Recommendation SFCG 29-1

EFFICIENT SHARING OF THE 25.5 - 27.0 GHz BAND BETWEEN EESS (s-E) AND SRS (s-E)

The SFCG,

CONSIDERING

a) that the 25.5 - 27.0 GHz band is allocated to the Earth exploration-satellite service (EESS) (space-to-Earth), the space research service (SRS) (space-to-Earth) and the 25.25 - 27.50 GHz band is allocated to the inter-satellite service[1] (ISS);

b) that EESS and SRS near-Earth missions in the 25.5 – 27.0 GHz band may be compatible under certain conditions;

c) that the power flux densities at the Earth’s surface from SRS missions are very low for Lunar missions and extremely low for sun-Earth Lagrange and deep-space missions;

d) that due to the low power flux density, deep-space missions are very vulnerable to interference and have stringent protection criteria;

e) that multiple administrations are planning to fly manned missions to the Lunar environment and beyond;

f) that manned missions have more stringent protection criteria than unmanned missions;

g) that due to atmospheric attenuation, specifically rain attenuation and the power flux density limits specified in Article 21 of the Radio Regulations, it may be difficult to achieve link availabilities greater than 99.9% in the 25.5 – 27.0 GHz band;

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[1] Use of the 25.25-27.5 GHz band by the inter-satellite service is limited to space research and Earth exploration-satellite applications.

h) that the planned use of the 25.5 to 27 GHz band by SRS and EESS missions is not compatible with manned SRS mission protection criteria specified in Recommendation ITU-R SA.609;

i) that the 25.5 to 27 GHz band is planned to be used by EESS missions for various Earth observing, Earth exploration, and climate monitoring missions;

j) that the availability of the 25.5 – 27.0 GHz band is crucial to near-Earth SRS and EESS missions with high data rate requirements;

k) that interference from transmitting geostationary satellites has the potential to significantly degrade link margins and even cause loss of sensitive links of SRS missions if these satellites operate near the currently applicable PFD limits (see Annex 1);

l) that Article **21** of the Radio Regulations limits the power flux density at the surface of the Earth to levels between -115 and -105 dB(W/m^2/MHz) depending on the angle of arrival;

m) that reducing the power flux density limits below the limits specified in Article 21 of the Radio Regulations for geostationary satellites would provide necessary protection to Lunar and Lagrange SRS missions;

n) that space-to-Earth links of typical non-GSO satellites can always meet the power flux-density limit required to protect a DRS satellite while non-GSO satellites with orbits above 1 370 km may need some allowance to exceed it for a small percentage of time,

RECOGNIZING

1) that the space-based collection of global weather and climate data in support of the Global Earth Observation System of Systems (GEOSS) is becoming increasingly important to the worldwide community;

2) that the 25.5 to 27 GHz band is planned to be used by manned SRS missions for data transmissions that do not involve astronauts and vehicle safety;

3) that non-GSO satellites should also comply with Recommendation ITU-R SA.1155 “Protection criteria related to the operation of data relay satellite systems”;

RECOMMENDS

1) that deep-space missions not use the 25.5 - 27.0 GHz SRS (space-to-Earth) band unless mission requirements cannot be satisfied in other bands specifically allocated for deep-space operations;

2) that if, for a compelling reason, a deep-space mission requires the use of the 25.5 – 27.0 GHz band, the mission not claim interference protection from near-Earth missions in excess of the protection criteria of Recommendation ITU-R SA.609 applicable to unmanned missions in the 25.5 - 27.0 GHz band;

3) that manned SRS missions not claim interference protection from EESS and unmanned SRS missions in excess of the protection criteria of Recommendation ITU-R SA.609 applicable to unmanned missions in the 25.5 - 27.0 GHz band;

4) that to provide additional protection to lunar and Lagrange SRS missions, EESS and SRS missions in geostationary orbits restrict their PFD levels to -115 dB(W/m^2/MHz) in the band 25.5 to 27.0 GHz for all angles of arrival at the surface of the Earth (see Annex 1).

5) that EESS or SRS satellites in non-geostationary orbits with space-to-Earth satellite links shall not produce a power-flux-density (pfd) greater than –133 dB(W/m2) in 1 MHz at any DRS satellite location on the geostationary orbit. This limit may be exceeded no more than 0.1% of the time for non-GSO systems with altitudes greater than 1370 km (see Annex 2).

Annex 1

Potential impact of geostationary satellites on sensitive links of SRS missions

1 Introduction

The 25.5-27.0 GHz band is an important downlink band for the Earth exploration-satellite (EESS) and space research services (SRS). This band is planned to be used for EESS as well as SRS missions. The latter ones could operate at any distance from a low Earth orbit to the Sun-Earth Lagrange points. A number of extensive studies addressed compatibility between various types of missions concluding that all potential applications can share the band 25.5-27.0 GHz without problems except for geostationary satellites operating close to the power flux-density limits of Article 21 of the Radio Regulations. This Annex provides a summary of the various study results and the background for the corresponding reduced power flux-density limits for geostationary satellites.

2 Characteristics of potential victim SRS systems

The most sensitive SRS missions are satellites near the Lagrangian points L1/L2 and near the moon. Figure 1 illustrates such science applications and the corresponding interference constellation.

FIGURE 1

Various mission types with potential deployment in the band 25.5-27.0 GHz

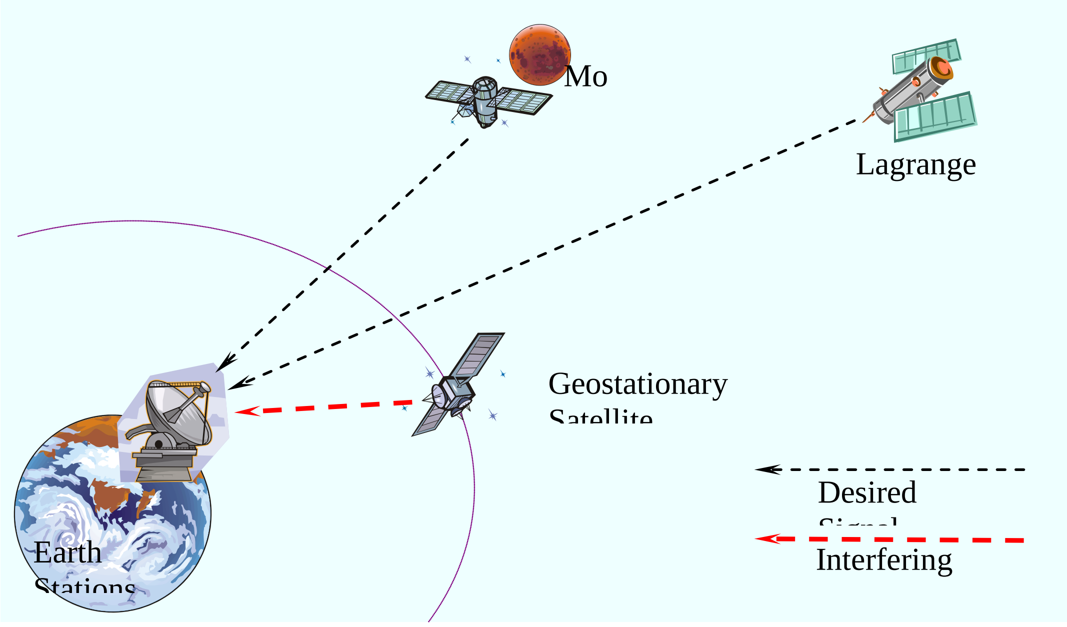


Table 1 shows characteristics for lunar systems analysed in one of the detailed studies. As shown in this table, the link margin is equivalent to Co/No – Co/No required. These margins are calculated from the system data using standard assumptions related to data rate, coding, and availability.

TABLE 1

Essential characteristics for representative Lunar SRS victim systems

		Representative 26 GHz satellite victim systems	
Parameters	**Units**	**LRO Lunar**	**Cx Lunar, 50 MHz**
Frequency	MHz	25 650	26 000
Slant range	km	401 427	404 943
Tx power	dB(W)	16.0	17.0
Tx power split	dB	–3.0	0.0
Tx gain	dBi	42.9	43.5
Max. pfd at Earth	dB(W/m^2/MHz)	–143.0	–141.4
Data rate	Mbps	50.0	25.0
Rx gain	dBi	71.3	70.4
Link losses	dB	–7.5	–9.7
Rain/Atmos loss	dB	–1.25	–2.8
Temp	K	510.0	446.7
Co/No	dB	10.3	13.6
Co/No Required	dB	2.9	2.2
Margin	dB	7.4	11.4

Another detailed study used the James Web Space Telescope (JWST) as a representative example for Lagrangian missions. Two different data rates have been considered with 14 and 56 Ms/s. The adjustable data rate helps to maintain a link in case of heavy rain events. Table 2 shows a summary of the assumptions for Lagrangian SRS victim missions.

TABLE 2

Essential characteristics for Lagrangian SRS victim systems

	JWST-14	**JWST-56**	
SRS satellite orbit height	1 500 000	1 500 000	km
Power of SRS satellite	13.1	13.1	dBW
Bandwidth of main lobe with QPSK	14	56	MHz
SRS satellite antenna diameter	1.05	1.05	m
SRS satellite maximum antenna gain	46.2	46.2	dBi
SRS earth station antenna diameter	34.0	34.0	m
SRS system noise temperature	200	200	K
Technical receiver and pointing losses	3.0	3.0	dB
Required Es/No for QPSK with channel coding	2.5	2.5	dB
Margin for atmospheric attenuation	20.0	13.9	dB

For all assessments, the protection criteria as contained in Recommendation ITU-R SA.609 have been taken as the baseline. It specifies an interference density level of -156 dBW/MHz not to be exceeded for more than 0.1% of time.

3 Assumed characteristics of interfering geostationary systems

Relevant link budget characteristics for some potential geostationary systems are shown in Table 3. GSO-1 is representative for the Alpha-Sat mission with a channel bandwidth of 405 MHz. The satellite design is based on a 0.7 m parabolic antenna. For the simulations, an earth station in Madrid has been assumed as a worst case. GSO-1 is expected to be quite representative for several types geostationary systems planned for deployment in this band. GSO-2 is a hypothetical system and could be representative for a low elevation system with high availability for a dedicated earth station. The satellite was assumed at a GSO position of 48° E. The elevation angle towards central Spain is 20°. GSO-3 may be representative for a high availability system with several smaller earth stations within a sub-region. An example could be a system transmitting to a number of direct data read-out stations. GSO-3 was assumed at 14° E serving a number of smaller user stations in Spain. Even with a 1.4 m onboard parabolic antenna, the main beam covers a rather large region as shown in Fig. 2. Similar situations may be found with other sensitive SRS earth station locations.

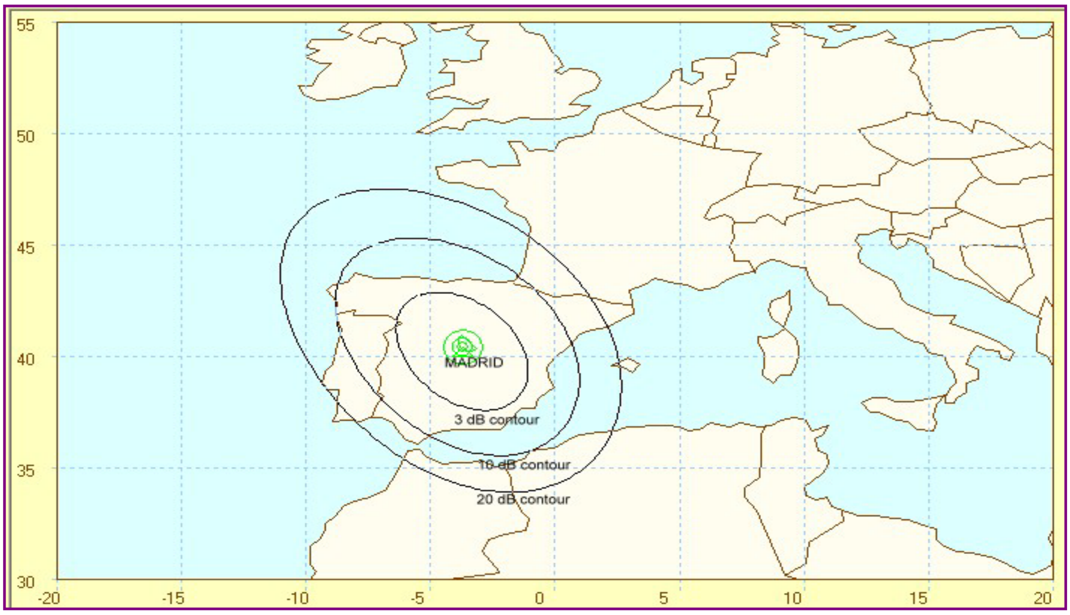
TABLE 3

Key parameters for geostationary satellite systems

	GSO-1	**GSO-2**	**GSO-3**
Transmit power (dBW)	14.0	20.0	23.0
Satellite antenna gain (dBi)	43.1	46.2	49.7
Satellite EIRP (dBW)	57.3	66.2	72.7
Bandwidth of main lobe for 600 Mbit/s and QPSK (MHz)	600	600	600
Maximum PFD at receive site (dBW/m^2/MHz)	–130.2	–121.5	–114.6
Assumed link availability (%)	99.90	99.98	99.98
Signal attenuation for assumed availability (dB)	8.4	21.5	15.0
Earth station antenna diameter (m)	7.3	10.0	2.0

FIGURE 2

Footprint contours towards Madrid for a geostationary satellite at 14° E



4 Assessment of interference to SRS missions

One approach was based on an *I*/*N* criterion is typically used to determine if intersystem interference will result in unacceptable interference to any of the available SRS or EESS systems.

Based on Recommendation ITU-R SA.609, the received interference level from all sources should not exceed the following aggregate level:

Io/No not to exceed –6 dB more than 0.1% of the time.

This analysis moved beyond the basic Io/No interference criterion and took into account the relatively large link margins that many of the SRS and EESS systems have. It looked at the degraded link margin, denoted simply by "margin":

$$\text{margin} = Co/(No+Io)_{\text{measured}} - Co/No_{\text{required}}$$

The basic criterion for determining whether interference is within acceptable levels was that the following:

margin not to fall below α dB more than 0.1 % of the time.

where "α" is a value that is discussed below. A possible value for α would be 0, as this is the level below which the link could not be closed.

However, it was considered not to be prudent to allow the entire link margin to be consumed by interference from other non-GSO or GSO systems, so α may in fact be a value greater than 0. It should be emphasized that use of this type of interference criterion allows the study to move beyond the traditional *I*/*N* interference analysis approach to analyze the degradation to the systems' link margins.

Some key assumptions used for the simulation were that victim and interfering sources are assumed to operate using the same centre frequency. Furthermore, the interferer's total power is averaged over its bandwidth and 3 dB is added to account for the peak density, assuming PSK modulation. High-gain satellite antenna patterns follow the reference radiation pattern of Recommendation ITU-R S.672. Earth station antenna patterns follow the pattern in Recommendation ITU-R F.1245.

Robledo and Cebreros are two locations in central Spain which support sensitive SRS missions such as to Lagrangian points or, potentially, to the Moon. In view of the long distances to L1 and L2, the power flux-density of the received signals is rather low, requiring large earth stations up to 35 m with a high *G*/*T*. As far as interference statistics are concerned, all earth stations at similar latitudes will show similar results. The only significant difference will be the atmospheric attenuation which can differ to a large degree between the various potential sites.

Regarding potential interference to Lagrangian SRS missions caused by geostationary satellites with characteristics as provided in Table 3, some studies concluded that typical implementation such as AlphaSat would just meet the SA.609 criterion assuming its earth station would be located in central Spain. For the systems GSO-2 and GSO-3, an excess of the SA.609 criterion by 8 to 15 dB would occur even with a reduced PFD limit of –115 dBW/m^2/MHz. However, non-compliance with Recommendation ITU-R SA.609 does not necessarily mean that harmful interference will occur. Links around 26 GHz need significant margins to achieve a link availability in excess of 99% down to elevation angles of 5 to 10 degrees. For example, Robledo and Cebreros need margins of around 10 dB to close a link down to elevation angles of 5° for 99% of time. For operation down to 10°, a margin of 5.4 dB would still be required. This results in a practical situation where the interference events in excess of the SA.609 criterion in many cases only reduce the margin without causing a loss of the link. The link outage due to atmospheric attenuation is much higher as compared to interference. When considering the actual data loss due to interference, the required Es/(No+Io) can be met for 99.98% of time even in the case of geostationary satellites operating at a reduced PFD limit of –115 dBW/m^2/MHz. However, a geostationary satellite operating at the PFD limits of RR 21.16 could cause harmful interference resulting in a loss of the link. Potential interference to Lunar SRS missions caused by the same satellites are of similar magnitude.

Table 4 presents a summary of the results of other analyses regarding interference from a hypothetical GSO satellite mission into a number of victim missions similar to the ones listed in Table 1. Table 4 shows the margin without interference as well as the degraded margins into the SRS missions due to interference from a GSO mission at 107º W with

PFD levels of –105 to –125 dBW/m^2 MHz.. GSO-107 W transmits to WSC (White Sands) with an elevation angle to the earth station greater than 25 deg.

A hypothetical GSO mission that operated at the PFD limit of –105 dB(W/m^2/MHz) could cause interference levels in excess of the interference criterion, as a GSO mission may be always in view of a victim earth station, while an non-GSO mission is not. However, such a high PFD level would only be necessary if very small earth stations were used (e.g. 1 or 2 m) and if a high availability were required.

TABLE 4

Single-entry interference margin results for GSO case at the 0.1% level

			Margins at 0.1% level		
Victim Mission	**Rx Station**	**C/N Margin (dB) w/o interference**	**GSO 107W; PFD=-105 @90EL**	**GSO 107W; PFD=-115 @90EL**	**GSO 107W; PFD=-125 @90EL**
LRO	WSC	7.4	-0.1	6.1	7.4
Cx Lunar, 50 MHz	WSC	11.4	3.0	9.7	11.4

Based on the results shown in Table 4, it may be seen that the margin at the 0.1% level is negative or substantially degraded for the lunar missions LRO and Cx Lunar if the interfering GSO satellite uses a power flux-density that just meets the limits contained in Article 21 of the Radio Regulations. For interference into LRO, the margin is reduced from 7.4 to –0.1 dB and for Cx Lunar it is reduced from 11.4 to 3.0 dB. In both of these cases, the margins are reduced to values which can be considered too small. Figures 3 and 4 show the corresponding interference statistics for the LRO and Lunar Cx missions. However, if the PFD is limited to a maximum value of –115 dBW/m^2/MHz for all angles of arrival then degradation due to interference is substantially reduced. Further reducing the PFD to a maximum value of –125 dBW/m^2/MHz for all angles of arrival would not offer much additional improvement.

In summary, all studies concluded that interference from geostationary satellites operating at the same power flux-density as Earth observation satellites would cause interference levels which are at least an order of magnitude above the SA.609 criteria and significantly higher as compared to non-GSO EESS missions due to the increased visibility. Nevertheless, excess of SA.609 interference density criteria will not lead to unacceptable Es/(No+Io) conditions if the geostationary satellites operate below –115 dBW/m^2/MHz. However, geostationary satellite operating at the PFD limits of RR 21.16 could cause substantial interference. In many regions of the world with small or moderate rain attenuation, geostationary systems can generally be deployed without the need to operate even close to the current PFD limits. A PFD limit of around –115 dBW/m^2/MHz for geostationary satellite systems at all angles of arrival would therefore provide adequate protection to SRS missions without putting undue constraints on geostationary satellites.

FIGURE 1

Interference margin chart for GSO-107W into LRO

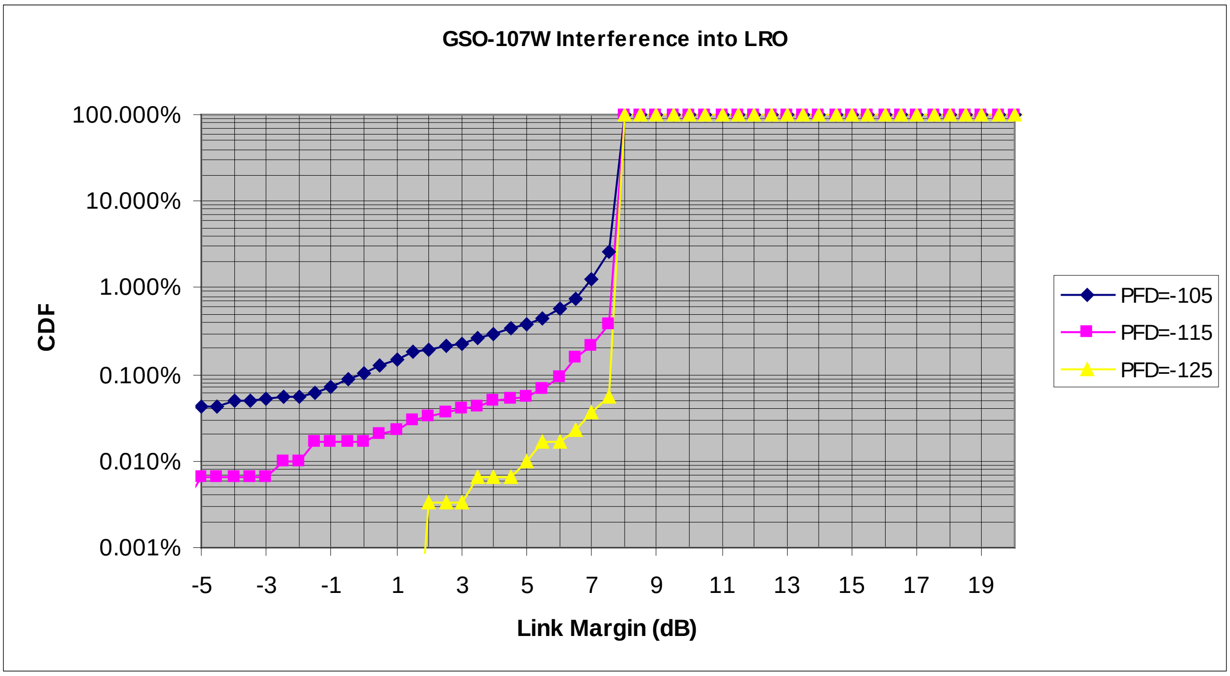
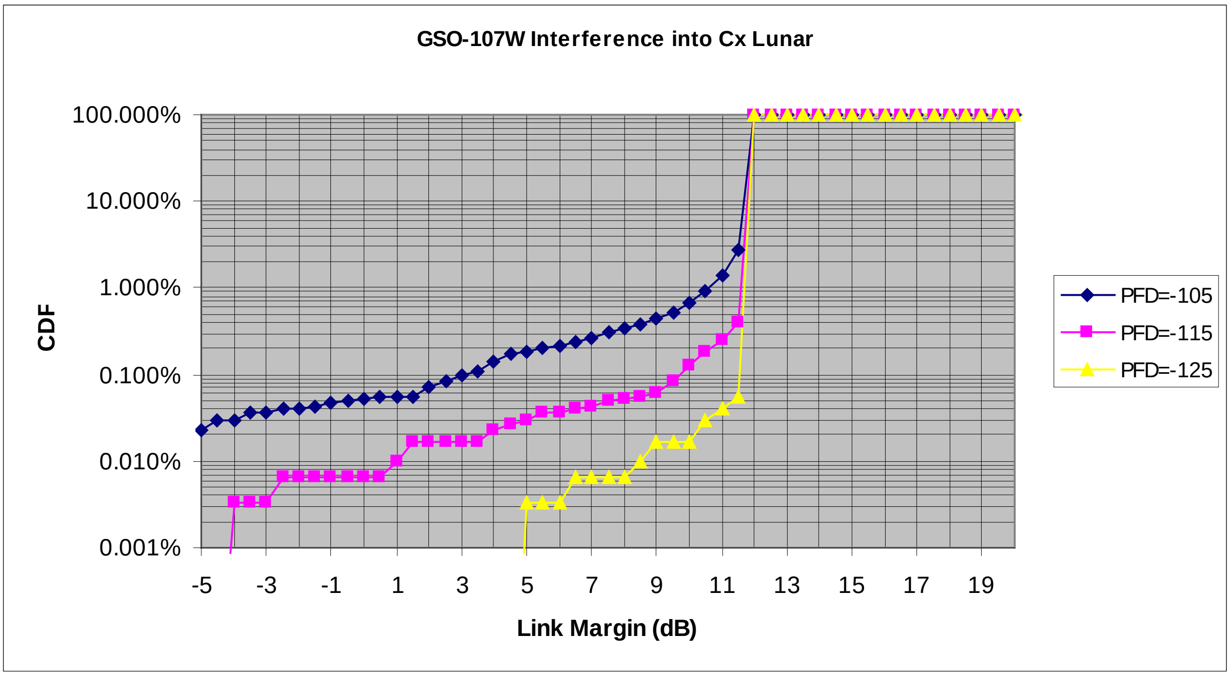


FIGURE 2

Interference margin chart for GSO-107W into Cx Lunar



Annex 2

Power flux-density limits on the geostationary orbit for non-GSO satellites

Recommendation ITU-R SA.1155 specifies a maximum allowable interference power spectral density of $P_{sd} = -178$ dBW/kHz which can be converted to −148 dBW/MHz in view of the generally very wide receiver bandwidth of DRS satellites. The corresponding pfd value can be calculated by taking into account the effective antenna area:

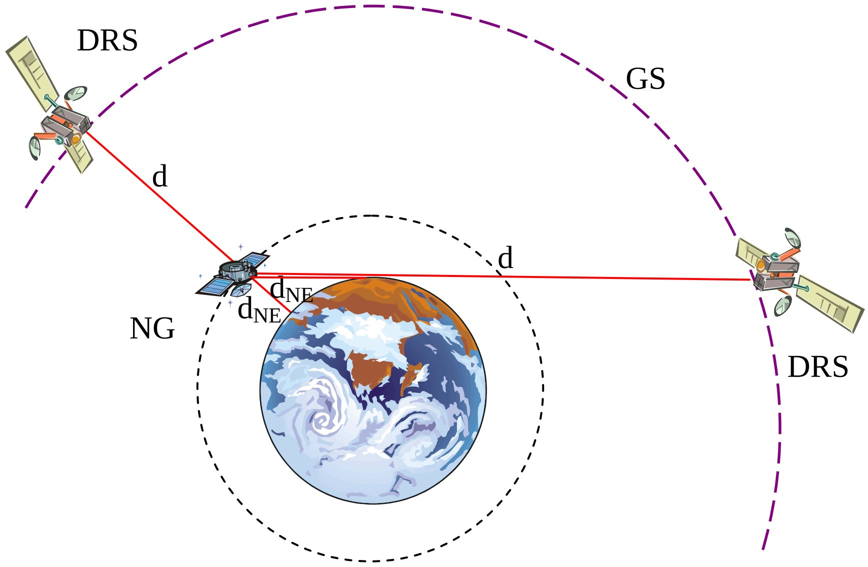
$$PFD_{\mathrm{lim}it} = P_{sd} - 10 \cdot \log(\eta\pi\frac{D^2}{4}) = -148 + 1.05 - 10 \cdot \log(\eta D^2)$$

The largest antenna of current DRS satellites has a diameter of 4.9 metres. The efficiency η can be assumed with 50%. The corresponding pfd value would be –157.7 dBW/m^2/MHz. The allowable time percentage of 0.1% specified in Recommendation ITU-R SA.1155 cannot be applied to the pfd limit, as this would neglect the fact that both antennas are moving relative to each other, and that exposure of the DRS GSO location with the specified pfd limit results only in maximum allowable interference when the DRS antenna is pointing directly at the EESS satellite.

It is assumed that a percentage of interference excess is acceptable that corresponds to the main-lobe beamwidth. For a 4.9 m antenna, the first side-lobe angle is around 0.22 degrees (one-sided). The probability of another satellite with asynchronous orbit parameters to be within this main-lobe beamwidth is around 3.7×10^{-6}, thus considerably less than 1×10^{-3} as specified in Recommendation ITU-R SA.1155. The first side-lobe gain is assumed to be around 25 dB lower according to Recommendation ITU-R S.672. This results in a pfd limit of –132.7 dBW/m^2/MHz. In order to determine a suitable distance d_{NE}, operation of a non-GSO satellite at the PFD limit has been assumed. The following two cases may then be considered as illustrated in Fig. 5.

FIGURE 5

Non-GSO satellite interference to data relay system satellites on GSO



Case 1 assumes maximum PFD of –115 dBW/m^2/MHz towards a 5° angle of incidence at the surface of the Earth and consequently also maximum PFD towards DRSS-1. This is typically the case with parabolic antennas or due to shielding by the spacecraft itself in case of cardioid antennas. For simplicity, the PFD towards DRSS-1 has been assumed equal to the PFD towards the 5° angle of incidence. In reality, the level will be more than 3 dB lower due to a slightly longer distance and shielding of half of the antenna main lobe by the Earth.

Case 2 assumes maximum PFD of –105 dBW/m^2/MHz towards a 90° angle of incidence at the surface of the Earth and also maximum PFD towards DRSS-2 via the antenna backlobes. This could be the situation for transmissions via omni-directional antennas.

The related distances can be derived from the following equations:

$$PFD = \frac{EIRP}{4 \cdot \pi \cdot d^2}$$

$$EIRP = PFD_1 \cdot (4 \cdot \pi \cdot d_{NE}{}^2) = PFD_2 \cdot (4 \cdot \pi \cdot d_{NG}{}^2)$$

$$d_{NE} = \sqrt{\frac{PFD_2}{PFD_1}} \cdot d_{NG}$$

$$h_O = \sqrt{R^2 + d_{NE}{}^2} - R$$

where:

d_{NE1} : distance from the non-GSO satellite to the 0° angle of arrival location;

d_{NG1} : distance from the non-GSO satellite to DRSS-1 ($d_{NG1} = d_{NE1} +$ 41 680 km);

d_{NE2} : distance from the non-GSO satellite to its sub-satellite point (90° angle of arrival);

d_{NG2} : distance from the non-GSO satellite to DRSS-2 (d_{NG2} = 35 787 km - d_{NE2});

h_0 : orbit height of non-GSO satellite;

R : Earth radius (6 378 km).

For case 1, PFD_1 = –115 dBW/m^2/MHz, PFD_2 = –133 dBW/m^2/MHz and the corresponding minimum non-GSO orbit height would be 2 380 km.

For case 2, PFD_1 = –105 dBW/m^2/MHz, PFD_2 = –133 dBW/m^2/MHz and the corresponding minimum non-GSO orbit height would be 1 370 km.

As the minimum orbit height of 1 370 km represents the worst case, this distance has been taken as the basis for the Recommendation.