RECOMMENDATION ITU-R S.483-3*,**

Maximum permissible level of interference in a television channel of a geostationary-satellite network in the fixed-satellite service employing frequency modulation, caused by other networks of this service

(1974-1978-1992-1997)

The ITU Radiocommunication Assembly,

considering

a) that TV/FM carriers are sensitive to interference from other fixed-satellite service (FSS) carriers;

b) that in particular, TV/FM carriers are sensitive to interference from other TV/FM carriers;

c) that interference between networks in the FSS contributes to the noise in the system;

d) that it is desirable that the interference noise in television channels of networks in the FSS caused by transmitters of different networks of this service should be such as to give a reasonable orbit utilization efficiency;

e) that the overall performance of a network should essentially be under the control of the system designer;

f) that it is necessary to protect a network in the FSS from interference by other networks of this service;

g) that it is necessary to specify the maximum permissible interference power in a television channel, in order to determine space station and earth station characteristics such as required protection ratios and minimum orbital spacing;

h) that protection ratio masks are useful to determine minimum orbital spacing and in coordination exercises;

j) that for direct to home (DTH) reception quality grade 4, as defined in Recommendation ITU-R BT.500, is usually adequate,

recommends

1 that different geostationary-satellite networks, in the FSS operating in the same frequency bands, be designed in such a manner that the interference noise power in a hypothetical reference circuit for television of a network in the FSS employing frequency modulation caused by the aggregate of the earth station and space station transmitters of other networks, should not exceed 15% of the permissible video noise in the hypothetical reference circuit for more than 1% of any month;

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* This Recommendation should be brought to the attention of Radiocommunication Working Party 10-11S.

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

2 that the maximum level of interference noise power caused by any one satellite network into another satellite network should not exceed 4/10 of the interference noise allowance recommended in § 1 but in some cases it may be necessary to limit the single entry value to less than 4/10 of the interference noise allowance quoted above;

3 that the protection ratio masks in Annex 2 (§ 8) be used in cases where the interferer is another TV/FM carrier (see Note 6);

4 that the maximum level of interference noise power caused to that network should be calculated on the basis of the following values for the receiving earth station antenna gain in a direction at an angle φ (degrees) referred to the main beam direction:

$$G = 32 - 25 \log \varphi \quad \text{dBi} \quad \text{for} \quad 1° \leq \varphi < 48°$$

$$G = -10 \quad \text{dBi} \quad \text{for} \quad 48° \leq \varphi \leq 180°$$

except when the actual gain is known and is less than the above value, in which case the actual value should be used;

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

NOTE 1 – The above values of interference noise shall be included in the total noise allowances as defined in Recommendation ITU-R S.354.

NOTE 2 – In segments of the geostationary-satellite orbit not likely to be crowded, interference allowances less than those recommended above may be utilized, allowing a corresponding increase in other noise contributions within total acceptable noise limits.

NOTE 3 – Particularly in cases where interference is caused by transmitters using code-division-multiple-access techniques, the interference from another fixed-satellite network referred to in § 2 is the composite interference from all transmissions having overlapping spectra in that network.

NOTE 4 – The methods referred to in Recommendation ITU-R S.741 and other relevant ITU-R texts can be used to calculate the carrier-to-interference ratio.

NOTE 5 – Annexes 1 and 2 contain further information relevant to this Recommendation.

NOTE 6 – The masks provided in Annex 2 do not take into account the TV audio requirements of certain systems. When there are such requirements, the protection ratio masks may be replaced with other masks specific for such requirements, if necessary. This needs to be further studied.

ANNEX 1

1 Multiple carrier interference

As TV is generally a wideband transmission, there will be cases where the interference will consist of a number of narrower bandwidth carriers. In such cases the analysis and calculation should take account of the total power of the interfering carriers that are contained within the TV bandwidth to determine the *C*/*I*.

2 TV sound

Television sound can be transmitted along with the TV carrier using a subcarrier frequency modulated by the programme signal and multiplexed with the composite video signal with the subcarrier placed above the TV baseband or using sound-in-sync techniques (SIS). A single, high quality 15 kHz audio channel is commonly provided.

For techniques of transmitting TV sound on a separate carrier, such as SCPC, there is no specific criterion in ITU-R texts and study is needed.

ANNEX 2

Interference between TV/FM signals

1 Introduction

Interference between TV/FM signals is of special importance because the impairments introduced by a TV/FM interferer have a different subjective effect on a TV picture than the effect caused by thermal noise. This Annex provides a method to evaluate the impairments caused by thermal noise and TV/FM interference and the derivation of the protection ratio masks.

2 Subjective assessment of TV picture quality

The impact of various types of impairments on the picture quality is usually determined using subjective assessments of a number of viewers, mostly non-experts. The methodology for the assessments specifying the viewing conditions, grading scales and other details is recommended by the ITU-R in Recommendation ITU-R BT.500. A five-grade scale is usually used to describe the quality and level of impairment of the TV picture.

3 Impairments due to thermal noise

The results of extensive assessments of impairments in a NTSC signal introduced by thermal noise lead to the following expressions, which approximate the impairments introduced by thermal noise:

$$I_{th} = \exp\left[30.9 - 8.41\ln(S/N_w)\right] \tag{1}$$

In equation (1), I_{th} denotes the impairments caused by thermal noise and is related to the impairment grade via a general equation:

$$I = (5 - Q) / (Q - 1) \tag{2}$$

where:

Q: impairment grade on the five-grade scale

S/N_w: weighted (unified) signal-to-noise ratio in (dB).

Expression (3) also provides a very good fit of the mean opinion scores as shown in Fig. 1:

$$I_{th} = [10^{(-S/N_w)/25} / 0.027]^{2.2} \tag{3}$$

4 Impairments due to co-channel interference caused by another TV/FM carrier

Many studies support the following conclusions in respect to interference from another TV/FM carrier:

– the impact of co-channel interference on the picture quality is more significant than the impact of the same amount of thermal noise;

– the subjective effects of the impairments caused by the co-channel interference are dependent on the desired TV picture content; the picture content of the interfering TV signal seems to play a less significant role;

– the deviation of the desired signal is an important factor.

Expression (4) has been suggested earlier to relate the impairments introduced into a TV picture and the protection ratio between two co-channel NTSC TV/FM signals:

$$PR_0 = 16.9 - 8.7 \log I_{int} - 20 \log (D/12) \tag{4}$$

where:

PR_0: protection ratio

I_{int}: impairment introduced by co-channel interference

D: peak-to-peak deviation in (MHz) of the wanted TV signal.

Equation (2) relates the impairments due to interference with the corresponding impairment grade Q.

Comparing the impairments introduced by thermal noise and interference, an important observation can be made; the impairments caused by co-channel interference correspond to the impairments caused by the thermal noise whose level is about 6 dB higher than the interference noise. This observation suggests the use of equation (3) adjusted for the 6 dB higher impact in modelling the impairments due to co-channel interference. Applying this approach to the example in Fig. 2, the relation between the protection ratio and the impairments due to co-channel interference with an adjustment factor of 6.2 dB is given by equation (5). For this example, $S/N_w = C/N + 30$ (dB). Then, $S/N_{int} = C/I + 30 - 6.2 = C/I + 23.8 = PR_0 + 23.8$ (dB) and equation (5) follows:

$$I_{int} = [10^{-(PR_0 + 23.8)/25} / 0.027]^{2.2} \tag{5}$$

As shown in Fig. 3, this approach better describes the mean opinion scores for co-channel interference, especially at lower grades, than equation (4).

FIGURE 1

Impairments due to thermal noise

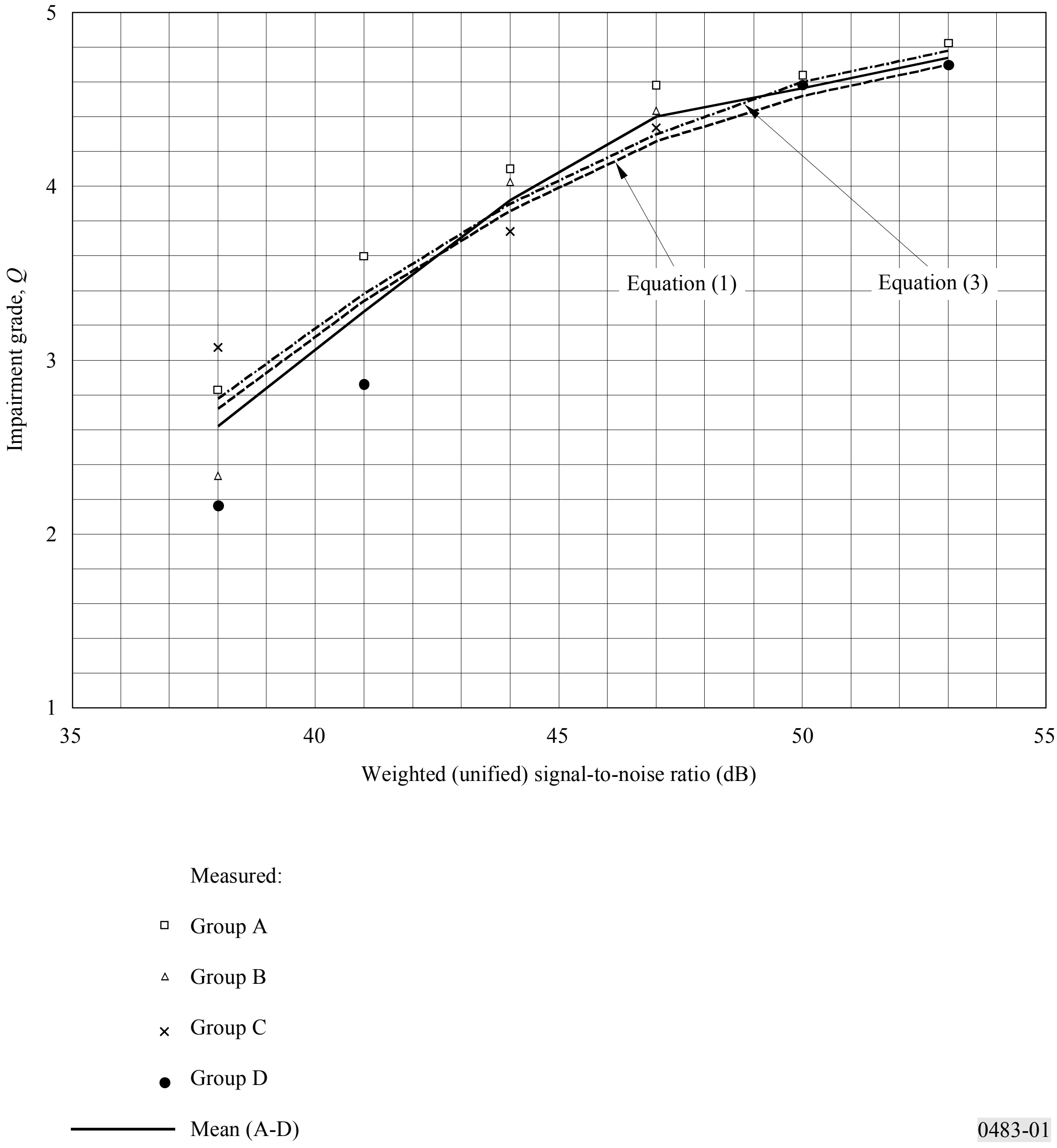

FIGURE 2

Impairments due to co-channel interference

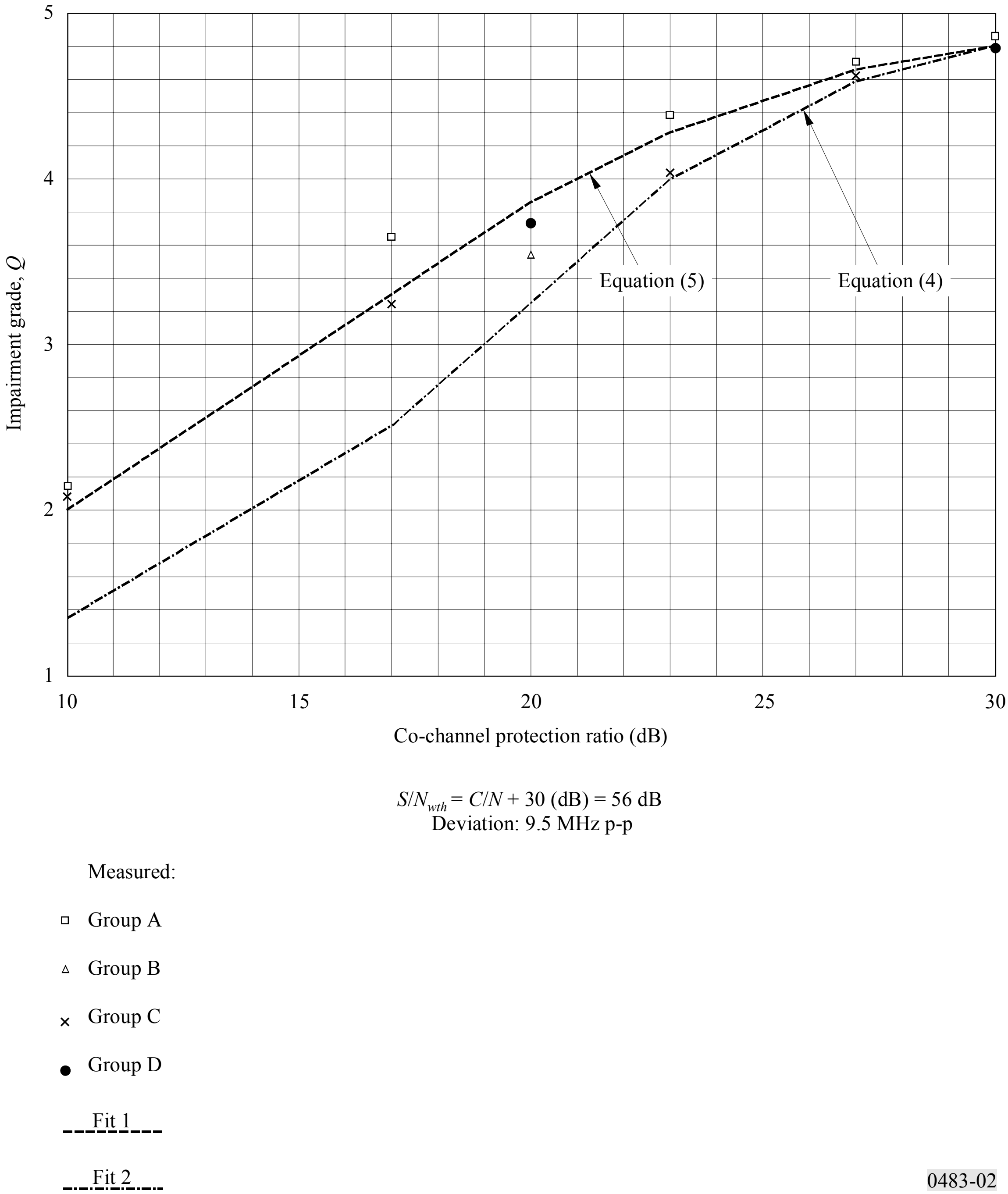

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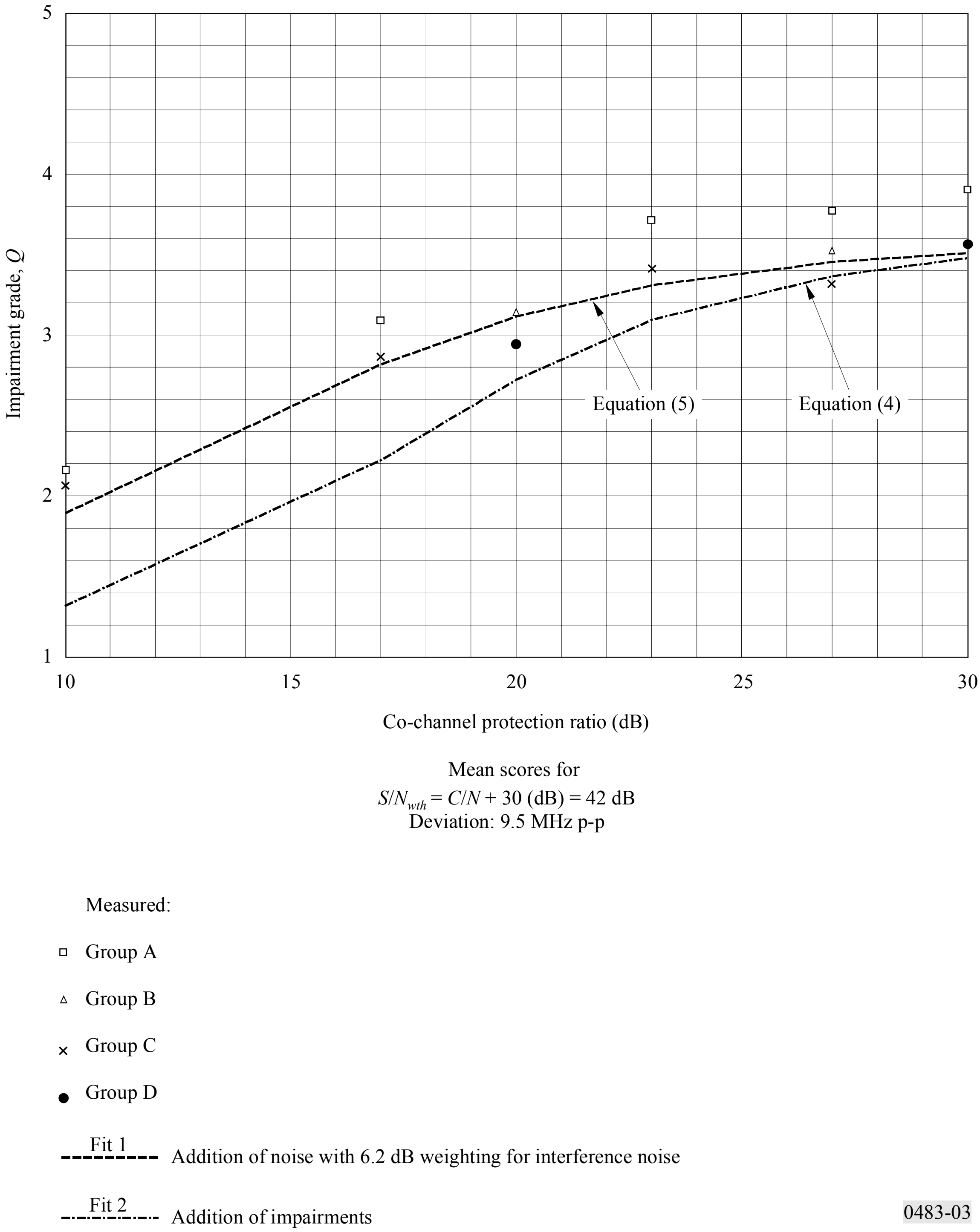
FIGURE 3

Impairments due to co-channel interference and thermal noise



5 Multiple co-channel interferers

Studies have shown that the impact of three equal level co-channel interferers is equivalent to the impact of a single interferer having a 3 to 5 dB higher power. These results suggest that the power addition law corresponds to the worst case.

6 Impairments due to aggregate thermal noise and co-channel interference

When both thermal noise and co-channel interference are present in a TV signal, the modelling of the impairments introduced in the picture is not straightforward. It is known that a simple addition of the interference power to the thermal noise power does not adequately model the resulting impairments. Another method based on the addition of impairments caused by thermal noise and co-channel interference provides a better approach, but it is not reliable for low impairment grades. A new method based on the summation of thermal noise and weighted co-channel interference noise, proposed here, appears to provide a reasonably good approximation of the mean opinion scores over the full range of the impairment grades.

The proposed method is based on the observation made in § 4 that the impairments caused by co-channel interference are approximately equivalent to the impairments caused by the thermal noise having a power of about 6 dB higher than the co-channel interference power. This suggests that the noise power present in the TV signal and the co-channel interference power increased by about 6 dB can be summed up, an equivalent S/N_w can be found and the impairments introduced can then be determined by using equation (3). The method of summation of impairments is also given for comparison. Following the proposed method a set of curves for a range of S/N_w from 42 to 56 dB and a range of protection ratios from 10 to 40 dB is generated and shown in Fig. 4 for the NTSC TV standard with a peak-to-peak FM deviation of 9.5 MHz.

7 Impact of desired TV/FM signal deviation

The deviation of the desired TV signal has a significant effect on the impact of the co-channel interference. Many studies have shown that a "20 log" law can be applied. In other words, if the impact of a co-channel interferer at a protection ratio PR_0 into a TV signal with a deviation D_0 is determined, then the same interferer will have the same impact into a TV signal whose deviation is D_1 at a protection ratio $PR_1 = PR_0 - 20 \log (D_1/D_0)$. Applying this, the results in Fig. 4 are generalized by denoting the X-axis as $X = PR_0 + 20 \log (D/9.5)$ (dB).

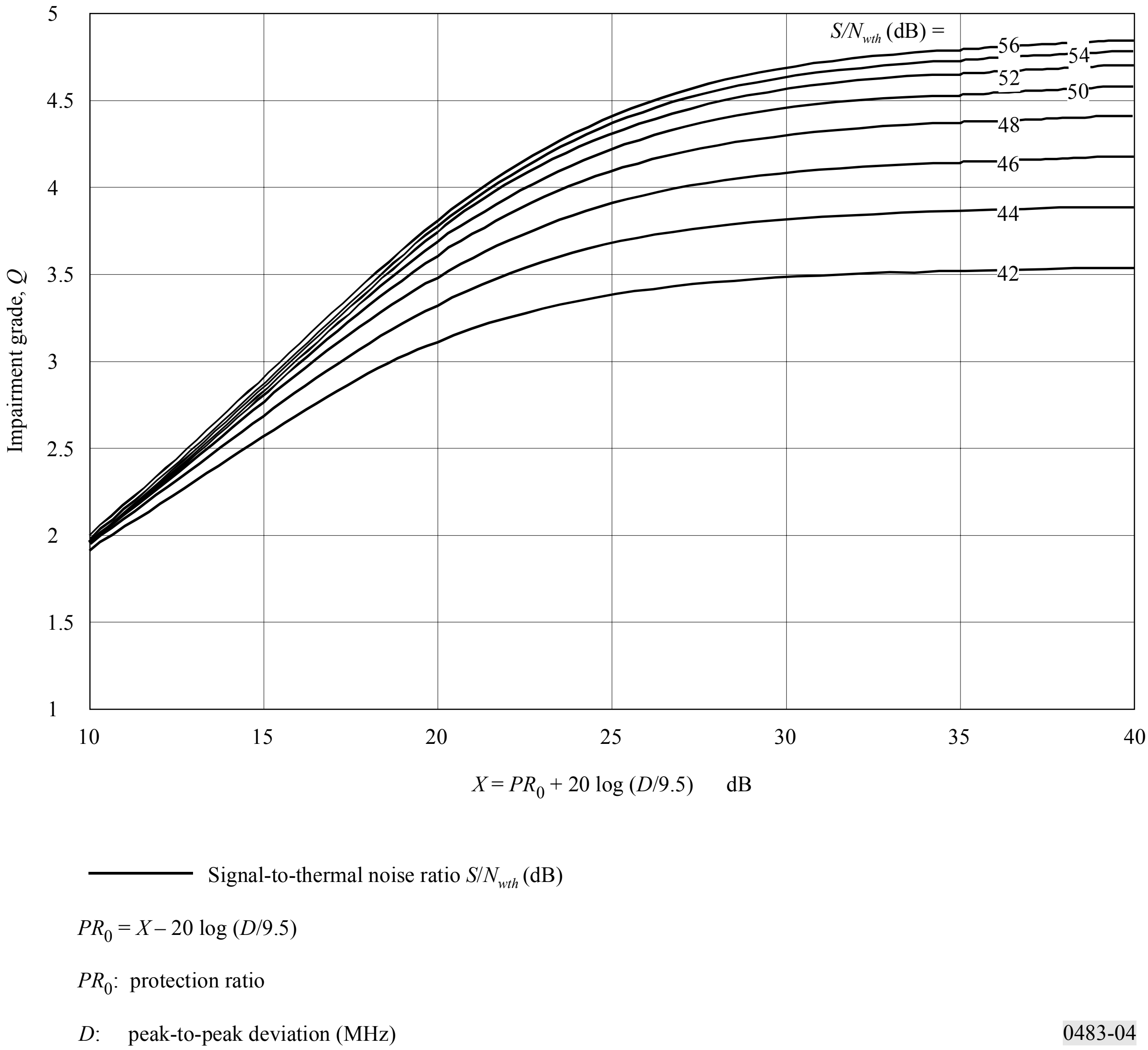
The effect of over deviation of the desired TV signal has not been modelled and needs to be further studied.

8 Development of protection masks

All the preceding results were based on the assumption that the desired and the interfering signal are exactly co-channel. In practical applications, however, the signals are often frequency offset. Therefore, the masks providing the required protection ratios as a function of the frequency offset need to be developed. Such a mask can generally be defined by a protection ratio PR_0 in the flat pedestal around the zero frequency offset and the slopes for positive and negative frequency offsets. The previous sections provide a basis for determining the PR_0 (for NTSC TV standard). The width of the pedestal and the slopes are discussed in the following sections.

FIGURE 4

Impairments due to thermal noise and co-channel interference



8.1 Protection ratio at zero offset (PR_0)

The curves in Fig. 4 can be used to determine the required protection ratio at zero frequency offset for any degradation of NTSC TV picture which is deemed permissible.

For example, if a TV/FM signal with a signal-to-thermal noise ratio of 42 dB and a peak-to-peak deviation of 9.5 MHz is interfered with by another TV/FM signal at zero frequency offset and the protection ratio is 25 dB, the combined impact of the thermal noise and interference will result in the impairment grade 3.4. If, however, the wanted signal peak-to-peak deviation is 19 MHz, the same interferer and thermal noise would result in the grade 3.5 (Fig. 4, $X = 25 + 20 \log (19/9.5) = 31$ dB).

8.2 Width of the plateau and slopes of the mask

Based on the available data, the width of the plateau seems to be ±5 MHz.

The slopes of the mask can be approximated by:

$$S = K\left[9.5/D - 0.295 \log (D/9.5)\right] \tag{6}$$

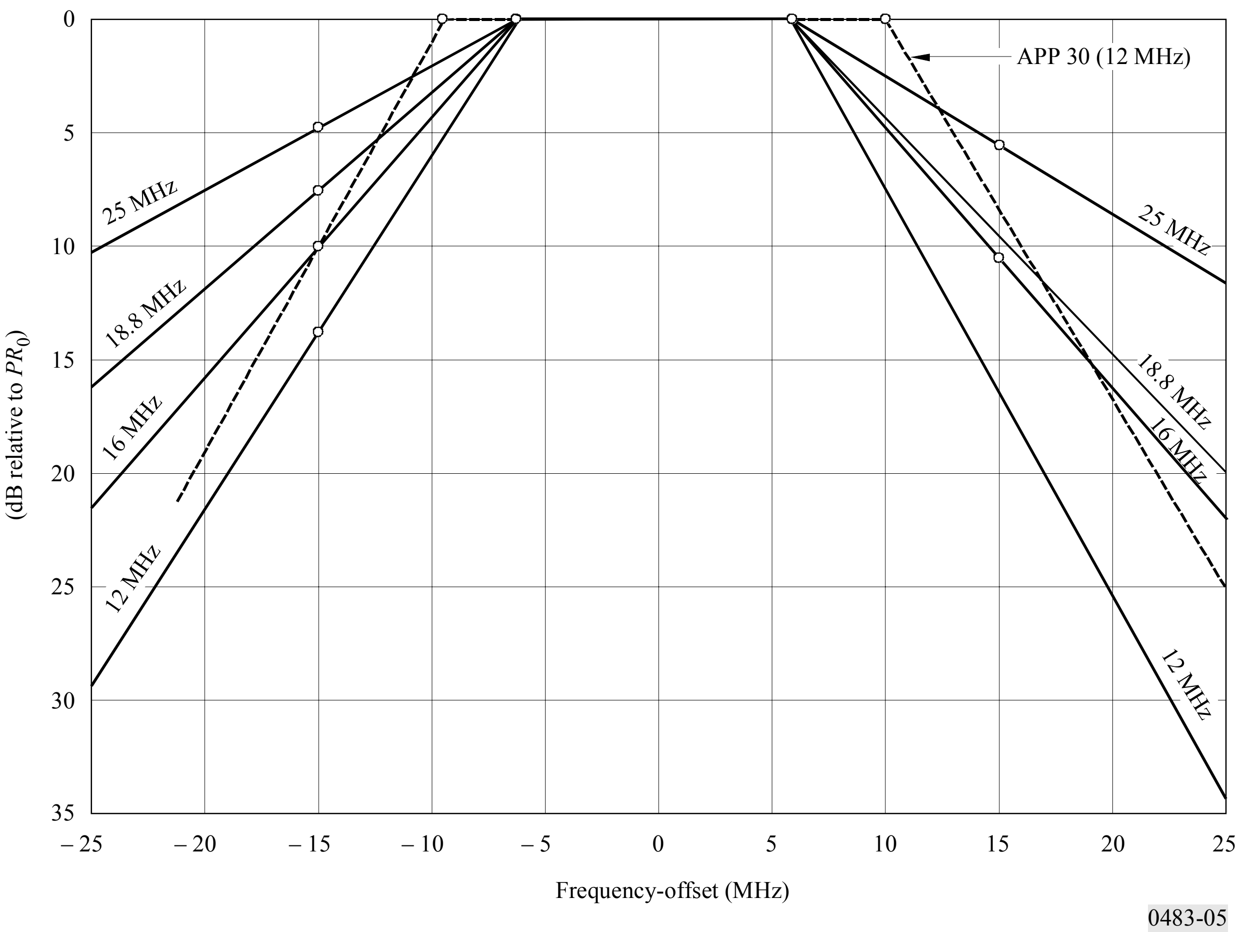
where D is peak-to-peak deviation of the desired TV signal (MHz) and $K = 2.3$ and 1.9 for the right and left slope, respectively.

The above results have been derived from TV/FM signals using 2 $MHz_{p\text{-}p}$ energy dispersal in the absence of the video signal and 1 $MHz_{p\text{-}p}$ in its presence. Further studies are needed to determine the impact of other energy dispersal bandwidths.

The method presented above was used to generate the protection ratio masks for various frequency deviations shown in Fig. 5.

FIGURE 5

Protection ratio masks



9 Permissible level of interference

The permissible level of interference in a carrier is usually defined as a percentage (or a fraction) of the total premodulation noise. If this approach is applied to interference coming from another TV/FM carrier, then the protection ratio is:

$$PR_0 = \frac{C}{N_{tot}} + 10 \log \frac{1}{i} \qquad \text{dB} \tag{7}$$

or

$$PR_0 = \frac{C}{N_{th}} + 10 \log \frac{1-i}{i} \qquad \text{dB} \tag{8}$$

In the above equations, N_{tot} and N_{th} denote the total premodulation noise and thermal noise, respectively and i is the fraction of the total premodulation noise coming from interference (in this case from another TV/FM).

Using the method explained in the previous text, the impact of the TV/FM interference is determined for $i = 4\%$ to 20% and shown in Fig. 6.

Table 1 also shows the protection ratios for various TV/FM carriers, various percentages of interference and the corresponding impairment grades. It is recommended that $i = 15\%$ be used as the aggregate permissible level of interference and $i = 6\%$ as the permissible single entry interference level.

Using these percentages and the method to determine the slopes of the protection ratio mask, the masks can be derived for any TV/FM (NTSC) system.

FIGURE 6

Impairments due to thermal noise and interference

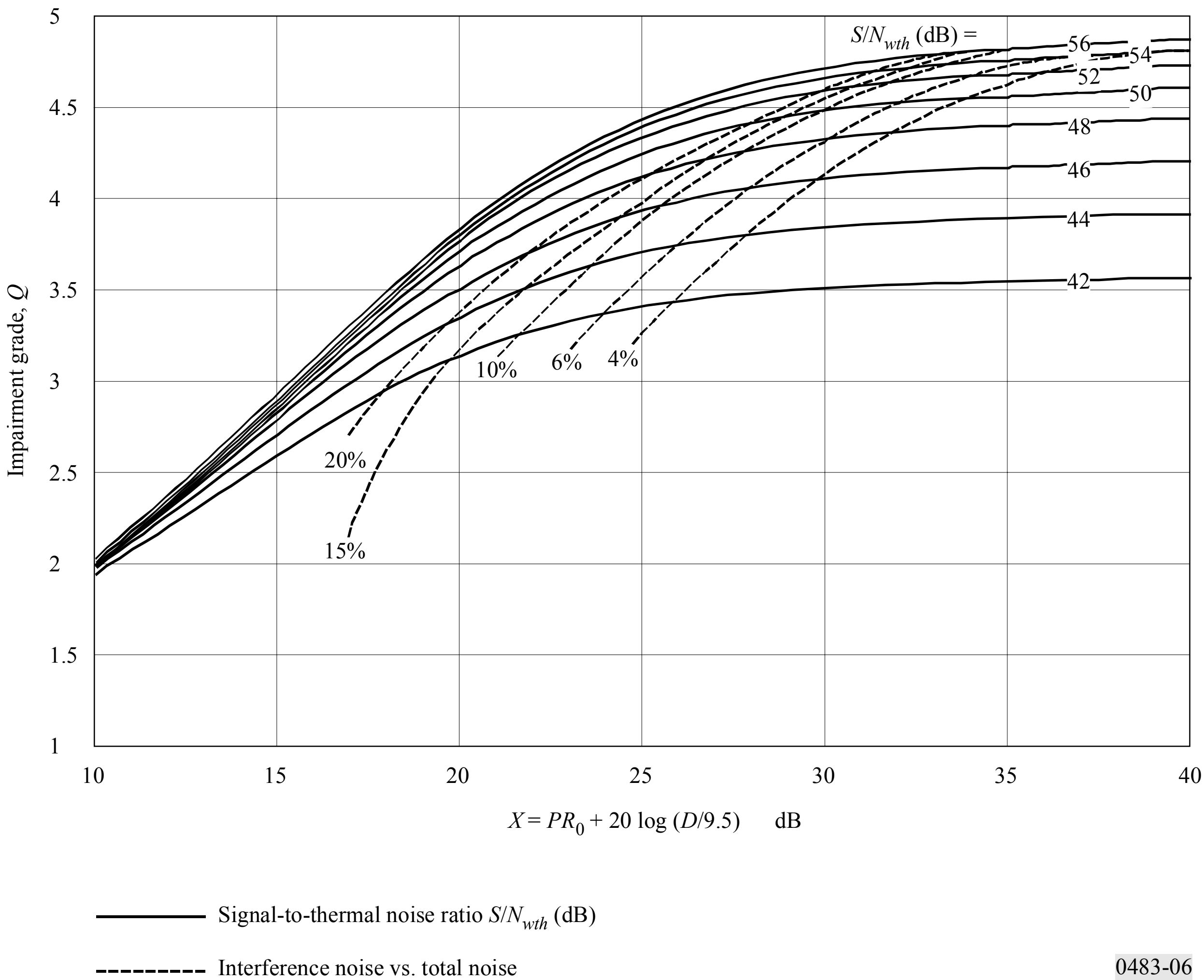


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TABLE 1

Protection ratios PR_0 based on percentage of total noise and impairment levels

C/N (dB) \ Frequency deviation		Δ = 12 MHz			Δ = 16 MHz			Δ = 18.8 MHz			Δ = 25 MHz		
		10%	15%	20%	10%	15%	20%	10%	15%	20%	10%	15%	20%
12	PR_0 (dB)	22	20.2	19	22	20.2	19	22	20.2	19	22	20.2	19
	S/N_{th} (dB)	44			46.5			48			50.4		
	Impairment, Q	3.7	3.6	3.5	4.1	4.1	4	4.3	4.3	4.2	4.4	4.4	4.3
18	PR_0 (dB)	28	26.2	25	28	26.2	25	28	26.2	25	28	26.2	25
	S/N_{th} (dB)	50			52.5			54			56.4		
	Impairment, Q	4.5	4.4	4.4	4.65	4.6	4.6	4.75	4.7	4.7	4.9	4.9	4.9

10 Direct-to-home (DTH) TV/FM transmission

Due to the use of ultra small earth station antennas, this type of transmission is extremely vulnerable to adjacent satellite interference. Recent studies have shown that the level of impairment for this type of transmission can be higher than in other types of TV transmissions. It was found that the picture quality 4 (“good”) on a five-grade scale is adequate. This fact allows the determination of required protection ratios to achieve this picture quality. From Fig. 4 protection ratios required for grade 4 were found for different TV/FM systems and are given in Table 2.

TABLE 2

Protection ratio PR_0 required for quality 4 (C/N = 12 dB)

Frequency Deviation p-p (MHz)	16	18	18.8	21.5	25
Derived from Fig. 4 (NTSC)	21.5	18.5	17	15.5	14
Measured PAL (Fig. 10)	21.5-23.5	–	–	–	14-16

11 Comparison of the developed masks with the available measured data

The developed masks are checked against the measured data available for high-quality TV/FM (PAL) and (D2-MAC) transmissions and show good agreement.

Figs. 7, 8 and 9 compare the measured data with the developed protection ratio masks for DTH transmissions at the quality grade 4.

FIGURE 7

Required protection ratio

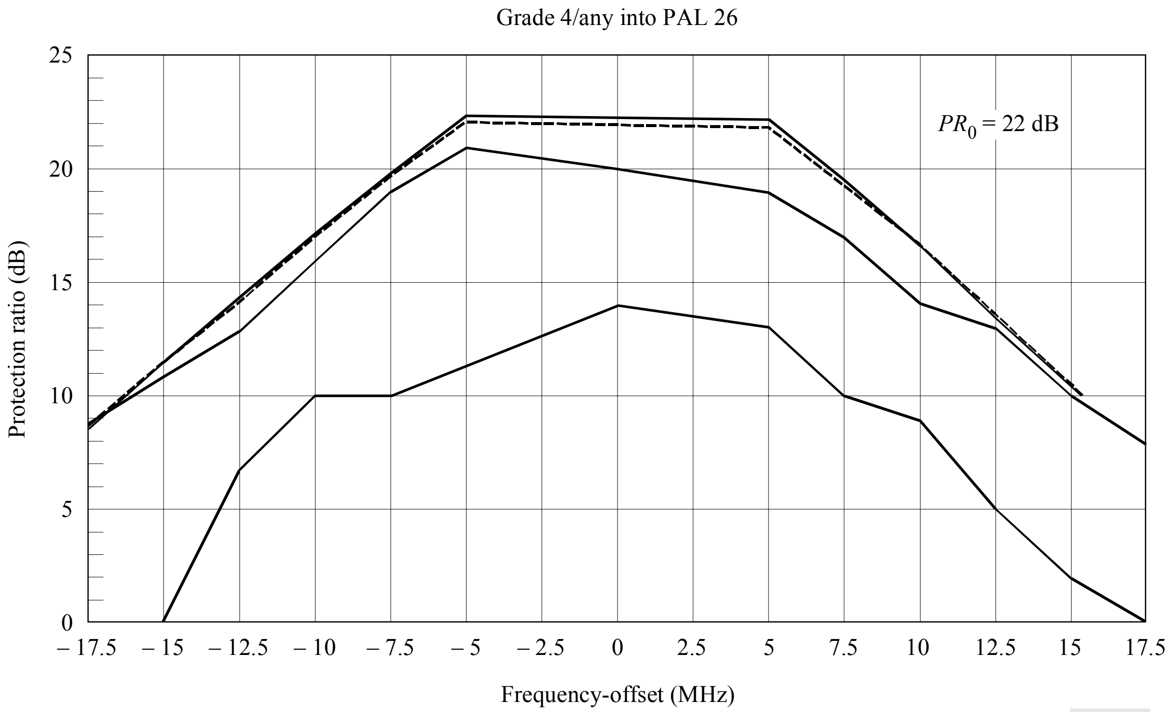

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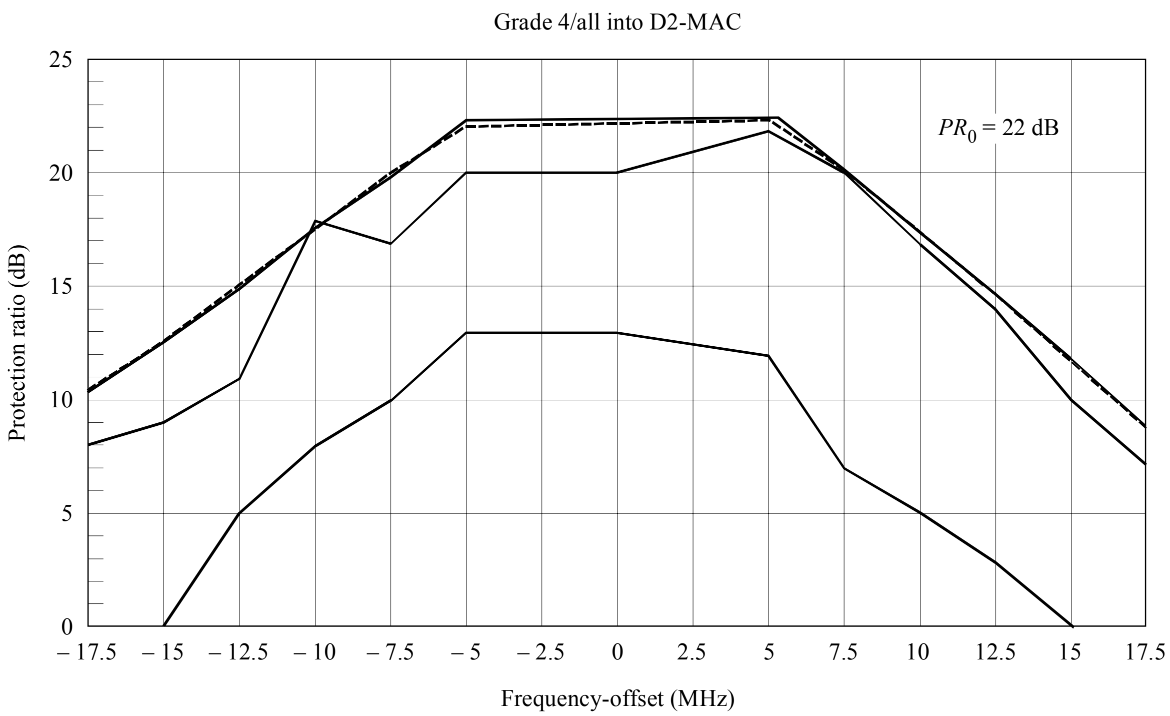
FIGURE 8

Required protection ratio



Wanted: still picture
Interferer: still picture/colour bars

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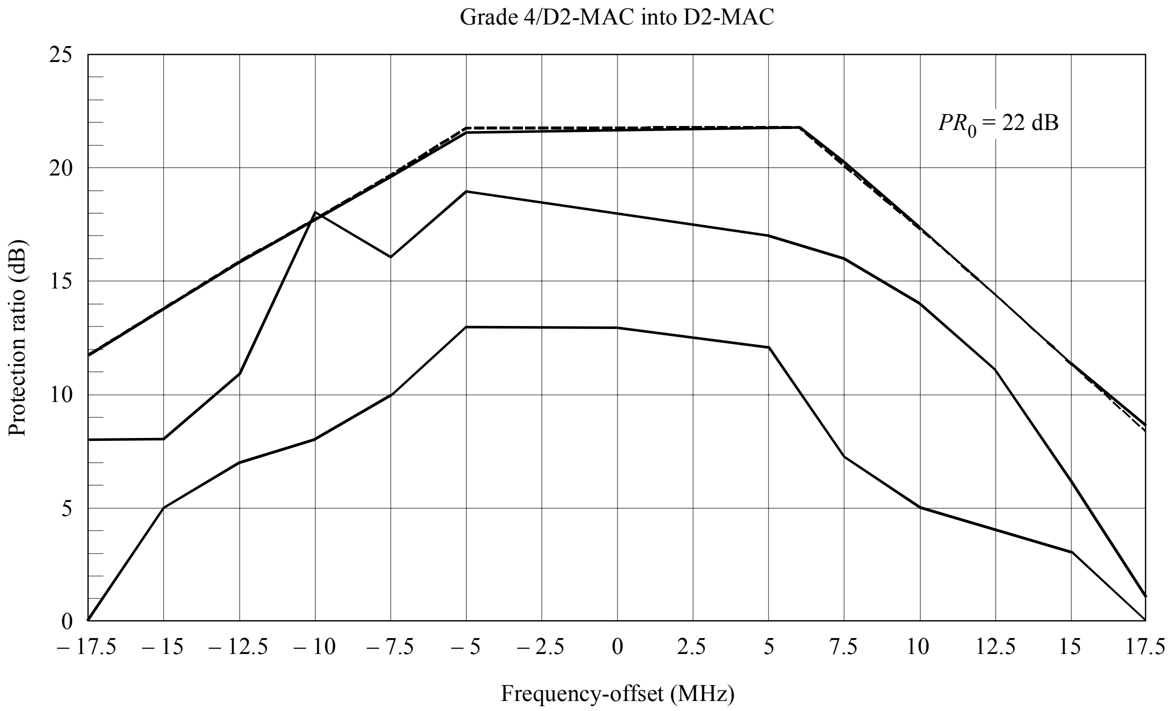
FIGURE 9

Required protection ratio



Wanted: still picture
Interferer: still picture/colour bars

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12 Usable results from further measurements

Figs. 10 and 11 show the net results from an additional set of measurements on PAL DTH signals, which summarize, respectively, the protection ratio requirements for wanted signal frequency deviations of 25 MHz/V and 16 MHz/V for the case of co-frequency wanted and interfering TV/FM (PAL) signals. Each figure shows lower and upper bounds on the protection ratio requirements for each C/N which correspond to the requirements for normal picture material (slide) and critical picture material (test pattern) respectively.

FIGURE 10

Required protection ratio for FM frequency deviation of 25 MHz/V

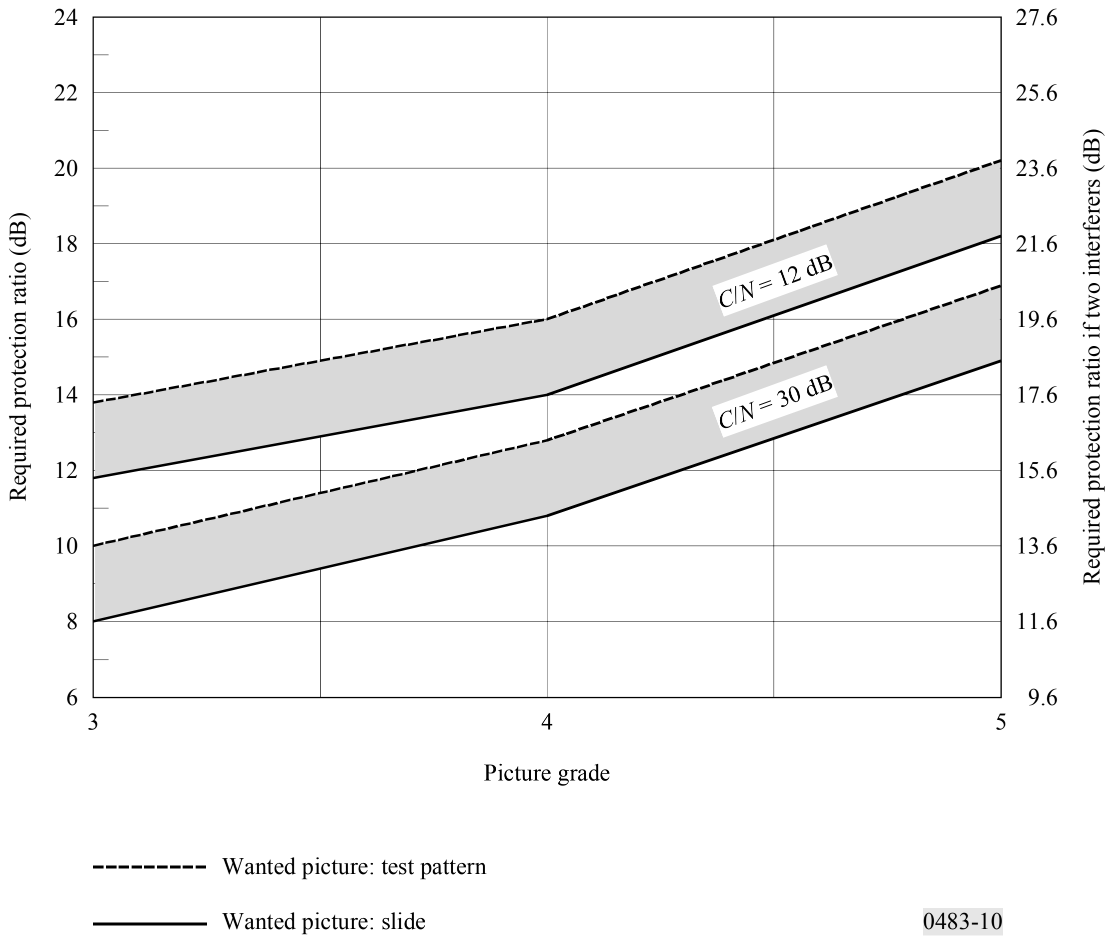
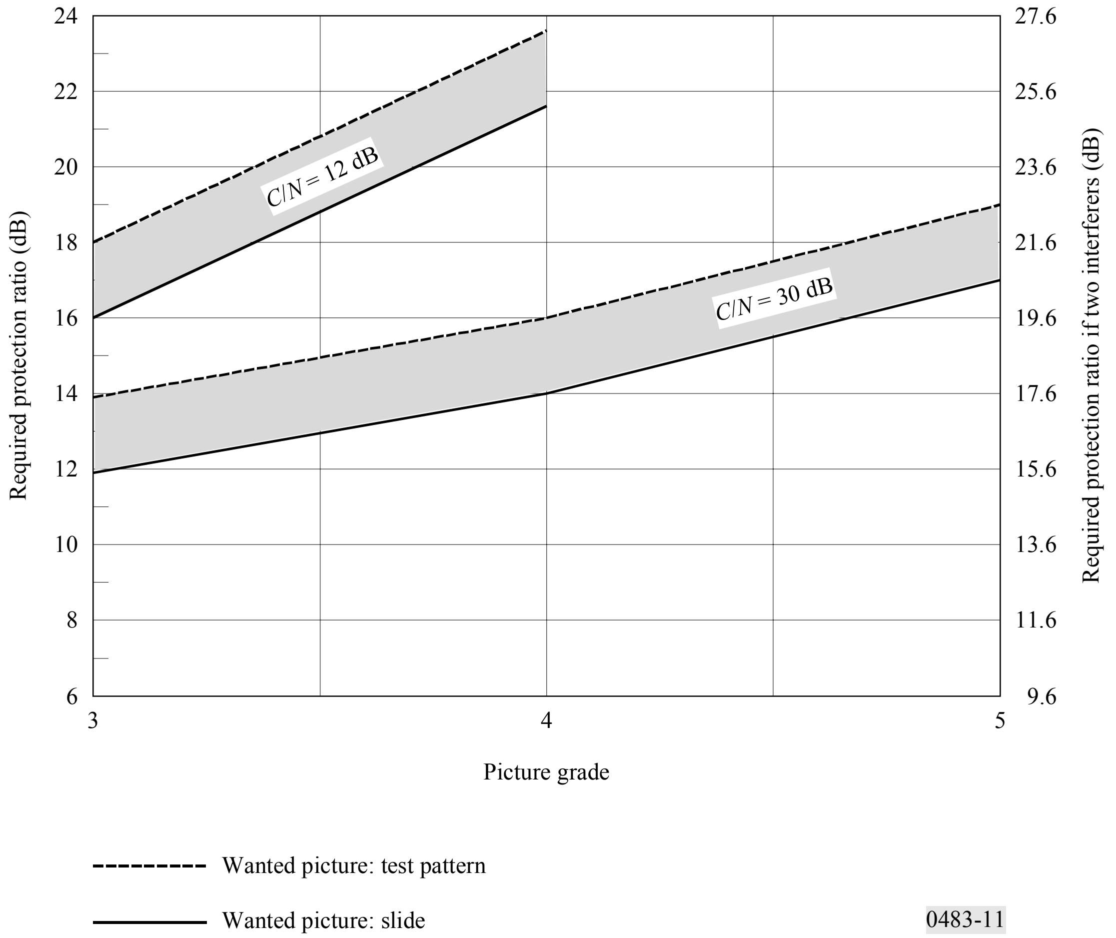


FIGURE 11

Required protection ratio for FM frequency deviation of 16 MHz/V



13 Conclusions

The comparison of the developed protection masks and the available measured results shows a very good agreement. It appears that the masks developed mainly on the NTSC TV system measurement data fit the PAL results as well. The PAL measurements generally show the required protection ratios for grade 4 quality about 1 dB more than predicted by the developed masks. The masks for higher grade transmissions (not DTH) show good agreement for both PAL and NTSC.

Based on the above it appears that the developed masks with PR_0 based on the percentage of total noise are suitable for general application other than DTH. The 15% aggregate and 6% single entry criteria are recommended.

For DTH, the aggregate protection ratios in Table 2 and the masks in Fig. 5 are recommended. Single entry protection ratios should be 4 dB higher than aggregate.