RECOMMENDATION ITU-R S.671-3

NECESSARY PROTECTION RATIOS FOR NARROW-BAND SINGLE CHANNEL-PER-CARRIER TRANSMISSIONS INTERFERED WITH BY ANALOGUE TELEVISION CARRIERS

(Question ITU-R 50/4)

(1990-1992-1993-1994)

The ITU Radiocommunication Assembly,

considering

a) that narrow-band SCPC carriers are sensitive to the interference caused by analogue television carriers, especially when such TV carriers are only modulated with energy dispersal signals at the television frame rate;

b) that interference from FM-TV into SCPC transmissions is generally a determining factor in the coordination of closely spaced satellites;

c) that the calculation methods required for determining the level of permissible interference in such cases are unique to this class of signals;

d) that the uniqueness of this situation is recognized in Appendix 4 of the Radio Regulations,

recommends

1. for the purposes of calculating the permissible levels of interference between analogue television and narrow-band SCPC carriers, the protection ratio of SCPC carriers interfered with by analogue TV carriers modulated only by energy dispersal at the TV frame rate, be calculated from the following:

1.1 for 64 kbit/s SCPC, without forward error correction (FEC);

$$C/I = C/N + 6.4 + 3 \log \delta - 8 \log (i/10) \quad \text{dB}$$

1.2 for companded frequency modulation (CFM) SCPC;

$$C/I = 13.5 + 2 \log \delta - 3 \log (i/10) \quad \text{dB}$$

where:

C/I: ratio of the interfered with SCPC carrier power to the total carrier power of the interfering dispersed TV signal

C/N: operating carrier-to-noise power ratio of the SCPC carrier which corresponds to a BER of 1×10^{-6}

δ: ratio of the occupied bandwidth of the SCPC carrier to the TV peak-to-peak deviation due to dispersal

i: the total allocated pre-demodulation interference power in the SCPC bandwidth, consisting of the interference power contributed by the TV carrier as well as the noise-like interference coming from other interfering carriers (see Annex 1), expressed as a percentage of the total pre-demodulation noise power ($10 \leq i \leq 25$);

2. that the following Notes should be regarded as part of the Recommendation:

Note 1 – The interference criteria in § 1.1 and 1.2 are applicable for interfering TV signals using frame rate energy dispersal only.

Note 2 – The formulae in § 1.1 and 1.2 are correct on the assumption that the interference determined by the relative power value i is caused by a TV carrier I and noise-like interference I_N, for a ratio $I_N/I = 2.5$ and for a power spectral density of the noise-like interference of –62 dBc/Hz.

Note 3 – To protect 64 kbit/s SCPC carriers having FEC coding at rates between 1/2 and 7/8 using soft decision Viterbi decoding, the following expression may be used:

$$C/I = C/N + 9.4 + 3.5 \log \delta - 6 \log (i/10) \quad \text{dB}$$

This interference criterion is valid for interfering FM-TV signals modulated only by a dispersal signal.

Note 4 – Significant additional protection for narrow-band SCPC carriers can be obtained if they are appropriately offset in frequency from the centre frequency of the TV carrier. This applies, in different degrees, both when the TV carrier is modulated with live programme material and otherwise and in such cases the effect of power spectral density of FM-TV carriers should be taken into account for determining the interference at frequencies outside the energy dispersal bandwidth.

Note 5 – Further study is needed to determine the level of additional protection which can be realized when the TV carrier is modulated with live programme material or otherwise.

Note 6 – Annex 1 contains methods for performing the calculations which utilize the protection ratios in § 1 and the results of measurements in support of both § 1 and 2.

Note 7 – Further study is needed to develop appropriate interference criteria for interfering FM-TV carriers with a line rate energy dispersal or a composite line rate and frame rate dispersal.

ANNEX 1

Calculation of protection ratio for FM-TV interference into single-channel-per-carrier transmissions in networks of the fixed-satellite service

1. Interference in uncoded 8-bit PCM 4-phase PSK single-channel-per-carrier transmissions

One of the most common carriers in use is 8-bit PCM 4-phase PSK (QPSK) SCPC at 64 kbit/s and the establishment of an interference criterion is based on the following considerations.

Monitoring of TV transmissions in the INTELSAT system indicates that TV carriers are modulated by video signals or test patterns most of the time and that for only very short periods the TV carriers are modulated by energy dispersal signals (EDS) alone. These periods are of the order of 0.6% of the total transmission time. The average length of such periods is about 5 min. The longest continuous such period was found to be about 18 min. Thus, the probability of simultaneous occurrences of two or more such interferers is very small.

Additional measurements are needed to examine the validity of these statistical results in other satellite systems.

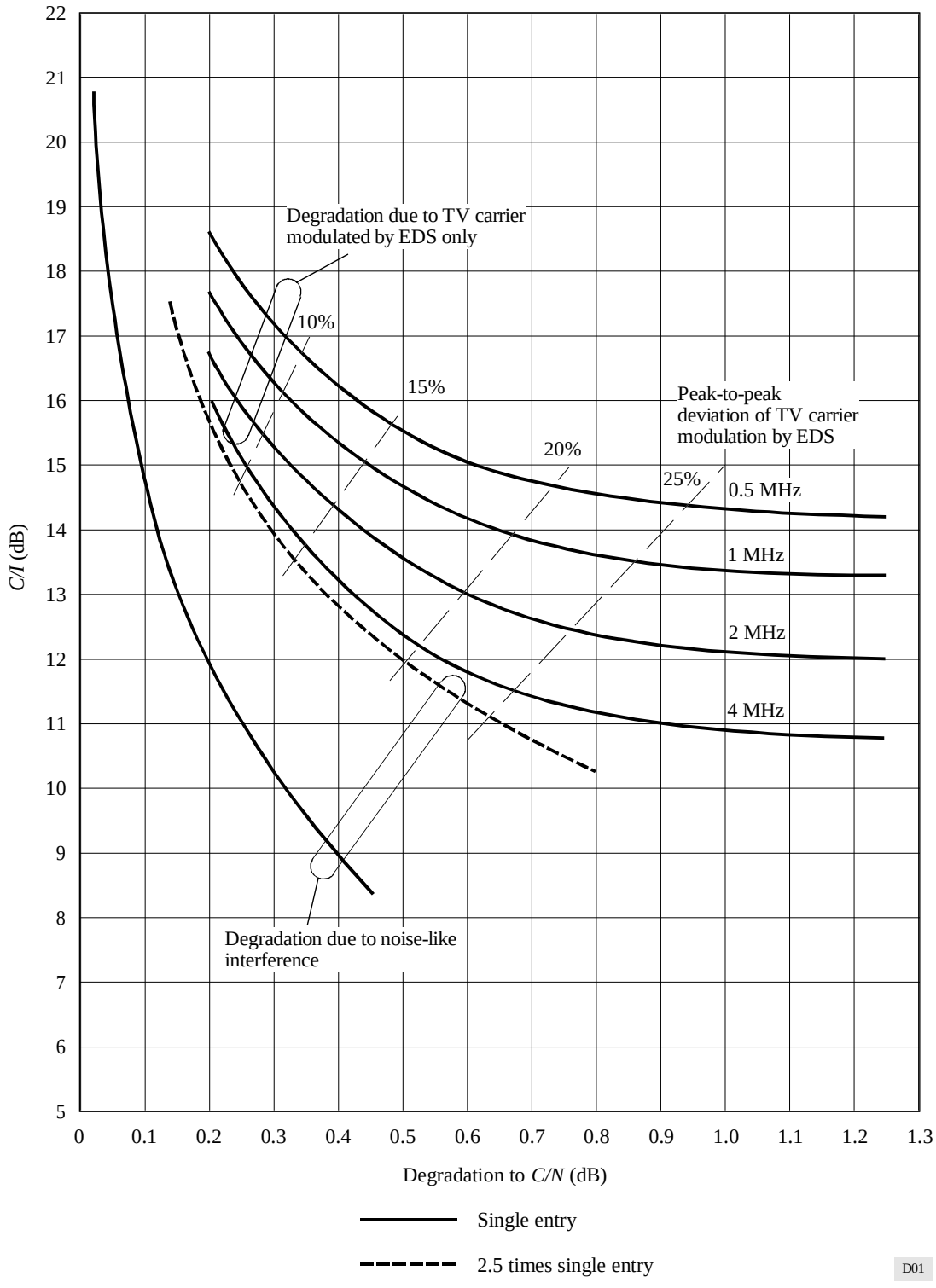
To establish a criterion to be used for protecting the uncoded SCPC/QPSK (64 kbit/s) transmissions, one TV carrier modulated with EDS alone is assumed to be present all of the time (one such entry representing time addition of all such interfering signals from different satellites). This type of interference is assumed to coexist with other noise-like interferers. Therefore, the total pre-demodulation interference noise allowed by Recommendation ITU-R S.523 should be divided between these two dissimilar types of interference.

A model has been developed to derive the apportionment of the total allowed interference between the two types of interferers. The model assumes a contribution coming from an energy dispersal modulated TV carrier and a noise-like contribution which is equal to 2.5 times the single entry interference. The noise-like single entry interference is assumed to originate from a modulated carrier, whose spectral density (power in a bandwidth of 1 Hz relative to the total carrier power) in the proximity of the carrier frequency is –62 dBc/Hz. This value is appropriate for representing a high density FM carrier or a modulated TV carrier.

The following laboratory measurements were made. The SCPC transmission was operated at different carrier-to-noise ratio values above C/N = 14.6 dB (E_b /N_0 = 12.3 dB) which corresponds to BER = 10^{-6}. Then, the energy dispersal modulated TV interferer was added and the value of the carrier-to-interferer carrier power was recorded which restored the BER to 10^{-6}. The results are presented in Fig. 1 for different peak-to-peak energy dispersal signal deviations. In the same figure, the relationship between the noise-like interference C/I (for both single entry and total noise-like interference) and degradation is shown.

FIGURE 1

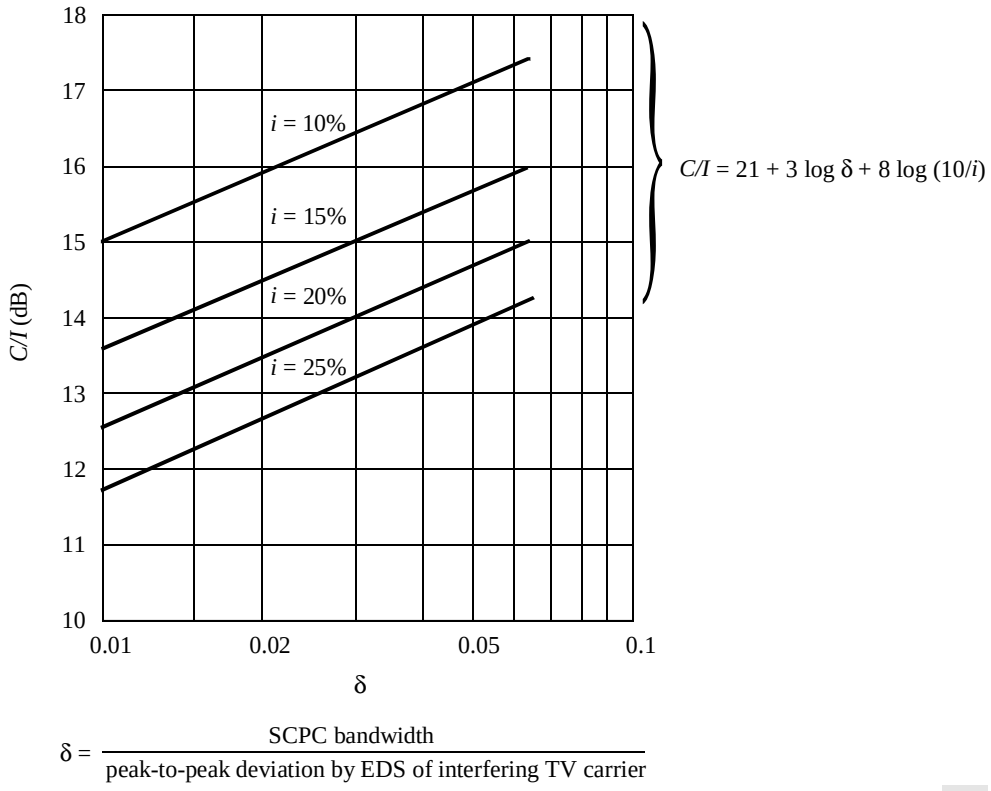
***C/I* vs degradation of *C/N* ratio**



Using Fig. 1, by equating the total degradation caused by the TV (EDS modulated only) interference and noise-like interference with the criterion defined in Recommendation ITU-R S.523, the protection ratios for uncoded SCPC/QPSK (64 kbit/s) were determined, as shown in Fig. 2.

FIGURE 2

Protection criteria



These results can be approximated by the equation:

$$C/I = 21 + 3 \log \delta + 8 \log (10/i) \quad \text{dB} \tag{1}$$

or:

$$C/I = C/N + 6.4 + 3 \log \delta - 8 \log (i/10) \quad \text{dB}$$

where:

C/I: ratio of the SCPC carrier power to the total carrier power of the interfering dispersed TV signal

C/N: operating carrier-to-noise ratio which corresponds to BER = 10^{-6}

δ: (SCPC occupied bandwidth)/(TV peak-to-peak deviation by EDS)

i: the total allocated pre-demodulation interference power in the SCPC bandwidth, consisting of the interference power contributed by the TV carrier as well as the noise-like interference coming from other interfering carriers (see Annex 1), expressed as a percentage of the total pre-demodulation noise power ($10 \leq i \leq 25$).

2. Interference in 8-bit PCM 4-phase PSK single-channel-per-carrier transmissions with FEC coding

Measurements have been carried out on two 64 kbit/s SCPC/QPSK systems with rate 1/2 FEC coding, i.e. EUTELSAT SMS carriers and INTELSAT Business Service (IBS) carriers. The signal parameters are listed in Table 1 and are in accordance with the specification of these systems.

TABLE 1

Encoded QPSK transmission parameters

Transmission parameter	INTELSAT, EUTELSAT
Information rate (IR) (kbit/s)	64
Overhead bits (OH)	16/15
Composite rate (CR) (kbit/s)	68.27
FEC code rate (C)	1/2
Transmission rate (TR) (kbit/s) (CR/C)	136.5
Nyquist bandwidth (0.5 TR)	68 k
Composite rate E_b/N_0 (1) (dB) for 10^{-6} BER	5.4
C/N (1) (dB) for 10^{-6} BER	5.4

(1) The values for E_b/N_0 and C/N relate to the actual demodulator performance of the equipment used in the measurements.

The measurements resulted in curves of C/I versus degradation for BER values 10^{-6} .

The protection criterion which has been developed is based on measurements using two different interference models. One model is the same as described in § 1 for uncoded QPSK transmission. The model divides the total allowed interference between two types of interferers: one TV carrier modulated only with an energy dispersal signal (EDS), and other carriers modulated by noise-like signals. In the model, the apportionment of the total allowed interference is determined from the different interference effects of the two types of interferers. The spectral density of –62 dBc/Hz is used to derive the noise-like interference.

The other model considered an interference scenario in which total interference is equivalent to 20% of the pre-modulation noise, shared equally between noise-like interference and a single TV carrier modulated by an energy dispersal signal. The energy dispersed carrier is, therefore, assumed to represent 10% of the total pre-demodulation noise, hence leading to an equivalent thermal noise increase of 0.5 dB (referred to as "C/N degradation").

The tests involved the measurement of the increase in mean BER caused by the introduction of the interferer for a given constant value of the C/N ratio (carrier-to-thermal noise power ratio), set to give a BER of 1×10^{-6} in the absence of interference (5.4 dB for 64 kbit/s carriers). The measured increase in mean BER was converted into an equivalent thermal noise increase using the back-to-back modem noise performance curve.

The measurements thus provide a relationship between the C/I (ratio of the SCPC carrier power to the total carrier power of the interfering TV signal) and the degradation of the C/N in the SCPC channel caused by the presence of the TV interference as single source interference (modulated by EDS only).

Results using the two above-mentioned models agree well and lead to the following single entry interference criterion which can be used for intersystem coordination purposes:

$$C/I = C/N + 9.4 + 3.5 \log \delta - 6 \log (i/10) \quad \text{dB} \tag{2}$$

where:

C/N: carrier-to-noise ratio which corresponds to a BER of 1×10^{-6}

i: total allowed interference power in the carrier bandwidth expressed as a percentage of the total pre-demodulation noise power ($10 \leq i \leq 25$, as defined in Recommendation ITU-R S.523).

3. Interference in FM-SCPC transmissions using syllabic companding

Based on the assumption used in § 1, protection criteria have been developed for SCPC-CFM using two distinct bases for the criteria:

– impulse noise counts above a threshold of –21 dBm0, and

– subjective evaluations.

The modem employed was designed to operate in the INTELSAT system in accordance with INTELSAT performance specifications for its VISTA service. The carrier-to-noise density C/N_0 at the normal operating point is 54.2 dB(Hz) which corresponds to a C/N of 10.2 dB. The threshold of this equipment is approximately a C/N_0 of 50.2 dB(Hz). The nominal IF noise bandwidth is 25 kHz with the deviation established such that for a 0 dBm0 test tone at 1 kHz the corresponding r.m.s. deviation is 5.1 kHz. The pre-emphasis cross-over frequency is at 1 kHz. The companding is 2:1 syllabic according to ITU-T Recommendation G.162 with an unaffected level of 0 dBm0.

For the impulse count measurements, a threshold value of –21 dBm0 was used in accordance with ITU-T Recommendation M.1020. The test instrument used for the impulse counts employed a 1 kHz tone at the transmit side which was removed by a notch filter at the receive side. The level of this tone was –10 dBm0. Degradations to the C/N, for this tone level and with the compander on, for the case of 6 impulses per 15 min, were measured as a function of the C/I ratios.

These results are shown in Fig. 3 where C/I versus the degradation to the C/N is shown for the four values of energy dispersal peak-to-peak deviations. The calculated noise-like interference curve is shown in Fig. 4 from which the protection criterion is derived.

$$C/I = 13.5 + 2 \log \delta - 3 \log (i/10) \quad \text{dB} \tag{3}$$

where δ and i are as defined above.

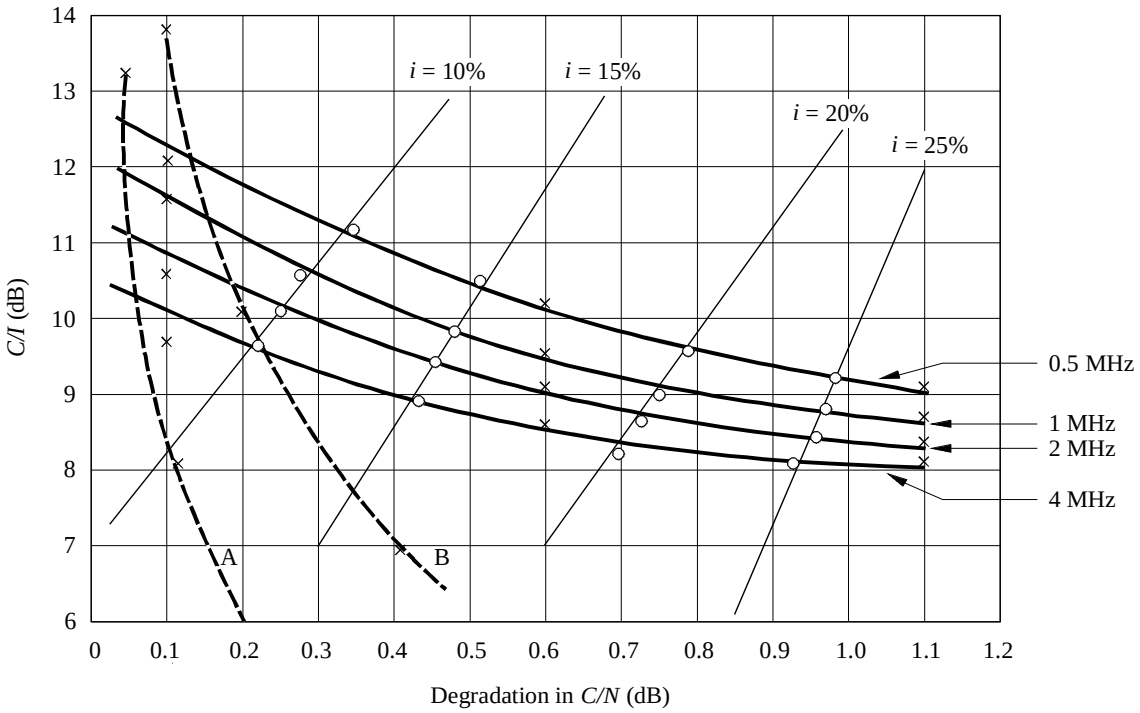
In the same way, subjective assessments of the degradation to the SCPC-CFM channel were made with a criterion based upon one audible “pop” per minute. The characteristic interference on the EDS at or near the nominal 54.2 dB(Hz) operating point is observed in the form of impulsive noise or “pops”. These results are shown in Fig. 5. The resulting criteria are of the form

$$C/I = 13 + 2 \log \delta - 3 \log (i/10) \quad \text{dB} \tag{4}$$

as shown in Fig. 6 and are slightly lower than those based on impulse counts. Comparing equations (3) and (4), it is concluded that the criterion of equation (3) should be used as a single criterion for SCPC-CFM for both impulse count and subjective impairments, and graphically shown in Fig. 4.

FIGURE 3

***C/I* vs degradation in *C/N* for a SCPC-CFM modem based upon impulse noise counts (a constant impulse count criterion of six counts exceeding a threshold of –21 dBm0 in a 15 min interval was used)**



A: C/I_{sn1} (carrier to single entry noise-like interference ratio)
B: C/I_{n1} (carrier to noise-like interference ratio)

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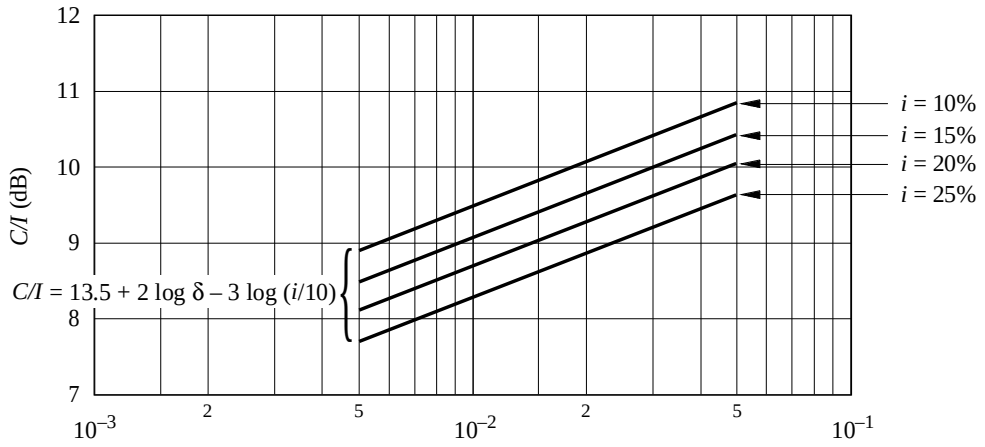
FIGURE 4

***C/I* vs duty cycle based upon impulse noise count for a SCPC-CFM modem**



$$\delta = \frac{\text{SCPC bandwidth}}{\text{peak-to-peak deviation by EDS of interfering TV carrier}}$$

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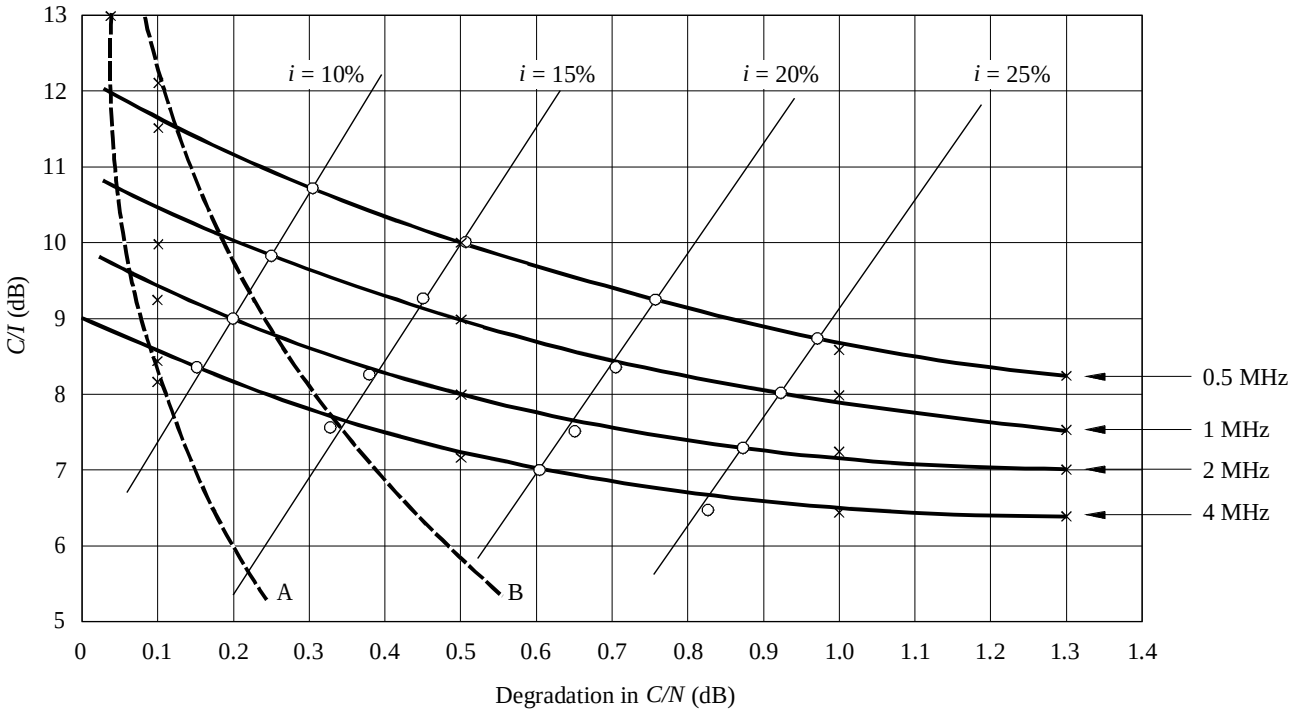
FIGURE 5

***C/I* vs degradation in *C/N* for a SCPC-CFM modem based upon subjective evaluation (1 pop/min)**

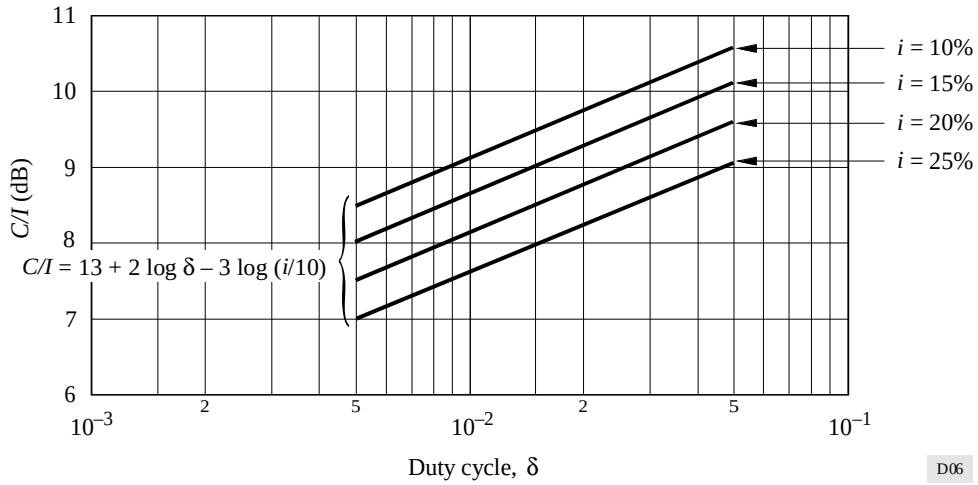


A: C/I_{sn1} (carrier to single entry noise-like interference ratio)
B: C/I_{n1} (carrier to noise-like interference ratio)

D05

FIGURE 6

***C/I* vs duty cycle based upon subjective evaluation of a SCPC-CFM modem (1 pop/min)**



D06