RECOMMENDATION ITU-R S.739*

Additional methods for determining if detailed coordination is necessary between geostationary-satellite networks in the fixed-satellite service sharing the same frequency bands

(1992)

The ITU Radiocommunication Assembly,

considering

a) that FSS networks may share the same frequency bands;

b) that these networks may cause and experience mutual interference;

c) that this mutual interference can be minimized through coordination;

d) that the method described in Recommendation ITU-R S.738 is very conservative;

e) that additional methods may be useful to determine if detailed coordination is necessary,

recommends

1 that, to the extent data is available, the following methods be used, by mutual agreement between the administrations concerned, to determine if detailed coordination is necessary:

– the normalized $\Delta T/T$ method described in Annex 1;

– the power density-averaging bandwidth method described in Annex 2;

2 that the following Notes should form part of this Recommendation:

NOTE 1 – The normalized $\Delta T/T$ method for determining the interference level using the normalized values of the apparent increase in equivalent noise temperature, is based on the technique shown in Appendix S8 to the Radio Regulations, appropriately modified to give more accurate results. This approach consists in using a set of predetermined values for $\Delta T/T$ which depends upon the types of wanted and interfering carriers involved, instead of the single 6% value given in Appendix S8.

NOTE 2 – The power density-averaging bandwidth method is an extension of the Appendix S8 $\Delta T/T$ method that allows the calculation of the interference power for any interfered-with carrier bandwidth. This method may be applied for determining the need for detailed coordination and may also be used in more detailed coordination.

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* Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

ANNEX 1

Method of the normalized equivalent noise temperature of the satellite link

1 Introduction

This method is based on the technique shown in Appendix S8 to the Radio Regulations and described in Recommendation ITU-R S.738 appropriately modified to give accurate results. To do so, the threshold of 6% used in Appendix S8 is replaced by thresholds which depend on the carriers involved and which meet the ITU-R criteria.

2 Normalized values for the relative increase in the admissible equivalent link noise temperature

2.1 Definition

The method involves determining the overall increase in equivalent link noise temperature due to the various types of transmission in the two networks.

The normalized values for the relative increase in equivalent link noise temperature are given by:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{I}{N_0\, B_2}$$

where:

N_0: thermal noise density corresponding to the equivalent noise temperature of the satellite link

I/N_0: ratio of interfering power to the thermal noise density of the wanted carrier

B_2: bandwidth defined by the ratio of the interfering carrier power P' to its maximum spectral power density p'_m:

$$p'_m = P'/B_2$$

2.2 Values for various carrier types

The method for computing I/N_0 and $(\Delta T/T)_N$ is given in § 3 to 9.

The calculation method for $(\Delta T/T)_N$ depends on the type of wanted and interfering carriers. Five types are considered:

– FDM-FM,

– SCPC-FM,

– digital SCPC (SCPC-DIG),

– wideband digital (DIG-BB),

– FM-television (FM-TV).

For a given type of wanted carrier and a given type of interfering carrier, the $(\Delta T/T)_N$ value obtained (using the method which corresponds to this pair of carrier types) depends on carrier parameters such as bandwidth and coding.

In order to limit the necessary computations, each general carrier type is broken down into various sub-headings so that, for each pair of carrier types, the carrier parameters no longer affect $(\Delta T/T)_N$ (as long as these parameters lie in the range specified for each type) (see Table 1). Thus $(\Delta T/T)_N$ can be determined simply from the knowledge of the type of the two carriers.

Carriers are classified according to their type.

An initial analysis of the carriers leads to the identification of about 50 different types:

– about 20 FDM-FM, characterized by the number of channels and allocated band,

– several SCPC-FM, characterized by the allocated band,

– about 15 DIG-BB, characterized by the bit rate, type of coding, and number of states,

– several SCPC-DIG, characterized by the bit rate, type of coding, and number of states,

– several FM-TV, characterized by the allocated band and energy dispersal characteristics.

In order to simplify the presentation of the table of thresholds, the 50 types of carriers have been gathered in 12 categories as given in Table 2.

The corresponding values of $\Delta T/T$ for each pair of wanted and interfering categories of types of carriers is given in Table 3.

3 Parameters used in the computation of I/N_0 and $(\Delta T/T)_N$

The parameters used are as follows:

B_0: bandwidth of the wanted signal (Hz)

B_1: bandwidth of the interfering signal (Hz)

I/N_0: ratio of interfering carrier power-to-noise power density

C/N_0: ratio of wanted carrier power-to-noise power density

C/I: ratio of wanted-to-interfering carrier power

B_2: bandwidth defined by the ratio of interfering power P' to its maximum spectral power density p'_m:

$$p'_m = P'/B_2$$

α: fraction of interfering signal power received after filtering by the wanted signal receiver filter

N_0: thermal noise power density corresponding to the equivalent noise temperature of the satellite link

N: noise power $N = N_0 \cdot B_0$.

Admissible normalized values for the relative increase in equivalent link noise temperature are given by:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{I}{N_0\, B_2}$$

TABLE 1

Standard carrier types

FDM-FM No.	Type		N/V	B_{oc} (MHz)	f_{min} (kHz)	f_{max} (kHz)	Δf_{st} (kHz)	Δf_m (kHz)
1	12	1.3	12	1.13	12.0	60.0	108.5	159.0
2	12	2.5	12	2.2	12.0	60.0	238.9	350.0
3	24	2.5	24	1.96	12.0	108.0	163.4	275.0
4	60	2.5	60	2.25	12.0	252.0	136.5	276.0
5	72	2.5	72	2.25	12.0	300.0	124.5	261.0
6	60	5.0	60	3.96	12.0	252.0	270.1	546.0
7	132	5.0	132	4.45	12.0	552.0	223.5	529.0
8	192	5.0	192	4.51	12.0	804.0	180.0	459.0
9	96	7.5	96	5.87	12.0	408.0	359.8	799.0
10	192	7.5	192	6.40	12.0	804.0	297.2	758.0
11	252	7.5	252	6.74	12.0	1 052.0	259.7	733.0
12	132	10.0	132	7.50	12.0	552.0	430.0	1 020.0
13	252	10.0	252	8.49	12.0	1 052.0	357.4	1 009.0
14	312	10.0	312	8.96	12.0	1 300.0	320.0	1 005.0
15	252	15.0	252	12.39	12.0	1 052.0	576.4	1 627.0
16	432	15.0	432	12.95	12.0	1 796.0	400.2	1 479.0
17	432	20.0	432	17.99	12.0	1 796.0	615.8	2 276.0
18	612	20.0	612	17.70	12.0	2 540.0	453.7	1 996.0
19	432	25.0	432	20.59	12.0	1 796.0	727.3	2 688.0
20	792	25.0	792	22.34	12.0	3 284.0	498.4	2 494.0
21	972	25.0	972	25.00	12.0	4 028.0	410.0	2 274.0
22	972	36.0	972	35.99	12.0	4 028.0	796.7	4 417.0

SCPCA No.	Type		B_{oc} (kHz)	f_{min} (kHz)	f_{max} (kHz)	Δf (kHz)
23	0.020	–	20.0	0.3	3.4	5.8
24	0.025	–	25.0	0.3	3.4	12.0
25	0.030	–	30.0	0.3	3.4	8.5
26	0.090	–	90.0	0.3	3.4	3.4
27	0.180	–	180.0	0.3	3.4	3.3

SCPCN No.	Type	N/E	B_{oc} (kHz)	Bite rate (kbit/s)
28	0.064	4	38.0	64.0
29	0.085	4	50.0	85.0
30	0.128	4	150.0	128.0
31	0.256	4	300.0	256.0
32	0.512	4	600.0	512.0

NUM-LB No.	Type	N/E	B_{oc} (MHz)	Bite rate (kbit/s)
33	2Q	4	1.44	2.048
34	3Q	4	1.84	3.072
35	4Q	4	2.25	4.096
36	8Q	4	5.0	8.448
37	10Q	4	5.0	10.0
38	17Q	4	10.2	17.0
39	25Q	4	18.0	24.6
40	34Q	4	20.6	34.368
41	40Q	4	20.0	40.0
42	50Q	4	25.6	50.0
43	120Q	4	75.0	120.0
44	139Q	4	82.0	139.264
45	147Q	4	110.0	147.0

FM-TV No.	Type	Δf (MHz)	B_{oc} (MHz)	Δf_{pm} (MHz)	Δf_{pnm} (MHz)	f_{bal} (Hz)
46	TV.17	4.75	17.5	1.0	2.0	60/30
47	TV.20	4.8	20.0	1.0	2.0	50
48	TV.30	6.2	30.0	2.0	4.0	50
49	TV.35	5.0	30.0	2.0	4.0	50/25
50	TV.36	11.0	32.0	1.0	2.0	50

SCPCA: SCPC (analogue)
SCPCN: SCPC (digital)
NUM-LB: wideband (digital)
N/V: number of channels
N/E: number of states
B_{oc}: occupied bandwidth
Δf: frequency deviation
Δf_{pm}: frequency deviation (modulated carrier)
Δf_{pnm}: frequency deviation (unmodulated carrier)
f_{bal}: sweep frequency
Δf_{st}: frequency deviation (signal test)
Δf_m: frequency deviation (multiplex signal)

TABLE 2

Categories of carrier

Type of carrier		No.
FDM-FM	$B_{oc} \leq 3$ MHz	1-5
	3 MHz < $B_{oc} \leq 7$ MHz	6-11
	7 MHz < $B_{oc} \leq 15$ MHz	12-16
	$B_{oc} > 15$ MHz	17-22
Wideband digital	$B_{oc} \leq 3$ MHz	33-35
	3 MHz < $B_{oc} \leq 7$ MHz	36-37
	7 MHz < $B_{oc} \leq 15$ MHz	38
	$B_{oc} > 15$ MHz	39-45
SCPC	PSK	28-32
	CFM	23-27
FM-TV	$\Delta f \leq 7$ MHz	46-49
	$\Delta f > 7$ MHz	50

B_{oc}: occupied bandwidth

Δf: frequency deviation

TABLE 3

Single carrier to single carrier $\Delta T/T$ threshold values

Wanted [1] carrier	Interfering carrier	FDM-FM				Wideband digital				SCPC		FM-TV	
	B_{oc} (MHz)	< 3	3-7	7-15	> 15	< 3	3-7	7-15	> 15	PSK	CFM [2]	$\Delta f \leq 7$	$\Delta f > 7$
FDM-FM [3]	< 3	13	12	12	11	8	10	10	8	9	1 223	11	11
	3-7	23	14	12	12	11	10	10	8	29	4 350	11	13
	7-15	40	20	14	12	17	10	10	8	56	8 458	12	19
	> 15	102	46	24	14	40	19	11	8	148	22 257	23	45
Wideband digital [4]	< 3	15	10	9	9	9	9	9	9	21	3 085	9	9
	3-7	49	21	12	9	19	9	9	9	71	10 712	11	21
	7-15	100	44	21	11	39	17	9	9	146	21 853	22	44
	> 15	176	77	38	15	69	31	15	9	257	38 565	39	77
SCPC	PSK [4]	9	9	9	9	9	9	9	9	9	9	2	2
	CFM [3]	11	11	11	11	11	11	11	11	11	11	21	36
FM-TV	$\Delta f \leq 7$	73	32	16	6	29	13	6	2	107	16 046	16	32
	$\Delta f > 7$	23	10	5	2	9	4	2	1	34	5 098	5	10

NOTE 1 – When several equal power interfering carriers of one of the types given in Table 1 are included in the wanted bandwidth, these values should be decreased in accordance with the number of these interfering carrier.

(1) The Table reflects the value for the most sensitive carrier in any range.

(2) This Table should not be used for carrier types not included in Table 1.

(3) Criterion used: 800 pW0p single entry and 7 000 pW0p total. For FM-TV interference a 20% allocation to external satellite interference is assumed.

(4) Criterion used: 6% single entry and 70% total. For FM-TV interference a 20% allocation to external satellite interferences is assumed and a value of 12.3 dB is assumed for energy per bit to noise power density ratio (BER = 1×10^{-6}).

4 Interference criteria

In the computation of $(\Delta T/T)_N$ for analogue FDM-FM signals, the equivalent link noise temperature should correspond to a noise power in a telephone channel of 7 000 pW0p for systems with frequency re-use and 6 500 pW0p for systems without frequency re-use (Recommendations ITU-R S.466 and ITU-R SF.356).

For digital signals, the equivalent link noise temperature should correspond to 70% (for systems with frequency re-use) and 65% (for systems without frequency re-use) of the total noise power level which would give rise to a bit error ratio of 10^{-6} (Recommendations ITU-R S.523 and ITU-R SF.558).

For TV/FM type signals, the criterion given in Recommendation ITU-R S.483 should be applied. Accordingly, taking into account interference from terrestrial radio links, the single-entry interference criterion referred to permissible video noise is 5%.

For an SCPC-FM signal, the criterion for interference from other than TV-FM signals is assumed to be 600 pW0p in a channel for an equivalent link noise temperature of 7 000 pW0p for systems with frequency re-use and 6 500 pW0p for systems without frequency re-use.

For SCPC-PSK and SCPC-CFM carriers, the criterion for interference from TV-FM signals should correspond to Recommendation ITU-R S.671.

It should be noted that if the spectrum of the wanted signal is broader than the spectrum of the interfering signal, total interference due to all interfering signals from the same network within the bandwidth of the wanted signal should be considered.

5 FDM-FM wanted carriers

At a 1 mW reference point, the psophometrically-weighted level N_p of noise-like baseband interference is given in pW0p by:

$$\begin{aligned} 10 \log N_p &= 87.5 - B - 10 \log \frac{C}{I} \qquad \text{dB} \\ &= 87.5 - P + 10 \log b + 10 \log D(f, f_0) - 20 \log \frac{\delta f}{f} \\ &= -3 - 10 \log \frac{C}{I} \end{aligned}$$

where:

B: interference reduction factor

b: telephone channel bandwidth (Hz)

δf: r.m.s. test-tone deviation of the wanted signal (Hz)

f_m: top baseband frequency of the wanted multiplex signal (Hz)

$D(f, f_0)$: convolution product of wanted and interfering spectra

f_0: separation between carrier frequencies of wanted and interfering signals (Hz)

f: central frequency of the selected channel, located in the baseband of the wanted signal (Hz)

P = $10 \log p(f/f_m)$: pre-emphasis (dB).

Thermal noise after demodulation is given by:

$$10 \log N_{th} = 87.5 - P - 10 \log \frac{C}{N_0} + 10 \log b - 20 \log \frac{\delta f}{f} \quad \text{dB}$$

where:

$N_0 = kT$: noise density power on the wanted link

with k: Boltzmann's constant

and T: equivalent satellite link noise temperature as defined in RR No. S1.174

thus:

$$10 \log \frac{N_p}{N_{th}} = 10 \log \frac{I}{N_0} - 3 + 10 \log D(f, f_0) \quad \text{dB}$$

$$\frac{N_p}{N_{th}} = \frac{I}{N_0} \cdot \frac{D(f, f_0)}{2}$$

The single entry criterion established by Recommendation ITU-R S.466 corresponds to $N_p = 800$ pW0p, for an N_{th} value equal to 7 000 or 6 500 pW0p. As an example, for 7 000 pW0p which is applicable to systems with frequency re-use:

$$\frac{I}{N_0} = 0.1143 \frac{2}{D(f, f_0)} = \frac{0.2286}{D(f, f_0)}$$

hence:

$$\left(\frac{\Delta T}{T} \right)_N = \frac{0.2286}{D(f, f_0)} \cdot \frac{1}{B_2}$$

6 SCPC-FM wanted carrier

6.1 Interference from an FM-TV carrier

In this case the 10 log C/I = 13.5 + 2 log δ – 3 log (i/10) criteria must be respected (Recommendation ITU-R S.671),

thus:

$$\frac{I}{N_0} = \frac{C}{N_0} \cdot \frac{I}{C} = \frac{C}{N_0} \cdot \frac{i^{0.3}}{10^{1.65} \cdot \delta^{0.2}}$$

thus:

$$\left(\frac{\Delta T}{T} \right)_N = \frac{C}{N_0} \cdot \frac{i^{0.3}}{10^{1.65} \cdot \delta^{0.2}} \cdot \frac{1}{B_2}$$

with:

$$\delta = \frac{B_0}{\Delta f} \text{ and } B_2 = \Delta f$$

where:

Δf: peak-to-peak frequency deviation of TV signal due to energy dispersal (Hz)

i: percentage of total predemodulation noise allocated to internetwork interference.

For the example given in Table 1, thermal noise is given by:

$$10 \log N_{th} = 188.7 - 10 \log C/N_0 - 20 \log \delta f \quad \text{dB}$$

δf: r.m.s. deviation of the SCPC-FM wanted signal (Hz).

After companding, the following is generally obtained:

$$C/N_0 = 0^{14.9}/\delta f^2$$

6.2 Interference from a carrier other than FM-TV

All other interfering signals have spectra significantly broader than the wanted signal spectrum (SCPC), thus:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{N_p}{N_{th}}$$

where:

N_p = 800 pW0p: permissible single-entry interference criterion

N_{th} = 6 500 pW0p or 7 000 pW0p corresponding to systems without or with frequency re-use. Thus for 7 000 pW0p:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{800}{7\,000} = 11.4\%$$

7 Digital SCPC wanted carrier

7.1 Interference from an FM-TV carrier

In this case the criterion $10 \log C/I = 10 \log C/N + 6.4 + 3 \log \delta - 8 \log (i/10)$ must be respected (Recommendation ITU-R S.671).

thus:

$$\frac{I}{N_0} = \frac{C}{N_0} \cdot \frac{I}{C} = \frac{N}{N_0} \cdot \frac{i^{0.8}}{10^{1.44} \cdot \delta^{0.3}}$$

thus:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{i^{0.8}}{10^{1.44} \cdot \delta^{0.3}} \cdot \frac{B_0}{B_2}$$

with:

$$\delta = \frac{B_0}{\Delta f} \text{ and } B_2 = \Delta f$$

Δf: peak-to-peak frequency deviation of TV signal due to energy dispersal (Hz)

i: percentage of total pre-demodulation noise allocated to internetwork interference.

For the example given in Table 1, C/N_0 is given by:

$$C/N_0 = \frac{E}{N_0} \cdot D_u$$

where:

E: energy per bit

D_u: useful bit rate

N_0: noise power density.

7.2 Interference from a carrier other than FM-TV

All other signals have spectra significantly broader than the wanted signal spectrum (SCPC). Thus for systems with frequency re-use:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{0.06}{0.7} = 8.57\%$$

8 Broadband digital wanted carrier

Recommendation ITU-R S.523 gives the ITU-R criterion: $\alpha I/N_{th} = \frac{6}{70} = 8.75\%$ (for systems with frequency re-use).

8.1 Interference from a digital carrier

– if $B_0 > B_1$: $\alpha = 1$

then:

$$\frac{I}{N_0} = \frac{I}{N_{th}} \cdot \frac{N_{th}}{N_0} = \frac{I}{N_{th}} \cdot B_0 = 0.0857\ B_0 \quad \text{and} \quad B_2 = B_1$$

thus:

$$\left(\frac{\Delta T}{T}\right)_N = 0.0857 \cdot \frac{B_0}{B_2} = 0.0857 \cdot \frac{B_0}{B_1}$$

– if $B_0 < B_1$: $\alpha = B_0/B_1$

then:

$$\frac{I}{N_0} = \frac{\alpha I}{N_{th}} \cdot \frac{N_{th}}{N_0} \frac{1}{\alpha} = 0.0857\ B_0 \cdot \frac{B_1}{B_0} = 0.0857\ B_1 \quad \text{and} \quad B_2 = B_1$$

hence:

$$\left(\frac{\Delta T}{T}\right)_N = 0.0857 \cdot \frac{B_1}{B_2} = 0.0857$$

8.2 Interference from an analogue carrier

– if $B_0 > B_1$: $\alpha = 1$

then:

$$\frac{I}{N_0} = \frac{I}{N_{th}} \cdot \frac{N_{th}}{N_0} = 0.0857\ B_0 \quad \text{and} \quad \left(\frac{\Delta T}{T}\right)_N = 0.0857 \cdot \frac{B_0}{B_2}$$

– if $B_0 < B_1$:

$$\frac{I}{N_0} = \frac{\alpha I}{N_{th}} \cdot \frac{N_{th}}{N_0} \frac{1}{\alpha} = 0.0857 \cdot \frac{B_0}{B_\alpha} \quad \text{and} \quad \left(\frac{\Delta T}{T}\right)_N = 0.0857 \cdot \frac{B_0}{\alpha \cdot B_2}$$

9 FM-TV wanted carrier

In this case, the criterion is: 10 log $C/\alpha I \geq X$ dB, where X could be a variable. However, for the example given in Table 1, the value of X has been taken as 35 dB.

Thus:

$$\frac{I}{N_0} = \frac{I}{C} \cdot \frac{C}{N_0} = \frac{1}{10^{3.5}} \cdot \frac{C}{\alpha \cdot N_0}$$

– if $B_0 > B_1$: $\alpha = 1$

$$\left(\frac{\Delta T}{T}\right)_N = \frac{C}{N_0} \cdot \frac{1}{10^{3.5}} \cdot \frac{1}{B_2}$$

– if $B_0 < B_1$:

$$\left(\frac{\Delta T}{T}\right)_N = \frac{C}{N_0} \cdot \frac{1}{10^{3.5}} \cdot \frac{1}{\alpha \cdot B_2}$$

For the example given in Table 1, according to Recommendation ITU-R S.567, the required S/N is 53 dB. Allowing 20% of the total noise to external interference, the following must be satisfied:

$$\frac{S}{N_{th}} \geq 54 \text{ dB for 99\% of the time.}$$

The TV video signal-to-noise ratio after demodulation is given by:

$$10 \log \frac{S}{N_{th}} = 10 \log \frac{C}{N_0} + 20 \log \frac{r_1 \cdot \Delta F}{F_m} - 10 \log \frac{F_m}{3} + P + Q$$

ΔF: frequency deviation at low FM-TV signal frequencies (Hz)

F_m: maximum baseband frequency (Hz) of the FM-TV signal

P: pre-emphasis

Q: weighting

r_1: video-to-luminance signal ratio.

– In the case of a 625/50 TV system:

$$Q = 13.2 \text{ dB} \qquad P = 11 \text{ dB} \qquad r_1 = 0.714$$

$$P + Q = 24.2 \text{ dB}$$

thus:

$$C/N_0 = 10^{(54 - K_{TV})/10}$$

with:

$$K_{TV} = P + Q + 10 \log 3\, r_1^2 \cdot \frac{\Delta F^2}{F_m^3}$$

$$= 24.2 + 10 \log 1.53 \cdot \frac{\Delta F^2}{F_m^3}$$

10 Conclusion

This method can be used for determining the need for coordination and as it reflects better than Appendix S8 to the Radio Regulations the actual interference situation, a certain number of coordination procedures might be eliminated.

Also, as a contribution to future planning efforts based on multilateral coordination, this method can provide a more precise means of determining mutual interference.

ANNEX 2

A power density-averaging bandwidth method of determining interference between satellite networks

This method for determining the mutual interference between satellite networks is based on using available information to develop a worst-case power density versus averaging bandwidth (the bandwidth over which the power density is averaged) function from which the interference power in any interfered-with carrier bandwidth can be estimated. When the interfering power density corresponding to an interfered-with carrier is used in the calculations given in Recommendation ITU-R S.738, the result is the I/N for the interfered-with carrier which is also numerically equal to the $\Delta T/T$ for that carrier bandwidth. Since the I represents an interfering carrier power of the same bandwidth as the interfered-with carrier, a C/I may also be computed by the method described in Annex 2 to Recommendation ITU-R S.740. Reasonably accurate interference estimates may be made with a minimal amount of data which can be used to determine if detail coordination is necessary. This method is described in detail in Annex 3 to Recommendation ITU-R S.740.