International Telecommunication Union

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Recommendation ITU-R SA.1026-5
(07/2017)

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

SA Series
Space applications and meteorology

International Telecommunication Union

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

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RECOMMENDATION ITU-R SA.1026-5

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)

(1994-1995-1997-1999-2009-2017)

Scope

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

Keywords

EESS, METSAT, non-GSO satellites, aggregate interference criteria

Related Recommendations and Reports

Recommendations ITU-R SA.514, ITU-R SA.1020, ITU-R SA.1021, ITU-R SA.1022, ITU-R SA.1023, ITU-R SA.1027, ITU-R SA.1159

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.1159 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 criteria 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 are 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 interference criteria for space-to-Earth transmissions in the Earth exploration-satellite and meteorological-satellite services in some frequency bands,

recommends

1 that the interference criteria for the frequency bands specified in Table 1 should be used as the permissible aggregate 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;

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	**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.1159)**
137-138 MHz	−142 dBW per 150 kHz(1)	−136 dBW per 150 kHz(1)
400.15-401.00 MHz	−157 dBW per 177.5 kHz	−147 dBW per 177.5 kHz
1 698-1 710 MHz	−146 dBW per 2 668 kHz	−138 dBW per 2 668 kHz
7 750-7 900 MHz	−144 dBW per 10 MHz	−127 dBW per 10 MHz
8 025-8 400 MHz	−147 dBW per 10 MHz	−133 dBW per 10 MHz
25.5-27.0 GHz	−140 dBW per 10 MHz	−116 dBW per 10 MHz

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

Notes to Table 1

NOTE 1 – The aggregate 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.

Notes to Table 1 (end):

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 determination of interference criteria

1 Introduction

This Annex presents, on a band-by-band basis, 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.1159. The performance analyses for a number of reference systems are summarized in Table 2. In all cases, the representative systems utilize satellites in highly-inclined circular orbits.

It should be noted that in Table 2 and §§ 2 to 7 below, the terms M_{min}, M_{min} (long-term) and M_{min} (short-term) are to be understood in the sense of the methodology described in Recommendation ITU-R SA.1022, i.e. “the smallest interference-free margin for which the victim system must be fully protected”. It should not be taken as representative for all EESS and METSAT systems, in particular those in Table 2, among of which certain systems present lower power margins.

TABLE 2

Performance analyses used as a basis for interference criteria

Frequency band (MHz)	137-138					
Type of earth station	Low gain earth station (APT) (system A)		Tracking earth station (LRPT) (system B)		Low gain earth station (LRPT) (system C)	
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 or type of transmission	Non-tracking antenna (omnidirectional) (system A)		Direct Data readout (system A)		Direct data readout (system B)	
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)	2.1	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	−146	−138

TABLE 2 (*continued*)

Frequency band (MHz)	1 698-1 710		7 750-7 900			
Type of earth station or type of transmission	Direct data readout (system C)		Recorded data playback (system A)		Direct data readout (system B)	
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)	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)
M_{min} (dB)	4.5		4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−144	−134	−146	−129	−144	−126

TABLE 2 (*continued*)

Frequency band (MHz)	7 750-7 900			
Type of earth station or type of transmission	Direct data readout (system C)		Direct data readout (system D)	
Percentage of time for link margin not met, *p*	0.05	20	0.05	20
Elevation angle (exceeded for *p*)	5	8	5	13
Satellite antenna input power (dBW)	9.6		19.4	
Satellite antenna gain (dBic)	9.6	9.6	3.3	3.3
Satellite e.i.r.p. (dBWi)	19.2	19.2	22.7	22.7
Free space loss (dB)	179	177	179.4	177
Excess path loss (dB)	0.5	0.5	2.9	0.5
Earth station antenna gain (dBic)	44.9		44.3	
Antenna mispointing loss (dB)	0.5		1	
Polarization mismatch loss (dB)	0.5		0.1	
Modulator and demodulator losses (dB)	2.5		3.2	
Receiver reference bandwidth (MHz)	10		10	
Data rate (dB-Hz)	71.1		79.0	
Received energy per bit E_b (dB(W/Hz))	−190	−188	−198.6	−193.8
Receiver system noise temperature (K)	343	343	252.5	252.5
Thermal noise power density (dB(W/Hz))	−203	−203	−204.6	−204.6
E_b/N_0 (dB)	13.0	15.0	5.9	10.7
Link bit-error ratio	10^{-6}		10^{-6}	
Threshold E_b/N_0 (dB)	5.0		2.63	
Power margin (dB)	8.0	10	3.3	8.1
***q* factor (lt: long-term. st: short-term)**	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)
M_{min} (dB)	4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−140	–123	–144	–127

TABLE 2 (*continued*)

Frequency band (MHz)	8 025-8 400					
Type of earth station or type of transmission	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)	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)
M_{min} (dB)	4.5		4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−151	−133	−145	−127	−144	−129

TABLE 2 (*continued*)

Frequency band (MHz)	8 025-8 400			
Type of earth station	Recorded data playback (System D)		Recorded data playback (System E)	
Percentage of time for link margin not met, *p*	0.05	20	0.05	20.0
Elevation angle (exceeded for *p*)	5°	13°	5°	13°
Satellite antenna input power (dBW)	15.3		10.0	
Satellite antenna gain (dBic)	5.5	5.0	3.5	
Satellite e.i.r.p. (dBWi)	20.8	20.3	13.5	
Free space loss (dB)	179.8	177.6	179.8	177.6
Excess path loss (dB)	1.6	1.0	1.6	1.0
Earth station antenna gain (dBic)	54.8		57.0	
Antenna mispointing loss (dB)	0.5		0.5	
Polarization mismatch loss (dB)	0.6		0.6	
Modulator and demodulator losses (dB)	4.9		2.4	
Receiver reference bandwidth (MHz)	10		10	
Data rate (dB-Hz)	84.2		84.45	
Received energy per bit, E_b (dB(W/Hz))	−196.0	−193.7	−198.85	−196.05
Receiver system noise temperature (K)	125	125	120	120
Thermal noise power density (dB(W/Hz))	−207.6	−207.6	−207.8	−207.8
Total internal noise power density N_0 (dB(W/Hz))	−207.6	−207.6	−207.8	−207.8
E_b/N_0 (dB)	11.6	13.9	8.95	11.75
Link bit-error ratio	$< 10^{-10}$	$< 10^{-10}$	$< 10^{-10}$	$< 10^{-10}$
Overall received bit-error ratio	$< 10^{-10}$		$< 10^{-10}$	
Threshold E_b/N_0 (dB)	7.6		5.6	
Power margin (dB)	4.0	6.3	3.35	6.15
***q* factor (lt: long-term. st: short-term)**	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)
M_{min} (dB)	4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−147	−132	−147	−133

TABLE 2 (*continued*)

Frequency band (MHz)	25 500-27 000							
Type of earth station or type of transmission	Stored mission data (system A Mode 1)		Direct data readout (system A Mode 2)		Direct high-speed data readout (system B)		Stored mission data (system C)	
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)**	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)	0.1 (lt)	1 (st)
M_{min} (dB)	4.5		4.5		4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−140	−119	−140	−121	−141	−122	−134	−107

TABLE 2 (*end*)

Frequency band (MHz)	25 500-27 000			
Type of earth station or type of transmission	Stored mission data (system D)		Stored mission data (system E)	
Percentage of time for link margin not met, *p*	0.05	20	0.05	20
Elevation angle (exceeded for *p*)	5	13	5	13
Satellite antenna input power (dBW)	9.0		14.8	
Satellite antenna gain (dBic)	38.0	38.0	27.5	27.5
Satellite e.i.r.p. (dBWi)	47.0	47.0	42.3	42.3
Free space loss (dB)	190	188	190.04	188
Excess path loss (dB)	6.4	1.0	8.72	1
Earth station antenna gain (dBic)	55.4		59.6	
Antenna mispointing loss (dB)	0.5		0.3	
Polarization mismatch loss (dB)	0.2		0	
Modulator and demodulator losses (dB)	2.0		5.7	
Receiver reference bandwidth (MHz)	10		10	
Data rate (dB-Hz)	81.1		85.9	
Received energy per bit E_b (dB(W/Hz))	−178	−170	–188.8	−179
Receiver system noise temperature (K)	363	363	395.5	395.5
Thermal noise power density (dB(W/Hz))	−203	−203	−202.6	−202.6
E_b/N_0 (dB)	25.0	32.6	13.9	23.6
Link bit-error ratio	10^{-6}		10^{-6}	
Threshold E_b/N_0 (dB)	5.0		6.93	
Power margin (dB)	20.0	27.6	6.9	16.7
***q* factor (lt: long-term. st: short-term)**	0.1 (lt)	1 (st)	0.1 (lt)	1
M_{min} (dB)	4.5		4.5	
Percentage of time for interference criteria	20	0.0125	20	0.0125
Interference criteria dBW in reference bandwidth	−135	−105	−140	−116

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. 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 (short-term) = 1	q (long-term) = 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

On this basis, considering the systems described in Table 2 above, System C could be considered as the most representative system, hence leading to the following criteria to be considered in the band 137-138 MHz:

– long-term criteria = –142 dBW/150 kHz

– short-term criteria (0.0125%) = –136 dBW/150 kHz.

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:

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

On this basis, considering the system described in Table 2 above, the following criteria to be considered in the band 400.15-401 MHz:

– long-term criteria = –157 dBW/177.5 kHz

– short-term criteria (0.0125%) = –147 dBW/177.5 kHz.

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 degrees, 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:

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

On this basis, considering the systems described in Table 2 above, System B could be considered as the most representative system, hence leading to the following criteria to be considered in the band 1 698-1 710 MHz:

– long-term criteria = –146 dBW/2 668 kHz

– short-term criteria (0.0125%) = –138 dBW/2 668 kHz.

5 Meteorological-satellite service in the 7 750-7 900 MHz band

Several new low-Earth orbiting meteorological-satellite systems are already operating or planned to be operating in the band 7 750-7 900 MHz.

Some 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.

Other satellites using this frequency band transmit high rate data system (up to around 80 Mbit/s) from the satellite to three types of earth stations with 2 m, 3 m and 10 m antennas. The 2- and 3-metre antennas are more 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:

$$q \text{ (long-term)} = 0.1$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 4.5 \text{ dB.}$$

On this basis, considering the systems described in Table 2 above, System D could be considered as the most representative system, hence leading to the following criteria to be considered in the band 7 750-7 900 MHz:

– long-term criteria = –144 dBW/10 MHz

– short-term criteria (0.0125%) = –127 dBW/10 MHz.

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

Five 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. 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. System D is similar to System A but with 8PSK modulation. System E is also similar to System A but at 820 km orbit.

Except System D, 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:

$$q \text{ (long-term)} = 0.1$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 4.5 \text{ dB.}$$

On this basis, considering the systems described in Table 2 above, System E could be considered as the most representative system, hence leading to the following criteria to be considered in the band 8 025-8 400 MHz:

– long-term criteria = −147 dBW/10 MHz

– short-term criteria (0.0125%) = −133 dBW/10 MHz.

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 A features a satellite in an 822 km orbit which transmits in two modes. The first mode is a very high data rate (1 Gbit/s) recorded data transmission to a major data acquisition facility. Mode 2 features a lower rate (40 Mbit/s) direct data readout transmission of real-time instrument data to distributed low-cost earth stations.

Reference system B features a satellite in a 698 km orbit with a very high rate (1 Gbit/s) direct high speed data readout link of real-time instrument data to low-cost distributed earth stations.

Reference systems C and D transmit a stored mission data signal at around 131.2 Mbit/s from a satellite at around 828 km altitude. Reference system E also transmits stored mission data at around 390 MBit/s from a satellite at around 832 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:

$$q \text{ (long-term)} = 0.1$$
$$q \text{ (short-term)} = 1$$
$$M_{min} \text{ (long-term)} = M_{min} \text{ (short-term)} = 4.5 \text{ dB.}$$

On this basis, considering the systems described in Table 2 above, System E could be considered as the most representative system, hence leading to the following criteria to be considered in the band 25.5-27 GHz:

– long-term criteria = −140 dBW/10 MHz

– short-term criteria (0.0125%) = −116 dBW/10 MHz.