REPORT 634-4*

BROADCASTING-SATELLITE SERVICE (Sound and Television)

Measured interference protection ratios for planning television broadcasting systems

(Question 1/10 and 11, Study Programmes 1C/10 and 11, 1D/10 and 11 and 2C/10 and 11)

(1974-1978-1982-1986-1990)

1. Introduction

A knowledge of interference protection ratios (the ratio of wanted-to-unwanted signal power at the receiver input) as a function of subjectively assessed picture quality is vital to the planning of television systems. Thus protection ratios for interference between two amplitude-modulation, vestigial-sideband (AM-VSB) signals have long been necessary in planning terrestrial broadcasting systems. Now, the many allocations of the frequency bands to the BSS on a shared basis with various terrestrial and space services have made the subject of protection ratios required by many different modulation methods of great importance. Indeed with the imminence of digital transmissions both as interferers and as wanted signals a knowledge of protection ratios among such signals and between them and analogue signals is also necessary.

This Report summarizes the results of protection ratio tests made by several administrations in cases where the wanted and unwanted signals are modulated by colour television signals or other transmissions such as multiple sound channels. (See Note.) In considering these results, it should be noted that particular combinations of signals are not, in general, confined to a single band of frequencies. Thus the protection ratio measured for interference between frequency-modulation and amplitude-modulation, vestigial-sideband signals is important not only for sharing in the band 620 to 790 MHz but also for the bands 2500 to 2690 MHz and 11.7 to 12.5 GHz.

Note. – Protection ratio data for interference between an amplitude-modulation, vestigial-sideband or a frequency-modulation television signal and the types of signals used in the fixed and mobile services will be found in Report 449.

2. Measurements of protection ratios

2.1 *Subjective measurements for television*

Subjective measurements of protection ratios for television should be made according to Recommendation 600.

2.2 *Objective measurements for sound transmissions*

In all cases of sound broadcasting it is convenient to carry out the measurement of protection ratio by means of an objective method. Such a method consists in carrying out the measurement of the noise after demodulation in order to obtain the condition that the signal-to-noise ratio within the sound channel does not exceed a given value. Table I gives a list of parameters influencing the protection ratio for sound signals together with a suggested reference case to establish a common set of test conditions for measurements made by different administrations.

* This Report should be brought to the attention of the IEC (WG 8, SC 12A).

TABLE I – *Factors affecting objectively measured protection ratios for sound signals and a set of reference case conditions for these factors*

Factor	Reference case condition	
Receivers Wanted signal characteristics Unwanted signal characteristics Carrier frequency offset	Note 1 Note 2 Note 3 Note 4	
	High quality sound	Sound with television signal
Signal-to-weighted noise ratio (Note 6) The proposed reference case value may be arrived at from the two components being:	≥ 47 dB	≥ 42 dB
Signal-to-weighted thermal noise ratio	≥ 50 dB	≥ 45 dB
Signal-to-weighted noise ratio due to interference (Note 7)	≥ 50 dB	≥ 45 dB
Other interference and sources of sound degradation	Note 5	

Note 1. – The receivers used in the test should represent equipment which is fairly sensitive to the particular type of impairment being investigated. Account should be taken of domestic receivers, and the type of receivers which may be used at re-broadcast relay stations. Measurement of RF and IF filter characteristics should be made to assist in the interpretation of results obtained when there are frequency offsets between the wanted and unwanted signals. As far as possible, filter characteristics should be adjusted to the standards applicable to the wanted signal. Baseband output frequencies should be limited to the minimum required for the television standard used for the wanted signal. Excessive filter bandwidths permit the observation of noise and interference that would not be encountered with properly adjusted receivers.

Note 2. – If the wanted signal is a multiple sound system, several systems can be envisaged requiring the same or less bandwidth than a television channel. An example of such a system is given in Annex I, § 4.

Note 3. – In most cases the unwanted signal has the same characteristics as the wanted signal. There is, however, also a need for the determination of protection ratios between dissimilar systems. In these cases the unwanted signal can have characteristics different from the wanted signal or can be another type of transmission such as multiple sound channels.

Note 4. – For co-channel protection ratio measurements there is no carrier frequency offset: Carrier frequency offset is defined as the difference between the unmodulated carrier frequencies of the unwanted and wanted signals, $(f_{wanted} - f_{unwanted})$, if the same type of modulator is used in both channels. However, if the interference is sensitive to particular offset frequencies, these should be identified by the testing programme. For adjacent channel protection ratios, a series of measurements should be made for frequencies of the unwanted signal varying approximately ± 30 MHz from the wanted signal.

Note 5. – No account should be taken of other sources of interference, etc. (except thermal noise, as mentioned above), when assessing the protection ratio.

Note 6. – The indicated values represent the difference between the maximum signal level and the noise measured according to Recommendation 468. (Quasi-peak value and new weighting network.)

Note 7. – The objective method for the measurement of protection ratios in sound channels is described in Report 796.

3. Protection ratios for a wanted television signal

This section discusses the protection ratios needed for television signals. The protection ratio is a function of the modulation characteristics of both the wanted and unwanted signals. Certain values of protection ratios for television signals have already been used for planning purposes by the WARC-BS-77. These values based on measurements made up to that time are set forth in § 3.1.1. Protection ratio values based on recent measurements have been used for planning purposes by the RARC SAT-83. These values are also set forth in § 3.1.1.

The remainder of § 3.1 cites measurements of protection ratios for television signals subject to interference from other television signals employing both analogue and digital modulation. § 3.2 cites measurements of protection ratios for television signals subject to interference from signals other than television.

Section 3.3 discusses the effects of several deviations in test conditions from the reference case test conditions set forth in Recommendation 600.

Measurements of required protection ratios given in this Report were conducted under a wide variation of test conditions using different subjective criteria. Further studies conducted in accordance with the provisions of Recommendation 600 and for all combinations of wanted and unwanted signal modulation methods to be encountered in practice are desirable, so that values can be agreed on for future planning purposes. Suggestions for certain additional tests are given in Annex II.

3.1 *Interference from a television signal*

3.1.1 *Protection ratio templates used for planning*

Figure 1a and Table II give the protection ratio template used for planning at the WARC-BS-77 which is based on measurements made up to that time.

Measurements made in Canada and the United States of America addressed several aspects of interference between frequency modulated television signals of system M/NTSC. In particular:

- a relationship between the picture impairment level and the single-entry co-channel interference was found;
- the subjective effect of adjacent-channel interferers was analyzed;
- the composite effect of co-channel and adjacent-channel interference was assessed.

Based on the results of these measurements the protection ratio template in Fig. 1b was derived for Region 2 with a co-channel protection ratio value of 28 dB.

Detailed information on test conditions and measurement results is given in Annex I, § 3.1 and in [CCIR, 1982-86a and b].

3.1.2 *Interference between two amplitude-modulation, vestigial-sideband television signals*

Values of protection ratio for this important case will be found in Report 306.

3.1.3 *Interference to an amplitude-modulation, vestigial-sideband television signal from a frequency-modulation television signal*

Data in Annex I, for this case, is summarized in Table III showing co-channel protection ratios (PR_0) for interference that is just perceptible.

More detailed information for different systems is given in Annex I, § 1.1.

3.1.4 *Interference to a frequency-modulation, television signal from an amplitude-modulation vestigial-sideband television signal*

In this case measurements have been made for 525-line M/NTSC and 625-line K/SECAM systems as the wanted signal. For system M, co-channel protection ratio values ranging from approximately 28 to 32 dB are indicated for the reference case. The adjacent channel protection ratios are given in Annex I, § 2, for 18 MHz/V deviation. These results may serve as a guide until more complete measurements are performed.

For system K/SECAM, details are given in § 5 of Annex I.

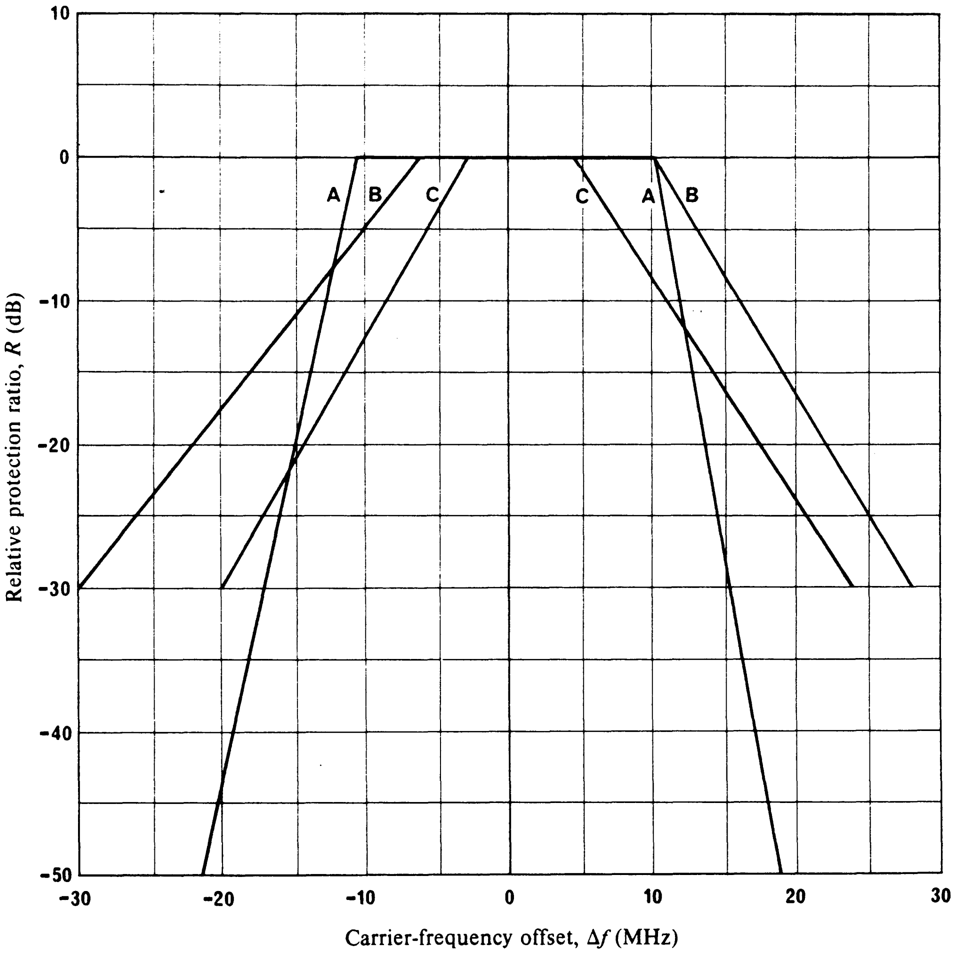

FIGURE 1a – *Reference case protection ratios relative to co-channel values*

Δf: ($f_{interfering} - f_{wanted}$)

Curves A: Television/vestigial sideband modulation-wanted, television/frequency modulation interfering, co-channel value: 50 dB

B: Television/frequency modulation-wanted, television/frequency modulation interfering, co-channel value: 30 dB (Regions 1 and 3)

C: Television/frequency modulation-wanted, television/vestigial sideband modulation interfering, co-channel value: 30 dB

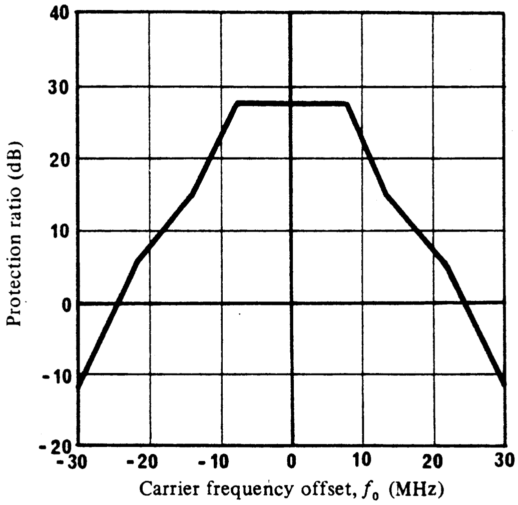

FIGURE 1b – *Protection ratio template (FM-TV) Region 2*

Protection ratio (peak-to-peak frequency deviation: D_v = 12 MHz):

28.0 dB	for	$|f_0| \leq 8.36$ MHz
$-2.762\ |f_0| + 51.09$ dB	for	$8.36 < |f_0| \leq 12.87$ MHz
$-1.154\ |f_0| + 30.4$ dB	for	$12.87 < |f_0| \leq 21.25$ MHz
$-2.00\ |f_0| + 48.38$ dB	for	$|f_0| > 21.25$ MHz

TABLE II

Wanted signal	Unwanted signal	Protection ratio		Region
		Co-channel (dB)	Adjacent channel	
Amplitude-modulation vestigial sideband	Frequency modulation	50	Fig. 1a, curve A	1, 2, 3
Frequency modulation	Amplitude-modulation vestigial sideband	30	Fig. 1a, curve C	1, 2, 3
Frequency modulation	Frequency modulation	30	Fig. 1a, curve B	1, 3
Frequency modulation	Frequency modulation	28	Fig. 1b	2

TABLE III

Wanted signal	Unwanted signal deviation, D_v(1) (MHz)	PR_0 (dB)
625-line systems I/PAL, G/PAL	12	54
625-line system K/SECAM	22	46
525-line system M/NTSC and 625-line system L/SECAM	12	50

(1) D_v: Nominal peak-to-peak frequency deviation.

3.1.5 *Interference between two frequency-modulation television signals*

When the modulation parameters of the wanted and unwanted signals are the same and there is no carrier frequency offset, the value PR_0 of the protection ratio measured under the reference conditions described in Recommendation 600 may be represented by the following formulae:

– for all systems except 525-line M/NTSC

$$PR_0 = C - 20 \log (D_v/12) - Q + 1.1 \, Q^2 \qquad (1a)$$

where:

D_v: nominal peak-to-peak frequency deviation (MHz);

Q: the impairment grade, concerning the effect of interference only, measured on the 5-point scale recommended in Recommendation 500 [CCIR, 1970-74a];

C: a constant depending on the television system which is:

12.5, for 625-line systems I/PAL, G/PAL, L/SECAM;

18.5, for 625-line system K/SECAM.

For high Q values, e.g. 4 to 4.5, the measured co-channel protection ratios reported in § 3 of Annex I were found to fit equation (1a) within 1 dB after adjustments were made for deviations from the "reference case". Protection ratio data from Report 449 also was within 1 dB of equation (1a). The limited data available for low Q values (see Annex I, § 3.1) differed from equation (1a) by approximately 4 dB. Equation (1a) is useful for system design where high Q values are generally required. Refinement of equation (1a) for low Q values requires further studies.

– for 525-line system M/NTSC

$$PR_0 = 16.9 - 8.7 \log I_u - 20 \log (D_v/12) \qquad (1b)$$

where:

$$I_u = \frac{5 - Q}{Q - 1} \qquad \text{for } 1 < Q < 5 \qquad \text{(see Report 405)}$$

Equation (1b) is based on data obtained from measurements carried out in Canada and the United States of America using 525-line system M/NTSC [Bouchard *et al.*, 1984; CCIR, 1982-86c]. This equation was found to provide a reasonably good fit to these data over the full range of Q.

Detailed information on interference between two frequency-modulation television signals is given in Annex I, § 3, and in [CCIR, 1974-78a].

3.1.6 *Interference to a frequency-modulated television signal by multiple frequency-modulated television signals*

Measurements have recently been carried out in Canada and the United States of America, using 525-line system M/NTSC in order to examine the method by which multiple co-channel interferers combine. The results of subjective tests show that the combination is nearly power addition.

Additional measurements in the United States of America have shown that multiple adjacent-channel interfering signals combine to produce an effect which is 2-6 dB more severe than power addition.

The combined effect of co-channel and adjacent-channel interferers is a power addition of the individual interference effects over the entire C/I range. At high C/I, the subjective effects are dominated by the co-channel interference, while at low C/I, the adjacent channel is dominant.

Detailed information on interference to an FM television signal by multiple FM television signals is given in Annex I, § 3.1.6.4, 3.1.7.2, 3.1.7.4, 3.1.7.5 and in [CCIR, 1982-86a and b].

3.1.7 *Interference between FM television signals using digital modulation and time division multiplex for the sound and data (625-line systems)*

Subjective measurements (for the image) and objective measurements (for the sound) have been carried out by the EBU [CCIR, 1982-86d] with a view to demonstrating compatibility with the provisions of the WARC-BS-77 of the C-MAC/packet system (see Reports 1073 and 632).

The results are set out in Table IV for the image, in terms of the relative impairment due to the addition of the interfering signal evaluated on the 5-grade impairment scale, and for the sound in Table V, in terms of the bit error ratio.

TABLE IV – *Subjective grades for the image on the 5-grade impairment scale in the presence of interference*

(Mean and standard deviation (SD))

(Co-channel interference at −31 dB and adjacent-channel interference at −15 dB)

Relative impairment of vision quality		Co-channel	Upper adjacent channel	Lower adjacent channel	No interference
C-MAC/packet signal interfering with a C-MAC/packet signal					
High *C/N* (25 dB)	Mean SD	4.8 0.40	4.9 0.35	4.6 0.60	4.9 0.31
Low *C/N* (10 dB)	Mean SD	4.8 0.49	4.7 0.46	4.7 0.52	4.8 0.39
C-MAC/packet signal interfering with a WARC-BS-77 reference signal					
High *C/N* (25 dB)	Mean SD	4.9 0.35	4.9 0.23	4.9 0.31	4.9 0.31
Low *C/N* (10 dB)	Mean SD	4.2 0.71	4.5 0.66	3.9 0.78	4.7 0.52

TABLE V – *Bit error ratio measured in a digital sound channel at low C/N ratio (7 dB)*

Wanted	Interfering	Co-channel −31 dB	Adjacent channel		No interference (¹)
			Upper −15 dB	Lower −15 dB	
C-MAC	C-MAC	2.7×10^{-3}	2.6×10^{-3}	2.6×10^{-3}	2.3×10^{-3}

(¹) Without use of satellite simulation in the wanted channel.

If reference is made to the fact that the worst levels of interference allowed by the WARC-BS-77 in the same channel (−31 dB) and in the adjacent channels (−15 dB) correspond to an impairment grade of 4.5 (with high carrier-to-noise ratio), it may be concluded from these results that the C-MAC/packet system is compatible with the down-link Plan for Regions 1 and 3.

Measurements were carried out in France [CCIR, 1982-86e] to study the compatibility of the D2-MAC/packet system (see Reports 1073 and 632) with the Final Acts of the WARC-BS-77. The measurements were made on the D2-MAC/packet system and a system corresponding to the reference used for the WARC-BS-77 format (PAL/SECAM system with an FM sound sub-carrier).

The results are given in Table VI for the picture in terms of the C/I ratio corresponding to the interference visibility threshold.

TABLE VI – *Protection ratios between D2-MAC/packet and PAL/SECAM (WARC-BS-77)*

Wanted signal	Unwanted signal	C/I corresponding to the visibility threshold		
		Co-channel (dB)	Lower adjacent channel (dB)	Upper adjacent channel (dB)
D2-MAC/ packet	D2-MAC/ packet	20	11	12
PAL/SECAM (WARC-BS-77)	D2-MAC/ packet	27	12	13

The results apply to the most critical cases for both the wanted and the interfering signals.

In relation to the digital component of the D2-MAC/packet signal, the equivalent impairment expressed in terms of the C/N ratio always remains below 0.5 dB for a bit error ratio of 10^{-3} with adjacent channel and co-channel C/I ratios of 15 and 31 dB respectively.

These measurements demonstrate that the D2-MAC/packet system satisfies the requirements for protection ratios adopted at the WARC-BS-77.

Measurements were carried out in the UK [Priestman and O'Neill, 1987] to study the compatibility of the D-MAC/packet system using frequency modulation (see Report 1073) with the Final Acts of the WARC-BS-77.

The wanted signal was either of the PAL system (i.e. reference system as defined by WARC-BS-77) or of the D-MAC/packet system using frequency modulation.

In these tests the interfering signal was transmitted through satellite channel simulation equipment consisting of a high power klystron transmitter and a simulated satellite transponder, using a low power travelling wave tube.

The results of these measurements are given in Table VII for the subjectively evaluated protection ratios for the wanted vision channel signal, and apply to the most critical picture combinations.

It can be seen that in all cases there is a positive margin with respect to the protection ratios adopted by WARC-BS-77 (i.e., 31 dB for co-channel interference and 15 dB for adjacent channel interference).

In relation to the digital component of the D-MAC/packet signal, the equivalent impairment expressed in terms of the C/N ratio always remains below 0.5 dB for a bit error ratio of 10^{-3} with adjacent and co-channel C/I ratios of 15 and 31 dB respectively.

These measurements demonstrate that the D-MAC/packet system satisfies the protection ratio requirements adopted at the WARC-BS 77.

TABLE VII - Protection Ratios for the D-MAC/packet System Using Frequency Modulation

Wanted Signal (1)	Interfering Signal (1)	Protection ratio required for just perceptible interference on the wanted channel picture (dB) Co-channel	Lower Adjacent Channel	Upper Adjacent Channel
D-MAC/packet	D-MAC/packet continuous data	17	3	1
D-MAC/packet	C-MAC/packet	27	10	6
PAL System (WARC-BS 77) (2)	D-MAC/packet continuous data	22	7	6
PAL System	C-MAC/packet	29	11	8

(1) The wanted channel and interfering channel pictures were synchronised with a 1/2 line offset between each other.

(2) Deviation sensitivity 13.5 MHz/V.

Additional subjective evaluation tests have been carried out by the EBU concerning the perceptibility of interference when including the scrambling and descrambling processes into the BSS with the C-MAC/packet system described in Report 1073.

These tests conducted according to Recommendations 500 and 600, indicated that the protection ratios for scrambled C-MAC/packet signals can be slightly less stringent as compared to the protection ratios for non-scrambled C-MAC/packet signals*.

The average reductions of the protection ratio (PR) as a result of scrambling are set out in Table VIII.

* It is expected that similar results would be obtained in the case of the D-MAC/packet system and the D2-MAC/packet system.

TABLE VIII

	Average reduction of protection ratio (dB)
Lower adjacent channel (−19.18 MHz)	2.6
Higher adjacent channel (+19.18 MHz)	1.8
Co-channel	2.0

It can be seen from Table VIII that the inclusion of scrambling reduces both the co-channel as well as the adjacent-channel interferences. It is valid for any of the scrambling schemes and also for degraded C/N operation.

The above subjective tests therefore indicate that the interference protection ratios for scrambled C-MAC/packet signals also fully correspond to the WARC-BS-77 specification.

Further tests with C-MAC signals passed through a complete hardware simulation of a satellite broadcasting channel, including both representative feeder and down links, show little difference in the effect of interference in the feeder link to that experienced with the same amount of interference in the down link, with a transponder having a low value of AM/PM conversion ($< 2°/\text{dB}$) [Shelswell, 1984]. Higher values of AM/PM conversion should have an impact on the apparent effect of interference on the feeder link, much in the way that the effective feeder link C/N is reduced (see Report 952, § 3.3 and 4.5). This result should be valid for any system, nevertheless further studies are needed.

3.1.8 *Interference between FM television signals using digital modulation and time division multiplex for the sound and data (525-line systems)*

Subjective measurements to characterize the noise and interference performance of the vision portion of the B-MAC system have been conducted in Canada [Chouinard and Barry, 1984]. The interference tests involved a comparison of the susceptibility of both the MAC and NTSC encoded vision signals to either MAC or NTSC encoded interfering signals.

The NTSC vision signal deviating the FM carrier by 12 MHz (peak-to-peak), was accompanied by 3 audio sub-carriers each deviating the main carrier by 2 MHz (peak-to-peak). The pre-emphasis used was according to Recommendation 405. The MAC signal (see Report 1073 for a detailed description) was also deviating the FM carrier by 12 MHz. The data burst during the line-blanking interval was replaced by a 7 MHz synchronization burst at full amplitude. The pre-emphasis used was a slightly modified version of the one specified in Report 1073 with the zero crossing frequency at 2.335 MHz. Both wanted and interfering signals had the same modulation characteristics.

The tests were conducted with a linear RF channel and the frequency demodulation was made with a conventional limiter-discriminator receiver. The pre-detection channel filter was a 4-pole, Chebychev-type filter with an equivalent noise bandwidth of 22.7 MHz and no group-delay equalization. Tests were done in accordance with Recommendation 500 with trained viewers sitting at 5 times picture height and based on the threshold of perceptibility of picture impairments.

3.1.8.1 *Co-channel interference*

The results of the co-channel interference tests averaged over 4 test slides and 17 viewers are given in Table IX. The results indicate the C/I (dB) at the just perceptible level of impairment for two interfering signals: the multiburst test signal (MB) and 75% colour bar test signal (CB). The average for these two test signals is also given. The MAC signal was found to be slightly more immune to co-channel interference than the NTSC signal. In the case of the wider deviation specified in Report 1073 for the B-MAC signal, it is expected that the required protection for the B-MAC signal will be 3-4 dB less than the reference NTSC signal. In the case of the mixed interference situation, the interference was found to be no worse than the reference NTSC into NTSC case. With the wider deviation specified for the B-MAC signal, the mixed cases are expected to be less severe by 1-3 dB relative to the reference case. It can thus be concluded that the utilization of B-MAC is compatible with the co-channel interference characteristics of the RARC SAT-83 Plan.

TABLE IX – *Co-channel interference results (C/I in dB)*

		Interfering signal	
		NTSC	B-MAC
Wanted signal	NTSC	MB = 24.3 CB = 26.1 Average = 25.2	MB = 24.4 CB = 26.2 Average = 25.3
	B-MAC	MB = 24.3 CB = 25.1 Average = 24.4	MB = 23.6 CB = 25.1 Average = 24.4

MB: Multiburst video test signal

CB: 75% colour bar test signal

3.1.8.2 *Adjacent-channel interference*

The results of the subjective tests dealing with upper and lower adjacent-channel interference averaged over 4 test slides and 17 viewers are given in Tables X and XI respectively. The level of C/I (dB) at the just perceptible level of impairment are indicated for two different interfering signals: multiburst (MB) and 75% colour bar (CB) test signals. The average of the results obtained for the two interfering signals is also indicated. The results indicate that a B-MAC signal produces more interference in both upper and lower adjacent channels than NTSC. The protection of a B-MAC signal from another B-MAC signal is found to be 2-5 dB higher than the protection required for the reference NTSC into NTSC case although it is less than the value used for planning the BSS at the RARC SAT-83 (13.6 dB). It should be noted however that the adjacent-channel interference is strictly a domestic problem in the case of the North American BSS since all channels from the same orbital location have been assigned to the same administration in the Plan.

It was also found that the synchronization burst was the constraining factor in only a very few cases. Since the data burst in the B-MAC system is specified at lower amplitude, it is unlikely that the data burst will be found as the constraining factor in interference situations.

TABLE X – *Upper adjacent-channel interference results (C/I in dB)*

		Interfering signal	
		NTSC	B-MAC
Wanted signal	NTSC	MB = 4.3 CB = 4.4 Average = 4.3	MB = 7.4 CB = 7.2 Average = 7.3
	B-MAC	MB = 4.2 CB = 2.4 Average = 3.3	MB = 6.1 CB = 6.8 Average = 6.5

MB: Multiburst video text signal

CB: 75% colour bar test signal

TABLE XI – *Lower adjacent-channel interference results (C/I in dB)*

		Interfering signal	
		NTSC	B-MAC
Wanted signal	NTSC	MB = 5.5 CB = 2.9 Average = 4.2	MB = 7.2 CB = 5.1 Average = 6.2
	B-MAC	MB = 5.7 CB = 3.9 Average = 4.8	MB = 9.1 CB = 9.2 Average = 9.2

MB: Multiburst video test signal

CB: 75% colour bar test signal

3.1.9 *Interference between FM television signals using digital sub-carrier for the sound and data (525-line systems)*

Subjective evaluation tests have been carried out in Japan [CCIR, 1982-86f] using the 525-line system M/NTSC with a peak-to-peak frequency deviation of 17 MHz due to picture signals which are accompanied by a digitally-modulated sound sub-carrier. The viewing distance was four times the picture height. Colour bars were used for the wanted as well as for the interfering signal.

Of the modulation parameters, the bit rate, the peak-to-peak main carrier deviation due to the digitally modulated sub-carrier, and the sub-carrier frequency are respectively 2.048 Mbit/s, 6.5 MHz and 5.727272 MHz. The results show the following:

- mean values for just perceptible interference levels for picture impairment are 29.8 dB and 9.4 dB in the case of co- and adjacent-channel interferences respectively (19.18 MHz channel spacing);
- with respect to sound impairment, there is no degradation in the sound quality even when the degradation in the picture quality is just perceptible.

In consequence it was demodulated by these tests that the above-mentioned modulation system as specified satisfies the requirements for protection ratios adopted at the WARC-BS-77.

3.1.10 *Interference between two dissimilar frequency-modulation television signals*

Tests have been carried out by the BBC and TDF for interference between 625-line PAL and SECAM systems and in Japan for interference between 525-line system M/NTSC and different 625-line systems. As a general result it can be concluded that the measured television protection ratio for two dissimilar systems is not significantly different from the protection ratio measured for the more demanding system interfering with itself.

3.1.11 *Interference to a frequency-modulation television signal from digital signals (television and data)*

Measurements of protection ratios for system M/NTSC were made with a 43 Mbit/s, digital television, 4-PSK interferer. Results indicate that a frequency modulated television system with an apparent signal-to-noise ratio (signal-to-interference ratio) ranging from 45 to 35 dB requires co-channel protection ratios of 24 to 14 dB, respectively.

Details of the measurements are given in Annex I, § 4.1.3.

The protection ratio template used for evaluating FM-TV to FM-TV interference (Fig. 1b) is not directly applicable to digital TV interference with FM-TV. However, under the condition that the digital bit rate to bandwidth ratio (R_{bt}/B) is of the order of 1.7 or less (utilizing staggered 4-PSK modulation), the interference for a given frequency offset is comparable to the corresponding values for FM-TV to FM-TV interference. Limiting R_{bt}/B to less than approximately 1.7 will minimize the effects of spectral spreading on the second adjacent channel.

Hence, a 40 Mbit/s digital 4-PSK signal (with 4 dB of TWTA input back-off) could be transmitted in a 24 MHz channel with only nominal degradation to the second adjacent channel, even if it is co-polar. Further details are given in [CPM SAT-R2, 1982]. FM-TV to digital-TV interference is not a controlling factor in system planning.

Measurements of protection ratios for system D/PAL were made with interference from a single-frequency signal (CW), a PSK signal or an ASK signal with rates of 2.048 Mbit/s and 8.448 Mbit/s respectively. Details of measurements are given in Annex I, § 4.1.3.

Some experiments on C/I requirements for 4-PSK to FM-TV and *vice versa* were carried out [CCIR, 1982-86g] using 4-PSK with a bit rate of 24.6 Mbit/s and FM-TV, 525-line NTSC with digital audio sub-carriers (see Report 1073). The just perceptible interference ratios are shown in Tables XIIa and XIIb.

3.1.12 *Interference to digitally encoded television signals*

For digitally encoded, system M/NTSC television, measurements were made of protection ratios against analogue FM television interference. The results are given in Table XIII, where E_b/N_0 = ratio of energy per bit to noise power spectral density.

TABLE XIIa – *Just perceptible C/I of FM-TV to 4-PSK*

	Just perceptible C/I for picture (1)		C/I at which influence on BER becomes negligible, for sound (2)
	Colour bar	Woman	
Co-channel (dB)	29.1	25.0	24.0-28.0
Upper adjacent channel (dB)	11.1	7.2	10.0-14.0

(1) Under the condition of C/N = 26 dB, viewing distance = 4 H, 20 in. colour monitor and 10 experts.

(2) Under the condition of C/N = 8 to 12 dB.

TABLE XIIb – *Just perceptible C/I of 4-PSK to FM-TV*

	C/I at which influence on BER becomes negligible (1)
Co-channel (dB)	28.0
Upper and lower adjacent channel (dB)	8.0

(1) Under the condition of C/N = 7 to 11 dB.

TABLE XIII – *Peak protection ratios for frequency-modulation television interference to a digital television signal*

E_b/N_0 (dB)	Protection ratio at 10^{-8} BER (dB)	E_b/N_0 (dB)	Protection ratio at 10^{-6} BER (dB)
15.1	24.2	13.6	22
18.1	14.5	16.6	13

For the same digitally encoded M/NTSC television system, measurements were made of protection ratios against interference from other digitally encoded systems (including both digital television and pseudo-random data) [CCIR, 1982-86h]. For an energy contrast ratio (E_b/N_0) of 14.7 dB, the co-channel protection ratio at 2×10^{-8} BER was approximately 22 dB for interference of equal data rate from both digital television and pseudo-random digital data. These measurements also showed that the relative bandwidth (i.e. data rates) between the wanted and interfering signals has a significant effect on the co-channel and adjacent-channel allowable carrier-to-interference ratio. Interfering signals with a bandwidth less than the desired signal require greater co-channel protection than the interfering signals which have a wider bandwidth than the desired signal. In addition, the fall-off in protection ratio versus frequency offset is more rapid when the interfering data rate is less than the wanted data rate (i.e. small in relative bandwidth).

Details of the measurements are given in § 4.2 of Annex I.

3.1.13 Interference between digital television systems

When digital modulation is used to carry sound or vision signals in digitally-coded form, the perceived quality is dependent on the bit-error ratio (BER). Bit errors will be caused by the combined effects of noise and interference. Unlike the situation with analogue transmission, there is some scope for trade-off between the two. Noise and interference are apportioned in order to obtain a reasonable link budget and a reasonable protection ratio, leading to efficient use of the spectrum.

The trade-off between C/N and C/I for PSK-type digital modulation has been explored in [Newland, 1988]. The effect of a single or dominant co-channel interferer is shown to be similar to that of a sinusoid, and is thus less severe than that of the equivalent amount of added Gaussian noise. As the number of interferers increase then the effect of the interference closely approaches that of the equivalent amount of added noise, as confirmed in [Priestman and O'Neill, 1987]. The results can be extended to take account of adjacent-channel interference if appropriate account is taken of the channel filtering.

As an example of possible trade-off between C/N and C/I (co-channel protection ratio), Table XIV gives typical values with the following conditions.

- digital modulation is a 2 bit /Hz system
- equivalent noise bandwidth: bit rate/2
- required BER = 10^{-5}
- margin (including channel impairment effect) = 1.5 dB
- contribution of adjacent channel interference = 1 dB

Under these conditions the overall C/(N+I) is 15 dB.

TABLE XIV

C/N (dB)	C/I (dB)
16	22
17	19.5
18	18
20	16.5
22	16

Further study of the use of convolutional coding [CCIR, 1986-90a] has demonstrated by experiment that the use of Viterbi decoding can result in an even greater tolerance of mutual interference. For example, with a code having rate 1/2 and constraint length 6, the degradation caused by a single interferer of C/I = 10 dB is equivalent to a loss of only 1 dB in C/N, even for a BER of 10^{-2}. The distinction between single/dominant and multiple interferers remains; multiple interferers should be treated as additive noise.

3.1.14 Protection ratio for HDTV and conventional television systems using modulation in the planned 12 GHz band

Tests were made in the framework of the EUREKA-95 project.

The results of this test have been obtained with the first experimental HDTV chain in 1989 using the French TDF-1 satellite as well as a satellite simulator [CCIR, 1986-90b].

Measurements of first adjacent channel (±19.18 MHz) and co-channel interference levels giving just perceptible impairment on vision have been done in the two following configurations:

— HDMAC interfering with HD-MAC;

— HDMAC interfering with the reference WARC-77 system (SECAM with a sound subcarrier).

An approach known as the method of limits was used during these channel interference studies. This method involves reducing the level of interference progressively downwards, from an obviously perceptible level, past the point where it becomes invisible, and then increasing the level past the point where it re-appears. Subjects are asked, at various stages, to record whether the impairment is visible or not. Seven levels are chosen around the estimated threshold. The visibility threshold is the mean between the last visible level (decreasing threshold) and the first one (increasing threshold).

From these tests, the following preliminary conclusions can be drawn:

- When the wanted signal is the WARC reference signal, then the minimum protection ratios required by the WARC-BS 77 Plan are met with a margin greater than 9 dB. The HD-MAC signal is not more critical than a conventional MAC signal.

- Two HD-MAC signals can co-exist in the WARC-BS 77 broadcasting Plan.

An HD-MAC receiver, using a WARC reference filter (4th order Butterworth with a 3 dB bandwidth of 27 MHz), would not perform adequately with regard to the rejection of incoming interference from other "conventional" WARC signals. However, a SAW filter was incorporated in the receiver to obtain the adjacent-channel protection ratios shown in Table XV, without compromising other aspects of receiver performance.

Tests were made in Japan in 1989 [CCIR, 1986-90c].

Protection ratio measurements were made between two MUSE signals and between MUSE and a 525-line M/NTSC signals.

The results of these tests indicate that the co- and adjacent-channel protection ratios for interference between MUSE and M/NTSC, and between two MUSE signals met the technical criteria for the planning of the BSS in the 12 GHz band, with sufficient margins.

The results of both the MUSE and HD-MAC measurements are given in Table XV.

Note that some of the parameters used in both the MUSE and HD-MAC tests are interim values from Recommendation 710 which can be used until values recommended in the table itself become technically feasible.

Moreover, neither test included "bench-mark" comparisons with conventional television, as discussed below in sections 3.1.5 and 3.1.6 of this Report. Therefore, the results of the new tests should be considered as preliminary.

TABLE XV - Results of measurements of protection ratios for just-perceptible interference involving certain HDTV and conventional television systems

Wanted signal (test slides)	Unwanted signal	Channel protection ratios (dB)			Note
		Lower adjacent*	Co-channel	Upper adjacent*	
NTSC SMPTE #1 SMPTE #14	MUSE	10 12	18 19	11 12	1)
MUSE "Fruits" "Congress hall"	NTSC	8 7	18 20	8 11	1)
MUSE "Fruits" "Congress hall"	MUSE	9 8	24 24	8 9	1)
HDMAC	HDMAC	6	22	7	2) 3)
SECAM	HDMAC	11	25	11	2) 4)

* Adjacent-channel frequency spacing: ±19.18 MHz.

Notes to Table XV:

1) The significant viewing conditions were as follows:

	MUSE	M/NTSC digital subcarrier system
Test pictures Wanted signal	test slides * Fruits Congress-Hall	Test slides SMPTE #1 SMPTE #14
Unwanted signal	Colour bar	Colour bar
Ratio of viewing distance to picture height	3	6
Picture monitor	30" RGB monitor	20" NTSC monitor
Peak luminance on the screen (cd/m^2)	70	70
Ratio of the luminance of the screen when displaying only black level in a completely dark room to that corresponding to peak white	Approximately 0.01	Approximately 0.01
Room illumination	low	low
Grading scales	Five-grade impairment scale	Five-grade impairment scale
Observers	12 Non-experts	12 Non-experts

* Compositions of these slides are similar to those of SMPTE test slides #1 and #14.

2) The significant viewing conditions were as following :

- Viewing distance : 3 H
- Peak luminance : 80 Cd/m^2
- Contrast ratio : 30:1
- Monitor : 1250/50/2
- Display tube : Shadow mask, 77 cm diag.

Six expert observers were used for all the tests.

The electronic picture transmitted on the unwanted channel has been specially built to be theoretically as critical as possible (electronic grid pattern for HDMAC interfering with HDMAC).

3) For the co-channel measurement, the slide "BOATS" was used as the wanted signal while for the adjacent-channel measurements, the slide "CIRCUS" was used as the wanted signal.

4) For these measurements the slide "BOATS" was used as the wanted signals.

3.2 *Interference from other types of signal*

3.2.1 *Interference to frequency-modulation television signals*

Measurements have been carried out by the TDF for interference to a frequency-modulated television signal from a frequency-modulated sound multiplex signal and a PSK-telephony signal. The results concerning only the co-channel protection ratio, PR_0, are the following:

Wanted signal	FM-TV		
Interfering signal	FM-sound multiplex	4-PSK telephony	
		32 Mbit/s	52 Mbit/s
Co-channel protection ratio (PR_0) (dB)	27	19	19

More information on the characteristics of the signals is given in § 4.1.1 of Annex I and in [CCIR, 1974-78b].

3.2.2 *Interference to AM-VSB signals*

Measurements of multiple audio channels interfering into AM-VSB television, system M/NTSC, were made by the USA. From these tests, where the interfering signals were limited to the frequency band 1 to 3 MHz above the vision carrier, it was concluded that a protection ratio near 50 dB is indicated.

More detailed information is given in Annex I, § 1.2.

3.3 *Deviations from the reference case*

Based on the information given in Annex I, the effects of several deviations from the reference case (see Recommendation 600) can be quantified and qualified as described below.

3.3.1 *Viewer expertise*

The relationship between expert and non-expert viewers has been examined for the 525-line system M/NTSC amplitude-modulation vestigial-sideband protection ratio against barely perceptible frequency-modulation interference. The expert viewers were found to require 2 to 4 dB greater protection ratio (see Annex I, § 1.1). For other wanted and unwanted signals, the relationship may be different and should be determined by experiments.

3.3.2 *Deviation of the main carrier by the sound sub-carrier*

Tests carried out by the BBC for interference between two frequency-modulation television signals, system I/PAL, indicate that a slight reduction of adjacent-channel protection ratio can be achieved by reducing the deviation on the main carrier caused by the sound sub-carrier (from a value of ± 2.8 MHz). Tests carried out in Japan for interference between two frequency-modulation television signals, system M/NTSC, showed that the presence of 1 or 2 sound sub-carriers has a negligible effect on the protection ratio.

3.3.3 *Scanning synchronization*

If the line-scanning frequencies of the wanted and the unwanted transmissions are not frequency-locked, the protection ratio is likely to be slightly higher than the reference condition.

3.3.4 *Picture type*

Measurements in the United States of America [CCIR, 1982-86b] indicate that a decrease of 5 to 6 dB in the measured co-channel protection ratio might result from using typical programme material in place of reasonably critical still scenes.

3.3.5 *Modulation index*

Increasing the modulation index reduces the co-channel protection ratio for two frequency modulation signals as given by equations (1a) and (1b). To compare co-channel protection ratios measured at peak deviations different from the reference case with those measured at the reference case (12 MHz/V) the measured values should be modified by an additive correction constant of 20 log $D_v/12$, where D_v is the peak-to-peak frequency deviation in MHz.

This correction applies approximately to VSB-AM signals affecting FM signals, but a smaller correction applies when FM signals affect VSB-AM signals (see examples in Table XVII of Annex I). It does not apply when appreciable frequency offsets exist.

3.3.6 *Pre-emphasis*

In the case of interference to an amplitude-modulation, vestigial-sideband system from a frequency-modulation system, the co-channel protection ratio decreases by 1.0 dB if pre-emphasis is not used on the interfering signal. To compare with measurements made at the reference conditions, the measured protection ratios, in this case, should be modified by an additive constant of 1.0 dB. In the case of interference between two frequency-modulation systems, pre-emphasis has negligible effect on the co-channel protection ratio whereas for the adjacent channel a somewhat higher carrier offset is required to reach the same protection ratio when no pre-emphasis is used.

3.3.7 *Energy dispersal*

In the case of interference to an amplitude-modulation vestigial-sideband system from a frequency-modulation system the use of energy dispersal reduces the co-channel protection ratio by 1.5 dB per MHz of peak-to-peak deviation caused by energy dispersion. To compare measurements made with energy dispersion to measurements made at the reference conditions, the measured co-channel protection ratio, in this case, should be modified by a constant of 1.5 dB/MHz.

3.3.8 *Small carrier frequency offset*

Generally the protection ratio is constant near zero frequency offset. In some cases variations are introduced by the susceptibility to interference of some components of the signal, such as the colour sub-carrier.

3.3.9 *Effects of noise*

Some administrations feel that system planning could take account of the masking of interference by random noise. In this case, a lower value, PR_1 of protection ratio could be adopted. If the peak-to-peak luminance signal-to-r.m.s. weighted-noise ratio is S/N, results obtained for 525-line system M suggest that:

$$\left.\begin{array}{ll} PR_1 = PR_0 - (49 - S/N) & \text{for } S/N < 49 \text{ dB} \\ PR_1 = PR_0 & \text{for } S/N \geqslant 49 \text{ dB} \end{array}\right\} \qquad (2)$$

where PR_0 is the protection ratio under the reference conditions (see Recommendation 600). Other administrations have obtained results where the presence of noise tends to raise the required protection ratio. Data for the effects of noise are given in § 1.1.1.3, 1.1.1.4, 1.3, 3.1 and 3.3 of Annex I.

Measurements in the United States of America [CCIR, 1982-86b] show the effect of both interference and noise on the co-channel protection ratio. The combined effect of interference and the system signal-to-noise ratio determine the protection ratio for a specified grade of service. Details of the measurements are given in Annex I, § 3.1.7.

Tests were performed in Canada on the impairment due to noise and interference to determine the validity of the law of addition of impairment units. The results show that the law of addition gives slightly lower calculated values of opinion score than the observed values, to a maximum difference of 0.3. Details are given in Report 405.

3.3.10 *Viewing condition*

Most protection ratio measurements have been carried out using a ratio of viewing distance to picture height of 4 to 6, in accordance with Recommendation 500. Measurements carried out in Japan [CCIR, 1978-82a], where a viewing ratio of 1 to 1.5 was used, resulted in a protection ratio of 38 dB for just perceptible interference between two frequency-modulation TV-signals, system M/NTSC.

More detailed information on these tests is contained in § 3.1, § 4.1.2 and 4.1.3 of Annex I.

4. Interference to a sound multiplex from other signals

Co-channel protection ratios have been measured by the TDF for the interference to a frequency-modulated sound multiplex signal from a frequency-modulated television signal, a PSK-telephony signal and a frequency-modulated sound multiplex signal. The results obtained are the following:

Wanted signal	FM-sound multiplex			
Interfering signal	FM-TV	4-PSK telephony		FM-sound multiplex
		32 Mbit/s	52 Mbit/s	
Co-channnel protection ratio (PR_0) (dB)	19	18	18	25

Adjacent-channel protection ratio tests have now to be completed. More information on these measurements is shown in § 4 of Annex I.

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[1970-74]: **a.** 11/318 (EBU).

[1974-78]: **a.** 11/25 (EBU); **b.** 11/101 + 11/114 (France).

[1978-82]: **a.** 10-11S/19 (Japan).

[1982-86]: **a.** 10/11S/190 (Canada); **b.** 10-11S/49 + Corr.1 (USA); **c.** 10-11S/55 + Add.1 (Canada); **d.** 10/11S/40 (EBU); **e.** 10/11S/173 (France); **f.** 10-11S/5 (Japan); **g.** 10-11S/136 (Japan); **h.** 10-11S/161 + Corr.1 (USA).

[1986-90]: a. 10-11S/12 (United Kingdom); b. 10-11S/115 + 138 (Germany (Federal Republic of), Finland, France, Netherlands, United Kingdom, Sweden); c. 10-11S/106 (Japan).

ANNEX I

RESULTS OF PROTECTION RATIO TESTS

This Annex summarizes protection ratio data obtained by several administrations for television involving both frequency modulation and amplitude modulation by video signals in formats M/NTSC, B/PAL, G/PAL, D/PAL, I/PAL, K/SECAM and L/SECAM. It also provides data on a sound multiplex system and digital telephony systems used in protection ratio measurements. Table XVI may be used as a guide to the contents of Annex I.

1. Interference to an amplitude-modulation, vestigial-sideband television signal

1.1 *Interference to an amplitude modulation, vestigial sideband television signal from a frequency modulation television signal*

1.1.1 *525-line system M/NTSC*

The following data are based on the preliminary results of tests conducted in the USA and in Japan [Kaneda, 1972]. System M was used for both the frequency-modulation and the amplitude-modulation, vestigial-sideband colour television signals.

1.1.1.1 *Co-channel protection ratio*

In the subjective assessment of the co-channel protection ratio of AM-VSB television signal against interference from the FM-television signal, the salient conditions used for the measurements made in Japan are the following:

- Signal-to-unweighted noise ratio of video signal used is not less than 42 dB.
- Picture slides of SMPTE Nos. 1, 9, 14 and colour bar signal are used.
- Number of observers is 24 including 12 experts.
- Viewing distance is six times the picture height.

1.1.1.2 *Protection ratio as a function of carrier-frequency offset*

Tests performed by the USA and reported in § 1.1.1.2, 1.1.1.3, 1.1.1.4 used the following test conditions. The protection ratios measured were for just perceptible visual interference. Audio-frequency interference was not evaluated. The picture tube diagonal was 38 cm (15 in.). Viewing distances ranged from 135 to 165 cm (4½ to 5½ feet). The centre of the viewed picture was at the viewer's eye level, and the maximum side-viewing angle was 30°. Light measured during peak white luminance was approximately 20 foot-candles (200 lux). The light from the area surrounding the picture tube measured approximately 0.1 foot-candles (1 lux). The wanted amplitude-modulation, vestigial-sideband signal carried "off-the-air" programme material. The interfering frequency-modulation signal carried various stationary test signals and used a peak-to-peak frequency deviation of 18 MHz. The modulating signal polarity was such that the deviation produced by synchronizing pulses was towards lower frequencies. No pre-emphasis was used with the frequency-modulation signal.

The amplitude-modulation, vestigial-sideband protection ratio against frequency-modulation interference is shown as a function of the carrier-frequency offset in Fig. 2 from [Miller and Myhre, 1970]. The amplitude-modulation, vestigial-sideband signal-to-random noise ratio for these tests was 49 dB (weighted). The judgments of just perceptible interference were made by a single expert viewer.

The curves of Fig. 2 show that interference from still scenes is more easily perceived than interference from scenes with motion. The shaded area in Fig. 3 encompasses the data from the individual test curves and indicates the upper and lower limits of the amplitude-modulation, vestigial-sideband protection ratio. To guarantee no perceptible interference from both still and moving scenes, a protection ratio exceeding the upper boundary of the shaded area in Fig. 3 should be used.

TABLE XVI – *Index to the protection ratio measurements given in this Annex*

Section	System	Wanted	Interferer	Test/Interference condition	Administration
1.1.1.1	M/NTSC	AM-VSB	FM-TV	Co-channel/ Just perceptible	Japan
1.1.1.2	M/NTSC	AM-VSB	FM-TV	Frequency offset/ Just perceptible	USA
1.1.1.3	M/NTSC	AM-VSB	FM-TV	Function of AM-VSB S/N	USA
1.1.1.4	M/NTSC	AM-VSB	FM-TV	Just perceptible (Expert/non-expert)	USA
1.2	M/NTSC, K/SECAM, G/PAL	AM-VSB	Multiple sound	Co-channel/ Just perceptible	USA, USSR
1.3	I/PAL	AM-VSB	FM-TV	C/I impairment/ co-channel	BBC
1.4	G/PAL	AM-VSB	FM-TV	Co-channel/ Just perceptible	IRT
1.5	L/SECAM	AM-VSB	FM-TV	Co-channel/ Just perceptible	TDF
1.6	K/SECAM, B/PAL, M/NTSC	AM-VSB	FM-TV	PR_0 calculation for AM-VSB	USSR
1.7	G/PAL, L/SECAM	AM-VSB	FM-TV	Frequency offset/ Just perceptible	(European)
2.1	M/NTSC	FM-TV	AM-VSB	Frequency offset, co-channel/ Just perceptible	USA
2.2	K/SECAM	FM-TV	AM-VSB	(Details in § 5)	USSR
3.1.1	M/NTSC	FM-TV	FM-TV	Frequency offset/ Just perceptible	USA
3.1.2	M/NTSC	FM-TV	FM-TV	Frequency offset/ Just perceptible	Canada
3.1.3	Mixed M/NTSC, PAL, SECAM	FM-TV	FM-TV	Co-channel/ Just perceptible	Japan
3.1.4	M/NTSC	FM-TV	FM-TV	Co-channel/ Just perceptible (1.5 picture height)	Japan
3.1.5	M/NTSC	FM-TV	FM-TV	C/I impairment/ co-channel	USA
3.1.6	M/NTSC	FM-TV	FM-TV	Co-channel interference, adjacent channel interference, noise, multiple interference, noise and interference	Canada
3.1.7	M/NTSC	FM-TV	FM-TV	Co-channel interference, adjacent channel interference, noise, multiple interference noise and interference	USA

TABLE XVI *(continued)*

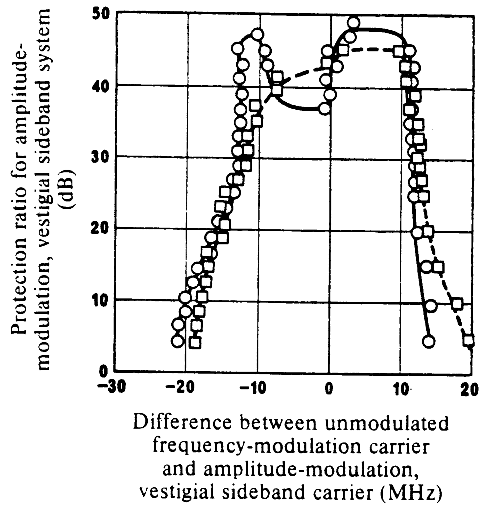
Section	System	Wanted	Interferer	Test/Interference condition	Administration
3.2	B/PAL, G/PAL, I/PAL, L/SECAM	FM-TV	FM-TV	Frequency offsets (WARC-BS-77 template)	(European)
3.3		Wide deviation FM sound	Same	Co-channel/ Just perceptible	BBC
4.1.1	PAL	FM-TV	FM sound multiplex		TDF
4.1.2	M/NTSC	FM-TV	FDM-FM multiplex		Japan
4.1.3	M/NTSC, D/PAL	FM-TV	Digital TV, data	Frequency offset/ Just perceptible	USA, China (People's Republic of)
4.2.1	M/NTSC	Digital TV	FM-TV	Frequency offset/ Just perceptible	USA
4.2.2	M/NTSC	Digital TV	Digital TV, data	Frequency offset/ Just perceptible	USA
4.2.3	M/NTSC	Digital data	Digital TV	Frequency offset/ Just perceptible	USA
5.	K/SECAM	FM-TV	CW	Frequency offset/ Just perceptible	USSR
	K/SECAM	FM-TV	AM-VSB	Frequency offset/ Just perceptible	USSR
	K/SECAM	FM-TV	FM-TV	Frequency offset/ Just perceptible	USSR
	K/SECAM	FM-TV	FM-TV	*S/N* versus protection ratio, co-channel/ Just perceptible	USSR
6.	TTC interference considerations (protection of TV signals)				
7.	Discussion of results				

Table XVII shows the summary of co-channel protection ratios for just perceptible interference. It appears to be in fairly good agreement with the data described in § 1.1.1.2.

TABLE XVII – *Summary of co-channel protection ratios*

Wanted signal: amplitude-modulation vestigial sideband television Unwanted signal: frequency-modulation television			Wanted signal: frequency-modulation television Unwanted signal: amplitude-modulation vestigial sideband television		
D_v (1) (MHz)	For just perceptible interference level (dB)	For impairment grade 3.5 (dB)	D_v (1) (MHz)	For just perceptible interference level (dB)	For impairment grade 3.5 (dB)
8	52	46	8	36	28
16	49	42	16	30	24
24	48	43	20	28	22

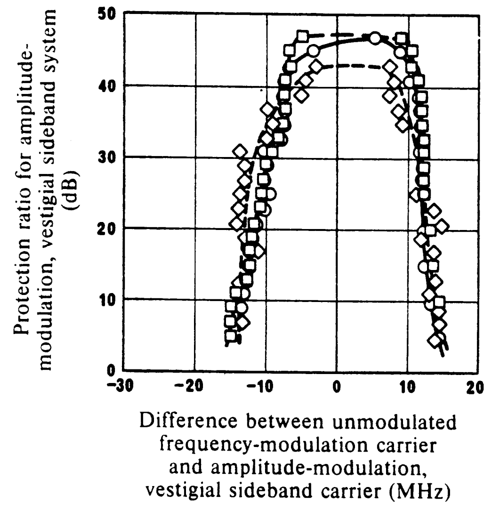
(1) D_v is the peak-to-peak frequency deviation of the frequency-modulation television signal.



White window on frequency-modulation system

Bars on frequency-modulation system

(a) White window and colour bars on frequency-modulation system



Kitchen scene on frequency-modulation system

Girl slide on frequency-modulation system

"Off-the-air" programme material on frequency-modulation system

(b) Kitchen scene, girl slide, and "off-the-air" programme material on frequency-modulation system

FIGURE 2 - *Protection ratio for an amplitude-modulation, vestigial sideband system as function of carrier frequency offset*

$$\frac{(P_{SYNC\ PK\ AV})_{AM\text{-}VSB}}{(P_{AV})_{FM}}$$

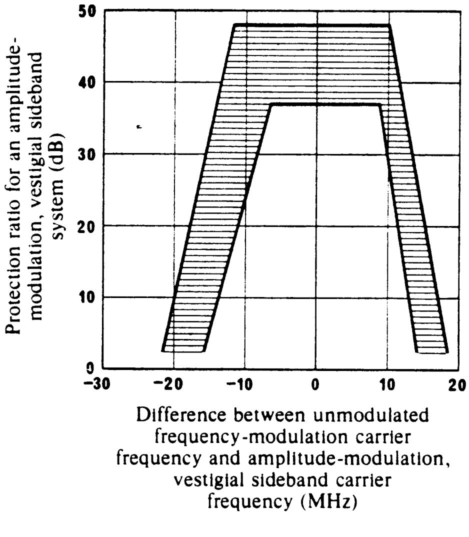


FIGURE 3 — *Protection ratio required for just perceptible interference in an amplitude-modulation, vestigial-sideband system subjected to interference by a frequency-modulation television system*

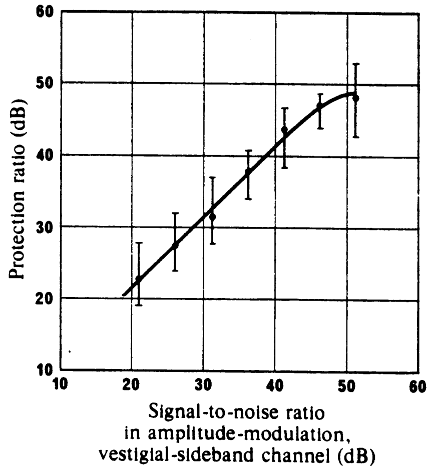
$$\frac{(P_{SYNC\ PK\ AV})_{AM\text{-}VSB}}{(P_{AV})_{FM}}$$

More recently, tests were performed by the USA [Barnes and Miller, 1978]. This series of tests examined a wide range of parameters for system M/NTSC wanted and unwanted signals. The parameters included: frequency offsets, 12 and 18 MHz peak-to-peak frequency deviations for frequency modulated signals, three and four section receiver filters, several test slides and colour bars as the wanted signal, and pre-emphasis for the frequency modulated signals. Because of the extensive number of tests, a single expert viewer was used to make judgments of just-perceptible interference. But, other test conditions were as in Recommendation 600. For the case of amplitude-modulation, vestigial sideband television, with FM interference, the measured co-channel protection ratios were 55 dB. This compares to 50 dB for the earlier measured results reported in this section. This difference is attributed to the change in wanted picture content and the use of pre-emphasis in these tests. It is concluded that the reference case test conditions as per Recommendation 600 produce higher measured protection ratios than the earlier test conditions reported in this section.

1.1.1.3 *Protection ratio as a function of the signal-to-noise ratio*

The amplitude-modulation, vestigial-sideband protection ratio against just perceptible frequency-modulation interference is shown in Fig. 4 as a function of the output picture signal-to-weighted noise ratio on the amplitude-modulation, vestigial-sideband television system [Miller and Myhre, 1970]. The data used in Fig. 4 is from tests with off-the-air programming on both the amplitude- and frequency-modulation systems. For signal-to-noise ratios of less than 45 dB the average protection ratio, as shown in Fig. 4, may be expressed by:

$$R_{AM/FM} = S/N_{WTD} + 2 \qquad \text{dB} \tag{3}$$



Carrier frequency offset: 0.5 MHz

Peak-to-peak frequency deviation: 18 MHz

Protection ratio for just perceptible interference: 34 observations by one expert viewer, averaged at each value of signal-to-noise ratio (*S/N*)

$$S/N = \frac{\text{White-to-blanking voltage}}{\text{R.m.s. noise voltage in 4.2 MHz (WTD)}}$$

No pre-emphasis on frequency-modulation system

FIGURE 4 — *Protection ratio for an amplitude-modulation, vestigial-sideband system as a function of signal-to-noise ratio in the amplitude-modulation, vestigial-sideband channel*

The ranges of the test data at the various signal-to-noise ratios are shown by the vertical lines through the curve in Fig. 4. Changes in programme material during the tests account for most of the variations in the test data. The interference is more easily perceived in dark-coloured areas than in light-coloured areas. Pictures having large areas of uniform colour show interference more readily than scenes with multi-coloured detail. To guarantee no perceptible interference for varied programme material on both systems, an amplitude-modulation, vestigial-sideband protection ratio exceeding the upper limits of the data should be used. In this case the protection ratio for signal-to-noise ratios less than 45 dB would be expressed by:

$$R_{AM/FM} = S/N_{WTD} + 7 \qquad \text{dB} \qquad (4)$$

1.1.1.4 *Protection ratio tests with many viewers*

The amplitude-modulation, vestigial-sideband protection ratio against just perceptible frequency-modulation interference is shown in Fig. 5 for tests with a total of 30 viewers. Each viewer witnessed a random sequence of test scenes having different ratios of wanted-to-unwanted signal power. The viewers were asked to judge only whether or not they could perceive any interference in the picture. The amplitude-modulation, vestigial-sideband picture was "off-the-air" programme material. The interfering frequency-modulation signal was either a kitchen scene, colour bars, the white window, or "off-the-air" programme material. The curve in Fig. 5 is the average of the percentage readings for the four different modulating signals on the frequency-modulation system. The ranges of the percentages over the four tests are shown by the vertical bars. At a given power ratio, the percentage of viewers perceiving no interference is a function of the amplitude-modulation, vestigial-sideband programme material. As in the tests with a single expert observer, still scenes with dark areas or with large areas of uniform colour required a greater power ratio to cause the interference to be imperceptible. Test conditions were:

AM-VSB signal-to-noise ratio: 46 dB (weighted)

Carrier-frequency offset: 0.5 MHz.

Of the 30 viewers, 3 were expert viewers. There were 3 female and 27 male viewers.

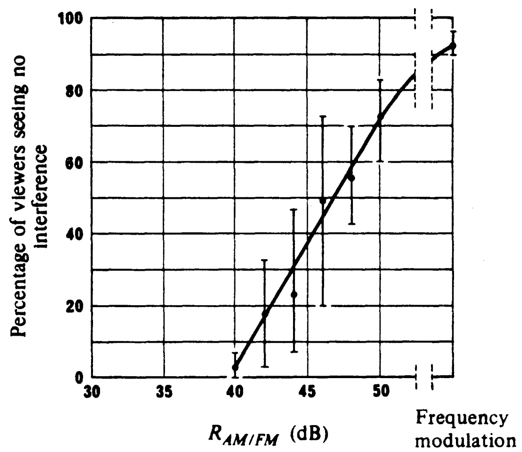


FIGURE 5 — *Percentage of viewers perceiving no interference, as a function of the protection ratio* $R_{AM/FM}$

On the basis of these limited tests, the amplitude-modulation, vestigial-sideband protection ratio, such that 50% of the viewers will perceive no interference, is given by the following expression:

$$R_{AM/FM} = S/N_{WTD} \qquad \text{dB} \qquad (5)$$

The expert viewers used to obtain the barely perceptible interference test results shown in the figures were administered this same test. For these expert observers to perceive no interference, the measured amplitude-modulation, vestigial-sideband protection ratio is given by the following expression:

$$R_{AM/FM} = S/N_{WTD} + 4 \quad \text{dB} \qquad (6)$$

These results indicate the expert viewers used in the other tests to be 4 dB more critical than the group of 30 viewers.

Equations (3) and (6) are based upon two different impairment criteria, and consequently are not directly comparable. Equation (3) expresses the protection ratio measured for an expert observer to notice just perceptible interference, while equation (6) expresses the protection ratio measured for expert observers to perceive no interference.

1.2 *Interference to amplitude-modulation, vestigial sideband television from multiple sound channels*

Tests were performed in the USA [CCIR, 1978-82a] with AM-VSB television as the wanted signal and multiple sound channels as the interference. Test conditions were in accordance with Recommendation 600. The wanted signal was system M/NTSC, AM-VSB television with a signal-to-noise (unweighted) ratio of 40 dB. Narrowband frequency modulated sound channels with 20 kHz peak deviation and wideband channels with 75 kHz peak deviation were used as the interfering signals. The sound channels were placed in the frequency band between 1 and 3 MHz above the vision carrier. Subjective evaluations of television impairments were made by four expert viewers and five non-expert viewers. The viewers determined the protection ratios $R_{AM/FM}$, the ratio of wanted AM-VSB carrier power at sync. peak to total average power in all interfering sound channels for just pérceptible interference. The results of the tests are shown in Tables XVIII and XIX.

TABLE XVIII – *Protection ratios ($R_{AM/FM}$)* for just perceptible interference on AM-VSB television with narrowband FM sound channels interfering*

Number of sound channels N	Spacing between channels (kHz)	$R_{AM/FM}$ (dB)				
		Broadcast television programme			Philips slide No. 14	SMPTE slide No. 1
		A	B	C	B	B
2	50	45-52(1)	44-50(1)	39-46(1)	47-53(1)	48-57(1)
4	50	47-56(1)	46-54(1)	42-49(1)	50-55(1)	51-56(1)
10	50	50-53(1)	50-53(1)	43-46(1)	50-54(1)	52-53(1)
20	100	50	50	46	50	49
40	50	53	52	49	50	48

$$* \; R_{AM/FM} = \frac{(P_{SYNC\ PK\ AV})_{AM-VSB}}{\sum_{i=1}^{N} (P_i)_{FM}}$$

(1) Measured values occurred in range shown. $R_{AM/FM}$ varied with exact location of channels within the 2 MHz bandwidth.

A: averaged over 4 expert viewers, sound carriers unmodulated

B: averaged over 4 expert viewers, sound carriers modulated with a 400 Hz sine wave

C: averaged over 5 non-expert viewers, sound carriers modulated with a 400 Hz sine wave.

TABLE XIX – *Protection ratios ($R_{AM/FM}$)* for just perceptible interference on AM-VSB television with wideband sound channels interfering*

(Philips slide No. 14 on AM-VSB channel)

Number of sound channels N	$R_{AM/FM}$ (dB)	
	A	B
2	44-46 (1)	43-53 (1)
4	46-53 (1)	44-51 (1)
10	49	46

$$* \; R_{AM/FM} = \frac{(P_{SYNC\ PK\ AV})_{AM-VSB}}{\sum_{i=1}^{N} (P_i)_{FM}}$$

(1) Measured values occurred in range shown. $R_{AM/FM}$ varied with exact location of channels within the 2 MHz bandwidth.

A: averaged over 4 expert viewers, sound carriers unmodulated.

B: averaged over 4 expert viewers, sound carriers modulated with 15 kHz sine wave.

Based upon this series of tests, one may conclude:

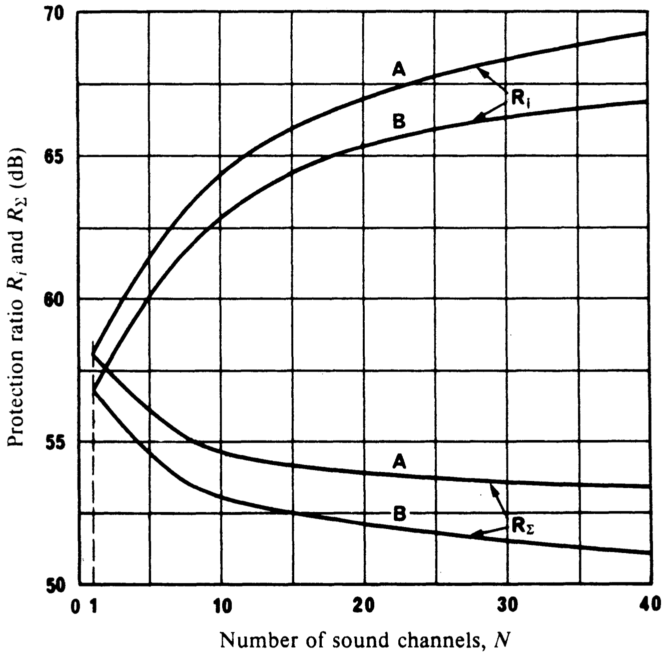
- protection ratios near 50 dB are indicated for system M/NTSC, AM-VSB television with multiple, interfering, frequency-modulation sound channels, where the interference is from either narrowband or wideband sound channels. There is a slight reduction in the measured protection ratio for wideband interfering sound channels compared to narrowband interfering channels.
- the test data support the hypothesis that the total power from a large number of interferers has essentially the same effect as that same amount of power from a single interferer.
- there is a slight reduction in protection ratio (1 to 3 dB) when modulation is applied to the interfering channels.

Studies of protection ratios for a similar case of interaction between a wanted signal and interference were carried out in the USSR [CCIR, 1978-82b] for M/NTSC, G/PAL and K/SECAM colour television systems. The measurement conditions were in keeping with the provisions of Recommendation 600. The observers taking part in the tests totalled 46 persons and included both experts and non-experts. The test pictures used were a real television program and slide SMPTE No. 14. The ratio of signal-to-unweighted noise in the television channel was taken as 40 dB. The interference applied ranged from 1 to 40 unmodulated or frequency-modulated carriers. The carrier frequency modulation was effected by a 1000 Hz sine wave; the peak-to-peak carrier deviation was 40 kHz and the frequency spacing between adjacent carriers was 50 kHz.

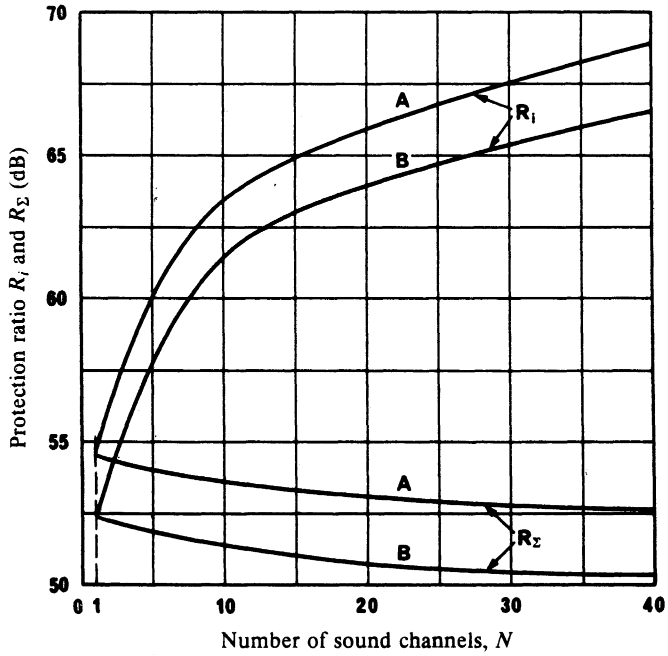
The protection ratio for all cases was determined for the interference perceptibility threshold (grade 4.5 on the CCIR impairment scale).

In the test process, it was established that the relations between permissible protection ratios and the number of interfering signals for the three colour television systems studied were sufficiently close (deviation of measured values not in excess of 1 dB) to permit representation of the final test results as unified curves for all three systems.

These results are presented in Figs. 6a) and 6b) to show the relationship between the permissible protection ratio for the sum of narrowband interfering signals (R_Σ) and for a single (from the given sum) interfering signal (R_i) both as a function of the number of interfering signals for unmodulated and frequency-modulated interfering signals respectively.



a) Sound carrier unmodulated



b) Sound carrier modulated

FIGURE 6 – *Protection ratios R_i and R_Σ for just perceptible interference on AM-VSB television with narrow-band FM sound channels interfering*

Curves A: SMPTE slide No. 14
B: broadcast television programme

$$R_i = \frac{(P_{SYNC\ PK\ AV})_{AM\text{-}VSB}}{(P_i)_{FM}}, \quad R_\Sigma = \frac{(P_{SYNC\ PK\ AV})_{AM\text{-}VSB}}{\sum_{i=1}^{N} (P_i)_{FM}}$$

The upper curves for R_Σ and R_i in these diagrams were obtained for the SMPTE No. 14 test picture, while the lower curves relate to the real television programme.

The following conclusions may be drawn from the results obtained:

- the effect of interference in the form of multiple narrowband FM signals on an AM-VSB television signal is roughly the same for the various colour television systems and is most perceptible when the interference falls within the luminance signal transmission band;
- the admissible protection ratio for the total interference is reduced with an increasing number of interfering signals; this reduction is greater when the number of interfering signals rises from 1 to 10;
- the removal of modulation from the carriers of the FM interference yields a slight increase in the protection ratio for the total interference (not more than 1.5 dB) when $N > 10$ and a considerable increase (up to 3 to 4 dB) when $N < 10$.

1.3 *625-line system I/PAL*

Figure 7 gives a summary of subjective tests performed by the BBC [Brown, 1971a]. The wanted amplitude-modulation, vestigial-sideband signal was modulated by a still picture of books, a box and silverware, and had a luminance-to-weighted-noise ratio of 43 dB. The interfering frequency-modulation signal was modulated by a colour bar using a nominal peak-to-peak deviation of 8 MHz, pre-emphasis according to curve B of Recommendation 405, and no energy dispersal.

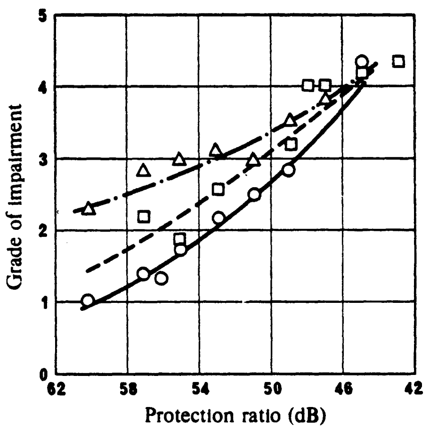


FIGURE 7 – *Grade of impairment caused by a combination of random noise and co-channel interference, present simultaneously*

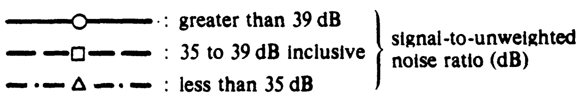


Figure 7 refers to video signal-to-unweighted-noise ratios; for weighted-noise (system I weighting) the numerical value is increased by 6.5 dB.

The results suggest that if the wanted signal has a signal-to-noise ratio of 36.5 dB, noise unweighted, or 43 dB noise weighted, a working protection ratio of 53 dB would cause a change of grade from less than 2.0 (in the case of an unweighted signal-to-noise ratio greater than 39 dB) to about 2.5.

Note. – The scale used is the EBU impairment scale, which is:

Interference	*Grade*
Imperceptible	1
Just perceptible	2
Definitely perceptible, but not disturbing	3
Somewhat objectionable	4
Definitely objectionable	5
Unusable	6

At high signal-to-noise ratios in the BBC tests the protection ratio was 56 dB. It may be noted that from the shapes of the curves in Fig. 7, the impairment caused by interference is not significantly masked by the noise.

Reduction of this protection ratio may be permissible under the following conditions:

- no pre-emphasis: 1.5 dB reduction;
- deviation increased from 8 to 12 MHz peak-to-peak: 2 dB reduction;
- use of energy dispersal: about 2 dB reduction per MHz of peak-to-peak deviation.

On the other hand, an interfering signal modulation of black level was found to require a higher protection ratio (by about 5 dB). Thus, for the reference condition the protection ratio may be taken as 54 dB.

1.4 *625-line system G/PAL*

The IRT in the Federal Republic of Germany have carried out tests on system B/PAL, which for the present purpose can be considered as equivalent to system G/PAL. The signal-to-noise ratio (weighted) was approximately 50 dB. The protection ratio was assessed for an impairment grade of 2, on the 6-point scale. At a peak-to-peak deviation of 8 MHz for the interfering signal, and with no pre-emphasis, the average value of the protection ratio was 59.7 dB. A separate series of tests suggested that, on average, pre-emphasis does not significantly affect the results. (This conclusion differs somewhat from the BBC tests, which suggested that pre-emphasis may be expected to increase the protection ratio by about 1.5 dB. The difference may be due to the different picture content of the interfering signal.)

The observers in this test were all experienced, and the pictures used tended to be fairly sensitive to the effects of interference. On the other hand, it must be remembered that the impairment grade corresponded to greater impairment than the reference condition. Taking these factors into account, the protection ratio for the reference conditions may be taken as about 54 dB (see Recommendation 600).

1.5 *625-line system L/SECAM*

The ORTF, in France, [CCIR, 1970-74a and b] investigated the case where the wanted signal is system L/SECAM, the interfering signal being PAL. In this case, the impairment grade was taken as 4, on the 5-point scale. In some separate tests, it was found that for an impairment grade of "just perceptible" (i.e., grade 2 on the 6-point scale), the protection ratio should be increased by about 5 dB. Using the conversion formula suggested in the Annex to Recommendation 500 this suggests that more than 5 dB should be added to obtain an impairment grade of 4.5 (5-point scale).

Pre-emphasis was included. The low frequency deviation was 3.8 MHz/V, so the equivalent value at the frequency of zero insertion loss (i.e. 1.5 MHz) would be 13.5 MHz peak-to-peak, and another correction is required (see § 3.3.5 of the body of this Report) to obtain results applicable to the reference condition of 12 MHz.

Referring to the reference conditions established in Recommendation 600, the TDF measurements lead to the following results:

Measured protection ratio for grade 4: 45 dB

Allowance to refer results to grade 4.5: +5 dB

Allowance to refer results to 12 MHz deviation: +0.5 dB

Thus, the final value of the protection ratio, applicable to the reference conditions, becomes 50.5 dB.

1.6 *625-line system K/SECAM*

Studies were carried out in the USSR [CCIR, 1978-1982c; Borovkov and Lokshin 1979], with a view to determining the value of protection ratios for AM-VSB television signals for the most widely used colour television sytems.

The test conditions were in keeping with those specified in Recommendation 500 and were as follows:

- wanted AM-VSB picture: colour slides SMPTE No. 14 and Philips No. 8;
- wanted signal: M/NTSC, G/PAL, K/SECAM;
- interfering picture: colour bars;
- interfering signal: deviation (peak-to-peak) 8, 16 and 22 MHz;
- assessment scale: 5-grade impairment scale; perceptibility threshold – grade 4.5 ($Q = 4.5$);
- observers: 40, of whom approximately half were experts;
- viewing distance: 6 picture heights;
- the ratio of the peak-to-peak amplitude of the wanted video signal to the unweighted noise voltage at the receiver output was not less than 40 dB;
- the carrier frequencies of the wanted and unwanted signals were close together so as to maximize the perceptibility of the interference;
- the interfering signal used standard pre-emphasis.

The dependence of picture impairment on the level of the interfering FM signal obtained for the various systems was sufficiently close to be generalized and presented on a single curve (see Fig. 8).

The tests also showed that the dispersal of the energy of an FM interferer by a saw-tooth signal reduces the interfering effect, while the advantage obtained from energy dispersal is reduced as the peak-to-peak amplitude of frequency deviation is increased, as shown in Fig. 9.

In the general case, i.e., with any value of peak-to-peak deviation of FM interference and of dispersal, the following formula (for a picture impairment of $Q \leq 4.5$) may be used for calculating the protection ratio of an AM-VSB television signal against interference from an FM television signal:

$$R_q = R_{oq} - 0.45\,(D_v - D_{ov}) - M_d\, D_{dv} \qquad \text{for } Q \leq 4.5 \qquad (7)$$

where

R_q: the required protection ratio, (dB);

R_{oq}: the protection ratio for the frequency deviation D_{ov} taken as reference (determined from the corresponding curve on Fig. 8);

D_{dv}: the peak-to-peak amplitude of the frequency deviation due to the dispersal signal (MHz);

M_d: a coefficient determined from Fig. 9.

1.7 *Frequency offset*

If the frequencies of the wanted and interfering signals are spaced by a few MHz, some reduction in protection ratio is possible, the difference depending on whether the interfering signal is of a higher or a lower frequency than the wanted signal. Tests by the BBC, IRT and TDF all showed that the protection ratio varies only with respect to the frequency spacing. Examples are shown in Figs. 10 and 11 which show results obtained by the IRT and TDF respectively (using deviations somewhat greater than the reference condition). Since the spacing between terrestrial channels in systems G, I and L is 8 MHz, the best offset which could be used would be that giving equal protection ratios at ± 4 MHz about the point of symmetry of the intefering spectrum. Figures 10 and 11 show that if this is done, the benefit is unlikely to exceed about 3 dB, compared with the case of using no offset.

2. **Interference to a frequency-modulation television signal from an amplitude-modulation vestigial-sideband television signal**

2.1 *525-line system M/NTSC*

Results for this case have been provided by the USA [Miller and Myhre, 1970] and Japan [Kaneda, 1972]. In the USA a series of tests was conducted where a frequency-modulation television signal was placed at the same frequencies as an amplitude-modulation, vestigial-sideband television signal. The video output of a frequency-modulation television receiver tuned to the frequency-modulation signal was evaluated for interference. The signals used in the tests were the same as those described in § 1.1.1.2 of this Annex, except that the frequency-modulation signal was now the wanted signal and the amplitude-modulation, vestigial-sideband signal was the interfering signal.

The results of the tests are shown in Fig. 12. The luminance signal-to-weighted noise ratio of the wanted picture signal used in these tests was approximately 54 dB. The judgements of just perceptible interference were made by a single expert viewer. Bandwidth of the frequency-modulation receiver was 30 MHz.

The curves of Fig. 12 show that interference from stationary scenes, having large areas of uniform colour, is more easily perceived than scenes with motion, as in most off-the-air programming. The shaded band in Fig. 13 encloses the curves of the measured protection ratios. To guarantee no perceptible interference from both still and moving scenes, a protection ratio exceeding the upper boundary of the shaded area in Fig. 13 should be used.

Table XVII also shows the results of the subjective assessment test carried out in Japan in the case of barely perceptible interference for a wanted FM-TV signal and an unwanted VSB-AM television signal under the same conditions as described in this Annex, § 1.1.1.1.

Later tests in the USA [Barnes and Miller, 1978] were made using the guidelines of Recommendation 600 except as noted in § 1.1.1.2 of this Annex.

Table XX summarizes the results.

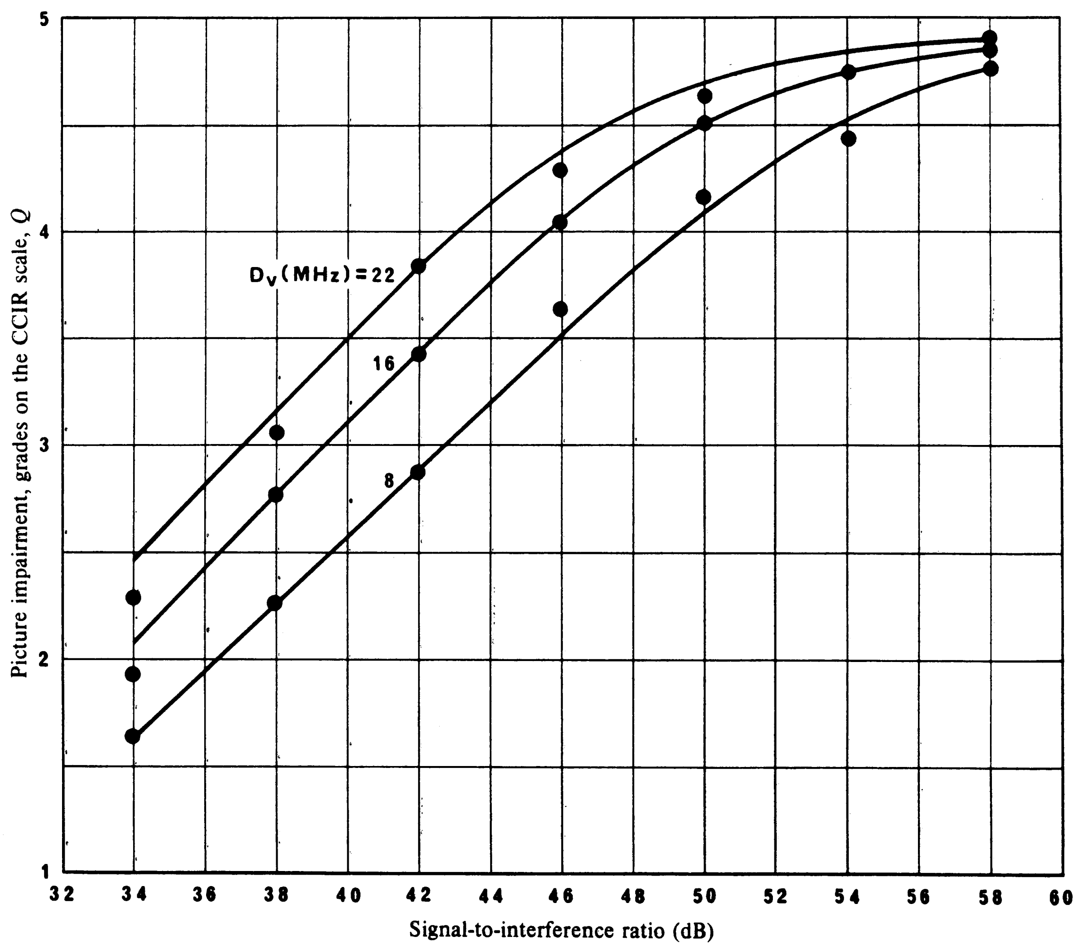


FIGURE 8 – *Television picture impairment (AM-VSB signal) as a function of the level of the interfering FM signal with different peak-to-peak deviation values*

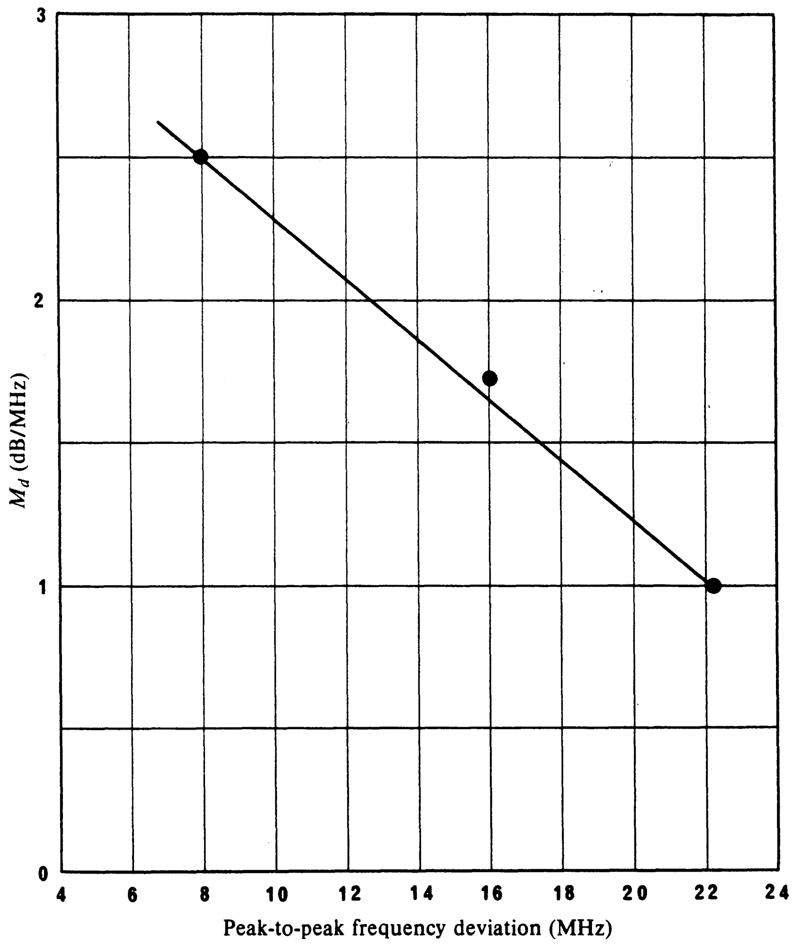


FIGURE 9 – *Coefficient M_d as a function of peak-to-peak deviaton of the interfering signal*

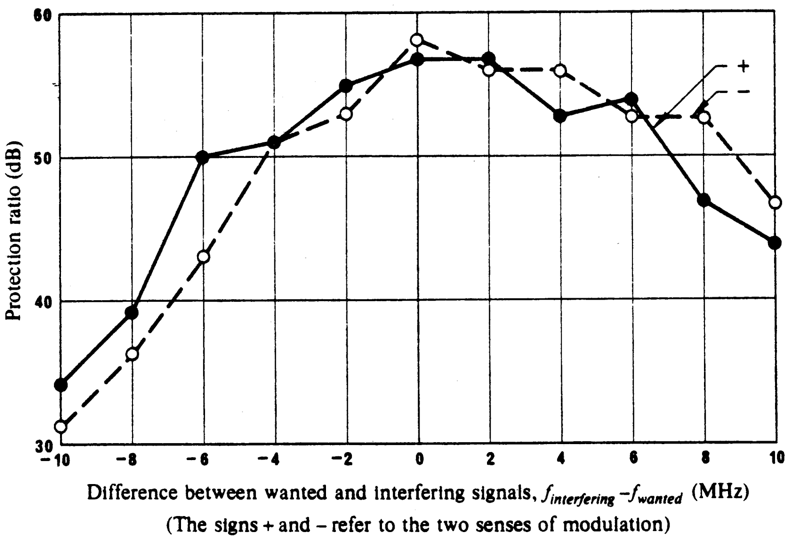


FIGURE 10 – *Variation of the protection ratio with respect to frequency spacing for system G/PAL*

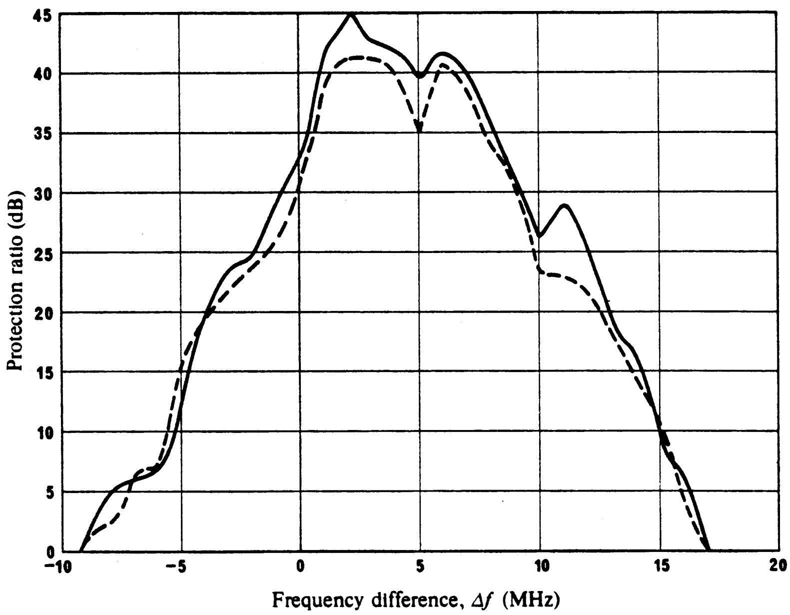


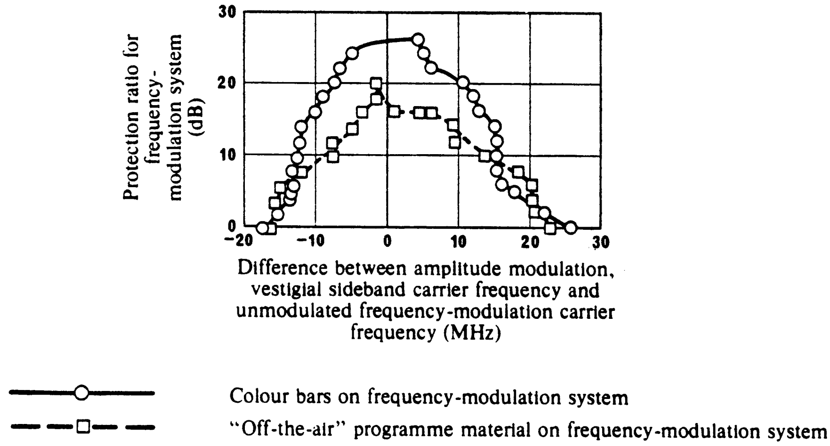
FIGURE 11 – *Variation of the protection ratio with respect to frequency spacing*

Wanted signal: L/SECAM colour bars (radio-frequency level: 60 dB(μV/m))

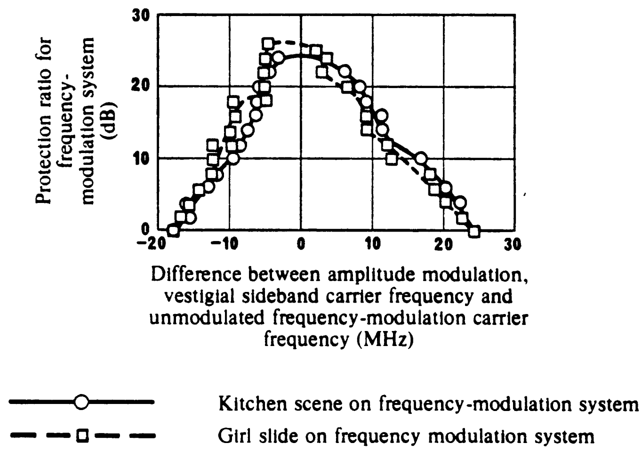
Interfering signal: G/PAL slide, synchronized scanning

——— : Measured without energy dispersal of the G/PAL signal

– – – : Measured with energy dispersal over 2 MHz of the G/PAL signal



(a) Colour bars and "off-the-air" programme material on frequency-modulation system



(b) Kitchen scene and girl slide on frequency-modulation system

FIGURE 12 – *Protection ratio for a frequency-modulation system as a function of the carrier-frequency offset*

$$\frac{(P_{AV})_{FM}}{(P_{SYNC\ PK\ AV})_{AM\text{-}VSB}}$$

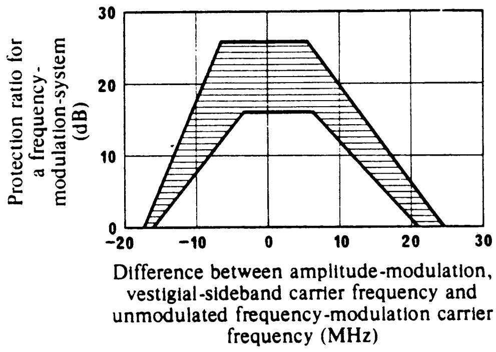


FIGURE 13 – *Protection ratio required for just perceptible interference in a frequency modulation television system subjected to interference by an amplitude-modulation, vestigial-sideband television system*

$$\frac{(P_{AV})\ FM}{(P_{SYNC\ PK\ AV})\ AM\text{-}VSB}$$

TABLE XX – *Measured co-channel protection ratios for just perceptible interference, system M/NTSC, SMPTE test slide No. 14 as wanted picture*

Wanted signal	Unwanted signal	Co-channel protection ratio (dB)
FM, 12 MHz deviation	AM-VSB	23 (1)
FM, 18 MHz deviation	AM-VSB	19

(1) Average for both four and six section Chebyshev filters.

The measured protection ratio is 4 dB less for 18 MHz deviation than for 12 MHz deviation. This suggests that the protection ratio for FM-wanted/AM-unwanted, decreases as 20 log (D_v/12), similar to equation (1a) in the body of this Report.

2.2 *625-line system K/SECAM*

Measurements in the USSR [CCIR, 1970-74c] determined protection ratios for frequency-modulation colour and monochrome signals against interference by CW, amplitude-modulation vestigial-sideband, and frequency-modulation signals. To facilitate intercomparison of the results of the system K measurements, they are presented separately in § 5 of this Annex.

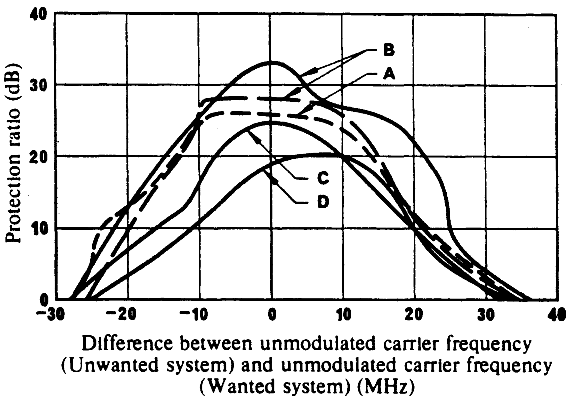
3. Interference between two frequency-modulation television signals

Measurements of interference between frequency-modulated television signals of the types used in the fixed-satellite service and the fixed service are presented in Report 449. Additional measurements for the broadcasting-satellite service are given below.

3.1 *525-line system M/NTSC*

3.1.1 *Two offset frequency modulation signals, tests in the United States of America*

Tests were conducted in the USA with two frequency-modulation signals operating at carrier frequency offsets in the range from −30 MHz to +36 MHz using an experimental arrangement similar to that described in § 1.1.1.2 of this Annex. The video frequency output of a frequency-modulation television receiver tuned to the wanted signal was evaluated by a single expert observer for just perceptible interference when the picture signal-to-weighted noise ratio was 50 dB. The bandwidth of the frequency-modulation receiver was 30 MHz. Figure 14 shows the measured protection ratios as functions of carrier frequency offset with off-the-air programming on the unwanted signal and various programmes on the wanted signal. The curves show that off-the-air programming, when there are scenes in motion, is less susceptible to interference than stationary scenes with large areas of uniform colour.



	Wanted system	Unwanted system
Peak-to-peak deviation	18 MHz	18 MHz
Signal-to-noise ratio (weighted)	50 dB	
Pre- and de-emphasis	none	none

Curve	Programme material	
	Wanted signal	Unwanted signal
A	white window	off-the-air
B	colour bars	off-the-air
C	kitchen scene	off-the-air
D	off-the-air	off-the-air

FIGURE 14 – *Protection ratio for just perceptible interference in a frequency-modulation television system subjected to interference by frequency-modulation television*

$$R_{FM/FM} = \frac{(P_{AV})_{FM}\text{ (Wanted)}}{(P_{AV})_{FM}\text{ (Unwanted)}}$$

The shaded band in Fig. 15 encloses the individual measured protection ratios. To guarantee no perceptible interference from both still and moving scenes, a protection ratio exceeding the upper boundary of the shaded area should be used.

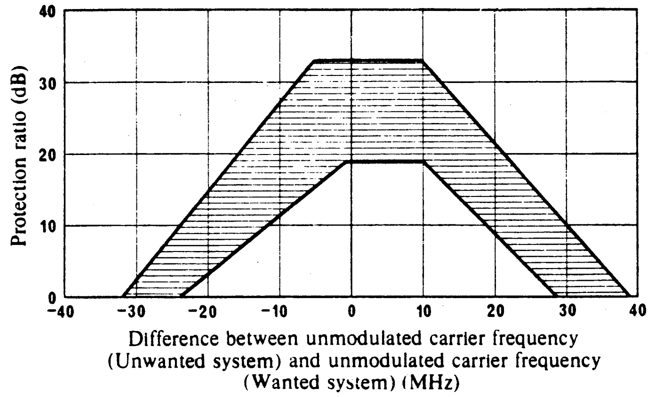


FIGURE 15 – *Protection ratio for just perceptible interference in a frequency-modulation television system subjected to interference by frequency-modulation television signals*

	Wanted system	Unwanted system
Peak-to-peak deviation	18 MHz	18 MHz
S/N (weighted)	50 dB	
Pre- and de-emphasis	None	None

Later protection ratio measurements for two FM television signals, performed in the USA [Barnes and Miller, 1978], were made in accordance with Recommendation 600 as noted in § 1.1.1.2 of this Annex. Figure 16 and Table XXI present the results.

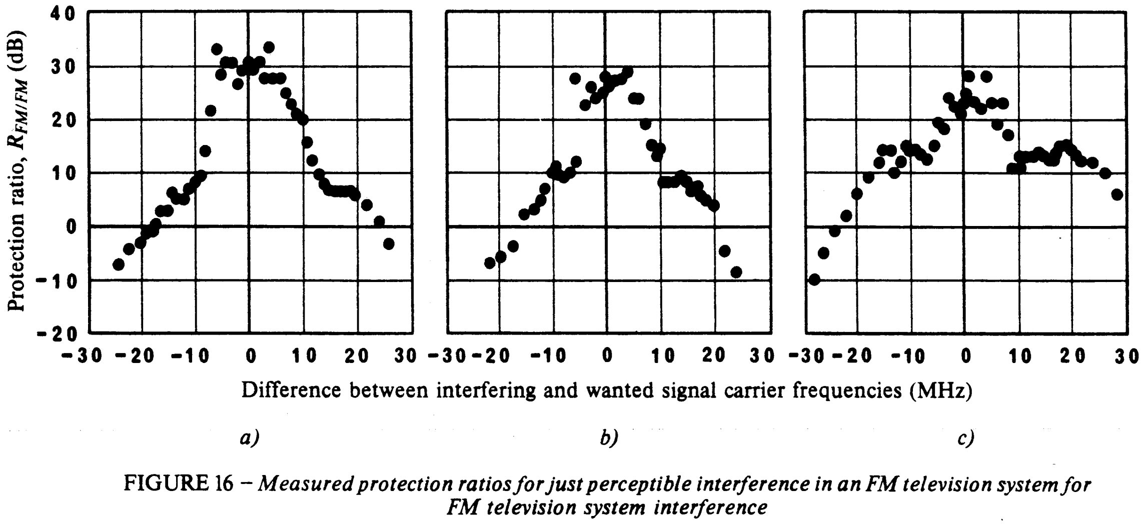


FIGURE 16 – *Measured protection ratios for just perceptible interference in an FM television system for FM television system interference*

	Peak-to-peak FM deviation (MHz)	*Number of filter section*
a)	12	4
b)	12	6
c)	18	6

TABLE XXI – *Measured co-channel protection ratios for just perceptible interference, system M/NTSC, SMPTE test slide No. 14 as wanted picture*

Wanted signal	Unwanted signal	Co-channel protection ratio (dB)
FM, 12 MHz deviation	FM, 12 MHz deviation	31 (1)
FM, 18 MHz deviation	FM, 18 MHz deviation	28

(1) Average for both four and six-section Chebyshev filters.

The co-channel protection ratios measured for an FM television signal interfering with another FM television signal agree quite closely with, and thus substantiate, prior extrapolations to the reference-case conditions. Also, the decrease in FM protection ratio by the approximate term of 20 log (D_v/12), as given in equation (1a) of the body of this Report, is substantiated by the measurements.

Figures 16a) and 16b) show that offsetting an interfering carrier by 10 to 12 MHz results in a 15 dB relaxation of the protection ratio. This is improved performance compared to Fig. 1a) in the body of the Report.

3.1.2 *Two offset frequency modulation signals, tests in Canada*

Measurements were carried out in Canada [CCIR, 1978-82d] for the protection ratio between two FM television signals of 525-line system M/NTSC. Test conditions were according to those specified in Recommendation 600. Some of the salient test features and parameters used for the measurements were as follows:

- the test method employed the comparison technique where the reference signal impairment was set according to the 5 level impairment scale (see Recommendation 500) based on TASO results for impairment due to random noise;
- picture slides used were SMPTE Nos. 1 and 14 for the wanted signal;
- split field colour bars were used for the interfering signal;
- 15 observers ranging from non-expert to expert were used;
- no sound sub-carrier was employed;
- no energy dispersal was used;
- pre-emphasis as per Recommendation 401 for system M was used.

A summary of the major results of the co-channel protection ratio measurements is as follows:

- variation of the protection ratio with frequency deviation and impairment level showed good agreement with that predicted by equation (1);
- variation of the wanted signal to weighted noise ratio over the range 42-50 dB at a constant impairment level of 4.5 indicated no masking of interference by random noise. In fact results indicated that at low values of S/N the protection ratio tends to increase, to maintain the signal at a constant impairment level;
- during the measurement programme, it was found that the 4.5 impairment grade as derived from TASO results was not equivalent to just perceptible interference. Further tests based on just perceptible interference resulted in protection ratios ranging from 5.4 to 8.8 dB higher than those obtained for the 4.5 grade TASO.

Results of frequency offset measurements carried out using a 3 pole IF receive filter at an impairment level of 4.5 and adjusted by 8.8 dB for just perceptible interference is shown in Fig. 17.

As indicated by this figure, the protection ratio is most sensitive to offset frequencies which are multiples of the colour sub-carrier.

Additional measurements using a 4 pole receive filter resulted in a lower protection ratio requirement than shown in Fig. 17 for the same value of frequency offset.

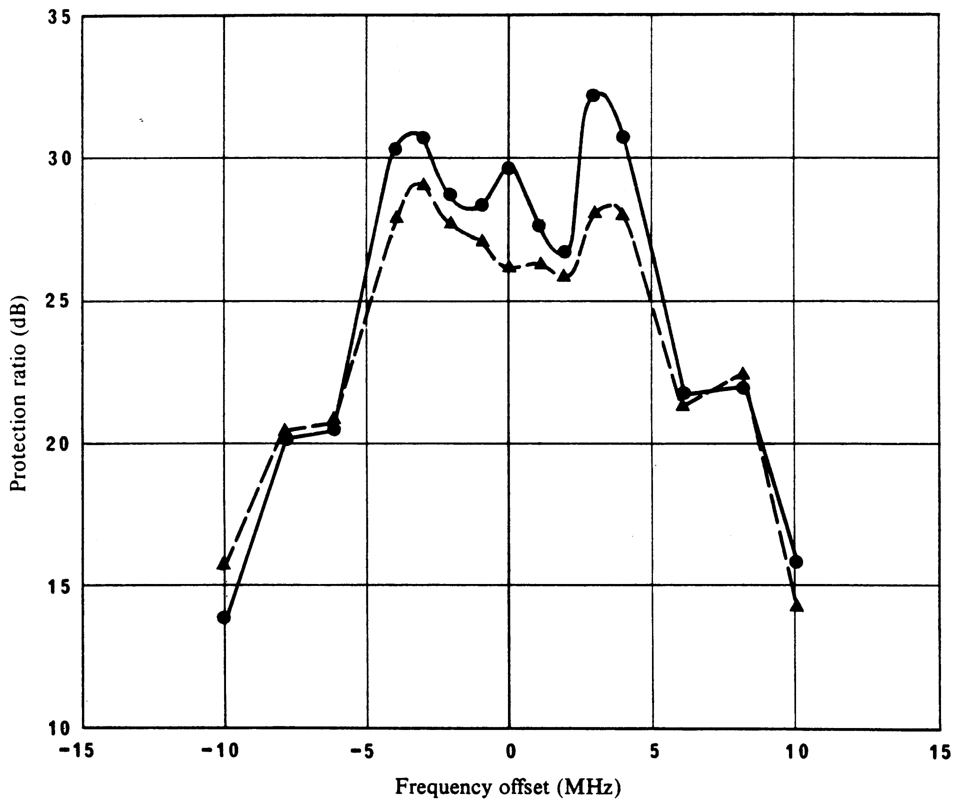


FIGURE 17 – *Protection ratio as a function of frequency offset with a 3 pole IF filter (peak-to-peak deviation of 8.4 MHz)*

—●— : SMPTE test slide No. 1

—▲— : SMPTE test slide No. 14

3.1.3 *Frequency modulation signals of different systems, tests in Japan*

In a study [CCIR, 1974-78a] made in Japan, measurements were made on co-channel protection ratios between two FM television signals of 525-line system M and between FM television 525- and 625-line system signals under the conditions described as follows:

– polarity of frequency-modulation is such that frequency of black level is lower than that of white level;

– receiving bandwidths are 23 MHz for 525-line system M/NTSC signal and 27 MHz for 625-line PAL and SECAM signals, respectively;

– peak-to-peak frequency deviations for the video signals of 525-line system and 625-line system are 12 MHz and 13 MHz respectively;

– there are three cases using television sound sub-carrier(s) for 525-line system M (none, or 4.5 MHz, or 4.5 and 5.05 MHz) and no sound sub-carrier for 625-line television systems;

– characteristics of pre-emphasis of the video signal are those shown in Recommendation 405, system M. The same circuit is used for the 625-line system because of unavailability at the time of measurement;

– the value of protection ratio used in this document corresponds to just perceptible interference, defined as the power ratio of carrier-to-interference at the receiver input when 50% of the observers give the grade 4 and the remainder gives grade 5;

- SMPTE No. 14 picture slide is used for the wanted signal, and No. 1 for the unwanted signal;
- ratio of viewing distance to picture height is 6;
- number of observers is 45 including 22 experts.

Table XXII shows the value of the protection ratio for just perceptible interference, which is defined as the power ratio of carrier-to-interference at the receiver input when 50% of the observers give grade 4 and the remainder give grade 5.

From this table, it may be concluded that there is no significant difference between protection ratios for systems using different television standards. From the measurements reported in [CCIR, 1974-78b] it may be indicated that the presence of 1 or 2 sound sub-carriers has negligible effects on the protection ratio.

TABLE XXII – *Summary of measured co-channel protection ratios (dB) between two FM television signals*

			Wanted signal		
			525-line system M/NTSC	625-line system L/SECAM	625-line system I/PAL
Unwanted signal	↓	Video peak-to-peak deviation (MHz) →	12	13	13
525-line system M/NTSC	12	Without pre-emphasis	31.5	32	32
		With pre-emphasis	31.5	31 (1)	31.5 (1)
625-line system L/SECAM	13	Without pre-emphasis	31.5	—	—
		With pre-emphasis	29.5 (1)		
625-line system B, G/PAL	13	Without pre-emphasis	30.5	—	—
		With pre-emphasis	29.0 (1)		

(1) These data are for reference, because pre-emphasis network was used only for system M.

3.1.4 *Two frequency modulation signals, tests in Japan*

Tests were carried out in Japan [CCIR, 1978-82e] on the interference between two FM television signals, with monitoring of picture quality in a studio with a ratio of viewing distance to picture height of 1 to 1.5 (a closer viewing distance than given in Recommendation 600). This resulted in a protection ratio of 38 dB for just perceptible interference.

The characteristics of the FM television signals were as follows:

- deviation by 525-line video signal: 12 MHz peak-to-peak;
- emphasis: Recommendation 405;
- energy dispersal deviation: 600 kHz;
- 4.5 MHz sound sub-carrier deviation: ± 1 MHz.

3.1.5 *Protection ratio versus impairment grade tests*

Measurements in the United States [CCIR, 1978-82f] have examined the variation in protection ratio as a function of impairment grade. Subjective evaluations of impairments were made for frequency modulation interference to another frequency modulation television system. Test conditions were as follows:

Wanted signal

Frequency modulated carrier, with system M/NTSC colour signals, with pre-emphasis according to Recommendation 405. Frequency modulated sound sub-carrier at 7.4 MHz. 12 MHz peak-to-peak frequency deviation (white to sync peak level) with white producing the highest frequency. No energy dispersal. Four test slides (SMPTE No. 1 and No. 14, and Philips No. 8 and No. 14) were used as the video signals. Video signal-to-noise ratio, 42 dB unweighted.

Interfering signal

Same as wanted signal except that video modulation was programme material with motion. Synchronization locked to wanted picture but offset to place vertical and horizontal synchronization bars within the visible portion of wanted picture. Sound sub-carrier at 7.6 MHz. Tests were co-channel, with the interfering signal at the same frequency as the wanted signal.

Viewing conditions

Consumer quality monitors with 64 cm diagonal screen. Viewing distance five times picture height. Picture brightness and room light controlled. 147 non-expert viewers were used in the tests. Evaluations were made using the five grade impairment scale in Recommendation 500.

Results of the tests are shown in Fig. 18. The curve shows that for the class of observers used in these tests, very little improvement in average impairment grade results from increasing *C/I* beyond 25 dB. The average impairment grade obtained for the test scenes with no interference may have been limited by the video signal-to-noise ratio used in the tests.

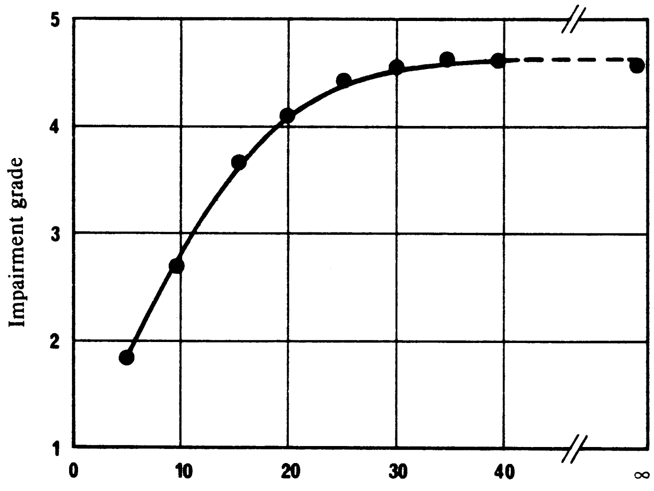


FIGURE 18 – *Impairment grade as a function of carrier-to-interference (C/I) ratio*

Data average for:
4 slides
147 observers

3.1.6 *Measurements carried out in Canada*

In preparation for the RARC SAT-83, measurements made in Canada addressed different aspects of interference between frequency modulated television signals of system M/NTSC. These tests were made with a deviation of 9.52 MHz/V and a receiver pre-detection filter with an equivalent noise bandwidth of 22.7 MHz (4-pole Chebyshev type). Pre-emphasis according to Recommendation 405 was used. The test slides used for the wanted signal were three of the four suggested in Recommendation 600: girl in a green dress, basket of fruit and beach scene. The interference-signal material consisted of unsynchronized off-air programmes.

The test procedures were in accordance with Recommendation 500-2 and Recommendation 600. Twenty-seven concerned viewers were subjected to 15 s viewing time separated by 10 s of 50 IRE Grey scale. A concerned viewer is considered to have a relatively broad knowledge of satellite communications but is not considered to be an expert viewer. Among the original 27 viewers, 2 were found inconsistent and rejected in the analysis of the results. The 5-grade CCIR impairment scale was used throughout the test.

3.1.6.1 *Impairment due to noise*

Figure 19 gives the results for a picture impaired by thermal FM noise for the average of the three slides. The high level of opinion score for the unimpaired picture (top anchor point at an S/N_w of 56 dB) indicates that the test results are not significantly limited by the instrumentation used. The figure indicates that the S/N_w ratio corresponding to an opinion grade of 4.5 is 47.3 dB.

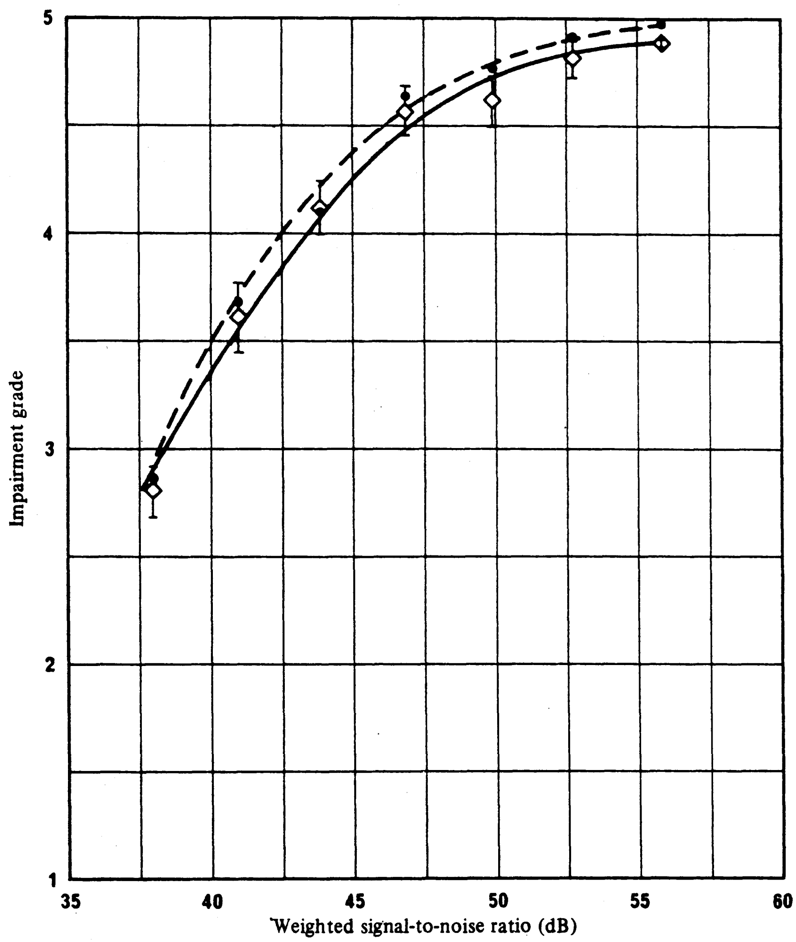


FIGURE 19 – *Impairment due to noise (average of three slides)*

◇ mean score of three slides

• median of three slides

3.1.6.2 *Impairment due to co-channel interference*

Figure 20 gives the results for single-entry co-channel interference. Table XXIII gives the relationship between opinion score and single entry co-channel *C/I*.

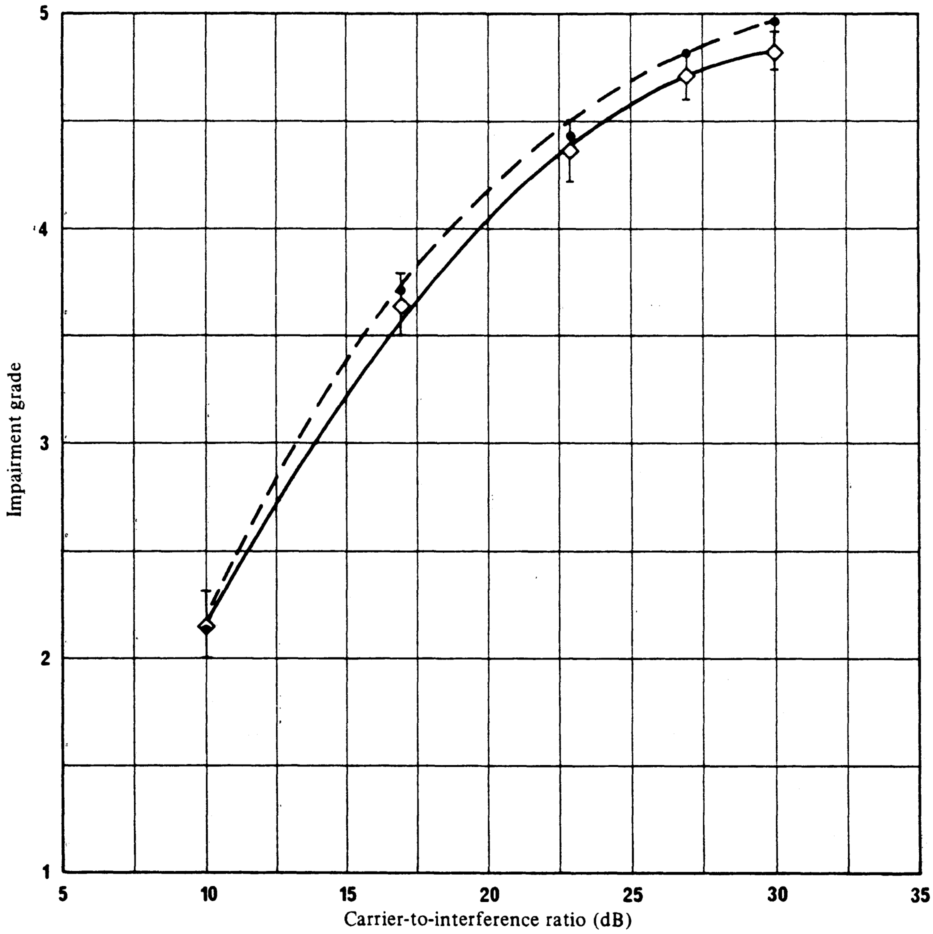


FIGURE 20 – *Impairment due to single-entry co-channel interference (average of three slides)*

◇ mean score of three slides

● median of three slides

TABLE XXIII – *Relationship between opinion score and the mean single-entry co-channel carrier-to-interference ratio for the average of the three slides*

Opinion grade	Single-entry co-channel *C/I* (dB)
4.3	22.2
4.5	24.2
4.7	26.8
4.8	29.0

A series of tests using a peak-to-peak deviation of 19.04 MHz has shown that, over a large range of opinion scores, the protection ratio requirement decreases as the square of the peak-to-peak deviation, thus verifying the normalization factor in terms of carrier deviation contained in equations (1a) and (1b) of the present Report.

The subjective tests on aggregate co-channel interference has shown that the law of power addition of interferers is not met in all cases. It was found that the impairment level produced by three equal power interferers could be obtained from a single interferer with 3 dB to 5 dB larger power with a mean at 3.8 dB for impairment grades between 4 and 5. The power addition would predict 4.8 dB. Nevertheless, the law of power addition is believed to be representative of the worst-case interference for multiple interfering carriers.

3.1.6.3 *Impairment due to adjacent-channel interference*

Tests were performed on the effect of aggregate interference from two adjacent channels, one lower and one upper. This arrangement of carriers was repeated for an inter-carrier spacing of 13 MHz and 15 MHz. Figure 21 shows the results of the tests on aggregate adjacent-channel interference for the 15 MHz spacing.

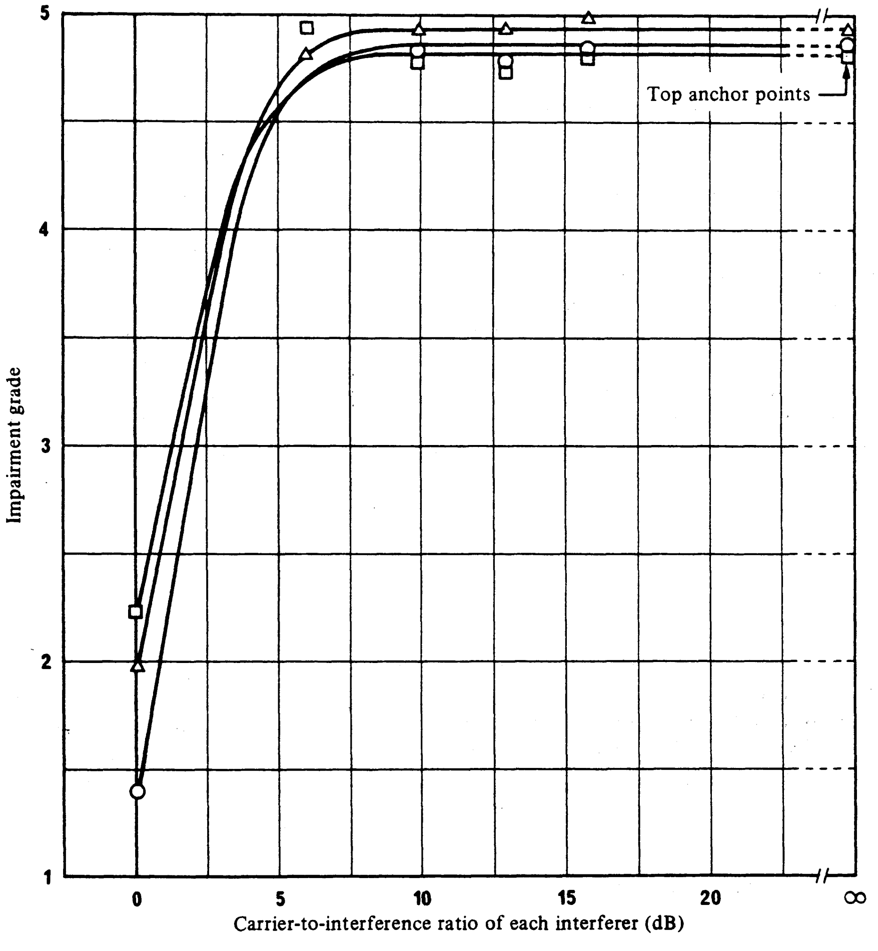


FIGURE 21 – *Impairment due to aggregate adjacent-channel interference for each slide. Two adjacent channels (101) are present, one upper and one lower which are separated by 15 MHz from the wanted carrier*

○ slide 1
△ slide 2
□ slide 3

The figure shows that the opinion score remains close to the unimpaired level for high values of the C/I ratio but decreases rapidly at low values of the C/I ratio. This sudden decrease in opinion score for adjacent-channel interference indicates the necessity of retaining a C/I ratio above the "cliff edge" in an operating system.

3.1.6.4 *Aggregate adjacent and co-channel interference*

Tests were performed on carrier arrangements* 121 and 111 where that ratio of powers between the individual interferers (co-channels) and the individual interferers (adjacent channels) was kept constant at 17 dB throughout the range of C/I ratios studied and where the carrier spacing was 15 MHz.

Figure 22 gives the results for slide 1, "girl in a green dress" for the 121 carrier arrangement. Similar results were obtained for the other carrier arrangement and the other two slides. The figure also shows the adjacent-channel interference only and the co-channel interference only for comparison purposes.

The figure shows that, at high carrier-to-interference ratio, the opinion score is mostly governed by the co-channel interference and that, at low carrier-to-interference ratio, the opinion score is governed by the adjacent-channel interference. The change-over between the two types of interference occurs near the "cliff edge" of adjacent-channel interference, between 6 to 8 dB for the 15 MHz carrier spacing.

3.1.7 *Measurements carried out in the United States of America*

Measurements were conducted in the United States of America in preparation for the RARC SAT-83 which addressed various aspects of interference between frequency modulated television signals of system M/NTSC. The tests were generally in accordance with Recommendations 600 and 500-2. Tests were conducted at two separate laboratories, each employing slightly different system characteristics and procedures. Details of measurements from both laboratories are contained in [CCIR, 1982-86a]. Pertinent differences are identified where applicable. Characteristics common to both sets of measurements were: 12 MHz/V peak-to-peak deviation, viewing distance of 5 times the picture height, critical test slides used for wanted signal, video taped programming used for interfering signal and horizontal and vertical synchronization bars of the interfering signals were locked in the video portion of the wanted signal. The 5-grade CCIR impairment scale was used throughout the tests. Pre- and de-emphasis were used according to Recommendation 405.

3.1.7.1 *Impairment due to noise*

Figure 23 shows the results of subjective evaluations of impairment grade as a function of signal-to-noise ratio with no interference. A simple relationship exists between impairment grade and S/N. A 6 dB increase in S/N results in an increase of approximately one impairment grade level over the region of S/N between 28 and 52 dB weighted for both effects, noise and pre- and de-emphasis. For an impairment grade of 4.5, Fig. 23 indicates a value of approximately 49 dB weighted signal-to-noise ratio.

3.1.7.2 *Impairment due to co-channel interference*

The results of co-channel interference tests are shown in Fig. 24. At an impairment grade of 4.5 the C/I required is approximately 28 dB. Little improvement in average impairment grade is gained by increasing C/I further. Additional tests with a 16 MHz peak-to-peak deviation substantiate the correction factor of 20 log ($D_v/12$), where D_v is the peak-to-peak frequency deviation. For the tests, a signal-to-noise ratio (S/N) of 55 dB, weighted for both noise and pre- and de-emphasis effects, was used.

* The carrier arrangement XYZ means: X carriers below, Y carriers co-, and Z carriers above the wanted channel.

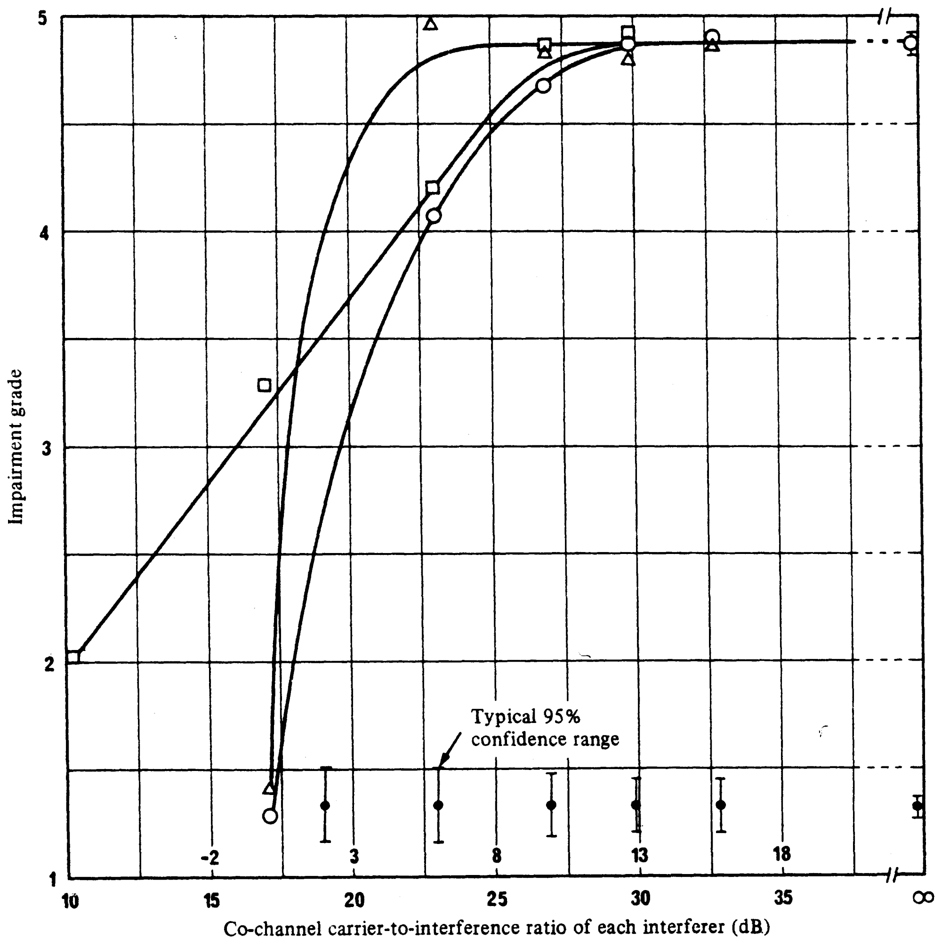


FIGURE 22 – *Impairment due to aggregate adjacent and co-channel interference*

(Carrier arrangement 121) (Δf = 15 MHz)

Slide 1 : Girl in a green dress

□ 020: two co-channel interferers

△ 101: two adjacent-channel interferers (upper and lower adjacent channels)

○ 121: two co-channel and two adjacent-channel interferers

Note. – Upper horizontal scale on the figure refers to adjacent channel.

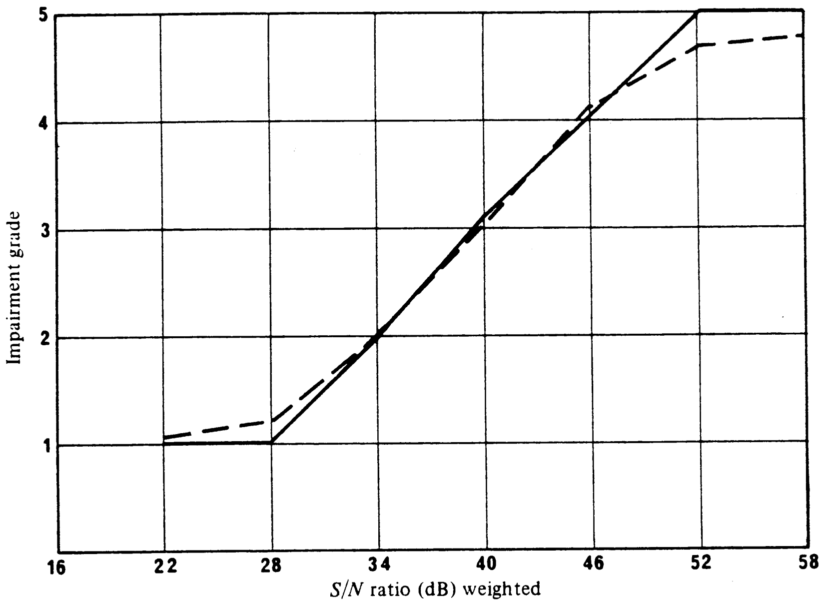


FIGURE 23 – *Impairment due to noise alone for M/NTSC systems*

(No interference, no sub-carrier)

——— median impairment
– – – mean impairment

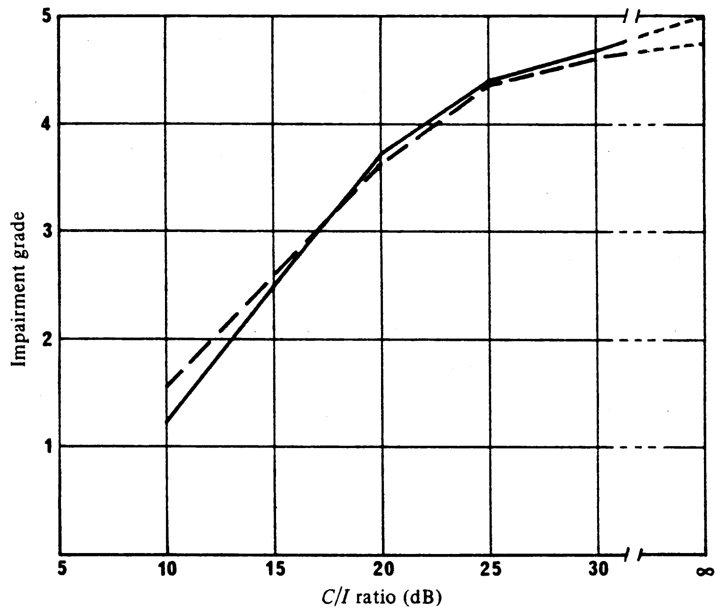


FIGURE 24 – *Impairment due to single-entry co-channel interference*

Δf = 12 MHz peak-to-peak
S/N = 55 dB (weighted)
C/N = 23.8 dB
——— median impairment
– – – mean impairment

Tests were conducted on measured protection ratios for multiple co-channel FM-TV sources interfering with a single FM-TV system. The test results indicate that multiple sources of co-channel interference add on a power basis. Therefore, the subjective effect of multiple co-channel FM-TV interferers is equivalent to a single FM-TV interferer for the same aggregate carrier-to-interference ratio, i.e. when:

$$C/I_{single} = C/I_{\Sigma\ multiple}$$

where:

C/I_{single} : carrier-to-interference ratio for one interferer

$C/I_{\Sigma\ multiple}$: aggregate carrier-to-interference ratio for more than one interferer.

The tests showed that over a range of carrier-to-interference ratios between 10 and 25 dB the aggregate interfering effect of two and four interferers was within 0.5 and 0.75 dB of power addition, respectively.

3.1.7.3 *Impairment due to noise and interference*

In selecting a suitable impairment grade for system planning, the combined degradation of noise and interference must be examined. It is desirable to plan systems which are noise limited rather than interference limited (i.e. the noise is the dominant degrader of the received picture).

Figure 23 shows that in the absence of interference, an S/N of 46 dB (weighted) produces an average impairment grade of 4.1. Figure 24 shows the effect of interference, when there is virtually no noise (S/N of 55 dB weighted was the best obtainable picture in the test set-up). At a C/I of 28 dB, a mean impairment grade of 4.5 was measured. Figure 25 shows the combined effect of noise and interference. At an S/N of 46 dB (weighted) *and* a C/I of 28 dB, a mean impairment grade of 4.0 was measured. Figure 25 shows that for C/I ratios beyond 28 dB very little improvement in the impairment grade is possible. In this combination of noise and interference, the noise is the dominant contributor to the impairment grade reduction.

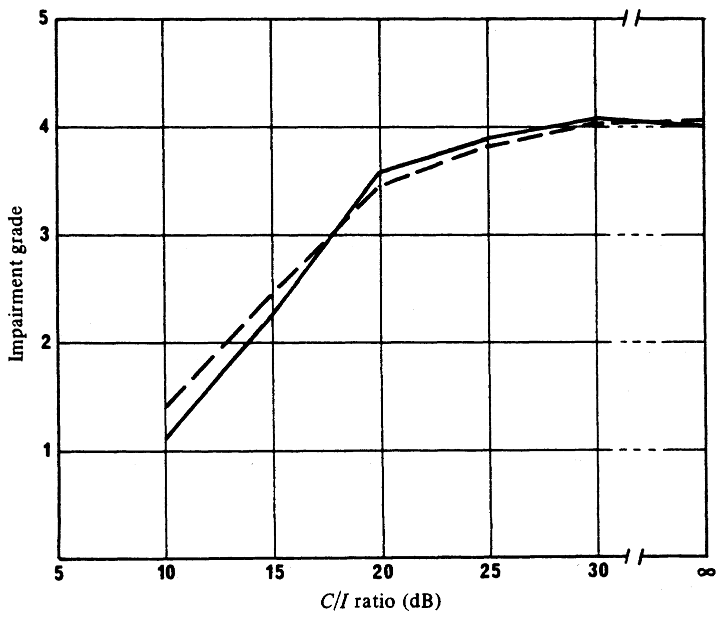


FIGURE 25 – *Impairment due to single-entry co-channel interference plus noise*

Δf = 12 MHz peak-to-peak

S/N = 46 dB (weighted)

C/N = 14.8 dB

——— median impairment

– – – mean impairment

Report 405, Annex II, presents a "law of addition" for unrelated impairments. This "law" predicts that, for an impairment grade of 4.1 from noise alone and an impairment grade of 4.5 from interference alone the resulting impairment grade due to the combined effect of noise and interference would be 3.8. This predicted value is somewhat conservative based upon the measured value of 4.0 from Fig. 25. However, for system planning at S/N ratios other than 46 dB (weighted), the "law of addition" of impairments does provide a reasonable, although conservative, estimate of total impairment grade when used with Figs. 23 and 24.

3.1.7.4 *Impairment due to adjacent-channel interference*

Figures 26, 27 and 28 show the results of measurements to examine the aggregate effect of adjacent-channel interference. Both single and multiple adjacent-channel interferers were investigated. The receive filter was a 4-pole Chebyshev type with an equivalent noise bandwidth of 22.5 MHz. The channel spacing used was 13 MHz.

Concerning impairment grades of interest (4.0 to 4.5), the aggregate interfering effect from one lower and one upper (101) adjacent-channel interferer is 2 to 3 dB worse than power addition when compared to curves for a single adjacent-channel interferer. For the cases of two lower (200) and two upper (002) adjacent-channel interferers, the aggregate interfering effect is 3 to 4 dB and 5 to 6 dB worse than power addition respectively*. Table XXIV. presents data for each of the seven conditions relating aggregate C/I levels required to achieve a specified impairment grade.

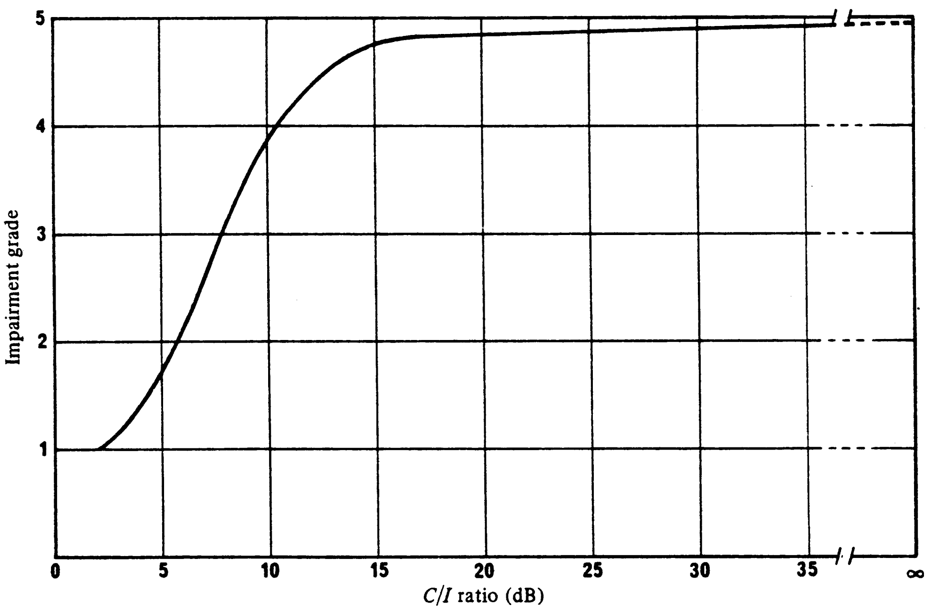


FIGURE 26 – *Impairment due to a single upper adjacent-channel interferer (001) separated by 13 MHz from the wanted carrier*

* The carrier arrangement XYZ means: X carriers below, Y carriers co-, and Z carriers above the wanted channel

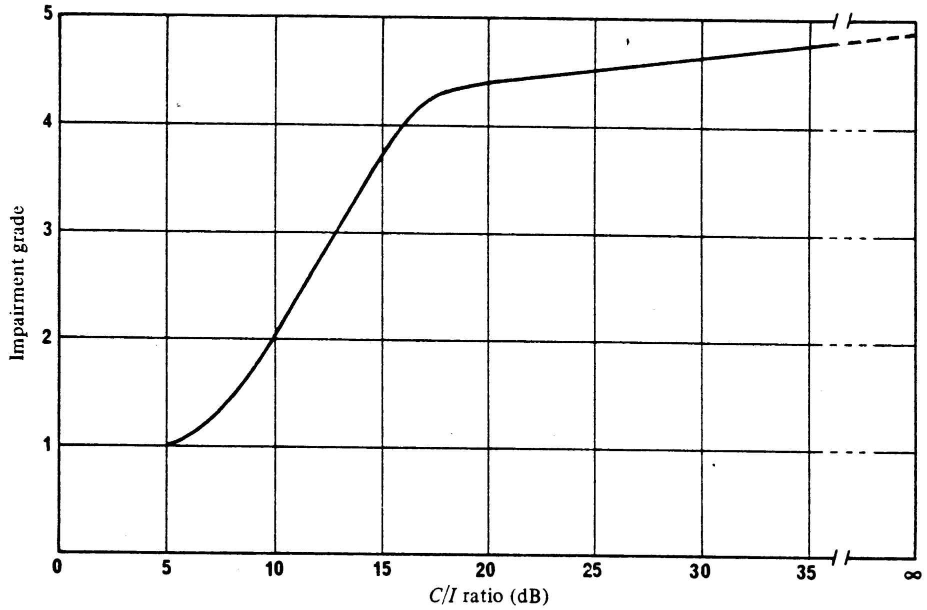


FIGURE 27 – *Impairment due to aggregate adjacent-channel interference.*
Two upper adjacent-channel interferers (002) separated by 13 MHz from the wanted carrier

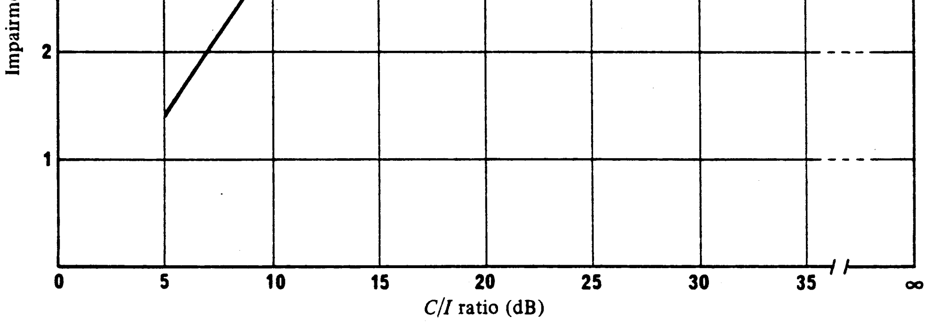


FIGURE 28 – *Impairment due to aggregate adjacent-channel interference.*
One upper and one lower adjacent-channel interferer (101) separated by 13 MHz from the wanted carrier

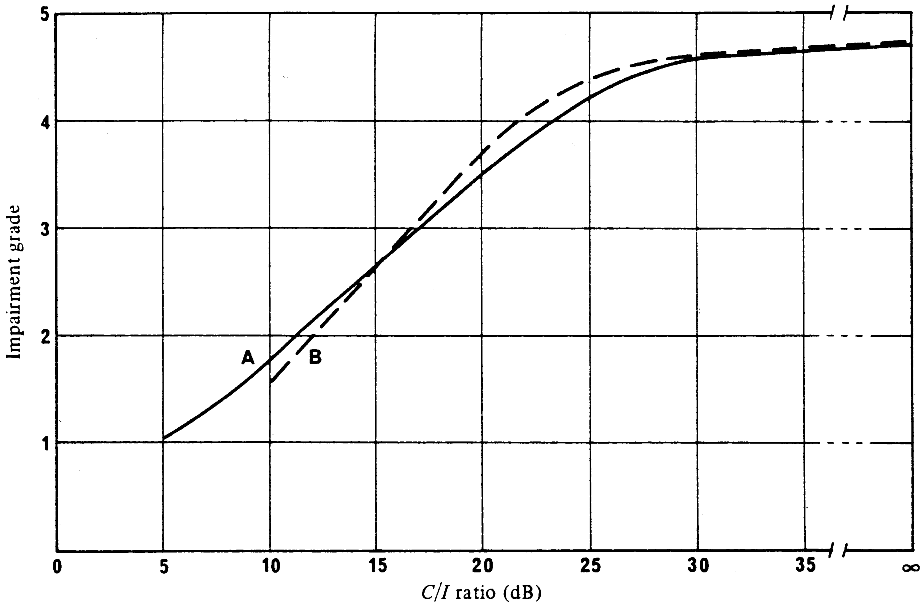


FIGURE 29 – *Impairment due to single-entry co-channel interference for tests conducted at:*

Curves A: NASA Lewis Research Center
B: CBS Laboratories

TABLE XXIV – *C/I ratio required for impairment grades of interest for all cases (dB)*

Case \ *Q*	3.50	3.75	4.00	4.25	4.50
001	9.0	9.7	10.5	11.7	13.0
100	10.0	11.0	11.75	12.8	13.9
002	14.5	15.3	16.3	17.1	19.0
200	13.0	14.0	15.0	16.0	17.8
101	12.4	13.3	14.4	15.4	16.8
010	19.7	21.4	23.1	25.3	28.7
111	22.7	24.1	25.5	27.5	31.0

3.1.7.5 *Aggregate adjacent and co-channel interference*

The combined interfering effects of adjacent and co-channel interference (111) were examined and the data are presented in Fig. 30. The relative levels were adjusted such that the interfering effect of the co-and adjacent-channels were approximately equal at an impairment grade between 4.0 and 4.5. Each adjacent channel interferer was set 6 dB above the co-channel interferer such that the aggregate adjacent channel interference was 9 dB greater than the co-channel interference. An 8-10 dB difference in aggregate C/I levels is obtained by examining Figs. 28 and 29 at impairment grades between 4.0 and 4.5. Therefore 9 dB was selected as the relative difference between the co- and aggregate adjacent-channel interference levels for the 111 case.

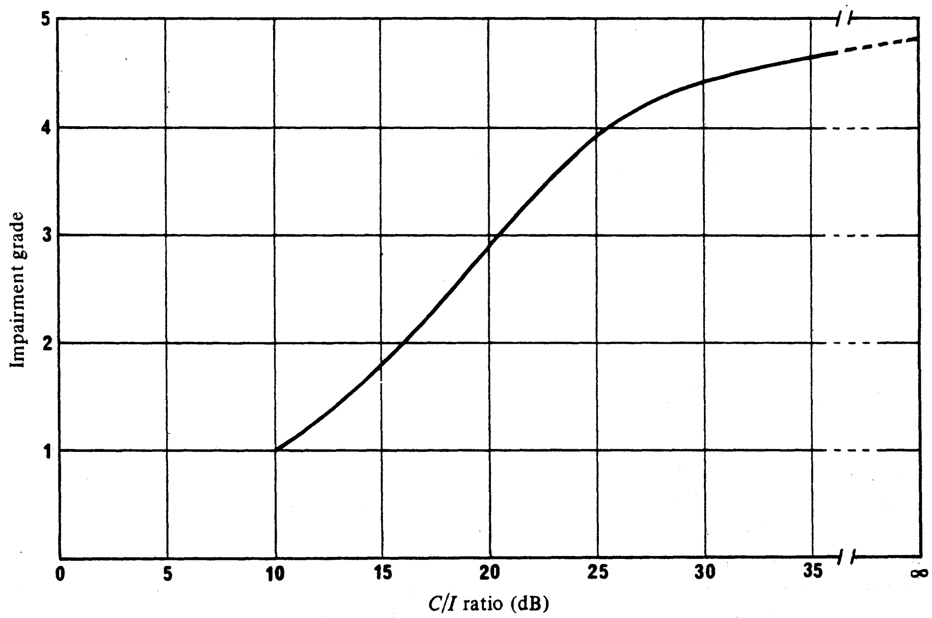


FIGURE 30 – *Impairment due to aggregate co-channel and upper and lower adjacent-channel interference (111). Adjacent-channel interferers separated by 13 MHz from the wanted carrier*

Figure 31 presents curves from Figs. 28 to 30. The 101 case, curve C, has been adjusted by 9 dB to agree with the condition for which the 111 case was tested. If the 010 and 101 cases, curves B and C, are added on a power basis the result, curve D, would lie within 1 dB of the measured 111 case, curve A. For impairment grade levels exceeding 4.0 the difference is less than 0.5 dB. The power addition curve lies to the right of the measured 111 case indicating that the measured results combine on slightly less than a power addition basis. It is believed therefore that co-channel and aggregate adjacent-channel interferers do add on a power basis. This result is dependent on the assumption of equal interference contributions from the co-channel interferer and the aggregate adjacent-channel interferers.

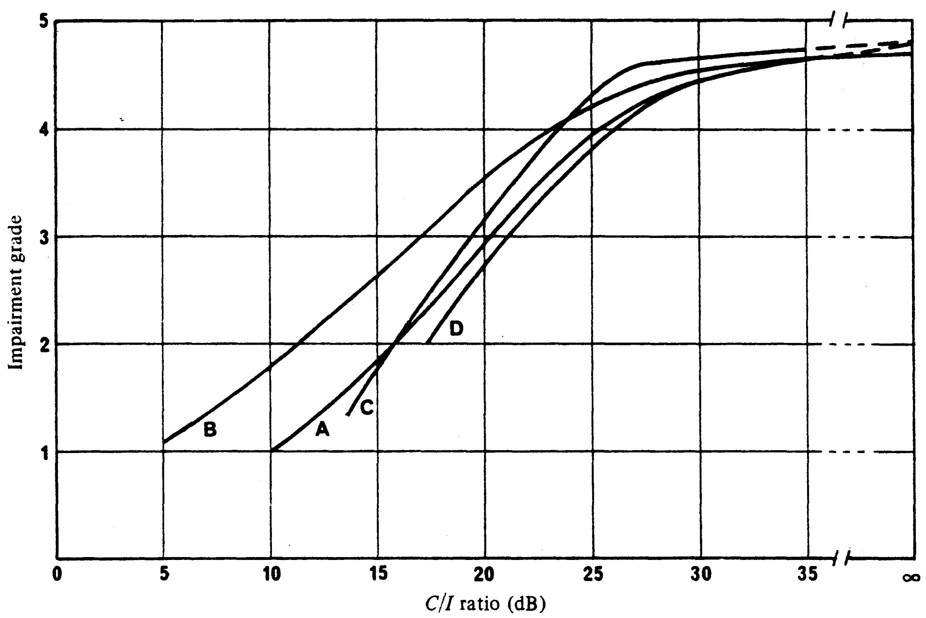


FIGURE 31 – *Comparison of impairment effects*

A: measured (111)

B: measured (010)

C: measured (101)

D: calculated by power addition (010 + 101)

3.2 *625-line system; B/PAL, G/PAL, I/PAL and L/SECAM*

Measurements of protection ratio for two frequency-modulation television signals with the same value for frequency deviation have been made in the United Kingdom by the BBC [Brown, 1971b], in Italy by RAI, in France by the TDF and in the Federal Republic of Germany by the IRT and DBP. A summary of these results [CCIR, 1974-78c] is given in this Report in § 3.1.5 and in Fig. 1a, curve B. The protection ratios were measured with a deviation of the sound sub-carrier on the main carrier which was in every case ± 2.8 MHz. The sub-carrier frequency was 6 MHz for system I, used by the BBC, 5.5 MHz for systems B and G used by the RAI, the IRT and DBP and 7.5 MHz used by the TDF. The protection ratio template (Fig. 1a, curve B) is asymmetrical about the carrier rest frequency. For exercises in planning, it would often be useful to use a common value for the protection ratios relating to the lower- and upper-adjacent channels. In this case the following compromise values can be used.

Channel spacing (MHz)	16	18	20	22	24	26	28	30
Protection ratio (dB)	20	16	13	10	7	4	2	0

More detailed information is given in [CCIR, 1974-78c].

Generally, for measurements performed by the various administrations indicated above, a conventional discriminator was used (staggered-circuit or delay line). Use of a phase locked loop (PLL) discriminator may lead to some differences in protection ratio. Measurements in France [CCIR, 1978-82g] show that in comparison with a conventional discriminator, the use of a PLL discriminator:

– does not change the protection ratio for co-channel interference;

– provides a reduction of 5 dB in the protection ratio for adjacent channel interference with frequency offsets between 12 and 20 MHz;

– increases the protection ratio for frequency offsets between 24 and 30 MHz.

For these measurements, no sound sub-carrier and no energy dispersal waveform were present.

Further studies with a large number of PLL discriminators are necessary for confirming these results and providing additional data in the case of greater frequency offsets.

3.3 *Co-channel protection ratio between wide-deviation frequency-modulation sound carriers*

In the broadcasting-satellite service it may be desirable to use a separate carrier, instead of a sub-carrier, for transmitting the television sound. In this case it may be necessary to use a deviation of about ± 300 kHz [CCIR, 1970-74d]. It is therefore important to know the co-channel protection ratio which should be specified for such signals, and also to find the minimum permissible spacing between the carriers, if several carriers were grouped together in a part of the frequency spectrum.

The BBC has carried out objective measurements of the interference between two frequency-modulation sound signals. The interfering signal was modulated by a 1 kHz tone to a peak deviation of ± 300 kHz, and the resulting signal-to-noise ratio in the wanted sound channel was measured using a modified Niese noise meter (for noise measurements this indicates the ratio of the r.m.s. signal to the r.m.s. noise) together with the recommended CCIR noise-weighting network (Recommendation 468).

For a signal-to-noise ratio of 50 dB, the co-channel protection ratio did not exceed 5 dB, the value depending to some extent on the exact frequency difference between the two carriers (over a range of about ± 200 kHz). For a signal-to-noise ratio of 60 dB, the protection ratio is not greater than 15 dB. The protection ratios determined for the sound signal are much lower than those for the television signal.

More tests were carried out to find suitable values for the carrier spacing (that is, the spacing between the carrier frequencies of adjacent sound channels). As in the case of television signals, it is assumed that the channel width is sufficiently large so that the adjacent-channel protection ratio is −6 dB. In this case, the tests showed that the carrier spacing should be about 0.8 MHz.

4. Protection ratio measurements between FM television and other signals

4.1 *Interference into FM television*

4.1.1 *Protection ratio measurements between frequency-modulation television signals and FM-sound multiplex systems*

Concerning the tests performed by the TDF [CCIR, 1974-78d], the modulation characteristics were the following:

FM-TV

- the video signal and a sound sub-carrier at 5.5 MHz are multiplexed;
- peak-to-peak frequency deviation of the carrier: 14 MHz/V;
- noise bandwidth: 27 MHz;
- pre-emphasis for video: Recommendation 405;
- frequency deviation of the sub-carrier: ± 75 kHz;
- pre-emphasis for audio signal: 50 μs;
- amplitude of the sub-carrier: 230 mV.

FM-sound multiplex

The carrier is modulated by an FDM-FM baseband made of 15 sub-carriers, each frequency modulated by an audio-frequency signal (frequency deviation of the sub-carrier = ± 75 kHz, pre-emphasis for audio-frequency signal = 50 μs).

The radio-frequency bandwidth is 27 MHz. The frequency deviations of the carrier by the different sub-carriers are such that the quality obtained is the same for each audio signal. Other transmission methods for a group of sound channels have also been investigated [Mertens *et al.*, 1976].

4.1.2 *Protection ratio measurements between frequency-modulation television signals and FDM-FM telephony signals*

Tests were carried out in Japan [CCIR, 1978-1982e] on interference between frequency-modulation television signals and FDM-FM telephony systems under the condition of monitoring the picture quality in a studio using a ratio of viewing distance to picture height of 1 to 1.5, which represents a closer viewing distance than given in Recommendation 600.

The characteristics of the FM television signal were the same as given in § 3.1.3 of this Annex and in [CCIR, 1978-1982e]. For an r.m.s. test-tone deviation of 270 and 800 kHz, corresponding to 60 and 970 channels, the measured protection ratios for just perceptible interference were 35 dB and 32 dB, respectively.

4.1.3 *Protection ratio measurements between frequency-modulation television signals and digital signals (television and data)*

Tests carried out in Japan [CCIR, 1978-1982e] using the same viewing conditions and modulation characteristics of the FM television wanted signal as described in § 3.1.3 of this Annex and a 64 Mbit/s, 4-PSK system interfering signal, resulted in a measured protection ratio for just perceptible interference of 25 dB.

Measurements made in the United States of America [CCIR, 1978-1982h; Barnes, 1979] involved interferences between a quadriphase shift keyed (4-PSK) modulated television signal and a frequency modulated television signal. Both signals were system M/NTSC. Other characteristics are given in Table XXV.

TABLE XXV – *Characteristics of digital and frequency-modulation television systems*

System	Digital television	Frequency-modulation television
Modulation	Differentially coded, 4-PSK modulator, coherent 4-PSK demodulator	Frequency-modulation, 12 MHz peak-to-peak deviation, with pre- and de-emphasis
Signal bandwidth (transmit filter)	45 MHz (3 pole, low ripple Chebyshev filter)	20 MHz
Receiver filter	33 MHz, 5 pole, equalized elliptical filter	21 MHz, 6 pole, low ripple Chebyshev
Audio	Multiplexed into data stream	7.5 MHz sub-carrier, 25 dB below video carrier
System output signal-to-noise ratio (unweighted) (dB)	45 (1)	50

(1) Subjectively measured.

In the measurements, a 4-PSK modulated digital television signal interfering with an FM television system degraded the received picture and the baseband signal in a noise-like manner. Since there are established measurement procedures for describing a television signal degraded by noise, the effect of digital television interference on an FM television system is described in terms of the apparent baseband signal-to-noise ratio.

Interference was added so as to produce apparent baseband signal to noise ratios of 45, 40 and 35 decibels. The ratio of wanted FM television signal power to interfering digital television signal power, for a specified apparent signal-to-noise ratio, $R_{FM/digital}$, is given by:

$$R_{FM/digital} = \frac{P_{AV\,(\text{FM, wanted})}}{P_{AV\,(\text{digital, interfering})}} \qquad (8)$$

For all measurements, white Gaussian noise was present in the communications channel in addition to the interfering signal.

Results of measurements to determine protection ratios for an FM television link with digitally modulated interferences are given in Fig. 32. The results show that there is a direct relationship between the measured protection ratio and the apparent signal to noise ratio, with protection ratios ranging from 24 to 14 dB for apparent baseband signal to noise ratios ranging from 45 to 35 dB.

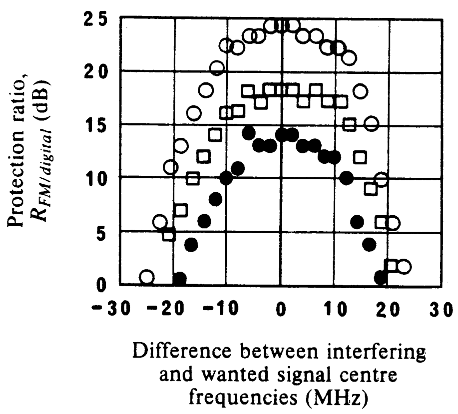


FIGURE 32 – *Apparent FM television system baseband signal-to-noise ratio (unweighted) for 4-PSK modulated digital signal interference*

Interference from a 43 Mbit/s digital television system

○ : 45 dB
□ : 40 dB
● : 35 dB
} Apparent signal-to-noise ratio

The subjective measurements for an FM television signal of system D/PAL subjected to interference by digital signals were carried out in China [CCIR, 1982-86b]. The unwanted signal sharing the same frequency band with the wanted signal was either a single-frequency signal (CW), a PSK signal or an ASK signal. The experiments were carried out according to Recommendations 500-2 and 600. The group of observers consisted of eight expert viewers. Two colour pictures that are standard pictures in China were used in the subjective measurements and the average of the measurement results was taken. The evaluations given by the viewers were only slightly different and have a good repeatability.

The C/I ratio for just perceptible interference is defined as the interference protection ratio. The measurement results are shown in Figs. 33 and 34. The results show that the interference from a single-frequency signal is most easily perceived and the protection ratio for a colour picture is about 1 dB higher than that for a black and white picture at zero carrier-frequency difference. There is a maximum at a carrier-frequency difference of 4.4 MHz because the centre frequency of the interference signal is near the sub-carrier frequency of the colour television signal. The protection ratio for PSK (8.448 Mbit/s) signal interference is about 1 dB lower than that for PSK (2.048 Mbit/s) signal interference. Compared with PSK signal interference, the protection ratio required for ASK signal interference is lower by generally less than 1 dB.

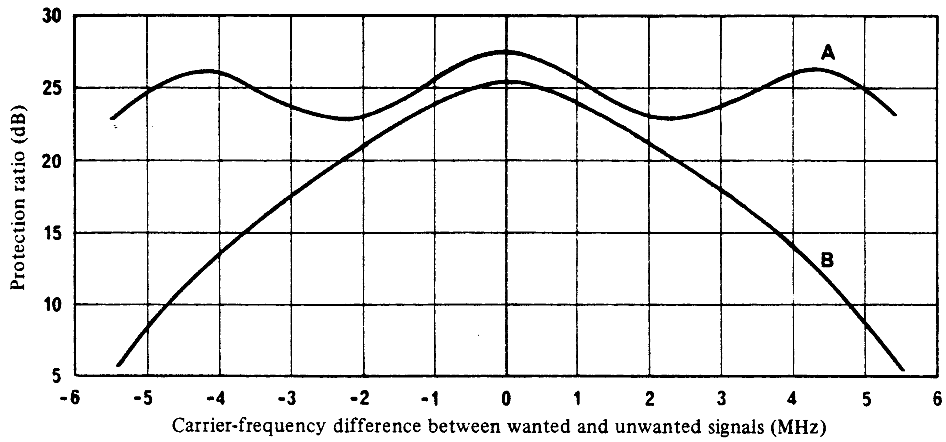


FIGURE 33 – *Protection ratio for just perceptible interference in an FM-TV system (Δf = 8 MHz, peak-to-peak) for CW interference*

A: colour picture

B: monochrome picture

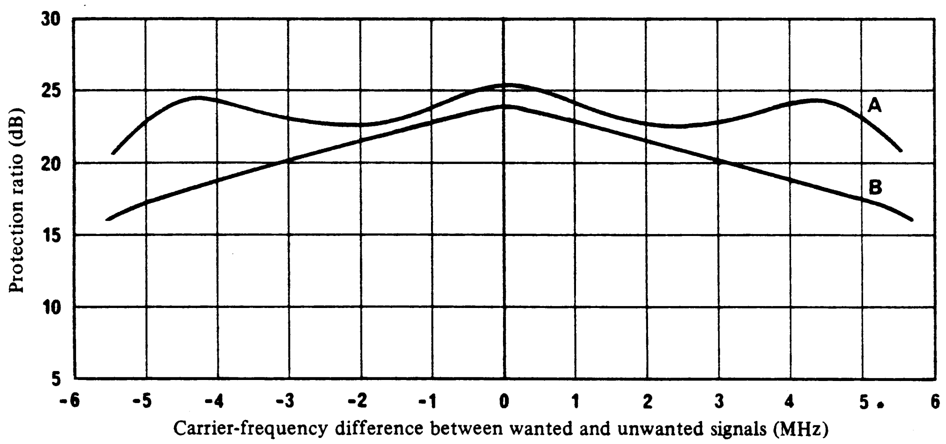


FIGURE 34 – *Protection ratio for just perceptible interference in an FM-TV system (Δf = 8 MHz, peak-to-peak) for PSK (2.048 Mbit/s) signal interference*

A: colour picture

B: monochrome picture

4.2 *Interference to digitally encoded television*

4.2.1 *Protection ratio measurements between digitally encoded television signals and frequency-modulated television signals*

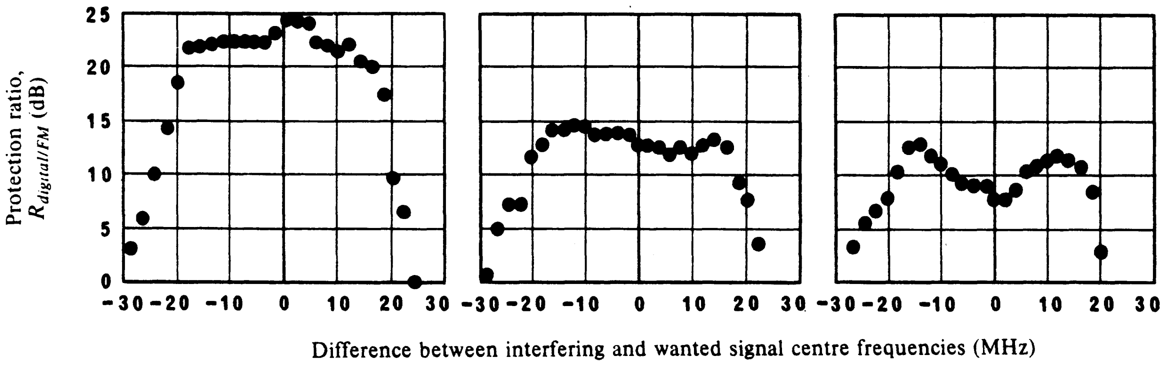
Experiments performed in the USA [CCIR, 1978-82h and Barnes, 1979] for system M/NTSC television included the measurement of protection ratios for digital television with analogue frequency modulation interference.

Additionally, the digital television system used inthese measurements employed one dimensional, fourth order, intraframe, differential pulse code modulation (DPCM), resulting in a data rate of 42.95 Mbit/s for the transmission of a system M/NTSC television signal at high quality. The coded television signal was transmitted using a 4-PSK modulator employing differential coding, and received using a coherent 4-PSK demodulator. The digital television system employed neither error correction nor error concealment circuitry. The characteristics of the digital television and the FM television system are listed in Table XXV.

A bit error ratio of approximately 10^{-8} in the coded digital television signal resulted in short duration impairments to the picture, at an average rate of one every five seconds. The error rate resulted in perceptible, but not annoying, impairments to the picture, as judged by a single expert viewer. For a communication link with ratios of energy per bit to noise power spectral density (E_b/N_0) which, in the absence of any interference, produced error ratios lower than 10^{-8}, FM television signal interference was added so as to raise the error ratio to 10^{-8}. Additional measurements were made to determine the protection ratios which resulted in an error ratio of 10^{-6}. For the specified bit error-ratio, the ratio of wanted digital television signal power to interfering FM television signal power, $R_{digital/FM}$, is given by:

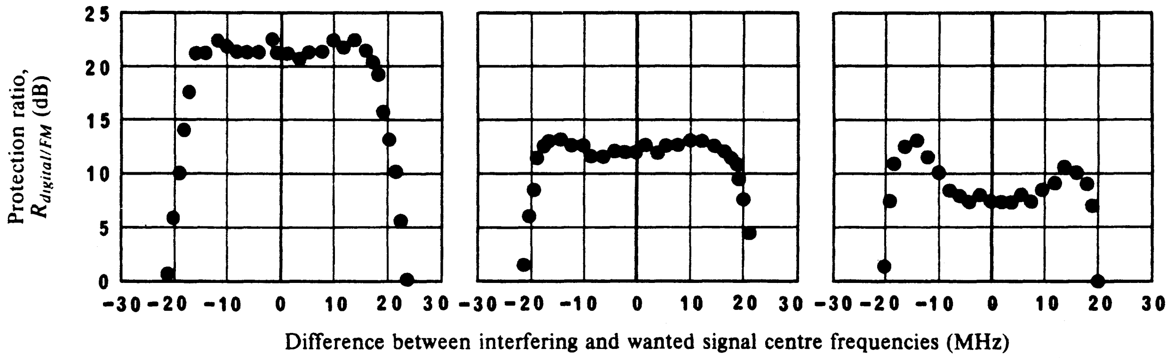
$$R_{digital/FM} = \frac{P_{AV\,(\text{digital, wanted})}}{P_{AV\,(\text{FM, interfering})}} \tag{9}$$

Measured protection ratios for FM television interference to a digital television system are shown in Fig. 35 for a bit error-ratio of 10^{-8} in the digital system, and Fig. 36 for a bit error-ratio of 10^{-6}. Protection ratios are shown for three values of link E_b/N_0. In the absence of any interference, a value of E_b/N_0 = 15.1 dB results in an error ratio of approximately 10^{-9}, and a value of E_b/N_0 = 13.6 dB results in an error ratio of approximately 10^{-7}. As shown in the figures, a small increase in E_b/N_0 (from 15.1 to 18.1 dB (for 10^{-8} error ratio) or from 13.6 to 16.6 dB (for 10^{-6} error ratio)) results in a large reduction in the measured protection ratios (9 to 10 dB). A large additional increase in E_b/N_0, however, results in only a 1 to 2 dB reduction in the measured protection ratios.



a) E_b/N_0 = 15.1 dB *b)* E_b/N_0 = 18.1 dB *c)* E_b/N_0 = 40 dB

FIGURE 35 – *Measured protection ratios for 10^{-8} bit error ratio in a digital television system for interference from an FM television system*



a) E_b/N_0 = 13.6 dB *b)* E_b/N_0 = 16.6 dB *c)* E_b/N_0 = 40 dB

FIGURE 36 – *Measured protection ratios for 10^{-6} bit error ratio in a digital television system for interference from an FM television system*

4.2.2 *Protection ratio measurements between digitally encoded television signals and other digitally encoded signals (television and data)*

Measurements performed in the United States of America for system M/NTSC have determined protection ratios for digitally encoded television with digital television and digital data interference.

The wanted digital television system was the 42.95 Mbit/s DPCM system described in § 4.2.1 of this Annex. The interfering digital television system was a two-dimensional orthogonal transform encoder with a data rate of 16.1 Mbit/s resulting in transmission of a system M/NTSC television signal at high quality. The encoded television signal was transmitted using a 4-PSK modulator employing differential encoding. The digital data interferer was generated using a pseudo-random data generator. This digital signal was modulated using an identical D-4-PSK modulator as the one used with the digital television interferer. In this portion of the test, an interferer data rate of 16.1 Mbit/s was used for the digital data. The characteristics of the desired digital television system are listed in Table XXV. The characteristics of the interfering systems (digital television and data) are listed similarly in Table XXVI.

TABLE XXVI – *Characteristics of signals*

System parameter	16 Mbit/s digital TV	PRBS (1)
Modulation	D-4-PSK (2)	D-4-PSK (2)
Signal bandwidth (transmit filter) (MHz)	25 (5 pole, low ripple Chebyshev filter)	(Transversal filter internal to modulator)
Receiver filter (MHz)		13.4 19.0 30.1 (5 pole, low ripple Chebyshev filters)
Signal bit rate (Mbit/s)	16.11	8.0 16.11 43.0

(1) Pseudo-random bit sequence.

(2) D-4-PSK: Differential 4-PSK.

Section 4.2.1 of this Annex indicates that for the wanted-signal television system, a bit error ratio of 10^{-8} produced interference which was perceptible, but not annoying. However, to aid in the measurement process, a bit error ratio of 2×10^{-8} was used in determining the protection ratio. At this bit error ratio a short duration impairment to the picture occurred at an average rate of one every 2 s. Protection ratio levels were found not to differ significantly (< 1 dB) from those obtained with a 10^{-8} bit error ratio. To allow headroom for interference to be added, the communication link energy contrast ratio was selected such that the bit error ratio, in the absence of any interference, was approximately 10^{-9}. An energy contrast ratio (E_b/N_0) of 14.7 dB produced a bit error ratio of approximately 10^{-9}.

Figure 37 shows that the interference to the DPCM digital television system was (approximately) the same for both the 16.1 Mbit/s digital television system and PRBS data interferers. The co-channel protection ratio is approximately 22 dB.

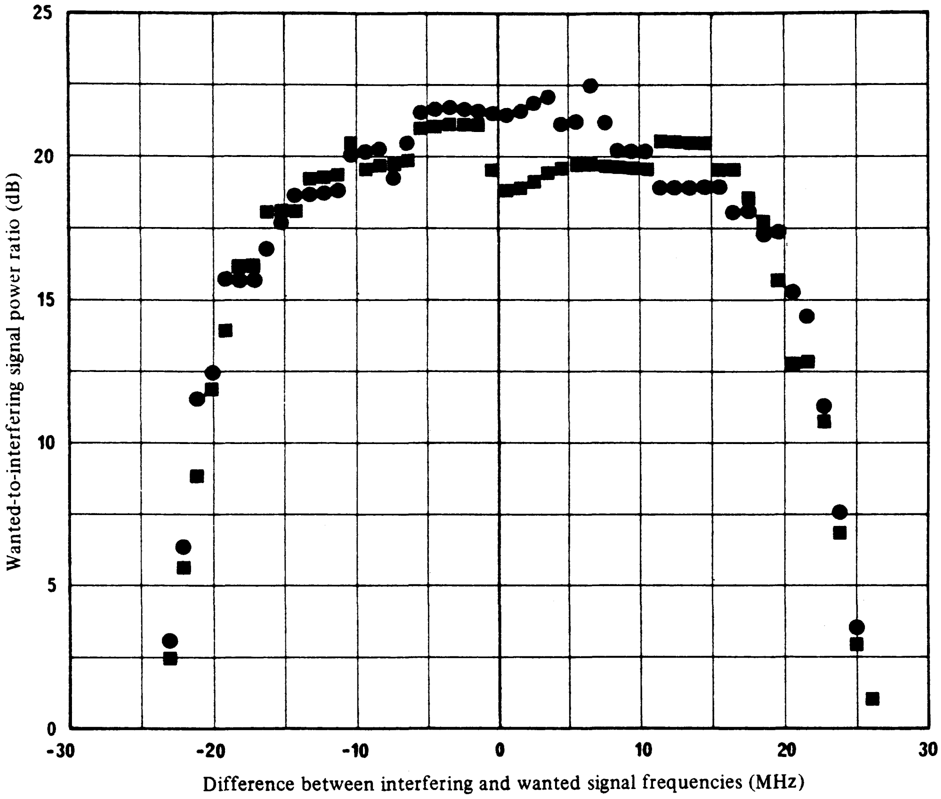


FIGURE 37 – *16 Mbit/s interference on 43 Mbit/s digital television*

E_b/N_0 = 14.7 dB

BER = 2×10^{-8}

Interfering system:

■ : 16 Mbit/s digital television

● : 16 Mbit/s pseudo-random bit sequence

4.2.3 *Protection ratio measurements between digitally encoded data signals and digitally encoded television signals*

Experiments performed in the United States of America included the measurement of protection ratios for D-4-PSK modulated data signals with digital television interference.

The digital systems used were those described in § 4.2.1 and 4.2.2 of this Annex. The wanted system consisted of pseudo-random data (PRBS) which was modulated for transmission using a D-4-PSK modulator and received using a coherent 4-PSK demodulator followed by an error detector. Wanted system data rates of 43 Mbit/s and 16.1 Mbit/s were used. Interferer digital television was supplied by the 42.95 Mbit/s DPCM system and the 16.1 Mbit/s orthogonal transform system previously described.

The purpose of the tests was to determine the trade-offs between the energy contrast ratio (E_b/N_0) and carrier-to-interference ratio (C/I) for a given level of bit error ratio performance. Additionally, the significance of relative bandwidth between the wanted and interfering signals on the allowable C/I was determined.

Table XXVII lists co-channel interference protection ratio levels for 16 Mbit/s digital television interference on a 43 Mbit/s pseudo-random bit sequence (PRBS). The operating condition for the wanted system was varied by changing the E_b/N_0. The values of E_b/N_0 for which measurements were taken were 13.3 dB, 16.3 dB and 40.0 dB (E_b/N_0 = 13.3 dB corresponds to a channel bit error ratio of approximately 1×10^{-9}). For each of these operating conditions, interference was added until the desired performance level (in terms of bit error ratio) was measured at the error detector. Three performance levels were used: 2×10^{-6}, 2×10^{-7} and 2×10^{-8}. Two trends are observable from the data in Table XXVII:

- within a given BER performance level (e.g. 2×10^{-8}) as the operating condition (i.e. E_b/N_0) increases the required protection ratio decreases;
- for a specified operating condition (e.g. E_b/N_0 = 13.3 dB) the required protection ratio increases as the BER performance level approaches the channel error rate.

Both of these trends are the result of the trade-off that exists in digital systems between noise and interference. The better the channel characteristics (i.e. lower noise, higher E_b/N_0) the more interference that can be tolerated.

TABLE XXVII – *Co-channel protection ratios for various energy contrast ratios and bit error ratio performance levels.*

Wanted system – 43 Mbit/s PRBS;*

interfering system – 16 Mbit/s digital television

E_b/N_0	BER performance	Co-channel protection ratio
13.3	2×10^{-6}	15.5
16.3	2×10^{-6}	12.1
40.0	2×10^{-6}	9.3
13.3	2×10^{-7}	18.0
16.3	2×10^{-7}	14.0
40.0	2×10^{-7}	10.0
13.3	2×10^{-8}	21.2
16.3	2×10^{-8}	14.8
40.0	2×10^{-8}	10.0

* PRBS: pseudo-random bit sequence.

Figure 38 gives protection ratios versus frequency offset for the three BER performance levels in Table XXVII (2×10^{-6}, 2×10^{-7}, 2×10^{-8}). The relative difference in protection ratio between the three BER performance levels is generally maintained for any offset.

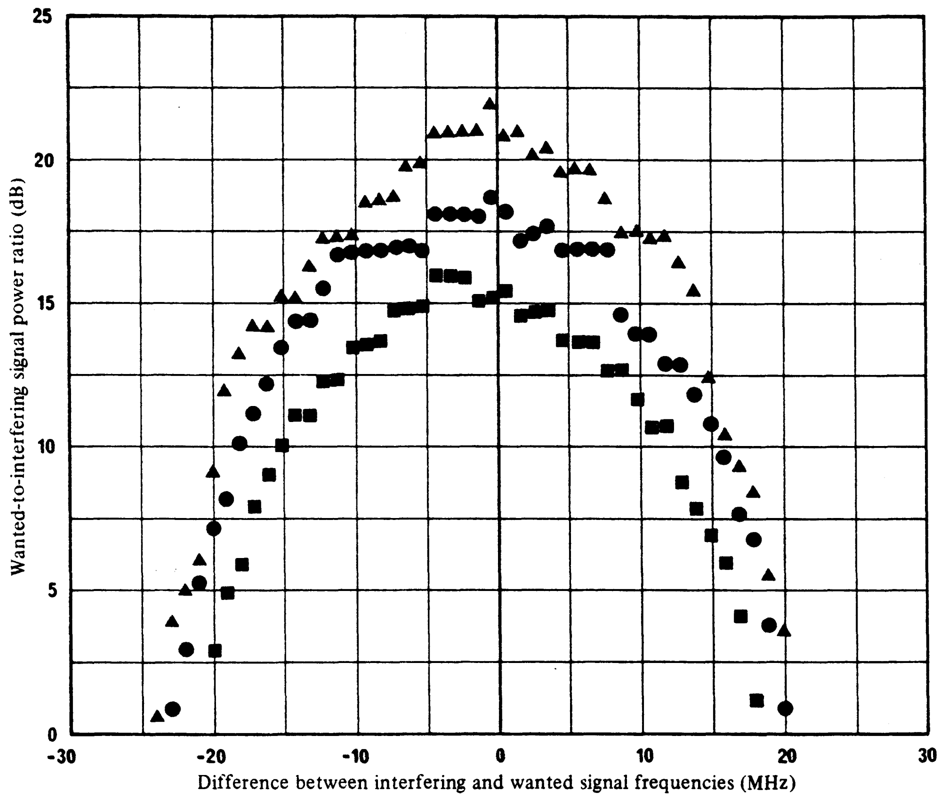


FIGURE 38 – *16 Mbit/s digital television interference on 43 Mbit/s pseudo-random bit sequence*

E_b/N_0 = 13.3 dB

■ : BER = 2×10^{-6}
● : BER = 2×10^{-7}
▲ : BER = 2×10^{-8}

Figure 39 shows the significance of the relative bandwidth between the wanted and interfering signals on allowable C/I. Two results can be obtained from the figure:

– interfering signals with a bandwidth less than the desired signal require greater co-channel protection than the interfering signals which have a wider bandwidth than the desired signal;

– the fall-off in protection ratio versus frequency offset is steeper when the interfering data rate is less than the wanted signal rate.

Both of these results have to do with the amount of interfering signal power present in the main spectral lobe of the wanted signal. For a narrow interferer most of the interfering signal power is within the main lobe of the wanted signal and therefore requires more co-channel protection. However, as the wanted and interfering signals are offset in frequency the effect of the narrow interfering signal drops out more rapidly than with a wider interferer.

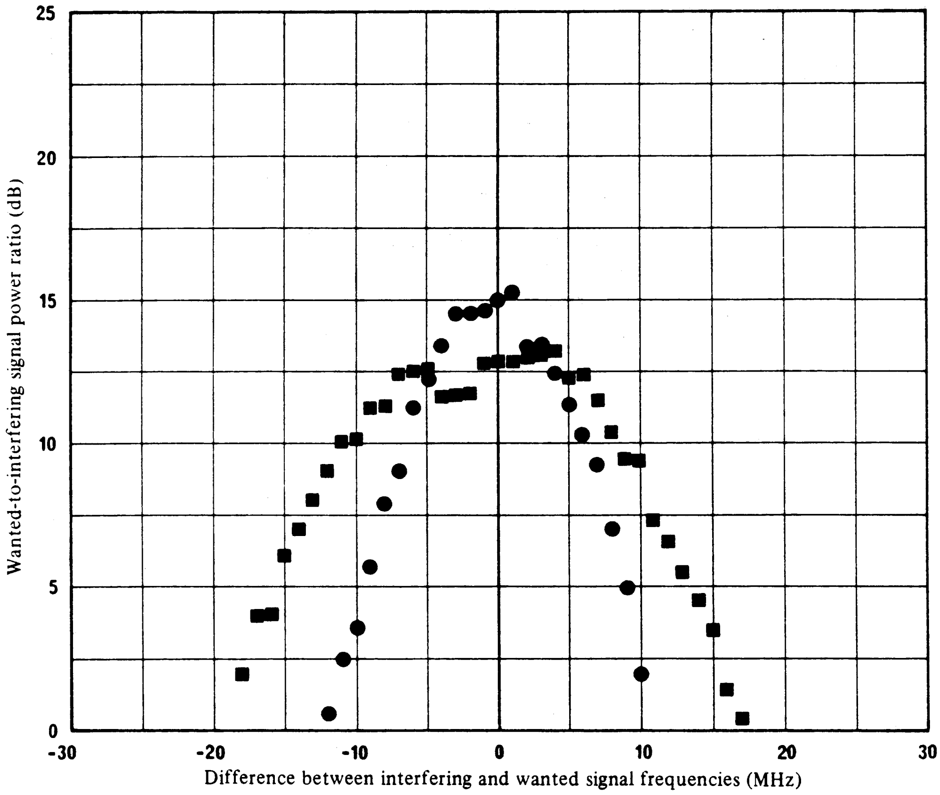


FIGURE 39 – *43 Mbit/s and 16 Mbit/s digital television interference on 16 Mbit/s pseudo-random bit sequence*

E_b/N_0 = 13.3 dB

BER = 2×10^{-6}

Digital television rates:

■ : 43 Mbit/s

● : 16 Mbit/s

5. Protection ratios for 625-line system K/SECAM

Measurements in the USSR [CCIR, 1970-74c] determined protection ratios for frequency-modulation signals against interference by CW, amplitude-modulation, vestigial-sideband and frequency-modulation signals.

5.1 *Measurement conditions*

Protection ratios were determined under the following conditions:

- peak deviation of the wanted frequency-modulation television signal (allowing transmission of sound component on a sub-carrier with a video signal/sound-component signal ratio of 4.5/1) was taken as ± 11 MHz;
- the ratio of the wanted signal to continuous random weighted noise at the frequency-modulation television receiver output was fixed at 57 dB (ratio of picture signal peak-to-peak amplitude, excluding synchronizing pulses, to the r.m.s. noise voltage in the frequency band from 10 kHz to the upper nominal limit of the video-frequency band). To establish this value, use was made of a low-pass filter and a weighting network with characteristics similar to those described in Recommendation 567, Annexes II and III for system K;
- coloured and monochrome test charts, coloured bars and real colour pictures were used for the tests;

- a CW, an amplitude-modulation television signal, and a frequency-modulation television signal were used as interfering signals;
- the video signal of the monochrome test chart was used as modulating signal for the interfering amplitude-modulation and frequency-modulation television signal;
- a binary statement of the type "Yes-No" was used to assess picture quality;
- the test group consisted largely of non-expert viewers. Expert viewers were used to determine the proposed central assessments. The test group consisted of ten to fifteen persons;
- dimensions of test picture: 475 × 375 mm;
- viewing distance: 5 to 6 times the picture height;
- the centre of the screen of the test television receiver was set at eye level of the observers;
- measurements were carried out in conditions of partial darkness;
- the level of illumination of the screen by external light sources did not exceed 0.01 of maximum screen brightness;
- sequence of changes in noise level: random, in 3 dB steps; in each measurement series, the observers were shown five values of signal-to-noise ratio. In consequence, the limits of the variation in noise level gave rise in each case to variations of ± 1 grade in the assessment picture quality;
- protection ratio measurements were made without a band-pass filter at the input to the frequency modulation receiver.

5.2 *Measurement results*

The results of the protection ratio measurements as a function of detuning of the carrier frequencies (carrier-frequency offset) of the wanted and unwanted signals, for transmission in colour (colour bars, colour test chart and real colour picture) are shown in Figs. 40 to 42, while Fig. 43 shows the results of transmission of a monochrome picture (test chart).

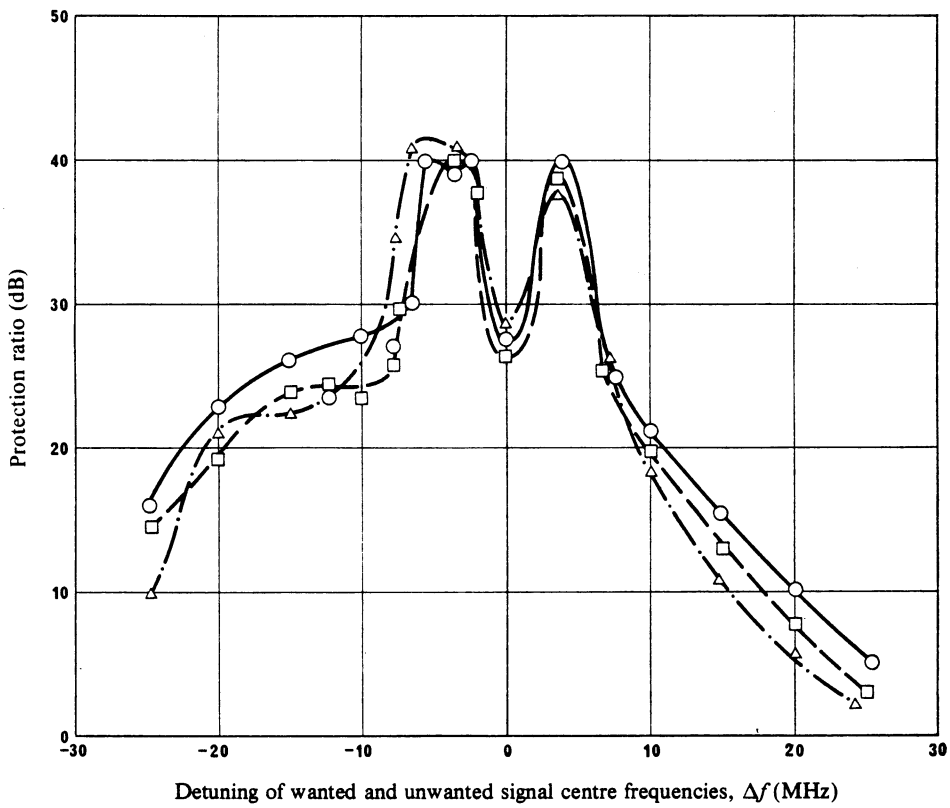


FIGURE 40 – *Frequency-modulation protection ratio against CW interference*

—○— : colour bars
— □ — : real colour picture
·—·△·—· : colour test chart

modulation on wanted signal

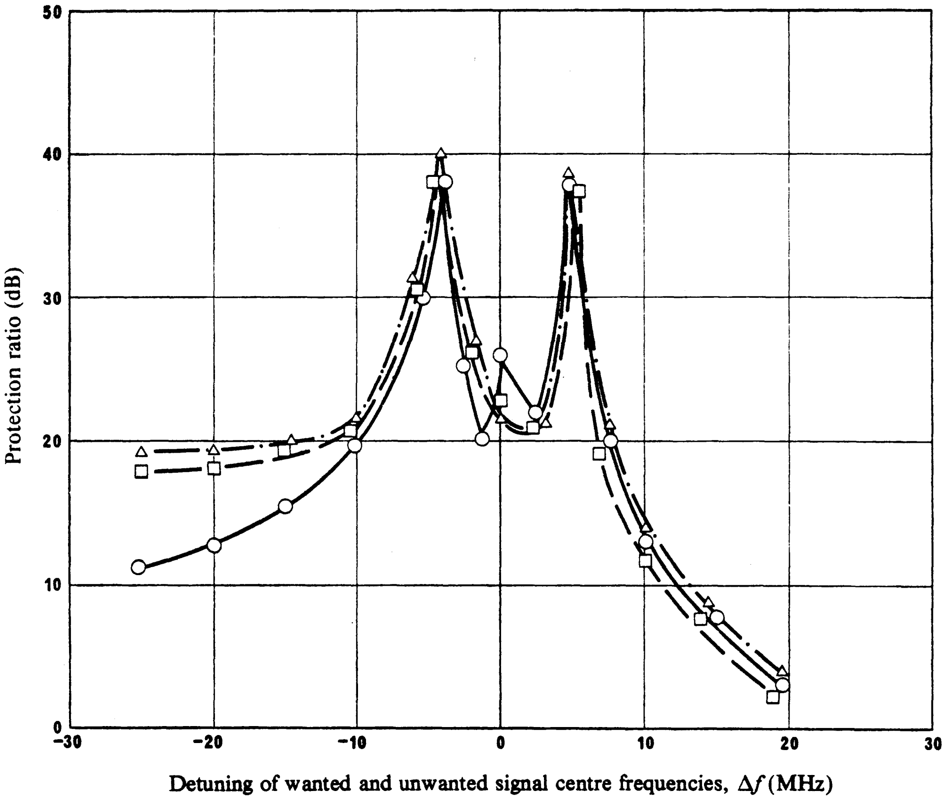


FIGURE 41 – *Frequency-modulation protection ratio against amplitude-modulation, vestigial-sideband interference*

—○— : colour bars
— —□— — : real colour picture
· — · △ · — · : colour test chart

} modulation on wanted signal

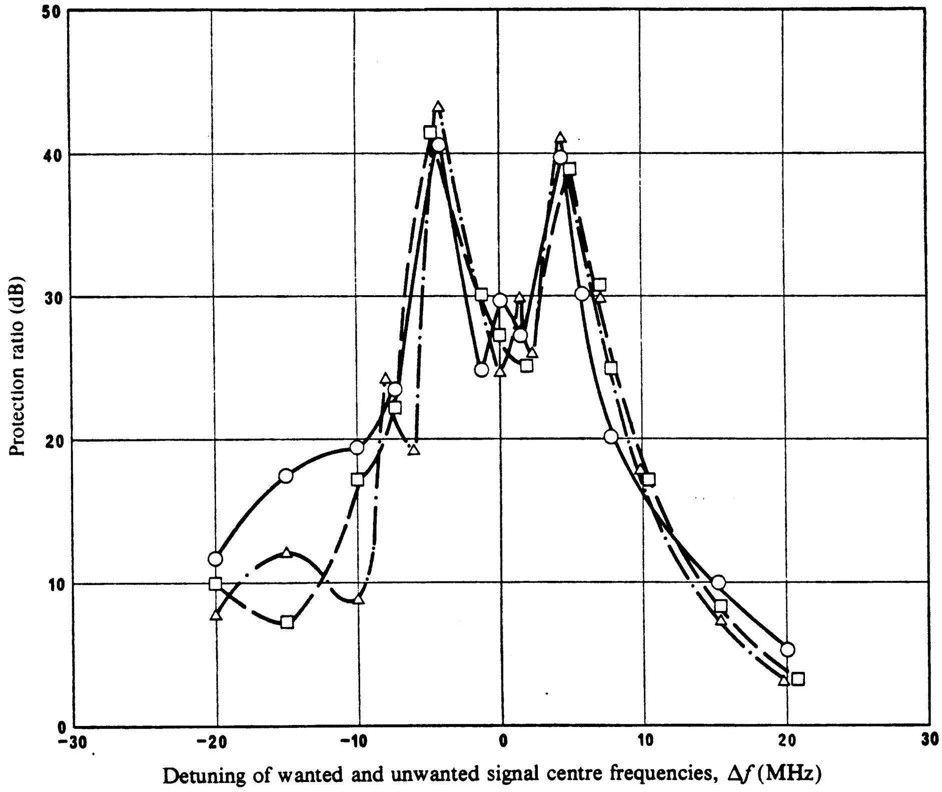


FIGURE 42 – *Frequency-modulation protection ratio against frequency-modulation interference*

———○——— : colour bars
– – –□– – – : real colour picture
· —— · △ · —— · : colour test chart

} modulation on wanted signal

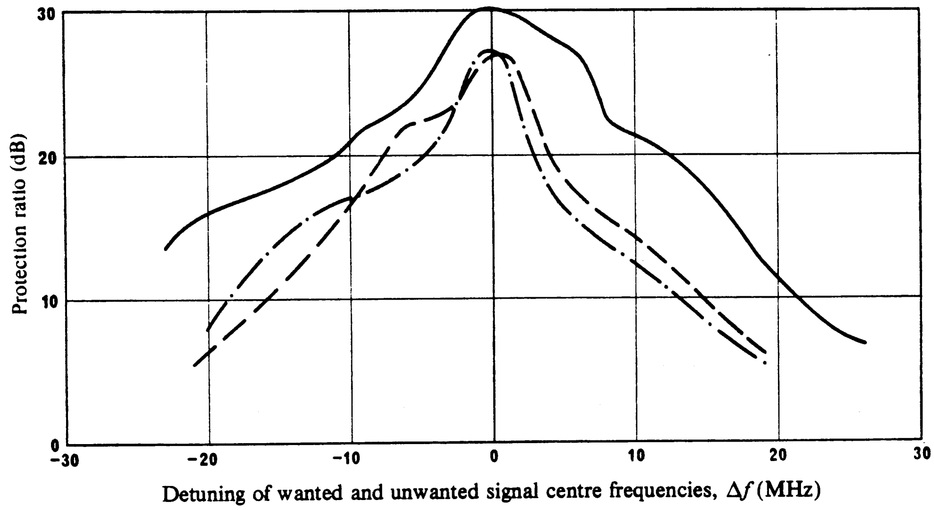


FIGURE 43 – *Protection ratios in the case of frequency-modulation transmission of a monochrome picture (test chart)*

——————— : frequency-modulation television interference
— — — — : amplitude-modulation television interference
·——·——·——· : CW interference

} modulation on interfering signal

Figure 40 describes the effect of CW interference on the wanted frequency-modulation television signal, Fig. 41, the effect of interference in the form of an amplitude-modulation signal and Fig. 42, the effect of interference in the form of a frequency-modulation signal with a peak frequency deviation ± 11 MHz.

Figure 44 shows the measurement results for protection ratios as a function of the level of random noise at the output of the frequency-modulation television receiver. A colour test chart was used in recording these correlations, while the detuning between the wanted and unwanted signal carriers was fixed by the maximum perceptibility of interference on the screen of the test television receiver.

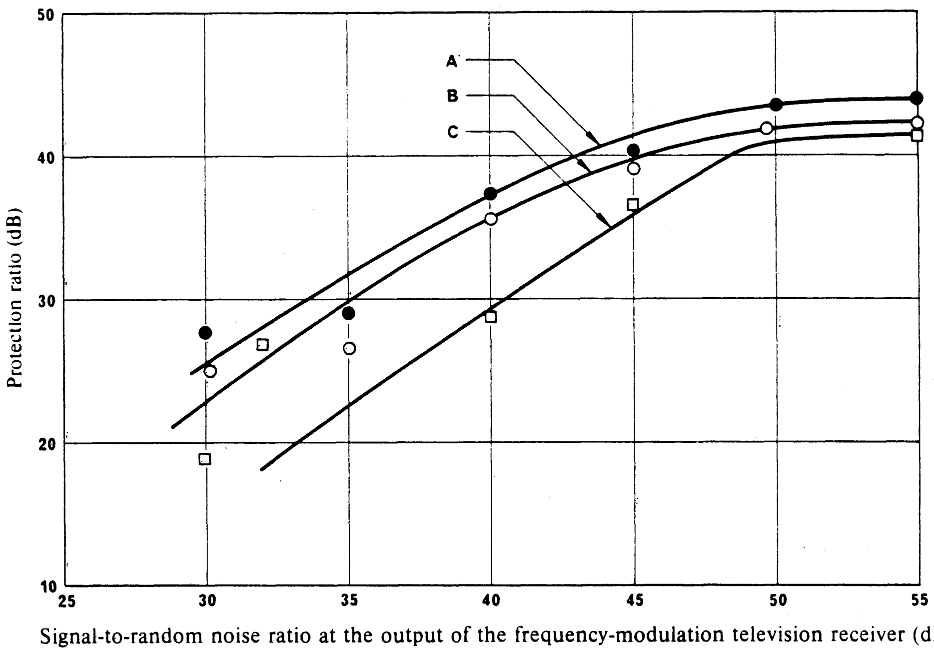


FIGURE 44 – *Frequency-modulation protection ratios as functions of signal-to-noise ratio*

A: CW interference
B: amplitude-modulation television interference
C: frequency-modulation interference

5.3 *Conclusions*

The following conclusions can be drawn from these results:

In the case of the wanted and unwanted signals in the same frequency channel (with identical centre frequencies), the protection ratio for frequency-modulated signals does not exceed 30 dB, for the reception of both monochrome and colour television signals, and is virtually independent of the picture content.

If the wanted and unwanted signal centre frequencies are detuned, the protection ratio for the reception of monochrome television signals decreases.

For the reception of colour television signals, the protection ratio with frequency detuning initially rises, reaching a maximum (40 to 42 dB) with a detuning of ± 4 to 5 MHz, and then falls. This is due to the occurrence of wanted and unwanted signal frequency beat products in the transmission of colour television signals.

The value of the protection ratio depends basically on the random noise level in the channel at ratios of less than 50 dB between the wanted signal and the weighted r.m.s. noise voltage at the frequency-modulation television receiver output, and is independent of the level of random noise with ratios equal to or greater than 50 dB.

6. Accommodation of space operations service functions (TTC) within the broadcasting-satellite and feeder-link service bands

The use of the guard bands assigned by feeder-link and down-link plans to the broadcasting-satellite service for space operation service functions, raises the problem of compatibility between the two services. Studies leading to agreed protection ratios are required in order to protect television signals, which are transmitted in the nearby channel, from such interference sources. The protection ratio is 20 dB for feeder links; further details may be found in Report 1076.

7. Discussion of the results

Comparisons of the data presented in this Annex are difficult because of the varying test conditions used. For some parameters in the case of interference on an amplitude-modulation, vestigial-sideband system, correction factors have been deduced to enable results to be referred to the standardized conditions established in Recommendation 600. These parameters relate to:

- deviation;
- pre-emphasis;
- quality grade;
- energy dispersal.

For frequency-modulation systems some factors in determining the required protection ratio for common radio-frequency co-channel sharing are:

- quality grade of the protection ratio assessment;
- the picture signal-to-noise ratio of the wanted signal;
- the deviation of the wanted signal;
- the programme content of both wanted and unwanted signals.

The deviation and the signal-to-noise ratio for the unwanted signal have only minor effects upon the protection ratio. Over the range of deviations studied, the protection ratio decreases with increasing deviation of the wanted signal. Wanted signals which have large areas of colour or uniform luminance are more susceptible to interference; similarly unwanted signals having large single spectral components are more perceptible.

Results for 525-line system M/NTSC and 625-line system K/SECAM show that noise in the wanted signal tends to mask coherent interference by degrading the quality of the uninterfered with portion of the picture and by breaking up any interference patterns. Other measurements on 625-line systems show little masking by noise. It is possible that this apparent difference in system vulnerability to interference can be explained in terms of the nature of the pictures carried by the wanted and interfering signals in the various measurements and the use of different noise-weighting when specifying the luminance-to-weighted-noise ratio in different television systems. A definitive answer must await additional test data and analysis.

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CCIR Documents

[1970-74]: **a.** 11/107 (France); **b.** 11/339 (France); **c.** 11/332 (USSR); **d.** 11/317 (EBU).

[1974-78]: **a.** 11/40 (Japan); b. 10/42 (Japan); **c.** 11/25 (EBU); **d.** 11/101 + 11/114 (France).

[1978-82]: **a.** 11/91 (USA); **b.** 10-11S/157 (USSR); **c.** 11/116 (USSR); **d.** 10-11S/61 (Canada); **e.** 10-11S/19 (Japan); **f.** 10-11S/138 (USA); **g.** 10-11S/149 (France); **h.** 11/32 (USA).

[1982-86]: **a.** 10-11S/49 + Corr.1 (USA); **b.** 10-11S/202 (China (People's Republic of)).

ANNEX II

SUGGESTED PROTECTION RATIO MEASUREMENTS

In digital television transmission, protection ratio measurements are needed to determine the susceptibility of digital systems to unwanted analogue modulated signals and unwanted digital signals. The following test matrix is suggested:

Wanted signal	*Unwanted signal*
Digital	Digital
Digital	FM
FM	Digital
Digital	AM-VSB
AM-VSB	Digital

The test conditions and procedures for the determination of the protection ratio recommended in Recommendation 600 have not been formulated specifically for digital modulation. Further studies are needed to define more precisely the test conditions and procedures for digital modulation. In the meantime, priority should be given to performing tests involving digital modulation techniques under the conditions given in Recommendation 600.

REPORT 951*

SHARING BETWEEN THE INTER-SATELLITE SERVICE AND THE BROADCASTING-SATELLITE SERVICE IN THE VICINITY OF 23 GHz

(Question 1/10 and 11)

(1982)

1. Introduction

The WARC-79 has allocated the band 22.5 to 23 GHz in Regions 2 and 3 to the broadcasting-satellite service (BSS), part of which, namely the band 22.55 to 23 GHz, is shared with, among others, the inter-satellite service (ISS).

On the basis of studies carried out in the USA and Japan this Report examines parametrically the orbital spacing required between space stations employing inter-satellite links and broadcasting satellites with respect to interference into the ISS link [CCIR, 1978-82a and b] and interference into the BSS receiver [CCIR, 1978-82c].

These analyses use new system characteristics from an example in Report 215 for high-definition TV using an RF bandwidth of 125 MHz. However, an example for conventional TV is also given in Report 215. The analyses presented in this Report can also be applied to that case. Preliminary calculations done in the United States show that the high-definition case presented here would prove to be the more conservative.

The parameters for the ISS assumed in the two analyses are given in §§ 2.1 and 3.1. As the definition of the ISS is in an early stage, the parameters assumed in the two sections are different. Further study is required.

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* This Report should be brought to the attention of Study Group 4.