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Compatibility between the space research service (Earth-to-space) and the systems in the fixed, mobile and inter-satellite service in the band 22.55-23.15 GHz

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REPORT ITU-R SA.2193

Compatibility between the space research service (Earth-to-space) and the systems in the fixed, mobile and inter-satellite service[1] in the band 22.55-23.15 GHz

(2010)

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[1] Compatibility between the SRS and the inter-satellite service links of HIBLEO-2 type satellite systems is analyzed in Report ITU-R SA.2192.

1 Introduction

It is envisioned that three types of space mission would be supported by SRS earth station transmissions in the 22.55-23.15 GHz band:

1. low-Earth orbiting scientific satellites;
2. manned and unmanned lunar exploration missions; and
3. scientific missions using satellites located in the vicinity of the Sun-Earth L1 and L2 Lagrangian points.

Data transmissions in the space-to-Earth direction for these types of missions are either currently operational or are planned to be operational in the 25.25-27.5 GHz band – a band allocated for both space-to-Earth and space-to-space transmissions to data relay satellites. Data relay satellites, which are operated by several administrations (Recommendations ITU-R SA.1018 and ITU-R SA.1414), use the 22.55-23.55 GHz band for forward inter-orbit links and the 25.25-27.5 GHz band for return inter-orbit links to near-Earth orbiting user satellites.

WRC-12 Agenda item 1.11 is "to consider a primary allocation to the space research service (Earth-to-space) within the band 22.55-23.15 GHz, taking into account the results of ITU-R studies, in accordance with Resolution 753 (WRC-07)". The Earth-to-space allocation will complement the existing space-to-space (25.25-27.5 GHz) and space-to-Earth (25.5-27.0 GHz) allocations and add the capability to support near-Earth missions using similar, if not identical technology, on board the user satellite. The 22.55-23.15 GHz band will be used for both command and control of the user satellite, and to support different applications within an exploration venture such as low-Earth orbit check-out, manned or un-manned spacecraft support during transfer phase, crew lander, surface operations, mission adjustment plans based on science and telemetry data with precise and high resolution instructions and graphics, habitat, data and software uploading, re-programming, payload check-out and ranging signals. Manned missions will additionally require voice and video links for communication with the Earth.

The number of SRS earth stations transmitting in the 22.55-23.15 GHz band will be small. Rather than building new SRS earth stations, upgrading selected existing SRS earth stations will predominate. Selecting which SRS earth stations to upgrade will be based on a number of factors, including the type of mission to be supported. The maximum number of SRS earth stations capable of supporting lunar and/or L2 missions is not expected to exceed ten to fifteen on a global basis over the next few decades. A similar number of SRS earth stations may support LEO missions, also on a global basis. These earth stations are typically located in rural, isolated areas at mid-latitudes.

Analyses have been performed to determine the criteria for transmitting earth stations in the space research service (SRS) to share with stations in the inter-satellite, fixed and mobile services in the 22.55-23.15 GHz band. Analysed is the compatibility of SRS earth stations supporting three typical types of space research missions in the Earth-to-space direction in the 23 GHz band. These uplinks are to an SRS satellite in low-Earth orbit; in an orbit around the Moon or on the surface of the Moon; and, in a halo orbit around the L2 Lagrange point. These analyses are presented in the following sections:

Section 2 describes the approach used to assess the compatibility between SRS earth stations and stations in the inter-satellite service (ISS). Section 2 presents the technical and operating characteristics of the SRS earth station.

Section 3 presents the characteristics of typical ISS space stations. The ISS systems are data relay satellite (DRS) users (this system is also representative of GSO-to-non-GSO inter-satellite links (ISLs)), GSO-to-GSO ISLs, GSO-to-non-GSO ISLs, non-GSO-to-GSO ISLs and non-GSO-to-non-GSO ISLs. Section 3 also contains subsections describing the orbital characteristics of the Moon and observations on the characteristics of interference events.

Sections 3 and 4 presents the results of the studies of sharing between transmitting SRS earth stations and space stations in the inter-satellite service. The conclusions of these studies are presented in § 4.4.

Section 5 addresses sharing between SRS earth stations and the fixed service. The subsections of § 5 describe the static and dynamic approaches used to assess sharing and summarizes the technical and operating characteristics of the fixed and mobile systems considered and the typical separation distances required to protect fixed wireless stations.

Section 5.4 presents the conclusions on the compatibility between a transmitting SRS earth station and P-P fixed wireless systems operating in the 22.55-23.15 GHz band.

Section 6 presents an analysis of the compatibility between transmitting fixed wireless systems and low-Earth orbiting SRS satellites.

Section 7 addresses the technical principles to protect mobile systems from interference due to the emissions of an SRS earth station operating in the 22.55-23.15 GHz band.

Section 8 provides a summary of the results of the analyses and the conclusions.

2 Characteristics of the SRS earth station emissions

The characteristics of the SRS earth station emissions in the 23 GHz band and the orbital and receiving characteristics of the mission satellites are summarized in Report ITU-R SA.2192.

3 Sharing between a transmitting SRS earth station and receiving stations in the inter-satellite service

Simulations have been used to determine the characteristics of interference caused by the emissions of an SRS earth station to the receiving system of DRS user satellites (GSO-to-non-GSO ISLs), to GSO-to-GSO ISLs, GSO-to-non-GSO ISLs, non-GSO-to-GSO ISLs, and to non-GSO-to-non-GSO ISLs, except with regard to HIBLEO-2.

To simplify the analysis, the interfering SRS earth station is assumed to be located at either WSC (32.5° N by 106.6° W) transmitting to a receiving station located at a low-Earth orbit satellite, or at the three DSN stations (Goldstone/United States of America, Canberra/Australia and Madrid/Spain) transmitting to a receive station at the centre of the Moon's disk or Goldstone (35.4° N by 116.9° W) transmitting to a receiving station in L2 orbit. The technical and operating characteristics of the uplink SRS earth station are typical of the transmission characteristics being considered to support lunar missions.

3.1 DRS user satellite characteristics (GSO-to-non-GSO ISL)

The characteristics of the DRS user satellite are given in Table 1[(1)].

3.2 GSO-to-GSO ISL receiving satellite characteristics

The characteristics of the receiving satellite of a GSO-to-GSO ISL are given in Table 2 and, according to Recommendation ITU-R S.1591, are typical of ISLs in the 23 GHz band. The longitude of the receiving GSO satellite is determined from typical elevation angles of 10, 20, 40 and 50° as viewed from an earth station located at 32.5° N latitude and at 35.4° N latitude.

TABLE 1

DRS user satellite characteristics

Parameter	Values
Orbital altitude (km)	705
Orbit type	Circular
Orbital inclination (degrees)	98.2
Antenna gain[(1)] (dBi)	47.0
Reference radiation pattern	Rec. ITU-R S.672-4[(2)], $L_N = -20$ dB
Antenna pointing	Boresight on DRS

(1) Recommendation ITU-R SA.1414 (1999) – Characteristics of data relay satellite systems.

(2) Recommendation ITU-R S.672-4 (1997) – Satellite antenna radiation pattern for use as a design objective in the fixed-satellite service employing geostationary satellites.

TABLE 2

GSO-to-GSO ISL receiving satellite characteristics

Parameter	Values
Longitude of sub-satellite point(1) (degrees)	38.8 W, 50.6 W, 76.2 W, 94.6 W
Longitude of sub-satellite point(2) (degrees)	49.9 W, 52.3 W, 75.2 W, 90.0 W
Orbit type	GSO
Central angle of the ISL span (degrees)	160.0
ISL length(3) (km)	83, 128
Antenna gain (dBi)	45.4
Reference radiation pattern	Rec. ITU-R S.672-4, LN = −25 dB
Antenna pointing	Boresight on transmitting GSO satellite
Receiving system noise temperature (K)	700

(1) Longitude of the sub-satellite point for each of the four scenarios is determined from elevation angles of 10, 20, 40 and 50° for ES at WSC.

(2) Longitude of the sub-satellite point for each of the four scenarios is determined from elevation angles of 10, 20, 40 and 50° for ES at Goldstone.

(3) Table 1 of Recommendation ITU-R S.1591.

3.3 GSO-to-non-GSO ISL receiving satellite characteristics

The technical characteristics of non-GSO satellites receiving transmissions from a GSO satellite have been taken to be similar to those of DRS user satellite presented in § 3.1.

3.4 Non-GSO-to-GSO ISL receiving satellite characteristics

The technical characteristics shown in Table 3 of a GSO receiving satellite in a non-GSO-to-GSO ISL have been taken from Recommendation ITU-R S.1591.

TABLE 3

Non-GSO-to-GSO ISL receiving satellite characteristics

Parameter	Value
Tx: orbit type	Circular
Tx: orbital altitude (km)	1 400
Tx: orbital inclination (degrees)	48
Rx: orbit type	GSO
WSC Rx: longitude of sub-satellite point (degrees)	38.8 W, 50.6 W, 76.2 W, 94.6 W
Goldstone Rx: longitude of sub-satellite point (degrees)	49.9 W, 52.3 W, 75.2 W, 90.0 W
Rx: antenna gain (dBi)	45.4
Rx: reference radiation pattern	Rec. ITU-R S.672-4, LN = −25 dB
Rx: antenna pointing	Boresight on closest non-GSO

3.5 Non-GSO-to-non-GSO ISL characteristics

The technical characteristics of a receiving ISL satellite in a non-GSO orbit have been derived from Recommendation ITU-R S.1591 as given in Table 4. In the absence of actual information, this data has been used for non-GSO-to-non-GSO inter-satellite links.

TABLE 4

Assumed non-GSO-to-non-GSO ISL system characteristics

Parameter	Value
Tx: Number of satellite planes	7
Tx: Number of satellites per plane	9
Tx: Orbit type	Circular
Tx: Orbital altitude (km)	1 400
Tx: Orbital inclination (degrees)	48
Rx: Orbit type	Circular
Rx: Orbital altitude (km)	1 400
Rx: Orbital inclination (degrees)	48
Rx: Antenna gain (dBi)	37.4
Rx: Reference radiation pattern	Annex IV to RR. App. 7
Rx: Antenna pointing	Towards intra-planar satellites: N, S Towards inter-planar satellites: NE, SE, NW, SW

3.6 Orbital characteristics of the Moon

The principle orbital characteristics of the Moon used in the analyses were obtained. The mean value of the Moon's semi-major axis is 384 400 km and its average side-real period is about 27.316 days. However, solar perturbations may vary the sidereal period by as much as 7 h. The mean eccentricity is about 0.055.

The mean value of the inclination of the Moon to the ecliptic is about 5.133°. However, unlike the Earth's equatorial plane whose orientation in inertial space is relatively fixed, the Moon's orbital plane rotates westward, making one revolution in 18.6 years. Since the Earth's equator is inclined to the ecliptic by 23.450°, the inclination of the Moon's orbital plane relative to the equator varies between 18.317° and 28.583° with a period of 18.6 years.

For the simulations, it was assumed that the Moon was in a circular orbit around the Earth at an altitude of 384 400 km and inclined by 22.5° with respect to the equatorial plane. The corresponding orbital period was 27.452 days.

3.7 Observations on the characteristics of an interference event

There are several factors that will tend to mitigate against interference from the emissions of an SRS earth station. One is the fact that SRS earth stations transmit only when the Moon is above the local horizon. The Moon will appear at least 5° above the local horizon for about 46% of the time at an earth station located at 32.5° N latitude.

Other factors involve the dynamics of the Earth, Moon and ISS satellite. The pointing of the SRS earth station antenna that is transmitting to the lunar station is determined by the dynamics of the Moon's orbit and the rotation of the Earth. The angular velocity of the Moon in its orbit is 0.549°/h, whereas, the angular velocity of the Earth about its axis of rotation is 15°/h – a rate that is some 27.32 times the rate of the Moon. Thus, the Earth's rotation rate will dominate the temporal characteristics of interference events affecting GSO satellites.

The temporal characteristics of the interference to a low-orbiting satellite will be similar, if not identical to the temporal characteristics of interference from the emissions of a stationary earth station antenna since the orbital angular velocity of the low-orbiting satellite will dominate. (The angular velocity of a satellite with an orbital period of 100 min is 216°/h.) The fact that the pointing angles of the SRS earth station transmitting antenna are determined by the Moon's orbit will tend to randomize the geographical locations of the sub-satellite point associated with each interference event.

4 Results for sharing with space stations in the inter-satellite service

A number of simulations have been run using the technical and operating characteristics listed in the previous sections. For each simulation, the interference power spectral density (I_0) over noise density (N_0) was computed for 30 000 random instances of time that spanned a period of 1 year. Each of the resulting sets of data was plotted as a cumulative probability distribution showing the probability that the interference I_0/N_0 exceeds a particular value.

4.1 Statistical interference to a DRS user satellite (GSO-to-non-GSO)

Figures 1a)-1c) show the results of a simulation of the interference to a low-orbiting DRS user satellite for differing elevation angles (E1) to the DRS as viewed from the SRS earth station. Figure 1a) shows the statistics of the interference to a DRS user satellite from the emissions of the SRS earth station supporting a low-Earth orbiting SRS satellite. I_0/N_0 results are presented for an elevation angle ranging from 10° up to 50°. At all elevation angles, the I_0/N_0 is less than –63 dB for more than 0.1% of the time. This level of interference is to be compared to the protection criteria given in Recommendation ITU-R SA.1155. The I_0/N_0 protection criterion is −10 dB for 0.1% of the time for the forward inter-orbit link operating in the 23 GHz band. From Fig. 1a), it is seen that the interference caused by the emissions of a single uplink to a low-Earth orbiting SRS satellite will be less than the ITU-R protection criterion by a margin of about 53 dB. Comparable levels of interference will be experienced by low-Earth orbiting satellites using GSO-to-non-GSO ISLs.

FIGURE 1a)

Statistical interference to a DRS user satellite from the emissions of an SRS (Earth-to-space) uplink to an SRS low-Earth orbiting satellite

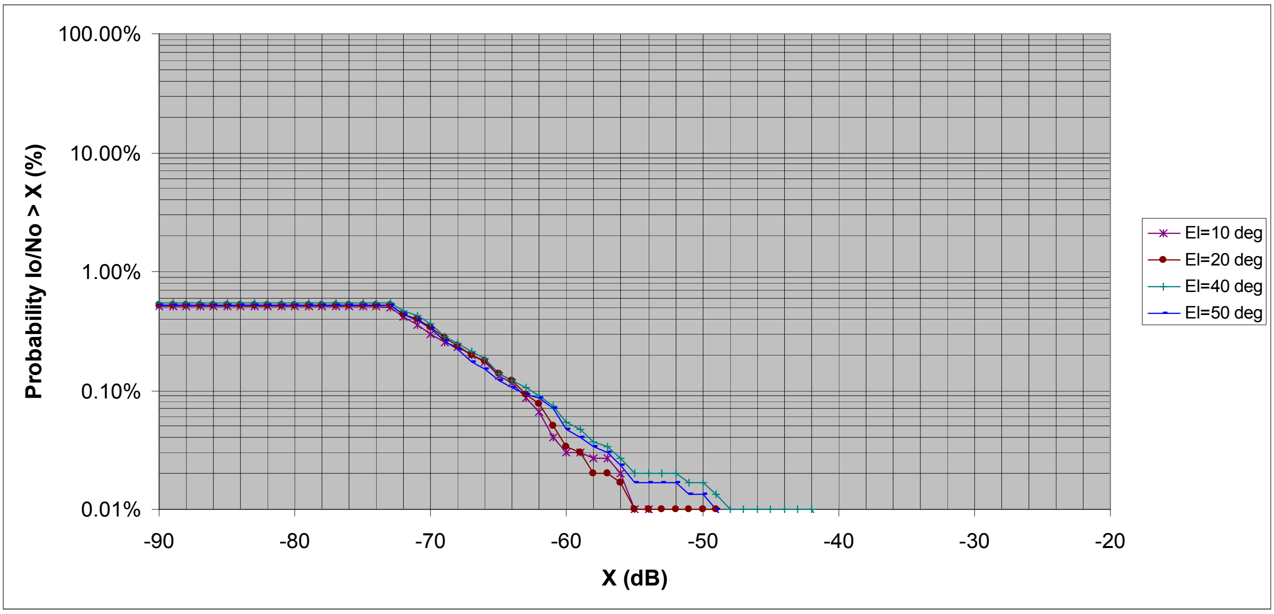


Figure 1b) shows the statistical interference to a DRS user satellite from the emissions of the SRS earth station supporting a lunar mission. For this scenario, the level of I_0/N_0 to DRS user satellite does not exceed –41.1 dB for more than 0.1% of the time. For this scenario, the margin above the agreed protection criterion is 31.1 dB.

FIGURE 1b)

Statistical interference to a DRS user satellite from the emissions of an SRS (Earth-to-space) uplink to the Moon

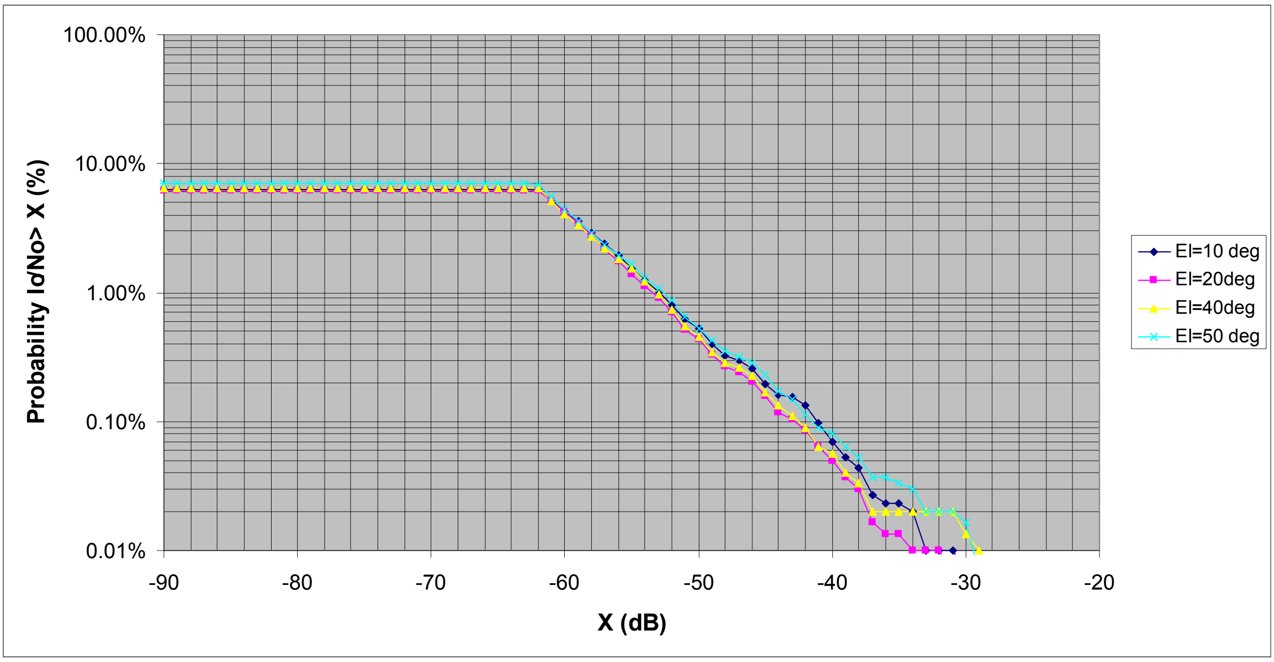
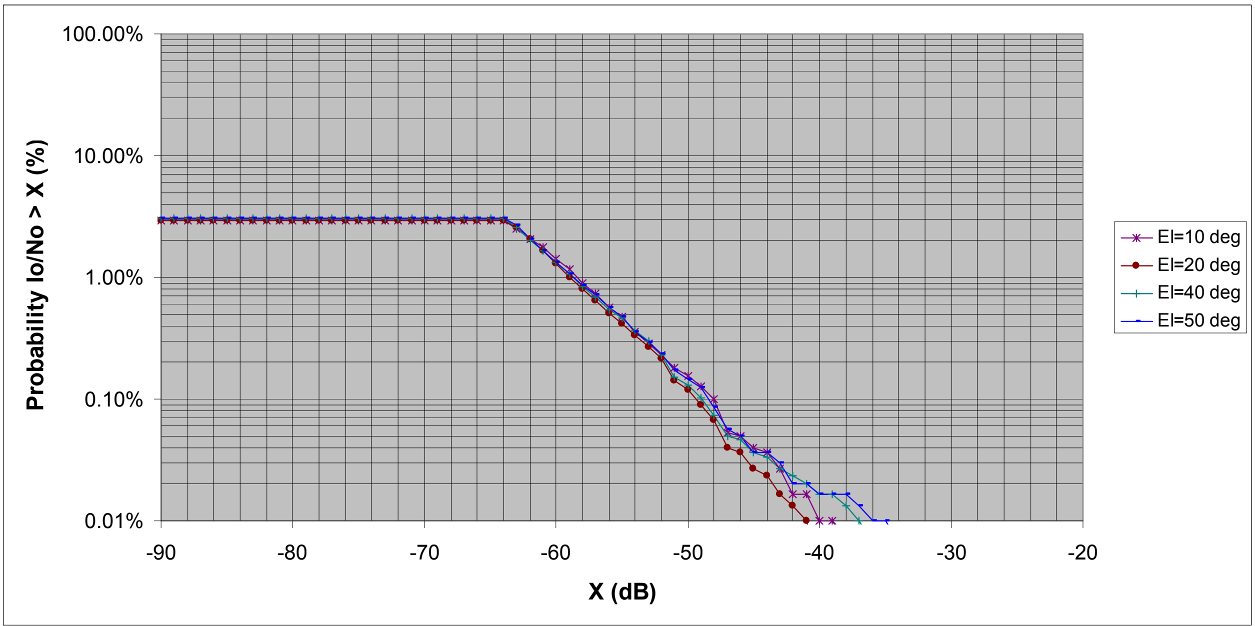


Figure 1c) shows the statistical interference to DRS user satellites from the emissions of an SRS earth station supporting an SRS satellite in a Halo orbit around L2. The level of I_0/N_0 is less than –48.0 dB for more than 0.1% of the time. For this scenario, there is a 38.0 dB margin above the Recommendation ITU-R SA.1155 protection criterion.

As mentioned previously, the statistics of interference to GSO-to-non-GSO ISLs may be expected to be comparable to the statistical interference to DRS user satellites.

FIGURE 1c)

Statistical interference to a DRS user satellite from the emissions of an SRS (Earth-to-space) uplink to a satellite in an L2 Halo orbit



4.2 Statistical interference to GSO-to-GSO inter-satellite link

Figures 2a)-2c) show the statistical interference to the receiving space station of a GSO-to-GSO inter-satellite link from the emissions of an SRS earth station supporting the three SRS missions in the 23 GHz band. The transmitting GSO satellite is located to the west of the receiving GSO satellite, which is located to the east of the SRS earth station. Results are presented for elevation angles ranging from 10° to 50°. As the figures show for the three SRS missions, for the worst case, which is the lunar scenario, the level of I_0/N_0 to the GSO satellite is less than 41.7 dB for more than 0.1% of the time for a 700 K noise temperature receiver. Thus, it may be concluded that the interference to GSO-to-GSO inter-satellite links will be negligible.

FIGURE 2a)

Statistical interference to a receiving space station in a GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to an SRS low-Earth orbiting satellite

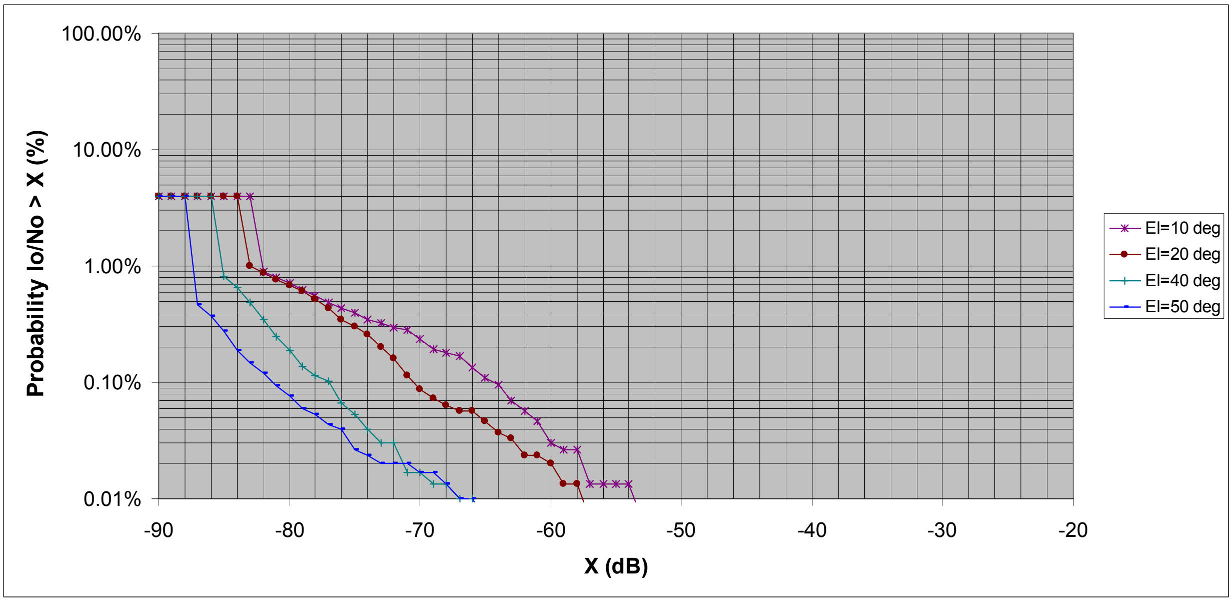


FIGURE 2b)

Statistical interference to a receiving space station in a GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to the Moon

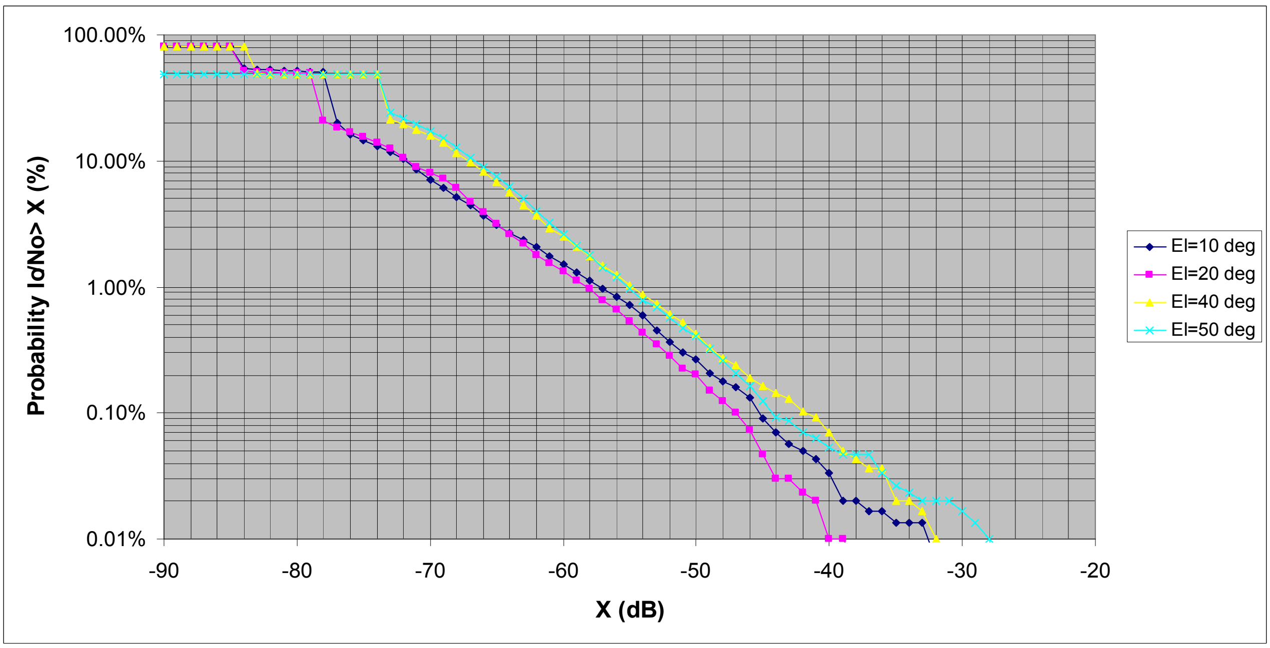
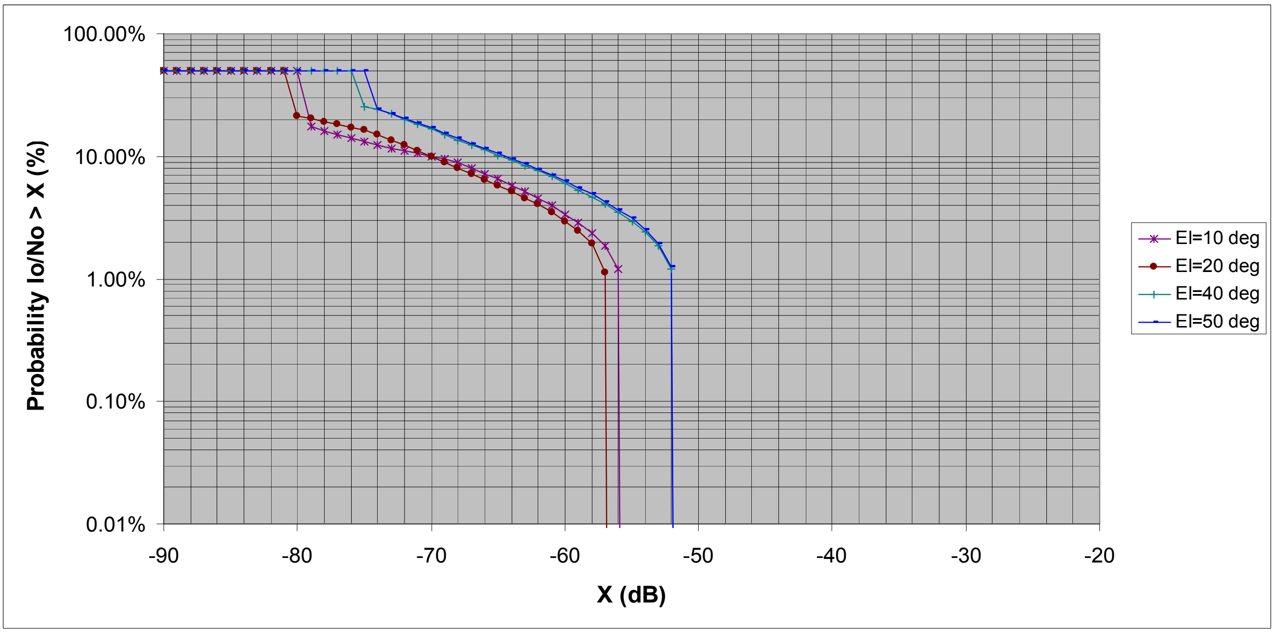


FIGURE 2c)

Statistical interference to a receiving space station in a GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to a satellite in an L2 Halo orbit



4.3 Statistical interference to non-GSO-to-GSO inter-satellite links

Figures 3a)-3c) show the statistical interference to the receiving space station of a non-GSO-to-GSO inter-satellite link from the emissions of an SRS earth station supporting the three SRS missions in the 23 GHz band. Again, results are presented for elevation angles ranging from 10° to 50°. As the figures show, there is a significant variation in the level of interference to the GSO satellite. In the worst-case, which is the SRS earth station transmitting to the SRS satellite in the lunar orbit, the level of I_0/N_0 is less than –39.3 dB for more than 0.1% of the time for a 700 K noise temperature receiver. Thus, it may be concluded that the interference to non-GSO-to-GSO inter-satellite links will be negligible.

FIGURE 3a)

Statistical interference to a receiving space station in a non-GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to an SRS low-Earth orbiting satellite

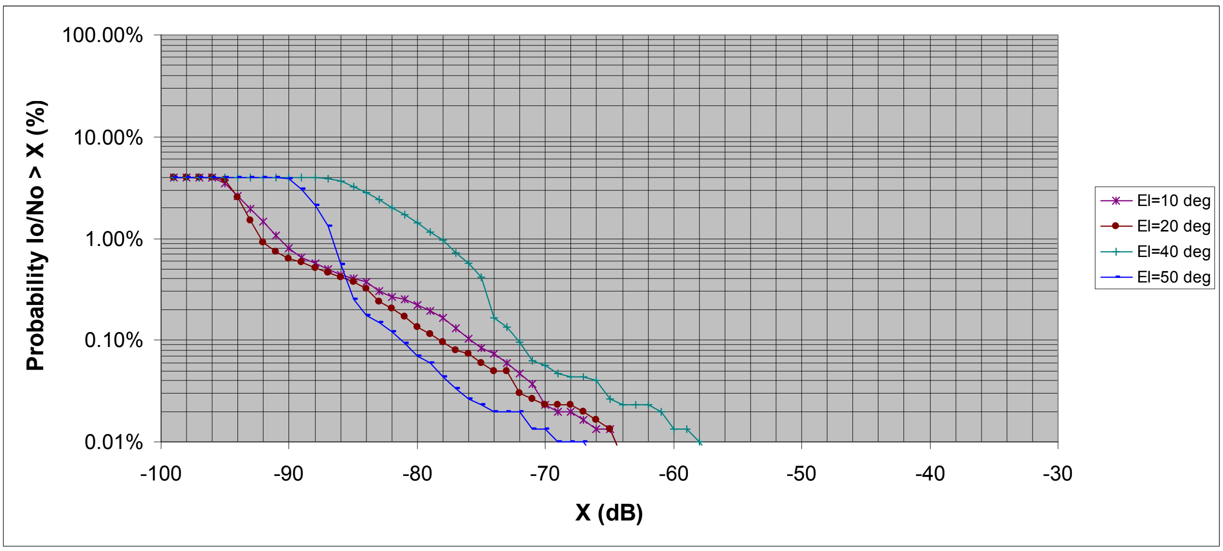


FIGURE 3b)

Statistical interference to a receiving space station in a non-GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to the Moon

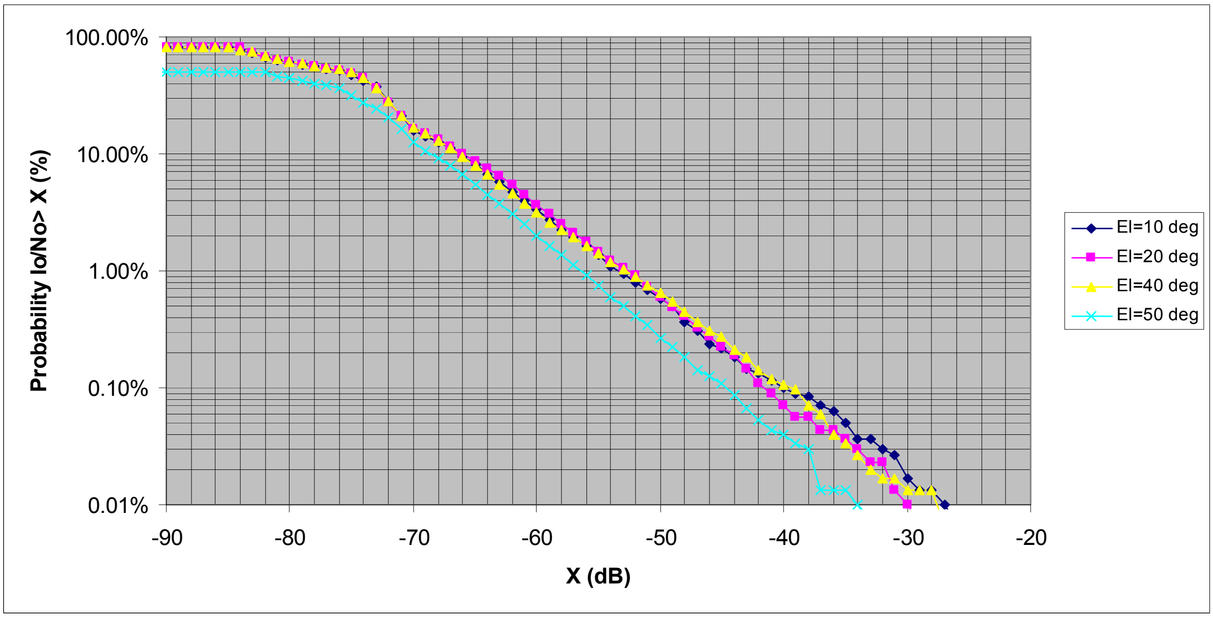
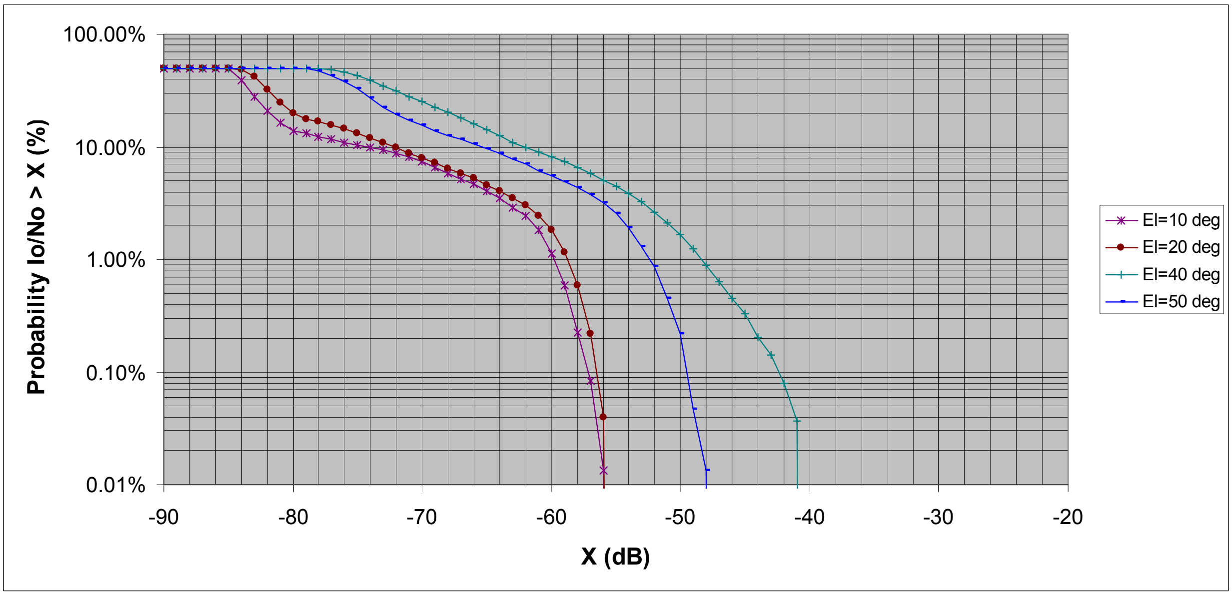


FIGURE 3c)

Statistical interference to a receiving space station in a non-GSO-to-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to a satellite in an L2 Halo orbit



4.4 Statistical interference to non-GSO-to-non-GSO inter-satellite links

Figures 4a)-4c) show the statistical interference to the receiving space station of a non-GSO-to-non-GSO inter-satellite link from the emissions of an SRS earth station supporting the three SRS missions in the 23 GHz band. Results are presented for the six potential pointing directions of the ISL links. As the figures show, in the worst-case which is the SRS earth station transmitting to the SRS satellite in the lunar orbit, the level of interference to the non-GSO satellite is less than –43.0 dB for more than 0.1% of the time. This level of interference is about 33 dB below the noise floor corresponding to a 700 K noise temperature receiver. Thus, it may be concluded that the interference to non-GSO-to-non-GSO inter-satellite links will be negligible.

FIGURE 4a)

Statistical interference to a receiving space station in a non-GSO-to-non-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to an SRS low-Earth orbiting satellite

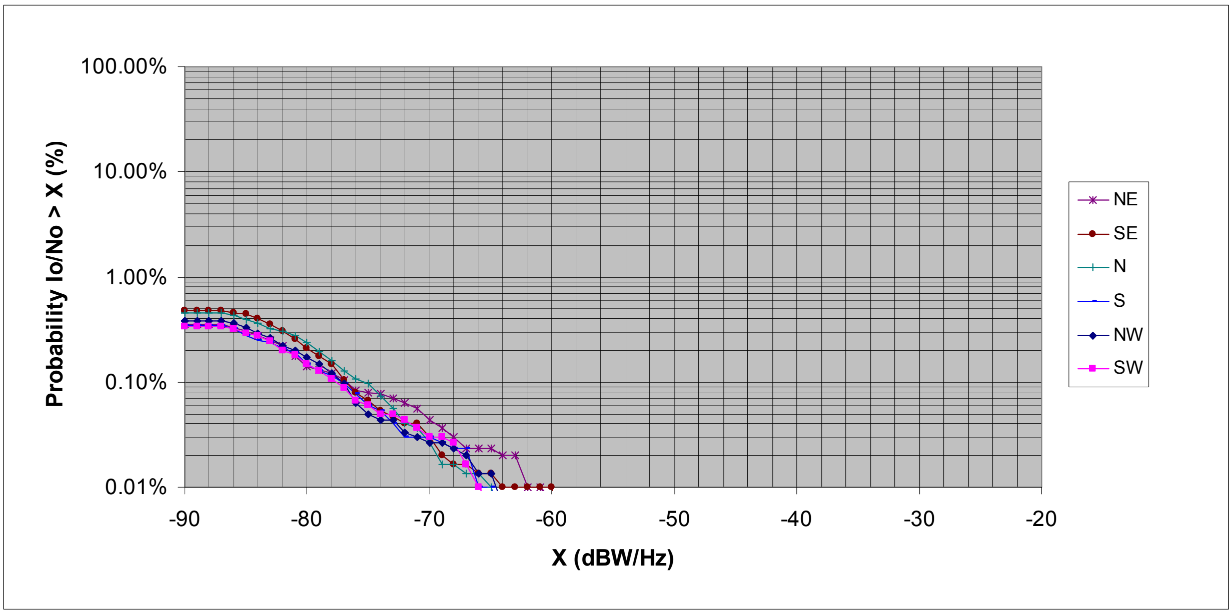


FIGURE 4b)

Statistical interference to a receiving space station in a non-GSO-to-non-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to the Moon

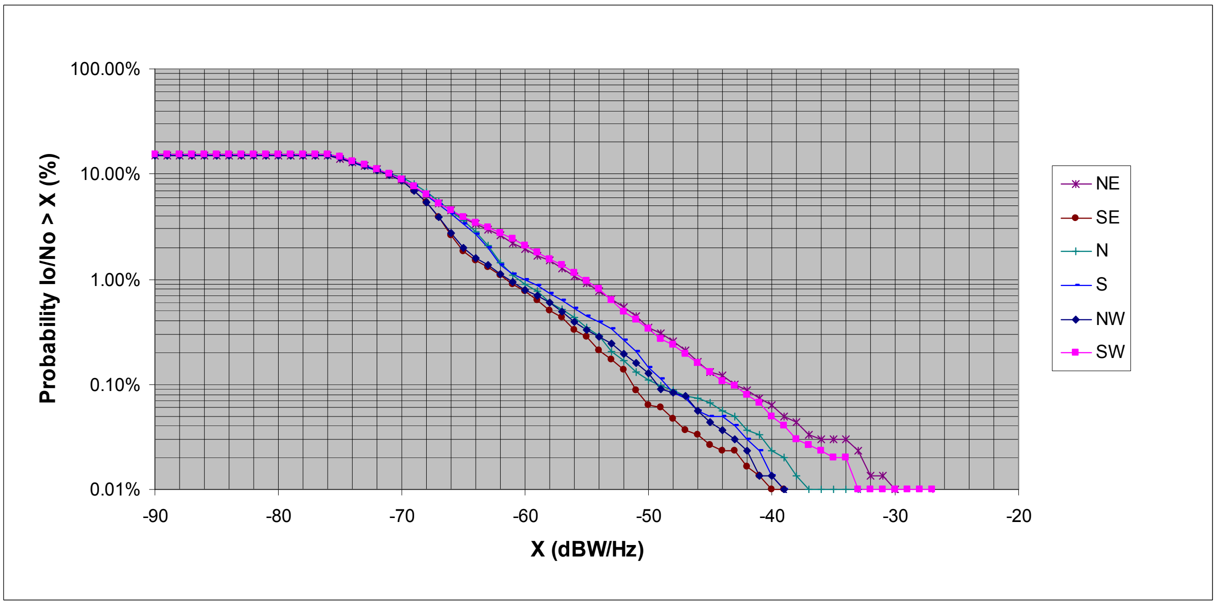
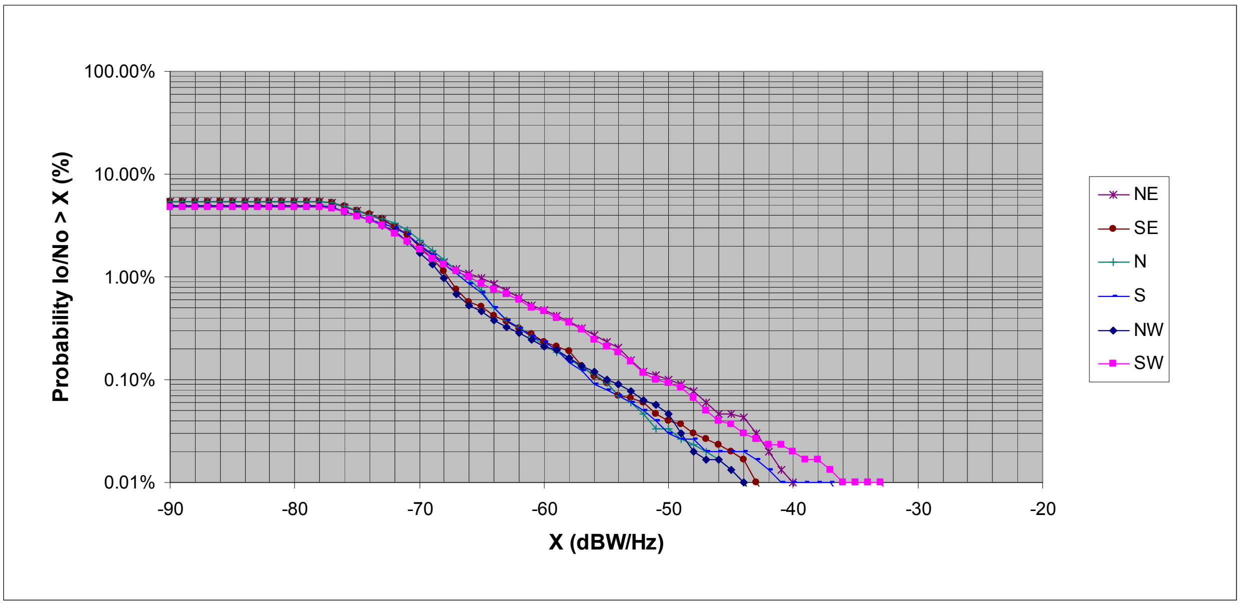


FIGURE 4c)

Statistical interference to a receiving space station in a non-GSO-to-non-GSO ISL from the emissions of an SRS (Earth-to-space) uplink to a satellite in an L2 Halo orbit



4.5 Conclusions

Based on these analyses, it is concluded that the introduction of transmitting SRS earth stations into the 22.55-23.15 GHz band is compatible with: GSO-to-non-GSO, GSO-to-GSO, non-GSO-to-GSO, and non-GSO-to-non-GSO, excluding HIBLEO-2 inter-satellite systems presented in Recommendation ITU-R S.1591.

5 Sharing between a transmitting SRS earth station and fixed wireless receiving stations in the fixed service

5.1 Approach for a static interference environment

The static analysis of compatibility of a transmitting SRS earth station with fixed wireless stations in proximity to the earth station has been evaluated using the procedures and algorithms of Recommendation ITU-R P.452-13. The analysis is limited to propagation mode (1) which accounts for anomalous clear air propagation phenomena such as tropospheric scatter, ducting, layer reflection/refraction, gaseous absorption and site shielding along a great-circle path. The radio-climatic zone was assumed to be A2, i.e. propagation was over land which was well away from coastal and shore areas, and, large bodies of water.

The following equation for the minimum basic transmission loss applies:

$$L_{btl}(p) = P_t + G_t + G_r - P_r(p) \qquad \text{dB} \qquad (1)$$

where:

- p: the maximum percentage of time for which the permissible interference power may be exceeded (%); L_{btl} is the minimum required basic transmission loss for p% of the time for propagation mode (1) (dB)
- P_t: the maximum available transmitting power density in the reference bandwidth (1 Hz) at the input to the transmitting antenna (dBW/Hz)

$P_r(p)$: the permissible interference power density in the reference bandwidth (1 Hz) to be exceeded for no more than p% of the time at the output of the receiving antenna (dBW/Hz)

G_t: the gain of the transmitting antenna towards the physical horizon in the direction of the receiving terrestrial station (dBi)

G_r: the gain of the receiving antenna of the terrestrial station in the direction of the transmitting earth station (dBi).

For this static analysis it has been assumed that the transmitting antenna of the SRS earth station is pointing toward the terrestrial station at an elevation angle of 5°. It has also been assumed that the receiving antenna of the terrestrial station points in any azimuthal direction with equal probability at an elevation angle of 0°. As a consequence, the variability of the receiving antenna gain in equation (1) may be characterized by its probability distribution. In turn, the separation distance required to satisfy equation (1) is also associated with a probability distribution.

The terrain along the great circle path between the SRS earth station and the fixed wireless station is assumed to be flat except for a single site shielding obstacle located 5 km from the SRS earth station. The basic transmission loss along the great circle path is evaluated for a site shielding obstacle height varying from 0 m to 50 m in steps of 10 m.

The required separation distances have been calculated for typical point-to-point (P-P) fixed wireless systems. The characteristics of these FS systems have been taken from what has been previously agreed upon.

It is noted that central stations and subscriber stations of point-to-multipoint (P-MP) fixed wireless stations will require smaller separation distances primarily because of smaller receiving antenna gain. Thus, the remainder of § 5 focuses on P-P fixed wireless systems.

5.1.1 Technical and operating characteristics of SRS earth station and P-P fixed wireless stations

The technical and operating characteristics of the SRS earth station used to evaluate the compatibility with fixed wireless stations are summarized in Table 5. Note that for an antenna with a gain greater than 47.4 dBi, the off-axis antenna gain is given by:

$$\begin{aligned} G(\varphi) &= 29 - 25\log(\varphi) \quad \text{dBi} \qquad 1° \le \varphi \le 48° \\ G(\varphi) &= -13 \quad \text{dBi} \qquad \varphi > 48° \end{aligned} \tag{2}$$

where φ is the off-axis angle (degrees).

TABLE 5

Technical and operating characteristics of the SRS earth station

Parameter	Value
SRS earth station latitude (degrees)	35.34 N
SRS earth station longitude (degrees)	116.87 W
Transmitting antenna diameter (m)	18
Operating frequency (GHz)	23.1
Antenna gain (dBi)	70.4
Power at the antenna input (dBW)	11.1

TABLE 5 (*end*)

Parameter	Value
Power spectral density at the antenna input (dBW/Hz)	−59.7
e.i.r.p. (dBW)	81.5
e.i.r.p. density (dBW/MHz)	70.7
e.i.r.p. density towards the horizon (dBW/MHz)	11.8
Antenna elevation angle (degrees)	5
Antenna height above local terrain (m)	11

Parameters for P-P fixed wireless stations operating in the 23 GHz band which are shown in Table 6 have been agreed upon. The short-term interference criterion is given in Table 6 as the ratio of the interference power density and receiver thermal noise power density (*I*/*N*) which may not exceed 25 dB (M_S = 25 dB) for more than 0.0025% of the time. The long-term interference criterion was obtained from Recommendation ITU-R F.758-4. The long-term criterion is that the *I*/*N* should not exceed −10 dB for more than 20% of the time. Note that the value of 25 dB for M_S is taken from Radio Regulations Appendix 7. However, it should be noted that modern fixed link planning tends to utilize the minimum necessary fade margins to maintain the minimum required performance and, therefore, fade margin figures between 10-15 dB are also commonplace for this band.

TABLE 6

Characteristics of Fixed Wireless Systems

Frequency bands (GHz)	22.55-23.15	
Receiving terrestrial service designations	Fixed, mobile	
Method to be used	§ 2.2	
Modulation at terrestrial station	Digital	
Terrestrial station interference parameters and criteria	p_0(%)	0.005
	n	2
	p(%)	0.0025
	N_L (dB)	0
	M_S (dB)	25
	W (dB)	0
Terrestrial station parameters	G_X (dBi)	48
	T_e (K)	1 100
Reference bandwidth	*B* (Hz)	10^6
Permissible interference power	$P_r(p)$ (dBW) in *B*	−113

5.1.2 Static analysis of separation distances to protect P-P fixed wireless systems

The receiving antenna gain in Table 6 is 48 dBi, and, for the purpose of a sharing analysis, the radiation pattern is assumed to conform to Recommendation ITU-R F.699. Assuming that the azimuth angle of the receiving antenna is uniformly distributed over 360°, the probability distribution of the receiving antenna gain in the direction of an SRS earth station may be calculated. The probability distribution is shown in Fig. 5 and is listed in Table 7 for selected values of probability and the associated basic transmission loss as determined from equation (1).

FIGURE 5

Probability distribution of the gain of an antenna conforming to the reference radiation pattern of: boresight gain = 48 dBi

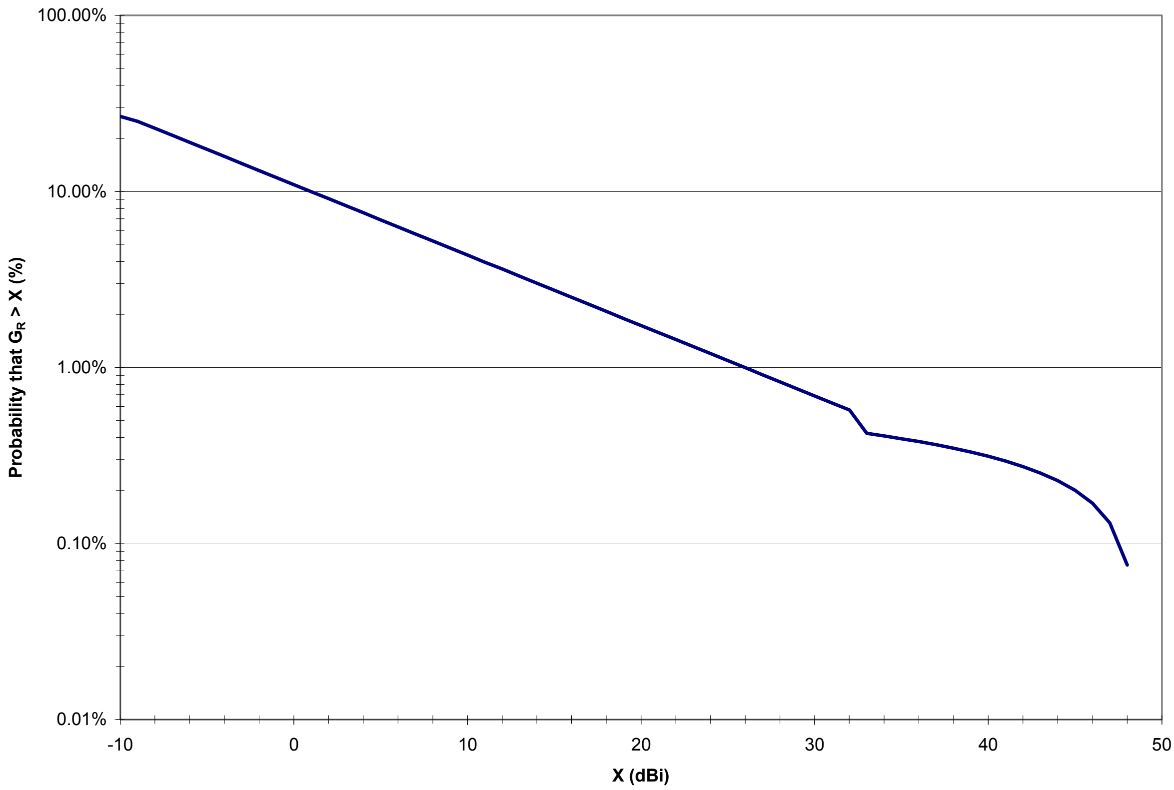


Table 7 shows that the required basic transmission loss for either percentage of time spans more than 47 dB. The basic transmission loss as a function of separation distance has been computed using the procedures and algorithms of Recommendation ITU-R P.452 and is shown graphically in Figs 6a) and 6b). Figure 6a) shows as a function of the separation distance, the value of the basic transmission loss that is exceeded for more than 0.0025% of the time for barrier heights ranging up to 50 m. Similar results are shown in Fig. 6b) for 20% of the time.

There are six curves in Figs 6a) and 6b) corresponding to the height of a site shielding barrier located 5 km from the transmitting antenna in the direction of the fixed wireless system. The height of the barrier ranges from 0 to 50 m in 10 m increments. The effectiveness of a barrier used to shield the transmitting site is demonstrated in the figures. For example, for both figures, there is about 35 dB difference in the basic transmission loss at a separation distance of 10 km with the introduction of a 40 m barrier located 5 km from the transmitting antenna.

FIGURE 6a)

Basic transmission loss exceeded for more than 0.0025% of the time as a function of separation distance: *f* = 23.0 GHz; h_t = 11 m; h_r = 30 m; and, a barrier located 5 km from the transmitting antenna with a height ranging from 0 to 50 m

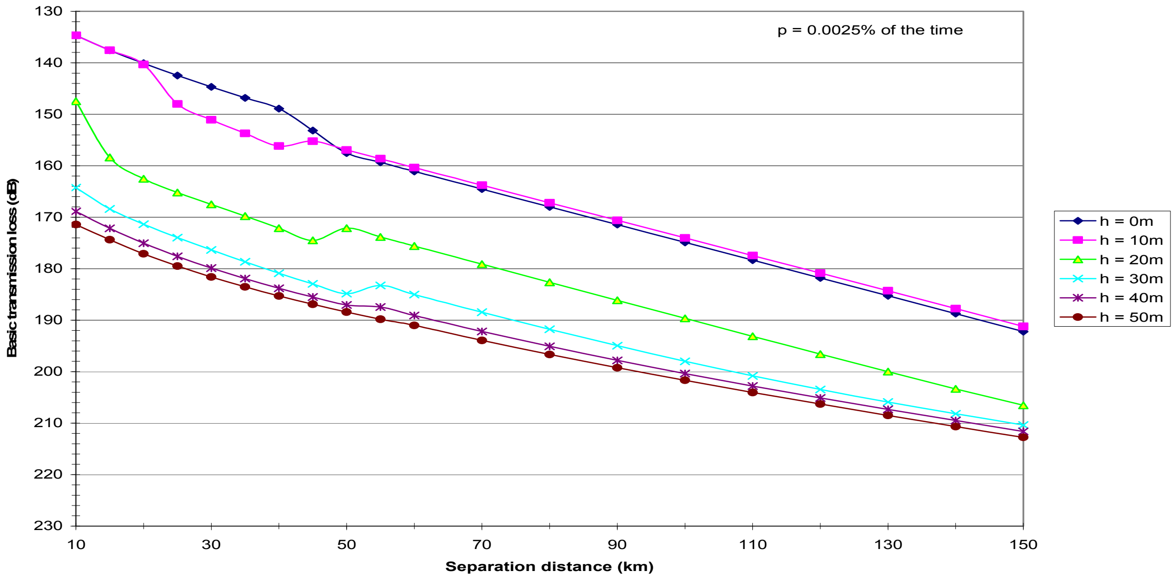


FIGURE 6b)

Basic transmission loss exceeded for more than 20% of the time as a function of separation distance: *f* = 23.0 GHz; h_t = 11 m; h_r = 30 m; and, a barrier located 5 km from the transmitting antenna with a height ranging from 0 to 50 m

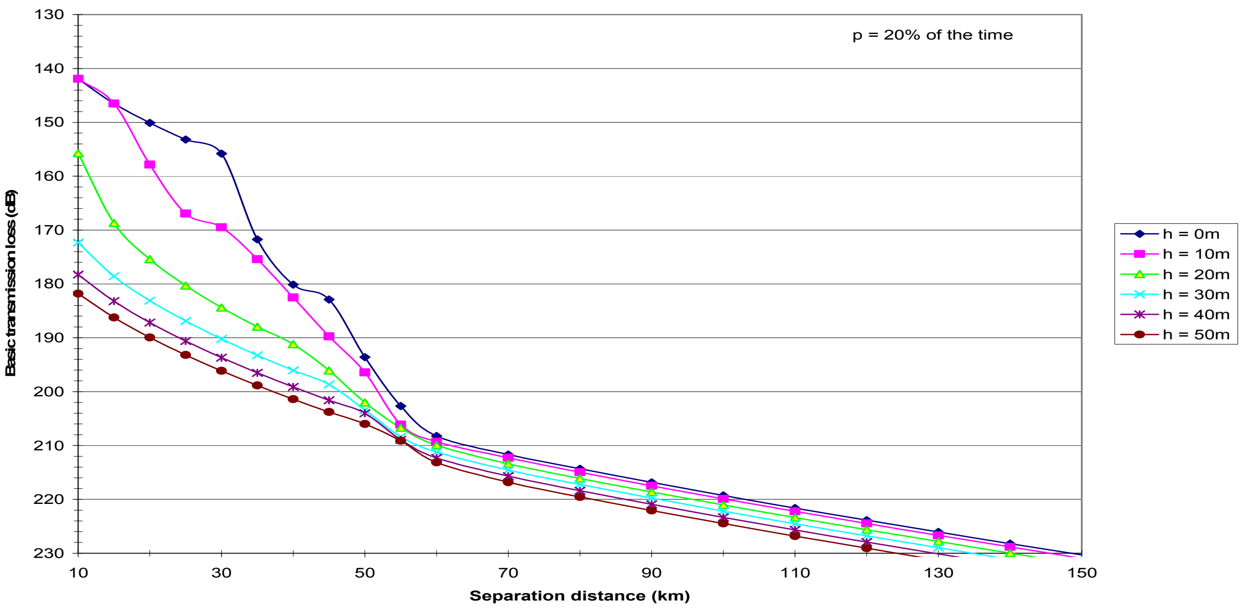


Table 7 lists the basic transmission loss required for 20% and 0.0025% of the time given the gain of the fixed wireless receiving antenna in the direction of the SRS earth station. The first column contains the percentage of fixed wireless stations with uniformly distributed azimuth angles whose gain will be less than the value shown in the second column. For example, for 99.5% of the cases, the gain of a fixed wireless receiving antenna in the direction of an SRS earth station will be less than 32.2 dBi. The separation distance corresponding to the required basic transmission loss has been calculated for both the long-term and short-term criteria, conditioned on the height of the site shielding barrier located 5 km from the SRS earth station. The results of the calculation are given in Table 8. The minimum separation distance is tabulated in columns 3-8. The colour of the cell indicates which criterion yields the minimum separation distance: the long-term criterion is indicated by light grey cells and the short-term criterion is indicated by dark grey cells.

TABLE 7

Probability antenna gain G is less than G_r and required basic transmission loss to protect fixed wireless system

$p_{Gr}(G < Gr)$ (%)	Gr (dBi)	L_{BTL} (dB)	
		p_{BTL} (20%)	p_{BTL} (0.0025%)
100.0	48.0	208.0	172/8
99.9	47.1	207.1	171.9
99.5	47.1	192.2	157.0
99.0	25.6	185.6	150.4
95.0	8.1	168.1	132.9
90.0	0.6	160.6	125.4

Table 8 shows that in situations where a high-gain fixed wireless receiving antenna is pointed towards the SRS earth station and there is either no barrier or a 10 m barrier, the minimum separation distance is determined by the short-term interference criterion. As the gain of the fixed wireless receiving antenna is reduced or the height of the barrier is increased, the minimum separation distance is determined by the long-term interference criterion.

Table 8 shows the minimum separation distance that may be achieved in coordination ranges from less than 10 km to 97 km, depending on the gain of the fixed wireless receiving antenna in the direction of the SRS earth station and the height of the site shielding barrier.

TABLE 8

Minimum separation distance to protect fixed wireless stations from the emissions of a transmitting SRS earth station. Permissible level of interference exceeded for less than 20% or 0.0025% of the time; f = 23.0 GHz; h_t = 11 m; h_r = 30 m; and, a barrier located 5 km from the transmitting antenna with a height ranging from 0 to 50 m

$p_{Gr}(G < G_r)$ (%)	G_r (dBi)	Separation distance (km)					
		h = 0 m	h = 10 m	h = 20 m	h = 30 m	h = 40 m	h = 50 m
100.00	48.0	94	97	57	54	54	53
99.9	47.1	92	94	56	53	53	52
99.5	32.2	49	50	41	33	< 10	< 10
99.0	25.6	46	42	31	< 10	< 10	< 10
95.0	8.1	< 32	28	< 10	< 10	< 10	< 10
90.0	0.6	< 32	< 17	< 10	< 10	< 10	< 10

NOTE 1 – Light grey cells indicate that the 0.0025% criterion controls separation distance and dark grey cells indicate that the 20% criterion controls separation distance.

The separation distances listed in Table 8 may be reduced further when account is taken of the actual terrain along the great-circle path and site shielding of the receiving fixed wireless station when located in urban, suburban and rural areas.

5.2 Time variant gain method to determine separation distances to protect point-to-point fixed wireless systems

Determination of interference in a dynamic environment is based on the "time-variant gain" (TVG) method described in Recommendation ITU-R SM.1448. The TVG method applies to the situation where there are receiving fixed and mobile service stations in the vicinity of an earth station transmitting to non-GSO satellites. For this scenario, the governing equation for propagation mode (1) is:

$$L_{btl}(p_v) - G_e(p_n) = P_t + G_x - P_r(p) \qquad \text{dB} \qquad (3a)$$

subject to:

$$p_v = \begin{cases} 100p/p_n & \text{for} \quad p_n \geq 2p \\ 50 & \text{for} \quad p_n < 2p \end{cases} \qquad (3b)$$

where:

- p%: the maximum percentage of time for which the level of interference may exceed the level of permissible interference
- p_n%: the percentage of time for which the horizon gain of the SRS earth station exceeds the value $G_e(p_n)$ at the specific azimuth angle
- $L_{btl}(p_v)$: the propagation mode (1) minimum required basic transmission loss (dB) for p_v% of the time
- $G_e(p_n)$: the horizon gain of the SRS earth station (dBi) that is exceeded for p_n% of the time on the azimuth angle under consideration

P_t: the maximum available transmitting power level in the reference bandwidth (1 MHz is used in this analysis) at the input to the SRS earth station transmitting antenna (dBW/Hz)

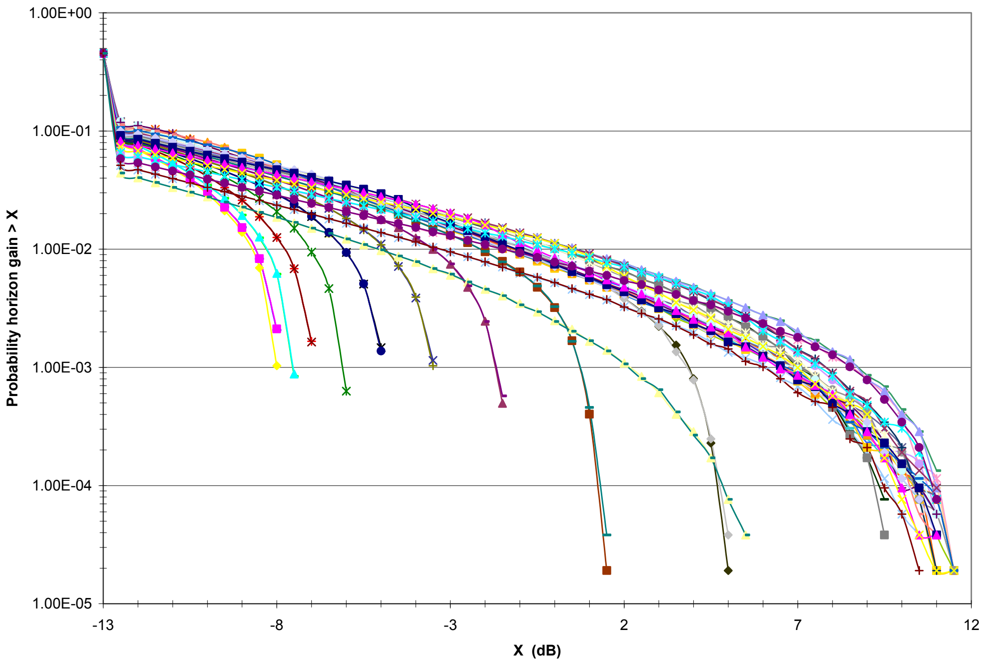
G_x: the maximum fixed wireless receiving antenna gain (dBi) in the direction of the SRS earth station;

$P_r(p)$: the permissible interference power density in the reference bandwidth (1 MHz for this analysis) to be exceeded for no more than p% of the time at the output of the fixed wireless receiving antenna (dBW/MHz).

The horizon gain for a range of azimuth angles has been obtained by simulation for an SRS earth station tracking the Moon for a period of one year. The earth station is assumed to be located at 35.34° N by 116.87° W (see Table 5). Tracking of the Moon spanned the year 2009 in increments of 10 min yielding more than 52,000 sets of azimuth and elevation angles for the time the Moon was above the horizon. For elevation angles greater than or equal to 5°, the off-axis angle to the great circle paths at azimuth angles from 0° to 355° in increments of 5° is calculated. The gain of the SRS transmitting antenna at the off-axis angle is calculated using equation (2). The results are shown in Fig. 7.

FIGURE 7

Probability distribution of the horizon gain for selected azimuth angles of an SRS earth station tracking the Moon for the year 2009: SRS earth station located at 35.34° N by 116.87° W



The worst-case horizon gain exceeded for less than 0.0134% of the time is 11 dBi at an azimuth angle around 125°. The separation distances have been calculated for these worst-case azimuth angles for various values of fixed wireless receiving antenna gain (see § 5.1.2) and for different height barriers located 5 km from the SRS earth station. Separation distances to satisfy both the long-term and short-term interference criteria have been calculated. The results are given in Table 9. The Light grey cells indicate that the separation distance required to satisfy the long-term criterion is greater than the separation distance required to satisfy the short-term criterion, whereas, the dark grey cells indicate that the long-term criterion controls.

Table 9 shows that the separation distances range from less than 10 km to 54 km with the greatest distances associated with the fixed wireless receiving antenna pointed directly towards the SRS earth station. The separation distances listed in Table 9 may be reduced further when account is taken of the horizon gain for the particular azimuth angle, the actual terrain along the great-circle path and site shielding of the receiving fixed wireless station when it is located in urban or suburban areas.

TABLE 9

Separation distance to protect fixed wireless stations from the emissions of a transmitting SRS earth station using the TVG method. Separation distances apply to fixed wireless stations located along the worst-case azimuth angle around 125°; f = 23.0 GHz; h_t = 11 m; h_r = 30 m; and, a barrier located 5 km from the transmitting antenna with a height ranging from 0 to 50 m

$p_{Gr}(G < G_r)$ (%)	G_r (dBi)	Separation distance (km)					
		h = 0 m	h = 10 m	h = 20 m	h = 30 m	h = 40 m	h = 50 m
100.00	48.0	52	54	49	50	51	49
99.9	47.1	50	52	48	49	50	47
99.5	32.2	41	41	36	29	24	20
99.0	25.6	38	37	27	20	15	12
95.0	8.1	33	24	13	< 10	< 10	< 10
90.0	0.6	32	20	10	< 10	< 10	< 10

NOTE 1 − Light grey cells indicate that the 0.0025% criterion controls separation distance and dark grey cells indicate that the 20% criterion controls separation distance.

5.3 Time-invariant gain method to determine separation distances to protect point-to-point fixed service systems

The time-invariant gain (TIG) method is similar to the TVG method in that it is based on equation (4a). It differs from equation (1) only in the value assigned to G_e, the gain of the coordinating earth station antenna towards the horizon at the azimuth and elevation angles under consideration.

$$L_{btl}(p) = P_t + G_e + G_r - P_r(p) \qquad \text{dB} \qquad (4a)$$

The value for G_e is determined by the difference in the maximum and minimum gain of the antenna along the azimuth angle under consideration in accordance with equation (4b).

$$\begin{aligned} G_e &= G_{max} && \text{for} && (G_{max} - G_{min}) \le 20\,\text{dB} \\ G_e &= G_{min} + 20 && \text{for} && 20\,\text{dB} < (G_{max} - G_{min}) < 30\,\text{dB} \\ G_e &= G_{max} - 10 && \text{for} && (G_{max} - G_{min}) \ge 30\,\text{dB} \end{aligned} \qquad (4b)$$

The maximum and minimum antenna gain at any particular azimuth angle in support of a lunar mission has been obtained as described in § 5.2 and shown in Fig. 7. The worst-case azimuth angle is around 125°. From Fig. 7, the difference between the maximum and minimum antenna gain is 24.5 dB, which from equation (4b) results in G_e = +7 dBi. Separation distances required to satisfy the long-term (20%) and short-term (0.0025%) criteria have been calculated and listed in Table 10.

For a particular set of fixed wireless receiving antenna gain and site shielding barrier height, the separation distance is calculated for both the short-term and long-term interference criteria and the larger value is listed in the Table. The colour of the particular cell shows which interference criterion determines the separation distance.

Separation distances shown in Table 10 range from less than 10 km up to 83 km. Worst-case distances are associated with boresight or near boresight gain of the fixed wireless receiving antenna in the direction of the SRS earth station. However, the Table also shows that, assuming that the pointing of any fixed wireless receiving antenna is uniformly distributed in azimuth, on average, 95% of fixed wireless stations will not experience interference when the separation distance is in the range of less than 10 km to less than 32 km. These distances will be smaller when taking into account actual terrain and other site shielding features.

TABLE 10

Separation distance to protect fixed wireless stations from the emissions of a transmitting SRS earth station using the TIG method. Separation distances apply to fixed wireless stations located along worst-case azimuth angles around 90° and 270°; f = 23.0 GHz; h_t = 11 m; h_r = 30 m; and, a barrier located 5 km from the transmitting antenna with a height ranging from 0 to 50 m

$p_{Gr}(G < G_r)$ (%)	G_r (dBi)	Separation distance (km)					
		h = 0 m	h = 10 m	h = 20 m	h = 30 m	h = 40 m	h = 50 m
100.00	48.0	81	83	51	50	49	44
99.9	47.1	79	81	50	49	47	42
99.5	32.2	47	43	34	26	< 10	< 10
99.0	25.6	44	39	25	< 10	< 10	< 10
95.0	8.1	< 32	22	< 10	< 10	< 10	< 10
90.0	0.6	< 32	< 17	< 10	< 10	< 10	< 10

NOTE 1 – Light grey cells indicate that the 0.0025% criterion controls separation distance and dark grey cells indicate that the 20% criterion controls separation distance.

5.4 Conclusions on the compatibility between P-P fixed service systems and SRS earth stations transmitting in the 22.55-23.15 GHz band

Tables 11 (a) and 11 (b) compare the separation distances obtained from using the three different methods: static, TVG and TIG. The static method yields the most conservative results for situations where the fixed wireless receiving antenna is pointed towards the SRS earth station and the site shielding barrier is 20 m or less. It assumes that the transmitting antenna of the SRS earth station is fixed and pointing towards the terrestrial station at a constant elevation angle of 5°, which results in conservative results as it cannot occur in actual operations. The TIG method yields the more conservative separation distances with decreasing gain of the fixed wireless receiving antenna in the direction of the SRS earth station and increasing height of the site shielding barrier above 20 m. It differs from the TVG method in that it uses a single value approximation for the value assigned to the gain of the coordinating earth station antenna towards the horizon at the azimuth and elevation angles under consideration. The TVG method is the most accurate method for this lunar satellite tracking scenario, irrespective of the shielding barrier height since it takes into account the different values for the off-axis angle of the SRS earth station transmitting antenna towards the fixed wireless receiving antenna as the former is moving to track the Moon.

Considering the various scenarios, it has been conservatively demonstrated that in 99% of the cases, separation distances less than 50 km are feasible with little or no site shielding. With increased site shielding, separation distances as small as 10 km or less are feasible. For 90% of the cases, separation distances of 32 km to less than 10 km are feasible.

Furthermore, in all these various scenarios, the separation distances apply to the deployment of SRS and FS stations within the territory of one particular country. The situation is further improved for an SRS earth station deployed in one country and the FS station being operated in another country as an FS station is deployed close to the border between two neighbouring countries. The latter will naturally always point away from the neighbouring country. Only an FS station at some distance from the border may point towards an FS station in the same direction as the SRS earth station, unless it is already a coordinated link across the border.

Additionally, high gain antennas with 48 dBi have been assumed for the worst case results. Such large antennas, although generally not used around 23 GHz, would allow for FS links far in excess of 10 km. This would further reduce the required separation from the neighbouring country by at least another 10 km. Smaller FS antennas have lower gains and therefore lower interference density levels, requiring consequently lower distances. Based on this aspect and realistic terrain around SRS earth stations, a worst case separation distance of 20 km would be sufficient for practically 100% of all cases.

TABLES 11 (a) and (b)

Comparison of the separation distances obtained using the static, TVG and TIG methods

$p_{Gr}(G < Gr)$ (%)	*Gr* (dBi)	Separation distance (km)								
		h = 0 m			h = 10 m			h = 20 m		
		Static	TVG	TIG	Static	TVG	TIG	Statoc	TVG	TIG
100.0	48.0	94	52	81	97	54	83	57	49	51
99.9	47.1	92	50	79	94	52	81	56	48	50
99.5	32.2	49	41	47	50	41	43	41	36	34
99.0	25.6	46	38	44	42	37	39	31	27	25
95.0	8.1	< 32	33	< 32	28	24	22	< 10	13	< 10
90.0	0.6	< 32	32	< 32	< 17	20	< 17	< 10	10	< 10

(a)

$p_{Gr}(G < Gr)$ (%)	*Gr* (dBi)	Separation distance (km)								
		h = 30 m			h = 40 m			h = 50 m		
		Static	TVG	TIG	Static	TVG	TIG	Statoc	TVG	TIG
100.0	48.0	54	50	50	54	51	49	53	49	44
99.9	47.1	53	49	49	53	50	47	52	47	42
99.5	32.2	33	29	26	< 10	24	< 10	< 10	20	< 10
99.0	25.6	< 10	20	< 10	< 10	15	< 10	< 10	12	< 10
95.0	8.1	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
90.0	0.6	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10

(b)

6 Compatibility of receiving SRS satellites with transmitting fixed wireless systems in the 22.55-23.15 GHz band

An analysis of the statistical interference to an SRS LEO satellite from the emissions of a deployment of fixed wireless stations has been completed. The deployment of the fixed wireless stations is based on the methodology described in § 2.1 of Annex 1 to Recommendation ITU-R F.1509. The technical and operating characteristics of the SRS LEO satellite are given in Recommendation ITU-R SA.1882. The technical and operating characteristics of the fixed wireless stations are summarized in Table 12.

Two scenarios were evaluated. The first was a deployment of fixed wireless stations within the field of view of an SRS LEO satellite at an altitude of 700 km near an SRS earth station at White Sands. Applying the Recommendation ITU-R F.1509 methodology resulted in 318 co-channel fixed wireless stations.

The second scenario was a similar deployment in Europe near an SRS earth station located near Madrid. This resulted in the deployment of 82 co-channel fixed wireless stations.

TABLE 12

Characteristics of fixed wireless stations

Parameter	Values
Operating frequency (GHz)	23.0
Transmitter power (dBW)	–10.0
Transmitter power density (dBW/MHz)	–24.0
Antenna gain (dBi)	34.8
Necessary bandwidth (MHz)	25.0
Power spectral density at antenna input (dBW/MHz)	–24.0
e.i.r.p. (dBW)	24.8
e.i.r.p. spectral density (dBW/MHz)	10.8
Antenna elevation angle (degrees)	–5 to +5

The results of the simulations are shown in Figs 8a) and 8b). The probabilities are the probability of an interference event conditioned on the probability that the SRS LEO satellite is in view of the particular earth station. The protection criterion from Recommendation ITU-R SA.1155 is used.

For the European scenario shown in Fig. 12a), there is an 11 dB margin and for the North American scenario shown in Fig. 12b), the margin is somewhat greater than 5 dB.

FIGURE 8a)

Statistical interference to an SRS LEO satellite when receiving from an SRS earth station located near Madrid, Spain

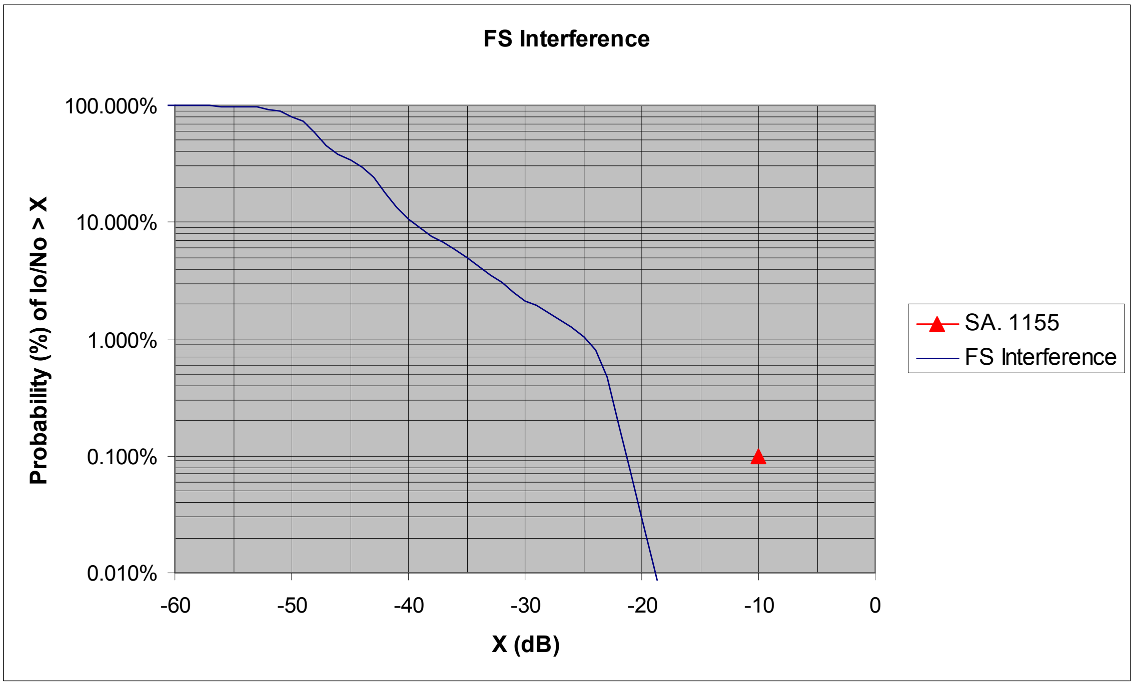
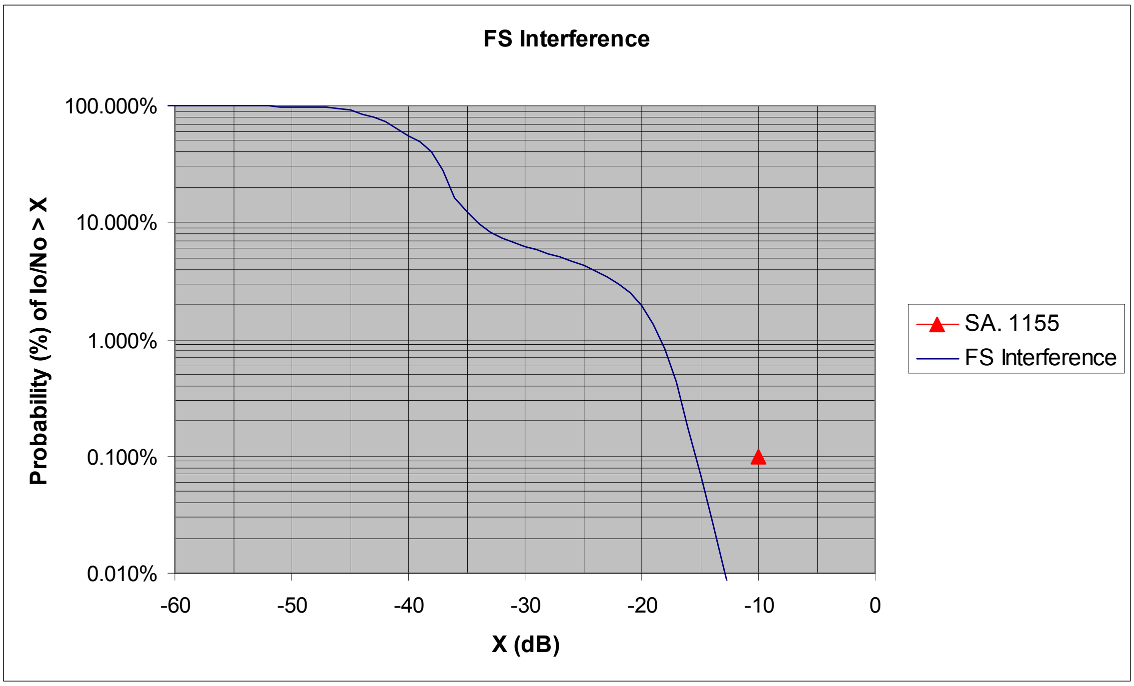


FIGURE 8b)

Statistical interference to an SRS LEO satellite when receiving from an SRS earth station located near WSC



7 Sharing between a transmitting SRS earth station and receiving stations in the mobile service

Technical and operating characteristics of mobile systems operating in the 22.55-23.15 GHz band are not available. Pending the availability of such characteristics, the worst-case distances developed for fixed service systems are expected to be adequate to protect mobile systems.

Concerning the use of the 22.55-23.15 GHz band by aeronautical mobile stations, it is not anticipated that any aeronautical mobile service applications will utilize the 22.55-23.15 GHz band, including Wireless Avionics Intra-Communications (WAIC) systems.

Based on these analyses, it is concluded that the introduction of transmitting SRS earth stations into the 22.55-23.15 GHz band is compatible with GSO-to-non-GSO, GSO-to-GSO, non-GSO-to-GSO and non-GSO-to-non-GSO inter-satellite systems presented in Recommendation ITU-R S.1591.

8 Summary and conclusions

This study has considered four issues associated with WRC-12 Agenda item 1.11:

1. determination of the compatibility between transmitting SRS earth stations and GSO-to-non-GSO, GSO-to-GSO, non-GSO-to-GSO and non-GSO-to-non-GSO space stations in the inter-satellite services in the 22.55-23.15 GHz band;
2. separation distances required to protect point-to-point fixed systems operating in the 22.55-23.15 GHz band from the emissions of an SRS earth station;
3. the compatibility between low-Earth orbiting SRS satellites and transmitting fixed wireless stations;
4. protection of mobile stations in the 22.55-23.15 GHz band.

Simulations were run to determine the statistical interference to inter-satellite links from the emissions of an SRS earth station for three scenarios:

1. when transmitting to a low-Earth orbiting SRS satellite;
2. when transmitting to an SRS lunar mission satellite;
3. when transmitting to an SRS L2 mission satellite.

The worst-case sharing scenario was the SRS earth station transmitting in support of a lunar mission. The earth station, which was located at the 3 DSN stations (Goldstone/CA, Canberra/AUS and Madrid/Spain), used an 18 m antenna driven by a transmitter with an output power spectral density of +0.3 dB (W/MHz). Four different types of inter-satellite links were considered: GSO-to-non-GSO; GSO-to-GSO; non-GSO-to-GSO and non-GSO-to-non-GSO. For inter-satellite links involving GSO satellites, the statistics of the level of interference were evaluated for four values of elevation angle as viewed from the SRS earth station, 10, 20, 40 and 50°. These different elevation angles provide an indication of the sensitivity of interference to elevation angle.

Table 13 is a summary of the maximum level of interference exceeded for less than 0.1% of the time for the various types of inter-satellite links when the interfering SRS earth station is supporting a lunar mission – the worst-case. Also shown in the Table is a reference level of interference and the corresponding margin. For the case of the DRS link, the reference level is the protection criteria given in Recommendation ITU-R SA.1155, whereas, for the other types of links, the reference level corresponds to the noise power spectral density of a 700 K receiver. It is important to note that the interference margins range from 27.5 dB to 31.7 dB. Hence, it is concluded that sharing between the SRS (Earth-to-space) and the inter-satellite service in the 22.55-23.15 GHz band is feasible.

TABLE 13

Summary of the worst-case level of interference to the different types of inter-satellite links, reference level, percentage of time and margin

Inter-satellite link type	I_{max}/N_0 (dB)	Reference level (dB)	Percent of time (%)	Margin (dB)
GSO-to-non-GSO	–41.1	–10	0.1	31.1
GSO-to-GSO	–41.7	–10	0.1	31.7
Non-GSO-to-GSO	–39.3	–10	0.1	29.3
Non-GSO-to-non-GSO	–43.0	–10	0.1	33.0

Compatibility of an SRS earth station transmitting in the Earth-to-space direction with point-to-point fixed service receiving stations in the 22.55-23.15 GHz band was also evaluated. The technical and operating characteristics of the fixed service stations, the long-term and short-term interference criteria, and, the procedures to determine the separation distances have been provided. The separation distances are the measure of compatibility used in this study. Separation distances have been determined for static and dynamic scenarios. The static scenario, i.e. the worst-case scenario, considers the azimuth and elevation angles of the SRS earth station to be fixed and determines the minimum separation distances accordingly. The dynamic scenarios apply the time-variant gain (TVG) and time-invariant gain (TIG) procedures from Recommendation ITU-R SM.1448.

As discussed in § 5.1, separation distances were calculated that satisfy both the short-term and long-term interference criteria, i.e. $p_0(\%) = 0.0025\%$ and $M_S = 25$ dB for the short-term and $p_0(\%) = 20\%$ and $I/N = -10$ dB for the long-term.

The dynamic procedures are based on the time variant gain (TVG) and time-invariant gain (TIG) methods described in Recommendation ITU-R SM.1448. As discussed in § 5.4, the TVG method is the most accurate method for the scenarios under study, which are based on SRS earth station transmitting to the Moon for a period of one year, and the following results correspond to this method. The separation distances required to protect the fixed wireless station are computed for the worst-case azimuth angle, which is around 125°. Assuming that the azimuth angle of the fixed wireless receiving antenna is uniformly distributed over 360°, the separation distance ranges from less than 10 km to about 54 km to satisfy both the long-term and short-term interference criteria.

The maximum distance may be reduced to a range from less than 10 km to 49 km with the introduction of a site shielding barrier. A 50 m barrier located 5 km away is an example of such a barrier. The actual separation distance depends on the gain of the fixed wireless receiving antenna in the direction of the SRS earth station. For 99% of the fixed wireless stations, a separation distance of 12 km is feasible with a barrier of 50 m.

The maximum separation distance applies to a fixed wireless station located along the worst-case azimuth angle as viewed at the SRS earth station. Along other azimuth angles, e.g. 0° and 180°, the separation distances will be much smaller. These separation distances are based on no other obstacles along the great circle path, flat terrain, no site shielding of the fixed wireless station when located in urban and suburban areas, cross border antennas pointing at each other, and a maximum gain of 48 dBi. Adjusting for these factors, a worst case separation distance of 20 km would be sufficient for practically 100% of all cases. However, based on the combination of all worst-case considerations, the 54 km distance is considered to be the maximum hypothetical separation distance required for protection of the FS. Any difficulties with sharing with fixed wireless systems should be diminished when account is taken of the fact that there will only be a small number of

SRS earth stations located in relatively isolated areas. Based on the results presented in this Annex, it may be concluded that sharing between the SRS (Earth-to-space) and the fixed service in the 22.55-23.15 GHz band is feasible.

Technical and operating characteristics of mobile systems operating in the 22.55-23.15 GHz band are not available. Pending the availability of such characteristics, the worst-case distances developed for fixed service systems are expected to be adequate to protect mobile systems, with the possible exception of aeronautical mobile systems.