RECOMMENDATION ITU-R SA.1026-4

Aggregate 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)

(1994-1995-1997-1999-2009)

Scope

The purpose of this Recommendation is to provide interference criteria for space-to-Earth transmissions from low-Earth orbiting satellites, applying to both the Earth exploration-satellite and the meteorological-satellite services.

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 playback 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,

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* Interference criteria do not imply automatically sharing criteria.

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 (see Notes 1, 2, 3, 4)

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 0.0125% of the time. (This value is based on the 99.9% performance requirement in Recommendation ITU-R SA.1025-3)
137-138 MHz	Analogue receiver 2 dBic antenna gain Direct data readout	−151 dBW per 50 kHz(1)	−145 dBW per 50 kHz(1)
	Digital receiver 10 dBic antenna gain Direct data readout	−141 dBW per 150 kHz	−133 dBW per 150 kHz
	Digital receiver 2 dBic antenna gain Direct data readout	−142 dBW per 150 kHz(1)	−136 dBW per 150 kHz(1)
400.15-401.00 MHz	0 dBic antenna gain Direct data readout	−157 dBW per 177.5 kHz	−147 dBW per 177.5 kHz
1 698-1 710 MHz	46.8 dBic antenna gain Recorded data playback	−128 dBW per 5 334 kHz	−121 dBW per 5 334 kHz
	29.8 dBic antenna gain Direct data readout	−147 dBW per 2 668 kHz	−138 dBW per 2 668 kHz
	22.5 dBic antenna gain Low rate data 1-metre antenna	−144 dBW per 6.0 MHz	−134 dBW per 6.0 MHz
7 750-7 850 MHz	55.2 dBic antenna gain Recorded data playback	−144 dBW per 10 MHz	−129 dBW per 10 MHz
	41.7 dBic antenna gain High rate data 2-metre antenna	−137 dBW per 10 MHz	−126 dBW per 10 MHz

TABLE 1 (*end*)

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 0.0125% of the time. (This value is based on the 99.9% performance requirement in Recommendation ITU-R SA.1025-3)
8 025-8 400 MHz	54.8 dBic antenna gain Recorded data playback System A	−145 dBW per 10 MHz	−133 dBW per 10 MHz
	41.7 dBic antenna gain Recorded data playback (System B)	−135 dBW per 10 MHz	−127 dBW per 10 MHz
	42.5 dBic antenna gain Direct data readout (System C)	−139 dBW per 10 MHz	−129 dBW per 10 MHz
25.5-27.0 GHz	55.2 dBic antenna gain Recorded data playback	−135 dBW per 10 MHz	−119 dBW per 10 MHz
	42.5 dBic antenna gain Direct data readout	−139 dBW per 10 MHz	−121 dBW per 10 MHz
	42.5 dBic antenna gain High-speed direct data readout	−136 dBW per 10 MHz	–122 dBW per 10 MHz
	58.2 dBic antenna gain Stored mission data	−126 dBW per 10 MHz	−107 dBW per 10 MHz

(1) The interfering signal powers (dBW) in the reference bandwidths are specified for reception at elevation angles $\geq 25°$; in all other cases the minimum elevation angle is 5°.

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 (0.0125% 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 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 Eb/N_0 and BER are monotonically related to elevation angle.

NOTE 3 – 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 Eb/N_0 and BER are monotonically related to elevation angle.

NOTE 4 – 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.

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 for link margin not met, p	0.05	20	0.05	20	0.05	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))	−179.2 (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		−196.2		−196.2	
Non-thermal receiver noise power density (dB(W/Hz))	–		–		–	
Total internal noise power density, N_0 (dB(W/Hz))	−194.6		−196.2		−196.2	
E_b/N_0 (dB)	15.4(C_0/N_0)	16.7(C_0/N_0)	15.3	18.1	14.1	15.4
Link bit-error ratio	–		10^{-10}		$< 10^{-10}$	
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	8.8	11.6	7.6	8.9
q factor (lt: long-term, st: short-term)	0.5 (lt)	1 (st)	0.6 (lt)	1 (st)	0.6 (lt)	1 (st)
M_{min} (dB)	0.8		1.2		1.2	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−151	−145	−141	−133	−142	−136

TABLE 2 (*continued*)

Frequency band (MHz)	400.15-401.00		1 698-1 710			
Type of earth station	Non-tracking antenna (omnidirectional)		Recorded data playback (HRPT)		Direct data readout	
Percentage of time for link margin not met, p	0.05	20	0.05	20	0.05	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. (dBWi)	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 (dB)	5.5	5.5	11.2		10.5	10.5
Power margin (dB)		4.3	9.6	12.7	−0.4	2.8
q factor (lt: long-term, st: short-term)	0.33 (lt)	1 (st)	0.6 (lt)	1 (st)	0.33 (lt)	1 (st)
M_{min} (dB)	1.2		1.2		1.2	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−157	−147	−128	−121	−147	−138

TABLE 2 (*continued*)

Frequency band (MHz)	1 698-1 710		7 750-7 850			
Type of earth station	Low rate data 1-metre antenna		Recorded data playback (10-m antenna)		High rate data 2-metre antenna	
Percentage of time for link margin not met, p	0.05	20	0.05	20	0.05	20
Elevation angle (exceeded for p)	5	8	5	13	5	8
Satellite antenna input power (dBW)	9.9		6.5		16.3	
Satellite antenna gain (dBic)	3.2	3.2	6.0	5.8	4.0	4.1
Satellite e.i.r.p. (dBWi)	13.1	13.0	12.5	12.3	20.3	20.4
Free space loss (dB)	166.1	164.0	179.5	177.3	179.4	177.2
Excess path loss (dB)	0.2	0.2	3.5	0.5	0.5	0.5
Earth station antenna gain (dBic)	22.5		55.2		41.7	
Antenna mispointing loss (dB)	0.5		0.5		0.5	
Polarization mismatch loss (dB)	0.5		0.2		0.5	
Modulator and demodulator losses (dB)	2.5		2.0		2.5	
Receiver reference bandwidth (MHz)	6.0		10		10	
Data rate (dB-Hz)	65.3		78.5		72.4	
Received energy per bit E_b (dB(W/Hz))	−199.6	−197.5	−196.4	−191.5	−193.8	−191.5
Receiver system noise temperature (K)	80	70	180	150	115	95
Thermal noise power density (dB(W/Hz))	−209.6	−210.1	−206.0	−206.8	−208.0	−208.8
E_b/N_0 (dB)	10.0	12.7	9.6	15.4	14.2	17.3
Link bit-error ratio	10^{-8}		10^{-7}		10^{-8}	
Threshold E_b/N_0 (dB)	3.6		7.20		4.1	
Power margin (dB)	6.4	9.1	2.40	8.2	10.1	13.2
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	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−144	−134	−144	−129	−137	−126

TABLE 2 (*continued*)

Frequency band (MHz)	8 025-8 400		8 025-8 400		8 025-8 400	
Type of earth station	Recorded data playback (System A)		Recorded data playback (System B)		Direct data readout (System C)	
Percentage of time for link margin not met, p	0.05	20	0.05	20	0.05	20.0
Elevation angle (exceeded for p)	5°	13°	5°	13°	5°	13°
Satellite antenna input power (dBW)	12		3		16.9	
Satellite antenna gain (dBic)	2.4	3.7	28		6.1	
Satellite e.i.r.p. (dBWi)	14.4	15.7	31		23	
Free space loss (dB)	179.3	177	180	177.8	179.3	177.0
Excess path loss (dB)	1.2	0.8	1.2	0.8	0.7	0.6
Earth station antenna gain (dBic)	54.8		41.7		42.5	
Antenna mispointing loss (dB)	0.5		0.1		0.5	
Polarization mismatch loss (dB)	0.4		0.2		0.5	
Modulator and demodulator losses (dB)	2.0		1.5		2.0	
Receiver reference bandwidth (MHz)	10		10		10	
Data rate (dB-Hz)	85.1		83		73	
Received energy per bit, E_b (dB(W/Hz))	−199.3	−195.3	−193.3	−190.8	−190.5	−188.1
Receiver system noise temperature (K)	50	50	100	100	292	275
Thermal noise power density (dB(W/Hz))	−211.6	−211.6	−208.6	−208.6	−203.9	−204.2
Total internal noise power density N_0 (dB(W/Hz))	−211.6	−211.6	−208.6	−208.6	−203.9	−204.2
E_b/N_0 (dB)	12.3	16.3	15.3	17.8	13.5	16.1
Link bit-error ratio	$< 10^{-10}$	$< 10^{-10}$	$< 10^{-7}$	$< 10^{-10}$	$< 10^{-7}$	$< 10^{-10}$
Overall received bit-error ratio	$< 10^{-10}$		$< 10^{-7}$	$< 10^{-10}$	$< 10^{-5}$	$< 10^{-5}$
Threshold E_b/N_0 (dB)	7.2		6.3		9.6	
Power margin (dB)	5.1	9.1	9.0	11.5	3.8	6.5
q factor (lt: long-term. st: short-term)	0.33 (lt)	1 (st)	0.33 (lt)	1 (st)	0.6 (lt)	1 (st)
M_{min} (dB)	1.2		1.2		1.2	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−145	−133	−135	−127	−139	−129

TABLE 2 (*end*)

Frequency band (MHz)	25 500-27 000							
Type of earth station	Recorded data playback		Direct data readout		Direct high-speed data readout		Stored mission data	
Percentage of time link margin not met, p	0.05	20.0	0.05	20.0	0.05	20.0	0.05	20
Elevation angle (exceeded for p)	5°	13°	5°	13°	5°	13°	5°	8°
Satellite antenna input power (dBW)	13.0		13.0		13.0	14.8	6.4	
Satellite antenna gain (dBic)	28.0		25.0		39.1		37.2	
Satellite e.i.r.p. (dBWi)	41.0		38.0		52.1	53.9	43.6	43.6
Free space loss (dB)	189.8	187.7	189.8	187.7	188.8	186.4	190.0	187.9
Excess path loss (dB)	6.4	1.0	6.4	1.0	6.4	1.0	1.0	1.0
Earth station antenna gain (dBic)	55.2		42.5		42.5	38.0	58.2	58.2
Antenna mispointing loss (dB)	0.5		0.5		0.5		0.5	
Polarization mismatch loss (dB)	0.2		0.2		0.2		0.5	
Modulator and demodulator losses (dB)	2.0		2.0		2.0		2.5	
Receiver reference bandwidth (MHz)	10		10		10		10	
Data rate (dB-Hz)	90.0		76.0		90.0		81.2	
Received energy per bit, E_b (dB(W/Hz))	−191.9	−184.1	−194.5	−186.9	−193.3	−188.2	−173.6	−171.5
Receiver system noise temperature (K)	715.9	557.6	715.9	557.6	552.7	272.8	350	300
Total internal noise power density N_0 (dB(W/Hz))	−200.1	−201.1	−200.1	−201.1	−201.2	−204.2	−203.1	−203.8
E_b/N_0 (dB)	7.3	16.0	5.6	14.3	7.9	16.0	29.5	32.4
Link bit-error ratio	10^{-6}		10^{-6}		10^{-6}		10^{-8}	
Satellite data handling error ratio	5×10^{-7}		–		–		–	
Overall received bit-error ratio	1.5×10^{-6}		10^{-6}		10^{-6}		10^{-8}	
Threshold E_b/N_0 (dB)	3.9	3.9	3.9	3.9	3.9	3.9	5.6	5.6
Power margin (dB)	3.4	12.1	1.7	10.4	4.0	12.1	23.9	26.8
q factor (lt: long-term, st: short-term)	0.33 (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	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−135	−119	−139	−121	−136	−123	−126	−107

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

The performance analysis for an automatic picture transmission (APT) system in the 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, implementation of the LRPT system having been started in the year 2006.

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) = 0.5	q (long-term) = 0.6
q (short-term) = 1	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

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

The performance analysis for a system in this band 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:

$$q \text{ (long-term)} = 0.33$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB}.$$

4 Meteorological-satellite service in the 1 698-1 710 MHz band

Within the allocation of 1 690 to 1 710 MHz the sub-band 1 698 to 1 710 MHz is used for low-Earth orbiting meteorological-satellite systems in accordance with Recommendation ITU-R SA.1745.

The performance analyses for high resolution picture transmission (HRPT) and command and data acquisition (CDA) systems using small and large 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.

A future system will be transmitting a low-rate data downlink at 3.393 Mbit/s from a spacecraft at 828 km altitude. Three types of earth stations will have antenna sizes of 1 m, 3 m and 13 m. The 1-metre antenna is the only one for which interference analysis is necessary.

The larger antennas have a smaller beamwidth and are therefore less susceptible to interference.

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

$$q \text{ (long-term)} = 0.33 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB}.$$

5 Meteorological-satellite service in the 7 750-7 850 MHz band

Several new low-Earth orbiting meteorological-satellite systems are already operating or planned to be operating in the band 7 750-7 850 MHz. Some will transmit stored mission data (recorded data play back) to the command and data acquisition (CDA) earth station in generally high northern latitudes. Earth station receiving antenna diameters are typically around 10 m, resulting in an antenna gain of 55 dBi. The system noise temperature of the earth station is around 180 K. Minimum elevation has been assumed with 5°. The theoretically required $E_b/(N_0 + I_0)$ is 7.2 dB to obtain a BER of 10^{-7}. A reference bandwidth of 10 MHz has been selected. The satellite orbit height is around 832 km.

An additional high rate data system transmits a 17.49 Mbit/s signal from a satellite at 828 km altitude. The signal is received by three types of earth stations with 2 m, 3 m and 13 m antennas. The 2-metre antenna is the only one for which interference analysis is necessary.

The larger antennas have a smaller beamwidth and are therefore less susceptible to interference.

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

$$q \text{ (long-term)} = 0.33$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB}.$$

6 Earth exploration-satellite service (EESS) in the 8 025-8 400 MHz band

Three reference systems are considered for EESS systems operating in the 8 025-8 400 MHz band. System A features a satellite in a 750 km orbit transmitting recorded data at very high data rates (325 Mbit/s) to a major data acquisition facility. The satellite employs an isoflux antenna. System B features a satellite in an 850 km orbit also transmitting recorded data at high rates (200 Mbit/s), but using a directional antenna. Finally, System C features a satellite in a 750 km orbit transmitting a direct data readout signal of real-time instrument data to multiple distributed low-cost earth stations at 20 Mbit/s. All systems employ QPSK modulation type. In applying the methodology of Recommendation ITU-R SA.1022, the following range of interference parameters can be used to calculate the interference criteria:

$$q \text{ (long-term)} = 0.33 \text{ to } 0.6$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB}.$$

7 EESS in the 25.5-27.0 GHz band

Several reference systems are also considered for EESS systems operating in the 25.5-27.0 GHz band. Reference system 1 (i.e. the first system in this band shown in Table 1) features a satellite in an 822 km orbit which transmits in one of two modes. The first mode is a very high data rate (1 Gbit/s) recorded data readout transmission to a major data acquisition facility. Mode 2 features a lower rate (40 Mbit/s) direct data readout transmission to distributed low-cost earth stations. Reference system 2 features a satellite in a 698 km orbit with a very high rate (1 Gbit/s) direct high speed data readout link to low-cost distributed earth stations.

Another new system transmits a stored mission data signal at 131.2 Mbit/s from a satellite at 828 km altitude.

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

$$q \text{ (long-term)} = 0.33$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 1.2 \text{ dB}.$$