NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-R10
AM Preemphasis Standards
April 7, 1986

NATIONAL ASSOCIATION OF BROADCASTERS

Consumer Electronics Association

NAB: 1771 N Street, N.W.
Washington, DC 20036
Tel: (202) 429-5356 Fax: (202) 775-4981

CEA: 1919 South Eads Street
Arlington, VA 22202
Tel: (703) 907-7660 Fax: (703) 907-8113

Co-sponsored by the Consumer Electronics Association and the National Association of Broadcasters
http://www.nrscstandards.org

NOTICE

NRSC Standards, Guidelines, Reports and other technical publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards, Guidelines, Reports and other technical publications shall not in any respect preclude any member or nonmember of the Consumer Electronics Association (CEA) or the National Association of Broadcasters (NAB) from manufacturing or selling products not conforming to such Standards, Guidelines, Reports and other technical publications, nor shall the existence of such Standards, Guidelines, Reports and other technical publications preclude their voluntary use by those other than CEA or NAB members, whether to be used either domestically or internationally.

Standards, Guidelines, Reports and other technical publications are adopted by the NRSC in accordance with the NRSC patent policy. By such action, CEA and NAB do not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Standard, Guideline, Report or other technical publication.

This Guideline does not purport to address all safety problems associated with its use or all applicable regulatory requirements. It is the responsibility of the user of this Guideline to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

Published by
CONSUMER ELECTRONICS ASSOCIATION
Technology & Standards Department
1919 S. Eads St.
Arlington, VA 22202

NATIONAL ASSOCIATION OF BROADCASTERS
Science and Technology Department
1771 N Street, NW
Washington, DC 20036

FOREWORD

NRSC-R10, AM Preemphasis Standards, is a proposal submitted to the NAB AM Improvement Committee for a standard AM preemphasis curve. This curve was ultimately standardized by the NRSC in NRSC-1, NRSC AM Preemphasis/Deemphasis and Broadcast Audio Transmission Bandwidth Specifications, first adopted in July, 1988. The NRSC co-conveners at the time of the submission of NRSC-R-10 were Charles Morgan, Bart Locanthi, and Alan Boyer.

The NRSC is jointly sponsored by the Consumer Electronics Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

4/7/86

To: The AM Improvement Committee

1301 E. Algonquin Rd.
Schaumburg, IL 60196
(312) 576-4893

Subject: Preemphasis Standards

Dear Sirs,

The intent of this paper is to suggest a standard preemphasis curve for use in the United States. Such a standard would allow receiver manufacturers to include equalization networks in production receivers based on broadcasting practice rather than subjective observations and comments of those people engaged in field testing radio designs. Presently there are several proposed equalization curves which have been proposed to the AM Improvement Committee. They include the following: 1) Double fifty microsecond, shelved, 2) Fifty microsecond , and 3) The inverse of the EIAJ standard IF filter response. The proposed preemphasis network proposed by the author is similar to the 50microsecond curve except that the breakpoint is lowered to 2100Hz. A single pole preemphasis is utilized with the exception that a "shelving" point of 9500Hz. is utilized to insure that the maximum proposed boost reaches a maximum of just under 10 dB at 9000Hz. The described curve is similar to the 75 microsecond preemphasis curve used for FM broadcast with one exception: a small amount of shelving is used to limit the maximum high frequency boost. This reduces adjacent channel interference in a band of frequencies at which a) a listener can not readily discern a 2-3dB drop in energy and b) a band of frequencies where a notch filter, which is anticipated to be found in most wideband radios, will color the response of the radio beyond that which could be corrected by any practical preemphasis curve. The attached report covers the following topics:

1) A description of the proposed preemphasis curve.

2) The effects of this proposed curve on narrow and medium bandwidth radios.

3) Deemphasis for use in wideband radios.

4) The effects of the proposed preemphasis curve upon RF spectrum.

5) The effects of narrow band antennas on highly processed/preemphasised source material.

6) The effects of clipping on RF spectrum.

THE PROPOSED PREEMPHASIS CURVE

The preemphasis curve proposed is a single pole curve which has a break frequency of 2100Hz. To reduce the peak boost at high frequencies, a simple shelving network with a break frequency of 9500Hz. is included. The maximum boost from such a curve is slightly under 10dB at 9000Hz. The curve proposed is similar to the 75 microsecond curve used for FM broadcast. The reasoning behind this choice is twofold. First, the curve described by a single pole network which breaks at 2100Hz. is an optimal one for increasing the <u>flat</u> audio response of medium bandwidth receivers, while allowing narrow band radios to take advantage of the 4dB boost at 3kHz. to provide sufficient intelligibility. A wideband radio can naturally take advantage of simple RC deemphasis to restore proper frequency response. In addition, wideband radios may be able to use the deemphasis networks already in FM stereo radios. Secondly, the modified single pole curve dramatically reduces adjacent channel interference as compared to higher order preemphasis networks. Located in Appendix A is a plot of the proposed preemphasis curve. Figure A1 represents the response achieved with the proposed curve. Figure A2, included for reference, indicates the response of a simple 75 microsecond preemphasis network. In addition to the 9500Hz. shelving network, a steep skirted, multipole filter should be included as a protection against splatter caused by clipping products and/or high frequency audio inputs to the processor. Figures A1 and A2 include a fifth order Butterworth filter with a break frequency of 12kHz.

There has been some discussion by the committee that the final filter be located at 10kHz. There are several reasons to use a 10kHz. filter especially since most receivers will not have audio response beyond 10kHz. Indeed, even a wideband radio should incorporate a notch filter to eliminate the 10kHz. whistle that would often times be present without it. However, the shape of the output filter would play a large role in determining the audio bandwidth of a processor. A three pole Butterworth filter at 10kHz. would probably have no better adjacent channel protection than a 12 kHz. fifth order elliptical filter; the latter allowing for near FM frequency response on wideband radios operated in the local coverage area of a station. Further testing would be necessary to determine the protection ratios that result with various filters. Although the response shown in Figure A1 includes a fifth order Butterworth filter, the preferred response would be an elliptical function of the same order. This would result in a steeper slope, increasing adjacent channel protection ratios. If the committee decides that a 10kHz. final filter is to be included with the final preemphasis network, the 9500Hz. deemphasis network would not be required if the response of the 10kHz. filter is properly chosen.

<u>EQUALIZED RECEIVER BANDWIDTH</u>

This section deals with the perceived bandwidth of several radios when the proposed preemphasis curve is used. I do not wish to ignore the narrow band radios that are commonplace today, however, one should not over correct the broadcast audio to compensate for these radios at the expense of newer, wideband radios. The proposed curve has approximately 4dB of boost at 3kHz., thereby increasing the intelligibility of even these narrow band radios to an acceptable level.

Located in Appendix B are the frequency response characteristics of 8 different radios that are available today. These radios, six of which are newer production receivers, range in audio bandwidth from 3.1kHz. to a moderate bandwidth of 6kHz.Audio bandwidth is defined as the -6dB high frequency limit of the radio. Although the trend toward higher bandwidth radios is present in most of the samples I have presented in Appendix B, the average new radio still has a -6dB frequency response limit of 4.5kHz. This is due in part to the large amounts of high frequency preemphasis used by most stations today. Studies have shown that people, especially women, do not enjoy the shrill, honky sound that a radio will reproduce if it has a wideband IF filter and the received station is using large amounts of preemphasis; especially multipole preemphasis. To combat customer complaint and radio return problems, the receiver manufactures have turned to the moderate 4.5kHz. bandwidths that are emerging today. I am confident that if a single preemphasis curve were selected and implemented, a great number of receiver manufactures would increase the audio bandwidth of AM receivers further. The few extreme wideband radios that are available today have been neglected since a simple RC deemphasis network would equalize the audio from these radios to the desired response. Receiver tests have shown that 7.5kHz. and greater bandwidth radios can be deemphasised to an acceptable level with the treble control or graphic equalizer when the proposed preemphasis network is used to encode the broadcast program material.

Each of the frequency response curves located in Appendix B has been modified to show the increased audio response possible from the proposed equalization curve. On each chart, the lower frequency response run is the actual response of the radio without equalization. Above each frequency response curve, I have plotted the equalized audio response when the proposed curve is used. Even though each radio utilized different ceramic IF filter and LC RF/IF filter combinations, it is interesting to note how flat each radio is made with the proposed equalization. In no case is more than 3dB worth of peaking achieved with respect to the 1kHz. reference response of the receiver. Radio "G" is the narrowest with a -6dB point of 3.1kHz. With the 75 uSec. preemphasis curve, the radio is made flat to 3kHz. and the -6dB point is moved to 4.1kHz. This radio is the narrowest one tested, yet even it is made more intelligible with the EQ curve that is proposed. Radio "D" is the average of the group. It has a -6dB point of 4.5kHz. With EQ the radio is essentially flat to 5.3kHz. and is -6dB at 7.2kHz. The response of these radios is smooth without excessive peaking near 3-4kHz. which would result with a sharper slope. The widest radio of the group was radio "B" which had a -6dB point at 6kHz. The equalized -6dB point falls at 8.9kHz. Beyond this point, a notch filter would probably destroy the response of any radio. Again notice that less than 3dB of peaking occurs, resulting in a natural sounding receiver. I am in agreement that wideband radios are necessary, but at night and in the fringe areas, the narrower filters shown in the average of these 8 radios will be needed. Therefore, it is important to choose a curve that does not cause excessive shrillness in wideband or medium bandwidth receivers, excessive ringing in sharp skirt IF filters, and one which can be easily equalized in wideband radios. I feel that the 75uSec. curve proposed within can accomplish these tasks.

DEEMPHASIS FOR WIDEBAND RADIOS

The proposal described within this paper was designed with wideband radios in mind. First, I will define wideband radios as those which have audio frequency response limits in excess of 7.5kHz. These radios can be adequately deemphasised by a simple RC network which is low in cost to implement and uses very little board space. The purist will note that even a 10kHz. wide radio will have approximately a 3dB loss in energy at

10kHz. if a simple RC deemphasis network is used, however, a 10kHz. notch filter will cause a much larger error in response than that of the shelving filter at 9500Hz. In an high end receiver with a switchable notch, a simple boost network can restore flat response if desired. One should also be aware that IM products caused by clipping and other audio processing artifacts will also color the audio at these high frequency limits and the additional rolloff is usually desirable to remove some of these products.

EFFECTS OF THE PROPOSED PREEMPHASIS CURVE ON SPECTRUM

Tests show that USASI noise still predicts the spectral energy content of most music. If we believe this is true, then one can make the assumption that, on the average, the energy density in programing at 10kHz. is 20 - 30 dB below that of 500Hz. Thru preemphasis and compression available in modern audio processors, these levels are increased until they are, at best, 10dB down at 10 kHz. and often times, not even this much. The curve I propose, would increase the energy at 9kHz by 10dB, lower amounts would occur below this. I believe that a minimum of 6dB improvement in adjacent channel interference protection could be encountered by many stations by incorporating this preemphasis response. In addition, many transmitters simply can not produce these high frequency energy densities without producing excessive amounts of spectrum spreading due to harmonic and intermodulation distortions, and incidental phase modulation components. Probably a worse condition, is the large number of narrow band antennas in existence today. Many DA's in use today have high sideband SWR's that cause large amounts of reflected high frequency sideband energy to return to the transmitter, causing excessive occupied bandwidth due to premature limiting of carrier envelope before pinch off. Also occurring is additional distortion products and phase modulation due to the varying impedance of the reactive load to the PA. This IPM would not be visible as an envelope distortion during the proof but would manifest itself as an increase in splatter. Therefore, on many stations, the splatter could be reduced much more than the 6dB I have indicated. Some preliminary tests have shown that the actual increase in protection ratio with the preemphasis network proposed may be closer to 12 -15dB as compared to another audio processor in use today.

EFFECTS OF CLIPPING ON SPECTRUM

Clipping will can have a large effect on the spectral signature of the station. I will not go into the effects of non-bandlimited clipping such as that which is often times done at the transmitter today. The impulse type interference can be as little as 30dB below the carrier and extends above and below the carrier frequency as far as the passband of the transmitter and array will allow it to go. However, modern audio processing, even with filtering, can produce legal but, never the less, large amounts of first and second adjacent channel interference. In Appendix C please find three spectral photos which show the effects of clipping on the spectrum of the station. These photos were taken on a laboratory mono generator that had less than .15% THD at 100% modulation and incidental phase modulation products less than 50dB below the carrier for the same conditions. The lab generator was operated into a flat, nonreactive load. The first photo, C1, shows the accumulated spectrum of one song which was processed by a popular audio processor. The preemphasis was a maximum of 15dB and the clipper consisted of the following: A 12kHz. elliptical filter followed by a hard clipper operating with approximately 6dB of clipping. This was followed by a 3 pole phase linear filter. This filter has to be phase linear to maintain the peak limiting without causing ringing. I find the picture interesting since one can see the skirts of the 12kHz. filter nicely defined for about 10 to 15dB. Beyond this point, the post filtering clipping products begin to show. The skirts on these products are a result of the third order linear phase protection filter. It is not my intention to upset the manufacturer of this product; Indeed I find the product to be very acceptable for mono or stereo. I wish to emphasize that the product does meet the FCC rules for occupied bandwidth with considerable margin and the clipping is a result of industry telling the manufacturer that what they want is a good sounding processor that is loud on the air. The technology in this processor does indeed accomplish these goals; a poorer design would result in much more splatter, less on air loudness and a much more fatiguing sound. What it comes down to is that to get loud you must pay a price. In photo C2, we see the same processor except that the final clipper was modified to produce 3.5dB of clipping. Notice the vast increase in first and second adjacent protection. The third and final photo in this section, C3, shows the spectrum of a different audio processor which utilized 15dB of peak preemphasis, 2dB of final clipping, and an 11kHz. elliptical final filter. In this case, the spectrum falls very clean. This is the only point I wish to make; the preemphasis alone does not cause the interference. It is a combination of things including preemphasis and clipping. One must also remember that no transmitter produced today is as clean as the lab generator that I used. The real world broadcast transmitter will produce additional spectral energy due to distortion and incidental phase modulation components. This will only add to the products which are created thru clipping in the audio processor. The typical transmitter on air today when fed into a nonreactive load will have spectral skirts 35-45dB down at 15kHz and falling from there. This is exaggerated further when the transmitter is connected to a typical antenna. The broadcasters must decide at what point they wish to trade splatter for loudness. I feel the committee should address this issue as well during the discussions regarding AM service improvement.

EFFECTS OF NONLINEAR ANTENNA ARRAYS ON SPECTRUM

In Appendix D, you will find scope photos which show the effects of a narrow band antenna system. The point I hope to make is that often times it is difficult or impossible to transmit large amounts of preemphasis from a real world transmitter/antenna combination. There are efforts by many broadcasters to improve their antenna systems, yet many simply can't afford it at this time. In an attempt to get loud and bright, they do some very nasty things to the spectrum. In photo D1 we see the lab generator connected to a nonreactive load. In this picture we see that the transmitter is downward modulated to nearly 100%. Next to this photo is picture D2. This photo shows the clean spectrum that is being radiated by such a system. Below photo D1 is photo D3. In this picture, the lab generator was connect to a model of a directional array I encountered in the field. The same exact modulation conditions which were present in photo D1 were present in photo D3; downward modulation of nearly 100% at 10kHz. Notice that the carrier as observed at the "common point" was only

modulated to 85%. This is due to the reactive return portion of the transmitted signal. As you can see in photo D4, the spectrum is still quite clean, however sideband tilt is present. Since this is a nonlinear load, it is
difficult if not impossible to equalize for this load in the audio processor. Attempts at doing so would probable only cause excessive losses in the transmitter and considerable heating due to the inefficient nature by which such a transmitter would be operated. This antenna problems should be corrected, yet often times the operator just "turns up" the modulation and brightness in an attempt to overcome the deficiencies of the system. In Photo D5 we see the effects of attempting to cause 100% downward modulation. The sine wave of envelope modulation is skewed until it does come close to -100% modulation. At this point, the transmitter has actually been cutoff for a good period of time. The resulting spectrum in Photo D6 shows the results of such overmodulation: A big increase in splatter. Note that this is not always the case, directional arrays can often times have the opposite effect in the far field. Apparent modulation can actually be higher than the transmitted modulation and once again receiver distortions can occur. My point is simple, excessive preemphasis simply can not be used by a number of stations if reduced splatter is to result and reduced preemphasis may result in greater reduction in splatter than one may expect due to the nonlinearities of many antenna systems in use today.

CONCLUSIONS

The information presented within represents only a small portion of the total data collected. The information presented is based on data and observations at many dozens of stations in the US and Canada as well as lab tests performed at Motorola. I would be pleased to furnish interested parties with any additional information upon request. I feel that the modified 75uSec. preemphasis system proposed has merit in that it is easy to encode and decode, has better spectral management than other proposals and is one that both the broadcasters <u>and</u> receiver manufactures can accept. It will provide an increase in intelligibility on narrow band radios without sacrificing quality in medium and wideband radios. The receiver manufacturer can use simple networks for restoring proper frequency response without a large cost or loss of premium board space. The committee must find a preemphasis system that is acceptable to both the broadcasters and receiver manufacturers. I feel that the proposal contained within answers the concerns of both parties.

Respectfully submitted,

Greg Buchwald

APPENDIX A

GRAPHIC ROUTINE PROGRAM

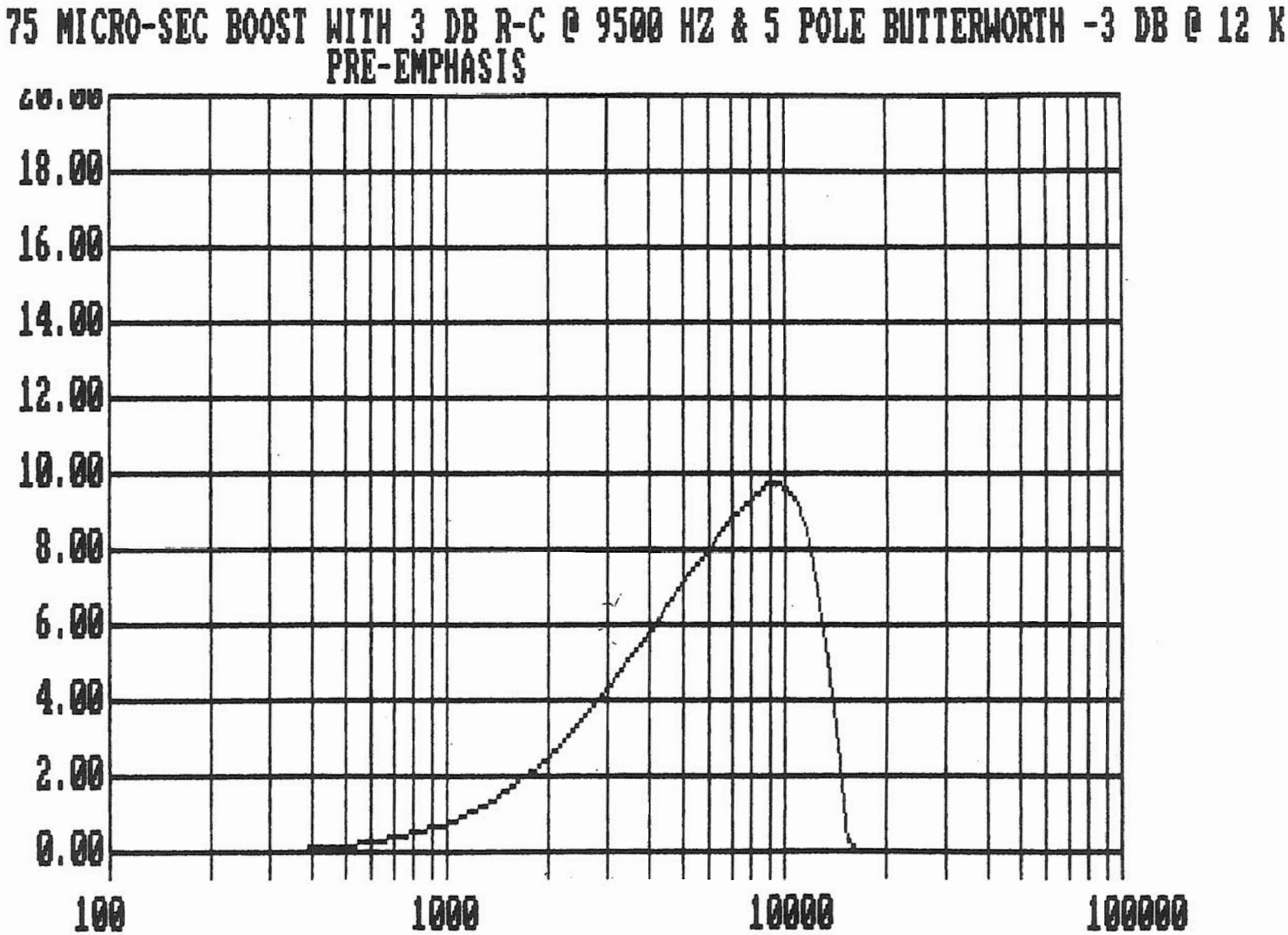


Figure A1

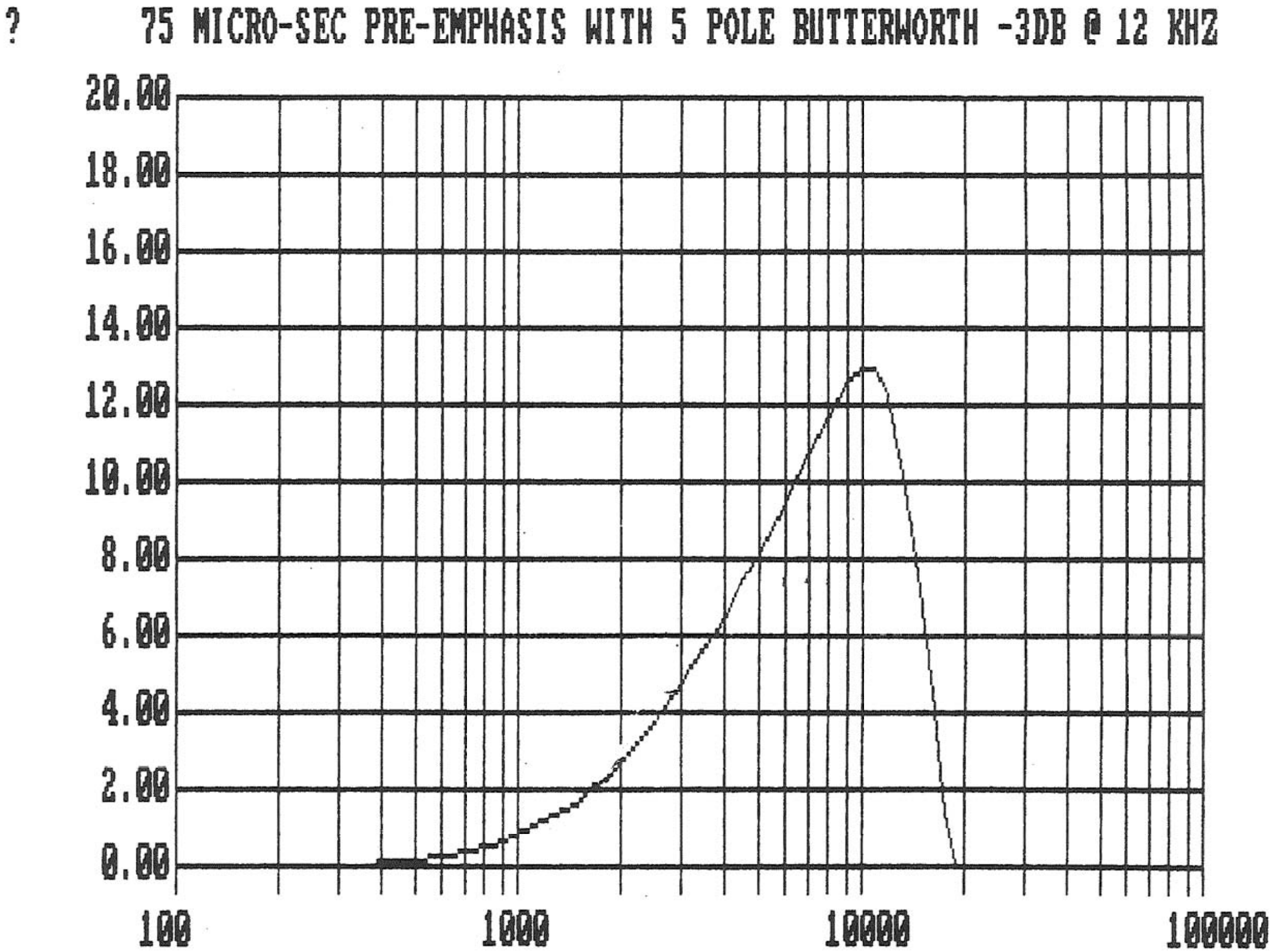
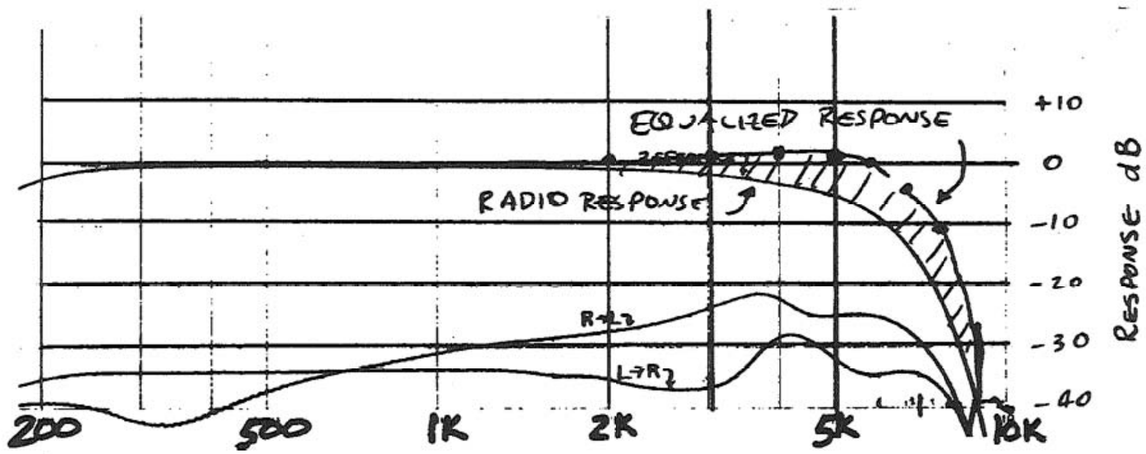

?
75 MICRO-SEC PRE-EMPHASIS WITH 5 POLE BUTTERWORTH -3DB @ 12 KHZ
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
100
1000
10000
100000

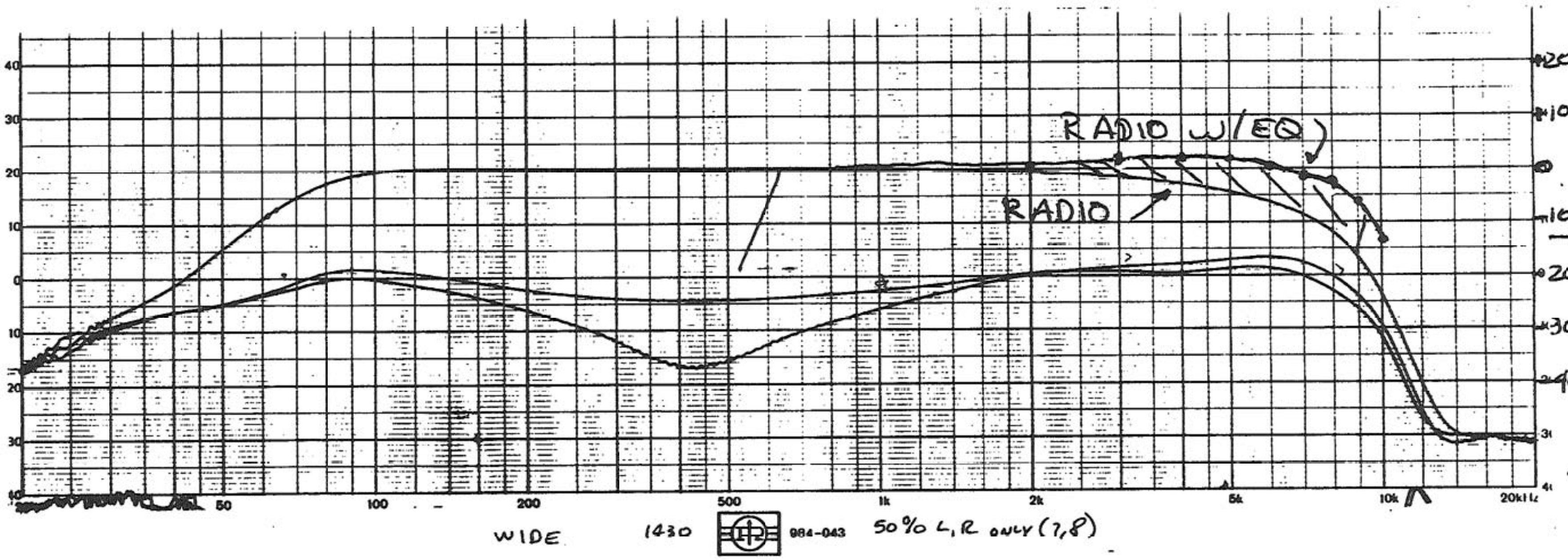
FIGURE A2

APPENDIX B



RADIO A

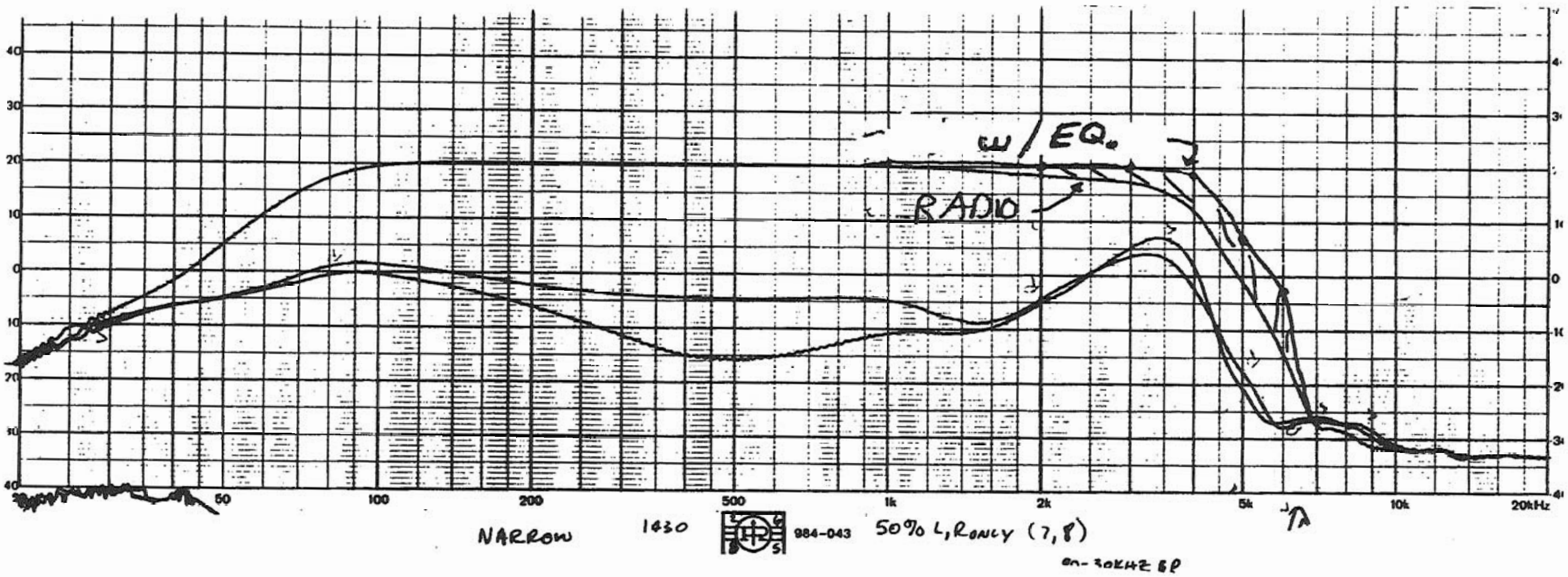
w/o EQ.	−6dB	5.2kHz.
w/ EQ.	−6dB	7.2kHz.



RADIO B

w/o EQ. −6dB 6kHz.

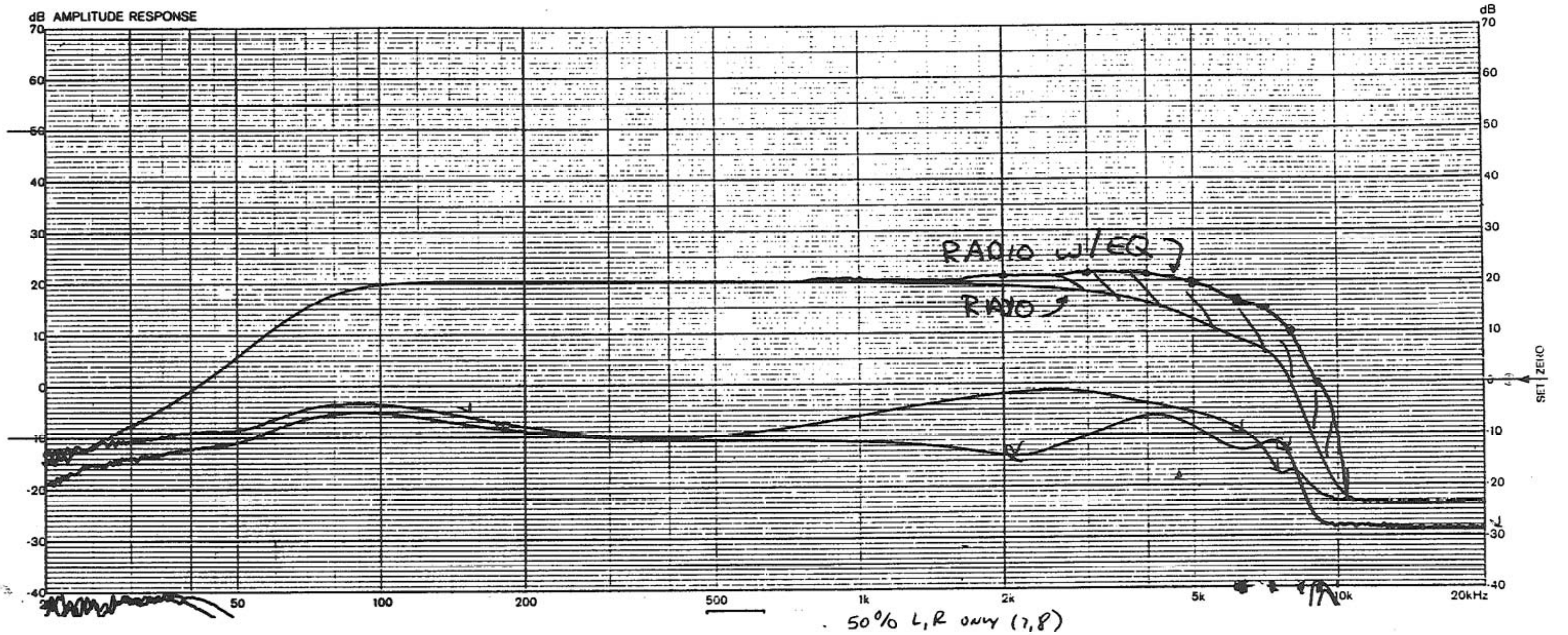
w/ EQ. −6dB 8.9kHz.



RADIO C

w/o EQ. −6dB 3.7kHz.

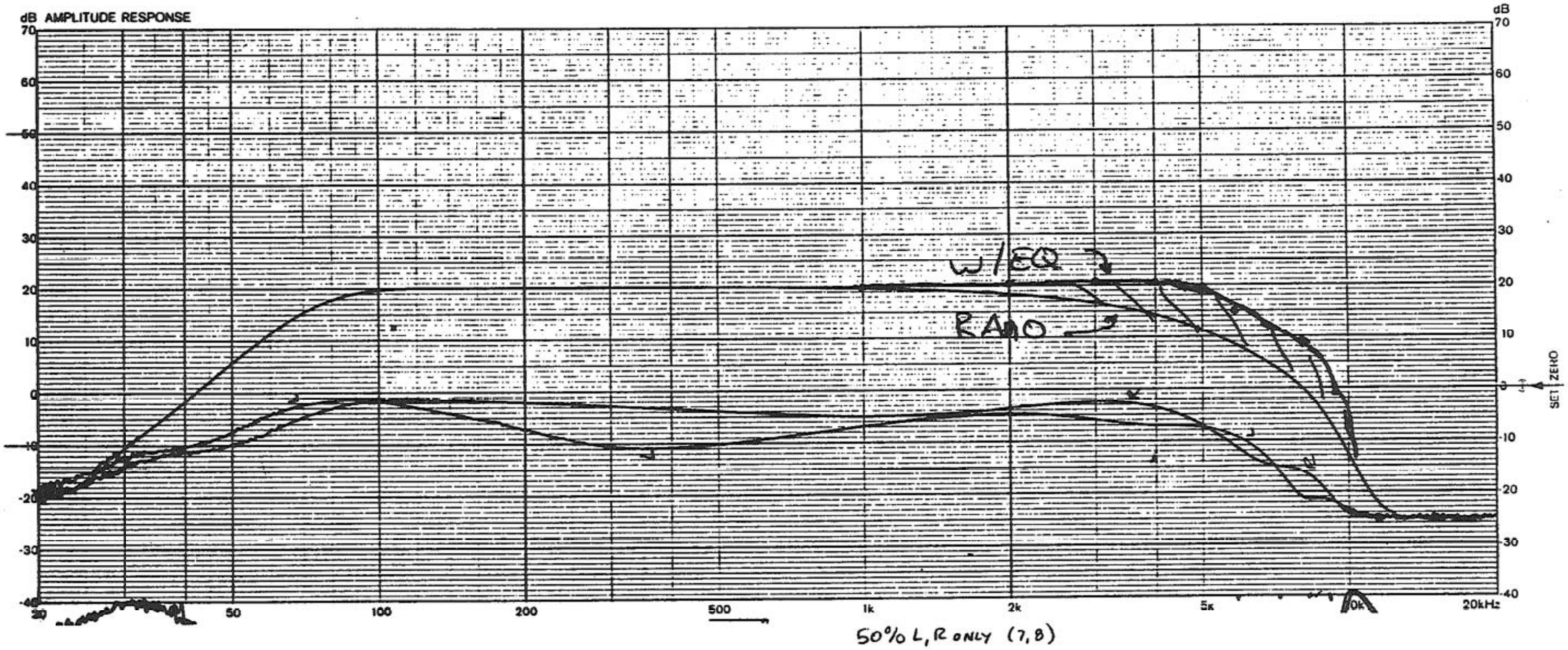
w/ EQ. −6dB 4.5kHz.



RADIO D

w/o EQ. −6dB 4.5kHz.

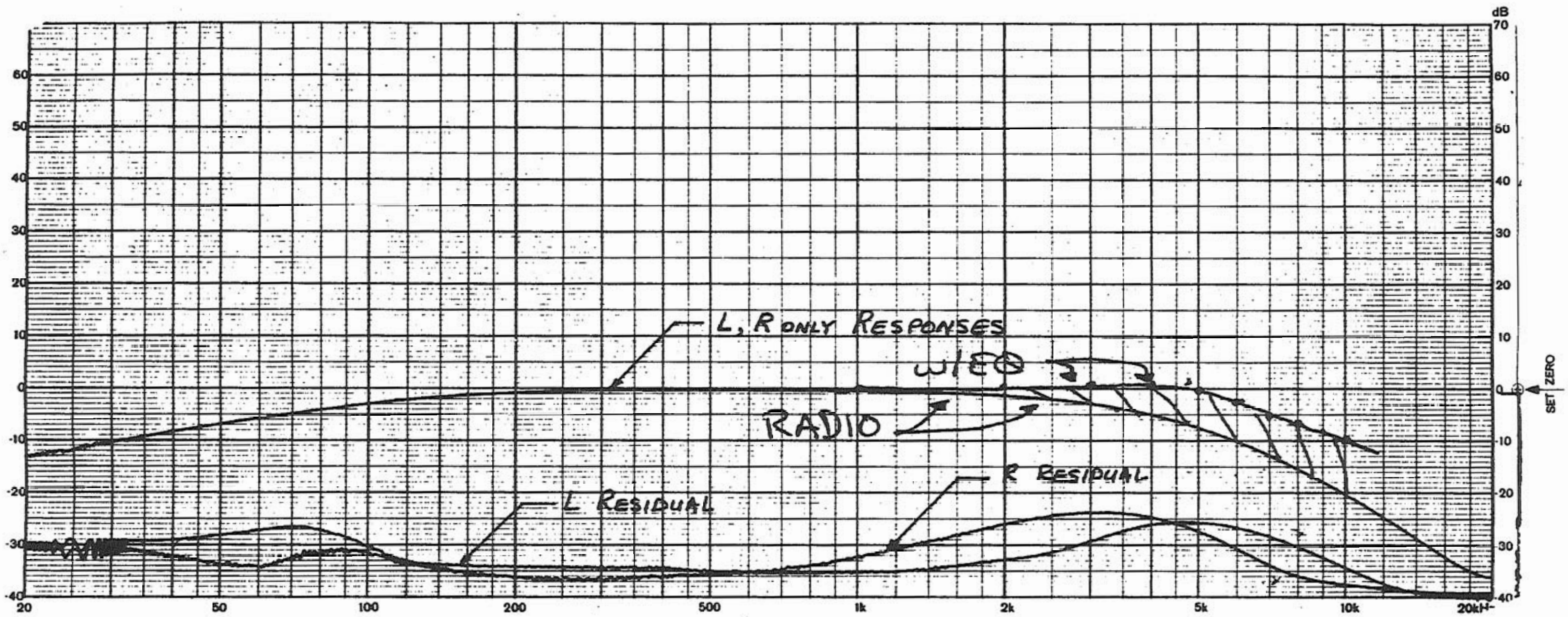
w/ EQ. −6dB 7.2kHz.



RADIO E

w/o EQ. −6dB 4.0kHz.

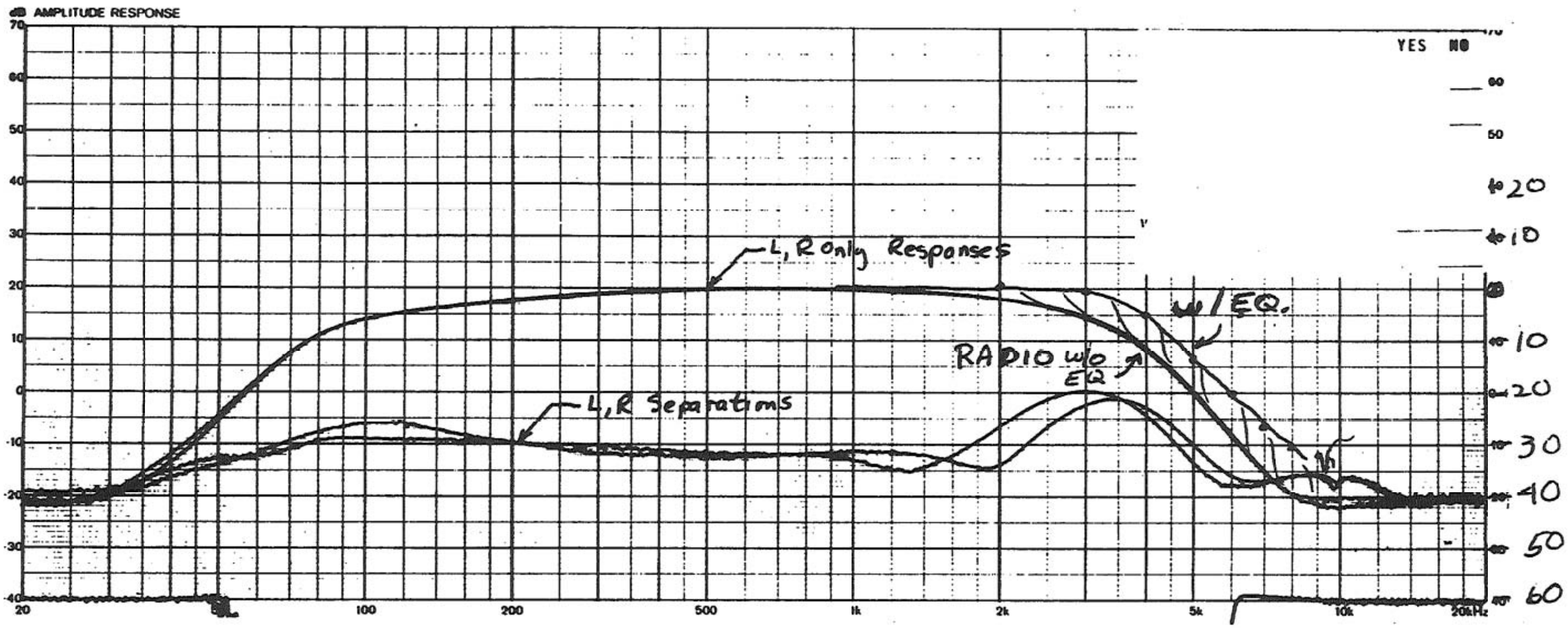
w/ EQ. −6dB 6.3kHz.



RADIO F

w/o EQ. −6dB 4.5kHz.

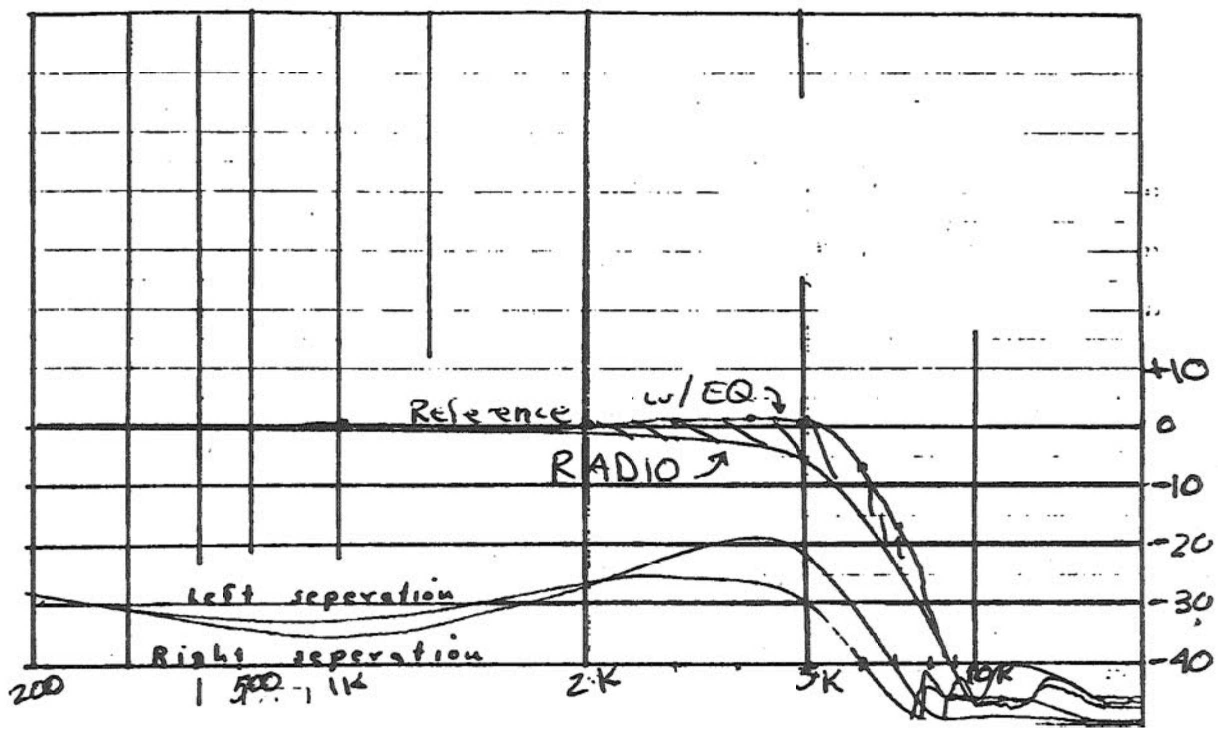
w/ EQ. −6dB 7.2kHz.



RADIO G

w/o EQ. −6dB 3.1kHz.

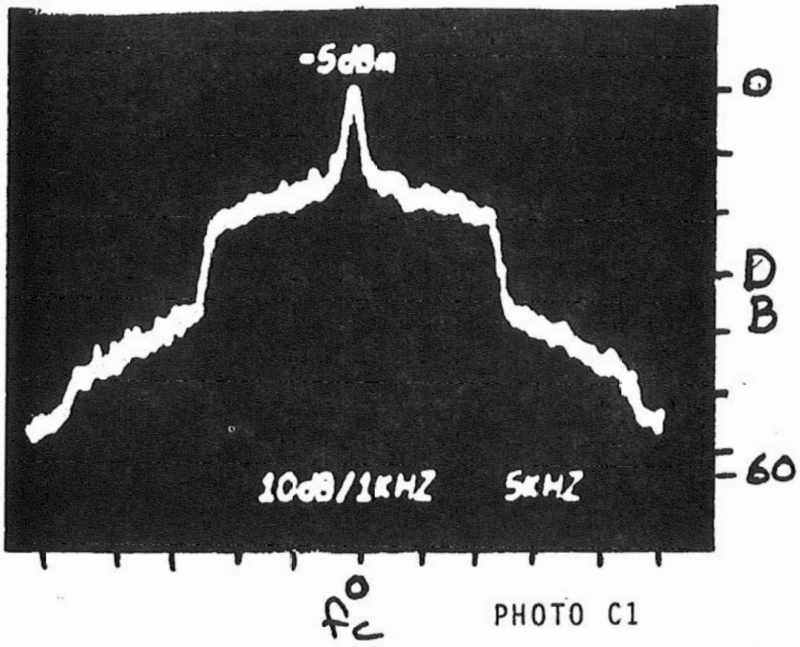
w/ EQ. −6dB 4.1kHz.



RADIO H

w/o EQ.	-6dB	5.2dB
w/ EQ.	-6dB	6.1dB

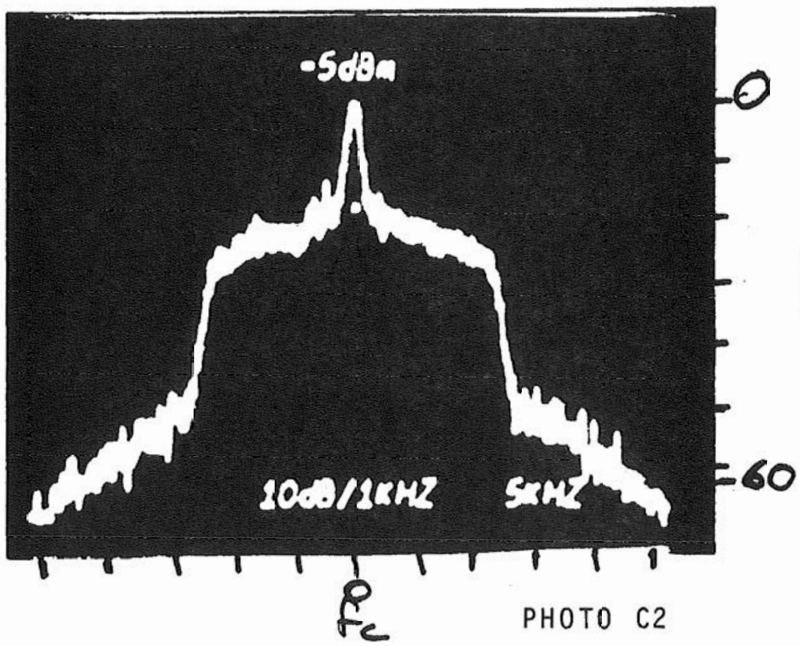
APPENDIX C



FINAL CLIPPING 6dB

OUTPUT FILTER "A"

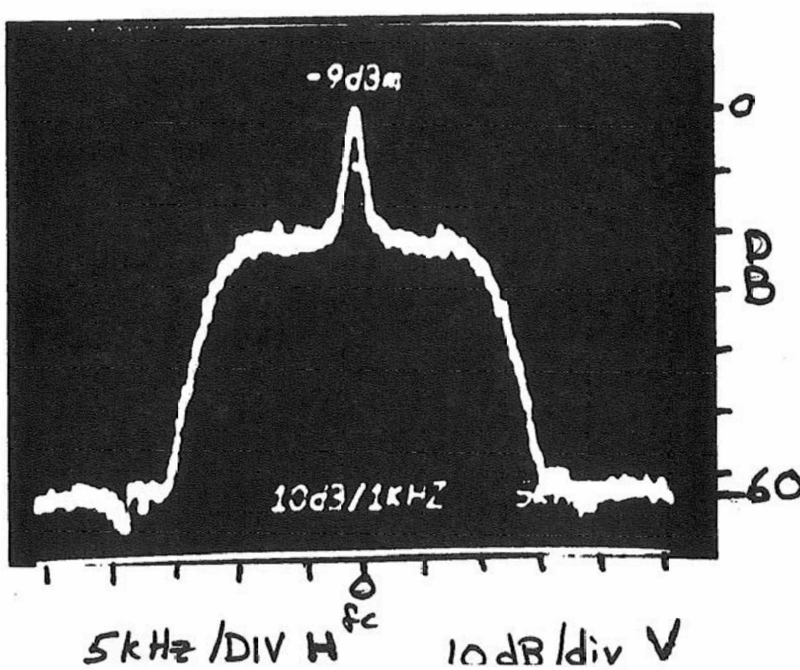
PHOTO C1



FINAL CLIPPING 3.5 dB

D
B
OUTPUT FILTER "A"

PHOTO C2



FINAL CLIPPING 2 dB

OUTPUT FILTER "B"

PHOTO C3

APPENDIX D

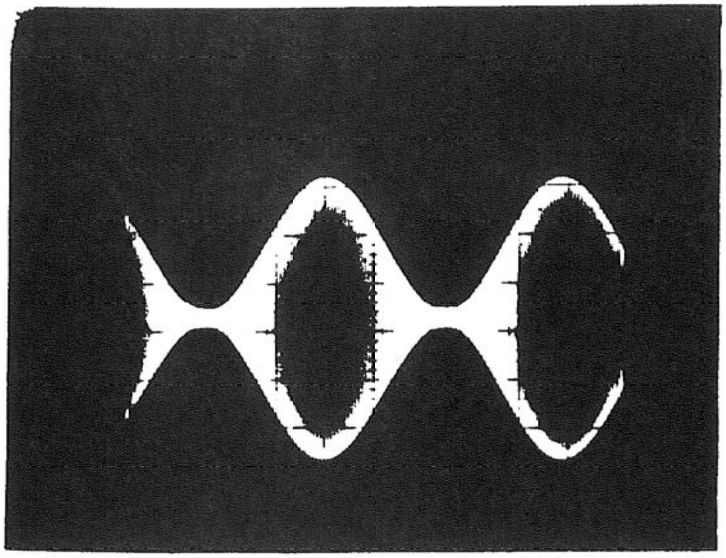


PHOTO D1

95% MODULATION INTO NON-REACTIVE LOAD

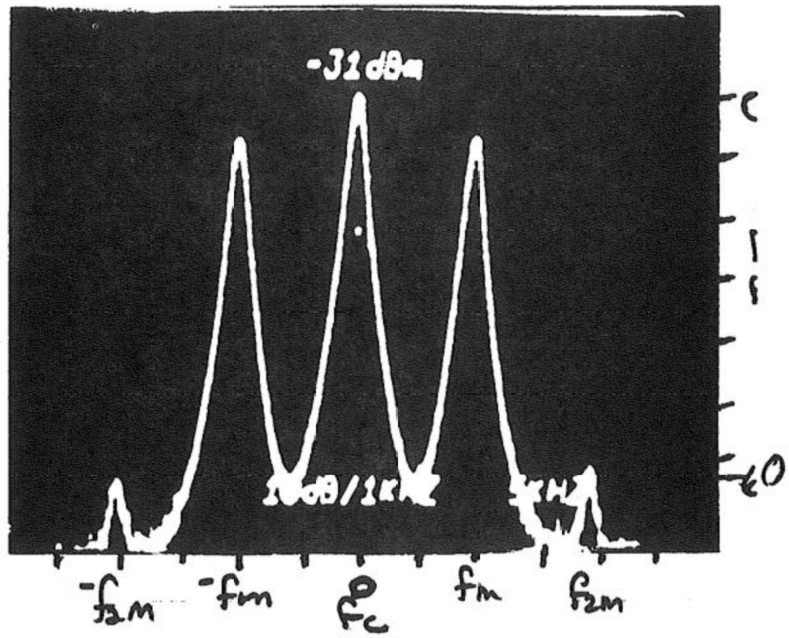


PHOTO D2

SAME SIGNAL AS LEFT
SPECTRUM OF SIGNAL

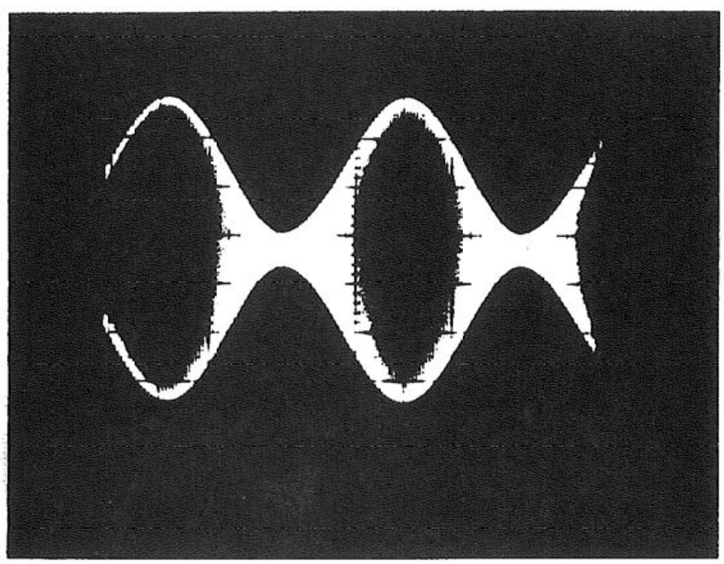


PHOTO D3

SAME SIGNAL AS ABOVE INTO REACTIVE LOAD

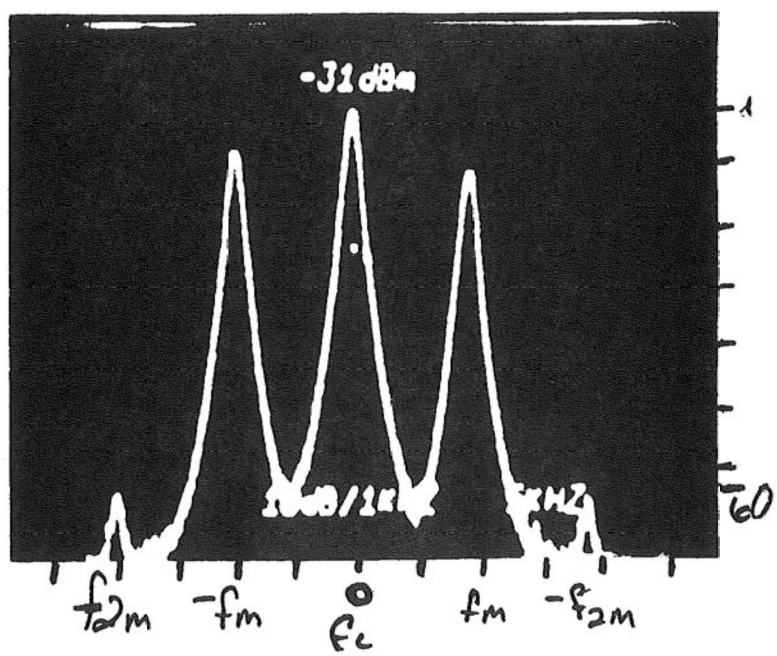


PHOTO D4

SPECTRUM OF SIGNAL AT LEFT

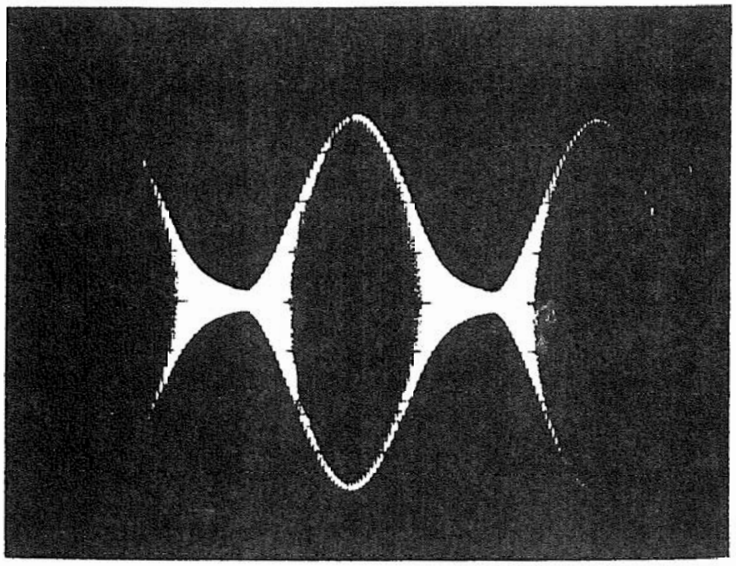


PHOTO D5

MODULATION APPROACHING 100% AT LOAD

REACTIVE LOAD

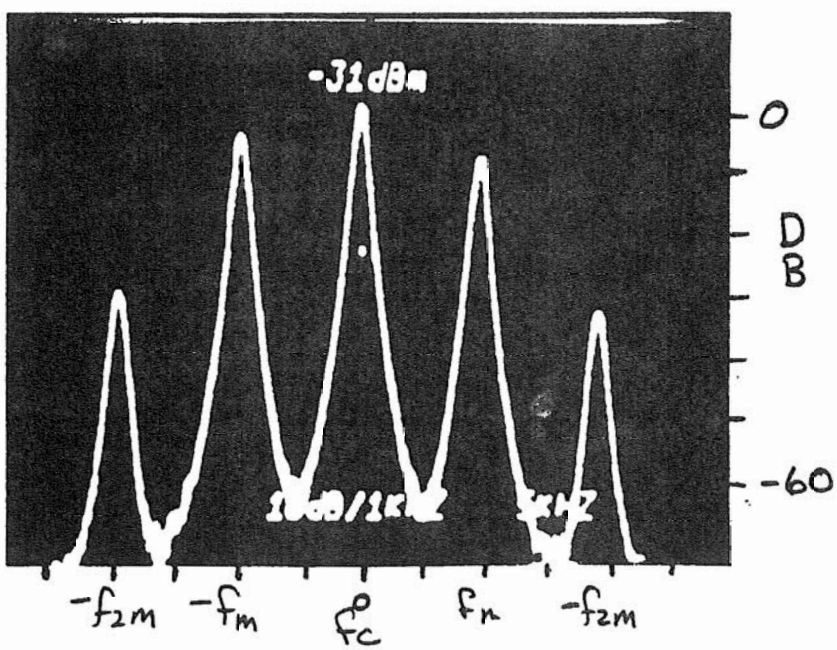


PHOTO D6

SPECTRUM OF ABOVE SIGNAL

NRSC Document Improvement Proposal

If in the review or use of this document a potential change appears needed for safety, health or technical reasons, please fill in the appropriate information below and email, mail or fax to:

National Radio Systems Committee
c/o Consumer Electronics Association
Technology & Standards Department
1919 S. Eads St.
Arlington, VA 22202
FAX: 703-907-4190
Email: standards@ce.org

DOCUMENT NO.	DOCUMENT TITLE:
SUBMITTER'S NAME: COMPANY:	TEL: FAX: EMAIL:
ADDRESS:	
URGENCY OF CHANGE: _____ Immediate	_____ At next revision
PROBLEM AREA (ATTACH ADDITIONAL SHEETS IF NECESSARY): a. Clause Number and/or Drawing: b. Recommended Changes: c. Reason/Rationale for Recommendation:	
ADDITIONAL REMARKS:	
SIGNATURE:	DATE:

FOR NRSC USE ONLY

Date forwarded to NAB S&T: ______________________

Responsible Committee: ______________________

Co-chairmen: ______________________

Date forwarded to co-chairmen: ______________________

CEA®
Consumer Electronics Association

NAB™
NATIONAL ASSOCIATION OF BROADCASTERS