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LABORATORY REPORT NO 63

TELEVISION RECEIVER PROTECTION RATIOS

An investigation conducted to establish the protection ratios required for television receivers when operated in the presence of interfering VHF FM and/or VHF TV services.

September 1978

TELEVISION RECEIVER PROTECTION RATIOS:

Introduction

An investigation was carried out in the laboratory to determine the typical performance characteristics (which have a particular signifance for planning purposes) of the latest generation of television receivers operating with various combinations of input signal levels and interfering VHF TV and/or VHF FM services.

From the measurements made on a total number of 30 receivers, protection ratios were developed for the following interfering signals:

(i) FM transmission operating at half the frequency of the wanted TV service.

(ii) Adjacent and co-channel FM service.

(iii) Intermodulation between an unwanted TV and FM service.

(iv) Adjacent channel TV service:

(a) with carrier separation of $\pm$7 MHz and $\pm$14 MHz;

(b) channels 0 and 1.

(v) TV service operating at the image frequency of the wanted signal.

(vi) FM transmission operating at a frequency such that

$$fFM - fTV = IF\ (TV)$$
$$\text{and } fTV - fFM = IF\ (TV)$$

(vii) CW signal occurring in the television intermediate frequency band.

In addition, (a) the local oscillator voltage appearing at the receiver aerial terminals was measured at three VHF channels, and where applicable, two UHF channels and (b) VHF and UHF noise threshold was determined.

Basis of Measurements

All measurements, except for the local oscillator aerial terminal voltage, were performed subjectively using a standard image as defined in the IEC Document 12A (Secretariat) 171 clause 105. Because of the time/cost factors involved in making the large number of measurements in this series of tests, the method by which a panel of viewers is used to assess the picture quality for every receiver as noted in CCIR Recommendation 500, was not possible. Therefore, to establish consistent results, all protection ratios were based on a "just perceptible" interference grading. This type of assessment is reapeatable with a relatively small tolerance, using different observers. To translate these performance figures into the practical environment where compromise is necessary, correction factors, which could be applied to the protection ratios, were developed using a viewing panel in accordance with CCIR Recommendation 500. These correction factors give an indication of the tolerance required in the practical system to change the impairment rating of the picture from "just perceptible" to "perceptible but not annoying".

Measurement Technique

Equipment layout is shown in figure 1. Suitable RF filters were inserted at appropriate points in the measuring system to reduce to an insignificant level any spurious signals generated by the test equipment. The unwanted interfering television signals were obtained by translating one of the local Melbourne television signals to the required channel.

All receivers were tested in the condition in which they were delivered and no internal adjustments were made.

1. FM service operating at half the frequency of the wanted television service.

If non linearity exists in the input stage of a television receiver, spurious signals will be generated and these may cause interference to the incoming wanted signal. This mechanism applies in the case where an FM service is operating at a frequency which is half the wanted TV channel frequency. Here, the second harmonic of the FM signal is produced in the non linear input circuitry of the receiver and then beats with the wanted television signal causing an interference pattern to be observed on the picture. In the Australian television system the TV channels which can be affected by this phenomenon are channels 6 to 10 inclusive. In this investigation, channel 8 was used as the wanted television service. However, equivalent tests were carried out on several receivers to confirm that the same interference relationships held for the other channels ie. channels 6, 7, 9 and 10. A family of protection ratio curves was derived for differing input levels of the wanted signal.

The effect of changing the preset AGC voltagewas investigated on several receivers to assess any variation in receiver performance for this type of interference.

Further measurements were carried out on a limited number (7) of receivers to establish the change in protection ratio required when two interfering FM services are operating simultaneously at equal signal levels but at various FM channel spacings. The frequencies of these interfering signals were selected so that they occurred at a point where the protection ratio was maximum ie the frequency of one signal was fixed so that its second harmonic occurred at 0.5 MHz above the wanted vision carrier frequency while the other interfering signals frequency was changed in 200 kHz increments from 200 kHz to 1400 kHz above the fixed frequency signal.

2. Adjacent and Co-Channel FM services.

Receiver performance was evaluated for interference from co-channel and adjacent channel FM services. A protection ratio curve was developed using channel 4 as the wanted TV service and a single interfering FM signal varying in frequency from 88 MHz to 108 MHz.

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3. Intermodulation between an unwanted TV and FM service.

Certain combinations of frequencies used for the VHF TV and FM services can, under conditions of non linearity in the television receivers tuner, produce spurious signals which occur at a frequency in the wanted television channel. Nearly all the TV channels combined with a suitable FM service can produce these intermodulation products in another wanted TV channel. However for this particular test the wanted TV channels were limited to channels 2 and 6 in accordance with the following equations:

(a) f channel 6 - fFM = f channel 2 (wanted); and

(b) f channel 2 (sound) + fFM = f channel 6 (wanted)

To limit the large number of combinations of frequencies and signal amplitudes that could be used in this test, the wanted and unwanted television signals were kept at the same level and the amplitude of the FM signal was varied to determine the protection ratio. The frequency of the FM signal was adjusted for the worst case condition for each measurement (which occurred when the frequency of the spurious signal was close to the wanted vision carrier or colour sub-carrier frequency) whilst ensuring that the interference was due to the intermodulation products only (this was necessary as in the case of the wanted channel being at the higher frequency, interference could be caused by the second harmonic of the unwanted FM signal generated in the receivers tuner, as noted in paragraph 1).

4. Adjacent channel TV transmissions.

In this test, protection ratios were derived for::

(a) an interfering TV service operating at 7 MHz and 14 MHz above and below the wanted television signal vision carrier ie for channels 6, 7 and 8;

(b) the special case of channels 0 and 1 where the vision carriers are separated by 11 MHz.

5. TV transmission operating at the image frequency of the wanted TV service.

Three VHF television channels in the Australian system could be susceptible to interference from other television services operating at their respective image frequencies.

The table below details these combinations:

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Wanted Channel	Image Channel
2	5A
5	6
5A	10

The wanted television channels used in this measurement were 2 and 5A.

6. FM service operating at a frequency such that fFM - fTV = IF (TV) and fTV - fFM = IF (TV).

Intermodulation products occurring at the television intermediate frequency are produced under conditions of non linearity in the television receivers input circuitry when the frequency separation of two incoming signals is equal to the intermediate frequency. This can result in interfering patterns being produced on the wanted picture.

For this test, channels 2 and 5A were selected as the wanted signals; the frequency of the FM service being adjusted for the "worst case" condition (ie the frequency of the spurious signal occurring close to the wanted vision carrier), for each measurement.

7. CW signal occurring in the television intermediate frequency band.

Protection ratios were determined using channels 0, 2 and 8 as the wanted signals; the frequency of the CW signal being adjusted for the "worst case" condition (just below the vision carrier intermediate frequency).

8. Local oscillator aerial terminal voltage.

The aerial terminal voltage of the local oscillator was measured at its fundamental and second harmonic frequencies for the VHF channels 2, 5A and 9 and for the highest and lowest frequency channels of the UHF band.

9. VHF and UHF noise threshold.

This measurement was assessed as the lowest input signal level needed to cause just perceptible noise on channels 0, 8 (VHF) and 43 (UHF).

10. Correction factors.

For each of the subjective tests, protection ratio correction factors were derived to indicate the amount by which the protection ratio could be reduced while still maintaining a useable system. These correction factors were based on a change in picture impairment rating from "just perceptible" to "perceptible but not annoying".

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As the picture impairment had to be graded to derive these correction factors, the judgement of one observer might not be valid for the "average" viewer. Hence a panel of viewers was used in accordance with CCIR Recommendation 500. This panel, consisting of 16 observers, assessed the picture impairment rating on one receiver in accordance with the following scale.

	Impairment
1	Imperceptible
2	Perceptible but not annoying
3	Slightly annoying
4	Annoying
5	Very annoying

Additionally, five other receivers were assessed by one observer. The results of these observations were then compared to the viewing panel's results to establish if similar correction factors hold for most types of receivers.

Results

1. Definitions

(a) Protection ratio is the ratio of the wanted signal to the unwanted signal and, in this report, is based on a "just perceptible" interference.

(b) All signal level voltages are referred to on impedance of 75 ohms.

2. Receivers

Of the total number of 30 receivers tested, 28 units were colour, the remainder being monochrome portable units. There was a moderate variation in performance of the various brands of receivers, but a correlation was established between the receiver design and one of the tests. Receivers using varactor diode tuners (continuous tuning) appeared to be more susceptible to interference generated by an FM service operating at half the frequency of the wanted TV service, than were those receivers which used a "turret" type tuner. As the number of continuously tuneable receivers sold is increasing (one manufacturer quoted a sales ratio of 6:1 for varactor diode tuner receiver to turret tuner receiver), the results of this particular test for both types of receiver have been shown separately. In the other tests involving tuner non linearity, the variation in performance of both types of tuner was not quite so obvious, therefore results from these tests show the mean level of all types of receivers tested.

Table 1 lists all the receivers investigated in this report.

3. Protection Ratios

Figures 2 to 4 and table 2 indicate the mean value of the protection ratios derived in this investigation. With reference to the graphs, the dotted portions show the assumed resultant, as the required output signal level from the test equipment could not be realized for these particular measurements.

On several sets, the effect of varying the RF AGC control was noted, to observe if an improvement in receiver performance could be obtained in the case where tuner non linearity was a problem. As stated previously, interference from FM services operating at half the frequency of the wanted TV service was the worst non linearity type of problem with the majority of receivers and therefore this aspect of the investigation was confined to this particular measurement. On five of the receivers, no improvement in performance could be obtained. However the protection ratios derived for these particular receivers was already comparable to the mean figures. An 8dB improvement could be realised for one receiver which, when first tested, had the worst protection ratio of all receivers (figure 11). However this improvement was still approximately 10dB worse than the mean figures.

Although this investigation was mainly confined to colour receivers, two monochrome units were evaluated. The main difference in response of the two types of receivers occurred in the colour sub-carrier region. A comparison of the colour receiver protection ratio graphs to these obtained for the monochrome units (figures 5 and 6) illustrates these differences.

4. Noise Threshold

Table 3 lists the mean minimum input signal level which will give just perceptible noise on the received picture for both VHF and UHF reception.

5. Local Oscillator Aerial Terminal Voltage

This was the only measurement which was not made subjectively. The voltages measured varied markedly for different types of receivers, and did not follow a normal distribution pattern. The mean figures, therefore, may be slightly misleading so the best and worst case figures have also been included in the results presented in table 4.

6. Correction Factors

(a) Correction factors, that can be added to the derived protection ratios to change the picture rating from "just perceptible" to "perceptible but not annoying" interference, were developed from the results obtained from the viewing panel. Although this panel observed only one receiver, the results compare favourably to the mean of the measurements made by one observer on five different receivers as shown in figures 7 to 9. In a similar manner, the noise threshold signal level can be reduced by the amount shown in figure 10. It should be noted that these figures were derived in a noise free laboratory environment and do not take into account any external sources of interference such as car ignition systems or power lines.

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The approach to the subjective assessment of television receivers adopted in this investigation (ie establish protection ratios on a "just perceptible" interference basis and then derive correction factors to indicate the degree of tolerance allowable to give a "perceptible but not annoying" interference by the use of a viewing panel observing a limited number of receivers) was the only practical method to use in the situation where a large number of measurements had to be made on a relatively large number of receivers.

(b) Table 5 lists the correction factors which must be added to the protection ratios, shown in figure 2 and 3 when two equal amplitude FM services are operating at various channel spacings. As noted previously, these correction factors were derived for the "worst case" condition ie where both FM services produce maximum interference.

Summary

1. Overall, the majority of the receivers gave satisfactory results with the various tests. The impression gained from this investigation was that the varactor diode type tuners generally gave worse results than those obtained from the turret type tuners in the tests which involved tuner non linearity.

2. In high signal strength areas, the receivers performance can be enhanced by the use of a suitable attenuator in the RF input.

3. From the results, it would be highly desirable to operate co-sited FM and TV transmitters (when conditions for interference, as noted in this report are met).

4. Co-sited TV transmitters operating on channels 0 and 1 appear to be a feasible proposition.

I.M. ALBURY

1. Philips KN637
2. National CP2000
3. Blaupunkt Z208C
4. Rank Area C1412
5. Philips K9
6. Sanyo CTP7601
7. Pye 22A3
8. HMV Diplomat 22
9. Kriesler 59-1
10. Pye 22A3
11. AWA C603
12. Philips 26 C8 20452
13. Pye 22A3
14. Philips 02 KH656
15. Philips 22 K20105
16. Philips 18"
17. AWA C617
18. AWA C3402
19. National TC2000A
20. National TC2251
21. HMV F3001 (Monochrome)
22. Rank Arena C2233
23. Rank Arena C2252B
24. Philips KD654
25. Korting 55735
26. Sharp 8C220
27. Sharp 8C223
28. Philips 02KE027
29. Sanyo CTP6607
30. Thorn 7333 (Monochrome)

Receivers Investigated In This Report

TABLE 1

INTERFERENCE SIGNAL	PROTECTION RATIO (dB)						DEN (dB)
	1mV TVw		10mV TVw		100mV TVw		
	Mean	Worst Case	Mean	Worst Case	Mean	Worst Case	For 1mV
1. Intermodulation between an unwanted TV service and FM service:							
(a) fTVu - fFM = fTVw	< -55	-36	< -37	-22	< -17	-2	-
(b) fTVu + fFM = fTVw	< -58	-28	< -39	-8	< -17	+10	-
2. Adjacent channel TV service:							
(a) 7 MHz carrier separation							
Upper Channel	-11	+2	-6	+8	0	+14	6
Lower Channel	+2	+20	+3	+22	+5	+24	12
(b) 14 MHz carrier separation							
Upper Channel	-31	-21	-18	-6	< -3	+4	5
Lower Channel	-35	-20	-21	-10	-2	+6	5
(c) Special case of channels 0 and 1							
Channel 1 (TVw = Channel 0)	-24	-12	-19	-10	< -6	+3	6
Channel 0 (TVw = Channel 1)	-20	-8	-17	-8	< -5	0	7
3. TV service operating at image frequency:							
(a) Channel 5A (TVw = Channel 2)	-30	-5	-23	-5	-1	+10	10
(b) Channel 10 (TVw = Channel 5A)	-24	-2	-17	-2	< -4	+14	12
4. FM service operating at a frequency such that:							
(a) fTVw - fFM = IF (TV) (TVw = Channel 5A)	-47	-30	-35	-20	-21	-7	9
(b) fFM - fTVw = IF (TV) (TVw = Channel 2)	-50	-30	-33	-25	< -14	-13	7
5. CW signal operating in IF (TV) band:							
(a) TVw = Channel 0	-6	+16	-		-		10
(b) TVw = Channel 2	-23	-5	-		-		13
(c) TVw = Channel 8	-33	-12	-		-		16

TVw = Wanted Television Signal; TVu = Unwanted Television Signal

PROTECTION RATIOS FOR TELEVISION SERVICE

TABLE 2

Operating Channel	Wanted Signal Terminal Voltage	Standard Deviation
0	0.8mV	0.2mV
8	0.8mV	0.2mV
43 (UHF)	1.1mV	0.3mV

RECEIVER NOISE THRESHOLD

TABLE 3

OPERATING CHANNEL	FUNDAMENTAL (uV)			SECOND HARMONIC (uV)		
	Mean	Best	Worst	Mean	Best	Worst
2	80	6	320	50	0	300
5A	50	0	160	40	0	130
9	230	8	1600	20	0	70
28 (UHF)	240	0	440	-		
63 (UHF)	270	0	1100	-		

LOCAL OSCILLATOR AERIAL TERMINAL VOLTAGE

TABLE 4

FM SPACING kHz	CORRECTION FACTOR (dB)		
	Wanted Signal 1mV	Wanted Signal 3mV	Wanted Signal 10mV
200	3	4	4
400	3	4	3
600	3	3	3
800	2	3	3
1000	2	2	2
1200	1	2	2
1400	1	1	2

Correction factor to be added to protection ratio when two FM services are operating at various channel spacings at half the wanted television channel frequency.

TABLE 5

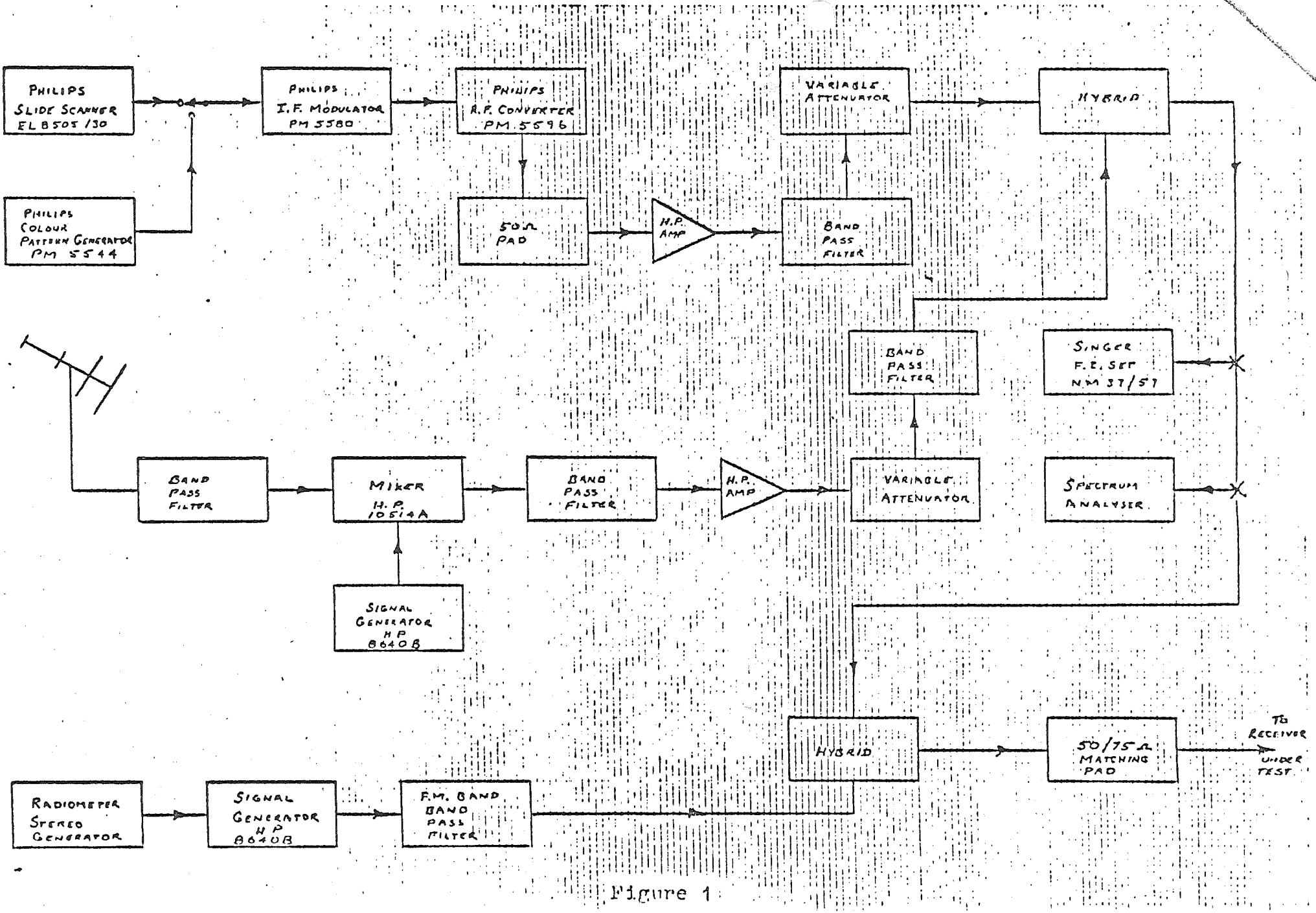
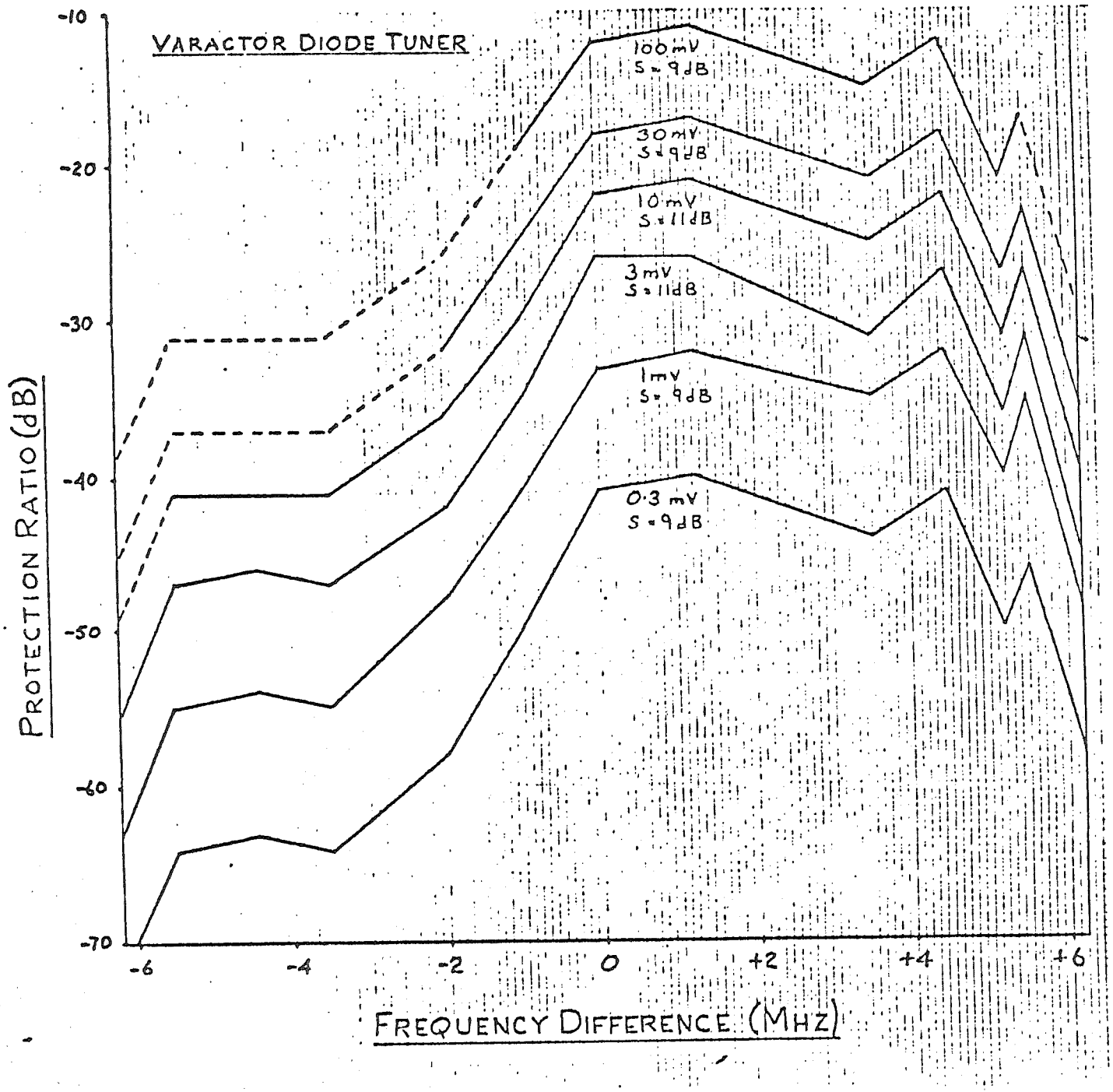

PHILIPS SLIDE SCANNER EL B505/30
PHILIPS I.F. MODULATOR PM 5580
PHILIPS R.F. CONVERTER PM 5596
VARIABLE ATTENUATOR
HYBRID
PHILIPS COLOUR PATTERN GENERATOR PM 5544
50Ω PAD
H.P. AMP
BAND PASS FILTER
BAND PASS FILTER
SINGER F.E. SET NM 37/51
BAND PASS FILTER
MIXER H.P. 10514A
BAND PASS FILTER
H.P. AMP
VARIABLE ATTENUATOR
SPECTRUM ANALYSER
SIGNAL GENERATOR HP 8640B
HYBRID
50/75Ω MATCHING PAD
TO RECEIVER UNDER TEST
RADIOMETER STEREO GENERATOR
SIGNAL GENERATOR HP 8640B
F.M. BAND BAND PASS FILTER

Figure 1



PROTECTION RATIO FOR COLOUR TELEVISION SERVICE
(Mean Levels)

Interference from an FM service operating at half the frequency of the wanted TV service.

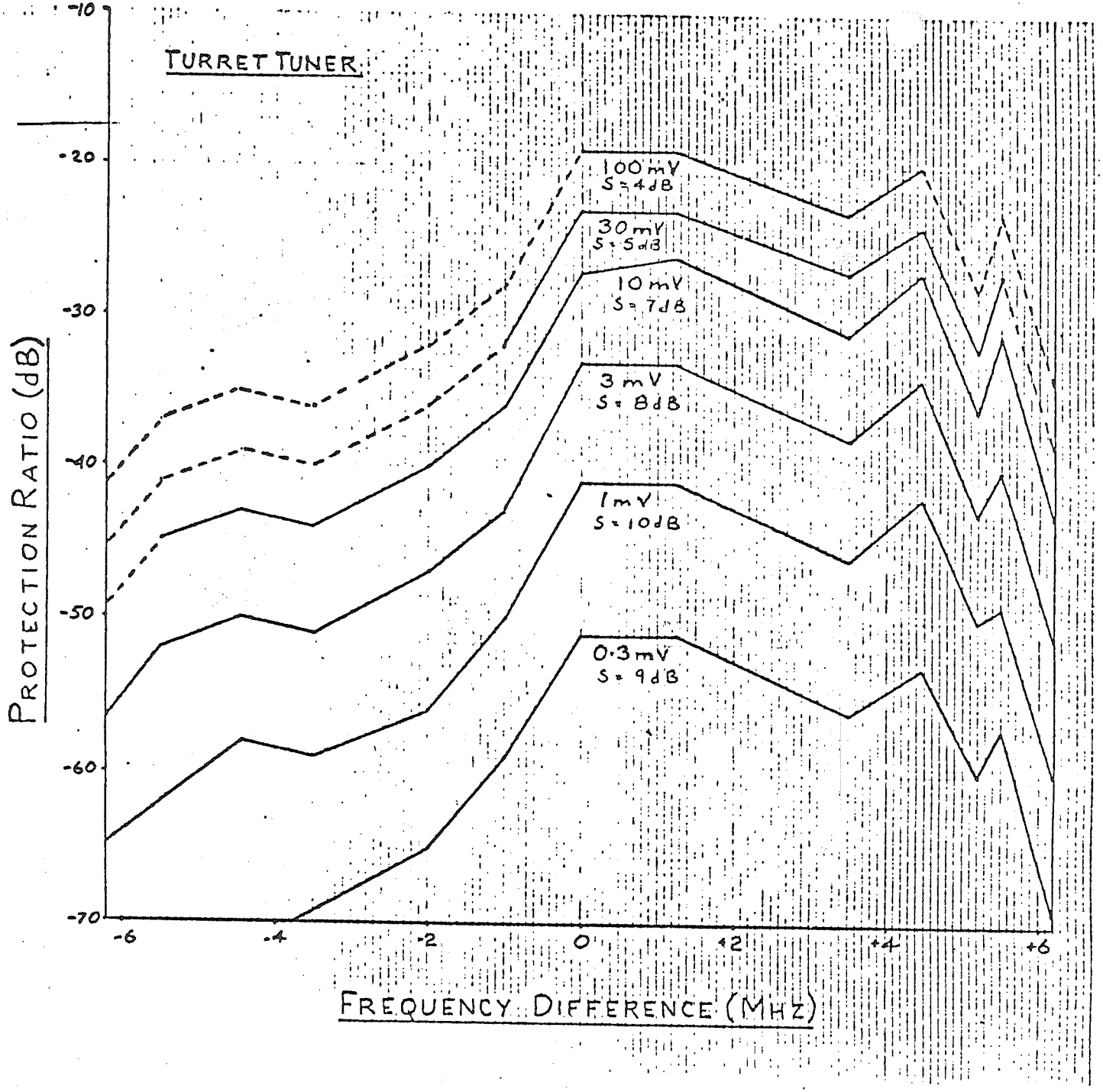
NOTE:

1. Frequency difference refers to difference between wanted vision carrier and internally generated second harmonic of unwanted FM service.

2. Voltage level refers to terminal voltage (75 ohms) of wanted TV service.

3. s = Standard Deviation

FIGURE 2



PROTECTION RATIO FOR COLOUR TELEVISION SERVICE
(Mean Levels)

Interference from an FM service operating at half the frequency of the wanted TV service:

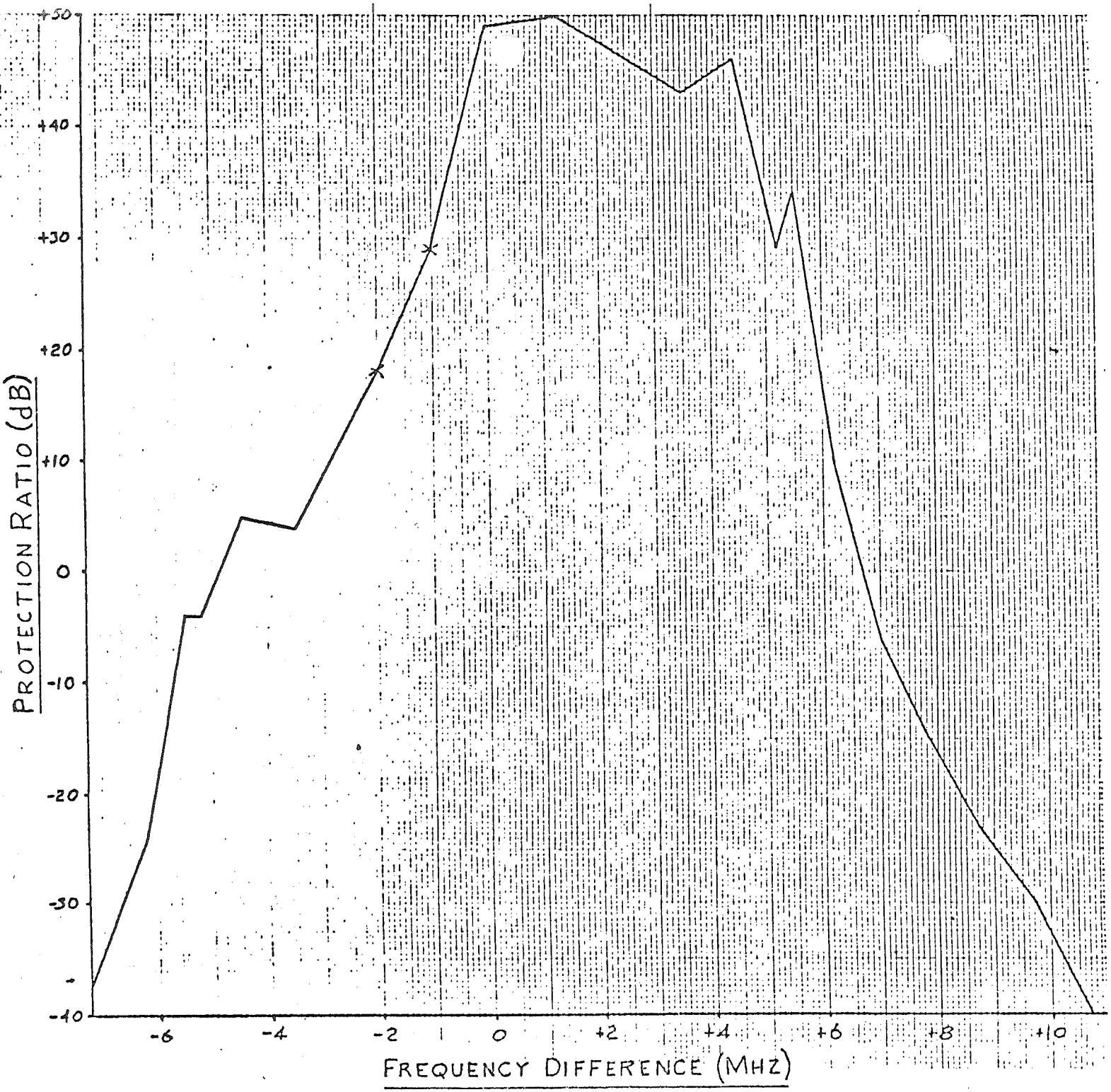
NOTE:

1. Frequency difference refers to difference between wanted vision carrier and internally generated second harmonic of unwanted FM service.

2. Voltage level refers to terminal voltage (75 ohms) of wanted TV service.

3. s = Standard Deviation.

FIGURE 3



PROTECTION RATIO FOR COL
TELEVISION SERVICE
(Mean Levels)

Interference from adjacent and co-channel FM service.

NOTE:

1. Frequency difference refers to difference between wanted vision carrier and unwanted FM service.

2. Wanted signal level is 1mV.

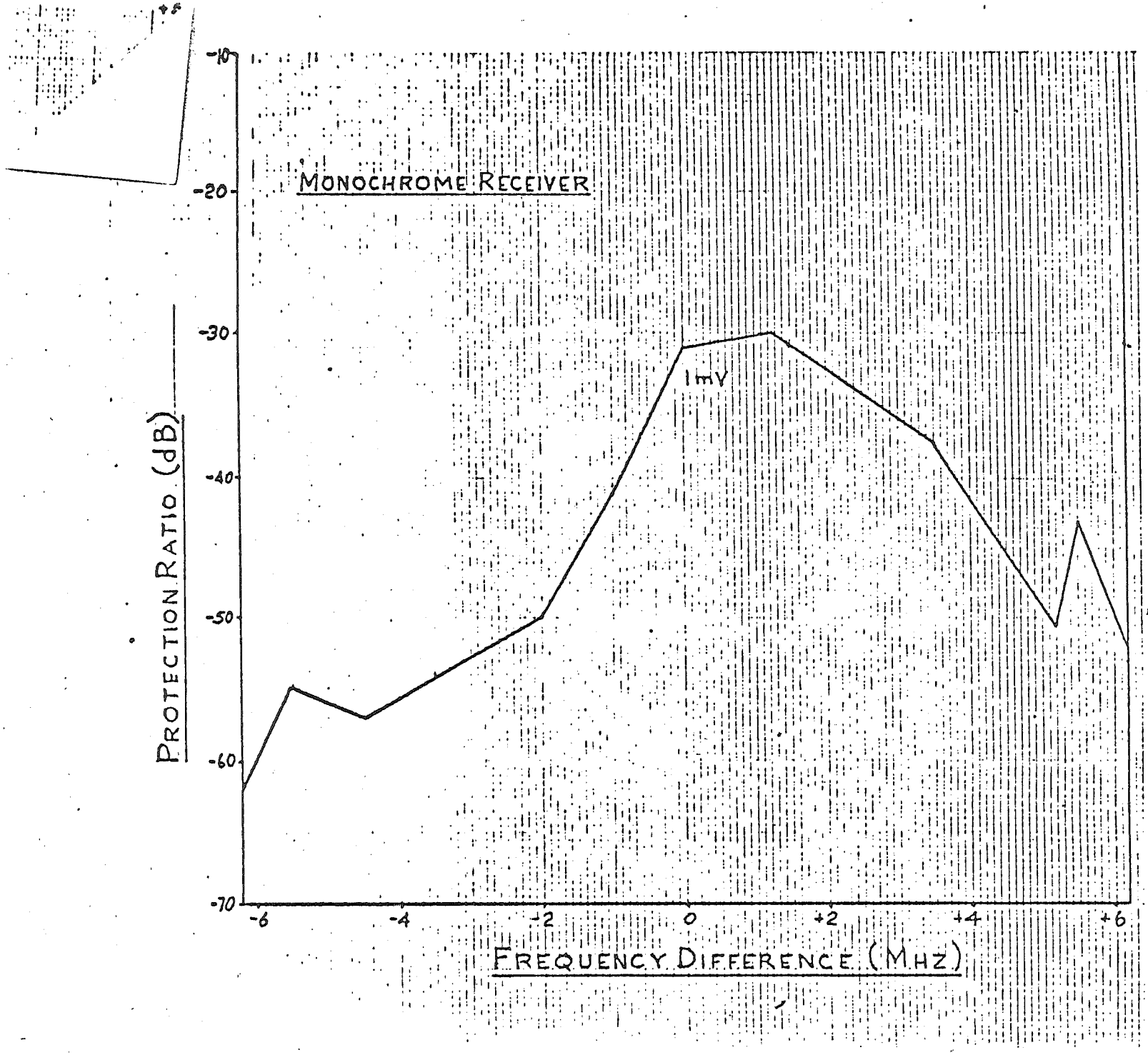
   (Terminal voltage at 75 ohms).

3. Standard Deviation

   = 1dB (in channel)

   = 6dB (out of channel)

FIGURE 4



PROTECTION RATIO FOR MONOCHROME TELEVISION SERVICE

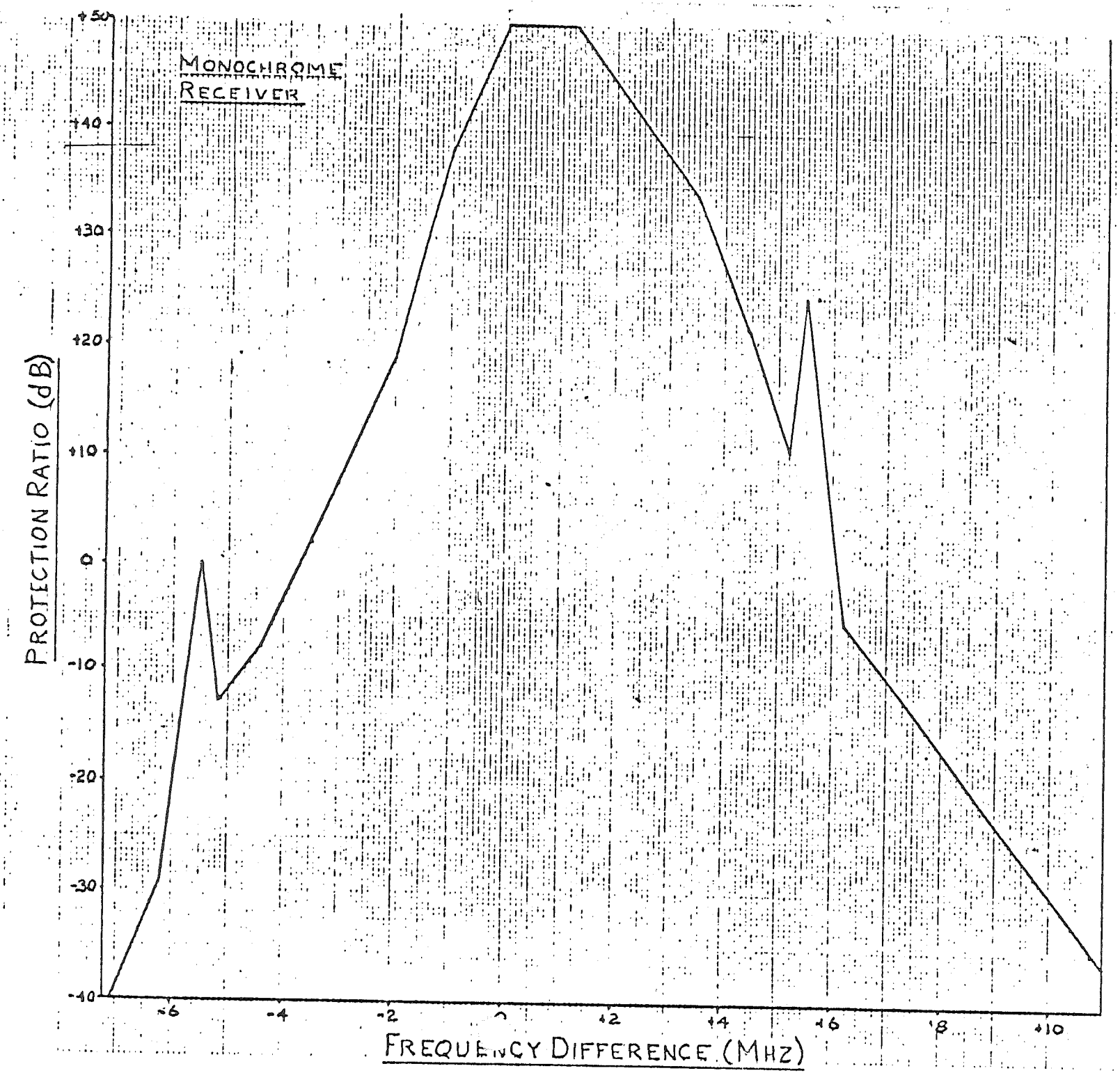
Interference from an FM service operating at half the frequency of the wanted TV service.

NOTE:

1. Frequency difference refers to difference between wanted vision carrier and internally generated second harmonic of unwanted FM service.

2. Voltage level refers to terminal voltage (75 ohms) of wanted TV service.

FIGURE 5



PROTECTION RATIO FOR MONOCHROME TELEVISION SERV

Interference from adjacent co-channel FM service.

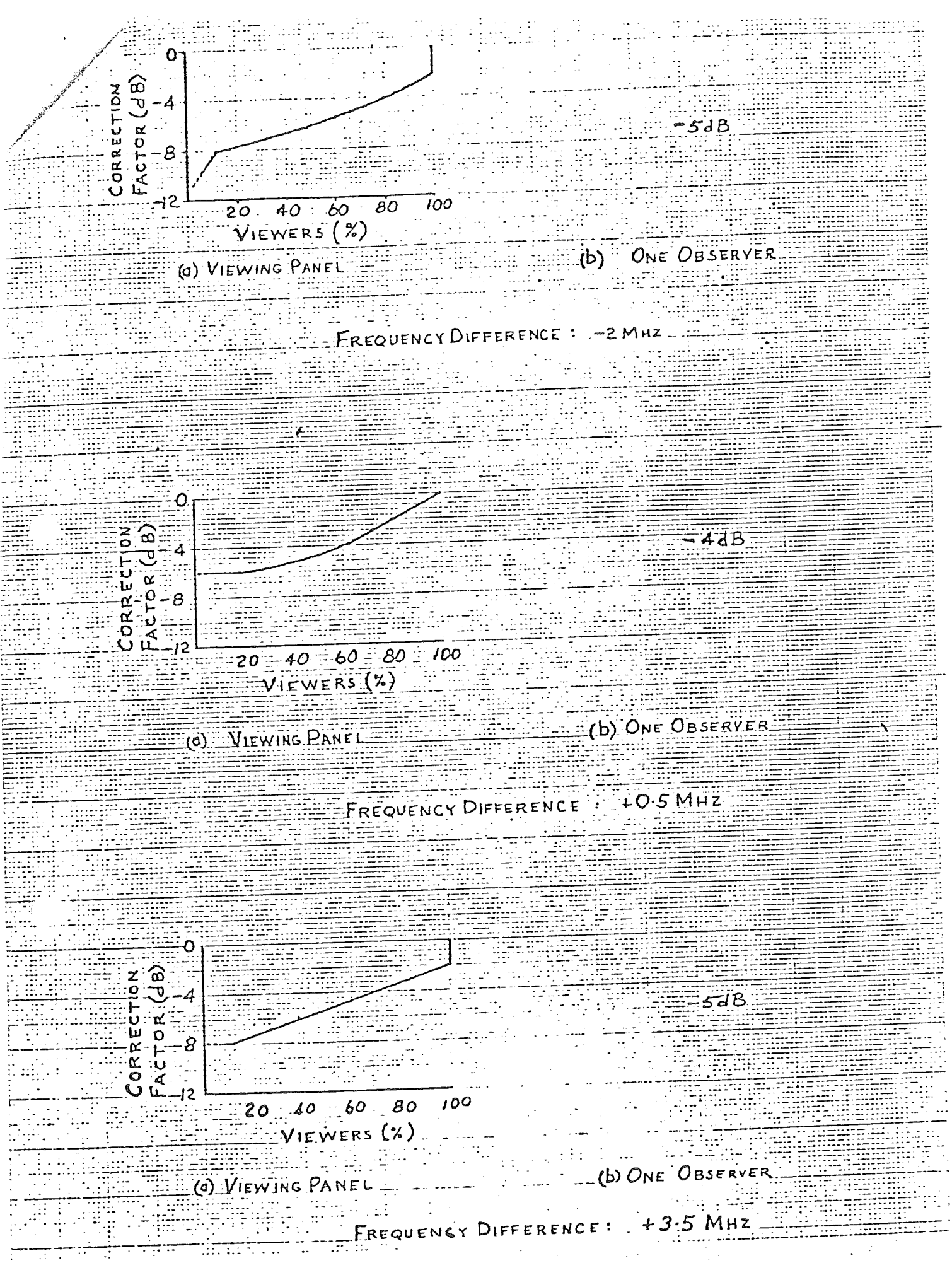
NOTE:

1. Frequency difference refers to difference between wanted vision carrier and unwanted FM service.

2. Wanted signal level is 1mV.

   (terminal voltage at 75 ohms)

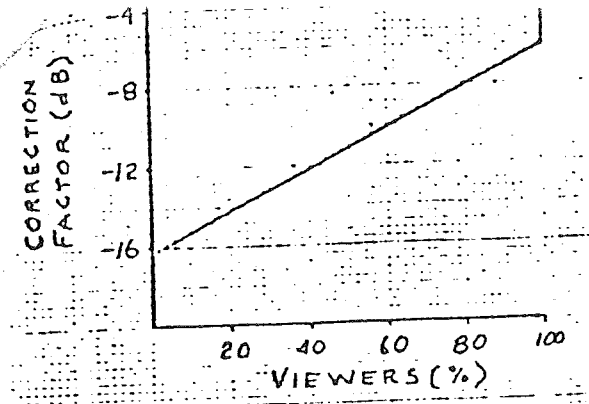
FIGURE 6



CORRECTION FACTOR FOR TELEVISION PROTECTION RATIO

Interference from FM service operating at half the frequency of the wanted TV service.

FIGURE 7

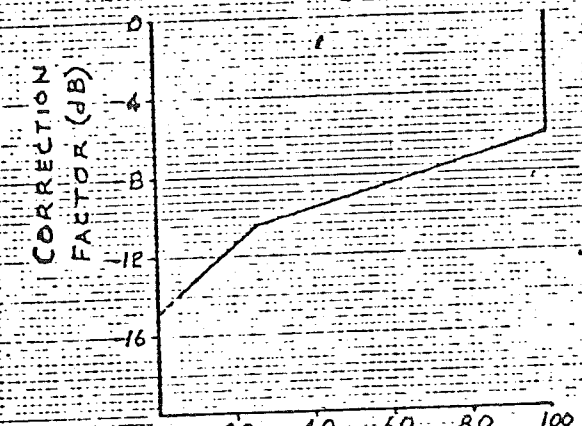


(a) VIEWING PANEL

-11dB

(b) ONE OBSERVER

FREQUENCY DIFFERENCE : -2 MHz

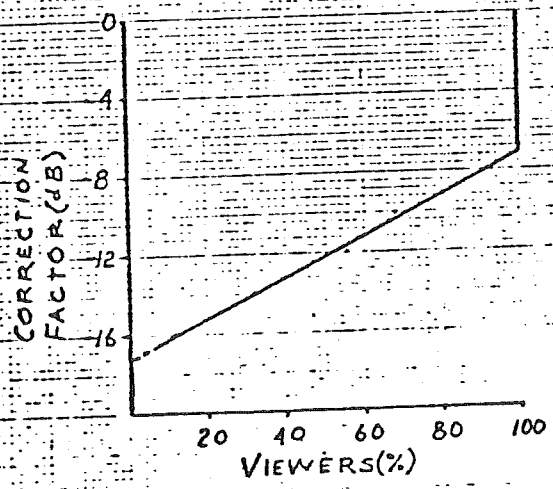


(a) VIEWING PANEL

-8dB

(b) ONE OBSERVER

FREQUENCY DIFFERENCE : +0·5 MHz



(a) VIEWING PANEL

-10dB

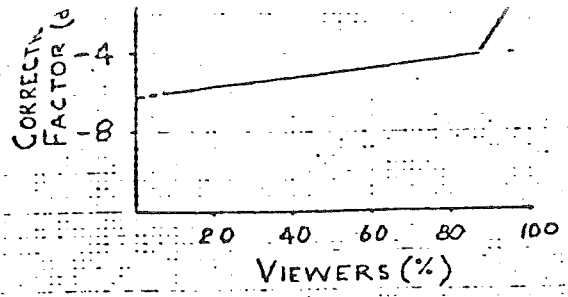
(b) ONE OBSERVER

FREQUENCY DIFFERENCE : +3·5 MHz

CORRECTION FACTOR FOR TELEVISION PROTECTION RATIO

Interference from adjacent and co-channel FM service.

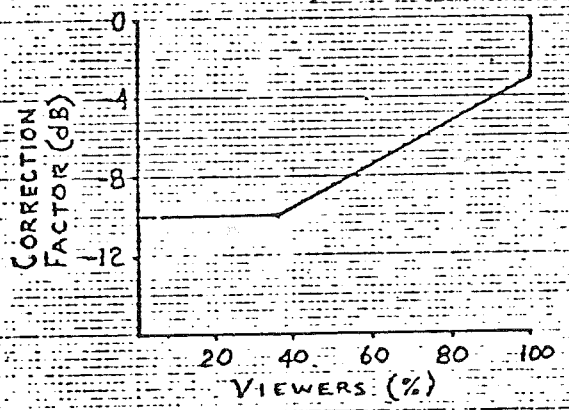
FIGURE 9



-3dB

(d) VIEWING PANEL (b) ONE OBSERVER

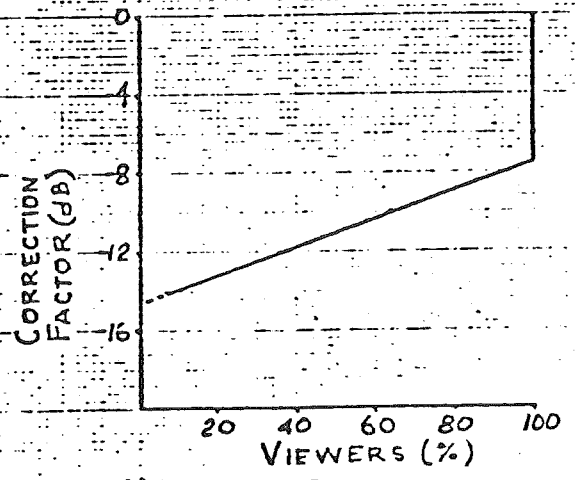
Interference from Channel 1. Wanted signal is channel 0.



-7dB

(d) VIEWING PANEL (b) ONE OBSERVER

Interference from TV service operating at the image frequency.



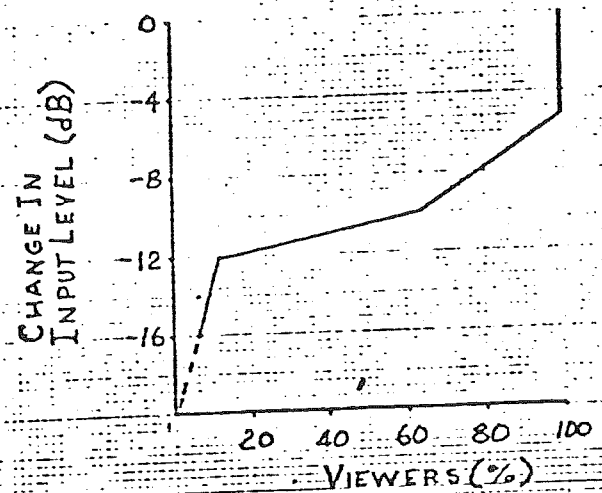
-6dB

(a) VIEWING PANEL (b) ONE OBSERVER

Interference from CW signal operating at IF (TV). Wanted signal is channel 0.

CORRECTION FACTORS FOR TELEVISION PROTECTION RATIOS

FIGURE 9



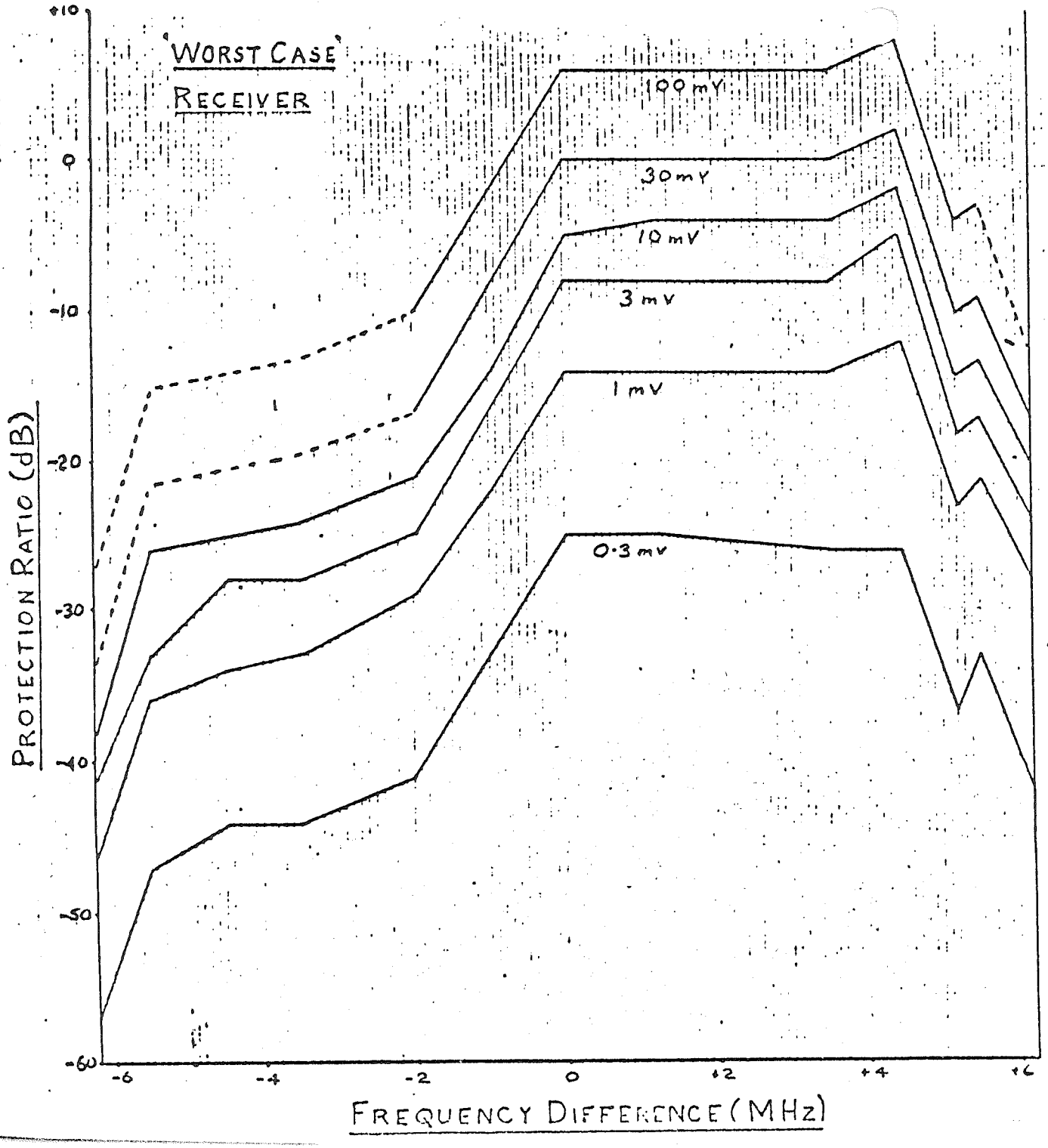
-6dB

(a) VIEWING PANEL

(b) ONE OBSERVER

CORRECTION FACTOR FOR NOISE THRESHOLD

FIGURE 10



PROTECTION RATIO FOR COLOUR TELEVISION SERVICE
(Worst Case)

Interference from an FM service operating at half the frequency of the wanted TV service.

NOTE:

1. Frequency difference refers to the difference between wanted vision carrier and internally generated second harmonic of unwanted FM service.

2. Voltage level refers to terminal voltage (75 ohms) of wanted TV service.

FIGURE 11