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REPORT 7207

LABORATORY TESTS ON A DELTA CODEC USED IN A COMMERCIALLY AVAILABLE PABX

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File: Y12/1/18

Case: 12022

SUMMARY

Stored programme controlled (SPC), TDM switched PABX equipment, using delta modulation codecs for analogue to digital and digital to analogue conversion is under evaluation within Telecom Australia.

In response to a request from the Switching Design Branch, the Transmission systems Branch of the Research Laboratories carried out tests on two sets of the delta codecs used in the above PABX equipment.

The codecs performance was determined for the following tests:-

1. Limits of Clock Duty Factor
2. Frequency Response
3. Variation of Gain with Input Level
4. Quantisation Distortion
5. Weighted Noise
6. Group Delay
7. Data Transmission Capabilities

Where appropriate, the results of the tests are compared with Telecom Australia Specification 1080 - PABX Design Objectives. However, Specification 1080 is essentially written for analogue PABX equipment and does not cover some of the characteristics associated with a digital modulation system. Consequently, where appropriate, the results of the tests performed on the delta codecs are compared with C.C.I.T.T. Recommendation G. 712 - Peformance Characteristics of PCM Channels at Audio Frequencies. Although this Recommendation is not directly applicable, it provides a good performance measure for particular characteristics (e.g. Quantisation Distortion).

The results of the tests show that the codecs performance is marginally out of specification for frequency response and well out of specification for group delay. In all other tests the codec performs well, particularly with respect to quantisation distortion. Data transmission performance is not covered by the two standards used for comparison in this report. Results of data transmission tests trough the codec show that satisfactory transmission at high bit rates may not be possible, particularly if digital errors occur on the codec digital stream. This aspect of the codecs performance requires further investigation.

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for Director Research

RESEARCH LABORATORIES REPORT No. 7207

LABORATORY TESTS ON A DELTA CODEC USED IN A COMMERCIALLY AVAILABLE P.A.B.X.

1. INTRODUCTION

The PABX Design Section of Telecom Australia is currently evaluating the L.M. Ericsson manufactured Automatic Call Distribution System (ACD), ASDP 162. The system uses adaptive delta modulation codecs for A/D (Analogue to Digital), and D/A conversion. Testing of PABX equipment is carried out in accordance with Telecom Australia Specification 1080 - PABX Design Objectives (Ref. 1). The PABX Design Section in testing the ASDP 162 system found that certain transmission requirements of Specification 1080 are not met by the ASDP 162 system. As delta codecs are a new inovation in PABX equipment, the Research Department was asked to conduct a series of tests on the delta codecs used in the ASDP 162. Specification 1080 is essentially written for analogue PABX equipment and does not cover some of the characteristics associated with a digital modulation system. Consequently, where appropriate, the results of the tests performed on the delta codecs are compared with C.C.I.T.T. Recommendation G. 712 (Ref. 2) - Peformance Characteristics of PCM Channels at Audio Frequencies. Although this Recommendation is not directly applicable, it provides a good performance measure for particular characteristics.

2. GENERAL INFORMATION ON THE TESTS

The delta codecs, as used in the ASDP 162 system supplied to the Research Laboratories for testing were in the form of a small printed circuit board. It contains an encoder-decoder I.C., an active input and output filter, and an additional operational amplifier. In one circuit diagram of the ASDP 162 system the additional operational amplifier is configured with a gain of approximately five and connected after the output filter of the delta decoder. Tests using this configuration show that the overload point of the overall codec configuration is limited by the overload point of the additional operational amplifier. This additional operational amplifier appeared to reduce the dynamic range of the codec by approximately 15 dB. From the limited information available it is not clear that testing in this manner is a realistic test. It was decided to test only the encoder-decoder I.C., together with the input and output filters, and not include the additional operational amplifier.

To enable accurate comparison to some aspects of Recommendation G. 712 the overload level of the codec must be known. The overload characteristics of delta codecs vary with frequency. Higher frequencies overload the codec at lower levels than low frequencies. With this in mind the overload level of the codec was measured at three different frequencies using the following method.

The input level was increased in 1 dB steps whilst monitoring the relative step increase of the output level. The point at which a 3 dB step increase in the input level gave only a 2 dB increase in the output level was taken to be the overload point. The overload levels obtained were:

+ 1 dBm at 1 kHz
- 2 dBm at 2 kHz
- 6 dBm at 3 kHz

Two codecs were supplied for testing. The manufacturer claims that superior performance in some tests can be attained using the same chip encoder-decoder. Most tests were therefore conducted using combinations of same and separate chip encoder-decoders.

3. DESCRIPTION AND RESULTS OF TESTS

3.1 Limits of Clock Duty Factor

Using the test setup shown in Fig. 14 for Quantisation Distortion the performance of the codec was checked for various clock duty factors. The codec gave results equivalent to those shown in Fig. 15 for a clock duty factor of ≥ 0.072 to ≤ 0.997. In all other tests the duty factor was set to 0.5.

3.2 Frequency Response

Fig. 1 shows the test setup used for this test. The analogue input was fed from a source impedance of 20.1 KΩ as recommended by the manufacturers. The analogue input and output were terminated in 600 Ω. Continuous checks were made to ensure that the 600 Ω termination on the analogue output did not affect the measurement results.

Results of the tests are given in Figs.2 to 10. Measurements were taken with the same chip encoder-decoder and separate chip encoder-decoder combinations.

With a passband of 0.2 to 3.4 kHz, and at input levels of -10 dBm and below, the maximum level variation was 1.5 dB (-10 dBm input level, same chip encoder-decoder), and the minimum level variation was 0.9 dB (-40 dBm input level, same chip encoder-decoder).

Limit values corresponding to Recommendation G. 712 and Specification 1080 have been superimposed on the results for the separate chip encoder-decoder combination with a -20 dBm input level (Fig. 5).

The codec response is outside the limits of both Specification 1080 and Recommendation G.712 for any of the input levels given in the results.

3.3 Variation of Gain with Input Level

Using the results obtained in Figs. 2 to 10 the variation of gain with input level was plotted for a separate encoder-decoder combination at three different frequencies. The results are given in Figs. 11 to 13. Specification 1080 gives no information on this test. Limit values corresponding to Recommendation G. 712 have been superimposed on Figs. 11 to 13 and show that this recommendation is met by the codec.

3.4 Quantisation Distortion

Fig. 14 shows the test setup used for this test. As shown, a facility to inject errors into the digital signal is included. Results are shown in Fig. 15, for the same chip encoder-decoder. Results obtained with separate chip encoder-decoder were within ±0.5 dB of those shown in Fig. 16. Tests were also performed with the lower limit of clock frequency (60.8 kHz), and the lower limit of power supply voltages (±4.75 V). Results are comparable with those shown in Fig. 15. Quantisation Distortion is not referred to in Specification 1080. Limit values corresponding to Recommendation G. 712 have been superimposed on the results and show that this recommendation is met. Even with a digital error rate of 1 in 10^3 the recommendation is nearly met.

3.5 Weighted Noise

The test setup shown in Fig. 2 was also used for this test. Results obtained with various digital error rates were as follows:

Digital Error Rate	Weighted Noise
No. errors	- 82 dBmp
1 in 10^4	- 80 dBmp
1 in 10^3	- 70 dBmp

These figures meet Specification 1080 for the no errors and 1 in 10^4 error rate, and meet Recommendation G. 712 in all cases.

3.6 Group Delay

The test setup shown in Fig. 16 was used for this test. Results are given in Fig. 17.

Group delay was difficult to measure due to excessive flicker of the meter reading on the receive group delay measuring set.

Results were similar for same and separate encoder-decoder configurations.

Limit values corresponding to Specification 1080 and Recommendation G. 712 have been superimposed on the results and show that the codec does not meet either of these standards.

3.7 Data Transmission Capabilities

The test setup shown in Fig. 18 was used for this test. To examine the degree of impairment produced by the codec and its effect on the operation of the modem, the reduction in the noise margin at its receiver was measured. This measurement was performed by adding noise from a gaussian noise generator to the data signal at the line input to the modem receiver. With the transmitter and receiver of the modem connected back to back the noise level was increased until a readable error rate was obtained. The modem was then connected via the codec and the noise level reduced until the same error rate as for the back to back test was obtained. The difference in the corresponding noise level for the two cases provides a measure of the reduction in noise margin resulting from the effect of the impairment produced by the codec.

The data tests were performed at 4.8 and 9.6 kbits/s for various input levels. With data transmitted through the codec and no added noise, errors were produced at input levels of $\geq$ 0 dBm for 4.8 kbits/s and $\geq$ -13 dBm for 9.6 kbits/s. This appeared to be due to the overload characteristics of the codec.

With data transmitted through the codec and no added noise, errors were also produced at input levels of $\leq$ - 50 dBm for 4.8 kbits/s and $\leq$ - 46 dBm for 9.6 kbits/s, but this was due to the modem receiver operating incorrectly with low input levels.

At 4.8 kbits/s and with input levels between - 5 dBm and - 40 dBm the reduction in noise margin was approximately 0.2 to 0.3 dB. Similarly, at 9.6 kbits/s and with input levels between -15 dBm and -40 dBm the reduction in noise margin was 0.8 to 0.9 dB.

Only the separate coder-decoder case was tested here.

The results of the test show that the codec is able to pass error free 4.8 kbits/s and 9.6 kbits/s data within a limited input level. The input level being more restrictive at 9.6 kbits/s.

To further test the ability of the codec to transmit data, errors were inserted into the codec digital stream under control of an error insertor.

To observe the effect of errors at the codec analogue output with a sinewave input, various frequencies at an input level of -10 dBm were inserted at the codec analogue input. The digital error rate was set to 1 in 10^4. Results in Fig. 19 show that the effects of errors at higher frequencies appears to be more pronounced than at lower frequencies.

Data was then transmitted through the codec at various input levels. The error rate of the data signal was noted for various inserted codec digital error rates. At 4.8 kbits/s and with a codec digital error of 1 in 10^4 there were no data errors at input levels of - 14 dBm and below. With a -10 dBm input level the data error rate was approximately 8 in 10^3. At 4.8 kbits/s and with a codec error rate of 1 in 10^3, errors occured at all input levels with a typical error rate at - 10dBm input level being 3 in 10^3. At 9.6 kbits/s and with an error rate of 1 in 10^4, errors occured at all input levels with a typical error rate at - 20 dBm input level being 6 in 10^2. The results of these tests show that if errors are present on the codec digital stream then at higher bit rates data transmission through the codec may not be possible.

4. CONCLUSIONS

The results of a series of tests on a delta codec have been recorded in this report. Reference has been made in some tests to Telecom Specification 1080 and C.C.I.T.T. Recommendation G. 712.

Specification 1080 relates to the performance of a complete PABX, whereas the results given in this report relate to a delta codec which is only part of a complete PABX. However, any additional circuitry should have little, if no, effect on the overall VF channel performance of the PABX equipment. Specification 1080 does not cover performance objectives specifically relating to delta codecs and therefore where appropriate the, C.C.I.T.T. Recommendation G. 712 has also been used as a reference for assessing the codecs performance.

The results of the tests show that the codecs performance is marginally out of specification for frequency response and well out of specification for group delay. In all other tests the codec performs well, particularly with respect to quantisation distortion. Data transmission performance is not covered by the two standards used for comparison in this report. Results of data transmission tests through the codec show that transmission at high bit rates could be a problem if digital errors occur on the codec digital stream but this requires further investigation.

ACKNOWLEDGEMENT

The author wishes to thank Mr. G. Semple for assistance in preparing this report.

REFERENCE

1. Telecom Australia Specification 1080 Issue 2.

2. C.C.I.T.T. Recommendation G. 712, Orange Book, Vol III 2, 1976, pp. 415-423.

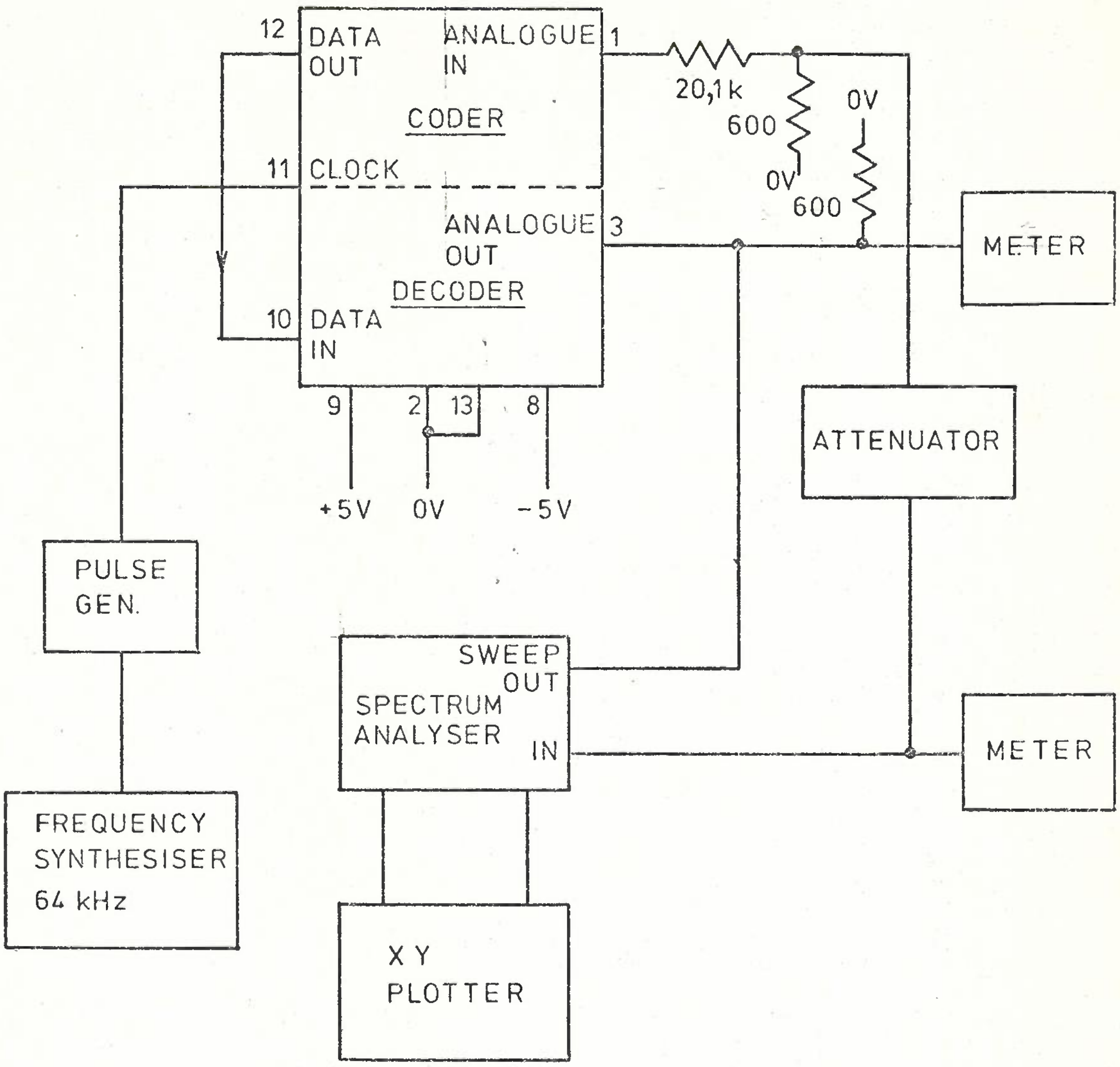

FIG. 1 TEST SETUP FOR MEASUREMENT OF FREQUENCY RESPONSE

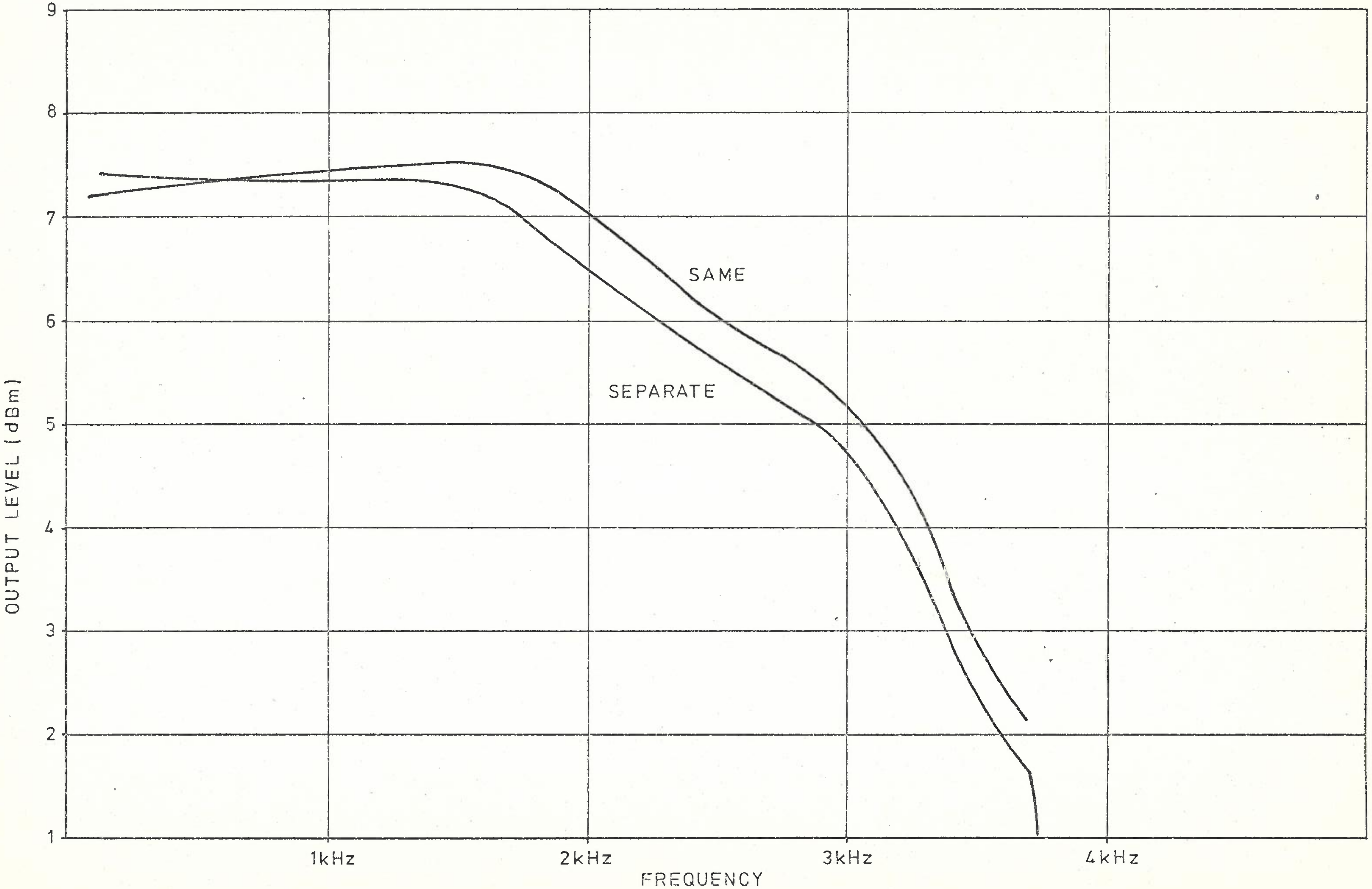

FIG. 2 FREQUENCY RESPONSE WITH 0 dBm INPUT

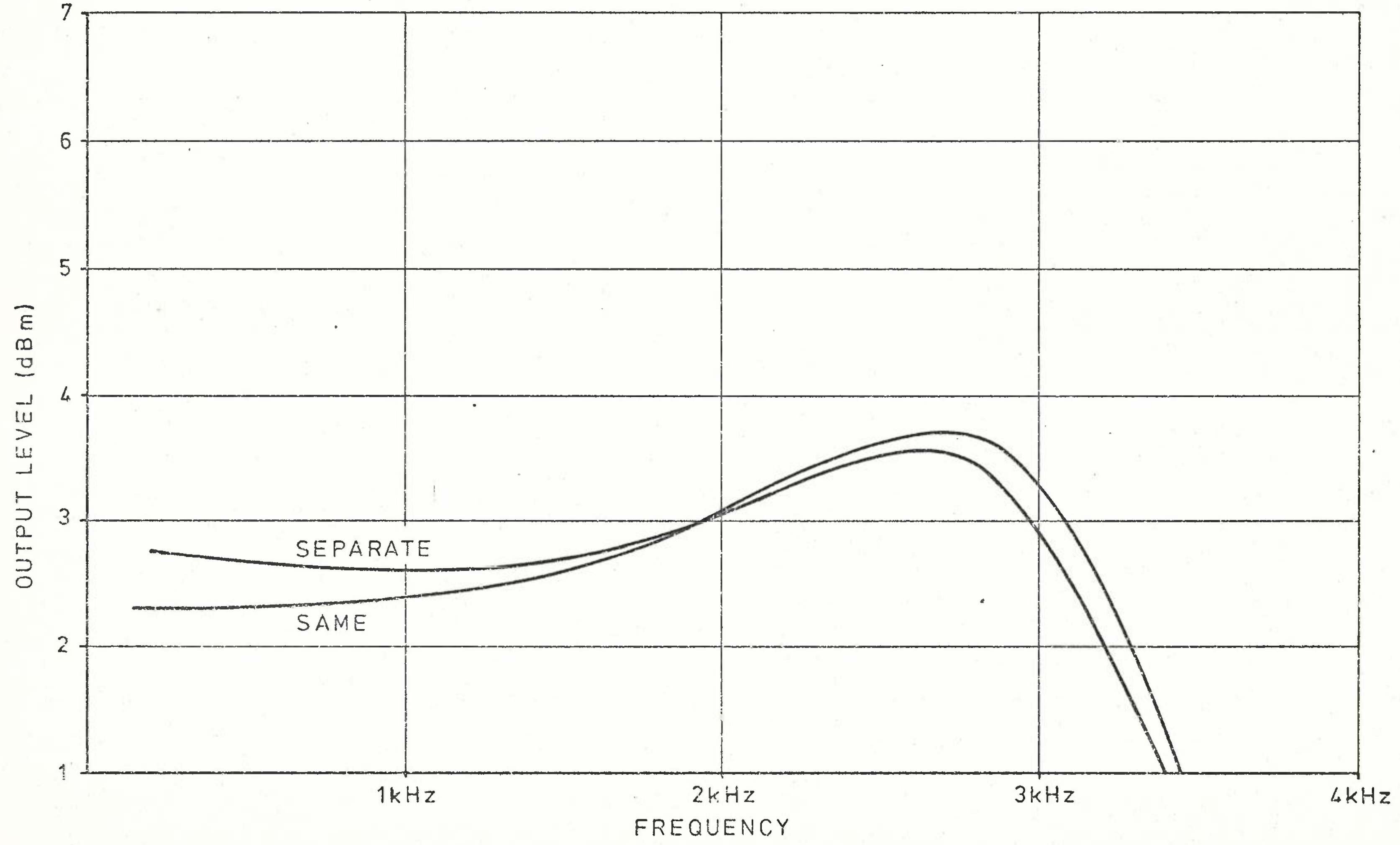

FIG. 3 FREQUENCY RESPONSE WITH -5 dBm INPUT

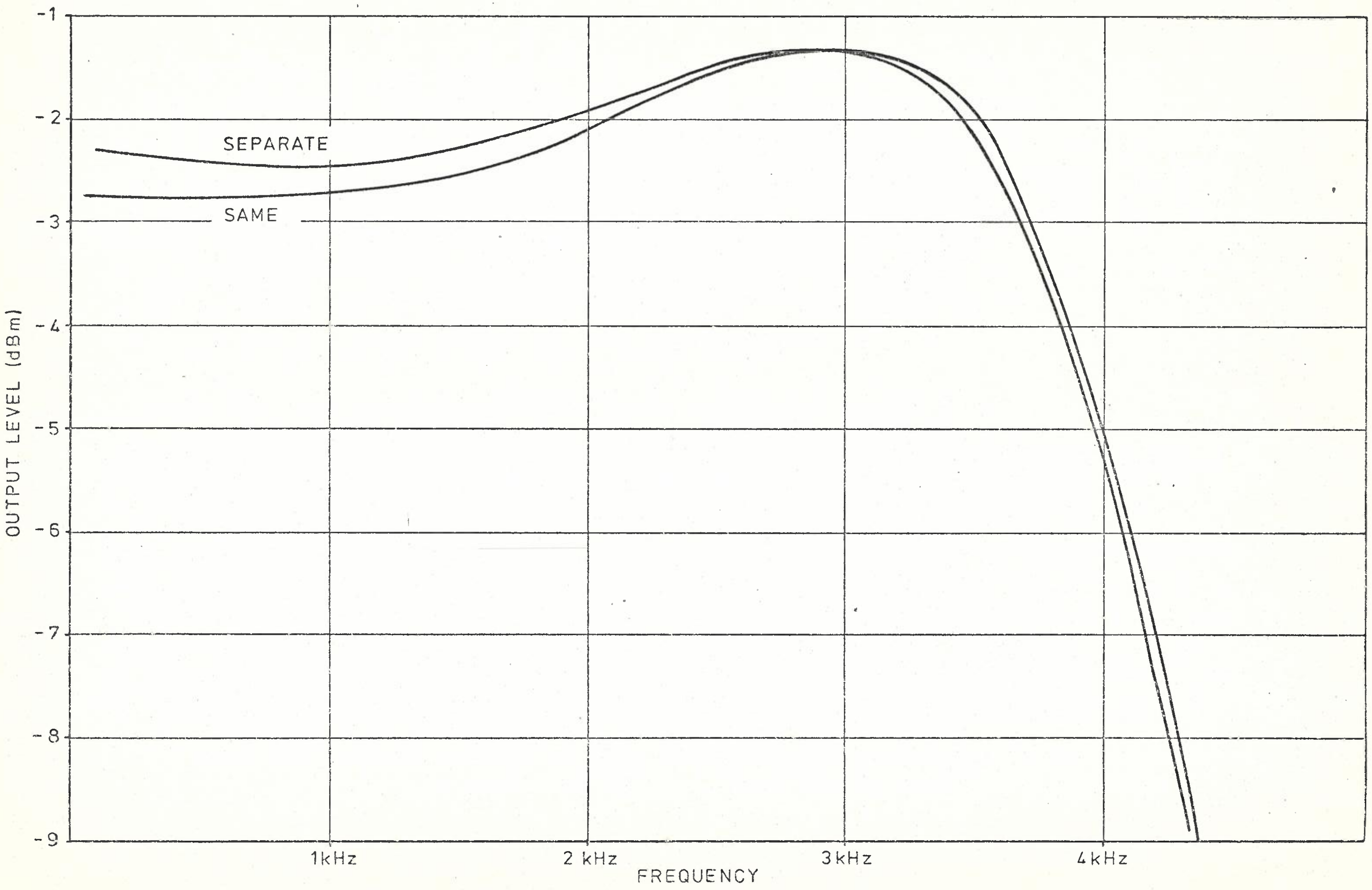

FIG. 4 FREQUENCY RESPONSE WITH -10 dBm INPUT

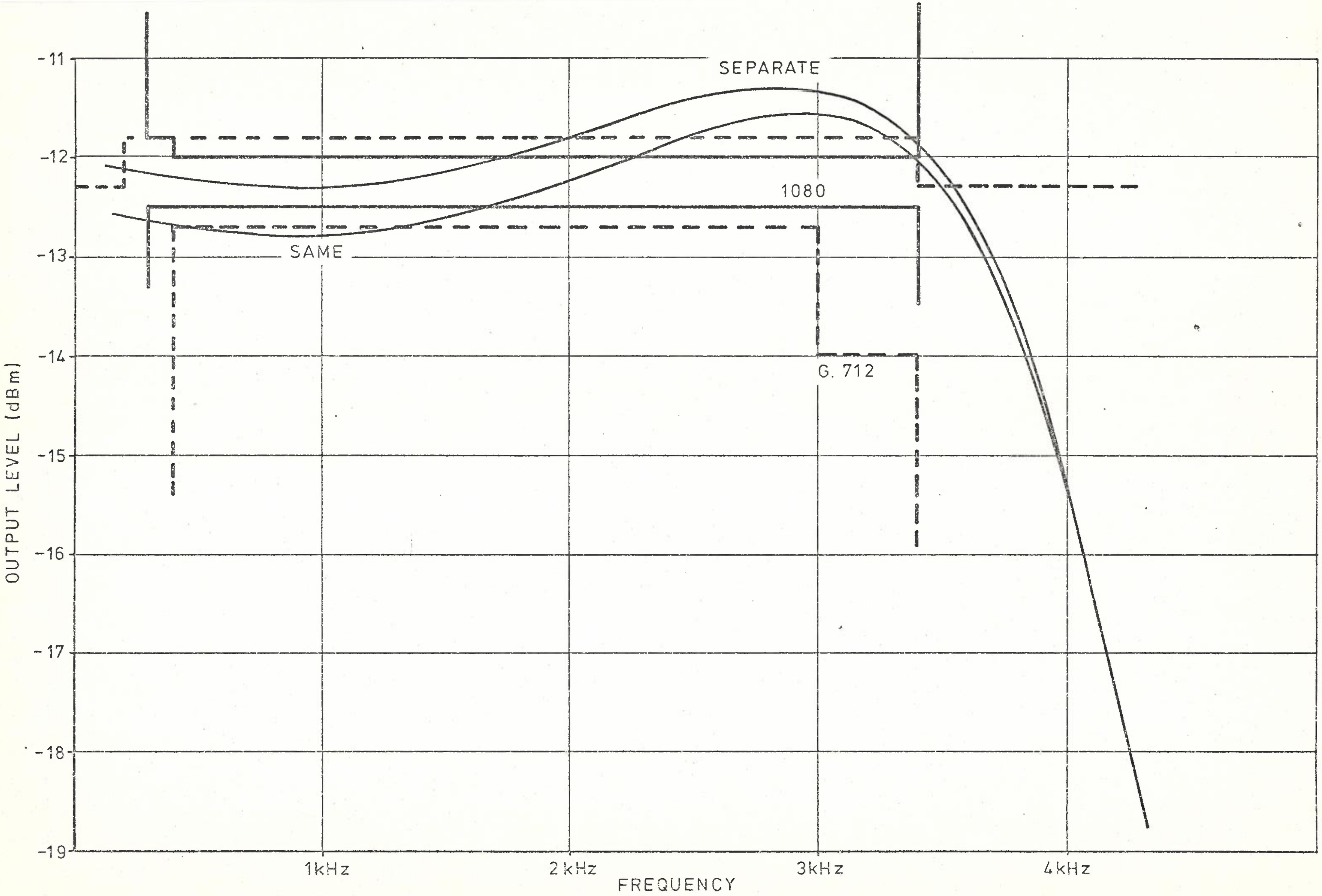

FIG. 5 FREQUENCY RESPONSE WITH -20 dBm INPUT

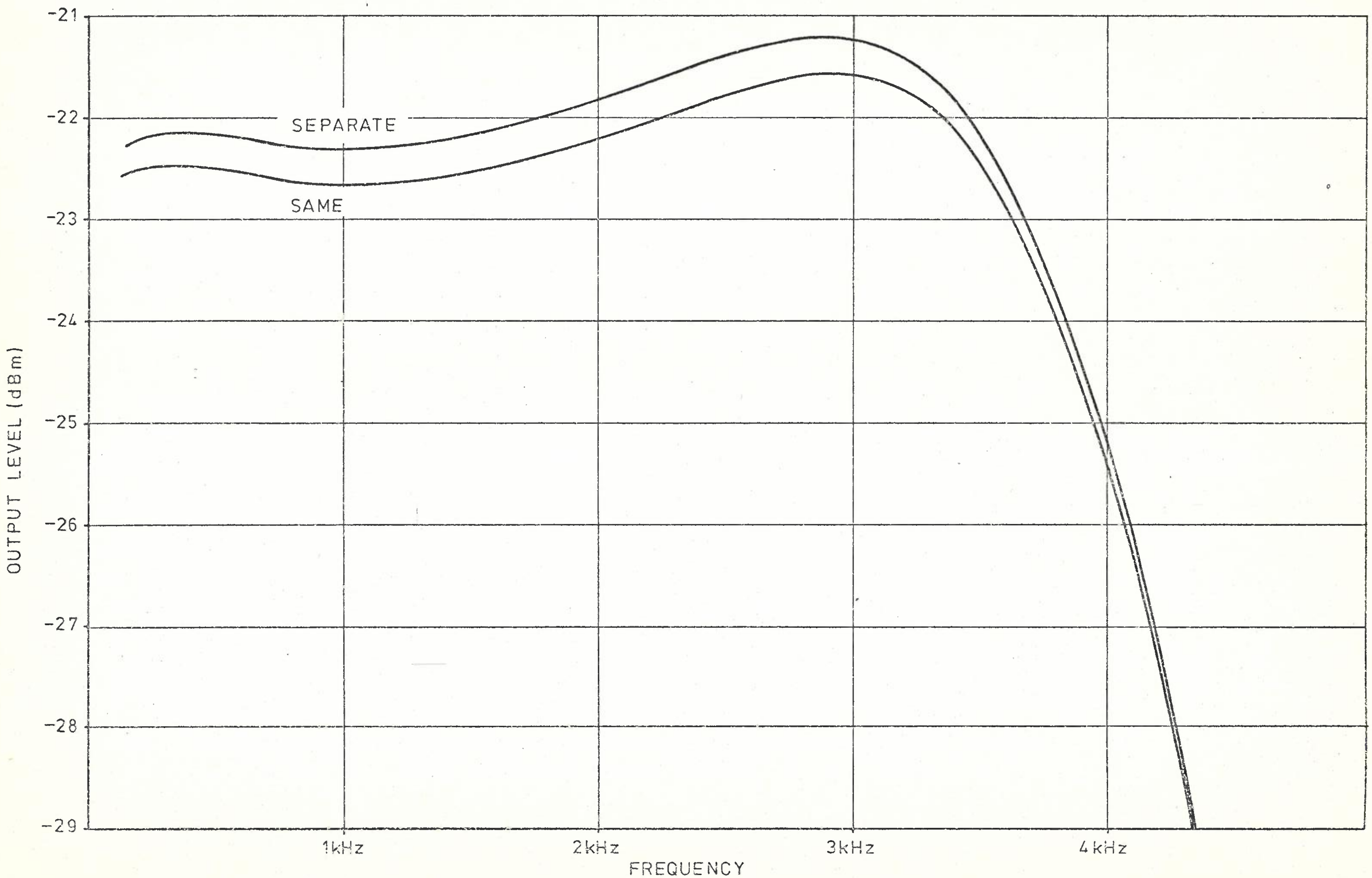

FIG. 6 FREQUENCY RESPONSE WITH -30 dBm INPUT

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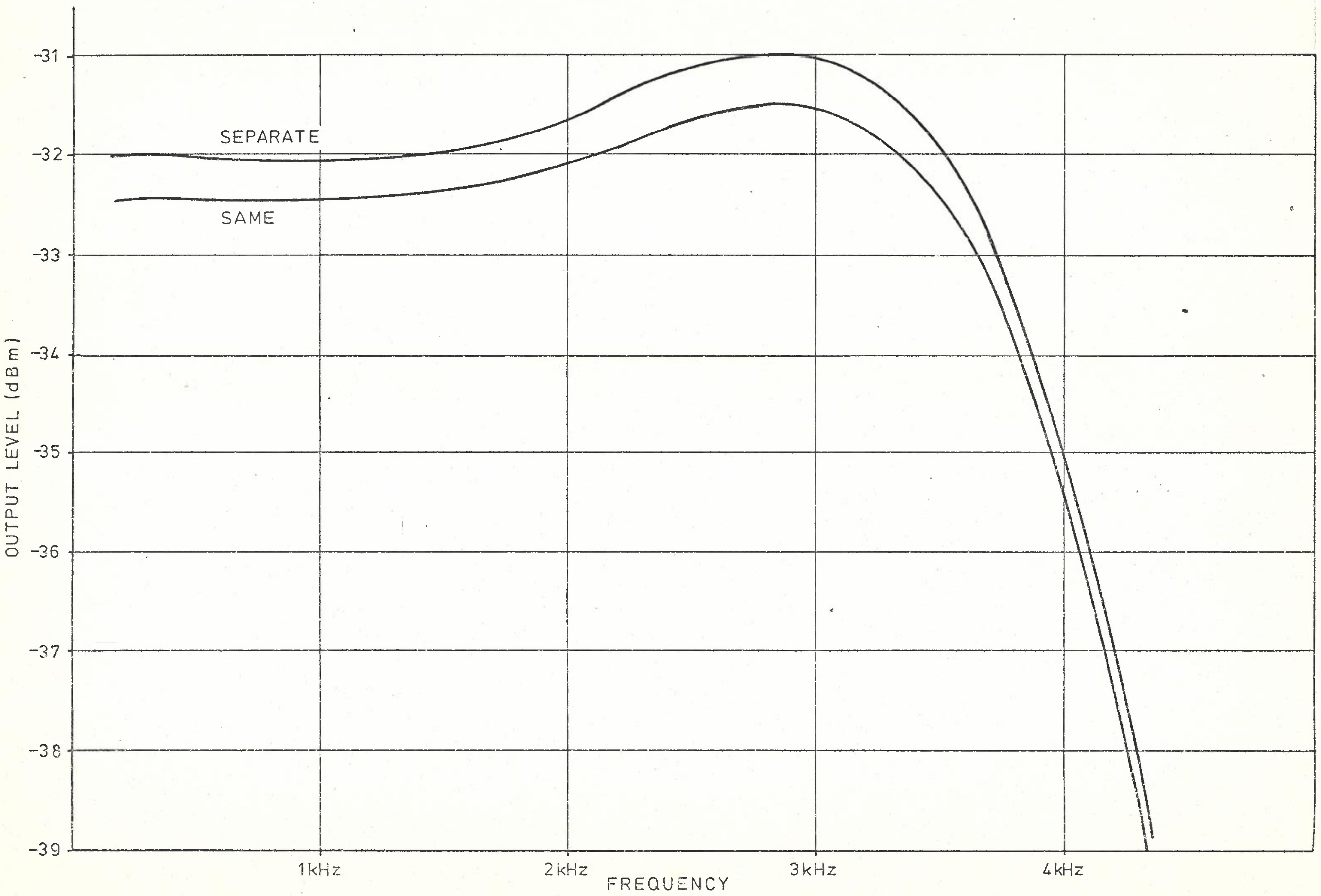

FIG. 7 FREQUENCY RESPONSE WITH -40 dBm INPUT

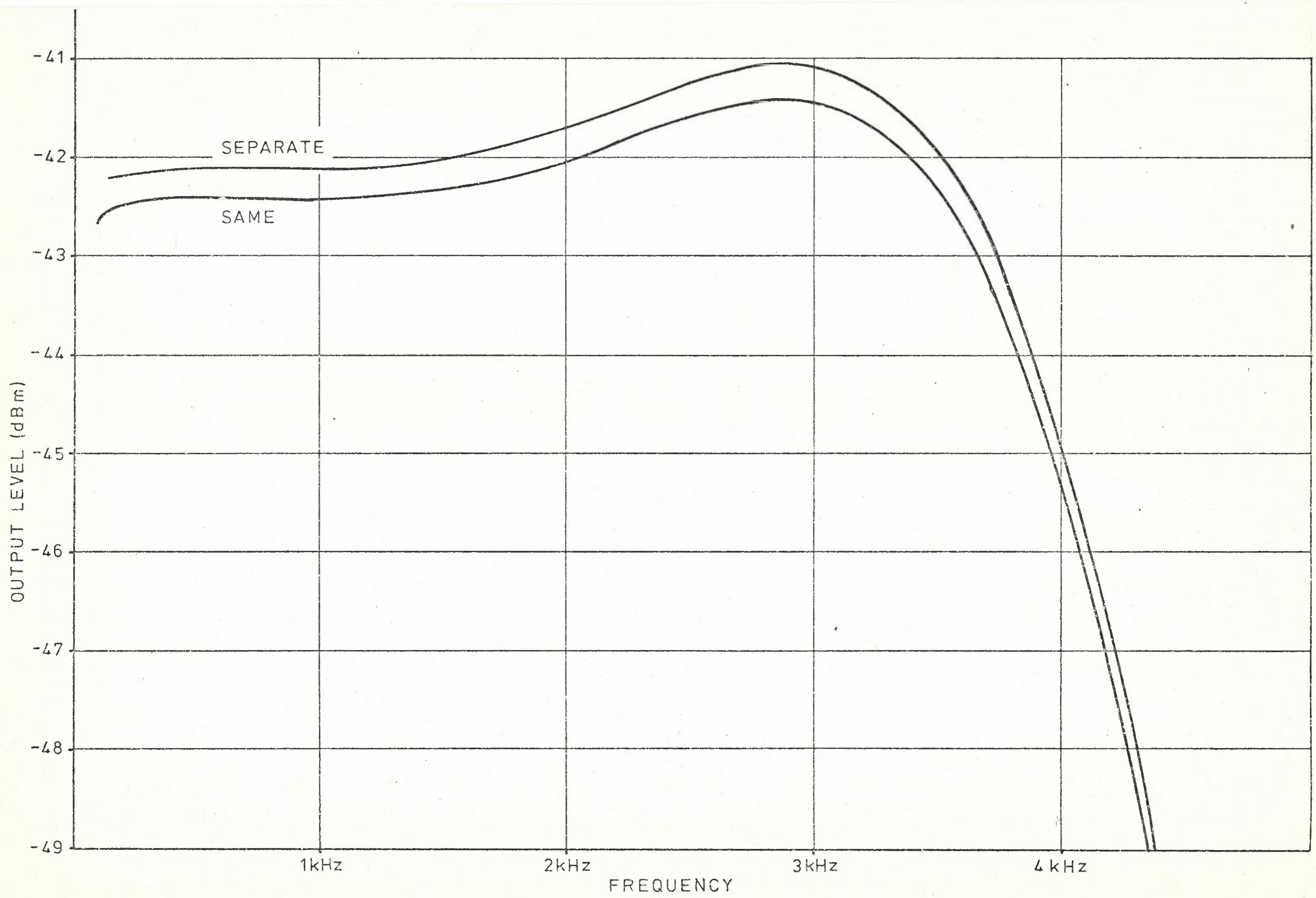

FIG. 8 FREQUENCY RESPONSE WITH -50 dBm INPUT

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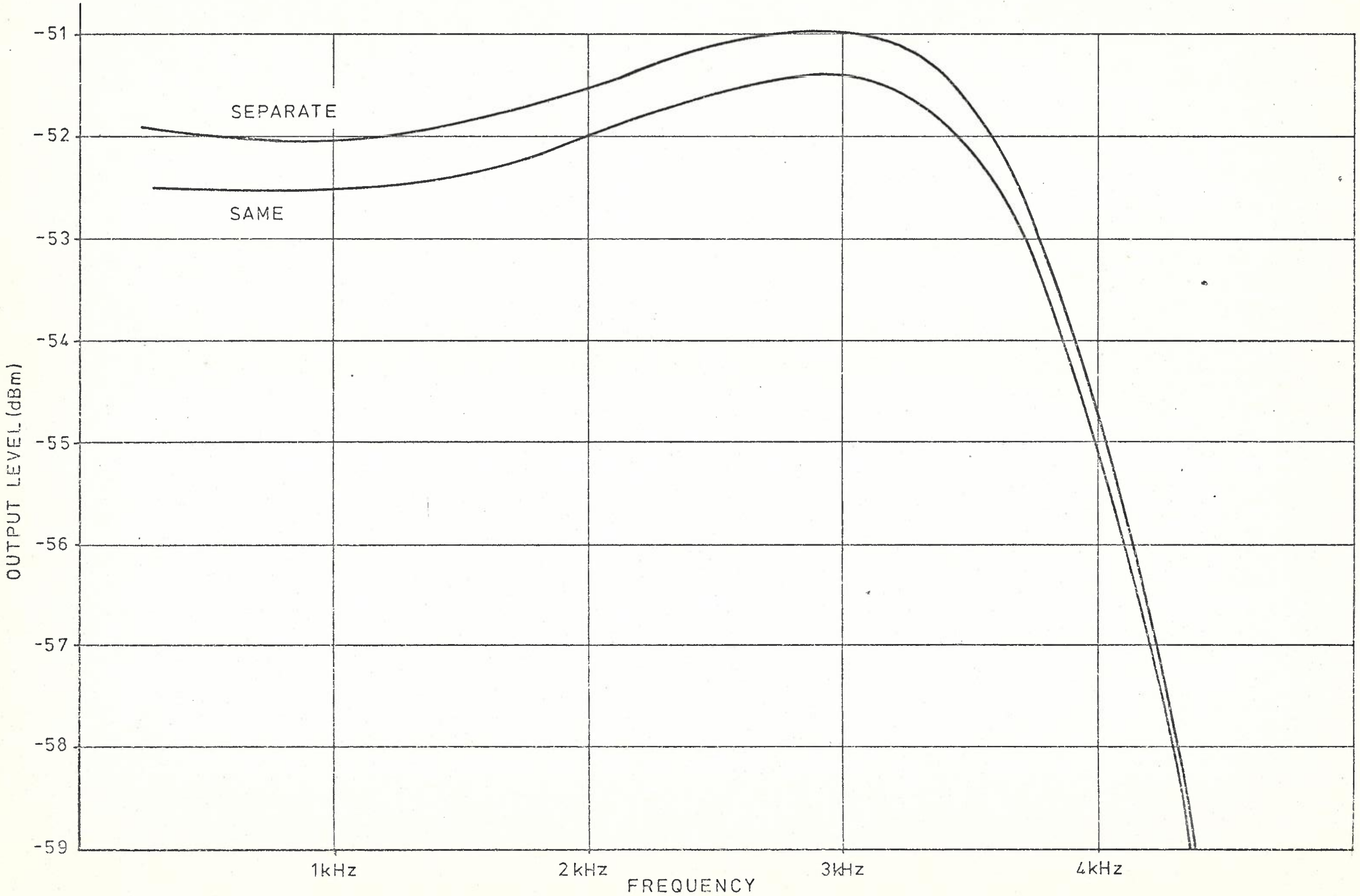

FIG. 9 FREQUENCY RESPONSE WITH -60 dBm INPUT

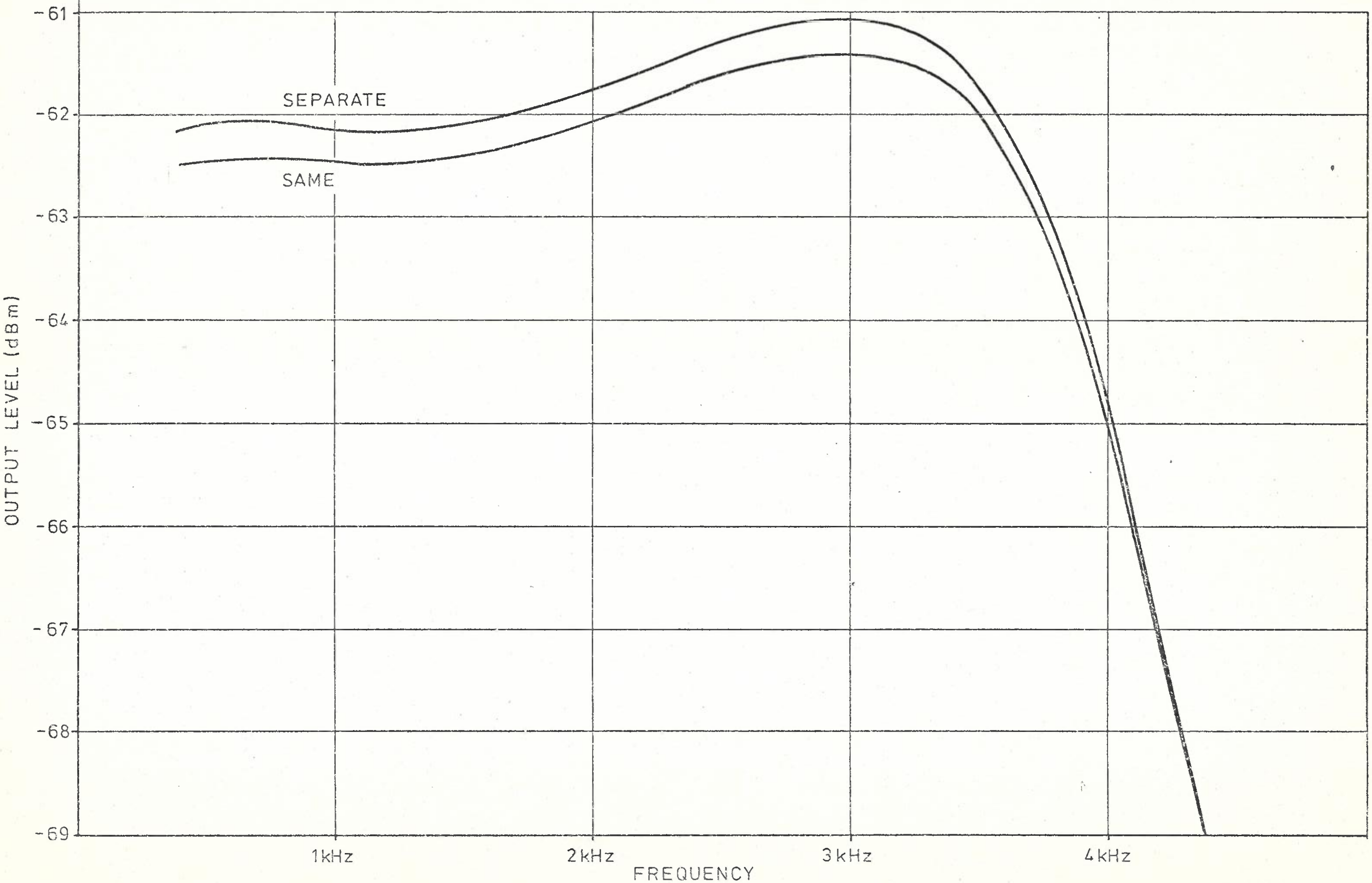

FIG. 10 FREQUENCY RESPONSE WITH -70 dBm INPUT

FIG. 11 VARIATION OF GAIN WITH INPUT LEVEL AT A FREQUENCY OF 1 kHz

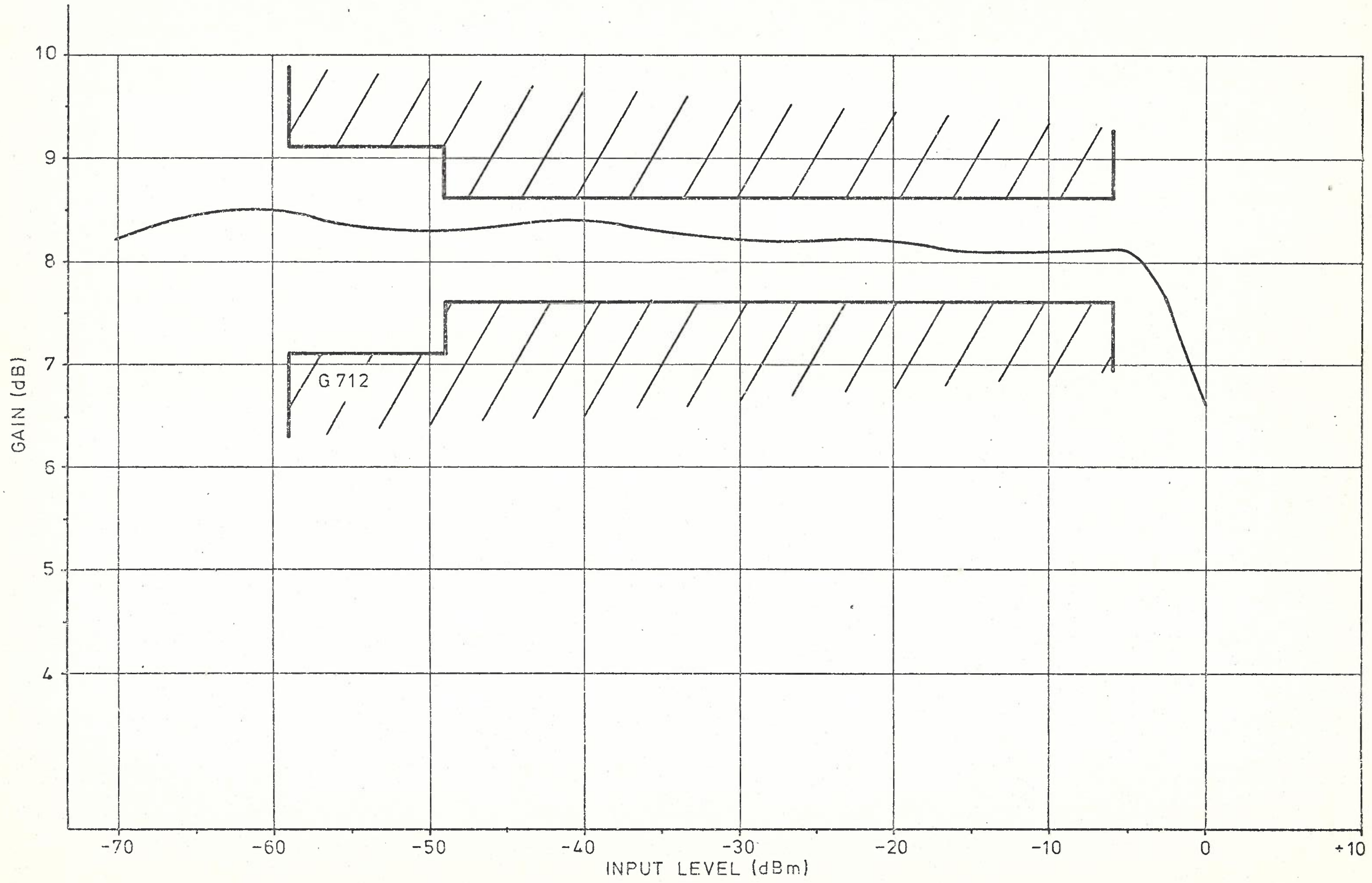

FIG. 12 VARIATION OF GAIN WITH INPUT LEVEL AT A FREQUENCY OF 2 kHz

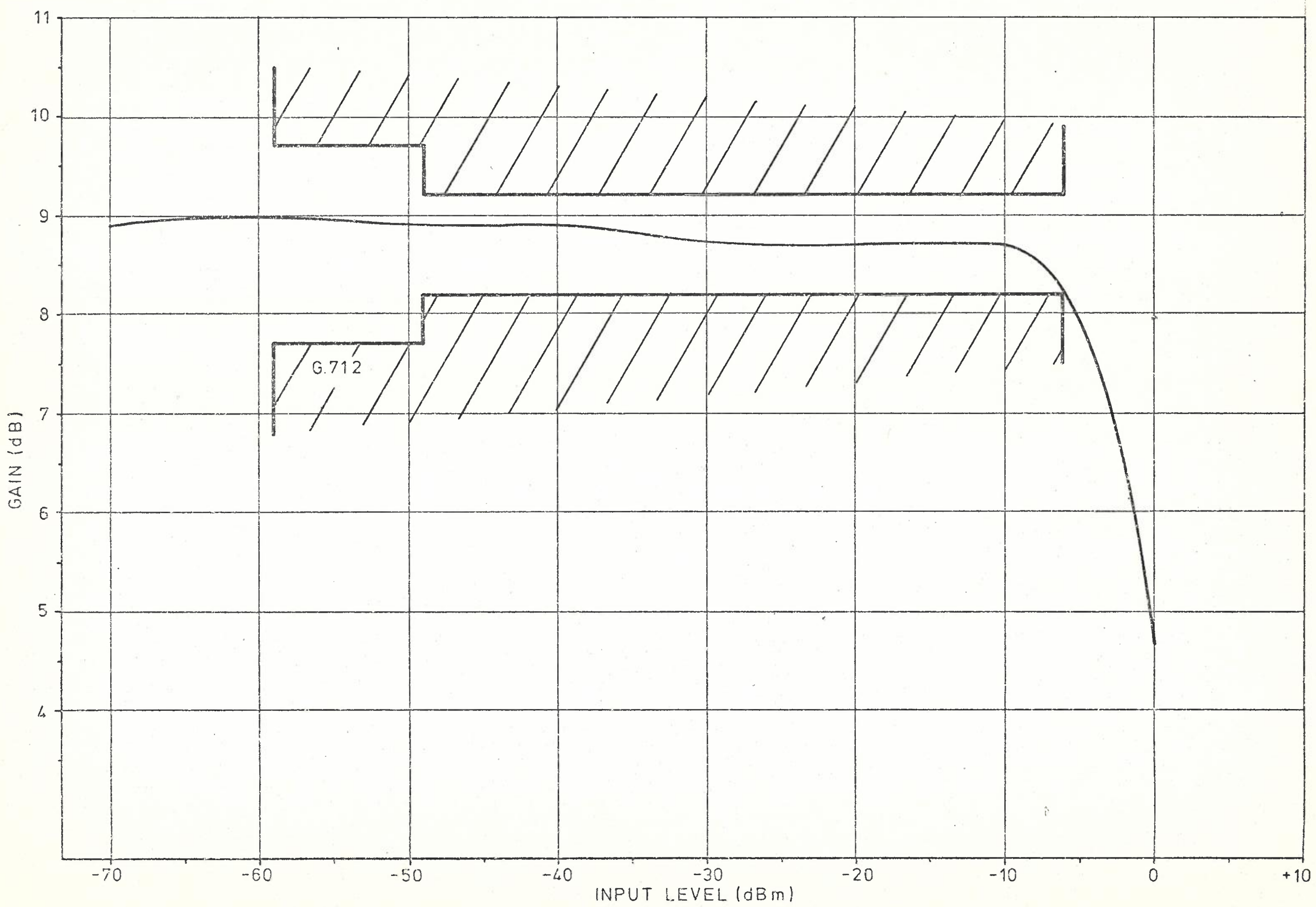

FIG.13 VARIATION OF GAIN WITH INPUT LEVEL AT A FREQUENCY OF 3kHz

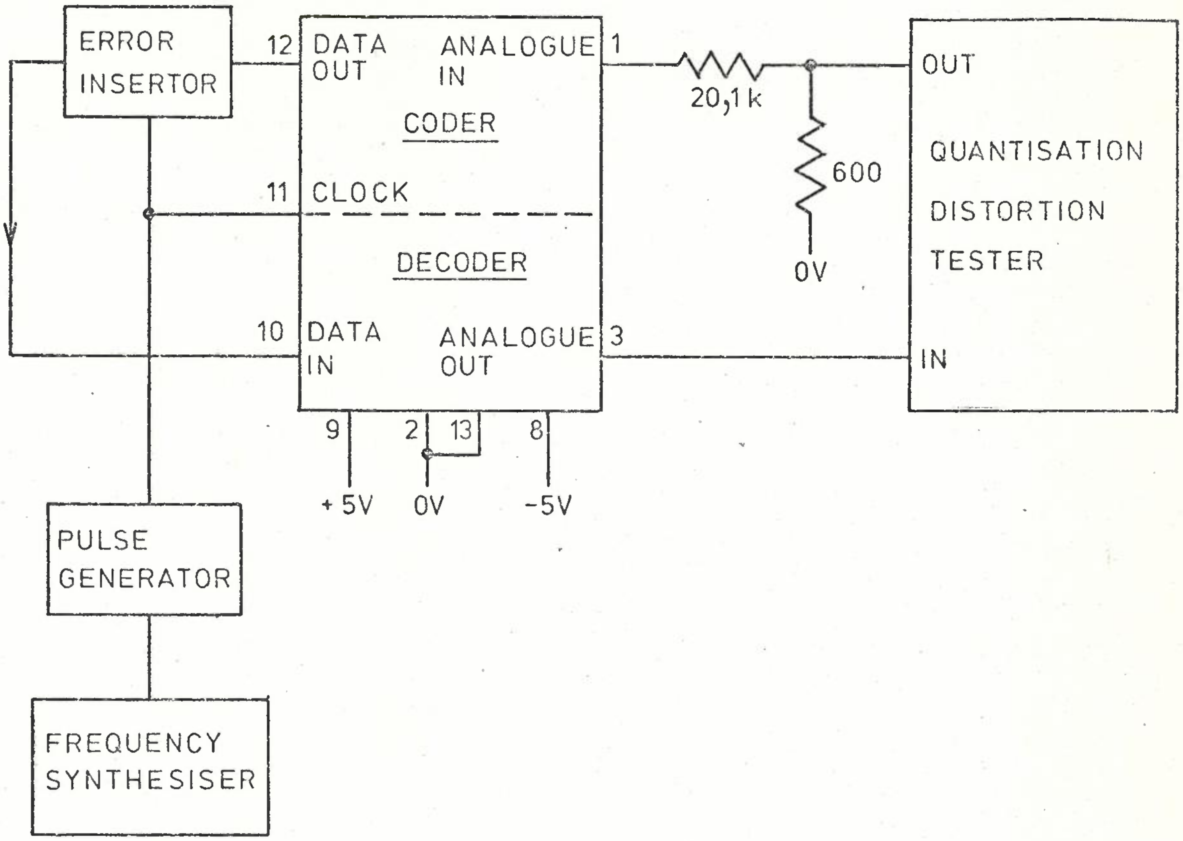

FIG. 14 TEST SETUP FOR MEASUREMENT OF QUANTISATION DISTORTION AND WEIGHTED NOISE

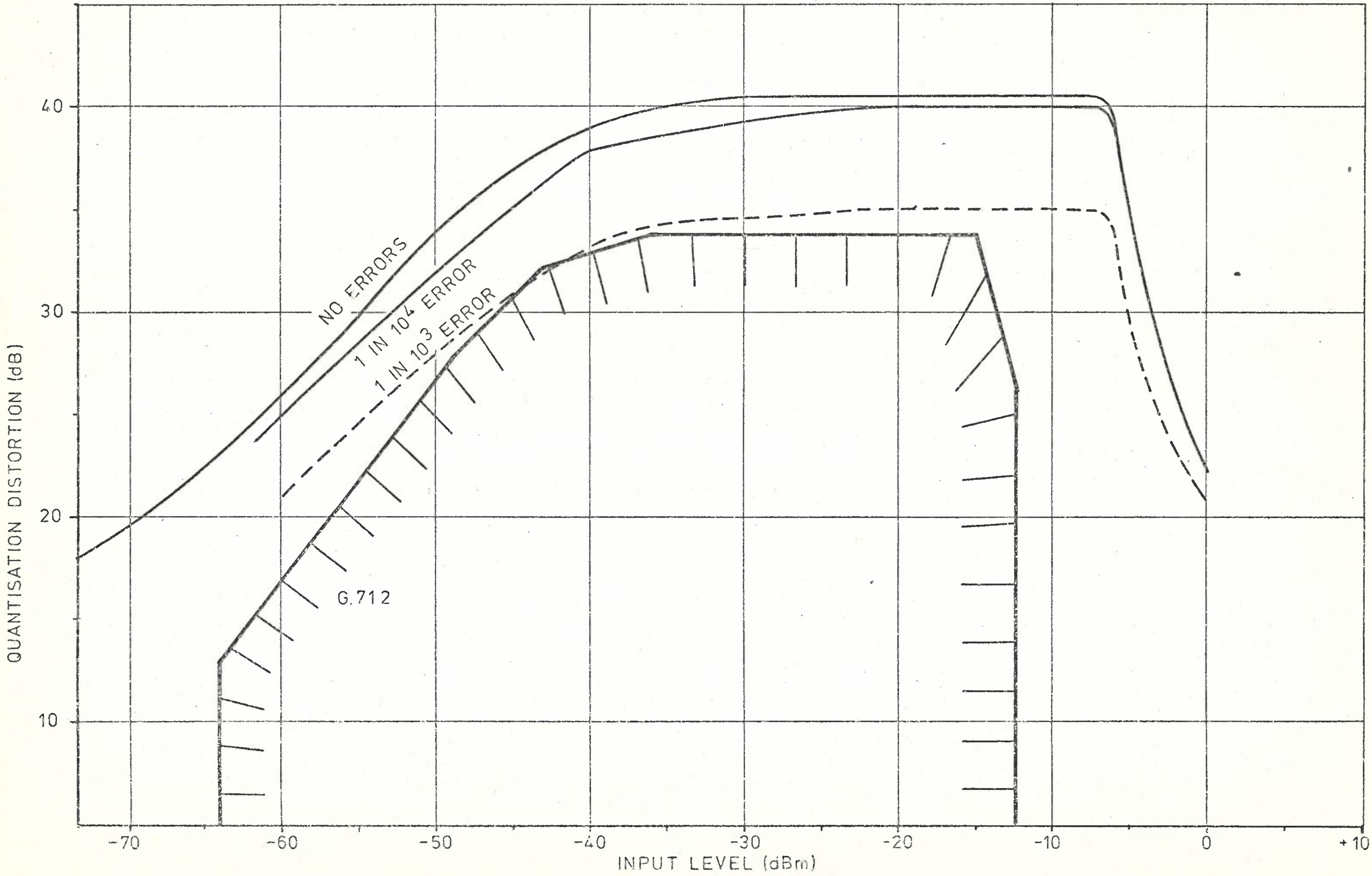

FIG. 15 QUANTISATION DISTORTION AS A FUNCTION OF INPUT LEVEL

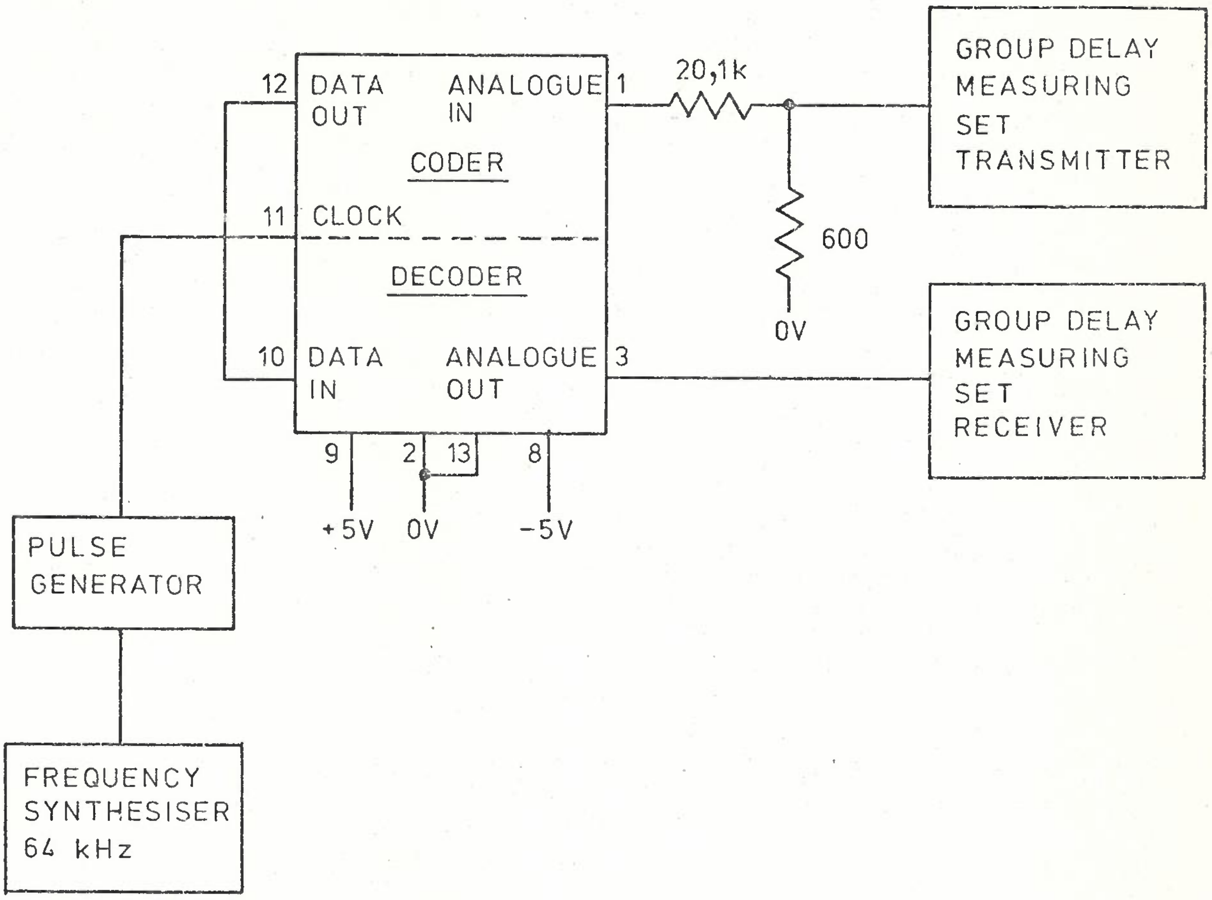

FIG. 16 TEST SETUP FOR MEASUREMENT OF GROUP DELAY

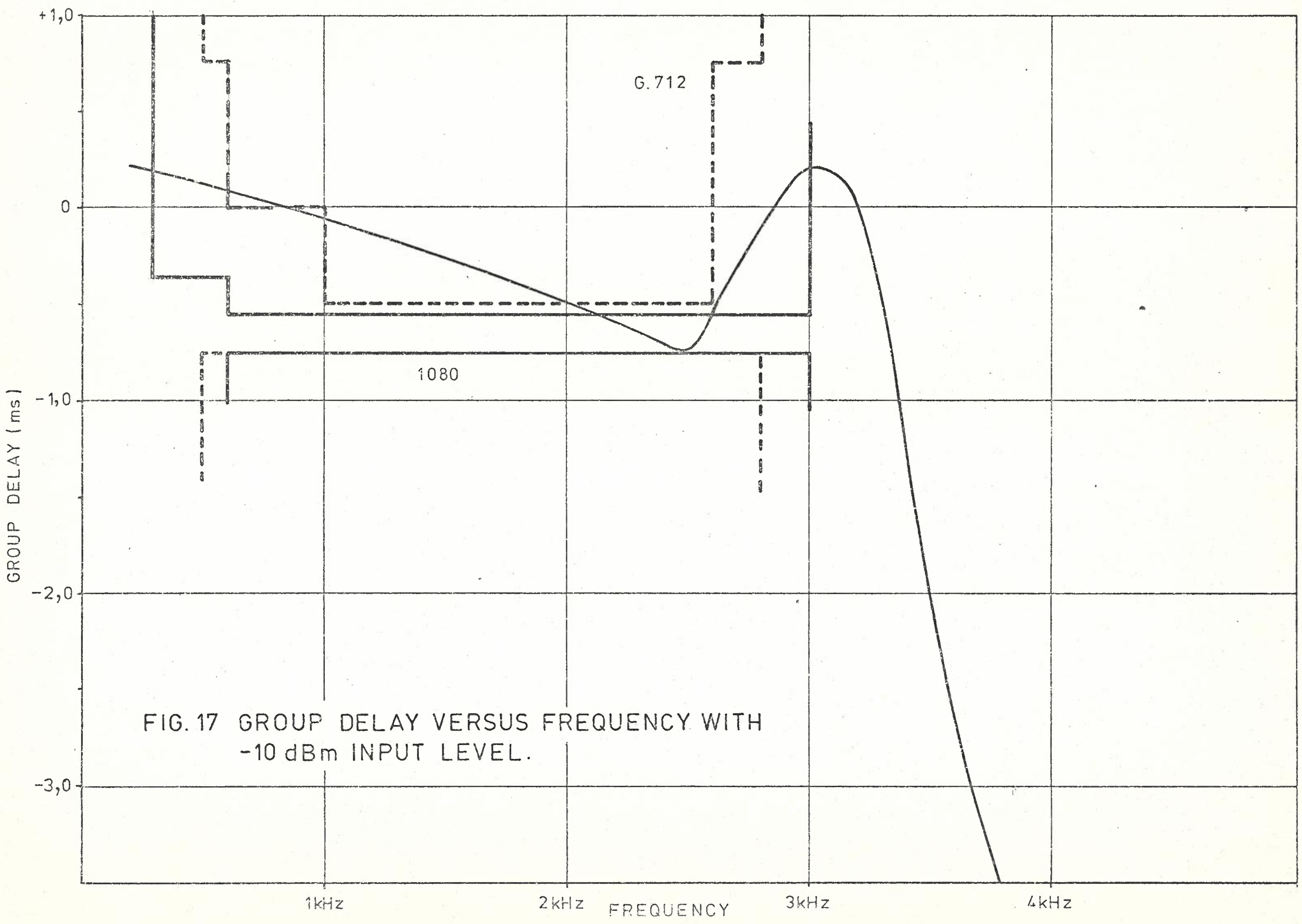

FIG. 17 GROUP DELAY VERSUS FREQUENCY WITH -10 dBm INPUT LEVEL.

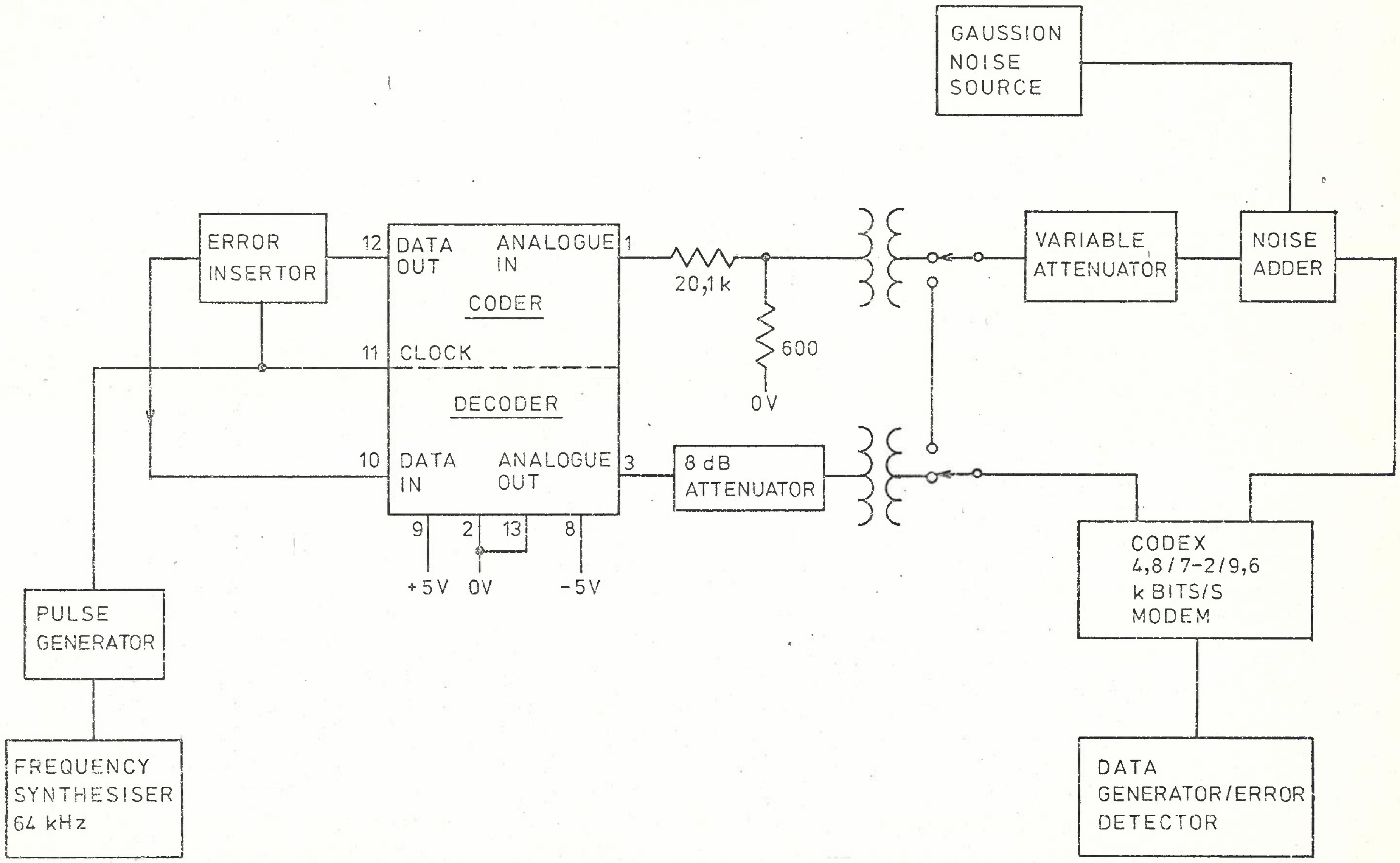

FIG. 18 TEST SETUP FOR MEASURING THE DATA TRANSMISSION CAPABILITIES OF THE CODEC.

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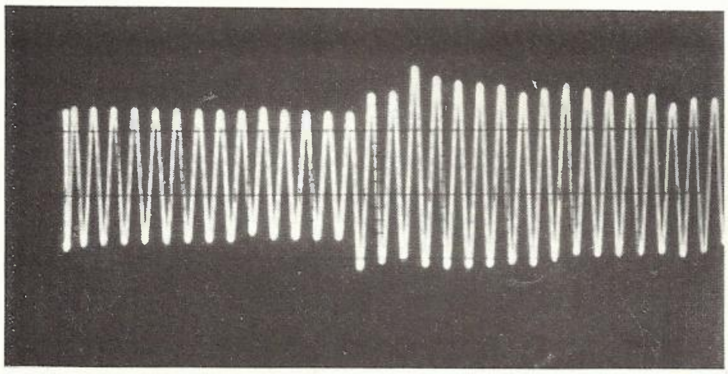
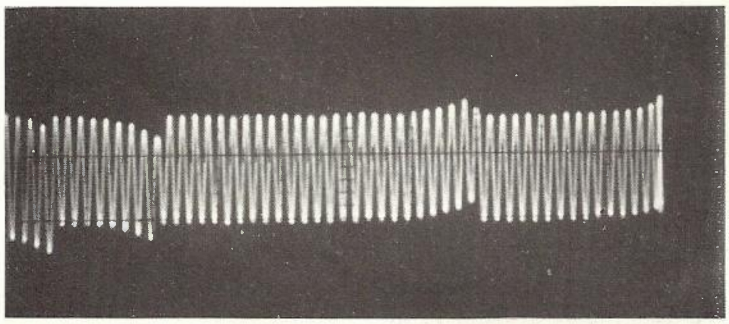
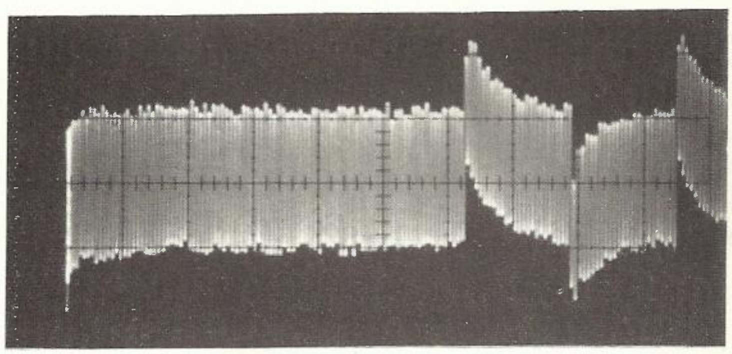


300 Hz



1 kHz



3 kHz

FIG. 19 EFFECT OF ERRORS AT VARIOUS FREQUENCIES