RECOMMENDATION ITU-R SA.1026-3

INTERFERENCE CRITERIA FOR SPACE-TO-EARTH DATA TRANSMISSION SYSTEMS OPERATING IN THE EARTH EXPLORATION-SATELLITE AND METEOROLOGICAL-SATELLITE SERVICES USING SATELLITES IN LOW-EARTH ORBIT

(Questions ITU-R 139/7 and ITU-R 141/7)

(1994-1995-1997-1999)

The ITU Radiocommunication Assembly,

considering

a) that the hypothetical reference system specified in Recommendation ITU-R SA.1020 defines space-to-Earth links for a number of functions including the direct readout of data and acquisition of recorded data;

b) that interference criteria are needed to ensure that systems can be designed to achieve adequate performance in the presence of interference and to assist in developing criteria for sharing bands among systems, including those operating in other services;

c) that spacecraft operating in the Earth exploration-satellite and meteorological-satellite services may utilize low-Earth orbits;

d) that performance objectives for the relevant space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services are specified in Recommendation ITU-R SA.1025 for several frequency bands;

e) that, although specific data transmission systems may have performance objectives that differ from those recommended for the Earth exploration-satellite and meteorological-satellite services, all systems operating in those services should accommodate interference thresholds greater than or equal to the permissible levels of interference that are recommended for the services;

f) that interference criteria for data transmission systems in the Earth exploration-satellite and meteorological-satellite services may be derived by using the methods in Recommendation ITU-R SA.1022;

g) that Annex 1 presents the parameters of representative systems that provide the basis for permissible levels of interference for space-to-Earth transmissions in the Earth exploration-satellite and meteorological-satellite services in some frequency bands,

recommends

1 that the interference levels for the frequency bands specified in Table 1 be used as the permissible total levels of interfering signal power at the antenna output of earth stations operating in the Earth exploration-satellite and meteorological-satellite services with satellites in low-Earth orbit;

2 that, in shared frequency bands, the interference thresholds of specific systems must be greater than or equal to the values recommended in Table 1.

TABLE 1

Interference criteria for Earth exploration-satellite and meteorological-satellite earth stations using spacecraft in low-Earth-orbit

Frequency band	Type of earth station	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
137-138 MHz	Analogue receiver 2 dBic antenna gain Direct data readout	–151 dBW per 50 kHz(1)	–145 dBW per 50 kHz(1) *p* = 0.025
	Digital receiver 10 dBic antenna gain Direct data readout	–141 dBW per 150 kHz(2)	–133 dBW per 150 kHz(2) *p* = 0.025
	Digital receiver 2 dBic antenna gain Direct data readout	–142 dBW per 150 kHz(1)	–136 dBW per 150 kHz(1) *p* = 0.025
400.15-401.00 MHz	0 dBic antenna gain Direct data readout	–158 dBW per 177.5 kHz(2)	–147 dBW per 177.5 kHz(2) *p* = 0.025
1 696-1 710 MHz	46.8 dBic(3) antenna gain Recorded data acquisition	–128 dBW per 5 334 kHz(2)	–121 dBW per 5 334 kHz(2) *p* = 0.025
	29.8 dBic(3) antenna gain Direct data readout	–147 dBW per 2 668 kHz(2)	–138 dBW per 2 668 kHz(2) *p* = 0.025
7 750-7 850 MHz	54.0 dBic antenna gain Recorded data acquisition	–128 dBW per 100 MHz(2)	–115 dBW per 100 MHz(2) *p* = 0.025
8 025-8 400 MHz	55.2 dBic antenna gain Recorded data acquisition	–131 dBW per 100 MHz(2)	–117 dBW per 100 MHz(2) *p* = 0.025
	42.5 dBic antenna gain Direct data readout (System A)	–136 dBW per 40 MHz(2)	–125 dBW per 40 MHz(2) *p* = 0.25
	56.3 dBic antenna gain Direct data readout (System B)	–125 dBW per 40 MHz(2)	–116 dBW per 40 MHz(2) *p* = 0.25
25.5-27.0 GHz	55.2 dBic antenna gain Recorded data acquisition	–134 dBW per 10 MHz(2)	–118 dBW per 10 MHz(2) *p* = 0.25
	42.5 dBic antenna gain Direct data readout	–137 dBW per 10 MHz(2)	–120 dBW per 10 MHz(2) *p* = 0.25
	42.5 dBic antenna gain High-speed direct data readout	–136 dBW per 10 MHz(2)	–122 dBW per 10 MHz(2) *p* = 0.25

(1) The interfering signal powers (dBW) in the reference bandwidths are specified for reception at elevation angles ≥ 25°.

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

(3) The justification of 1 696-1 710 MHz is given in Annex 1, § 4.

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 – The interference criteria can be expressed as permissible power flux-densities into the main beam of the receive antenna by subtracting $10 \log(G\,\lambda^2/4\pi)$ from the values given in Table 1, where G is the receive antenna gain and λ is the wavelength.

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 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 initial signal acquisition (i.e. before and during local ascension of the satellite), receiver synchronization of the data, and synchronized reception of data. Consequently, because 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 nine minutes, 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 approximated well 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 – For frequency bands other than those of Table 1, the interference criterion of Recommendation ITU-R SA.514 is applicable.

ANNEX 1

Basis for interference criteria

1 Introduction

This Annex presents the parameters used with the methodology of Recommendation ITU-R SA.1022 in the derivation of interference criteria for the Earth exploration-satellite and meteorological-satellite services using the performance objectives specified in Recommendation ITU-R SA.1025 for some frequency bands. The requisite performance analyses are summarized in Table 2. The prominent considerations for each band are discussed below. In all cases, the representative systems utilize satellites in highly-inclined circular orbits.

2 Meteorological-satellite service in the 137-138 MHz band

The performance analysis for an automatic picture transmission (APT) system in 137-138 MHz band assumes a satellite altitude of 844 km. The APT system uses analogue modulation with a bandwidth of 50 kHz. The performance analysis for the low resolution picture transmission (LRPT) system in the 137-138 MHz band assumes the same satellite altitude. It is anticipated that the APT system will be phased out around the year 2005, and that the LRPT system will be implemented around the year 2000.

The LRPT transmissions are digital (Nyquist-filtered QPSK modulation) and operate at a nominal data transmission rate of 72 kbit/s including concatenated Reed-Solomon/convolutional coding with interleaving. Two types of earth stations are foreseen to operate in LRPT systems:

– an earth station with an unsteered antenna having low gain 2 dBic that provides local data (i.e. meteorological data for areas on the order of 1 000 km from the earth station), and

– an earth station with a steerable antenna having a gain of 10 dBic that provides regional data (i.e. meteorological data for areas extending to over 2 000 km from the earth station). Earth stations may be mobile or transportable.

Only omnidirectional type antennas having low gain (e.g. 2 dBic) typically operate in APT systems.

In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

Analogue receiver	*Digital receiver*
q (long-term) = 0.3 to 0.6 q (short-term) = 1	q (long-term) = 0.3 to 0.6 q (short-term) = 1
M_{min} (long-term) = M_{min} (short-term) = 0.8 dB	M_{min} (long-term) = M_{min} (short-term) = 1.2 dB

TABLE 2

Performance analyses used as a basis for interference criteria

Frequency band (MHz)	137-138		137-138		137-138	
Type of earth station	Low gain earth station (APT)		Tracking earth station (LRPT)		Low gain earth station (LRPT)	
Percentage of time, *p*	0.1	20	0.1	20	0.1	20
Elevation angle (exceeded for *p*)	25°	30°	5°	13°	25°	30°
Satellite antenna input power (dBW)	4.9		6.8		6.8	
Satellite antenna gain (dBic)	0.7	1.1	–1.2	–0.5	0.7	1.1
Satellite e.i.r.p. (dBW)	5.6	6.0	5.6	6.3	7.5	7.9
Free space loss (dB)	139.4	138.5	144.3	142.2	139.4	138.5
Excess path loss (dB)	0.2		0.1	0.1	0.1	
Earth station antenna gain (dBic)	2.0		10.0	10.0	2.0	
Antenna mispointing loss (dB)	0.0		0.0	0.0	0.0	
Polarization mismatch loss (dB)	1.5		1.5	1.5	1.5	
Modulator and demodulator losses (dB)	0.0		2.0	2.0	2.0	
Receiver reference bandwidth (kHz)	50		150		150	
Data rate (dB/Hz)	45.7 occupied bandwidth		48.6		48.6	
Received energy per bit E_b(dB(W/Hz))	–179.9 (C_0)	–177.9 (C_0)	–180.9	–178.1	–182.1	–180.8
Receiver system noise temperature (K)	2 520		1 750		1 750	
Thermal noise power density (dB(W/Hz))	–194.6		–195.7		–195.7	
Non-thermal receiver noise power density (dB(W/Hz))	–		–		–	
Total internal noise power density N_0 (dB(W/Hz))	–194.6		–195.7		–195.7	
E_b/N_0 (dB)	15.4 (C_0/N_0)	16.7 (C_0/N_0)	14.8	17.6	13.6	14.9
Link bit-error ratio	–		10^{-10}		$< 10^{-10}$	
Satellite data handling error ratio	–		–		–	
Overall received bit-error ratio	–		$< 10^{-10}$		$< 10^{-10}$	
Threshold E_b/N_0 (or C/N) (dB)	12.0		6.5		6.5	
Power margin (dB)	3.4	4.7	8.3	11.1	7.1	8.4
q factor (lt: long-term, st: short-term)	0.5 (1t)	1 (st)	0.6 (lt)	1 (st)	0.6 (lt)	1 (st)
M_{min} (dB)	0.8		1.2		1.2	

TABLE 2 (*continued*)

Frequency band (MHz)	400.15-401.00		1 670-1 710		1 670-1 710	
Type of earth station	Non-tracking antenna (omnidirectional)		Recorded data acquisition		Direct data readout	
Percentage of time, *p*	0.1	20	0.1	20	0.1	20
Elevation angle (exceeded for *p*)	5°	13°	5°	13°	5°	13°
Satellite antenna input power (dBW)	11.1		6.1		6.1	
Satellite antenna gain (dBic)	0.0	0.0	2.1	2.0	2.1	2.0
Satellite e.i.r.p. (dBW)	11.1	11.1	8.2	8.1	8.2	8.1
Free space loss (dB)	153.6	151.4	166.3	164.0	166.3	164.0
Excess path loss (dB)	0.2		0.2	0.0	0.2	
Earth station antenna gain (dBic)	0.0		46.8		29.8	
Antenna mispointing loss (dB)	0.0		0.5		0.5	
Polarization mismatch loss (dB)	0.3		0.2		0.5	
Modulator and demodulator losses (dB)	2.0		2.7		2.7	
Receiver reference bandwidth (kHz)	177.5		5 334		2 668	
Data rate (dB/Hz)	49.5		64.2		58.2	
Received energy per bit E_b(dB(W/Hz))	–194.5	–192.3	–179.1	–176.7	–190.4	–188.2
Receiver system noise temperature (K)	400		320	210	370	240
Thermal noise power density (dB(W/Hz))	–202.6		–203.5	–205.4	–202.9	–204.8
Non-thermal receiver noise power density (dB(W/Hz))	–211.7		–202.4		–204.2	
Total internal noise power density N_0 (dB(W/Hz))	–202.1		–199.9	–200.6	–200.5	–201.5
E_b/N_0 (dB)	7.6	9.8	20.8	23.9	10.1	13.3
Link bit-error ratio	$< 10^{-8}$	$< 10^{-10}$	$<10^{-12}$		6×10^{-5}	$<10^{-9}$
Satellite data handling error ratio	–	–	5×10^{-7}		–	–
Overall received bit-error ratio	$< 10^{-8}$	$< 10^{-10}$	5×10^{-7}		6×10^{-5}	$<10^{-9}$
Threshold E_b/N_0 (or C/N) (dB)	5.5	5.5	11.2		10.5	10.5
Power margin (dB)	2.1	4.3	9.6	12.7	0.0	2.8
q factor (lt: long-term, st: short-term)	0.33 (1t)	1 (st)	0.6 (lt)	1 (st)	0.33 (lt)	1 (st)
M_{min} (dB)	1.2		1.2		1.2	

TABLE 2 (*continued*)

Frequency band (MHz)	7 750-7 850		8 025-8 400		8 025-8 400	
Type of earth station	Recorded data readout		Recorded data acquisition		Direct data readout (System A)	
Percentage of time, *p*	0.1	20	0.1	20	1.0	20
Elevation angle (exceeded for *p*)	5°	13°	5°	13°	5°	13°
Satellite antenna input power (dBW)	14.1		16.9		16.9	
Satellite antenna gain (dBic)	2.1	2.0	2.1	2.0	6.1	6.1
Satellite e.i.r.p. (dBW)	16.2	16.1	19.0	18.9	23.0	
Free space loss (dB)	179.1	176.8	181.0	178.7	181.0	178.7
Excess path loss (dB)	3.5	0.5	3.7	0.6	0.7	0.6
Earth station antenna gain (dBic)	54.0		55.2		42.5	
Antenna mispointing loss (dB)	0.5		0.5		0.5	
Polarization mismatch loss (dB)	0.2		0.5		0.5	
Modulator and demodulator losses (dB)	2.0		2.0		2.0	
Receiver reference bandwidth (MHz)	100		100		40	
Data rate (dB/Hz)	77.0		77.0		73.0	
Received energy per bit E_b(dB(W/Hz))	–192.1	–186.9	–190.5	–185.2	–192.2	–189.8
Receiver system noise temperature (K)	320	210	266	240	292	275
Thermal noise power density (dB(W/Hz))	–203.5	–205.4	–204.3	–204.8	–203.9	–204.2
Non-thermal receiver noise power density (dB(W/Hz))	–	–	–	–	–	–
Total internal noise power density N_0 (dB(W/Hz))	–203.5	–205.4	–204.3	–204.8	–203.9	–204.2
E_b/N_0 (dB)	11.4	18.5	13.8	19.6	11.7	14.4
Link bit-error ratio	$< 10^{-10}$		$< 10^{-9}$	$< 10^{-10}$	$< 10^{-7}$	$< 10^{-10}$
Satellite data handling error ratio	5×10^{-7}		5×10^{-7}		–	–
Overall received bit-error ratio	5×10^{-7}		5×10^{-7}		$< 10^{-7}$	$< 10^{-10}$
Threshold E_b/N_0 (or C/N) (dB)	7.2		11.2		9.7	
Power margin (dB)	4.2	11.3	2.6	8.4	2.0	4.7
q factor (lt: long-term. st: short-term)	0.33 (lt)	1 (st)	0.33 (lt)	1 (st)	0.33 (lt)	1 (st)
M_{min} (dB)	1.2		1.2		1.2	

TABLE 2 (*end*)

Frequency band (MHz)	8 025-8 400		25 500-27 000					
Type of earth station	Direct data readout (System B)		Recorded data acquisition		Direct data readout		Direct high-speed data readout	
Percentage of time, *p*	1.0	20.0	0.1	20.0	0.1	20.0	0.1	20.0
Elevation angle (exceeded for *p*)	5°	13°	5°	13°	5°	13°	5°	13°
Satellite antenna input power (dBW)	1.8		13.0		13.0		13.0	14.8
Satellite antenna gain (dBic)	25.3		28.0		25.0		39.1	
Satellite e.i.r.p. (dBW)	27.0		41.0		38.0		52.1	53.9
Free space loss (dB)	178.7	176.3	189.0	186.6	189.0	186.6	188.8	186.4
Excess path loss (dB)	2.5	0.6	6.4	1.0	6.4	1.0	6.4	1.0
Earth station antenna gain (dBic)	56.3		55.2		42.5		42.5	38.0
Antenna mispointing loss (dB)	0.5		0.5		0.5		0.5	
Polarization mismatch loss (dB)	0.2		0.2		0.2		0.2	
Modulator and demodulator losses (dB)	3.0		2.0		2.0		2.0	
Receiver reference bandwidth (MHz)	320.0		1 340.0		53.6		1 340.0	
Data rate (dB/Hz)	85.1		90.0		76.0		90.0	
Received energy per bit E_b(dB(W/Hz))	–186.4	–182.1	–191.9	–184.1	–193.6	–185.8	–193.3	–188.2
Receiver system noise temperature (K)	360	342	715.9	557.6	715.9	557.6	552.7	272.8
Thermal noise power density (dB(W/Hz))	–203.0	–203.3	–200.1	–201.1	–200.1	–201.1	–201.2	–204.2
Non-thermal receiver noise power density (dB(W/Hz))	–	–	–	–	–	–	–	–
Total internal noise power density N_0 (dB(W/Hz))	–203.0	–203.3	–200.1	–201.1	–200.1	–201.1	–201.2	–204.2
E_b/N_0 (dB)	16.6	21.2	8.2	17.0	6.5	15.3	7.9	16.1
Link bit-error ratio	$< 10^{-5}$	$< 10^{-7}$	10^{-6}		10^{-6}		10^{-6}	
Satellite data handling error ratio	–		5×10^{-7}		–		–	
Overall received bit-error ratio	$< 10^{-5}$	$< 10^{-7}$	1.5×10^{-6}		10^{-6}		10^{-6}	
Threshold E_b/N_0 (or C/N) (dB)	9.6		3.9	3.9	3.9	3.9	3.9	3.9
Power margin (dB)	7.0	11.6	4.3	13.1	2.6	11.4	4.0	12.2
q factor (lt: long-term, st: short-term)	0.6 (lt)	1 (st)	0.33 (lt)	1 (st)	0.33 (lt)	1 (st)	0.33 (lt)	1 (st)
M_{min} (dB)	1.2		1.2		1.2		1.2	

3 Meteorological-satellite service in the 400.15-401 MHz band

The performance analysis for the Block 5D system assumes a satellite altitude of 833 km. The data from spacecraft sensors is multiplexed into a data stream having a rate of 88.75 kbit/s, which is rate-one-half convolutionally encoded for error correction. The associated earth stations typically are mobile, which enables antenna designs that yield only 0 dBic gain.

In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

$$q \text{ (long-term)} = 0.3 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB.}$$

4 Meteorological-satellite service at 1 670-1 710 MHz and the Earth exploration-satellite service at 1 690-1 710 MHz

The performance analyses for high resolution picture transmission (HRPT) and command and data acquisition (CDA) systems using large and small earth stations, respectively, assume a satellite altitude of 844 km. These systems receive transmissions from the same satellite, which employs a shaped-beam antenna that partially offsets the increased propagation losses toward the Earth limb as compared to nadir. The deviation of the satellite’s phase shift keying modulator is about 67°, which results in a residual carrier to facilitate signal acquisition and coherent demodulation. This slightly reduces the data signal power. For the large station, a 2.667 Mbit/s data rate and NRZ-L coding are used, which yields a reference bandwidth of 5.334 MHz. For the small station, a baseband data rate of 0.667 Mbit/s is used with split-phase coding, which yields a 2.668 MHz reference bandwidth. Future HRPT systems (expected to be implemented around the year 2000) that use higher data rates will operate with intra-system noise levels and power margins that are comparable to those for the HRPT system addressed in the performance analysis (expected to be phased out around the year 2005); thus, comparable interference criteria may be applied.

In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

$$q \text{ (long-term)} = 0.3 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB.}$$

Operators of meteorological satellites, under the auspices of the World Meteorological Organization, have agreed to restrict the operation of non-geostationary satellites to the region above approximately 1 698 MHz in the 1 675-1 710 MHz band, in order to avoid mutual harmful interference with geostationary meteorological satellites, which will use the 1 675-1 698 MHz portion of the band.

It should be noted that the Earth exploration-satellite service is allocated (FN 671) in the 1 690-1 710 MHz band with a secondary status and consequently is likely to suffer significant interference from the meteorological-satellite service.

5 Meteorological-satellite service in the 7 450-7 550 MHz band

The performance analysis for a planned recorded data acquisition system operating near 7 500 MHz assumes a satellite altitude of 844 km. This system is referred to as the global recorded data (GRD) system. The satellite antenna is assumed to have a shaped pattern that partially offsets the increase in path loss for increasing off-nadir elevation angles. The assumed modulation is BPSK, although the results are also applicable to QPSK that is also being considered. It is expected that GRD will be implemented around the year 2005.

In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

$$q \text{ (long-term)} = 0.3 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB.}$$

6 Earth exploration-satellite service at 8 025-8 400 MHz

The performance analyses for transmissions to major and low-cost facilities assume satellite altitudes of 822 km for System A and 680 km for System B. For System A, a major data acquisition facility receives stored data and the low cost facility receives real time regional data. For System B, a major data acquisition facility is also used to receive wideband (420 Mbit/s) direct data readout. For both systems the modulation is QPSK. No adjacent channel interference is assumed to occur within the system because the two types of transmissions are not assumed to be provided from the same satellite at the same time.

In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

$$q \text{ (long-term)} = 0.3 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB.}$$