RECOMMENDATION ITU-R SA.1155*,**

Protection criteria related to the operation of data relay satellite systems

(1995)

The ITU Radiocommunication Assembly,

considering

a) that data relay satellite systems are in operation or are planned corresponding to the hypothetical reference system as described in Recommendation ITU-R SA.1018;

b) that these data relay satellite systems support links with widely different characteristics as described in Annex 1;

c) that preferred frequency bands for data relay satellite systems have been identified in Recommen-dation ITU-R SA.1019;

d) that sharing between data relay satellite systems and other space and terrestrial radio systems is required in all of the preferred frequency bands, identified in Recommendation ITU-R SA.1019;

e) that the numbers of space and terrestrial radio systems using the shared bands with data relay satellite systems will increase in the future, thus increasing the potential of interference situations;

f) that the link margins for data relay satellite forward and return links are typically 2 to 4 dB;

g) that the data relay satellite system will transmit and receive signals in the space operation, space research, Earth exploration-satellite (EES) and the fixed-satellite (FS) services;

h) that detailed technical information regarding protection criteria is contained in Annex 1,

recommends

1 that protection criteria, specified in maximum aggregate interference power spectral density levels, from all sources to be exceeded for no more than 0.1% of the time based on the orbital period of satellites (see § 3.2 of Annex 1) for the various links of data relay satellite systems are as indicated in Table 1;

2 that the maximum aggregate interference levels outlined in § 1 should be used as the basis for developing sharing criteria in studies with other terrestrial and space systems. The resultant criteria used to facilitate sharing may be different to those found in § 1.

---

* Radiocommunication Study Group 7 made editorial amendments to this Recommendation in 2003 in accordance with Resolution ITU-R 44.

** This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 8 and 9.

TABLE 1

Protection criteria

Data relay satellite link	Receiver location	Power spectral density (dB(W/kHz))
Forward inter-orbit link	User spacecraft	
2 025-2 110 MHz		–181
13.5-13.8 GHz		–178
22.55-23.55 GHz		–178
Return inter-orbit link	Data relay satellite	
2 200-2 290 MHz		–181
14.89-15.18 GHz		–178
25.25-27.5 GHz		–178
Forward feeder link	Data relay satellite	
14.5-15.35 GHz		–167
27.5-30.0 GHz		–169
Return feeder link	Earth station	
13.4-14.05 GHz		–176
10.81-10.86 GHz		–176
17.7-21.2 GHz		–172

Annex 1

Analysis of interference susceptibility of data relay satellite links

1 Introduction

Much of the spectrum suitable for space research is also allocated to one or more other services and consequently frequency sharing between the services is required. This Recommendation discusses factors which affect the susceptibility to interference of links towards geostationary space stations operating as data relay satellites from low-orbiting spacecraft in the space research, space operations and EES services and from earth stations operating both in these same services or in the FSS. It specifies appropriate protection criteria for these services in the frequency bands from 2 up to 30 GHz. The protection criteria are for use in coordination and interference analyses when actual system data are unavailable.

2 General considerations

Space research, space operations and Earth exploration systems in the near-Earth region have always been reliant on regular, interference-free two-way communications between spacecraft and control centres and other installations on the Earth. The evolution and expansion of these activities has become dependent on data relay satellites, described in Report ITU-R SA.848.

These operations are dependent on space-to-space links, which are more difficult to design and implement than the space-to-Earth links, described in Report ITU-R SA.985, because both the transmitting system and the receiving system are subject to the mass and power limitations, and in most cases also to remote-control and non-maintainability constraints, of space-borne systems.

The trend is for systems of these types to use bandwidth-efficient modulation schemes, such as 2-PSK and 4-PSK, supplemented by forward-error-correction coding techniques, such as convolutional coding and block coding, both to increase the signal quality and to reduce the necessary signal power. In some systems, spread-spectrum modulation techniques are used to reduce the power density of the signal and pseudo-random sequence modulation techniques (similar or identical to the spread-spectrum modulation techniques) are used for range measurements to determine the location of spacecraft. Phase-locked loop circuitry is also used during search, acquisition and tracking sequences.

3 Protection criteria

In space-to-Earth and Earth-to-space links there is an incentive to minimize link margins in order to save mass and power, to reduce interference and in the interests of economy. In space-to-space links this incentive is re-doubled as both ends of the link are space-borne. Typical overall link design margins, which consider in the case of data relay satellites the space-to-space link in tandem with the space-to-Earth or Earth-to-space link (sometimes referred to as the feeder link), are generally around 2-3 dB, after making allowance for any necessary margins to offset the effect of weather on the feeder link. The link design margin for the space-to-space link may be as small as 1 dB, due to the extreme constraints of launching both transmitting and receiving systems into space in contrast to the possibility of enlarging the antenna of a ground receiving station.

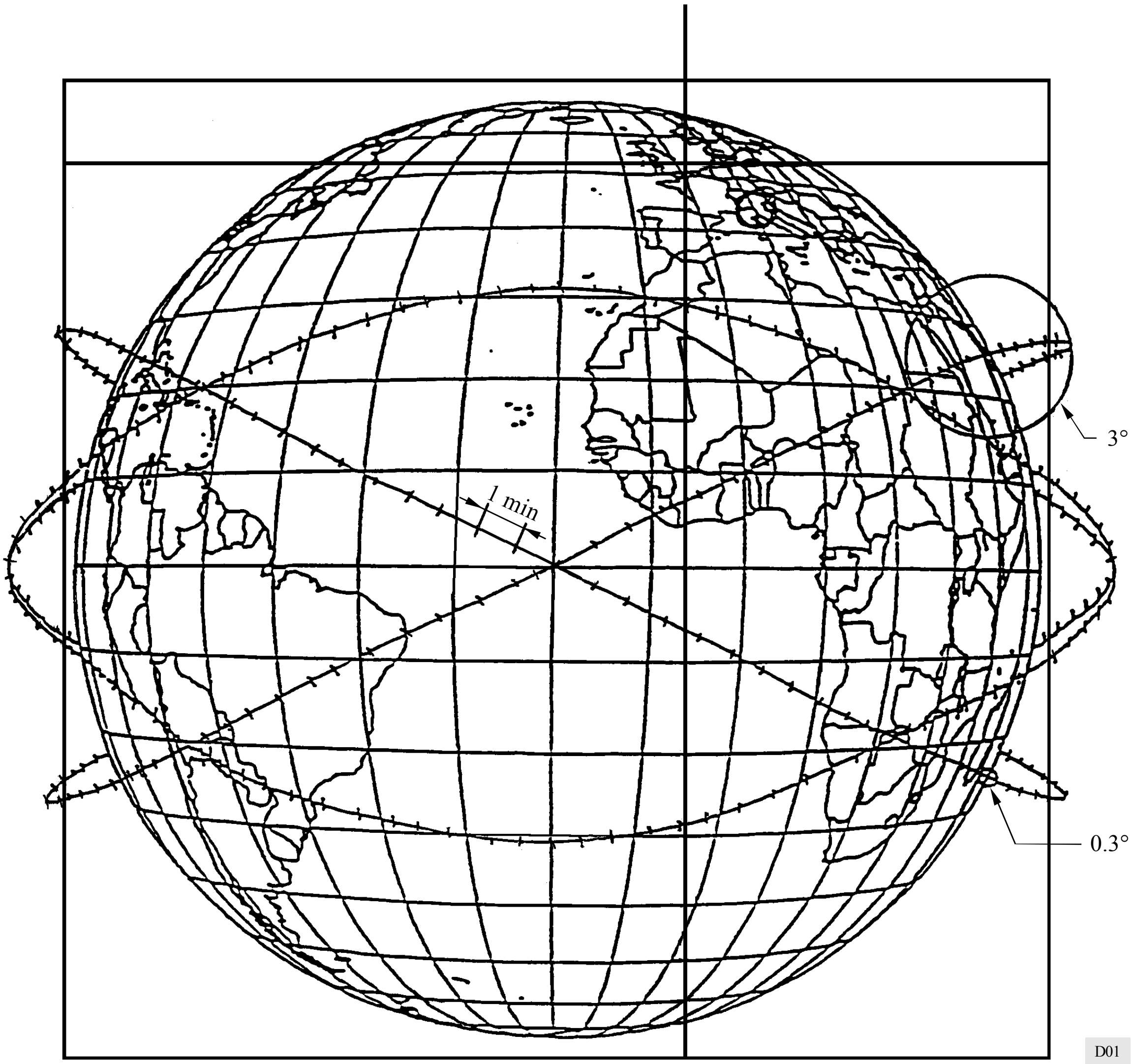
Considering these low design margins, levels of interference causing reduction of link margin by as little as 0.2 dB could be harmful to space-to-space links.

However, in most cases, particularly at higher frequencies, these links will not be permanently affected by a single source of interference from the ground, as the link geometry is constantly changing due to the movement of the low-orbiting spacecraft. The duration of interference will depend on the beamwidth of the receiving antenna on the relay satellite. Typical beamwidths are 3° at 2 GHz and 0.3° at 26 GHz. Corresponding durations of interference for a typical low-orbiting signal source are 17 min for a 3° beam and 1 min for a 0.3° beam, as illustrated in Fig. 1.

On the other hand, interference patterns which recur whenever a specific link geometry occurs will cause systematic problems to real-time observations of the Earth's surface below a low-orbit spacecraft.

FIGURE 1

Typical orbit of low-orbiting satellite, viewed from geostationary orbit



The levels causing harmful interference to the Earth-to-space links will depend on the apportionment of margins to the tandem Earth-to-space and space-to-space links. The geometry of the Earth-to-space links towards the data relay satellite does not vary with time.

In the analyses which follow, the bench-mark of link margin reduction by 0.4 dB due to single-entry interference has been assumed, which has been used in other similar cases (Reports ITU-R S.560, ITU-R S.872, ITU-R S.561 and ITU-R S.712). This corresponds to a required ratio of system noise power to interference power (*N*/*I*) within the referenced bandwidth of at least 10 dB.

3.1 Reference bandwidth

The systems use direct-modulation schemes, so that the reference bandwidth in which a protection ratio must be specified depends upon the lowest data rate and receiver bandwidth likely to be employed. For space-to-space links operating at frequencies in band 10, the minimum data rate is likely to be around 1 kbit/s whereas for band 9 it is likely to be around 100 bit/s. For simplicity, protection criteria have been quoted with reference to a bandwidth of 1 kHz, although in certain cases a smaller reference bandwidth would be more appropriate.

3.2 Reference percentage of time

For manned missions, a loss of communications for more than 5 min during critical phases, such as rendez-vous and docking or extra-vehicular activities, could seriously affect the mission.

For manned and unmanned missions, the reference is 0.1% of the time. The percentage of time shall be based on the orbital period of the satellites.

For missions engaged in Earth observation for meteorological, ecological, topographical and other purposes, regular interference from specific ground-based locations for periods as short as 1 min could prevent real-time observations of specific areas of the Earth's surface (generally, because of the geometry of interference, areas several hundred kilometres away from the source of interference). With a data relay satellite beamwidth of 0.3°, a satisfactory reference is 0.1% of the time. However, with a beamwidth of 3°, this time should be reduced, due to the extended time over which interference would be harmful, to 0.003% of time.

Also, for missions engaged in real-time operations such as robotic manipulation of instruments, machinery or chemicals (sometimes called "telescience"), any interruption in communications could have expensive consequences. Although such operations could perhaps be scheduled to avoid known sources of interference, the reference for these applications should also be 0.003% of time.

3.3 Required protection levels

Communications through a data relay satellite comprise two links in series, either "forward", being an Earth-to-space "feeder" link in tandem with a space-to-space "inter-orbit" link, or "return", being a space-to-Earth "feeder" link.

The determination of protection levels requires the consideration of both the feeder link and the inter-orbit link.

3.3.1 Space-station receivers

The total noise temperature of a typical space-station receiver is generally 600 K at around 2 GHz increasing to 1 200 K at around 20 GHz when the spacecraft antenna points at the Earth (290 K). Based on the requirement for N/I of 10 dB harmful interference can occur if the power density of noise-like interference or the total power of CW-type interference, in any single band or in all sets of bands 1 kHz wide, is greater than –181 dB(W/kHz) at around 2 GHz and −178 dB(W/kHz) at around 20 GHz at the input terminals of the receiver.

The noise contribution of the forward feeder link is small due to the negative transmission gain of the data relay satellites and has consequently not been considered.

3.3.2 Earth station receivers

In the frequency bands 10-20 GHz, the typical noise temperature of a receiving earth station is about 300 K, generating an end user noise power density, N_{eu}, of –203.8 dB(W/Hz), as shown in Table 2.

TABLE 2

Interference into a data relay satellite

Parameters	Earth station to data relay satellite		User spacecraft to data relay satellite		
Data relay satellite Rx frequency band (GHz)	30	15	26	15	2
Reference bandwidth (kHz)	1	1	1	1	1
Data relay satellite noise power density, N_r (dB(W/Hz))	–196.0	–196.8	–197.8	–198.6	–200.8
Transmission gain, y (dB)	–8.5	–11.0	6.4	2.5	20.7
End user noise power density, N_{eu} (dB(W/Hz))	–197.8	–198.6	–203.8	–203.8	–203.8
Equivalent noise power density, N_e (dB(W/Hz))	–197.0	–198.1	–191.8	–195.5	–180.1
Interference power density into end user (dB(W/Hz))	–207.0	–208.1	–201.8	–205.5	–190.1
Interference power density into data relay satellite (dB(W/Hz))	–198.5	–197.1	–207.6	–207.9	–210.8
Effective area of receiving antenna (dBm^2)	–10.0	1.0	6.2	8.3	8.5
Interference power flux-density at geostationary orbit (dB(W/Hz.m^2))	–188.5	–198.1	–213.8	–216.2	–219.3

However, the total equivalent noise power density, N_e, received from a data relay satellite which does not have on-board signal processing or remodulating repeaters includes the relay satellite noise power density, N_r, amplified by the transmission gain, y:

$$N_e = y\,N_r + N_{eu}$$

Using the parameters of a typical data relay satellite system, and assuming no simultaneous interference into the data relay satellite receiver, the threshold levels of interference into the end user earth station have been determined for typical parameters of the data relay satellite network, based on the requirement for N/I of 10 dB and are presented in Table 1.

3.3.3 Data relay satellites

Similarly, the total equivalent noise power density, N_{er}, referred back to the input of the data relay satellite includes the end user noise power density divided by the transmission gain:

$$N_{er} = N_r + N_{eu}/y$$

Thus, assuming no simultaneous interference into the end user, whether earth station (for a return link) or user spacecraft (for a forward link), the threshold levels of interference into the data relay satellite have been determined for typical parameters of the data relay satellite network, based on the requirement for N/I of 10 dB and are presented in Table 2.