RECOMMENDATION ITU-R SA.1163-2

INTERFERENCE CRITERIA FOR SERVICE LINKS IN DATA COLLECTION SYSTEMS IN THE EARTH EXPLORATION-SATELLITE AND METEOROLOGICAL-SATELLITE SERVICES

(Question ITU-R 142/7)

(1995-1997-1999)

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference system specified in Recommendation ITU-R SA.1020 defines links for data collection, and data collection platform interrogation;

b) that interference criteria are needed to ensure that systems can be designed to achieve adequate performance in the presence of interference;

c) that the interference criteria may be determined using the methodology described in Recommendation ITU-R SA.1022 and the performance objectives listed in Recommendation ITU-R SA.1162;

d) that interference criteria assists in the development of criteria for sharing bands among systems, including those operating in other services;

e) that systems in the Earth exploration-satellite (including meteorological-satellite) service must accept an interference threshold at least as high as the threshold of permissible interference;

f) that Annex 1 presents the parameters of representative systems that provide the basis for permissible levels of interference for pertinent transmissions in the Earth exploration-satellite service,

recommends

1 that the interference levels specified in Table 1 be used as the permissible total levels of interfering signal power at the antenna output of stations operating for service links in the Earth exploration-satellite and meteorological-satellite services.

TABLE 1

Interference criteria for service links of stations in the Earth exploration-satellite and meteorological-satellite services

Frequency band (MHz)	Function and type of earth station	Station subject to interference	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than *p*% of the time
401-403 Earth-to-space	Non-GSO data collection, low-gain antenna	Space station	–178.8 dBW per 1 600 Hz(1)	–174.7 dBW per 1 600 Hz(1) $p = 0.1$
137-138 space-to-Earth	Non-GSO data collection, command and data acquisition (CDA) station	Earth station	–158.3 dBW per 8.32 kHz(1)	–151.1 dBW per 8.32 kHz(1) $p = 0.1$
401-403 Earth-to-space	GSO data collection, low-gain antenna	Space station	–187.4 dBW per 100 Hz(2)	–173.4 dBW per 100 Hz(3) $p = 0.1$
1 670-1 690 space-to-Earth	GSO data collection, CDA station	Earth station	–194.0 dBW per 100 Hz(2)	–181.5 dBW per 100 Hz(3) $p = 0.025$

TABLE 1 (*end*)

Frequency band (MHz)	Function and type of earth station	Station subject to interference	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than *p*% of the time
2 025-2 110 Earth-to-space	GSO data collection, CDA station	Space station	–188.9 dBW per 100 Hz(2)	–183.7 dBW per 100 Hz(3) p = 0.025
460-470 space-to Earth	GSO data collection platform interrogation	Earth station	–187.3 dBW per 100 Hz(2)	–182.1 dBW per 100 Hz(3) p = 0.1

(1) The interfering signal powers (dBW) in the reference bandwidths are specified for reception at elevation angles > 5°.

(2) The interfering signal powers (dBW) in the reference bandwidths are specified for reception at elevation angles > 3°.

(3) The interfering signal powers (dBW) in the reference bandwidths are specified for reception at elevation angles > 0°.

NOTE 1 – The total interfering signal power level that may be exceeded for no more than *x*% of the time, where *x* is less than 20% but greater than the specified short-term time percentage (*p*% of the time), may be determined by interpolation between the specified values using a logarithmic scale (base 10) for percentage of time and a linear scale for interfering signal power density (dB).

NOTE 2 – Although the interference criteria are based on the systems described in Annex 1, the interference criteria apply to all systems that operate in the subject frequency bands and which provide the specified service functions.

NOTE 3 – The interference criteria are specified with respect to the percentage of time of reception by the earth station. Thus, receiver performance statistics associated with reception from or by one particular satellite (i.e., cumulative distribution of bit error rate (BER)) are the same as the statistics for reception from several similar satellites. The total time of reception includes time periods associated with signal acquisition (i.e. before and during local ascension of the satellite), receiver synchronization to the data, and synchronized reception of data. Consequently, for interrogation by satellites in low-Earth orbit, the time required for initial signal acquisition and synchronization may constitute up to several tens of seconds out of total satellite visibility periods averaging on the order of 9 min. However, the analyses of short-term performance that are presented in Annex 1 (i.e., performance exceeded for all but a small percentage of time p, $p \leq 1\%$) assume that the satellite is located at the minimum elevation angle associated with the applicable performance objective. This yields the BER performance exceeded for all but *p*% of the time because E_b/N_0 and BER are monotonically related to elevation angle.

NOTE 4 – The elevation angle exceeded for all but 20% of the time during reception is well approximated by the angle exceeded for all but 20% of the time that the satellite is visible above the minimum elevation angle specified in the performance objective. This approximation is made in the performance analyses presented in Annex 1 because the underlying cumulative time error cannot exceed 1% (i.e. *p*% of the time) and the associated total error in satellite antenna gain, free space loss, excess path loss, and earth station parameter values are negligible. The resulting elevation angle that is exceeded for all but 20% of the time of reception yields the BER performance exceeded for all but 20% of the time because E_b/N_0 and BER are monotonically related to elevation angle.

NOTE 5 – Data collection platform interrogation from non-GSO satellites will be available in the near future.

ANNEX 1

Basis for interference criteria

1 Introduction

This Annex presents the parameters used as inputs to the methodology described in Recommendation ITU-R SA.1022 to determine the interference criteria.

2 Meteorological-satellite service in the 401-403 MHz band uplink

2.1 ARGOS interfering criteria

The ARGOS data collection system (DCS) uplink (see Fig. 2) transmits split-phase, Manchester-encoded, phase-shift keyed (PSK) signals through satellites in low-Earth orbit and operates at a 400 bit/s data transmission rate. The data collection platform (DCP) typically uses a low-gain (5 dBi maximum at 20° elevation angle) antenna and can be a mobile or fixed platform.

The satellite DCS processor regenerates the uplink DCS data, multiplexes the data with other telemetry, and transmits the digital data to the ground in the 137-138 MHz band. Because of the DCS data regeneration in the satellite, downlink performance can be separated from uplink performance in deriving interference criteria. Figure 1 provides statistics of the ARGOS DCS uplink power measured at the satellite receiver. Table 2 provides the basis for developments of the ARGOS interference criteria.

FIGURE 1

ARGOS DCS uplink (measurements)

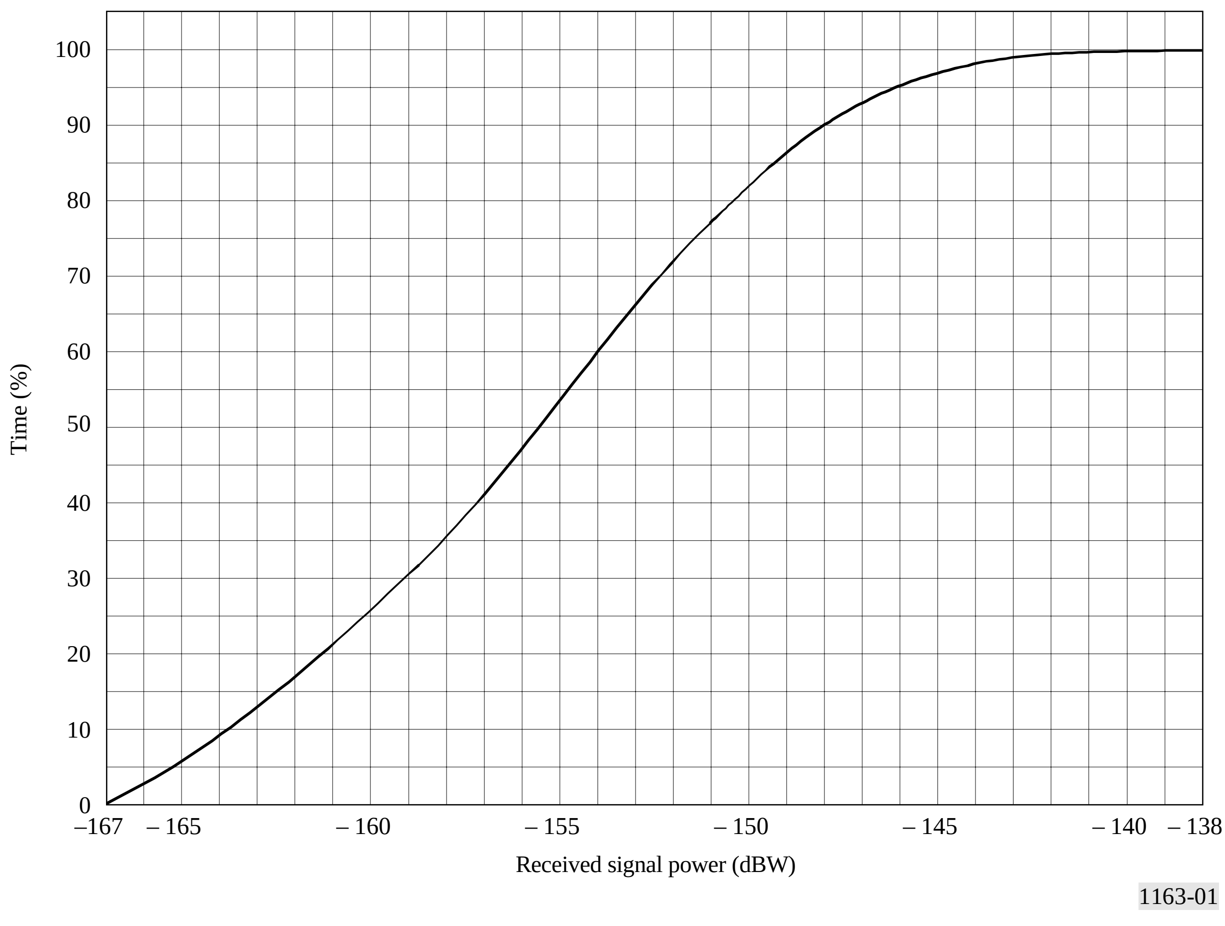


TABLE 2

System performance used as a basis for DCS interference criteria when using low orbiting satellites

Parameter	Value	Notes
Short-term (0.1%) uplink received power	–167 dBW	From Fig. 1
Long-term (20%) uplink received power	–161 dBW	From Fig. 1
Uplink noise temperature	600 K	
Short-term uplink C/N_0	33.8 dB/Hz	
Long-term uplink C/N_0	39.8 dB/Hz	
Data rate	400 bit/s	
Required uplink C/N_0	38.8 dB/Hz	BER = 1×10^{-5} 2 dB implementation loss 1.0 dB modulation loss
Short-term uplink margin	–5.0 dB	
Long-term uplink margin	1.0 dB	
Long-term uplink interference criterion	–178.8 dB(W/1.6 kHz)	$q = 1/3$, $M_{min} = 1.2$ dB
Short-term uplink interference criterion	–174.7 dB(W/1.6 kHz)	$q = 1$, $M_{min} = 1.0$ dB
Downlink e.i.r.p.	–17.5 dBW	
Downlink loss	145.8 dB	
Downlink G/T	–5.6 dB(K^{-1})	
Downlink C/N_0	59.7 dB/Hz	
Data rate	8.32 bit/s	
Required downlink C/N_0	53.4 dB/Hz	BER = 1×10^{-6} 3 dB implementation loss 0.7 dB modulation loss
Downlink margin	6.3 dB	
Noise power density	–195.4 dB(W/Hz)	
Long-term downlink interference criterion	–158.3 dB(W/8.32 kHz)	$q = 1/3$
Short-term downlink interference criterion	–151.1 dB(W/8.32 kHz)	$q = 1$

2.2 Interference to the GOES DCPR links

DCPs in the GOES DCS transmit Manchester-encoded BPSK signals (DCP reports) in the 401-403 MHz band to the GOES satellite at a data rate of 100 bit/s. The satellite relays these DCP reports (DCPR) to the CDA station in the 1 670-1 690 MHz band. The satellite transponder, which is channelized to accommodate several hundred simultaneous DCPR transmissions, has an automatic gain control (AGC) that maintains the downlink DCPR e.i.r.p. constant regardless of the transponder input power. Because the DCPR data are not regenerated in the satellite, the DCPR signals must share this fixed downlink power with interfering signals that enter the satellite transponder in the 401-403 MHz band. Moreover, interfering signals transmitted directly into the CDA station in the 1 670-1 690 MHz band will further affect DCPR performance.

The signal power received at the CDA station from a DCP via the GOES satellite is:

$$C = E_1 G_1 G_S G_2 / L_1 L_2$$

where:

E_1: DCP e.i.r.p.

G_1: satellite receive antenna gain

G_2: CDA station receive antenna gain

L_1 and L_2: uplink and downlink losses

G_S: satellite gain (excluding the satellite receive antenna).

The noise power density and interference power density at the input to the CDA station receiver are respectively:

$$N_0 = k\left(T_1 \frac{G_S G_2}{L_2} + T_2\right)$$

$$I_0 = I_{01} \frac{G_S G_2}{L_2} + I_{02}$$

where:

T_1 and T_2: satellite and station system noise temperatures

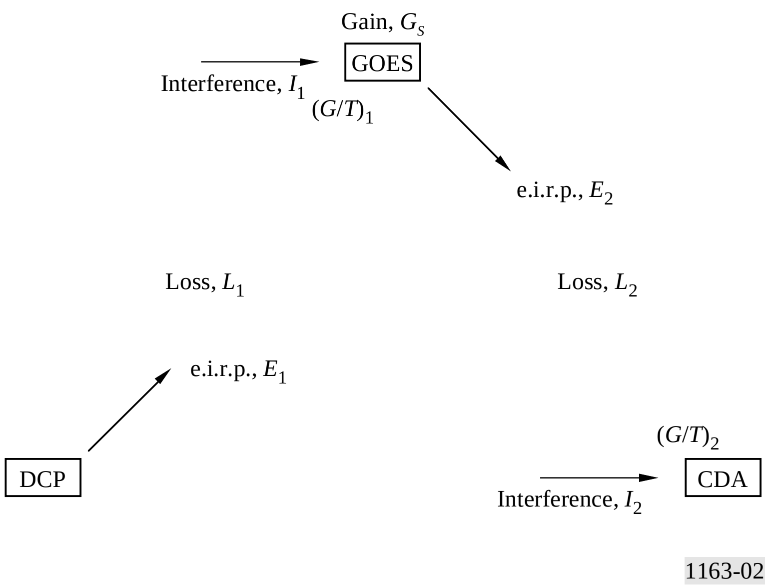
I_{01} and I_{02}: interference power densities transmitted into the satellite and into the CDA station

k: Boltzmann's constant.

Figure 2 illustrates these parameters.

FIGURE 2

GOES DCPR link parameters



From these equations, the carrier-to-noise plus interference density ratio at the input to the station receiver can be determined:

$$\frac{C}{N_0 + I_0} = \frac{E_1 \, (G/T)_1 / k \, L_1}{1 + \frac{I_{01}}{k \, T_1} + \frac{L_2}{T_1 \, G_S \, (G/T)_2} \left(1 + \frac{I_{02}}{k \, T_2} \right)}$$

Because the satellite e.i.r.p., E_2, is maintained constant by the AGC, G_S varies with the transponder input power as follows:

$$G_S = \frac{E_2}{\frac{P \, G_1}{L_1} + k \, T_1 \, B + I_{01} \, B}$$

where the denominator is the transponder input power. P is the sum of the DCP e.i.r.p.s accessing the satellite transponder, and B is the transponder bandwidth. To avoid the need to consider a variety of possible DCP locations, it is assumed that G_1/L_1 is the same for all DCPR links. It will be assumed that the interference allocation at the station receiver is such that a fraction p is received via the satellite and a fraction $1 - p$ is transmitted directly into the CDA station. Then:

$$I_{02} = \frac{1 - p}{p} \, \frac{I_{01} \, G_S \, G_2}{L_2}$$

From Recommendation ITU-R SA.1022, the carrier-to-noise plus interference density ratio can be expressed as:

$$\frac{C}{N_0 + I_0} = M^{-q} \, \frac{C}{N_0}$$

where M is the interference-free margin, and q is the fraction of the interference-free margin that is allowed to be consumed by the interference. From the foregoing equations:

$$\frac{C}{N_0} = \frac{E_1 \left(G/T \right)_1 / k \, L_1}{1 + \frac{L_2}{E_2 \left(G/T \right)_2} \left[\frac{P}{L_1} \left(G/T \right)_1 + k \, B \right]}$$

is the interference-free carrier-to-noise density ratio, and:

$$M^q = 1 + \frac{\frac{I_{01}}{k \, T_1} \left[\frac{1}{p} + \frac{L_2 \, k \, B}{E_2 \, (G/T)_2} \right]}{1 + \frac{L_2}{E_2 \, (G/T)_2} \left[\frac{P \, (G/T)_1}{L_1} + k \, B \right]}$$

is the factor by which interference degrades C/N_0. The permissible interference density at the satellite receiver input is therefore $I_{01} = k \, T_1 \, Q_1$, where:

$$Q_1 = (M^q - 1) \, \frac{1 + \frac{L_2}{E_2 \, (G/T)_2} \left[\frac{P \, (G/T)_1}{L_1} + k \, B \right]}{\frac{1}{p} + \frac{L_2 \, k \, B}{E_2 \, (G/T)_2}} \qquad \text{for } M > M_{min}$$

where M_{min} is the smallest interference-free margin for which only a fraction q of the margin is consumed by the interference. Correspondingly, the permissible interference density transmitted directly into the CDA station receiver in the 1 690-1 700 MHz band is $I_{02} = k\, T_2\, Q_2$, where:

$$Q_2 = \frac{1-p}{p}\, Q_1 \; \frac{E_2\,(G/T)_2\,/\,L_2}{\frac{P\,(G/T)_1}{L_1} + k\,B\,(1 + Q_1)} \qquad \text{for } M > M_{min}$$

Individual DCPs assigned to a given DCPR channel time-share that channel, the bandwidth of which is 1.5 kHz. Measurements of DCP e.i.r.p. in one GOES DCPR channel over a 24 h period have provided the statistics summarized in Table 3. Assuming that all DCPs assigned to a given channel time-share the channel equally, these data show that 20% of the time the e.i.r.p. will be 11 dBW or less, and that 0.1% of the time the e.i.r.p. will be 5 dBW or less. Permissible long-term interference will therefore be based on a short-term e.i.r.p. of 5 dBW, and permissible short-term interference will be based on a long-term e.i.r.p. of 11 dBW.

TABLE 3

DCPR e.i.r.p. statistics

e.i.r.p. of a single DCP in the channel (dBW)	Number of DCPs having this e.i.r.p. in the channel	Number of DCPs having this e.i.r.p. or less
4	0	0
5	3	3
6	1	4
7	4	8
8	0	8
9	5	13
10	17	30
11	12	42
12	12	54
13	16	70
14	28	98
15	36	134
16	46	180
17	34	214
18	5	219
19	1	220
20	0	220

Table 4 lists the values of the link parameters assumed in the calculation of the permissible interference densities I_{01} and I_{02}. To determine the total DCP e.i.r.p., the number of DCPR channels being occupied simultaneously must be postulated. Assuming an average DCP e.i.r.p. of 15 dBW, and assuming that 100 DCPR channels are simultaneously active, the sum P of the DCP e.i.r.p.s will be 35 dBW. Assume also that the interference allocation at the station receiver is split 50-50 between that received via the satellite and that transmitted directly into the station receiver, so that $p = 1/2$. Assume finally that $q = 1/3$ and $M_{min} = 1.2$ dB for long-term interference, and that $q = 1$ and $M_{min} = 1.2$ dB for short-term interference. Then, substituting the values from Table 4 into the equations given above for the interference densities, it is found that the interference criteria for the GOES DCPR service become:

I_{01} (long-term) = –207.4 dB(W/Hz), or –187.4 dB(W/100 Hz)

I_{01} (short-term) = –193.4 dB(W/Hz), or –173.4 dB(W/100 Hz)

I_{02} (long-term) = –214.0 dB(W/Hz), or –194.0 dB(W/100 Hz)

I_{02} (short-term) = –201.5 dB(W/Hz), or –181.5 dB(W/100 Hz)

TABLE 4

DCPR link parameters

Parameter	Value	Notes
E_1 (short-term)	5 dBW	From measured e.i.r.p. statistics
E_1(long-term)	11 dBW	From measured e.i.r.p. statistics
P	35 dBW	100 DCS channels
L_1	177.1 dB	Free-space and polarization loss
$(G/T)_1$	–18.0 dB(K^{-1})	
B	400 kHz	
E_2	3.7 dBW	
L_2	190.1 dB	Free-space, polarization, and pointing loss
$(G/T)_2$	26.0 dB(K^{-1})	
T_1	395 K	
T_2	100 K	
Data rate	100 bit/s	
$(C/N_0)_{required}$	31.6 dB/Hz	BER = 1×10^{-4} 2 dB implementation loss 1.2 dB modulation loss

3 Meteorological-satellite service in the 460-470 MHz band downlink

Geostationary satellites relay BPSK-modulated DCP interrogations (DCPI) from the CDA station in the 2 025-2 110 MHz band to the DCPs in the 460-470 MHz band. The satellite transponder is a hard-limiter that maintains the downlink DCPI e.i.r.p. constant. The downlink must therefore share its fixed power with interfering signals entering the transponder in the 2 025-2 110 MHz band. Interfering signals transmitted directly into the DCP receiver in the 460-470 MHz band further affect DCPI performance.

3.1 Interference to the GOES DCPI links

Though the satellite DCPI transponder is hard-limiting rather than linear, downlink power sharing is much the same as it is for the DCPR transponder. The equations given above for the DCPR service apply for the DCPI service as well, provided we neglect the effects of intermodulation and small-signal suppression caused by the limiting. Table 5 lists the values of the link parameters assumed for the DCPI service. As in the DCPR service, assume that $q = 1/3$ for long-term interference and that $q = 1$ for short-term interference. Assume also that $p = 1/2$ and $M_{min} = 1.2$ dB. Then, substituting the values from Table 5 into the equations given above for the interference densities, it is found that the interference criteria for the DCPI service become:

$$I_{01} \text{ (long-term)} = -186.4 \text{ dB(W/100 Hz)}$$

$$I_{01} \text{ (short-term)} = -180.5 \text{ dB(W/100 Hz)}$$

$$I_{02} \text{ (long-term)} = -201.8 \text{ dB(W/100 Hz)}$$

$$I_{02} \text{ (short-term)} = -197.9 \text{ dB(W/100 Hz)}$$

TABLE 5

DCPI link parameters

Parameter	Value	Notes
E_1	55.7 dBW	
P	55.7 dBW	One DCPI signal
L_1	191.7 dB	Free-space, polarization and pointing loss
$(G/T)_1$	–18.4 dB(K^{-1})	
B	200 kHz	
E_2	15.0 dBW	
L_2	178.5 dB	Free-space, polarization, and pointing loss
$(G/T)_2$	–29.3 dB(K^{-1})	
T_1	570 K	
T_2	1 338 K	
Data rate	100 bit/s	
$(C/N_0)_{required}$	33.0 dB/Hz	BER = 1×10^{-5} 2 dB implementation loss 1.2 dB modulation loss