International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SA.1155-2

(07/2017)

Protection criteria related to the operation of data relay satellite systems

SA Series

Space applications and meteorology

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2017

RECOMMENDATION ITU-R SA.1155-2*

Protection criteria related to the operation of data relay satellite systems

(1995-2013-2017)

Scope

This Recommendation specifies the protection criteria for data relay satellite systems and presents them in the form of I_0/N_0 values and provides a supporting analysis and text consistent with and relevant to the protection criteria.

Keywords

DRS, space-to-Earth, Earth-to-space, space-to-space, forward feeder link, return feeder link

Related ITU-R Recommendations

Recommendations ITU-R SA.510, ITU-R SA.1018, ITU-R SA.1019, ITU-R SA.1274, ITU-R SA.1275, ITU-R SA.1276, ITU-R SA.1414

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 Recommendation ITU-R SA.1414;

c) that preferred frequency bands for data relay satellite systems have been identified in Recommendation 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, but in some cases may be on the order of 1 dB;

g) that the link design margin for the space-to-space link is often the limiting factor;

h) that data relay satellite systems will transmit and receive signals in the space operation, space research, Earth exploration-satellite, fixed-satellite, and inter-satellite services;

i) that detailed technical information regarding protection criteria is contained in the Annex,

recommends

1 that protection criteria, specified in maximum aggregate interference power spectral density to system noise power density ratio, from all sources should not be exceeded for more than 0.1% of the time for the various links of data relay satellite systems as indicated in Table 1;

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* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4 and 5.

2 that the protection criteria in Table 1 should be used as the basis for developing sharing criteria in studies with other terrestrial and space systems.

TABLE 1

Protection criteria

Data relay satellite link	Receiver location	I_0/N_0 (dB)
Forward inter-orbit link	User spacecraft	
2 025-2 110 MHz 13.4-14.3 GHz 22.55-23.55 GHz		–10
Return inter-orbit link	Data relay satellite	
2 200-2 290 MHz 14.5-15.35 GHz 25.25-27.5 GHz		–10
Forward feeder link	Data relay satellite	
14.5-15.35 GHz 27.5-31.0 GHz		–6
Return feeder link	Earth station	
13.4-14.05 GHz 10.7-10.95 GHz 17.7-21.2 GHz 25.5-27 GHz (see Note)		–6

Note – In the frequency band 25.5-27 GHz, the return feeder link carries signals in the space research and Earth exploration-satellite services.

Annex

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 Recommendation ITU-R SA.1414.

These operations are dependent on space-to-space links, which are more difficult to design and implement than the space-to-Earth links 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 2-4 dB, but in some cases may be on the order of 1 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 is often the limiting factor, 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. 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.

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. This corresponds to a required ratio of interference power to system noise power (I/N) within the referenced bandwidth of at most –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 the 2 GHz band, the minimum data rate is likely to be around 1 kbit/s whereas for the higher frequency bands, it is likely to be at least 1 Mbit/s. Thus, the recommended value for the reference bandwidth in the 2 GHz band is 1 kHz and in the higher bands is 1 MHz.

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. For the space-to-space link, the percentage of time should be referenced to the period when the user satellite is in view of the corresponding data relay satellite (DRS), as this latter corresponds to the time when communications takes place, and receiving interference when communications does not take place is not relevant.

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-to-space links

The total noise temperature of a typical space-station receiver is generally 600 K at 2 GHz increasing to 1 200 K at 20 GHz when the spacecraft antenna points at the Earth (290 K). These noise values should be used when the actual values are not available in determining if the requirement for *I/N* of –10 dB is met.

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 DRS-to-Earth and Earth-to-DRS links

Table 2 shows some examples of the interaction between the two parts of the overall end-to-end link, both for return links and forward links, and for several different frequency bands. The link margins are typical values of representative system links. Since the links are typically "bent-pipe": i.e. there is no onboard processing at the DRS, noise is additive, so the overall link margin is determined by a cascaded combination of the individual link margins. In some cases, the two links have similar margins (e.g. Return 15 GHz/13 GHz) and so both links are about equally sensitive to noise. In other cases, the space-to-space link has a much lower margin than the feeder link (e.g. Return 2 GHz /13 GHz, Forward 15 GHz/13 GHz), so the former is much more sensitive to noise. This means that more interference can be allowed in the feeder links, so the *I*/*N* criterion is relaxed to –6 dB for those links.

TABLE 2

Interference into a data relay satellite

Return link	**Band →**	**2/13**		**15/13**	
User-to-DRS link	Margin at DRS (dB)	4.01	4.01	3.31	3.31
	Degradation (dB)	0.40	0.00	0.40	0.00
	Margin at DRS – degraded (dB)	3.61	4.01	2.91	3.31
DRS-to-Earth link	Margin at Earth (dB)	50.30	50.30	4.45	4.45
	Degradation (dB)	0.00	1.00	0.00	1.00
	Margin at Earth – degraded (dB)	50.30	49.30	4.45	3.45
End-to-end link	Margin – Total (dB)	4.01	4.01	0.83	0.83
	Degradation (dB)	0.40	0.00	0.23	0.46
	Margin Total – degraded (dB)	3.61	4.01	0.60	0.37
Forward link	**Band →**	**15/2**		**15/13**	
Earth-to-DRS link	Margin at DRS (dB)	35.04	35.04	23.63	23.63
	Degradation (dB)	0.00	1.00	0.00	1.00
	Margin at DRS – degraded (dB)	35.04	34.04	23.63	22.63
DRS-to-user link	Margin at user (dB)	3.90	3.90	3.50	3.50
	Degradation (dB)	0.40	0.00	0.40	0.00
	Margin at user – degraded (dB)	3.50	3.90	3.10	3.50
End-to-end link	Margin – Total (dB)	3.90	3.90	3.46	3.46
	Degradation (dB)	0.40	0.00	0.40	0.01
	Margin Total – degraded (dB)	3.50	3.90	3.06	3.45