REDUCTION OF CROSSTALK
IN THE AUDIO CHANNELS OF THE
CANADIAN COMMUNICATIONS SATELLITE TELEVISION NETWORK

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ABSTRACT

REDUCTION OF CROSSTALK
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Magdy E. H. Battikha

Domestic Television transmission using the Canadian satellite Communications system started in February 1973. Two audio channels and one control channel are transmitted in addition to colour television programs.

The equipment processing the audio portion is called the Audio Subcarrier Equipment. The latter uses a subcarrier frequency of 6.8 MHz to be modulated by the multiplexed audio and control channels.

Shortly after the above date, it was observed that certain programs in audio 2 channel interfered with audio I, which is the TV audio channel. The interference is of intelligible and unintelligible crosstalk varieties.

The purpose of this report is to present the various tests performed in order to determine the causes of the crosstalk problem. Several possible solutions to the problem are derived from the test results. It is shown that there is one solution that is simple and effective: The removal of preemphasis and deemphasis stages that are

part of the Audio Subcarrier Channel equipment. The above solution has been recommended and approved.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 General

The Canadian satellites are a part of a multi-purpose communications system[1]. The system includes tracking, telemetry and command facilities; a control center and numerous earth stations of different types scattered throughout Canada. Each satellite has twelve high capacity microwave channels, and each channel is capable of relaying up to 960 one-way multiplexed voice signals using a single carrier, or one colour television program.

The contents of a television channel are :

(i) One television video signal, of bandwidth = 4.2 MHz.

(ii) A television audio channel (called here Audio 1), of bandwidth = 5.0 kHz.

(iii) A radio program channel (called here Audio 2), of bandwidth = 5.0 kHz.

(iv) A control channel, of bandwidth = 3.1 kHz.

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1. This system is owned and operated by Telesat Canada, a Canadian Corporation.

(v) A continuity pilot, of frequency = 25.1 kHz.

Signals (ii) to (v) inclusive are multiplexed, frequency-modulated (FM), and combined with signal (i) to form the Transmission baseband. The FM carrier, known as audio subcarrier, is of frequency = 6.8 MHz. This subcarrier is modulated by the multiplexed signal of the following make-up.

(i) Audio 1 : 0 to 5.0 kHz.

(ii) Audio 2 : 7 to 12.0 kHz.

(iii) Control channel : 18 to 22 kHz.

(iv) Pilot : 25.1 kHz.

Thus, the transmission baseband contains the TV signal (10 Hz to 4.2 MHz), and the modulated audio subcarrier at 6.8 MHz.

1.2 History of the problem

During the first year of operation, it was observed that there is a noticeable - and sometimes objectionable - crosstalk among the contents of the television channels. More specifically, and at the receiving end, it was observed to be between the TV and audio signals, and from audio 2 to audio 1. Since marked crosstalk is a serious defect in communication systems, its elimination is essential. Although the problem is multifaced,

this report deals mainly with audio 2-to-audio 1 crosstalk.

To determine the causes of the observed crosstalk, several subjective tests were run by trained listeners. However, the extent of interference apparently varied according to the different audio 2 program content. In some cases, and in order to reduce the crosstalk, operators at the transmitting end would attenuate the power of audio 2 program, but still, high peaks would cause interference into audio 1 (e.g., at high musical notes, or with high human voice volumes). Then, it was decided to make an in-depth evaluation of the audio equipment, in order to quantitatively assess the performance of this particular design.

1.3 The author's assignment

The evaluation had the following objectives :

(i) To determine by test the limitations of the equipment that processes the audio signals of audio 1 and audio 2, and to determine the causes of the crosstalk from audio 2 to audio 1.

(ii) From the test results, the method of eliminating the crosstalk should evolve. A general approach would not exclude the possibility of equipment redesign by the manufacturer if necessary.

CHAPTER 2

THE VARIOUS TESTS OF THE AUDIO EQUIPMENT

2.1. General

To perform the tests, the audio equipment had to be isolated from the series of other stages that form the ground communications equipment. At one earth station, the author removed a transmit audio shelf with its power supply[1], audio 1, 2 and control multiplex modules, and the subcarrier modulator card[2]. The latter also contains the combining stages in front of the modulator. Also, a receive audio shelf was removed that houses the power supply, a FM demodulator unit which also includes a predetection band pass filter and splitting stages, and audio 1, 2 and control receiving units. Figures 2.1 and 2.2 are functional diagrams of the transmit and receive shelves respectively.

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1. i.e., The AC-to-DC converter that supplies DC power to all shelf modules.

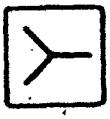
2. The terms "card", "unit" and "module" are used interchangeably in this report.

GLOSSARY OF SYMBOLS

AMPLIFIER

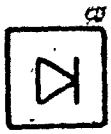
ATTENUATOR

COMBINER



FREQUENCY CONVERTER

AM, UNBALANCED DETECTOR



DE-EMPHASIS

PRE-EMPHASIS

HIGH PASS FILTER

LOW PASS FILTER

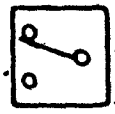
BAND PASS FILTER

LEVEL ADJUSTMENT

CRYSTAL

TRANSFORMER

SWITCH



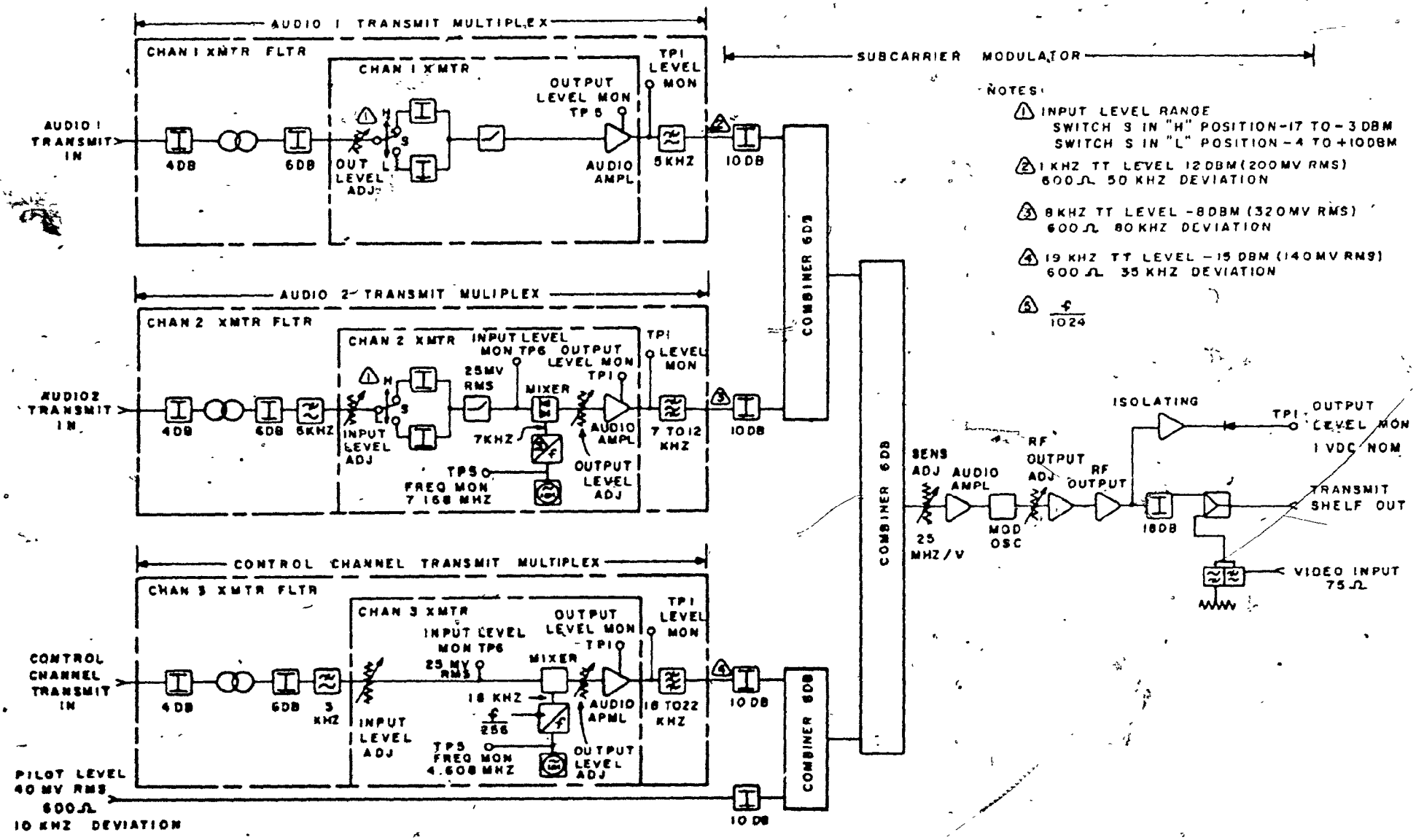


FIGURE 2-1 SUBCARRIER AUDIO TRANSMITTER, FUNCTIONAL DIAG.

(MODIFIED FROM RCA INSTRUCTION BOOK 802912Z)

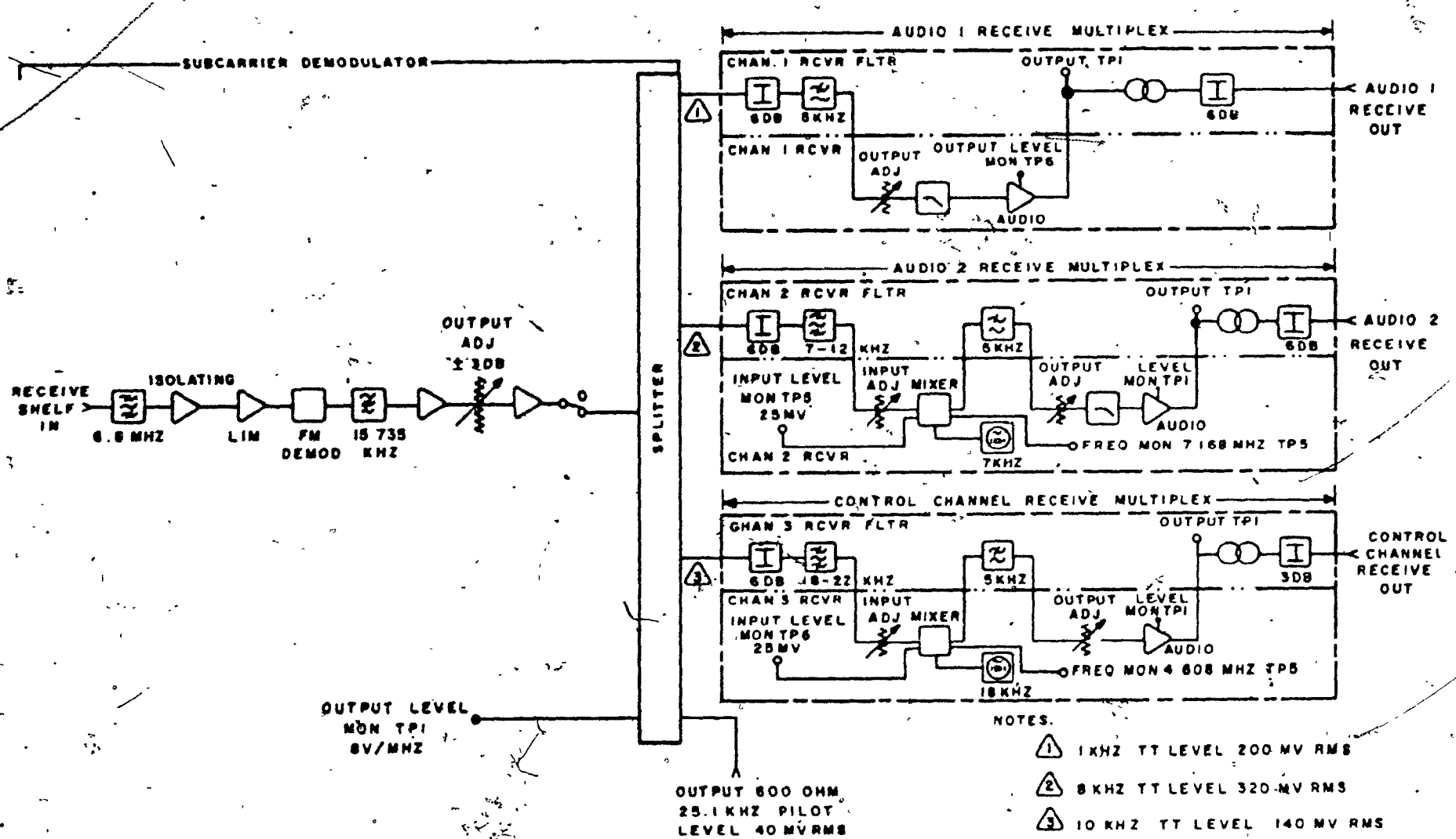


FIGURE 2-2 SUBCARRIER AUDIO RECEIVER, FUNCTIONAL DIAG

MODIFIED FROM RCA INSTRUCTION BOOK 8029123

The two shelves thus isolated were placed back-to-back (in an electrical sense) and formed the "system under test". This system was subjected to systematic tests that brought out the pertinent limitations of its stages.

The tests performed were[1] :

(i) Determination of total harmonic distortion (THD) of audio 1 and audio 2 channels. This was done in several steps. Firstly, the receiving multiplex stage alone was tested. This test configuration is depicted by solid lines in Figure 2.3. Secondly, the transmitting and receiving multiplex stages only were connected together and tested. Figure 2.4 shows this configuration. Thirdly, all stages of the transmitting and receiving shelves were placed in circuit and thus tested. This test configuration is shown in Figure 2.5. Finally, a THD test was performed on both audio channels with all stages in circuit except the preemphasis[2] and deemphasis stages.

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1. The actual order of tests presented later in this chapter is found in the Table of Content.

2. According to C.C.I.T.T., Rec. J-21, Geneva 1964. Ref. Appendix D.

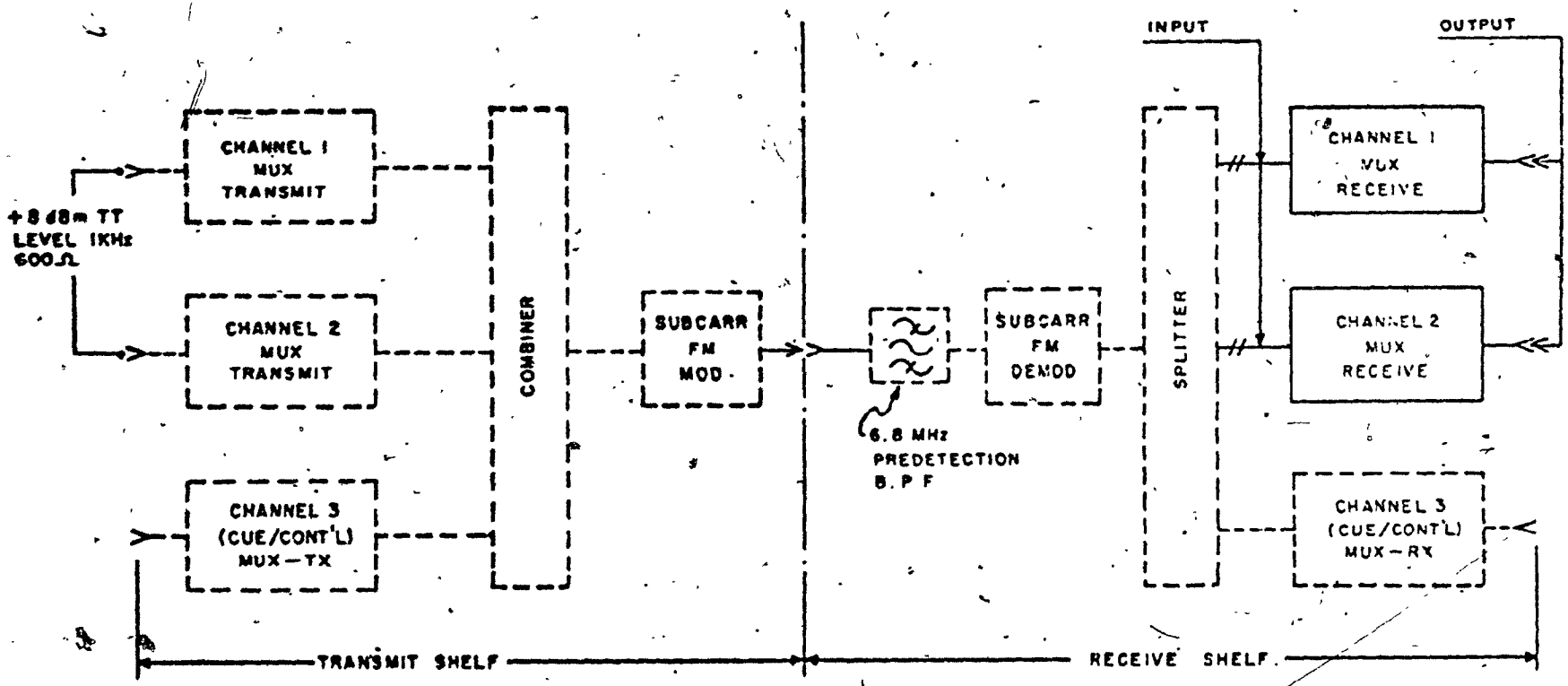

FIG. 2.3

RECEIVE MULTIPLEX, AUDIO 1 AND 2

(SOLID LINES INDICATE SECTIONS UNDER TEST)

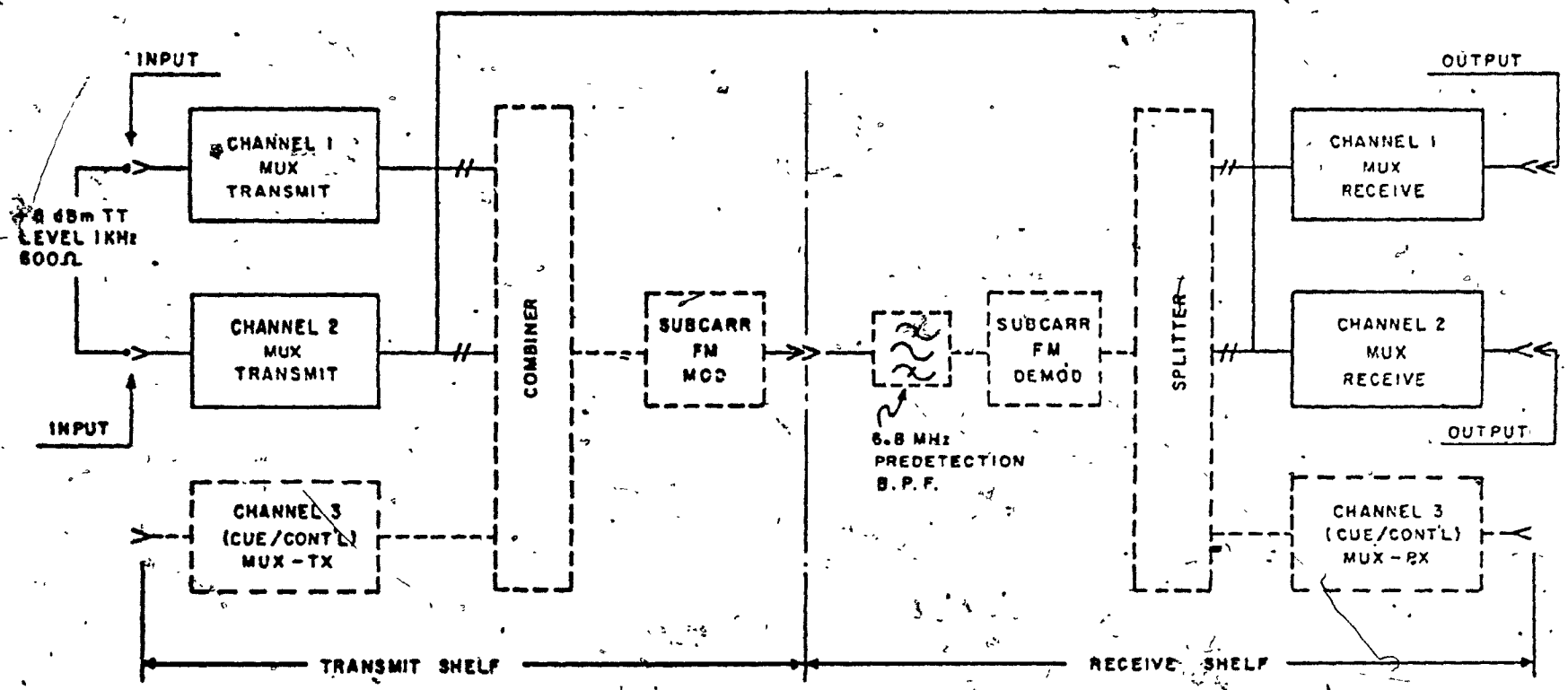

FIG. 2.4

TRANSMIT AND RECEIVE MULTIPLEX, AUDIO 1 AND 2

(SOLID LINES INDICATE SECTIONS UNDER TEST)

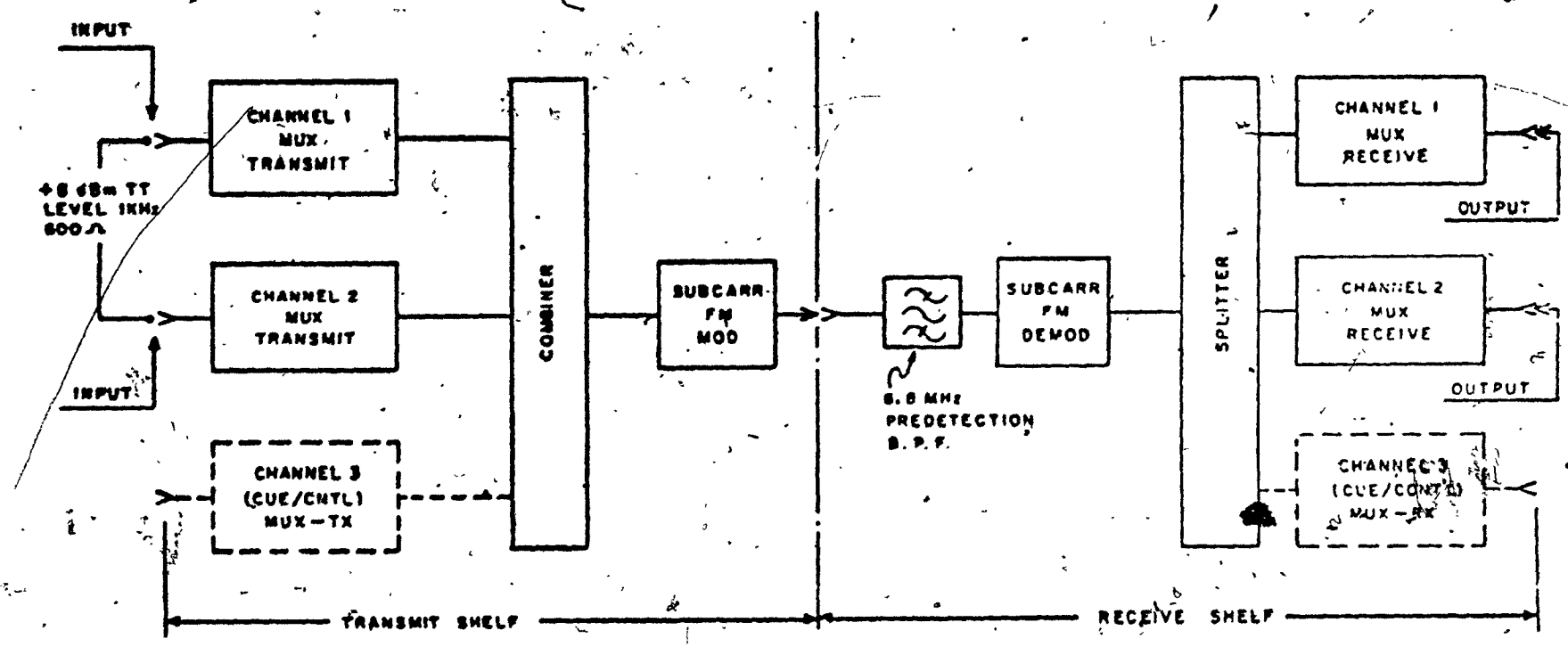

FIG. 2.5

COMPLETE TRANSMIT AND RECEIVE STAGES
AUDIO 1 AND 2
(SOLID LINES INDICATE SECTIONS UNDER TEST)

(ii) Determination of audio 2-to-audio 1 crosstalk, and of audio 1-to-audio 2 crosstalk[1], by gradually increasing the frequency and level into one audio channel, and observing the resulting increase above basic noise on the other audio channel. For this series of tests, and after testing audio 1 & 2 with all stages in circuit, certain stages were taken out and the equipment tested as follows : firstly, without pre-and-deemphasis stages and then without the receiving predetection band pass filter.

(iii) Frequency response curves were obtained for audio channels 1 and 2, for increasing input frequency and level. The purpose of these tests was to record actual variations in frequency response after the removal of the pre-and-deemphasis stages.

(iv) Verification of the characteristics of the predetection band pass filter.

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1. Audio 1-to-Audio 2 crosstalk tests were performed for comparison only.

2.2 Test results

In this section, an explanation is given about the conditions of every test performed, followed by the results obtained. The latter are in a table form first, then are displayed in a graph form for an easier grasp of the equipment performance.

2.2.1 Total harmonic distortion; Receive audio 1, multiplex only. Ref. Figure 2.3.

Input: Demodulator splitter OUT

Output: Audio channel OUT, at patch panel[1].

Receiving section lineup:

Input = 200 mV, at 1 kHz

Output = + 8.0 dBm

Test method: The input level is varied so as to obtain increased channel output levels, then THD is measured corresponding to the different channel output levels. This is repeated for the frequencies 400 Hz, 1 kHz and 2 kHz.

---

1. A patch panel was used to duplicate actual operating conditions. It is also a convenient point for the audio channel input and output, instead of screw-type terminals at the back of the audio shelves.

Test equipment:

RMS voltmeter, model HP 400 L - RCA serial number Co115S;

Distortion analyzer, model HP 330 B - RCA serial number L2A20 S;

Digital oscillator, model HP 4204 A.

Results[1]:

TABLE 2.1

THD - Audio 1 Receive Multiplex only

OUTPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	% THD AT f = 2 kHz
8	0.12	0.1	0.11
12	0.12	0.11	0.08
16	0.22	0.16	0.17
20	0.35	0.35	0.30

The above data is shown in Figure 2.6.

1. Oscillator THD is given in Appendix C.

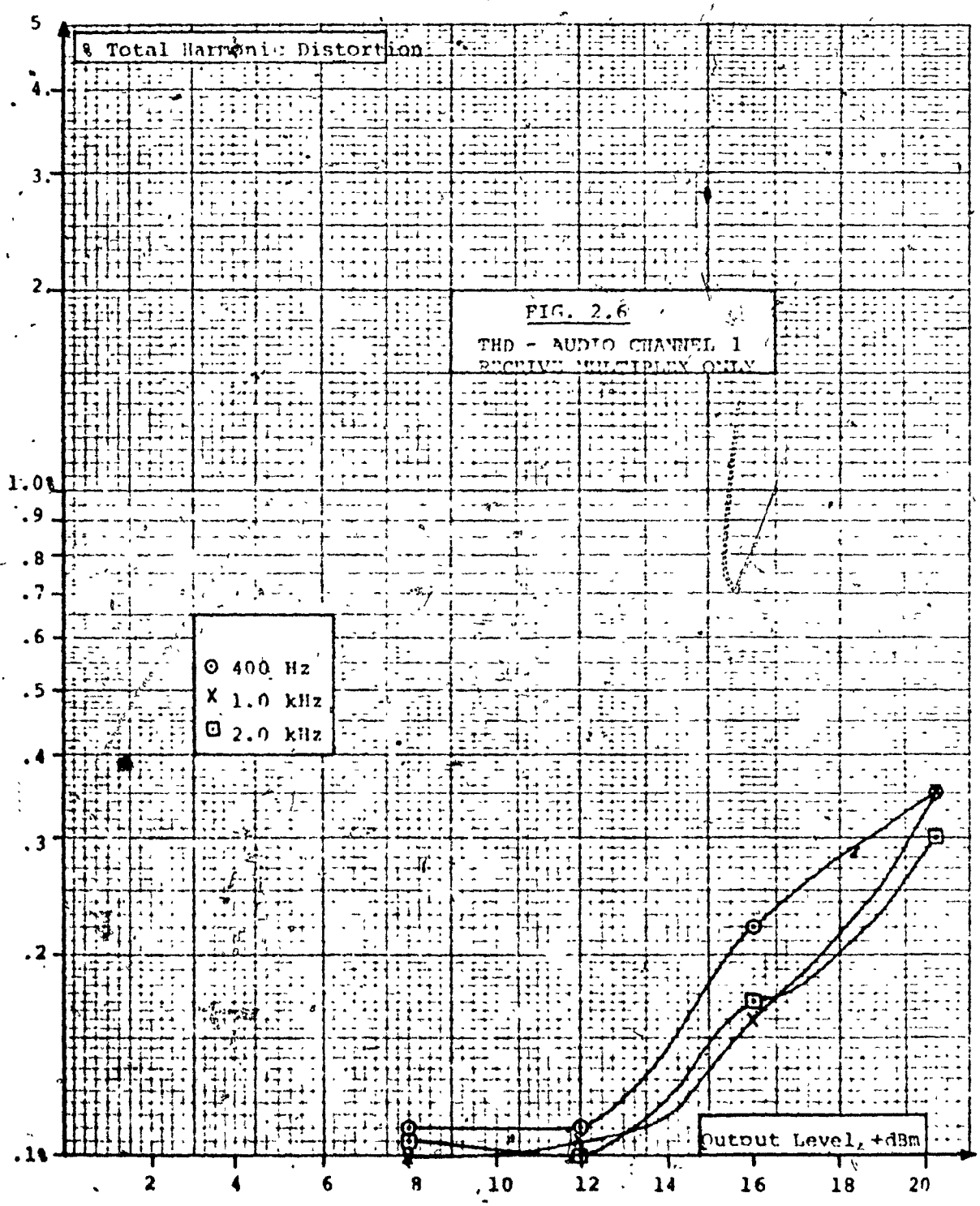


FIG. 2.6

THD - AUDIO CHANNEL 1
RECEIVE MULTIPLEX ONLY

2.2.2 Total harmonic distortion - Transmit and receive audio channel 1, multiplex. Ref. Figure 2.4. A combiner and a splitter are used in place of the subcarrier modulator and demodulator units.

Input: Audio channel 1 Transmit, at patch panel.

Output: Audio channel 1 Receive, at patch panel.

Lineup:

Transmit: With the Test Tone (TT) of 1 kHz at + 8.0 dBm, the Transmit output level is adjusted to produce 200 mV RMS (600 ohm) at the output of the 5 kHz low pass filter (L.P.F.) Ref. Figure 2.1.

Receive : Lineup unchanged from that of test 2.2.1.

Test method: The input level is varied so as to obtain increased channel output levels, then THD is measured corresponding to the different channel output levels. This is repeated for the frequencies 400 Hz, 1 kHz and 2 kHz.

Test equipment:

RMS Voltmeter, HP 400 L -

RCA Serial Number Co115S;

Distortion analyzer HP 330 B -

RCA Serial Number L2A20S;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.2

THD - Audio 1, Transmit and Receive Multiplex only -

OUTPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1.0 kHz	% THD AT f = 2.0 kHz
7.4	0.45	0.35	0.40
11.4	0.31	0.35	0.25
15.4	0.40	0.40	0.25
19.4	0.40	0.40	0.35
21.4	10.0	9.0	11.5

The above data is shown in Figure 2.7.

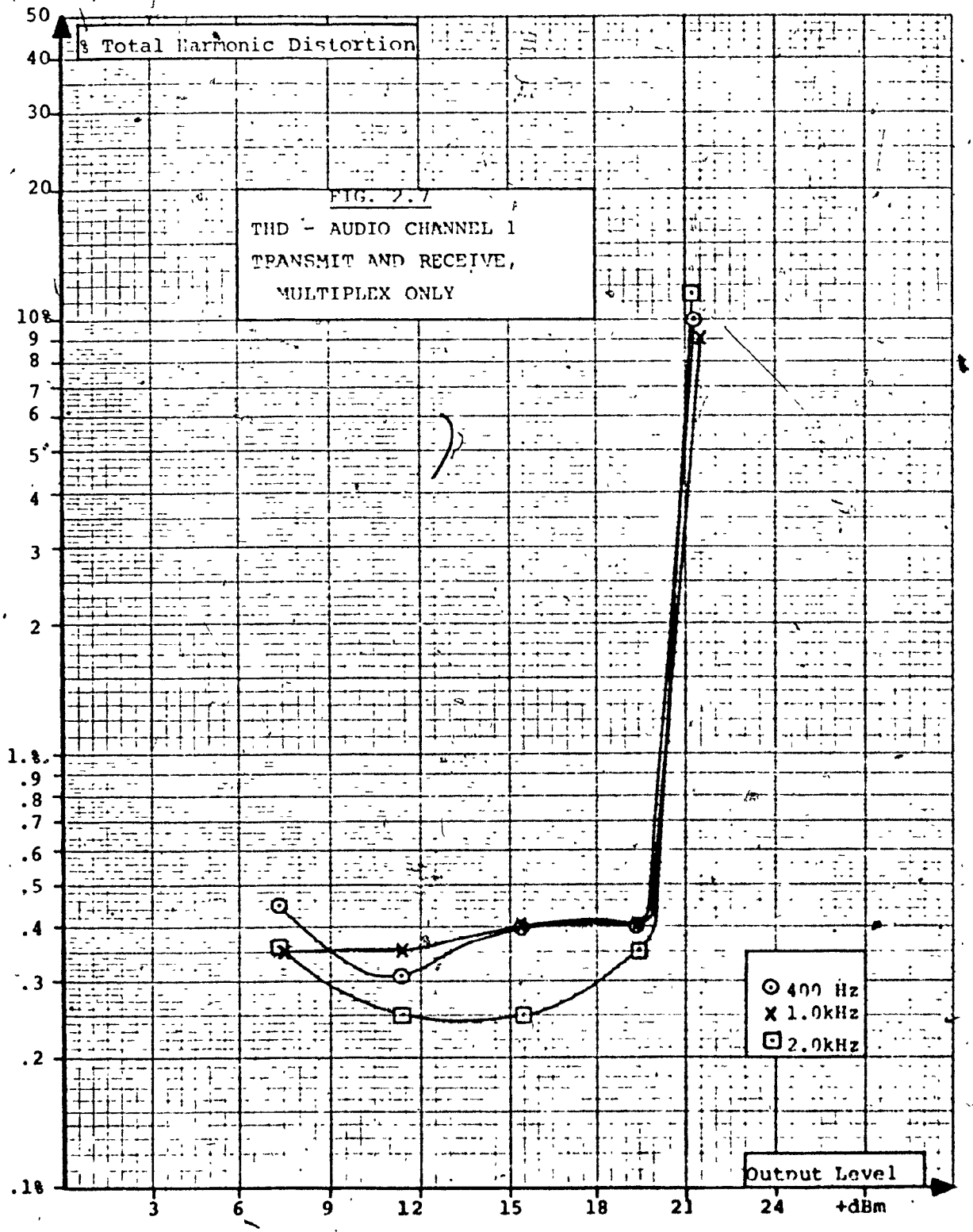


FIG. 2.7

THD - AUDIO CHANNEL 1
TRANSMIT AND RECEIVE,
MULTIPLEX ONLY

2.2.3 Total harmonic distortion - Audio channel 1 transmit section, including preemphasis, FM modulator channel 1 receive section, with 6.8 MHz B.P.F., demodulator and deemphasis. Ref. Figure 2.5.

Input: Audio channel 1 Transmit, at patch panel.

Output: Audio channel 1 Receive, at patch panel.

Lineup:

(i) 1 kHz Test Tone level: 200 mV RMS at combiner-in and splitter out.

(ii) With 4 kHz at -17.7 dBm, a Bessel Zero is obtained for 50 kHz RMS deviation.

(iii) With + 8 dBm input at 1 kHz its receive channel output is adjusted to obtain + 8 dBm at the patch panel.

Test Method: The input level is varied so as to obtain increased channel output levels, then THD is measured corresponding to the different channel output levels. This is repeated for the frequencies 400 Hz, 1 kHz and 2 kHz.

Test equipment: Panoramic spectrum analyzer Model SPA-3, RCA serial number 169U211

RMS Voltmeter, HP 400 L -

RCA serial number Co115S;

Distortion analyzer HP 330 B -

RCA serial number L2A20S;

Frequency counter HP 524 C -

RCA serial number R4LO3E;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.3

THD - Audio 1, Transmit and Receive, all stages in circuit

INPUT LEVEL (+ dBm)	% THD AT f= 400 Hz	% THD AT f= 1.0 kHz	% THD AT f= 2.0 kHz	% THD AT f= 3.0 kHz	% THD AT f= 4 kHz	% THD AT f= 5 kHz
4	----	----	----	0.70	0.70	0.80
8	0.70	0.62	0.56	0.40	.45	0.56
12	0.62	0.56	0.40	0.25	.28	0.35
16	0.56	0.50	0.40	0.22	2.8	4.0
18	0.50	0.45	0.31	0.28	3.2	2.5
20	0.56	0.50	0.35	2.0	13.0	Note at + 14, THD= .22%
22	2.5	20.0	2.30	13.0	----	

The above data is shown in Figure 2.8

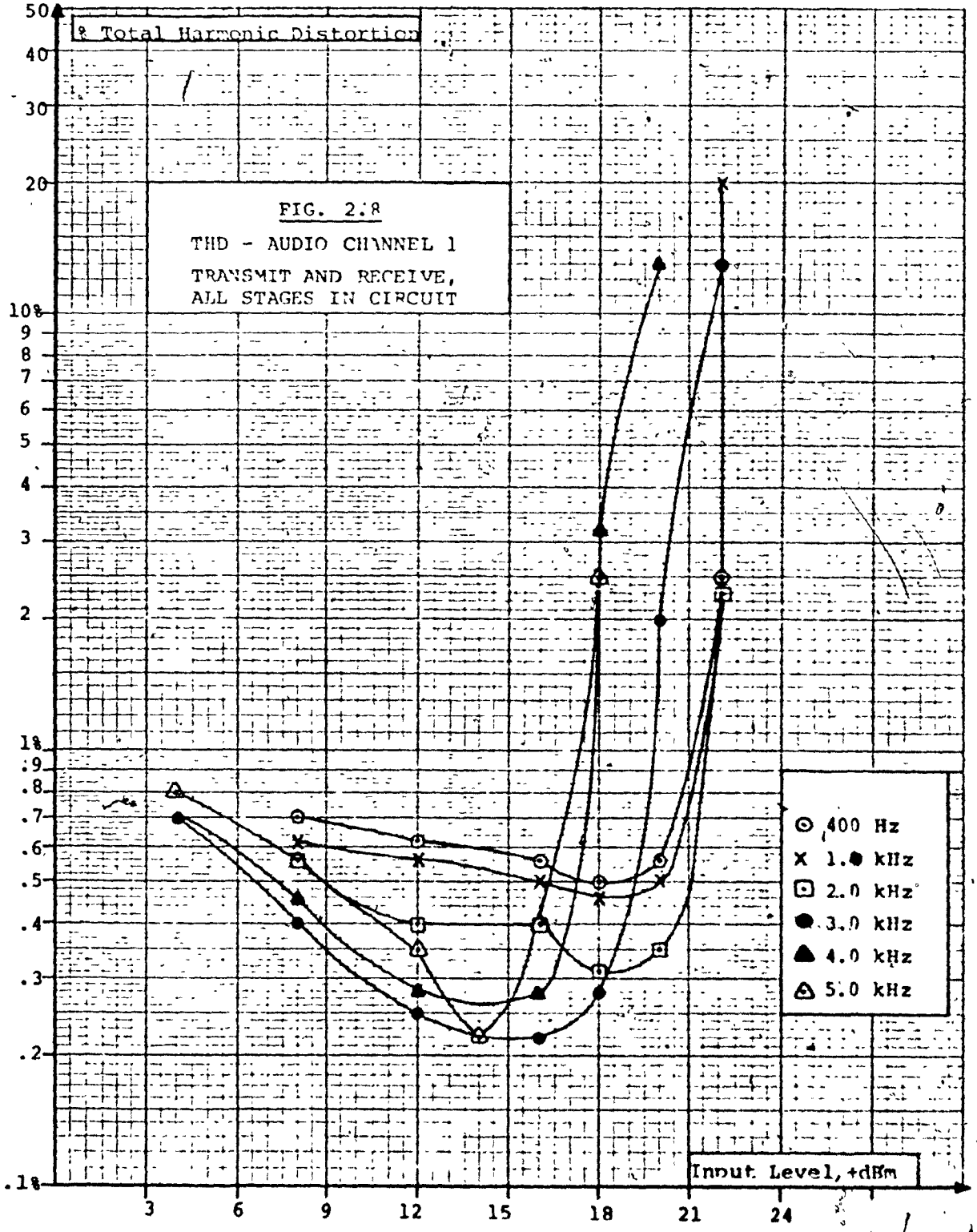


FIG. 2.8

THD - AUDIO CHANNEL 1

TRANSMIT AND RECEIVE, ALL STAGES IN CIRCUIT

2.2.4 Total harmonic distortion - Audio channel 1, transmit and receive with all stages except pre-and-deemphasis.

Input: Audio channel 1 Transmit-in, at patch panel

Output: Audio channel 1 Receive-out, at patch panel

Equipment lineup:

(i) With 4 kHz Test Tone level -17.7 dBm, the transmit output level is adjusted for Bessel Zero at Transmit Shelf OUT. Therefore, the same deviation is maintained as with preemphasis (50 kHz RMS).

(ii) With 1 kHz Test Tone level at + 8 dBm at input, the channel output, is adjusted to obtain + 8 dBm at the receive patch panel.

Test method: The input level is varied so as to obtain increased channel output levels, then THD is measured corresponding to the different channel output levels. This is repeated for the frequencies 400 Hz, 1 kHz, 2 kHz, 3 kHz and 4.5 kHz.

Test equipment:

Panoramic spectrum analyzer model SPA-3 -
RCA serial number 169U211;
RMS Voltmeter, HP 400 L -
RCA serial number Co115S;
Distortion analyzer HP 330 B -
RCA serial number L2A20S;
Frequency counter HP 524 C -
RCA serial number R4L03E;
Digital oscillator, model HP 4204 A.

Results:

TABLE 2.4

THD - Audio 1, all stages in circuit except pre-and-deemphasis

INPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	% THD AT f = 2 kHz	% THD AT f = 3 kHz	% THD AT f = 4.5 kHz
8	.35	.31	.25	.22	.25
12	.28	.25	.22	.15	.14
16	.28	.22	.22	.14	.1
18	.28	.22	.25	.17	---
20	.28	.28	.25	.22	.31
22	1.50	16.0	1.0	1.6	---

The above data is shown in Figure 2.9.

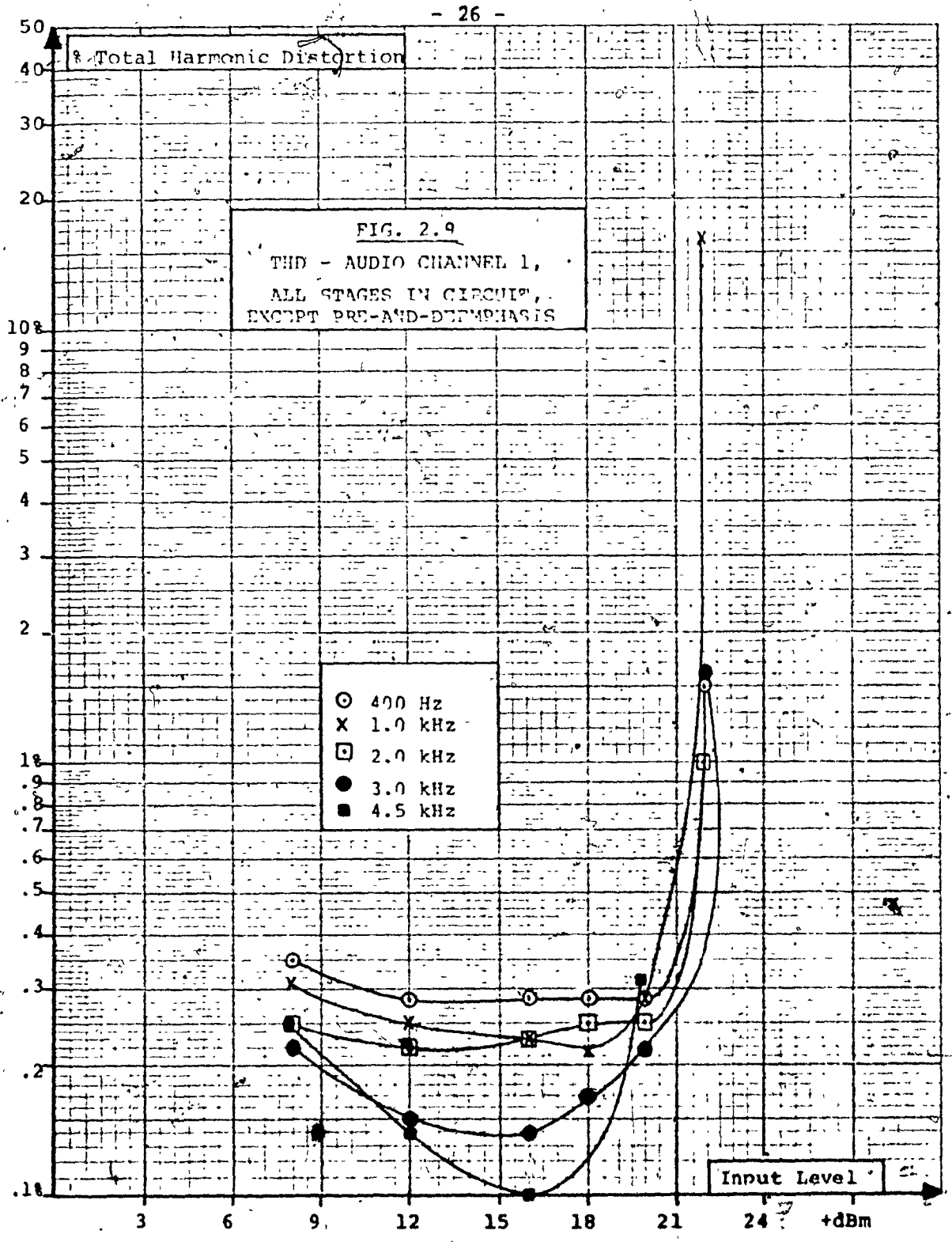


FIG. 2.9

THD - AUDIO CHANNEL 1,

ALL STAGES IN CIRCUIT,

EXCEPT PRE-AND-DEEMPHASIS

2.2.5 Audio 2 to Audio 1 crosstalk; Measurement of audio channel 1 output program weighted noise with increasing single tone interference from channel 2. This equipment includes pre-and-deemphasis, and subcarrier modulator and demodulator, and postdetection band pass filter stages.

Input to channel 2: 600 ohm - single tones at patch panel.

Output of channel 1: Patch panel into the Noise Measuring Set.

Equipment lineup: Continuity is checked with 1 kHz Test Tone at +8 dBm on both channels 1 and 2, in turn, and it is ensured that nominal channel receive outputs are obtained.

Test method:

(i) Basic noise on channel 1, Program Weighted is measured[1].

(ii) The output weighted noise on channel 1 is measured increasing frequency and level into channel 2.

1. Noise readings were in dBrn (Program Weighted) - they have been converted to noise in dBm using the conversion: dBm = -90 + dBrn reading.

Test equipment:

RMS voltmeter, HP 400 L -

RCA serial number Co115S;

3A Noise Measuring Set -

Western Electric RCA M3BoiT, with

program weighting: N.E., serial number 497 B;

Digital oscillator, model HP 42[illegible] A.

Results: Basic Noise on Audio 1 = -58 dBm.

TABLE 2.5

Audio 2 to Audio 1 crosstalk with all stages in circuit

INPUT LEVEL TO CH. 2 (+ dBm)	CROSSTALK IN CH. 1 AT f= 400 Hz (- dBm)	CROSSTALK IN CH. 1 AT f= 1 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 2 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 3 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 4 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 5 kHz (- dBm)
0	58	58	58	58	57	57.5
2	--	--	--	--	56.5	57
4	58	58	57.5	58	56	56.5
6	--	--	--	--	55	54
8	58	57.5	56	57.5	49.5	46
9	--	--	--	--	--	43
9.5	--	--	--	--	--	43
10	--	--	55	53.5	44	23
10.5	--	--	--	--	13	then
12	58	56.5	52	52.5	then	crash
13	--	--	--	37	crash	
14	--	--	51	then		
15	--	--	44	crash		
16	57.5	54.5	then			
18	--	49.5	crash			
19	--	49.5				
20	57	26.0				
22	53.5	then crash				

The above data is shown in Figure 2.10.

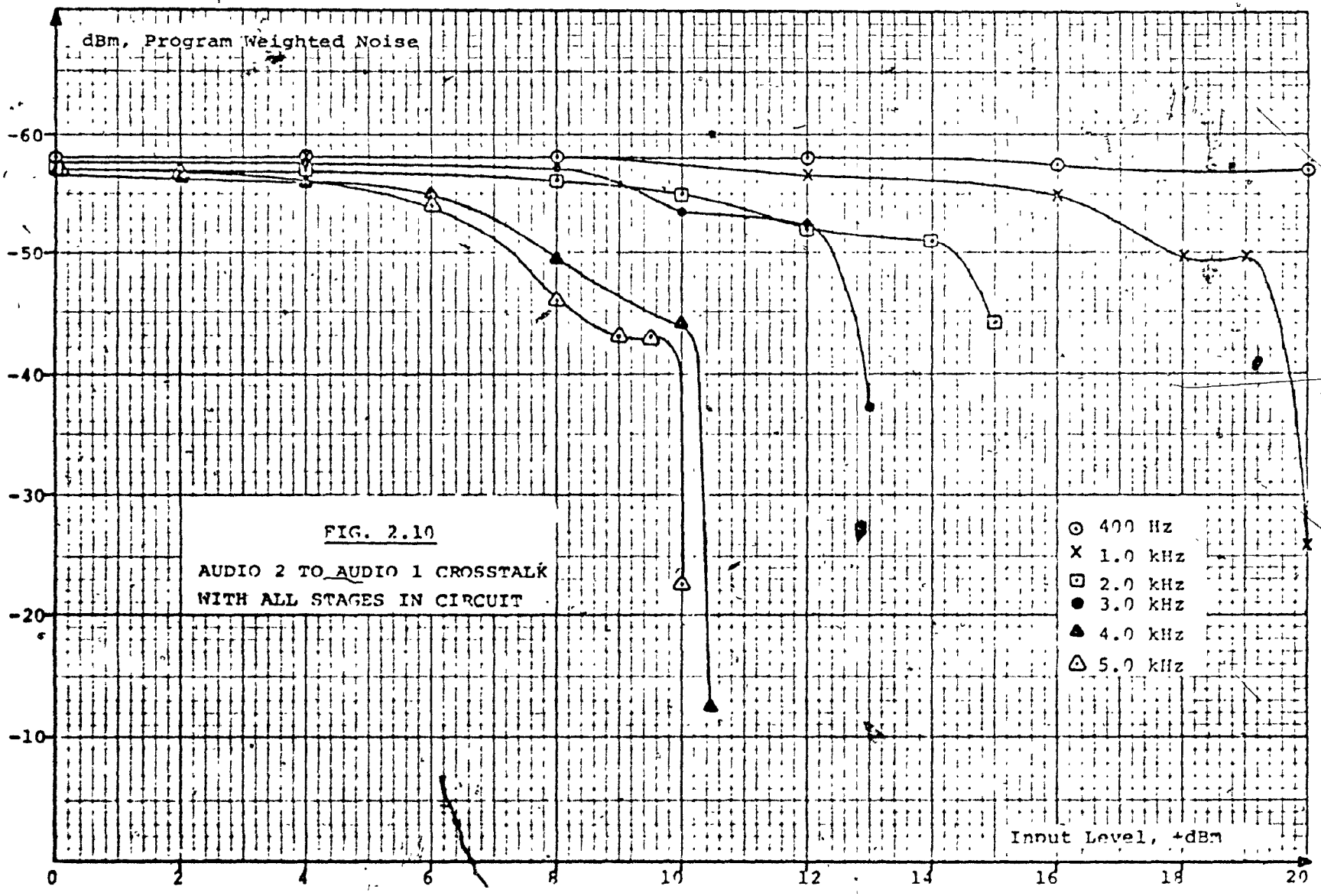


FIG. 2.10

AUDIO 2 TO AUDIO 1 CROSSTALK
WITH ALL STAGES IN CIRCUIT

2.2.6 Audio 2 Audio 1 crosstalk; Measurement of audio channel 1 output program weighted noise with increasing single tone interference from channel 2. The equipment includes subcarrier modulator and demodulator, and post-detection band pass filter stages. The pre-and-deemphasis stages are removed.

Input to channel 2: 600 ohm - single tones at patch panel.

Output of channel 1: From patch panel into the Noise Measuring Set.

Equipment lineup:

(i) The transmit shelf is adjusted for 50 kHz RMS deviation, given a 4 kHz, -17.7 dBm input to channel 1.

(ii) The receive output level is adjusted on the receive shelf to obtain +8 dBm at channel 1 out, patch panel, for 1 kHz Test Tone at +8 dBm input to channel 1 Transmit-in, at patch panel.

(iii) The deviation on channel 2 (80 kHz RMS) is adjusted with 1 kHz input at -7.4 dBm.

(iv) The output level on channel 2 is adjusted to obtain +8 dBm into channel 2 Transmit-in, at patch panel.

Test method:

(i) The Basic noise is measured on channel 1, Program Weighted.

(ii) The output weighted noise is measured on channel 1 with increasing frequency and level into channel 2.

Test equipment:

Panoramic spectrum analyzer, model SPA-3 - RCA serial number 169U211;

RMS voltmeter, HP 400 L - RCA serial number Co115S;

3A Noise Measuring Set - Western Electric RCA M3BoiT, with program weighting: N.E., serial number 497B;

Digital oscillator, model HP 4204 A.

Results: Basic Noise in Channel 1 = -53.5 dBm.

TABLE 2.6

Audio 2 to Audio 1 crosstalk, with pre-and-deemphasis removed

INPUT LEVEL TO CH. 2 (+ dBm)	CROSSTALK IN CH. 1 AT f= 400 Hz (- dBm)	CROSSTALK IN CH. 1 AT f= 1 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 2 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 3 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 4 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 5 kHz (- dBm)
2	--	--	--	--	--	52.5
4	--	--	--	--	--	52.2
6	--	--	52.5	--	--	52.0
8	53.5	52.5	51.5	52.5	52.0	51.5
10	--	52.5	51.0	52.0	51.0	50.5
12	53.5	52	50.0	52.0	50.5	48.5
14	--	51.0	48.5	51.0	49.0	48.0
16	52.0	50.0	47.0	50.0	47.0	46.0
18	50.5	48.5	45.0	49.5	44.5	44.5
18.5	49.5	46.0	41.5	48.5	--	43.5
19	then crash	then crash	then crash	then crash	then crash	then crash

The above data is shown in Figure 2.11.

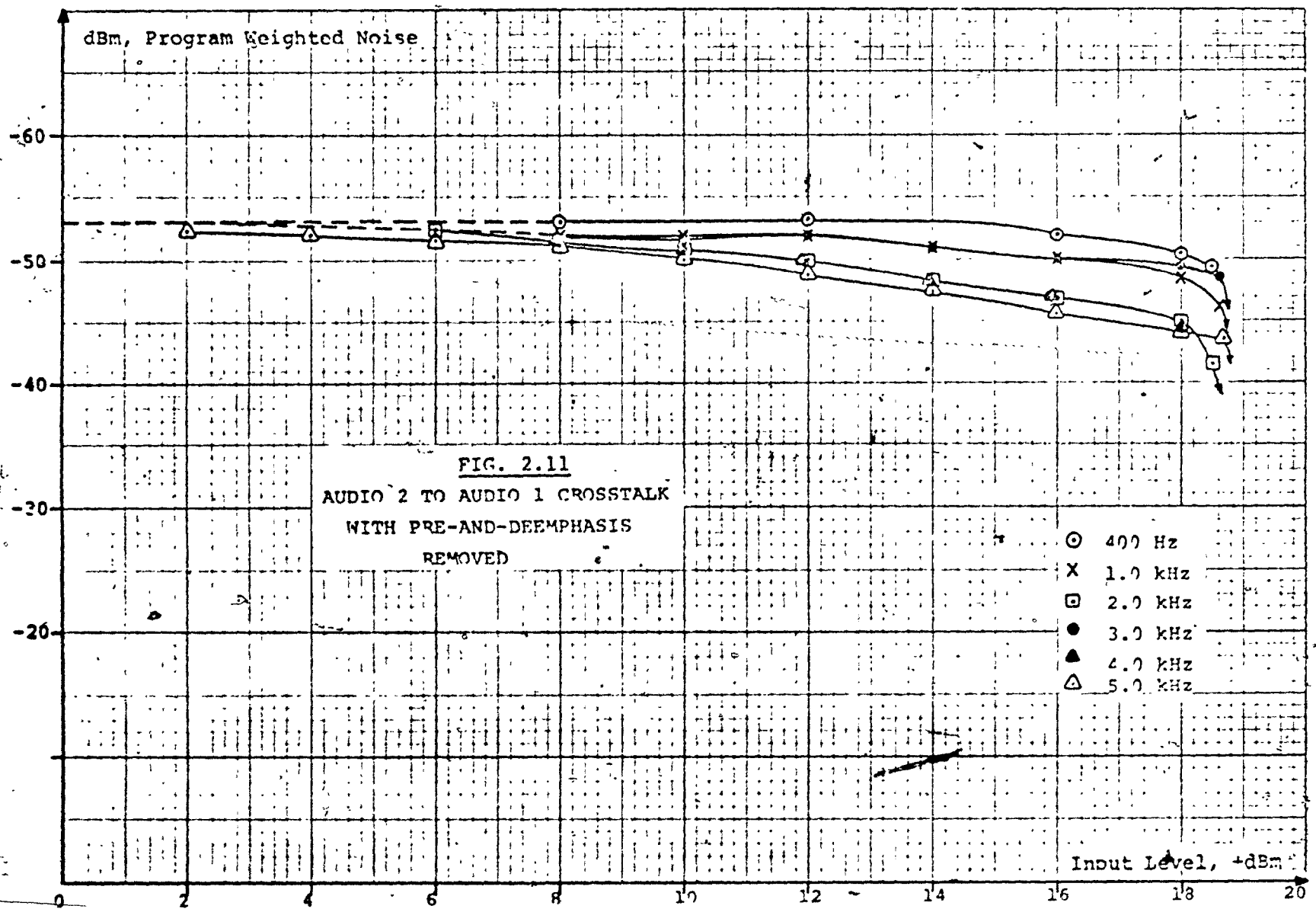


FIG. 2.11
AUDIO 2 TO AUDIO 1 CROSSTALK
WITH PRE-AND-DEEMPHASIS
REMOVED

2.2.7 Audio 2 to Audio 1 crosstalk; Measurement of audio channel 1 output program weighted noise with increasing single tone interference from channel 2. The equipment includes pre-and-deemphasis, and subcarrier modulator and demodulator. The 6.8 MHz postdetection band pass filter is removed.

Input to channel 2: 600 ohm - single tones at patch panel.

Output to channel 1: Patch panel into the Noise Measuring Set.

Equipment lineup:

(i) The insertion loss of the B.P.F. is simulated with 22 dB Attenuator, 75 ohm impedence.

(ii) Continuity is checked with 1 kHz Test Tone at +8 dBm on both channels 1 and 2, in turn, and it is ensured that nominal channel receive outputs are obtained.

Test method:

(i) Basic noise on channel 1, is measured Program Weighted.

(ii) The output weighted noise on channel 1 is measured increasing frequency and level into channel 2.

Test equipment:

RMS voltmeter, HP 400 L -

RCA serial number Coll5S;

3A Noise Measuring Set -

Western Electric RCA M3BoiT,

with program weighting:

N.E., serial number 497B;

Digital oscillator, model HP 4204 A.

Results: Basic Noise in Channel 1 = -58 dBm.

TABLE 2.7

Audio 2 to Audio 1 crosstalk, with predetection B.P.F. removed

INPUT LEVEL IN CH. 2 (+ dBm)	CROSSTALK IN CH. 1 AT F= 400 Hz (- dBm)	CROSSTALK IN CH. 1 AT f= 1 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 2 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 3 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 4 kHz (- dBm)	CROSSTALK IN CH. 1 AT f= 5 kHz (- dBm)
0	58	58	58	58	57.5	57.5
4	--	--	57.5	--	56.5	57
6	--	--	--	--	--	54.5
8	--	--	56.5	57.5	51.5	46
10	58	56.5	55.5	53.5	44	39.5
12	--	55.5	--	50.5	38.5	36
14	--	53	53	49	then	then
16	--	48	46.5	41.5	crash	crash
18	57.5	44	43	37.5		
20	57	39	39	then		
22	52.5	then	37	crash		
		crash	then			
			crash			

The above data is shown in Figure 2.12.

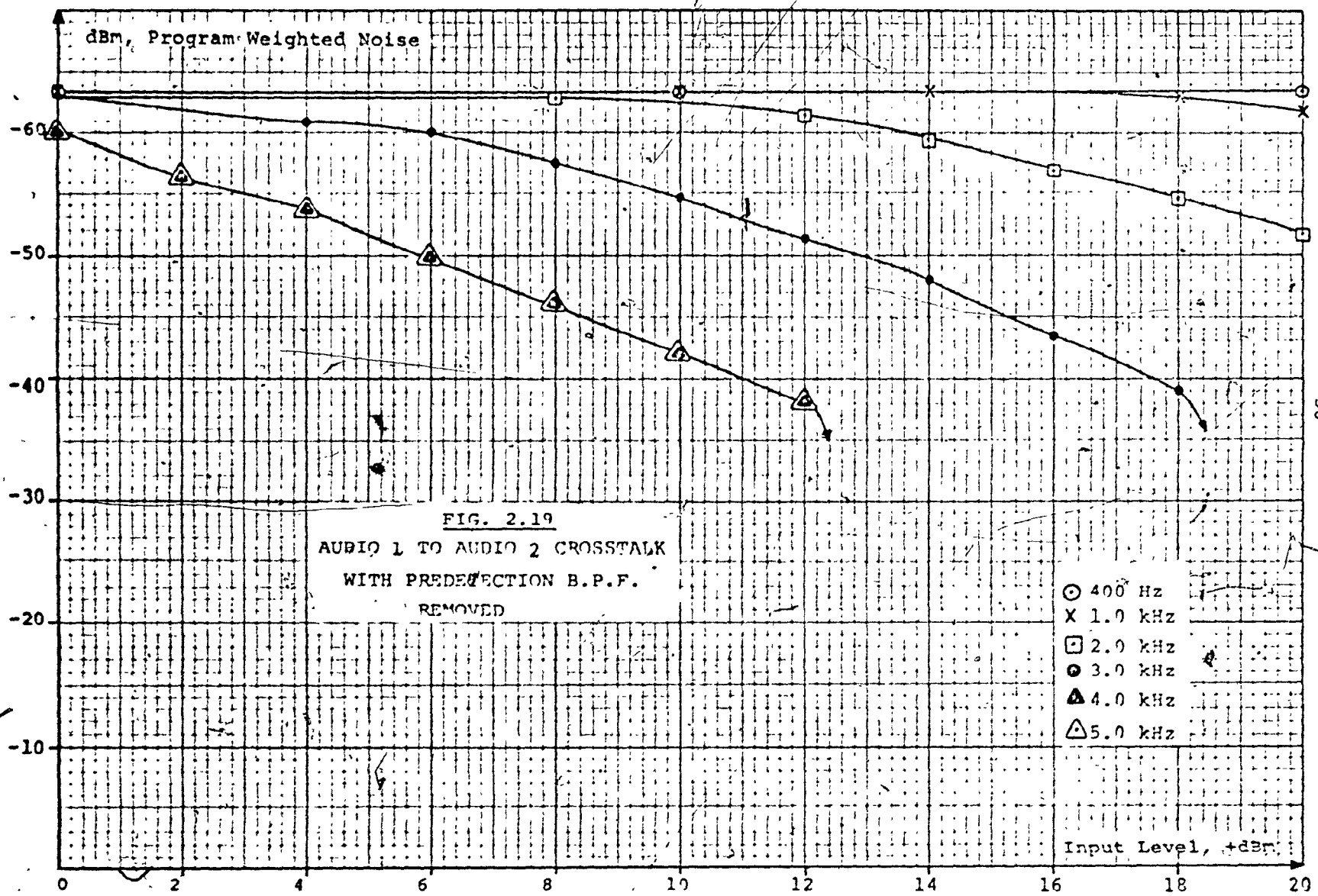


FIG. 2.19

AUDIO 1 TO AUDIO 2 CROSSTALK

WITH PREDETECTION B.P.F.

REMOVED

2.2.8 Total harmonic distortion; Receive Audio 2, multiplex only. Ref. Figure 2.3.

Input: Demodulator splitter-OUT.

Output: Audio channel-OUT, at patch panel.

Receiving section lineup:

Input = 320 mV, at 8 kHz

Output = +7.0 dBm, 1 kHz translated tone.

Test method: The input level is varied so as to obtain increased channel output levels, then THD is measured corresponding to the different channel output levels. This is repeated for the frequencies 400 Hz, 1 kHz and 2 kHz.

Test equipment:

RMS voltmeter, model HP 400 L - RCA serial number Co115S;

Distortion analyzer, HP 330 B - RCA serial number L2A20S;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.8

THD:- Audio 2, Receive multiplex only

OUTPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	% THD AT f = 2 kHz
7	0.22	0.22	0.42
11	0.14	0.14	0.40
15	0.11	0.10	0.40
19	0.22	0.17	0.90
21	8.0	10.0	8.0

The above data is shown in Figure 2.13.

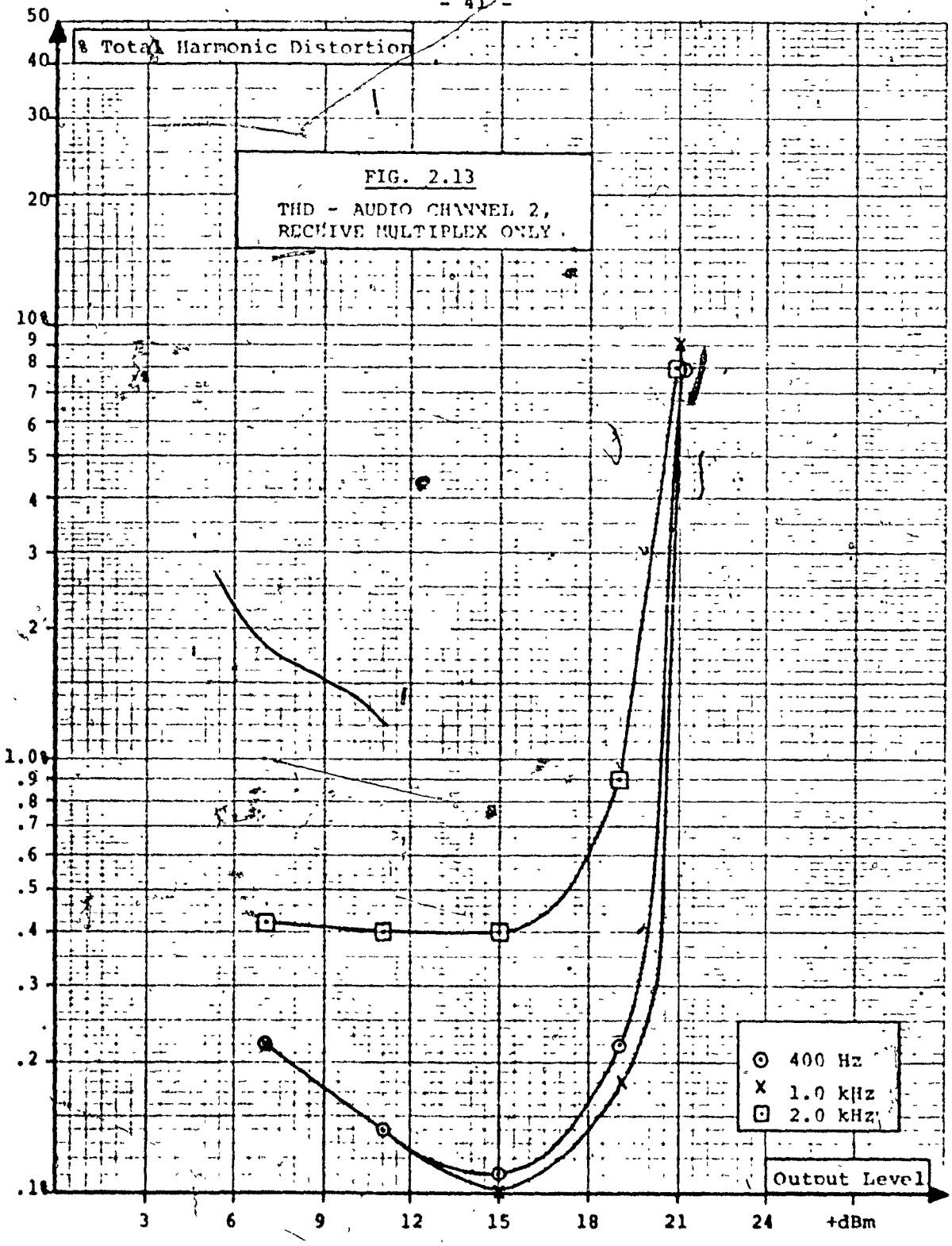


FIG. 2.13

THD - AUDIO CHANNEL 2, RECEIVE MULTIPLEX ONLY.

2.2.9 Total harmonic distortion - Transmit and receive audio channel 2, multiplex. Ref. Figure 2.4. A combiner and a splitter are used in place of the subcarrier modulator and demodulator units.

Input: Audio channel 2 Transmit, at patch panel.

Output: Audio channel 2 Receive, at patch panel.

Lineup:

Transmit: With Test Tone, the transmit output level is adjusted to produce 32 mV RMS (600 ohm) at the output of the channel 5 kHz B.P.F.

Receive: Lineup unchanged from that of test 2.2.8.

Test method: The input level is varied such as to increase the channel output level then THD is measured corresponding to the different channel output level. This is repeated for the frequencies 400 Hz, 1 kHz and 2 kHz.

Test equipment:

RMS voltmeter, HP 400 L -

RCA serial number Coll5S;

Distortion analyzer, HP 330 B -

RCA serial number L2A20S;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.9

THD - Audio 2, Transmit and Receive, multiplex only

OUTPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	f = 2 kHz	
			OUTPUT LEVEL (+ dBm)	% THD
6.6	.40	.40	7.1	.45
10.6	.35	.31	11.1	.42
14.6	.35	.31	15.1	.56
18.6	.40	.31	17.1	6.4
20.6	9.0	10.0		

The above data is shown in Figure 2.14.

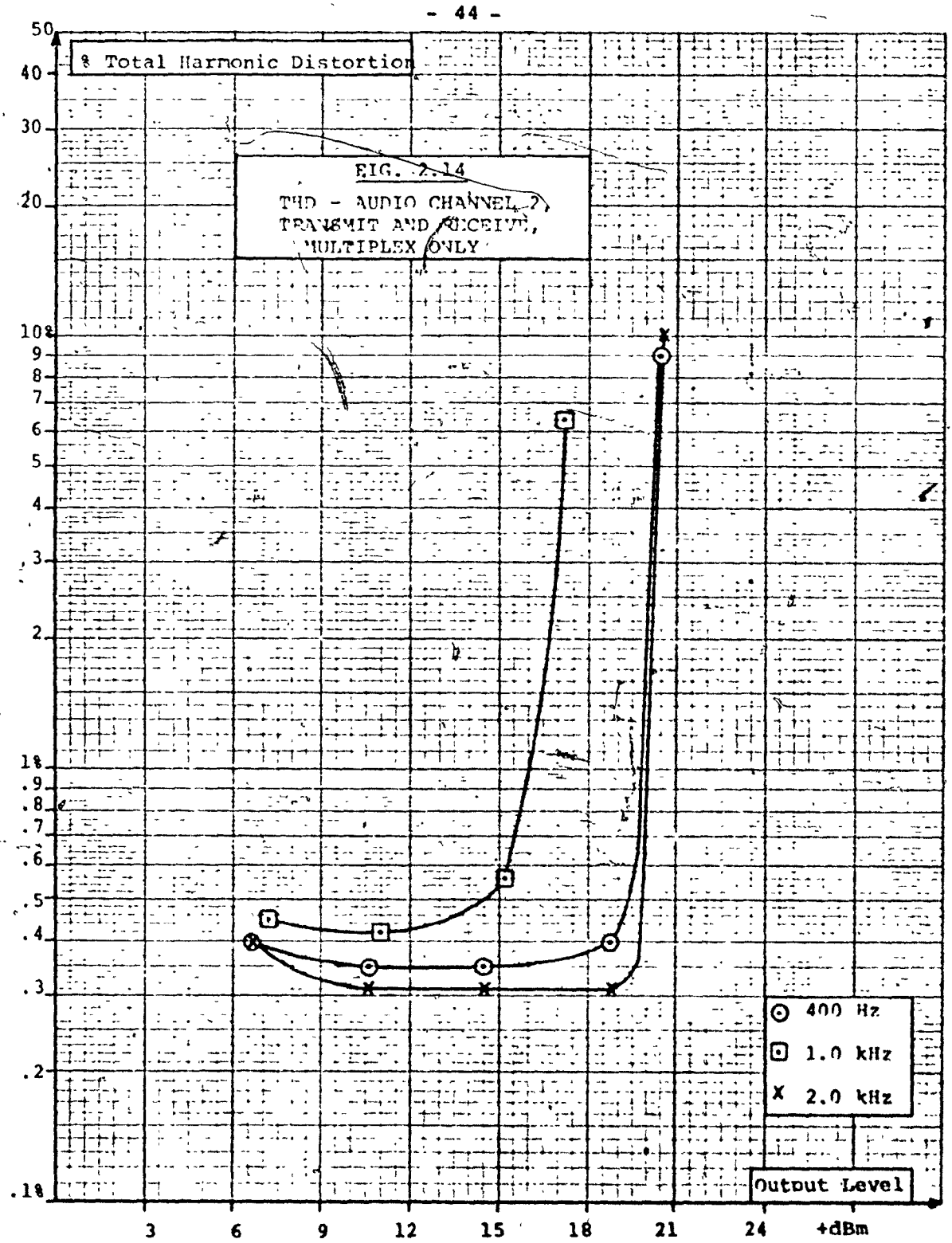


FIG. 2.14

THD - AUDIO CHANNEL 2, TRANSMIT AND RECEIVE, MULTIPLEX ONLY

2.2.10 Total harmonic distortion; Audio channel 2 transmit section, including preemphasis, FM modulator, channel 2 receive section, with 6.8 B.P.F., demodulator and deemphasis. Ref. Figure 2.5.

Input: Audio channel 2 Transmit, at patch panel.

Output: Audio channel 2 Receive, at patch panel.

Lineup:

(i) 8 kHz TT level: 320 mV RMS at combiner-in and splitter-out.

(ii) 1 kHz at -7.4 dBm, Bessel Zero is obtained for 80 kHz RMS deviation.

(iii) +8 dBm input at 1 kHz, the receive channel output is adjusted to obtain +8 dBm at patch panel.

Test method: The input level is increased, and THD is measured corresponding outputs. This is repeated for the frequencies 400 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz and 5 kHz.

Test equipment:

Panoramic spectrum analyzer, model SPA-3 - RCA serial number 169U211;

RMS voltmeter, HP 400 L - RCA serial number Co115S;

Distortion analyzer, HP 330 B -

RCA serial number L2A20S;

Frequency counter, HP 524 C -

RCA serial number R4LO3E;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.10

THD - Audio 2, Transmit and Receive, all stages in circuit

INPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	% THD AT f = 2 kHz	% THD AT f = 3 kHz	% THD AT f = 4 kHz	% THD AT f = 5 kHz
0	---	---	---	.61	1.1	1,5
4	---	---	---	.35	2.3	1.6
8	.61	.61	.5	.10	20.0	18.0
10	---	---	---	3.5		
12	.55	.61	.56	4.0		
14	---	.61	.56	7.0		
16	.55	.56	4.0			
18	---	.45				
19	---	.56				
20	.45	2.5				
22	.5					

The above data is shown in Figure 2.15.

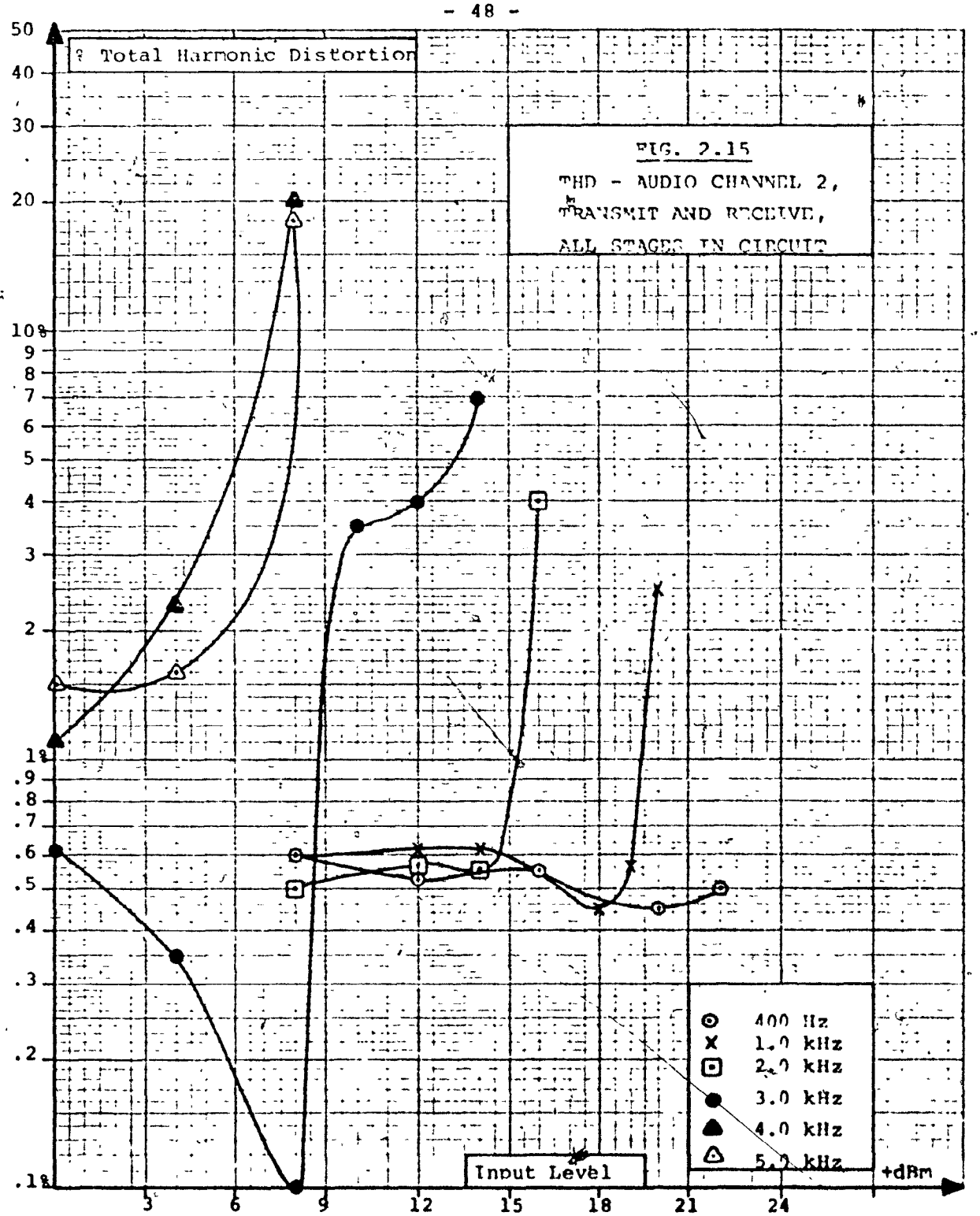


FIG. 2.15
THD - AUDIO CHANNEL 2,
TRANSMIT AND RECEIVE,
ALL STAGES IN CIRCUIT

2.2.11 Total harmonic distortion; Audio channel 2 transmit and receive sections with all stages <u>except pre-and-deemphasis</u>.

Input: Audio channel 2 Transmit-in, at patch panel.

Output: Audio channel 2 Receive-out, at patch panel.

Equipment lineup:

(i) With 1 kHz Test Tone level -7.4 dBm, the transmit output level is adjusted for Bessel Zero at Transmit Shelf OUT. Therefore, the same deviation is maintained as with preemphasis. (80 kHz RMS).

(ii) With 1 kHz Test Tone level +8 dBm at input, the channel 1 output is adjusted to obtain +8 dBm at the receive patch panel.

Test method: The input level is varied so as to obtain increased channel output levels. THD is measured corresponding to different input levels. This is repeated for the frequencies 400 Hz, 1 kHz, 2 kHz, 3 kHz and 4.5 kHz.

Test equipment:

Panoramic spectrum analyzer, model SPA-3 -

RCA serial number 169U211;

RMS voltmeter, HP 400 L -

RCA serial number Co115S;

Distortion analyzer, HP 330 B -

RCA serial number L2A20S;

Frequency counter, HP 524 C -

RCA serial number R4LO3E;

Digital oscillator, model HP 4204 A.

Results:

TABLE 2.11

THD - Audio 2, all stages in circuit except pre-and-deemphasis

INPUT LEVEL (+ dBm)	% THD AT f = 400 Hz	% THD AT f = 1 kHz	% THD AT f = 2 kHz	% THD AT f = 3 kHz	% THD AT f = 4.5 kHz
8	.45	.31	.50	.50	.66
12	.37	.28	.48	.45	.70
16	.4	.31	.48	.42	.76
18	.51	.56	.52	.42	.86
20	3.2	3.2	2.5	2.5	2.8
22	2.4	3.2	1.6	1.8	2.0

The above data is shown in Figure 2.16.

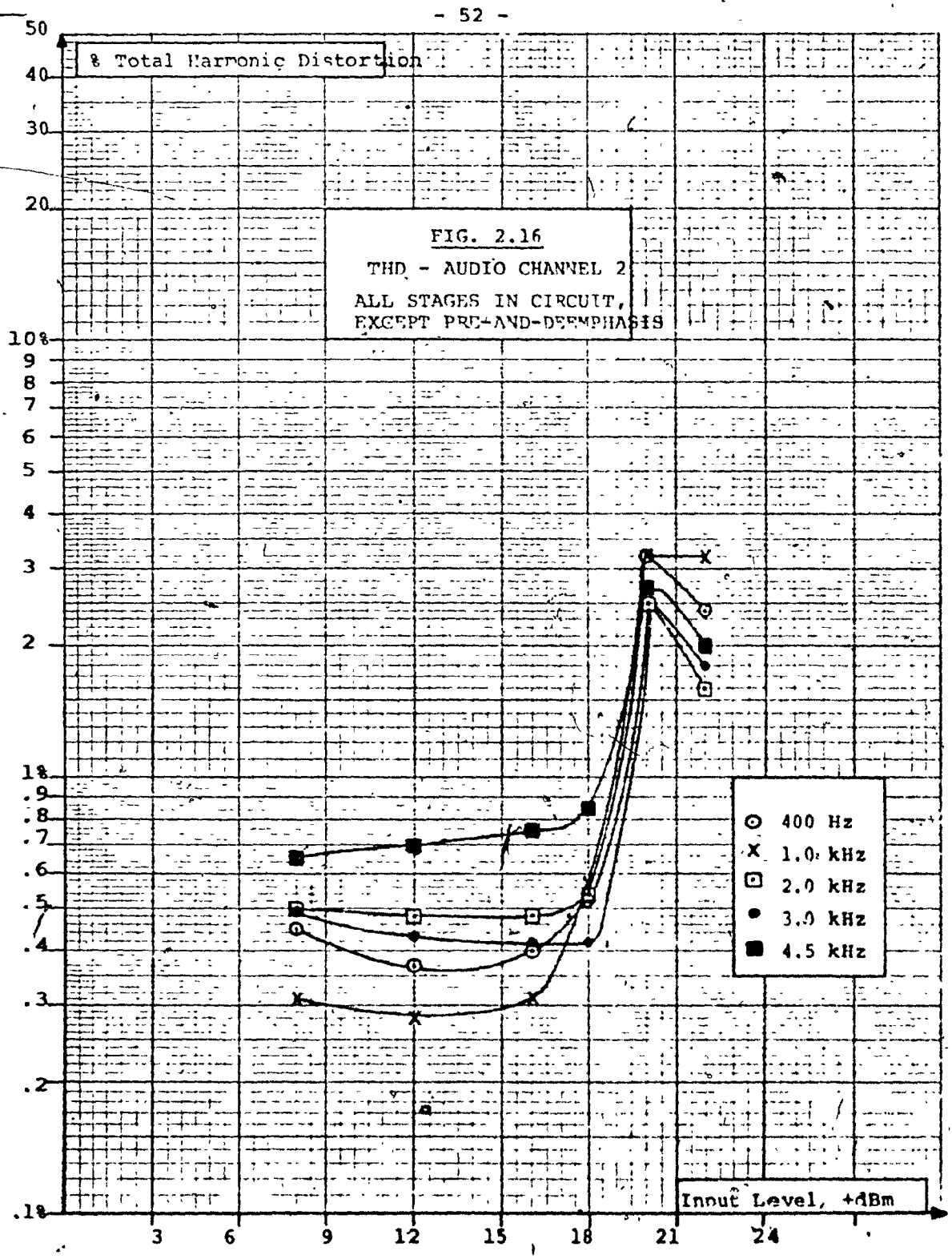


FIG. 2.16

THD - AUDIO CHANNEL 2

ALL STAGES IN CIRCUIT, EXCEPT PRE-AND-DEEMPHASIS

2.2.12 Audio 1 to Audio 2 crosstalk; Measurement of channel 2 output program weighted noise with increasing single tone interference from channel 1. The equipment includes pre-and-deemphasis, and subcarrier modulator and demodulator, and postdetection band pass filter stages.

Input to channel 1: 600 ohm - single tones at patch panel.

Output of channel 2: Patch panel into the Noise Measuring Set.

Equipment lineup: The continuity with 1 kHz test tone is checked +8 dBm on both channel 1 and 2, in turn, and it is ensured that nominal channel receive outputs are obtained.

Test method:

(i) The Basic noise is measured on channel 2, Program Weighted.

(ii) The output weighted noise on channel 2 is measured with increasing frequency and level into channel 1.

Test equipment:

RMS voltmeter, HP 400 L -

RCA serial number Coll5S;

3A Noise Measuring Set -

Western Electric RCA M3BoiT,

with program weighting:

N.E., serial number 497B;

Digital oscillator, model HP 4204 A.

Results: Basic Noise on Channel 2 = -63.7 dBm.

TABLE 2.12

Audio 1 to Audio 2 crosstalk, with all stages in circuit

INPUT LEVEL IN CH. 1 (+ dBm)	CROSSTALK IN CH. 2 AT f= 400 Hz (- dBm)	CROSSTALK IN CH. 2 AT f= 1 kHz (- dBm)	CROSSTALK IN CH. 2 AT f= 2 kHz (- dBm)	CROSSTALK IN CH. 2 AT f= 3 kHz (- dBm)	CROSSTALK IN CH. 2 AT f= 4 kHz (- dBm)	CROSSTALK IN CH. 2 AT f= 5 kHz (- dBm)
0	63.7	64	63.7	63	58.5	63
2	63.7	--	--	63	55.5	55.5
4	63.7	63.5	63.5	62.5	52	52
6	--	--	--	62.5	48.5	49
8	63.7	63.5	63.0	60.5	43	45.7
10	--	--	62.5	50.5	36.5	43.5
12	63.5	63.5	61	40	then	36
14	--	--	55.5	then	crash	then
16	63.7	63.5	47	crash		crash
18	63.7	62.7	38			
20	63.7	61	then			
22	63.7	48.7	crash			

The above data is shown in Figure 2.17.

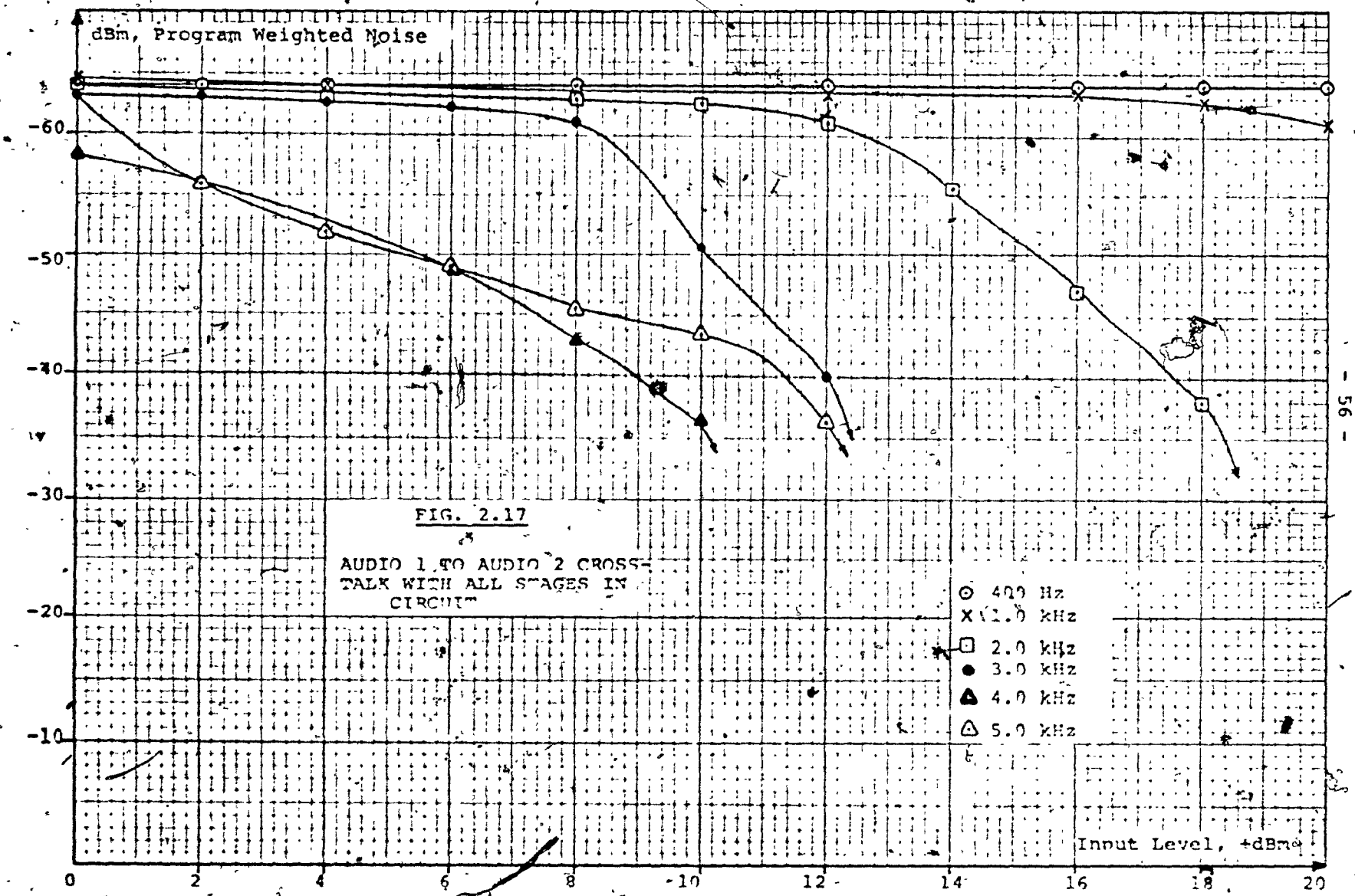


FIG. 2.17

AUDIO 1 TO AUDIO 2 CROSS-TALK WITH ALL STAGES IN CIRCUIT

2.2.13 Audio 1 to Audio 2 crosstalk; Measurement of audio channel 2 output program weighted noise with increasing single tone interference from channel 1. The equipment includes subcarrier modulator and demodulator, and postdetection band pass filter stages. The pre-and-deemphasis stages are removed.

Input to channel 1: 600 ohm - single tones at patch panel.

Output to channel 2: Patch panel into the Noise Measuring Set.

Equipment lineup:

(i) Channel 1 and 2 deviation adjustment, is maintained,

(ii) The continuity is checked with 1 kHz Test Tone at +8 dBm on both channel 1 and 2, in turn, and it is ensured that nominal channel receive outputs are obtained.

Test method:

(i) The Basic noise on channel 2 is measured, Program Weighted.

(ii) The output weighted noise is measured on channel 2 with increasing frequency and level into channel 1.

Test equipment:

Panoramic spectrum analyzer, model SPA-3 -

RCA serial number 169U211;

RMS voltmeter, HP 400 L -

RCA serial number Co115S;

3A Noise Measuring Set -

Western Electric - RCA M3BoiT,

with program weighting:

N.E. serial number 497B;

Digital oscillator, model HP 4204 A.

Results: Basic Noise in Channel 2 = -56.0 dBm.

TABLE 2.13

Audio 1 to Audio 2 crosstalk, with pre-and-deemphasis removed

INPUT LEVEL TO CH. 1 (+ dBm)	CROSSTALK IN CH. 2 AT f= 400 Hz (- dBm)	CROSSTALK IN CH. 2 AT f= 1 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 2 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 3 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 4 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 5 kHz (- dBm)
8	56	56	55.5	55.5	56.0	52.5
10	56	56	55.5	55.0	53.5	50.0
12	56	56	55.5	54.5	50.5	47.0
14	56	56	54.5	53.5	45.0	53.5
16	56	55.5	53.5	49	37.0	40.0
18	56	55.5	50.0	38.5	29.0	37.5
18.5	--	--	--	36.0	then	
19.5	--	--	46.0	then	crash	
20	56	54	then	crash		34
21	--	52.5	crash			(crashed)
22	56	41.5 (crashed)				24.5

The above data is shown in Figure 2.18.

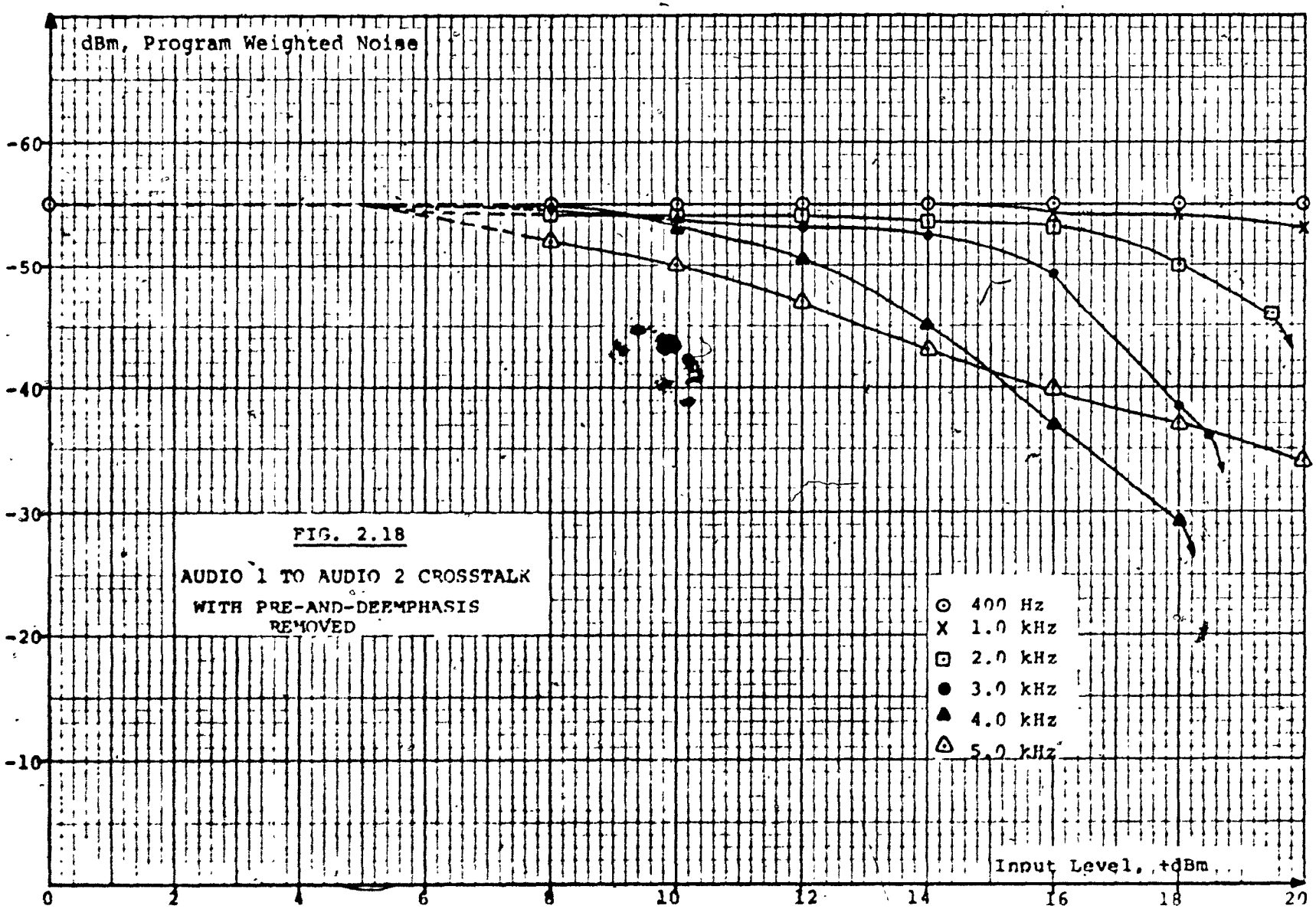


FIG. 2.18

AUDIO 1 TO AUDIO 2 CROSSTALK WITH PRE-AND-DEEMPHASIS REMOVED

2.2.14 Audio 1 to Audio 2 crosstalk; Measurement of audio channel 2 output program weighted noise with increasing single tone interference from channel 1. The equipment includes pre-and-deemphasis and subcarrier modulator and demodulator. The 6.8 MHz postdetection band pass filter is removed.

Input to channel 1: 600 ohm - single tones at patch panel.

Output to channel 2: Patch panel into the Noise Measuring Set.

Equipment lineup:

(i) The insertion loss of B.P.F. is simulated with 22 dB attenuator, 75 ohm impendance.

(ii) Continuity is checked with 1 kHz Test Tone at +8 dBm on both channels 1 and 2, in turn, and it is ensured that nominal channel receive outputs are obtained.

Test method:

(i) Basic noise on channel 2, is measured Program Weighted.

(ii) The output weighted noise on channel 2 is measured with increasing frequency and level into channel 1.

Test equipment:

RMS voltmeter, HP 400 L -

RCA serial number Co115S;

3A Noise Measuring Set -

Western Electric - RCA M3BoiT,

with program weighting,

N.E. serial number 497B;

Digital oscillator, model HP 4204 A.

Results: Basic Noise in Channel 2 = -63.5 dBm.

TABLE 2.14

Audio 1 to Audio 2 crosstalk, with predetection B.P.F. removed

INPUT LEVEL AT CH. 1 (+ dBm)	CROSSTALK IN CH. 2 AT f= 400 Hz (- dBm)	CROSSTALK IN CH. 2 AT f = 1 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 2 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 3 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 4 kHz (- dBm)	CROSSTALK IN CH. 2 AT f = 5 kHz (- dBm)
0	63.5	63.5	63.5	63.2	60.0	60.0
2	--	--	--	--	57.0	57.5
4	--	--	--	61.2	54.0	54.0
6	--	--	--	60.0	50.0	50.0
8	--	--	63.0	57.5	46.0	46.0
10	63.5	63.5	--	54.6	42.0	42.5
12	--	--	61.5	51.5	38.0	38.5
14	--	63.5	59.5	48.0	then	then
16	--	--	57.0	43.5	crash	crash
18	--	63.0	54.5	39.0		
20	63.5	61.7	52.0	then		
22	63.5	60.0	48.0	crash		

The above data is shown in Figure 2.19.

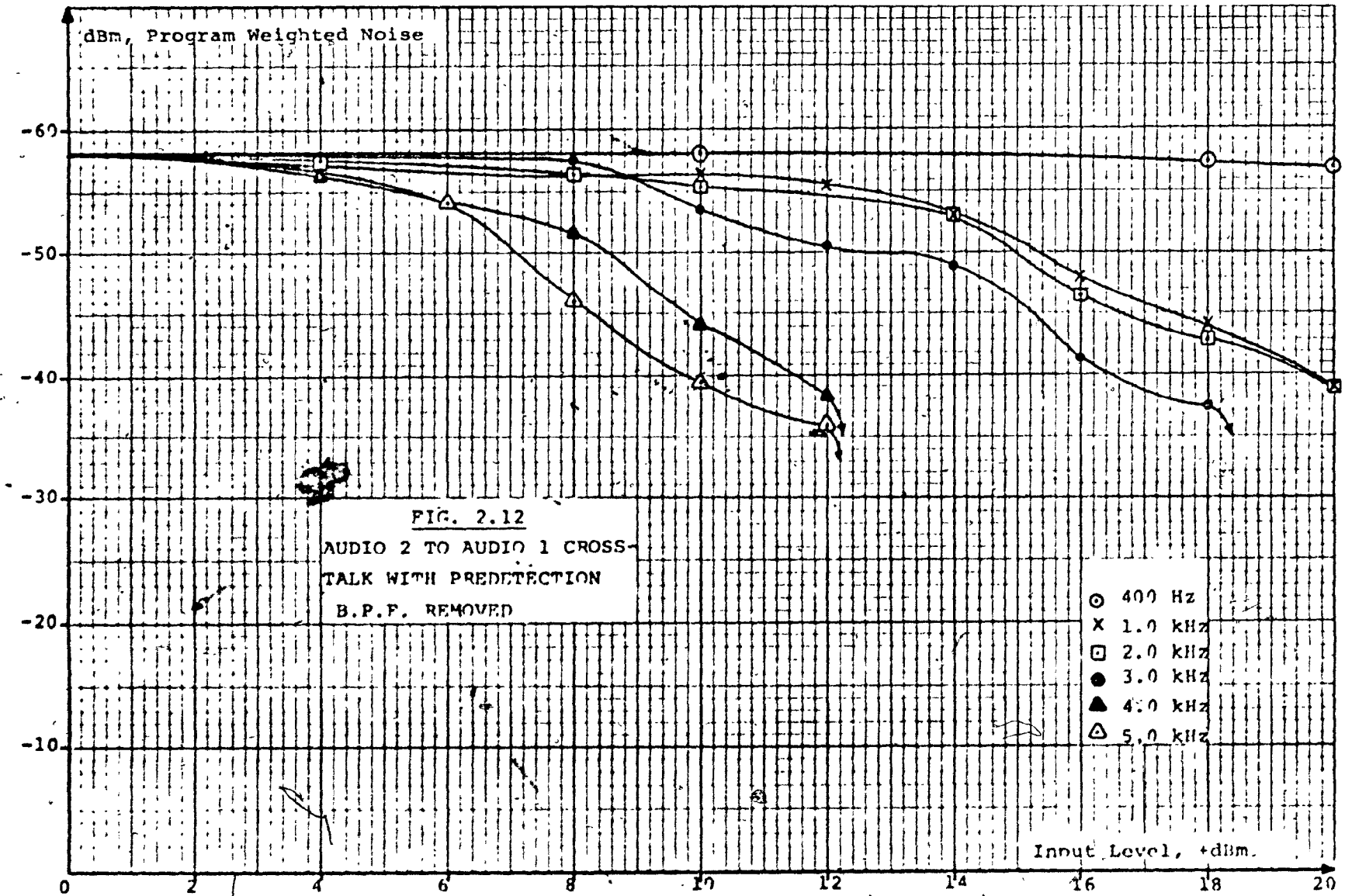


FIG. 2.12

AUDIO 2 TO AUDIO 1 CROSS-TALK WITH PREDETECTION B.P.F. REMOVED

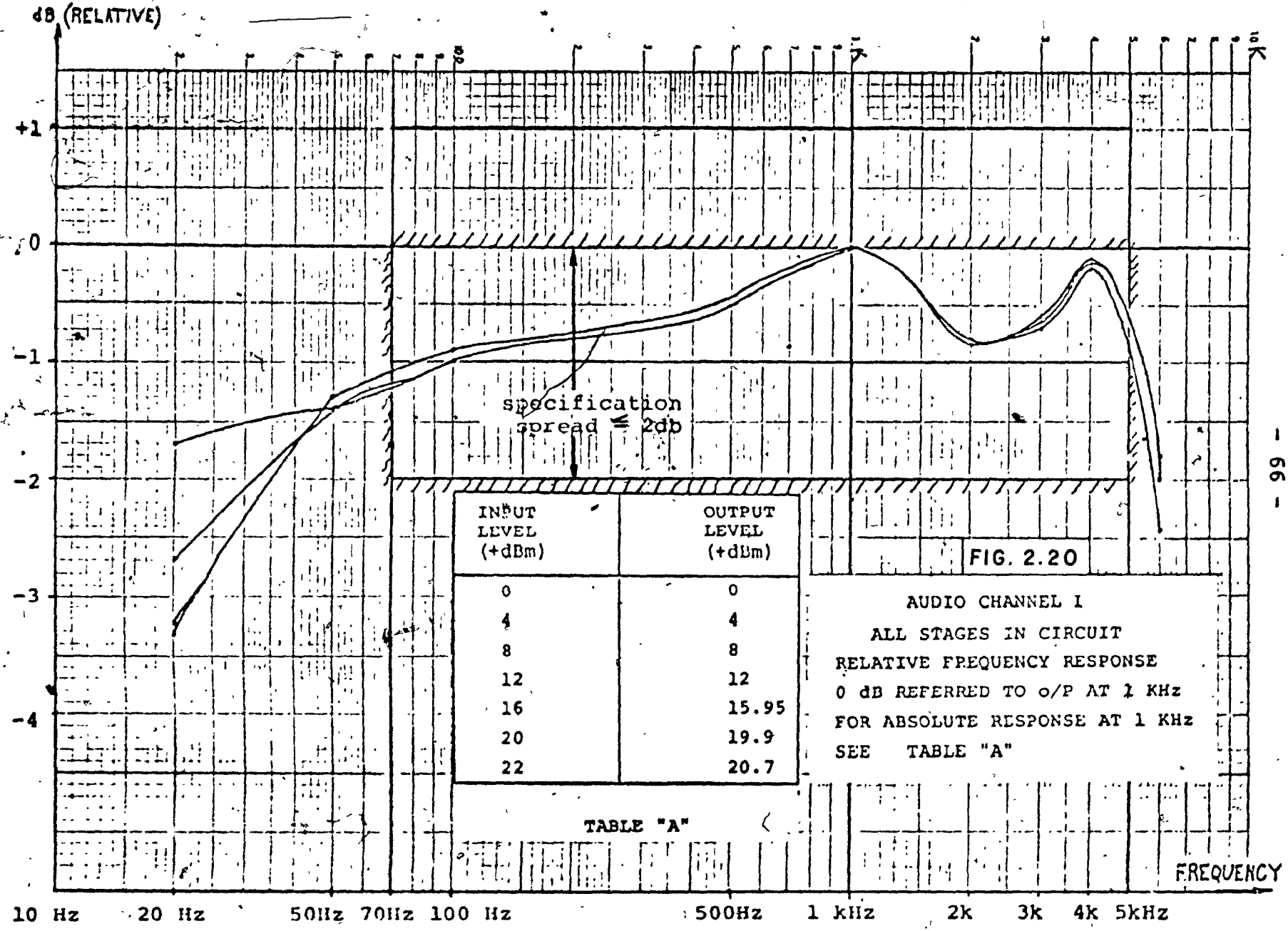
2.2.15 Audio channels frequency response:

The frequency response for both audio channels 1 and 2 is obtained under the following conditions:

(i) With all stages in circuit.

(ii) With all stages except for the pre-and-deemphasis stages.

Figures 2.20 to 2.23 show the frequency response curves for the above conditions. Each Figure summarizes the response of an audio channel to single tones injected at the channel input. The tones vary in frequency and in input level. The frequency range is 20 Hz to 5 kHz. The input level is varied from 0 to 22 dBm, in steps of 2 dB. At each input level and input frequency, the output level is measured, and normalized with respect to the output at 1 kHz. It is the difference in normalized output level that is significant for our purpose and therefore it is this difference that is shown in the graph as a point. The points are joined together and all the lines of a graph indicate the aggregate departure from the response at 1 kHz. Only unusual behaviour is identified with the corresponding frequency and level, e.g., for oscillating output. A table on each figure gives the absolute output level for increasing input levels in steps of 4 dB.

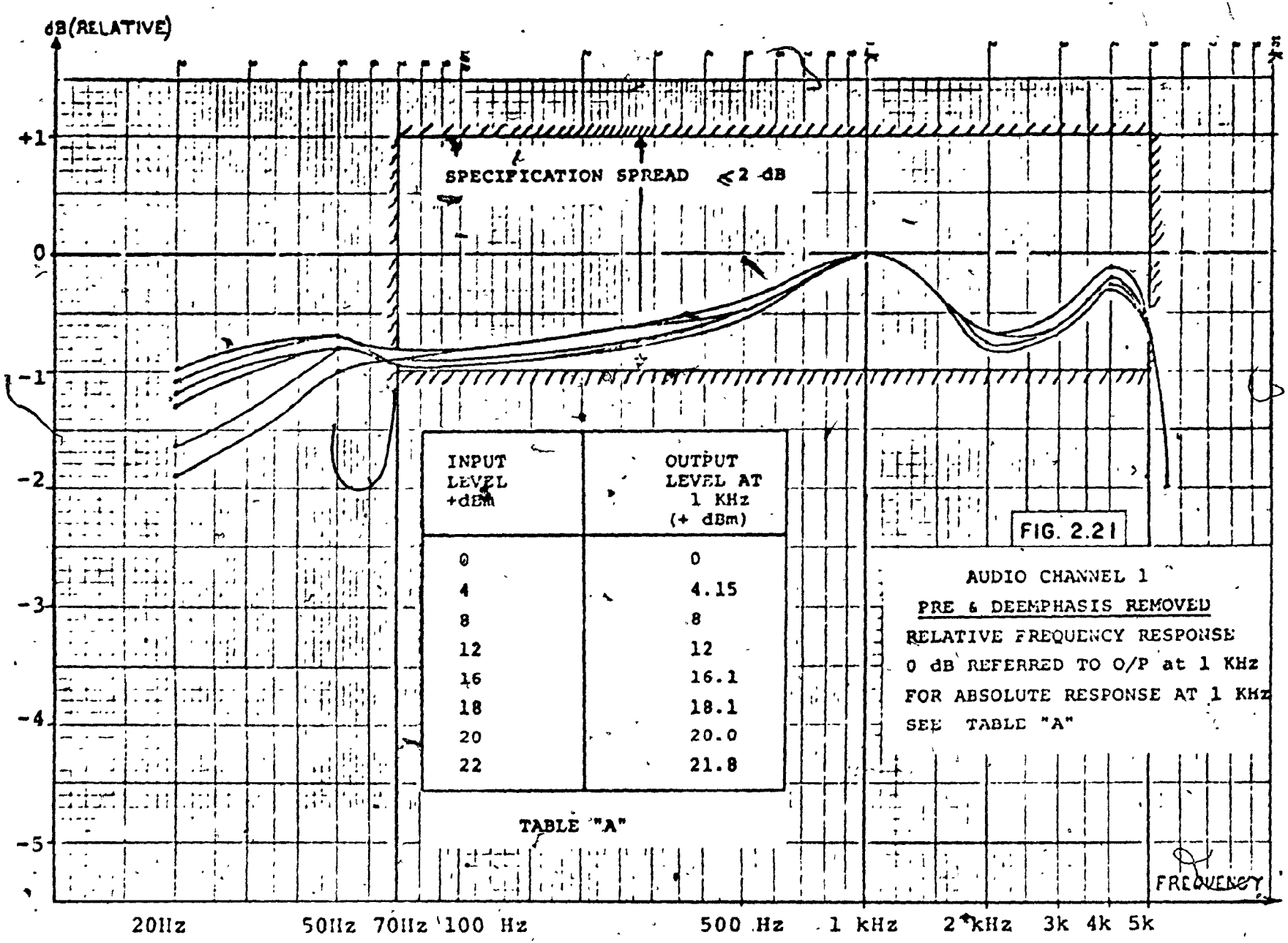


INPUT LEVEL (+dBm)	OUTPUT LEVEL (+dBm)
0	0
4	4
8	8
12	12
16	15.95
20	19.9
22	20.7

TABLE "A"

FIG. 2.20

AUDIO CHANNEL I
ALL STAGES IN CIRCUIT
RELATIVE FREQUENCY RESPONSE
0 dB REFERRED TO o/P AT 1 KHz
FOR ABSOLUTE RESPONSE AT 1 KHz
SEE TABLE "A"



INPUT LEVEL +dBm	OUTPUT LEVEL AT 1 KHz (+ dBm)
0	0
4	4.15
8	8
12	12
16	16.1
18	18.1
20	20.0
22	21.8

TABLE "A"

FIG. 2.21

AUDIO CHANNEL 1

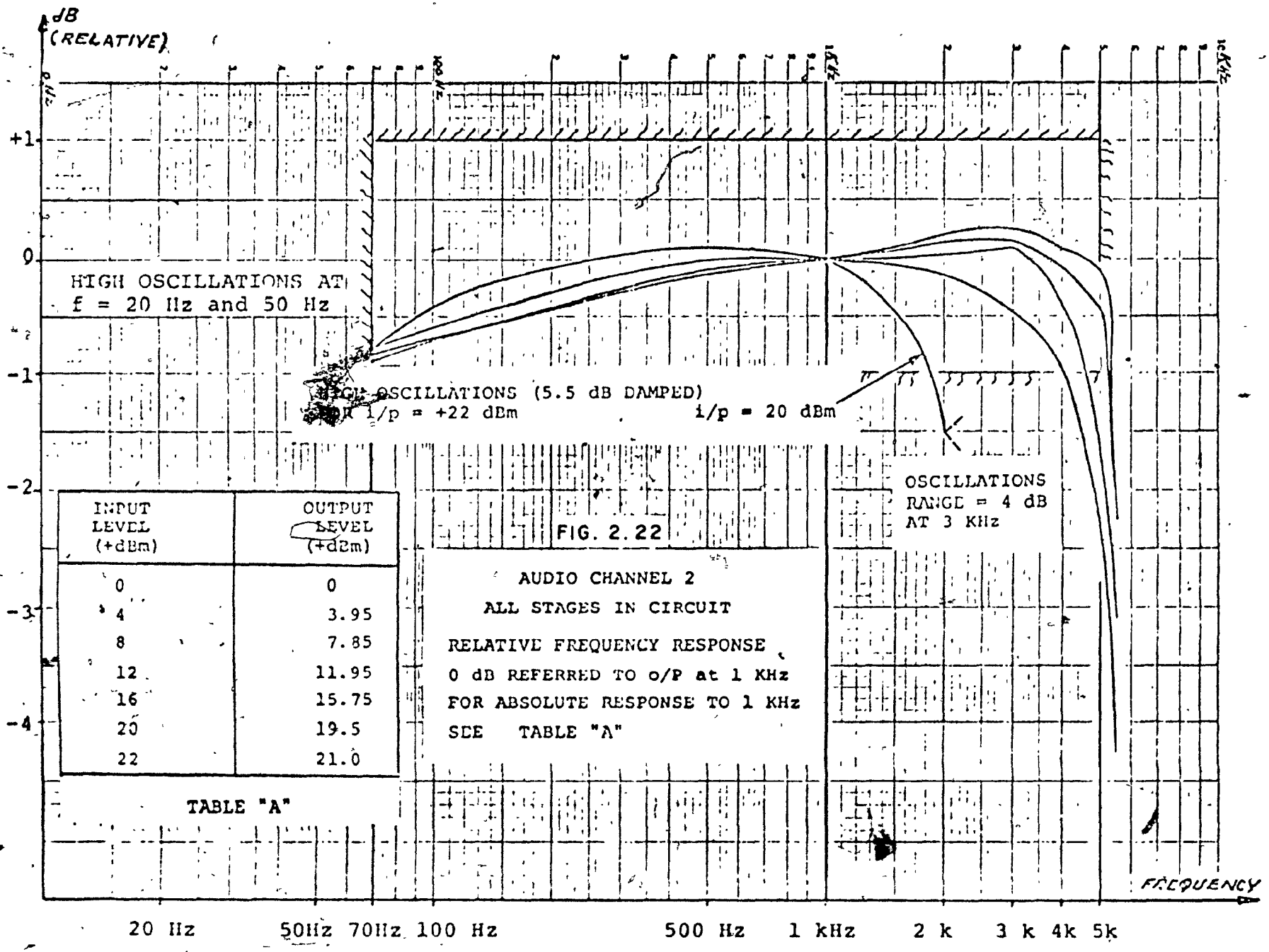
PRE & DEEMPHASIS REMOVED

RELATIVE FREQUENCY RESPONSE

0 dB REFERRED TO O/P at 1 KHz

FOR ABSOLUTE RESPONSE AT 1 KHz

SEE TABLE "A"



INPUT LEVEL (+dBm)	OUTPUT LEVEL (+dBm)
0	0
4	3.95
8	7.85
12	11.95
16	15.75
20	19.5
22	21.0

TABLE "A"

FIG. 2.22

AUDIO CHANNEL 2

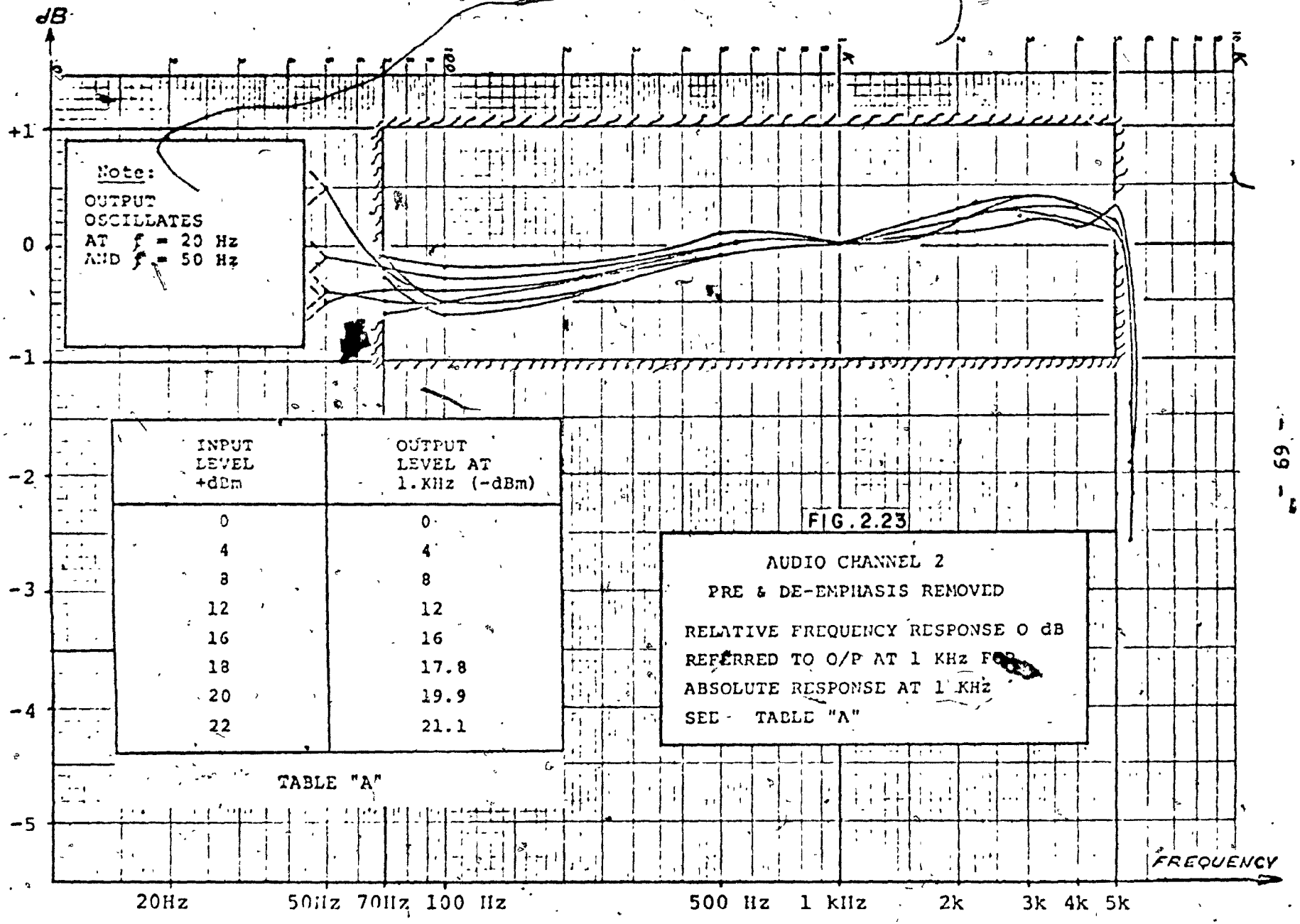
ALL STAGES IN CIRCUIT

RELATIVE FREQUENCY RESPONSE

0 dB REFERRED TO o/P at 1 KHz

FOR ABSOLUTE RESPONSE TO 1 KHz

SEE TABLE "A"



INPUT LEVEL +dBm	OUTPUT LEVEL AT 1.KHz (-dBm)
0	0
4	4
8	8
12	12
16	16
18	17.8
20	19.9
22	21.1

TABLE "A"

FIG.2.23

AUDIO CHANNEL 2
PRE & DE-EMPHASIS REMOVED

RELATIVE FREQUENCY RESPONSE 0 dB
REFERRED TO O/P AT 1 KHz FOR
ABSOLUTE RESPONSE AT 1 KHz
SEE - TABLE "A"

2.2.16. Frequency response of the predetection band pass filter.

Figure 2.24 shows the frequency response of the B.P.F. at the receiving end. This active filter serves to limit the noise as seen by the receive demodulator. The filter center frequency is 6.8 MHz. The following are the major characteristics specified for this filter:

(i) B.P.F. bandwidth, 3 dB points = 600 kHz.

(ii) B.P.F. amplitude response ±250 kHz within 1 dB.

(iii) B.P.F. insertion loss, maximum: 20 dB.

In addition to the above characteristics, the B.P.F. incorporates a "trap", or notch tuned at 7.16 MHz, which is the second harmonic of the colour subcarrier. The specification for the notch attenuation is: 20 dB from nominal level.

The purpose of this test is to ensure that the B.P.F. used meets all foregoing specifications, including those related to the notch; because although the notch attenuates video content, this feature is connected in the following manner to the global problem of video and audio crosstalk: If the notch frequency differs from 7.16 MHz, or if the attenuation at 7.16 MHz is insufficient, video-to-audio crosstalk results; The colour subcarrier second harmonic passes free in the audio

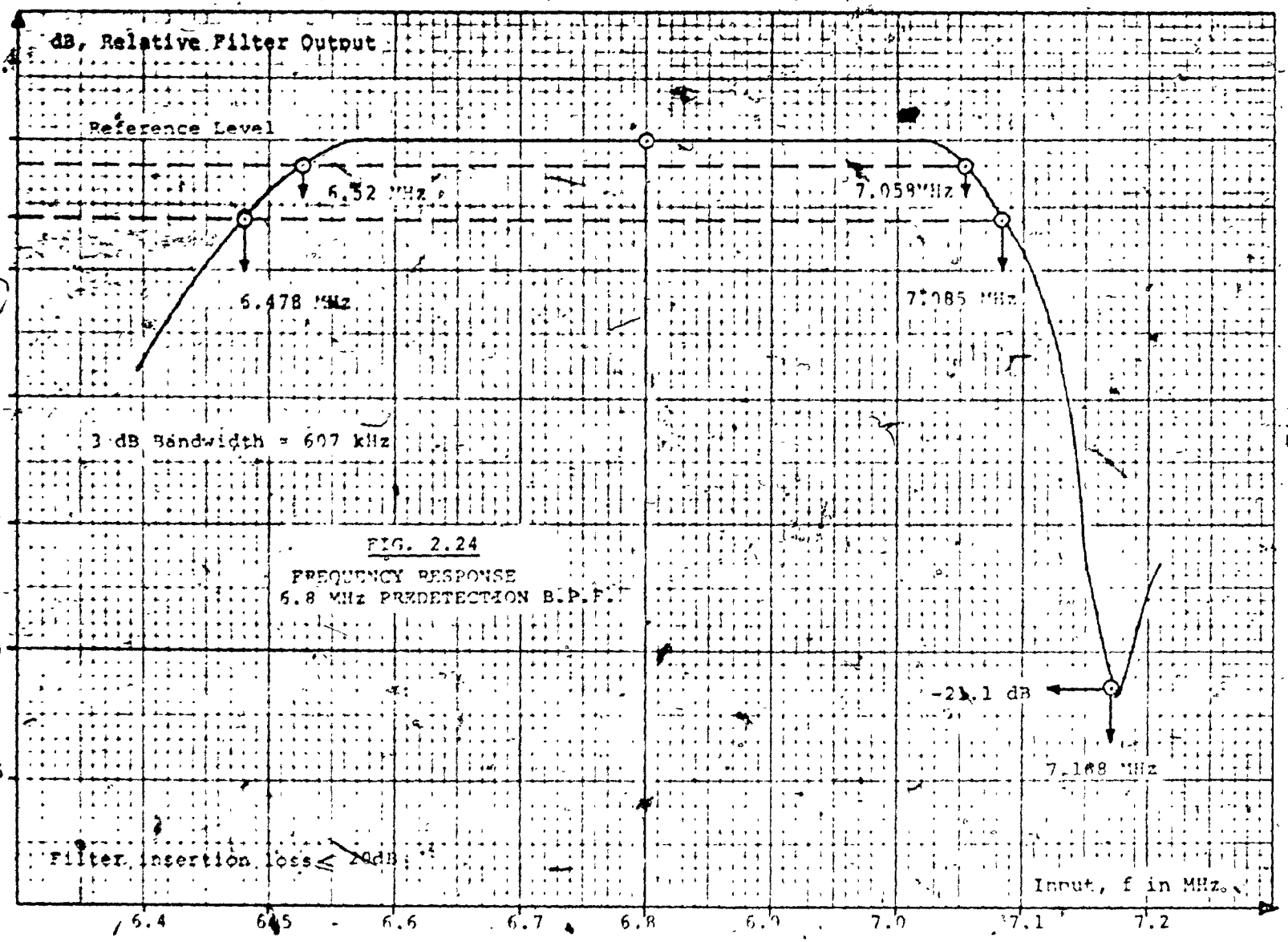


FIG. 2.24

FREQUENCY RESPONSE
6.8 MHz PREDETECTION B.P.F.

predetection B.P.F. and is demodulated down to interfering tones in the 5 kHz band of audio 1 and 2.

Considering Figure 2.24, it is observed that all specifications are met.

CHAPTER 3

DISCUSSION

3.1 General

The specification for total harmonic distortion for audio 1 and 2 is THD $\leq$ 1.0% for an input frequency of ~~400 Hz,~~ at +8 dBm.

The specification for audio Signal-to-Noise Ratio is S/N = 56 dB, with 1.0 kHz tone at +8.0 dBm input level.

The above specifications serve only as guidelines as we examine the results of the preceeding tests, for the following reasons:

(i) THD and crosstalk tests are performed using several single tones of different input frequencies and levels. Thus, in general, the specified values for THD and S/N are not directly applicable.

(ii) Only threshold points of the equipment performance are of interest. That is, levels at which the equipment exhibits a large departure from nominal behaviour.

(iii) The evaluation of audio performance is often subjective. The equipment is required to handle

high voice peaks as well as high musical notes with equal fidelity. It is estimated from previous tests that the audio equipment is acceptable if it can process without noticeable distortion (in the general sense) audio signals up to 10 dB above the test tone of +8 dBm at 1 kHz, i.e., up to +18 dBm input. This 10 dB is considered as the margin required to accommodate the dynamic range presented to the audio channel input.

3.2 Discussion of test results

Figure 2.6 indicates that the audio 1 receive amplifier saturates at an output level of approximately +20.0 dBm. From Figure 2.1, it is observed that the audio 1 amplifier is the only active element in the Receive Multiplex section. However, for audio 2, in addition to the amplifier, the receive mixer[1] is an active element that adds to the THD, especially at high input levels to the mixer. This is confirmed in Figure 2.13, where the saturation takes place at +19 dBm output level for a 2 kHz tone, as opposed to +20 dBm for 400 Hz and 1 kHz. The effect of saturation of audio 2 mixers (Transmit and Receive) becomes more evident as we place in circuit the Transmit multiplex section; while Figure

1. The 7 kHz local oscillator (L.O.).

2.7 shows the same saturation point for audio 2, Figure 2.14 shows a saturation at +16 dBm (2 kHz tone): The only difference between the two audio channels is the translation stage of audio 2 via mixers. When the subcarrier modulator, B.P.F., and demodulator stages are placed in circuit, the full extent of audio 2 distortion is exposed: In Figure 2.8 the audio 1 THD is still normal until about +18 dBm input, even at f= 5 kHz; This is 10 dB above Test Tone level. In contrast, Figure 2.15 shows that for f= 5 kHz even at 0 dBm input level, audio 2 THD exceeds 1%, and worsens rapidly thereafter. It is noted in the same figure that for f $\leq$ 2 kHz, input levels up to about 16 dBm are allowed before giving high THD: The results of Figure 2.15 are explained as follows: At 1 kHz, audio channel 2 deviation is 80 kHz RMS for an input level of +8 dBm. When the input frequency and level increase, so does the deviation such that for 1 kHz at +16.5 dBm input, the receiving predetection bandwidth of 600 kHz is completely filled. Now, to fill the same bandwidth with f= 5 kHz, an input level of +7.3 dBm is required. The difference of -9.2 dB is computed from the preemphasis curve, Figure D. Indeed, we see in Figure 2.15 that the crash point of the 5 kHz line is around 7 dBm input. Distortion occurs when the modulated frequency is restricted by the predetection filter. For the case of actual audio programs, with several overdeviating frequencies, the

distortion would be caused by intermodulation within the 600 kHz bandwidth. The latter becomes much smaller than the transmission bandwidth. The preemphasis action also affects the Transmit channel 2 mixer. Consider, in Figure D, the difference between 1 kHz and 2 kHz; it is 4.6 dB. The same difference exists in Figure 2.15 in the crash point of the two frequencies!

If the preemphasis is taken out, then all crash points should correspond to that of f= 400 Hz the equipment being only limited by the audio amplifier. To confirm in this, we have Figure 2.16, which shows that the crash point is extended back to about +20 dBm input when the pre-and-deemphasis stages are removed.

The extension of THD crash points is also observed in audio channel 1 (Figure 2.9). Here too, the sharp increase in THD occurs at the same point: +22 dBm input.

The removal of the pre-and-deemphasis greatly improves the crosstalk from audio 2 to audio 1; one has only to compare Figures 2.10 and 2.11: In Figure 2.10 the overdeviating frequencies, the saturated mixer and transmit amplifier in audio channel 2, generate high noise that is carried over the common points in the subcarrier system into audio 1. Without emphasis, the degradation of crosstalk into audio channel 1 is "graceful", and the crash point is extended to +18.5 dBm

input the audio channel 2. The objective of +18 dBm input is therefore met. Similarly, audio 1-to-audio 2 crosstalk improves as shown by the results in Figures 2.17 and 2.18.

Figures 2.12 and 2.19 reveal an interesting fact: only a small improvement is gained by just removing the 6.8 MHz B.P.F.; The harm is already done in the transmitting end, by overdeviation and saturation.

Finally, when we study frequency response Figures 2.20 to 2.23 we make the following observations:

(i) Audio channel 1 meets the response specifications[1] for the two cases indicated in Figures 2.20 and 2.21.

(ii) For both cases of Figures 2.22 and 2.23, audio 2 exhibits an oscillating output at low frequency (20 to 50 Hz): In channel 2 transmitter, there is, at the input, a 5 kHz L.P.F. and any variation in test oscillator frequency in the above range will encounter an appreciably different filter attenuation. If the oscillator variation is cyclic, the filter output will be cyclic, and hence the oscillations. This only happens at the lower skirt of the 5 kHz L.P.F.

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1. Amplitude variations $\leq$ 2 dB with respect to response at 1 kHz, in the range from 70 Hz to 5 kHz.

(iii) Audio channel 2 does not meet the specifications when all stages are in circuit. Ref. Figure 2.22.

(iv) When the pre-and-deemphasis stages are removed, the audio 2 response, Figure 2.23, is well within the specification limits.

To summarize, then, the following are the limitations of the audio equipment:

(i) Audio amplifier saturation at an absolute output level of approximately +20 dBm.

(ii) Premature audio 2 Transmit mixer saturation due to the presence of the preemphasis action.

(iii) Receiving bandwidth limitation, exerted by the predetection band pass filter.

3.3 Possible solutions

The test results show that there is high distortion and crosstalk with high[1] input levels. Consequently, there are two alternatives:

(i) To protect the equipment from high input levels.

(ii) To redesign the equipment in order to accommodate high input levels.

Under the first alternative, the solutions to the

1. As seen by the stages subsequent to the preemphasis.

crosstalk and distortions are:

(i) Reduce input levels before they arrive at the audio Transmitting shelf, using attenuators. This implies amplification at the output of the receiving shelf to maintain overall gain.

(ii) Place a level limiter at the audio channels input. There will be an inherent distortion due to the limiter action, but only in a controllable percentage of time. The crosstalk will be reduced corresponding to the degree of input level limitation.

(iii) Remove the pre-and-deemphasis stages; the automatic level enhancement would not take place and premature crosstalk and distortion would disappear.

Considering the second alternative, the solution is to meet all restricting elements with a new design that increases:

(i) The dynamic range of the audio channel amplifier.

(ii) The capability of channel 2 mixer to withstand higher input signal levels.

(iii) The receiving predetection bandwidth.

(iv) The "guard bands", or the spectral separation between audio channel 1 and 2 from 2 kHz to 5 kHz.

3.4 Comparison of possible solutions

The solution of equipment redesign implies shifting the audio subcarrier frequency of 6.8 MHz to a higher value, in order to clear the video portion of the base-band for a larger audio bandwidth. In addition, audio channel 2, (and channel 3) local oscillator frequencies have to be changed for larger channel spectral separation. Further, it is important to note that the shift in subcarrier frequency will increase the audio system noise. Finally, as a practical consideration, while a new audio amplifier and channel 2 mixer are not a problem, a complete implementation of the equipment redesign involves much time and effort[1].

Due to the above considerations, the attention is turned towards the more simple and effective solutions. When we compare the latter solutions, we note first that the solution of placing a limiter before the audio channel input is more complicated than in the case of telephony; here we are dealing with a wide range of audio programs: music, songs, etc... Therefore the amount of "clipping" or limiting has to be determined with actual test program as opposed to single tone testing. Further, a certain amount of limiting for a given type of program may be inadequate for others.

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1. The manufacturer estimates a year for a new-improved audio subcarrier system!

What remains, in terms of possible solutions, is either to place attenuators before the audio channel input, or to remove the pre-and-deemphasis. As mentioned above, with the attenuator solution, amplifiers have to be placed at the audio channel output at the receiving end. This is an expensive proposition, considering the number of receiving stations. And again, tests with actual audio programs have to be performed in order to arrive at the optimum input attenuation. Judging from the single-tone test results, an attenuation of 10 to 15 dB is required.

We are therefore left with the alternative of removing the preemphasis stage (and consequently the deemphasis stage) from the audio equipment. This solution really attacks the heart of the problem of increased input levels, and furthermore, it is relatively simple to implement: No extra equipment is required, and only level readjustment is necessary, which is a straightforward procedure. The disadvantage of this solution is that it removes the noise improvement factor gained with deemphasis, and allows back the linear relationship between detected noise and frequency. Hence, one has to ensure that after the removal of the pre-and-deemphasis stages, the signal-to-noise ratio is still acceptable.

CHAPTER 4

CONCLUSION

4.1 Final recommendation

In the previous chapter many solutions to the cross-talk problem were exposed, based on the test results of chapter 2. Only one proved to be the most effective, inexpensive, completely feasible and simple to implement: The removal of pre-and-deemphasis stages.

Therefore, this was the solution that the author recommended to the management in a report containing all test results.

4.2 Ensuing action

After discussing the author's report, it was agreed to proceed with the implementation of the recommended solution. It was first ensured that all receiving earth stations will produce an acceptable S/N without pre-and-deemphasis. The author then prepared a detailed procedure to modify, in the field, the audio equipment; the modification consists of:

(i) Removal of pre-and-deemphasis.

(ii) Realignment of transmission levels.

The modification procedure was submitted to the Operation Department for implementation.

APPENDIX A

LIST OF TEST EQUIPMENT USED AT ALLAN PARK HRS[1]

1. Transmission & Noise Measuring Set HP[2] 3555B

   T/C[3] Serial Number: 2430

2. Oscillator HP 204D

   T/C Serial Number: 2479

3. RMS Voltmeter HP 3400A (75 ohm)

   T/C Serial Number: 2031

4. AC Voltmeter HP 400EL (600 ohm)

   T/C Serial Number: 2038

5. Spectrum Analyzer AIL TECH 707

   T/C Serial Number: 1979

6. Frequency Counter Systron Donner Model 6057

   T/C Serial Number: 2353

7. Oscillator HP 4204A

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1. Heavy Route Station - A Telesat major earth station.
2. Hewlett Packard
3. Telesat Canada

APPENDIX B

LIST OF TEST EQUIPMENT USED AT RCA[1], MONTREAL

1. Panoramic Spectrum Analyzer Model SPA-3

   RCA Serial Number: 169U211

2. RMS Voltmeter, HP 400L

   RCA Serial Number: C0115S

3. RMS Voltmeter 400EL (Average response).

   RCA Serial Number: CoVo25

4. 3A Noise Measuring Set - Western Electric

   RCA M3BoiT, with program weighting:

   N.E.[2], Serial Number: 497B

5. Distortion Analyzer HP 330B

   RCA Serial Number: L2A20S

6. Frequency Counter HP 524C

   RCA Serial Number: R4LO3E

7. Digital Oscillator, Model HP 4204A

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1. Radio Corporation of America Limited.
2. Northern Electric Company Limited.

APPENDIX C

TOTAL HARMONIC DISTORTION OF HP 4204A DIGITAL OSCILLATOR

A) Manufacturer specification: 0.3%, 30 Hz to 100 kHz

B) Measured: (on model 333A Distortion analyzer):

Distortion analyzer HP 333A

T/C Serial Number: 2324

Fixed output level = +8 dBm

TABLE C

Measured THD of HP 4204A Oscillator

f (Hz)	% THD
400	0.2
800	0.18
1,000	0.18
2,000	0.17
3,000	0.17
4,000	0.17
5,000	0.165
5,500	0.160

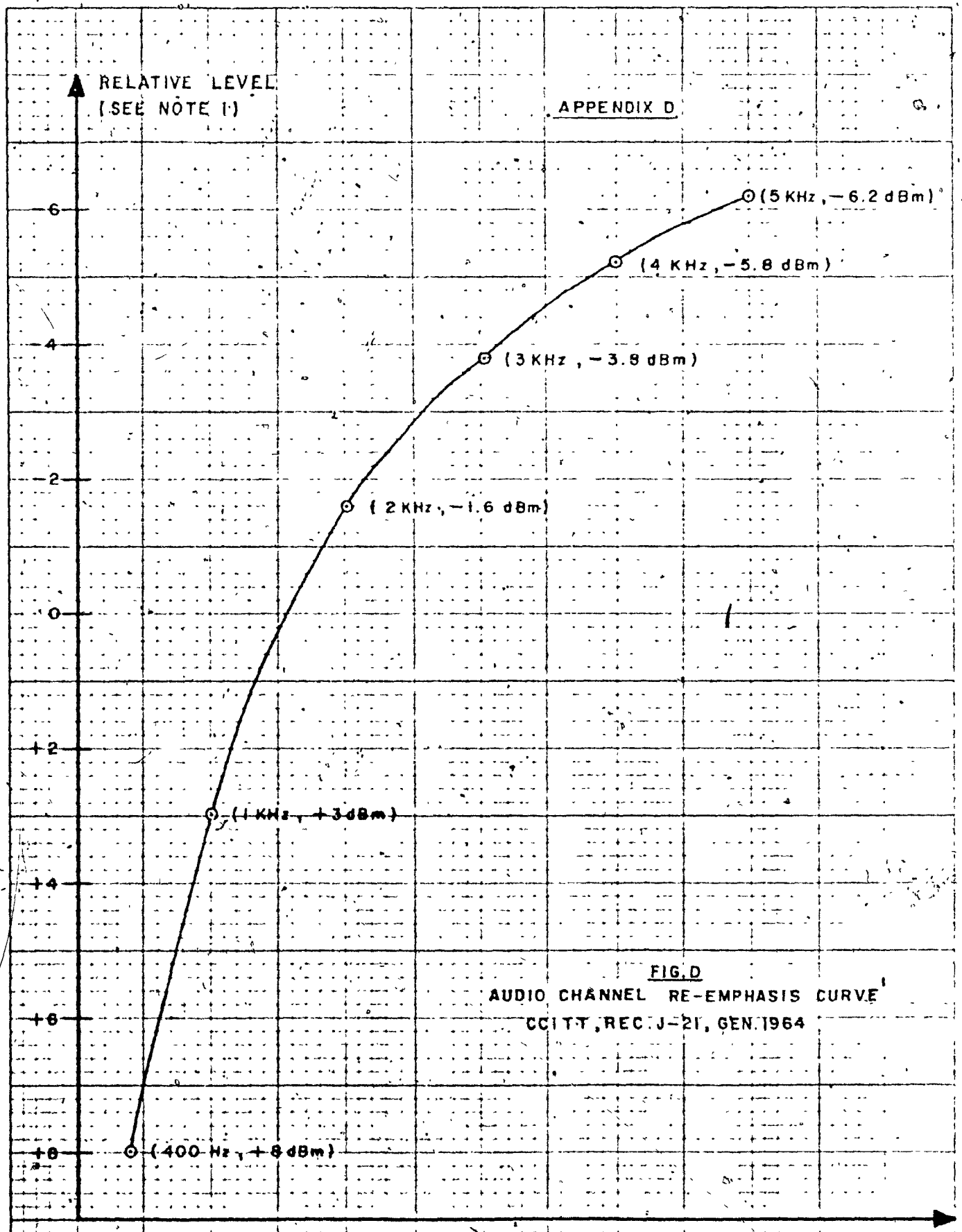

FIG. D
AUDIO CHANNEL RE-EMPHASIS CURVE
CCITT, REC. J-21, GEN. 1964

NOTE 1: DRAWN TO SHOW REQUIRED LEVEL REDUCTION IN ORDER TO MAINTAIN A FLAT OUTPUT. E.G., REQUIRED REDUCTION AT 5 KHz RELATIVE TO 1KHz IS = 9.2 dB.

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