RECOMMENDATION ITU-R S.741-2

CARRIER-TO-INTERFERENCE CALCULATIONS BETWEEN NETWORKS IN THE FIXED-SATELLITE SERVICE

(Question ITU-R 49/4)

(1992-1993-1994)

The ITU Radiocommunication Assembly,

considering

a) that during the planning stage of a satellite network it may be useful to calculate carrier-to-interference (*C*/*I*) ratios between carriers of the interfering and interfered-with networks for the purpose of determining levels of interference;

b) that such calculations depend on the relative geometry of the satellite network involved;

c) that the carrier-to-interference ratios can be used in the determination of interference levels contributing to performance degradation;

d) that the carrier-to-interference ratios can be used for all modulation methods and signal types;

e) that the carrier-to-interference calculation may be an element to complete frequency coordination of satellite networks in accordance with the Radio Regulations;

f) that alternative methods may be used, by agreement between the administrations concerned, to calculate levels of interference between satellite networks (see for example Recommendation ITU-R S.740),

recommends

1. that when carrier-to-interference ratios (*C*/*I*s) are used to calculate the levels of interference between satellite networks:

- the method shown in Annex 2 of Recommendation ITU-R S.740 be used as the basis for these calculations in so far as geometrical considerations are concerned;
- the methods given in Annex 1 to this Recommendation be used to calculate the interference power in the interfered-with carrier.

ANNEX 1

Determination of carrier-to-interference ratios and baseband noise power for coordination of carriers in the fixed-satellite service (FSS)

1. Types of interfering carriers

1.1 The types of interference experienced by the FSS carriers from adjacent networks can be classified as follows:

- noise-like interference;
- slowly swept interference arising from a TV-FM carrier modulated only with an energy dispersal (ED) signal;
- interference from one TV-FM carrier to another (this category is not addressed in this Annex).

2. Types of FSS carriers

2.1 The types of carriers normally used in FSS networks are:

- *Analogue*:
  - FDM-FM and CFDM-FM;
  - TV-FM;
  - single-channel-per-carrier (SCPC)-FM.
- *Digital*:
  - narrow-band and intermediate bandwidth carriers with and without FEC coding (e.g. SCPC-PSK);
  - large bandwidth carriers (e.g. TDMA, CDMA).

3. Methodologies used to assess interference into FSS carriers

3.1 Interference into FDM-FM and CFDM-FM carriers

The effect of interference into FDM-FM or CFDM-FM carriers is treated in terms of the baseband interference noise power in a telephony channel and is given by the following expression:

$$10 \log (np) = 87.5 - B - 10 \log (c/i) \quad (1)$$

where:

np : weighted interference power (pW0p)

B : interference reduction factor (dB)

c : power of the desired carrier (W)

i : power of the interfering carrier (W).

The factor B depends on the signal characteristics of both the desired and the interfering carriers and the frequency separation between the centre frequencies of the two carriers.

The expressions for the interference reduction factor for all types of interfering carriers are given in Recommendation ITU-R SF.766.

In the case of CFDM-FM, the applicable value of companding advantage (around 9 dB) should be considered along with the interference power level during speech excitation.

3.2 Interference into a non-FDM-FM carrier

The assessment of interference into a non-FDM-FM carrier depends on the nature (i.e. digital or analogue or slowly sweeping) of the interfering carrier and on whether the interfering carrier bandwidth is larger or smaller than the desired carrier occupied bandwidth.

Table 1 shows the *C*/*I* ratios for different combinations of the desired and interfering carriers.

3.3 Interference from noise-like digital carriers

The ratio of the carrier to interference power in the desired carrier signal bandwidth, for co-frequency operation of the desired and interfering carriers is given by:

$$C/I = 10 \log (c/i) - 10 \log (M) \quad \text{for } BW_D > BW_{Ia} \quad (2)$$

$$C/I = 10 \log (c/i) - 10 \log (BW_D / BW_{Io}) \quad \text{for } BW_D \leq BW_{Ia} \quad (3)$$

where:

C/I : ratio (dB) of desired carrier power and the total interference power in the desired carrier bandwidth

c : power of the desired carrier (W)

i : power of one interfering carrier (W)

$M \leq BW_D / BW_{Ia}$

BW_D : occupied bandwidth of the desired carrier

BW_{Io} : occupied bandwidth of the interfering carrier

BW_{Ia} : allocated bandwidth of the interfering carrier.

Expression (2) takes into account the effect of multiple interfering carriers (M) affecting a desired carrier which has a large bandwidth.

TABLE 1

Calculation of carrier-to-interference ratios for FSS carriers

<table>
<tr><th rowspan="2">Interfering carriers</th><th rowspan="2">Case</th><th colspan="5">Desired carriers</th></tr>
<tr><th>FDM-FM or CFDM-FM</th><th>SCPC-FM</th><th>Digital narrow-band</th><th>Digital wide band</th><th>TV-FM</th></tr>
<tr><td rowspan="2">FDM-FM or CFDM-FM or TV-FM with live modulation</td><td>$BW_{Ia} \leq BW_D$</td><td rowspan="6">See details in expression (1) or Rec. ITU-R SF.766</td><td>Not applicable</td><td colspan="3">$C/I = 10 \log (c/i) - 10 \log (BW_D / BW_{Ia})$</td></tr>
<tr><td>$BW_{Ia} > BW_D$</td><td colspan="4">$C/I = 10 \log (c/i) - A$</td></tr>
<tr><td rowspan="2">SCPC-FM or digital narrow-band
Digital wideband</td><td>$BW_{Ia} \leq BW_D$</td><td colspan="4">$C/I = 10 \log (c/i) - 10 \log (BW_D / BW_{Ia})$</td></tr>
<tr><td>$BW_{Ia} > BW_D$</td><td colspan="4">$C/I = 10 \log (c/i) - 10 \log (BW_D / BW_{Io})$</td></tr>
<tr><td rowspan="2">TV-MF (Energy dispersal signal modulation only)</td><td>$BW_{Ia} \leq BW_D$</td><td>Not applicable</td><td colspan="3">$C/I = 10 \log (c/i) - 10 \log (BW_D / BW_{Ia})$</td></tr>
<tr><td>$BW_{Ia} > BW_D$</td><td>$C/I = 10 \log (c/i)$ (Note 1)</td><td colspan="3">$C/I = 10 \log (c/i)$</td></tr>
</table>

BW_D : occupied bandwidth of the desired carrier

BW_{Io} : occupied bandwidth of the interfering carrier

BW_{Ia} : allocated bandwidth of the interfering carrier

c : power of the desired carrier (W)

i : power of one interfering carrier (W)

C/I : ratio (dB) of desired carrier power to the total interference power in the desired carrier bandwidth

A : bandwidth advantage factor (dB) as given in expressions (5)-(8).

Note 1 – Use criterion in Recommendation ITU-R S.671 if BW_D is smaller than energy dispersal bandwidth of the TV-FM carrier and use noise-like interference criterion if BW_D is larger than energy dispersal bandwidth.

Note 2 – The “assigned frequency band” may be used in place of the “occupied bandwidth” and the “allocated bandwidth”, when they are not available.

For the case of frequency offset between carriers, the resultant *C/I* can be determined by the following equation:

$$C/I = 10 \log (c/i) - A$$

where:

A : bandwidth advantage factor (dB).

The factor *A* is the ratio of the interfering carrier power contained in the desired signal bandwidth to the total interfering carrier power, under the assumption that the interfering carrier has uniform power spectral density across its occupied bandwidth.

3.4 Interference from noise-like analogue carriers

The ratio of carrier-to-interference power in the desired signal bandwidth due to interfering analogue carriers like FDM-FM or TV-FM modulated by live video is given by:

$$C/I = 10 \log (c/i) - 10 \log (M) \quad \text{for } BW_D > BW_{Ia} \tag{4}$$

$$C/I = 10 \log (c/i) - A \quad \text{for } BW_D \leq BW_{Ia} \tag{5}$$

where:

$M \leq BW_D/BW_{Ia}$

A : bandwidth advantage factor (dB).

Factor *A* is the ratio of the interfering carrier power contained in the desired signal bandwidth to the total interfering carrier power. The determination of factor *A* depends on the spectral characteristics of the interfering analogue carrier and is the ratio of the integral of the interfering power spectrum over the desired carrier bandwidth to the total power of the interfering carrier. Factor *A* is the inverse of the frequency-dependent rejection factor (FDR) given in Recommendation ITU-R SM.337, with the assumption that the receive filter selectivity ($H(f)$) = 1.

However, if the interfering power spectrum is not known, a worst case calculation of interference can be made with the approximation that the power spectral density of the interfering carrier is constant over the bandwidth of the desired carrier and is equal to the maximum value. The interfering power can then be calculated as the product of the maximum interfering power spectral density and the occupied bandwidth of the desired carrier, provided the result does not exceed the total power of the interfering carrier.

Defining the equivalent bandwidth (BW_{eql}) of the interfering carrier as the ratio of its total power to its maximum power spectral density, factor *A* may be written as:

$$A = 10 \log (BW_D / BW_{eql}) \quad \text{for } BW_D \leq BW_{eql} \tag{6}$$

$$A = 0 \quad \text{for } BW_D > BW_{eql} \tag{7}$$

$$BW_{eql} = i / i_0 \tag{8}$$

where:

i : total power of the interfering carrier

i_0 : maximum power spectral density of the interfering carrier.

In the case of interference from FDM-FM or CFDM-FM carriers, the power spectral distribution is very close to Gaussian with an r.m.s. deviation of σ and so the equivalent bandwidth can be written as:

$$BW_{eql} = \sigma \cdot \sqrt{2\pi}$$

3.5 Interference from slowly-swept TV carrier

The assessment of interference from slowly swept TV is carried out in terms of the ratio of the desired carrier power to the full TV carrier power.

The criterion for protecting narrow-band carriers from slowly swept TV carrier interference is dealt with in Recommendation ITU-R S.671. The noise-like interference criterion is used for assessing interference potential into wideband carriers whose bandwidths are larger than the energy dispersal bandwidth of the TV-FM carrier.

The effect of multiple interferers is given by expression (4) if the desired carrier bandwidth is larger than the allocated bandwidth of the interfering TV-FM carrier.

4. Protection criteria for FSS carriers

Recommendations ITU-R S.466, ITU-R S.483, ITU-R S.523, ITU-R S.671 and ITU-R S.735 deal with the interference noise allowance to be made in the noise budget for FSS carriers.

Table 2 shows the single entry interference (SEI) protection criteria for FSS carriers, which have been developed on the basis of the relevant ITU-R Recommendations.

TABLE 2

Single entry interference (SEI) protection criteria for FSS carriers

FSS carrier	ITU-R Recommendations for SEI	Type of interference	SEI protection criteria	
			API before 1987	API after 1987
FDM-FM CFDM-FM	Rec. ITU-R S.466	Any	600 pW0p	800 pW0p
TV-FM	Rec. ITU-R S.483	Noise-like	C/N + 14 (dB)	C/N + 14 (dB)
Digital	Rec. ITU-R S.523	Noise-like	C/N + 14 (dB)	C/N + 12.2 (dB)
SCPC-FM	(1)	Noise-like	C/N + 14 (dB)	C/N + 12.2 (dB)
SCPC-FM	Rec. ITU-R S.671	Slowly-swept	13.5 + 2 log (δ) – 3 log (i/10) (dB)	
Digital narrow-band:				
– with coding	Rec. ITU-R S.671	Slowly-swept	C/N + 9.4 + 3.5 log (δ) – 6 log (i/10) (dB)	
– without coding	Rec. ITU-R S.671	Slowly-swept	C/N + 6.4 + 3 log (δ) – 8 log (i/10) (dB)	

API : Advanced Publication of Information of networks

C/N : ratio (dB) of carrier to total noise power which includes all internal system noise and interference from other systems

δ : ratio of desired signal bandwidth to peak-to-peak deviation of the TV carrier caused by the energy dispersal signal

i : pre-demodulation interference power in the desired signal bandwidth expressed as a percentage of the total pre-demodulation noise power

(1) The criteria for noise-like interference are being used for the purposes of coordination.