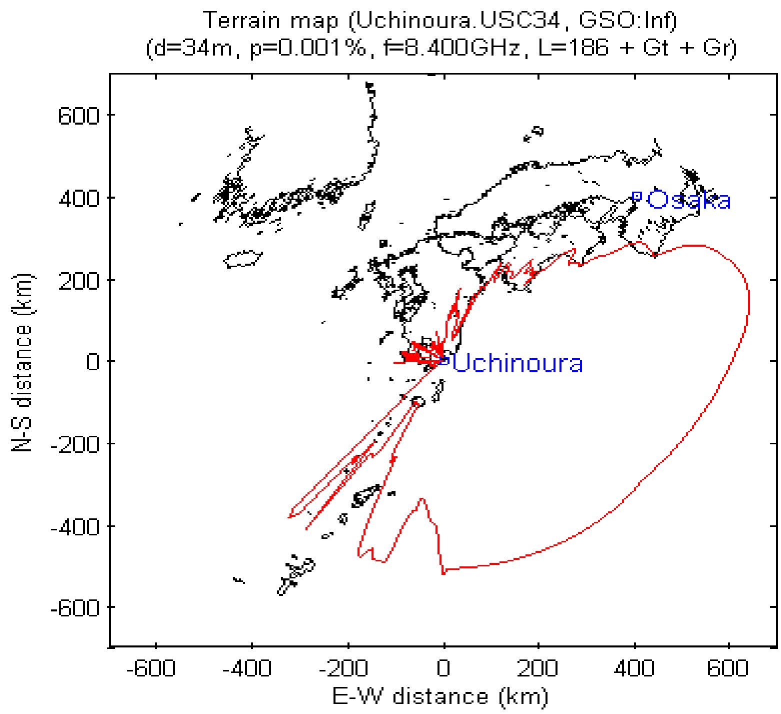


FIGURE A3-13D

Map of the required separation distances for the Uchinoura earth station vs GSO MMSS earth station (Case 1)



Figures A3-14A, A3-14B, A3-14C and A3-14D below show the separation distance analysis results about Uchinoura earth station against MMSS earth station's e.i.r.p. density derived from RR No. **21.8**.

FIGURE A3-14A

Required separation distances for the Uchinoura earth station vs NGSO MMSS earth station (Case 2)

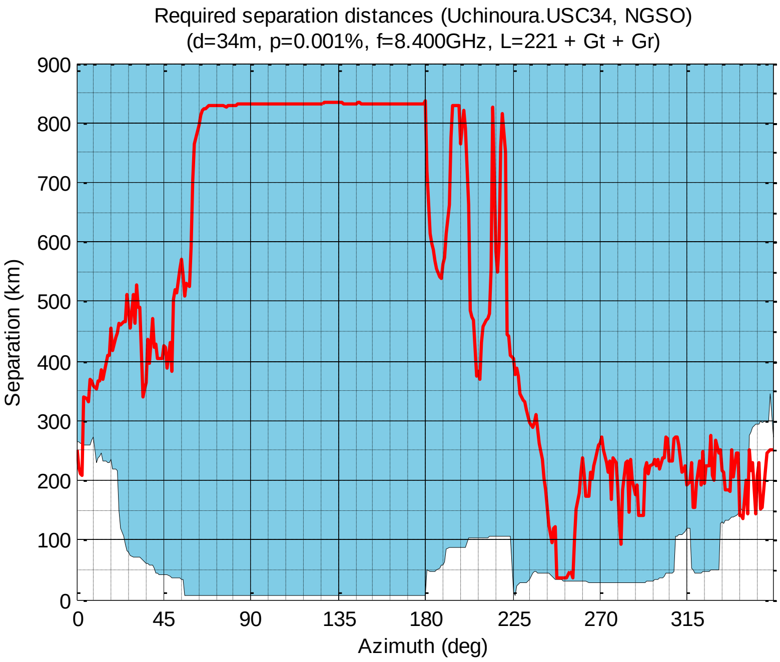


FIGURE A3-14B

Map of the required separation distances for the Uchinoura earth station vs NGSO MMSS earth station (Case 2)

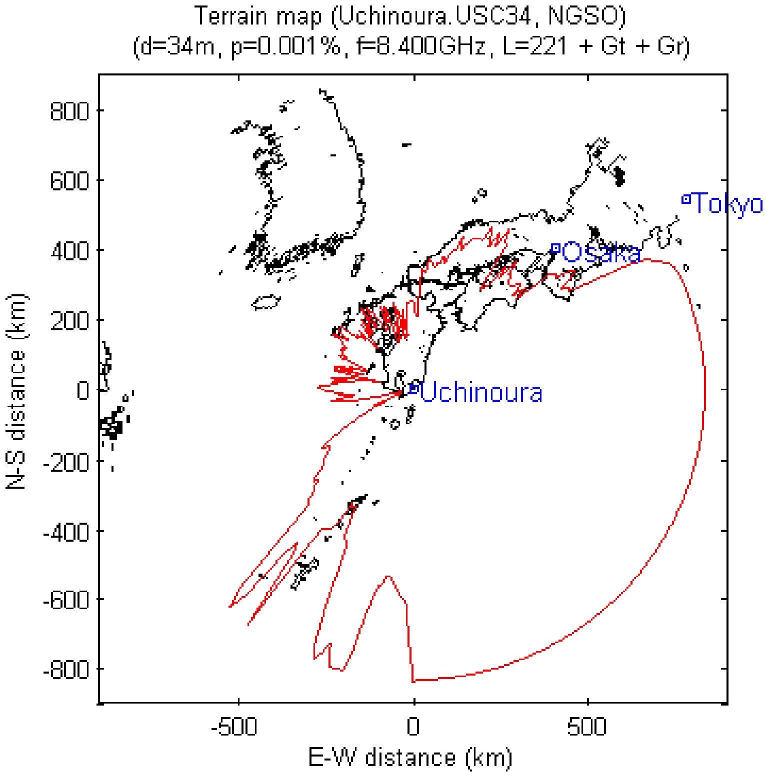


FIGURE A3-14C

Required separation distances for the Uchinoura earth station vs GSO MMSS earth station (Case 2)

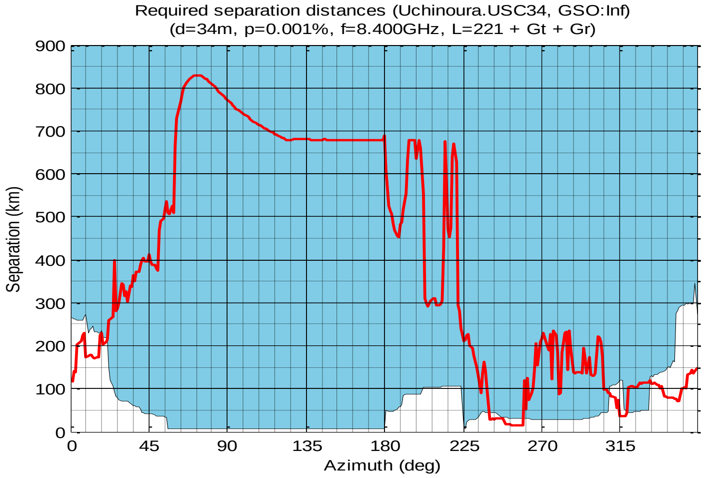
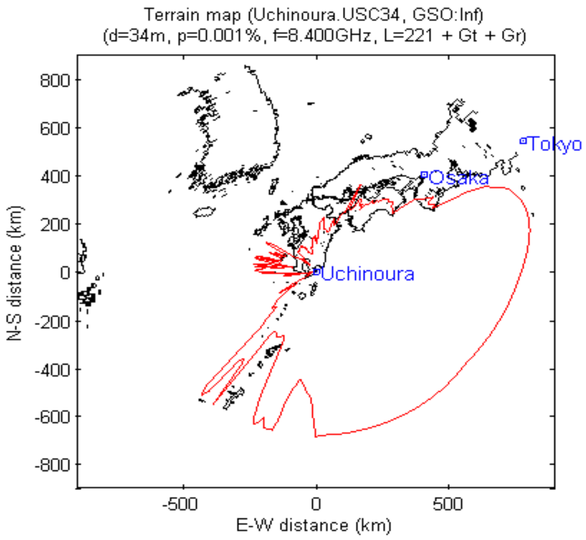


FIGURE A3-14D

Map of the required separation distances for the Uchinoura earth station vs GSO MMSS earth station (Case 2)



Figures A3-15A, A3-15B, A3-15C and A3-15D show the separation distance analysis results about Usuda earth station against MMSS earth station's characteristics in Table A3-1.

FIGURE A3-15A

Required separation distances for the Usuda earth station vs NGSO MMSS earth station (Case 1)

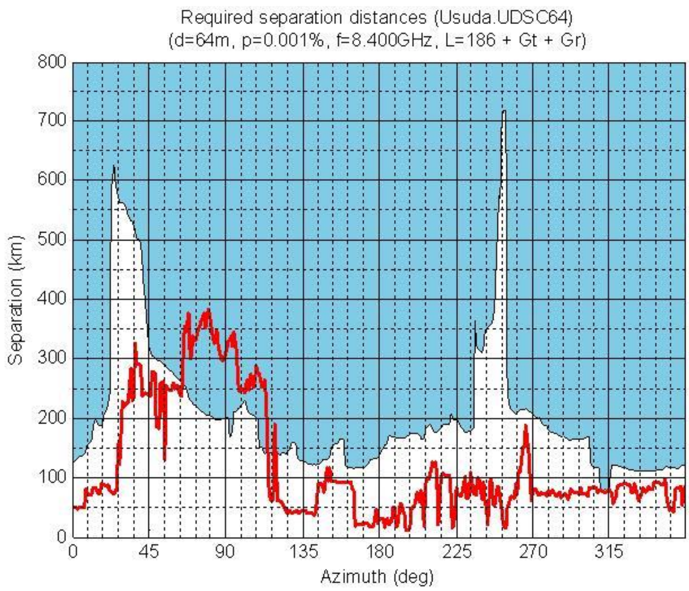


FIGURE A3-15B

Map of required separation distances for the Usuda earth station vs NGSO MMSS earth station (Case 1)

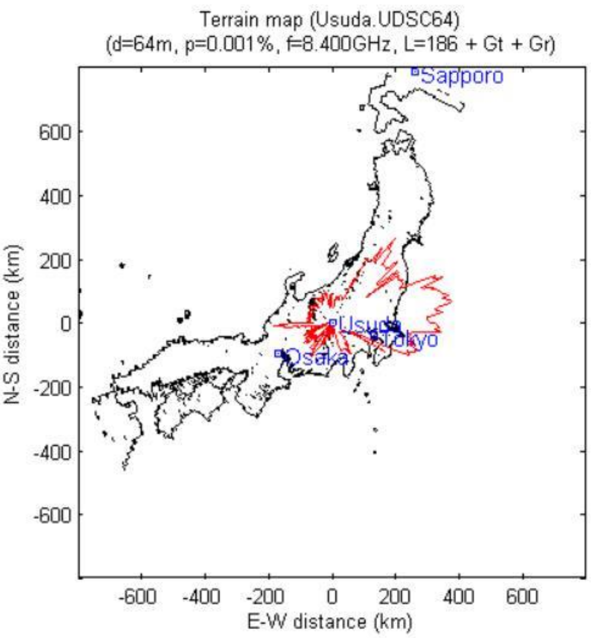


FIGURE A3-15C

Required separation distances for the Usuda earth station vs GSO MMSS earth station (Case 1)

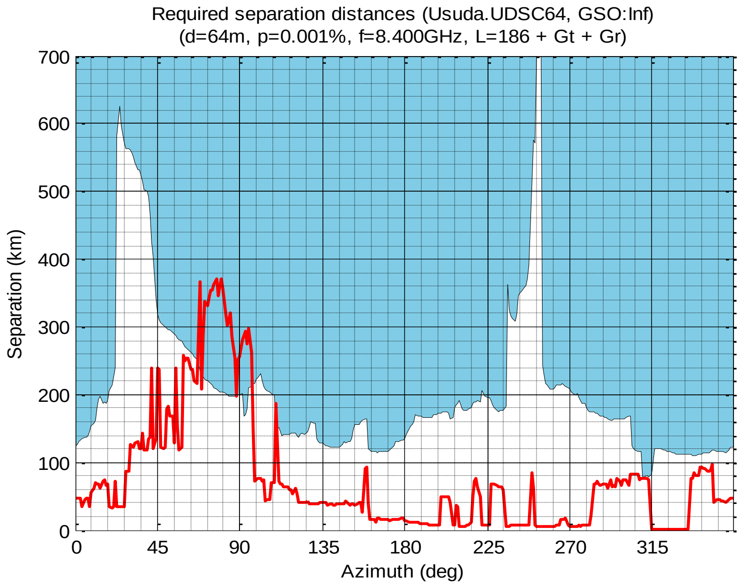
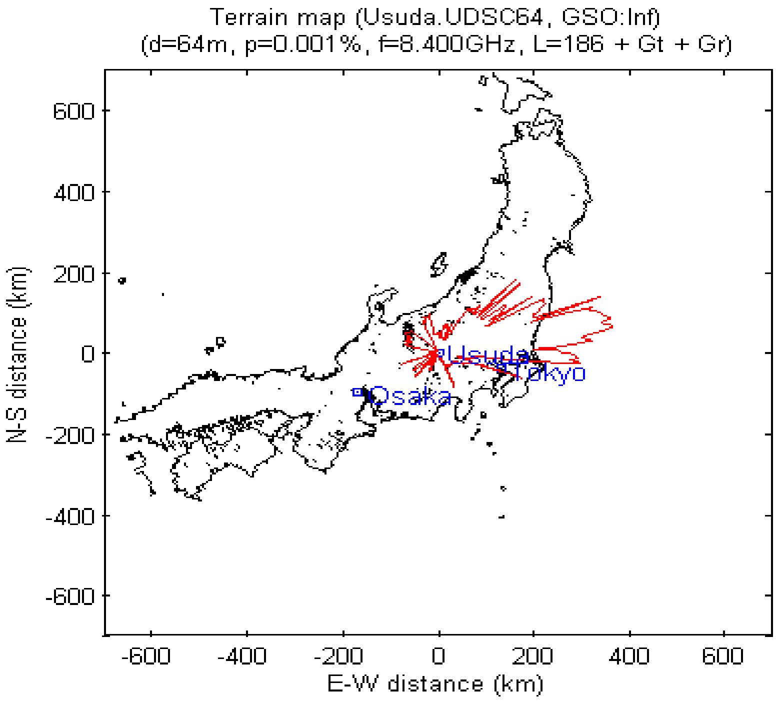


FIGURE A3-15D

Map of required separation distances for the Usuda earth station vs GSO MMSS earth station (Case 1)



Figures A3-16A, A3-16B, A3-16C and A3-16D show the separation distance analysis results about Usuda earth station against MMSS earth station's e.i.r.p. density derived from RR No. **21.8**.

FIGURE A3-16A

Required separation distances for the Usuda earth station vs NGSO MMSS earth station (Case 2)

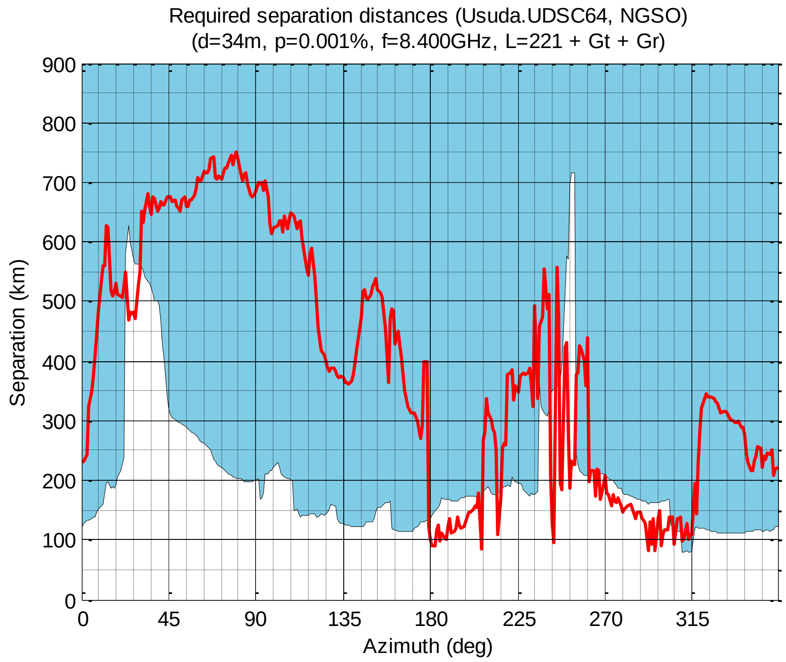


FIGURE A3-16B

Map of the required separation distances for the Usuda earth station vs NGSO MMSS earth station (Case 2)

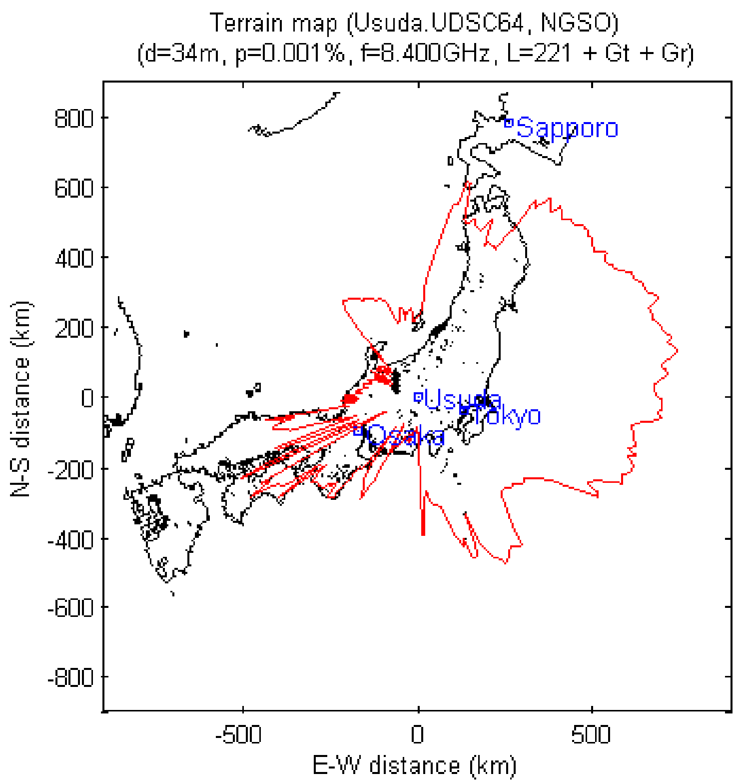


FIGURE A3-16C

Required separation distances for the Usuda earth station vs GSO MMSS earth station (Case 2)

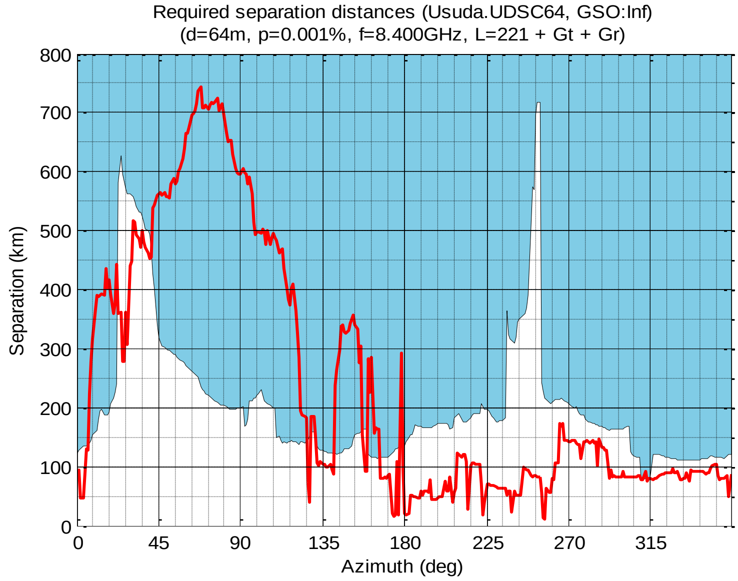
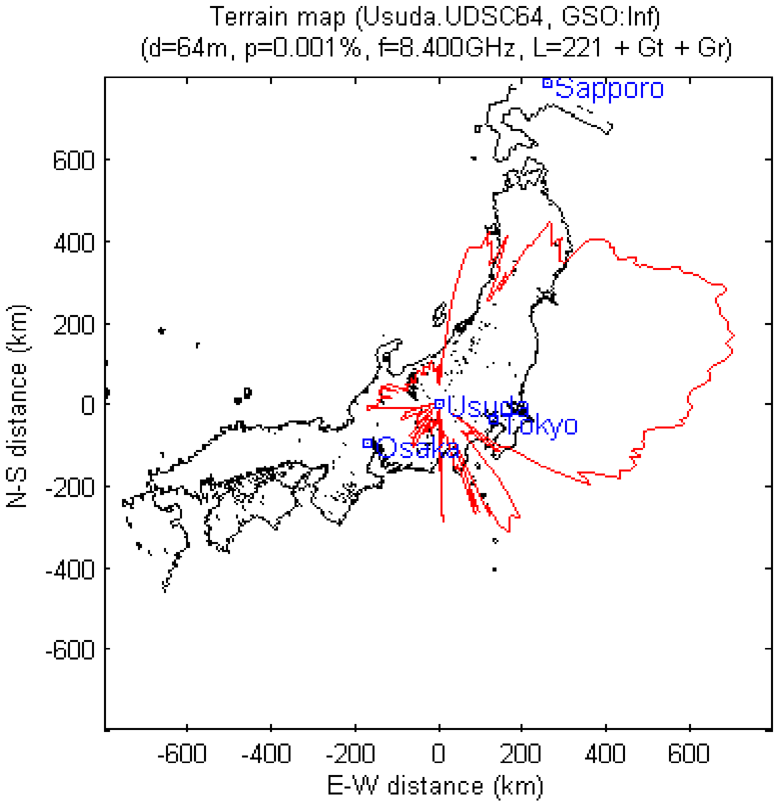


FIGURE A3-16D

Map of the required separation distances for the Usuda earth station vs GSO MMSS earth station (Case 2)



As seen from Figs A3-14 and A3-16, the analysis with e.i.r.p. density value in RR No. **21.8** shows that the required separation distance for Japan's SRS earth stations would go beyond Japanese territory and would be in territorial waters of other administrations. Thus, in case that MMSS is allocated in the 8 025-8 400 MHz band, it would be difficult to avoid potential harmful interference into deep-space earth stations.

Even in case that realistic MMSS earth station characteristics in Table A3-1 is assumed, the analysis results in Figs A3-13 and A3-15 show that the required separation distance for Japan's SRS earth stations would go beyond Japanese territory.

A3.2 Analysis 2

A3.2.1 Introduction

WRC-15 agenda item 1.9.2 invites the ITU-R to conduct technical and regulatory studies on the possibility of allocating the bands 7 375-7 750 MHz and 8 025-8 400 MHz to the maritime mobile-satellite service and additional regulatory measures, depending on the results of appropriate studies. This document presents a preliminary assessment of the compatibility between the MMSS (E-s) in the band 8 025-8 400 MHz and SRS mission downlink operating in the band 8 400-8 500 MHz when both operate in adjacent bands.

A3.2.2 Characteristics of MMSS earth station stations in the 7/8 GHz range

The main MMSS characteristics are described in Table A3-3.

TABLE A3-3

MMSS Earth station transmit characteristics

Characteristics of earth station	Units	Small	Large
Transmitter center frequency	(GHz)	8.2125	8.2125
Maximum transmit output power	(Watts)	100	2 000
Transmit antenna diameter	(m)	0.4	2.6
Transmit antenna peak gain	(dBi)	29	45
Transmit Antenna –3 dB beamwidth	(deg.)	6.2	0.8
Transmit antenna pattern type (ITU Recommendation, data (angle versus gain) or plot)		Rec. ITU-R S.580-6 or Appendix **8** of the RR	
Transmit antenna minimum elevation angle towards the satellite	(deg.)	10	10
Transmit antenna polarization (RHC, LHC, VL, HL or offset linear)		RHC	RHC
Uplink occupied bandwidth per carrier	(MHz)	0.004 to 4	
Transmit losses	(dB)	2	2
Transmit effective isotropic radiated power e.i.r.p.[7]	(dBW)	47	76
Transmit e.i.r.p. spectral density	(dBW/Hz)	–10	10
Transmit e.i.r.p. spectral density limit in a 10 MHz bandwidth[8]	(dBW/10 MHz)	47	76

A3.2.3 SRS Systems Interference Criteria

The characteristics and criteria of the SRS earth station are defined in Recommendations ITU-R SA.1014-2 and ITU-R SA.1157. The main characteristics are described in Tables A3-4, A3-5, and A3-6.

[7] Transmit effective isotropic radiated power e.i.r.p. = 10 * Log (maximum transmit output power) – Transmit losses + Transmit antenna peak gain.

[8] (dBW/10 MHz).

TABLE A3-4

SRS (deep-space) earth station locations

Station name	Location	Latitude (deg)	Longitude (deg)
Goldstone	USA	35.43	–116.89
Robledo	Spain	40.43	–4.25
Canberra	Australia	–35.40	148.98
Cebreros	Spain	40.4542	–4.3669
Malargüe Sur	Argentina	–35.7758	–69.3983
New Norcia	Australia	–31.0482	116.1915
Uchinoura	Japan	31.2	131.0
Usuda	Japan	36.1	138.3

TABLE A3-5

Characteristics of deep-space earth stations with 70 m antennas

Frequency (GHz)	Antenna gain (dBi)	Antenna beamwidth (degrees)	Transmitter power (dBW)	e.i.r.p. (dBW)	Receiving system noise temperature (K)	Receiving system noise power spectral density (dB(W/Hz))
7.145-7.190 Earth-to-space	72	0.04	43	115	--	--
8.400-8.450 Space-to-Earth	74	0.03	--	--	37 27	–213 –214

TABLE A3-6

Additional SRS characteristics

Antenna gain pattern (G_R)	RR AP8-Annex III		
Permissible interference level (P_{0r})	–221	dBW/Hz	SRS deep-space protection (Rec. ITU-R SA.1157)
Probability of exceedence (p) (due to weather statistics)	0.001	%	For trans-horizon interference sources (Rec. ITU-R SA.1157)

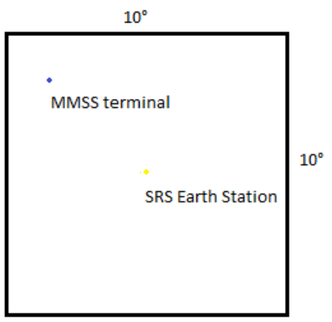
A3.2.4 Methodology

This section presents the methodology of statistical simulations to analyze potential interference to SRS stations from the operation of MMSS.

Parameters of SRS earth station were established in accordance with the main parameters set out in § 3 and the parameters of the MMSS in accordance to Table 2.1-1 in § 2.

This scenario describes the possibility that MMSS terminals are interfering into victim SRS receivers. The physical outline of this scenario was derived by randomly positioning 1 MMSS terminal within an area 9° x 9° from the SRS earth station. A snapshot taken from the status window of a statistical simulation is shown below in Fig. A3-17. The blue dot indicates the location of the MMSS Terminal, while the yellow dot indicates the location of the SRS earth station.

FIGURE A3-17



At each Snapshot, the MMSS has a different localization and the SRS antenna has a different pointing (in this case 5 000 snapshots are done for each simulation). The permissible basic transmission losses are calculated at each snapshot and can be stated as:

$$P_t + G_t(\theta_t) - Pi - G_r(\theta_r) - L_b(p\%)$$

where:

- P_t : MMSS transmitter power (dBW)
- $G_t(\theta_t)$: MMSS antenna gain in the direction of the SRS earth station (dBi)
- G_r : gain of the SRS earth station antenna (dBi)
- Pi: maximum permissible interference at the SRS earth station receiver input (dBW)
- θ_t : angle between the MMSS antenna axis and the interference path (degrees)
- $L_b(p\%)$: the value of minimum acceptable basic transmission loss to be exceeded for all but p% of the time along the interference path between the terrestrial transmitter and the earth station receiver (dB).

Also at each snapshot, the following parameters are chosen randomly and uniformly:

– *p* the percentage of time is randomly chosen between 0.0001 and 50;

– A communication time is randomly chosen between 1 and 60 min;

– MMSS earth station can be moving or fixed. If moving, a random direction and speed is also allocated to the station.

The minimum angular separation between the antenna's axis and the interference path is given by:

$$\theta_t = \alpha - \varepsilon_t$$

where:

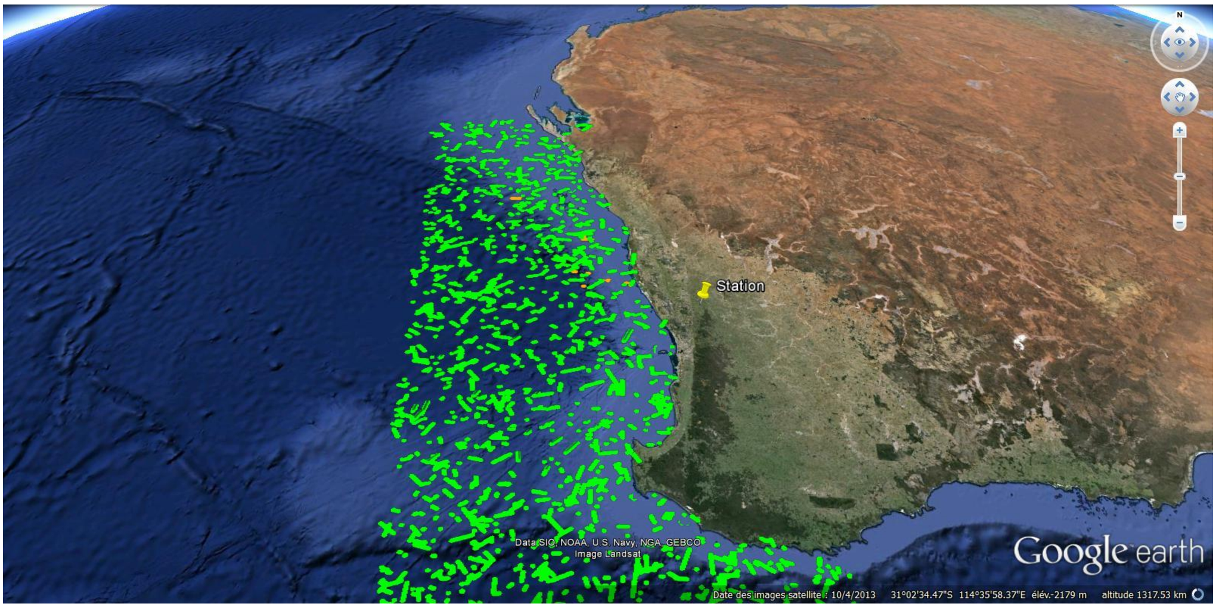
- α: elevation angle of the geostationary satellite relative to the MMSS earth station
- ε_t : the elevation of the MMSS earth station.

The separation distances are then derived from the propagation loss required using the Recommendation ITU-R P.452 taking into account the proportion of path over land or water.

This was calculated assuming terrain elevation.

Figure A3-18 provides an example of the simulation:

FIGURE A3-18



A3.2.5 Interference analysis SRS earth station victim

The results of simulation are provided in the following table:

Station name	Location	Percentage of time of interference	Percentage of time of interference with 250 km exclusion area
Goldstone	USA	< 0.001	< 0.001
Robledo	Spain	< 0.001	< 0.001
Canberra	Australia	< 0.001	< 0.001
Cebreros	Spain	< 0.001	< 0.001
Malargüe Sur	Argentina	< 0.001	< 0.001
New Norcia	Australia	0.0064	< 0.001
Uchinoura	Japan	0.0409	< 0.001
Usuda	Japan	0.0062	< 0.001

The simulation results show that the MMSS terminal can create interference into the SRS receivers. Nevertheless a 250 km exclusion area around the SRS station will be enough to ensure the protection of the SRS station.

A3.2.6 Conclusion

This study shows that an allocation to the maritime mobile-satellite service in the band 8 025-8 400 MHz will create a potential for interference to the receiving SRS earth stations in adjacent band 8 400-8 500 MHz located close to the coast worldwide.

Nevertheless the different simulations show that a 250 km exclusion area around the SRS earth station will be enough to ensure the protection of the SRS earth station.

It is to be noted that this analysis is based on the presence in the area of a single MMSS terminal operating on a single channel.

____