



Report ITU-R SA.2193
(10/2010)

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

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TABLE OF CONTENTS

	<i>Page</i>
1 Introduction	2
2 Characteristics of the SRS earth station emissions.....	3
3 Sharing between a transmitting SRS earth station and receiving stations in the inter-satellite service	4
3.1 DRS user satellite characteristics (GSO-to-non-GSO ISL).....	4
3.2 GSO-to-GSO ISL receiving satellite characteristics	4
3.3 GSO-to-non-GSO ISL receiving satellite characteristics	5
3.4 Non-GSO-to-GSO ISL receiving satellite characteristics	5
3.5 Non-GSO-to-non-GSO ISL characteristics	6
3.6 Orbital characteristics of the Moon	6
3.7 Observations on the characteristics of an interference event.....	6
4 Results for sharing with space stations in the inter-satellite service	7
4.1 Statistical interference to a DRS user satellite (GSO-to-non-GSO).....	7
4.2 Statistical interference to GSO-to-GSO inter-satellite link	9
4.3 Statistical interference to non-GSO-to-GSO inter-satellite links	11
4.4 Statistical interference to non-GSO-to-non-GSO inter-satellite links	12
4.5 Conclusions.....	14

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.

5	Sharing between a transmitting SRS earth station and fixed wireless receiving stations in the fixed service	14
5.1	Approach for a static interference environment	14
5.2	Time variant gain method to determine separation distances to protect point-to-point fixed wireless systems	20
5.3	Time-invariant gain method to determine separation distances to protect point-to-point fixed service systems	22
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	23
6	Compatibility of receiving SRS satellites with transmitting fixed wireless systems in the 22.55-23.15 GHz band.....	25
7	Sharing between a transmitting SRS earth station and receiving stations in the mobile service.....	27
8	Summary and conclusions.....	27

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 $0.549^\circ/\text{h}$, whereas, the angular velocity of the Earth about its axis of rotation is $15^\circ/\text{h}$ – 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 $216^\circ/\text{h}$.) 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 (E_1) 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

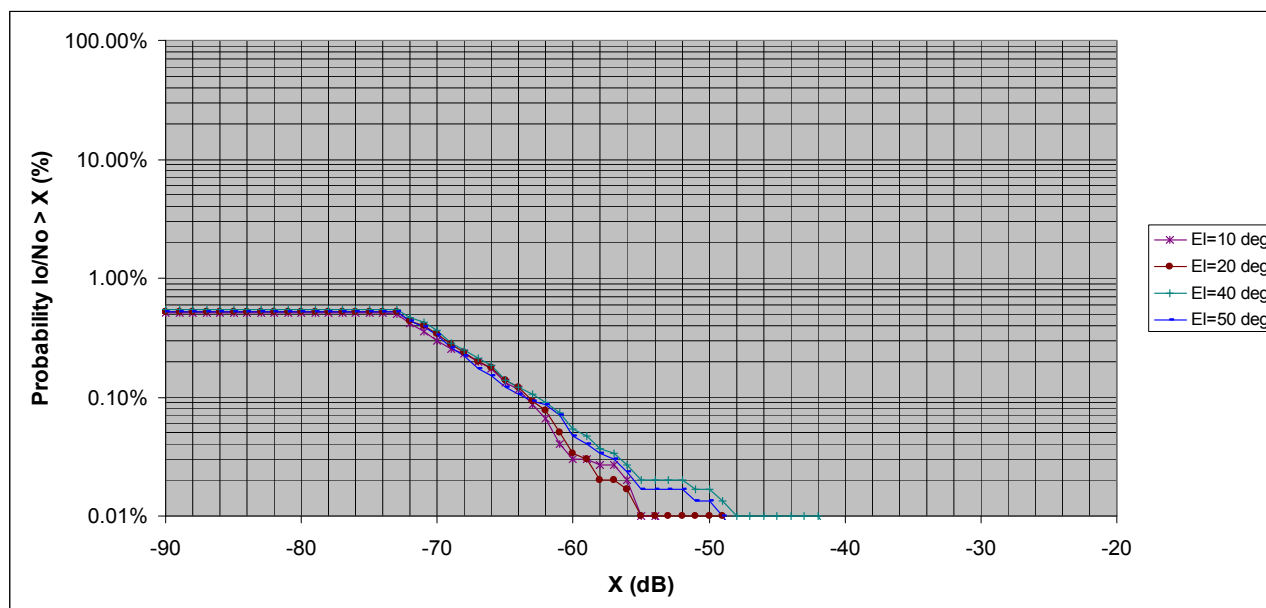


Figure 1b) shows the statistical interference to a DRS user satellite from the emissions of the SRS earth station supporting a lunar mission. For this scenario, the level of I_0/N_0 to DRS user satellite does not exceed -41.1 dB for more than 0.1% of the time. For this scenario, the margin above the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

