NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-R33
High-speed Subcarrier (Digital) HSSC Laboratory Test Report
May 1997

Part III - Appendices

NATIONAL ASSOCIATION OF BROADCASTERS

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FOREWORD

NRSC-R33, High-speed Subcarrier (Digital) HSSC Laboratory Test Report, is the first of three test reports submitted to the NRSC's High-Speed FM Subcarrier (HSSC) Subcommittee. Three digital FM subcarrier systems were evaluated during these tests—DARC (submitted by Digital DJ, Inc.), STIC (submitted by Mitre Corporation), and HSDS (submitted by Seiko, Inc.). The co-chairmen of the HSSC Subcommittee at the time of the submission of NRSC-R33 were Michael Rau and David Kelly. The NRSC Chairman at the time of the submission of NRSC-R33 was Charles Morgan.

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.

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Appendix A

HSSC SYSTEM DESCRIPTIONS

Digital DJ

STIC MITRE

HSDS Seiko

Digital DJ

PROPOSAL FOR HIGH-SPEED SUBCARRIER SYSTEM

February 14, 1994

4.0 Required elements for description

4.1 Narrative system description

Using a new digital modulation method called L-MSK (Level controlled Minimum Shift Keying), which is a type of MSK, this system has a transmission capacity of 16kbps, and is multipath proof. It is also compatible with RDS/RBDS because it uses different frequency band.

4.2. Technical description of the system

4.2.1 Transmitted signal description

4.2.1.1 Data transmission format

(1) Modulation

Modulation method, utilizes L-MSK method to control the level of multiplex signal (multiple level) according to the level of the stereo vocal (analog) signals (Left and Right).

(2) Base band center frequency (subcarrier frequency)

With coexistence of FM multiplex signal and stereo signal, cross-talk signal protection ratio, and CCIR advice (recommendation) to be considered, the subcarrier frequency will be at 76KHz.

(3) Base band frequency spectrum

Figure 1 indicates the arrangement of the FM multiplex signal and Stereo vocal (analog) signal.

Figure 2 indicates the base band frequency spectrum of the L-MSK 16kbps signal when the vocal signal of colored noise is modulated with RDS signal.

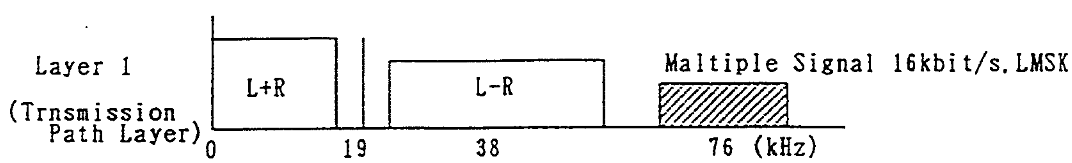


Fig. 6. 1-1: Hierarchical structure of character and graphic coding

Figure 1. FM multiplex signal and stereo vocal signal position

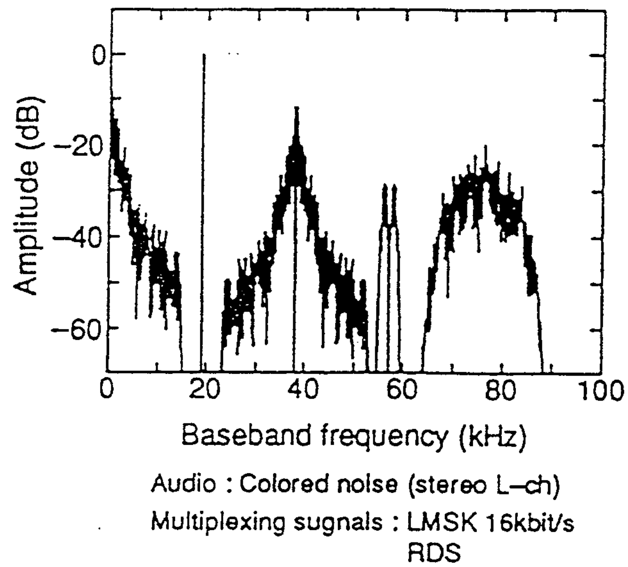


Figure 2. Baseband spectrum of L-MSK signal with RDS signals

(4) Subcarrier injection levels

Figure 3 shows the Multiplex level characteristics necessary to obtain multiplex signal bit error rate of less than 10^{-2} without error correction, and coexistence of multiplex signal and stereo signal.

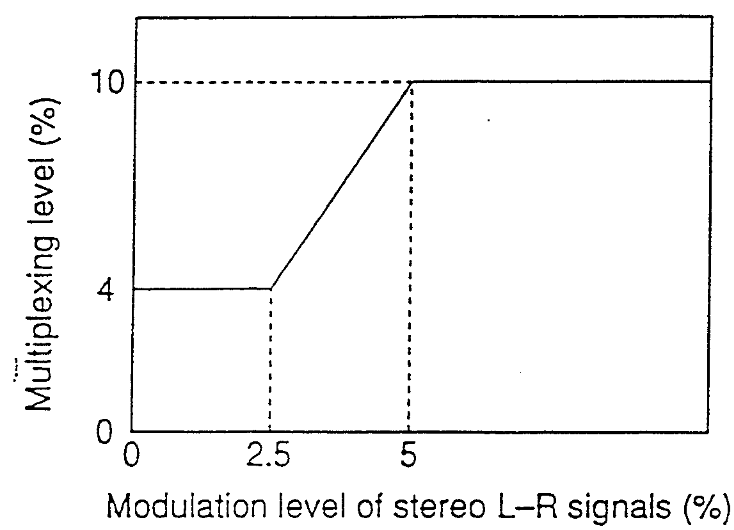


Figure 3. L-MSK method level control characteristics.

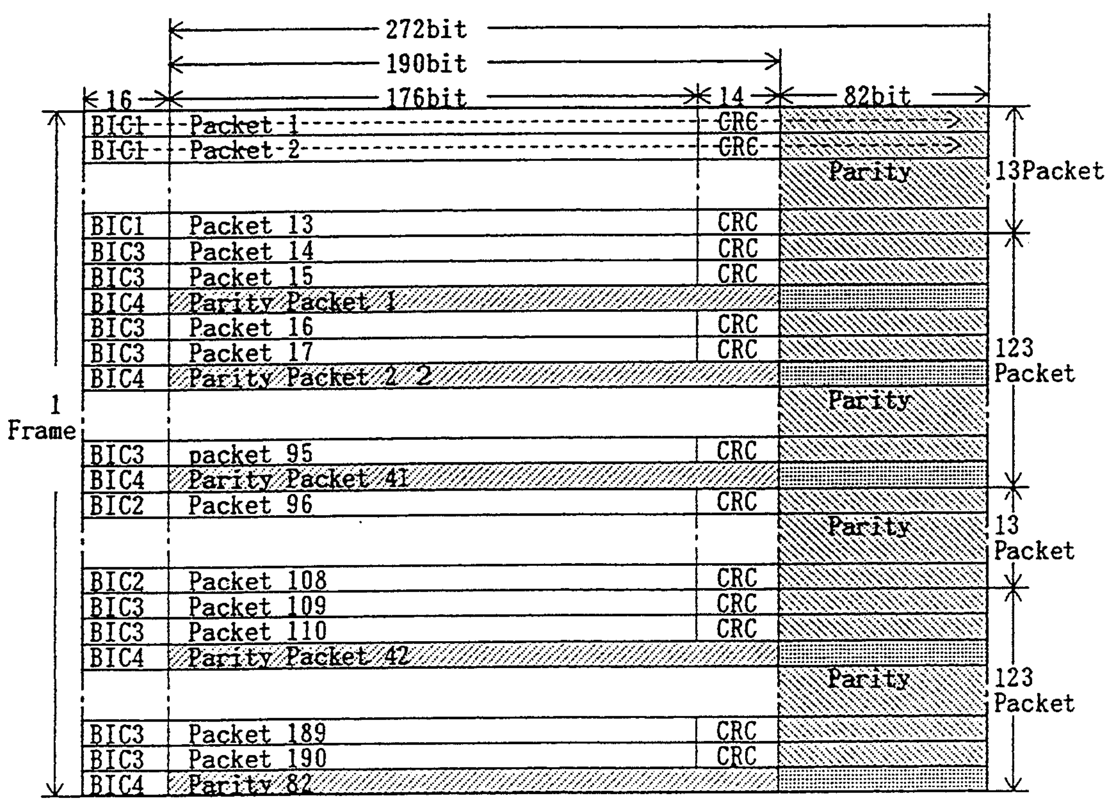
(5) Subcarrier channel symbol rate

Bit rate of multiplex signals is 16kbps.

(6) Word synchronization

Figure 4 indicates frame composition of a product code (279,190) *(279,190) using (279,190) coding. The largest element in the structure is called a "frame" with 78,336 bits. Each frame is comprised of 190 information blocks of 288 bits, and 82 parity blocks of 288 bits. Each information block is comprised of a block identification code of 16 bits, a data packet of 176 bits, a CRC of 14 bits, and a parity of 82 bits. Each parity block is comprised of a block identification code of 16 bits and a parity of 272 bits. Block synchronous pattern utilizes 4 patterns so that the possibility of creating individual correlation and interchangeable correlation is minimized.

BIC1	0001	0011	01010	1110
BIC2	0111	0100	1010	0110
BIC3	1010	0111	1001	0001
BIC4	1100	1000	0111	0101



BIC: Block Identification Code

– – → : Data transmission order

Figure 4, Frame structure after interleaving of FM Multiplex broadcast signal

(7) Error correction/detection

For Error correction, product code (272,190)*(272,190) known as "Shortened majority logic decodable difference set cyclic code", will be used. Figure 5 indicates the frame structure of the (272,190)*(272,190) product code. The total capacity of the 1 frame is 49,536 bits, with the data bits taking up 33,440 bits (4,180 byte).

A product code (272, 190)*(272, 190) is used to enable the receiver/decoder or detect and correct the errors which occur in reception. The generator polynomial for the product code (272,190)*(272,190) is given as follows:

$$g(x) = x^{82} + x^{77} + x^{76} + x^{71} + x^{67} + x^{66} + x^{56} + x^{52} + x^{48} + x^{40} + x^{36} + x^{34} + x^{24} + x^{22} + x^{18} + x^{10} + x^{4} + 1$$

14 bits of CRC (Cyclic Redundancy Check) is used to enable receiver/decoder to detect errors. From the 176 information bits, a CRC is calculated using the generator polynomial:

$$g(x) = x^{14} + x^{11} + x^{2} = 1$$

The interleaving of parity blocks is performed in order to be able to transmit information almost uniformly during the whole frame (see Fig. 4).

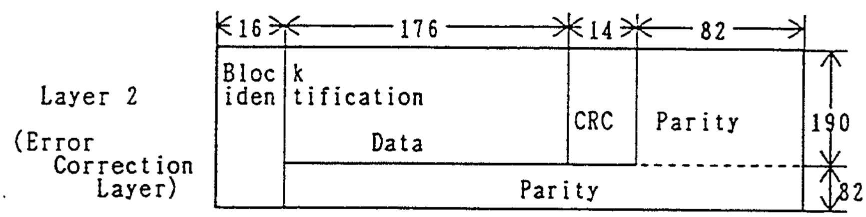


Figure 5. Frame structure of product code (279,190)(279,190)*

(8) Latency

As shown in Figure 5, the waiting period for error correction for horizontal parity only is 18msec. For both horizontal and vertical parity error correction, the waiting period increases to 4.896 sec.

(9) Information bit rate

Information bit rate when error correction is made only on horizontal parity is 9.778kbps. When error correction is made for both horizontal and vertical direction parity, the information bit rate is 6.830kbps.

(10) Potential Interference

(10-1) Multipath influence

With FM Multiplex broadcasting, if there is a multiple path on the transmission route on the upper limit area of the stereo analog signal for layering digital signal on the baseband, there is a tendency for interference and degradation of both analog signal and multiplex signal.

The need to confirm coexistence with present broadcasting, a research was conducted in regards to interference of FM multiplex signal to stereo analog signal under the multipath.

With L-MSK method and MSK method, (multiplex level 4%, 6%, and 10%), Figure 6 shows the multipath DU ratio to bit error characteristics with regards to multipath transmission route. L-MSK method has same characteristics as MSK method at multiplex level of 10%, and very effective in regards to multipath interference.

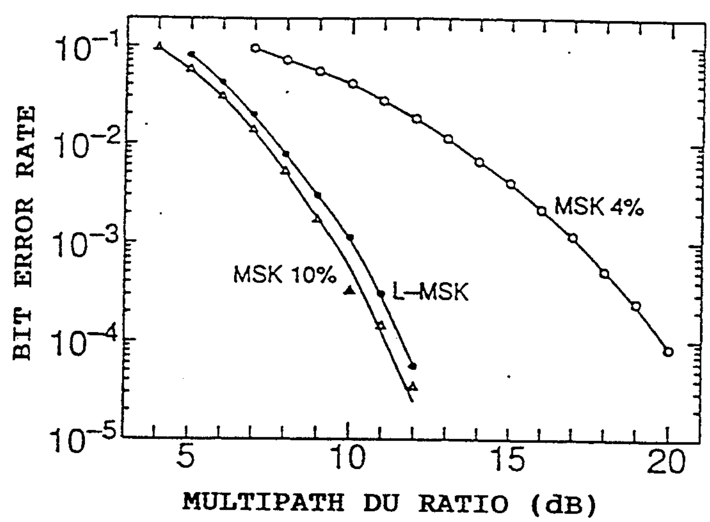


Figure 6, Multipath DU ration vs. Bit error rate

(10-2) "Fading" Influence

Figure 7 shows the input voltage vs. bit error rate characteristics during "fading". Mobile reception has the tendency to be affected by "fading", and the phenomenon known as 'flooring" occurs when the bit error rate does not improve with increased input voltage. On diagram 3.3-7, as the input voltage is increased to more than 40 dBμV, the bit error rate is the same for both L-MSK method and 10% multiplex level MSK method, and the bit error rate at this time is 7x 10^{-3}. From this, the hypothesis that L-MSK method is very effective against fading, with normal transmission path is used for mobile receiver.

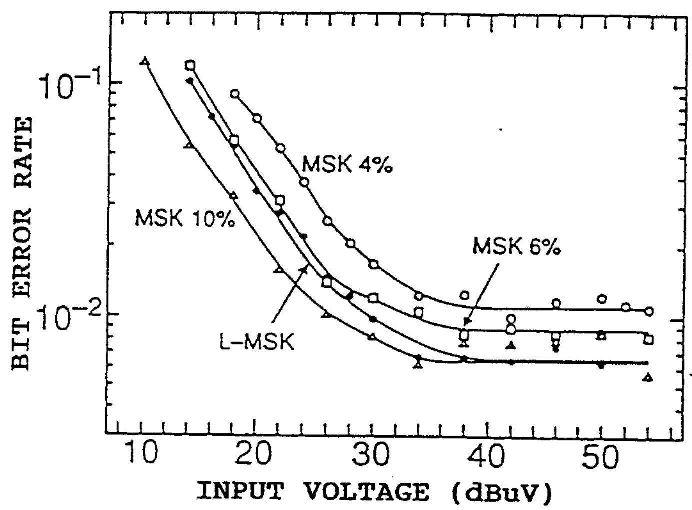


Figure 7, Input voltage vs. Bit error rate

Figure 8 shows bit error rates measured in field tests changing the bits rates, from 9.5KHz and 19KHz, and the modulation method. The bit error rates of RDS also have been measured for comparison. Two channel space diversity was sued for these tests. Three typical roads, ordinary , multipath, and highway were selected. Considering the recent progress in error correction code techniques, a bite error rate before error correction of a service boundary is about 10-2. Figure 8 shows that L-MSK has the best performance among all digital modulation methods considered there is a possibility of a high bit rate transmission at 9.5kbsp of 19kbps, and the performance of L-MSK is almost equal to that of RDS in terms of bit error rate.

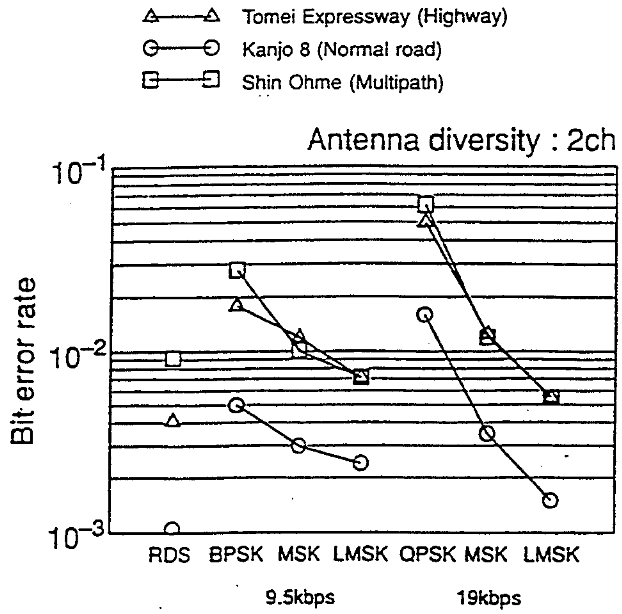


Figure 8, Bit error rate

(11) Service Area
Can secure FM broadcast (stereo vocal broadcast) and similar (equal) FM Multiple broadcast service area

5.0 Additional Information

5.1 Higher layer protocol capabilities

Capabilities of FM multiplex broadcast, multiplex signal layer structure

- Layer 1 Physical transmission path.
- Layer 2 Signal frame composition, error correction for transmission
- Layer 3 When sending several information in parallel, recognition of data packet method selection.
- Layer 4 Data group discernment and error correction for transmission of Multiple packet
- Layer 5 Discernment of program data structure and program selection
- Layer 6 Correspondence of characters and figures
- Layer 7 Application for news, weather, and traffic information

Figure 9 will show outline of FM multiplex signal broadcast layer structure.

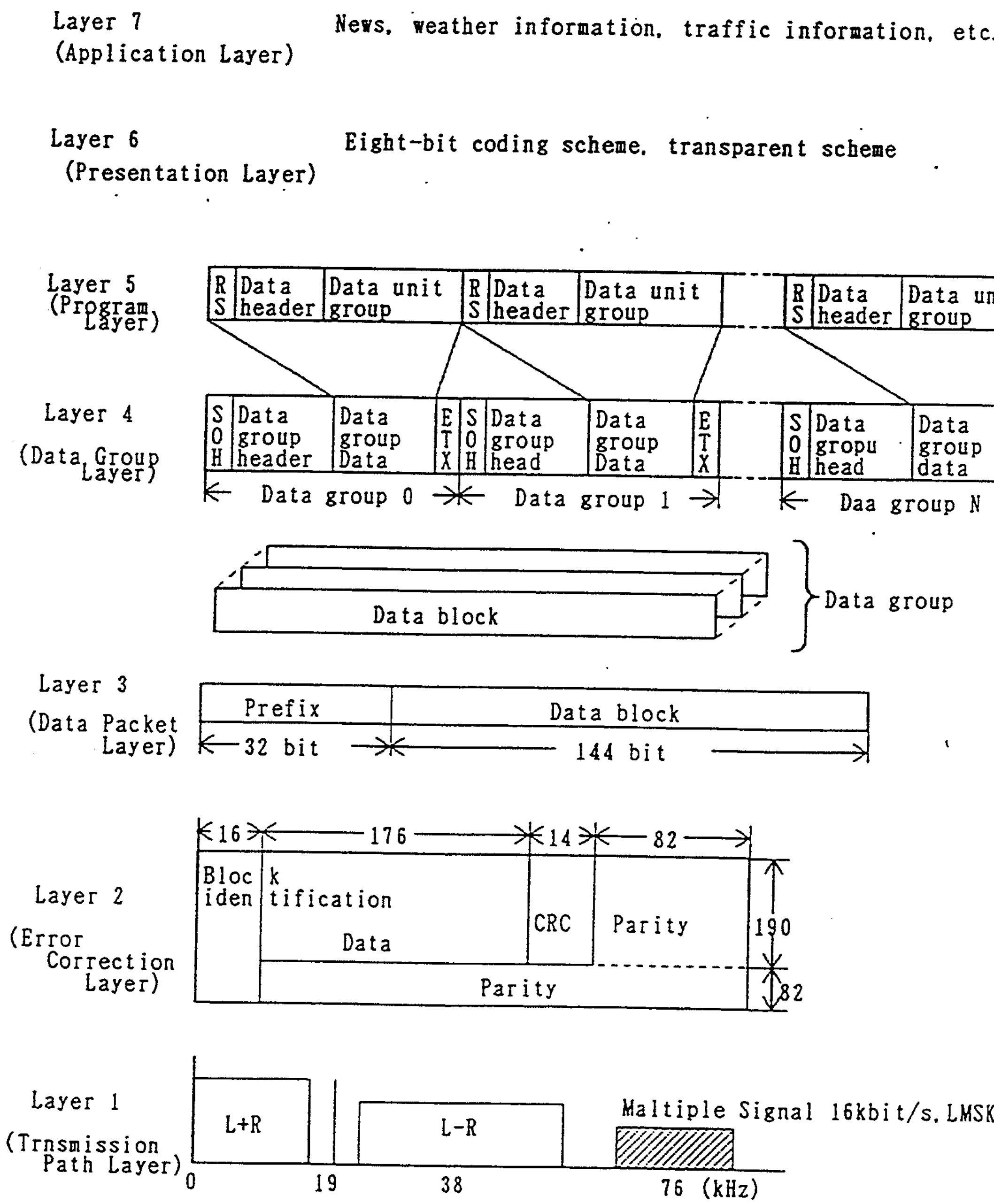


Figure 9: Higher Layer Protocol characters

5.2 Intended Application
Currently under planning
Data transmission application

Digital D.J.(DDJ) is a system that allows radio listeners to visually access a variety of information, 24 hours a day, regardless of the location, through an LCD screen installed on the radio receiver. DDJ will provide both 1)Audio related information, and 2) Independent information as follows:

1) Audio related information services will enable listeners to see various information such as names of the song, artist, album title, and concert schedules, etc., while the music is being broadcast.
2) Independent information will provide listeners with various information relating to Traffic, such as city maps highlighting areas of congestion; Events, such as movies, concerts, theater, and other activities in the area; News, such as stock prices, weather, headlines including local, regional and worldwide, and more. Also, all the information can be stored in the memory for later recall.

5.3 Product Availability

With cooperation from Sanyo Electric Co. Ltd., Sharp Corporation, and NHK Engineering Services, Digital DJ Inc., first introduced the basic system at the 93 NAB Radio Show in Dallas, in September. During the 94 NAB Show at Las Vegas in March, the total system will be available for demonstration. Alpha site testing is scheduled to begin in July 1994. After testing various information services, the product is scheduled for commercial availability in 1995.

5.4 Patents, Licensing

NHK and DDJ have filed U.S. patents respectively. Technologies will be licensed for a reasonable royalty fee after the alpha site testing.

6.0 Hardware availability for testing
(provide said equipment)

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Development of the Equipment for DARC Production, Transmission and Reception ~ A New High Capacity FM Multiplex Broadcasting System

Hironori Mitoh * , Yoshikazu Tomida * , Seiichi Ogawa ** , Osamu Yamada *** ,
Tadashi Isobe *** , Tsutomu Takahisa **** and Masao Fujiwara *****
* Sanyo Electric Co., Ltd. ** FMS Audio Sdn. Bhd.
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ABSTRACT

NHK has succeeded in development of a high capacity FM multiplex broadcasting system called DARC(Data Radio Channel). It is characterized by transmission rate ten times greater than the RDS method used in Europe and the United States, multipath interference resistant LMSK modulation method, and powerful error correction, enabling multiplex broadcasting to offer real−time traffic, DGPS (Differential GPS) and time information in addition to news and music broadcasting for mobile. We would like to report our success in developing the system necessary to implement FM multiplex broadcasting including transmission system for the broadcasting station, receiver and its core technology, LSI.

FM MULTIPLEX BROADCASTING

In addition to music programs offered by conventional FM broadcasting, FM multiplex broadcasting called DARC(Data Radio Channel) allows simultaneous reception of digital information. FM broadcasting separates the stereo signal into L+R signal and L−R signal transmitted at the power spectrum indicated in Figure 1. As indicated in Figure 1, although FM broadcasting band is approximately 100 kHz per channel, when transmitting music signal, only the lower half,that is, less than 50 kHz is being used. FM multiplex broadcasting multiplexes various digitized data in the upper 50 kHz gap to offer simultaneous broadcasting of digital information and music.

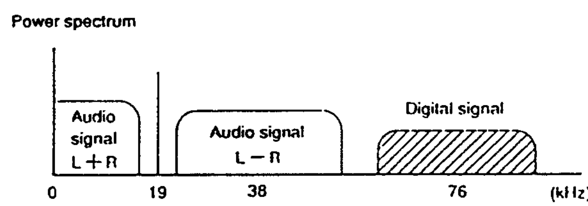

Figure 1. Power spectrum

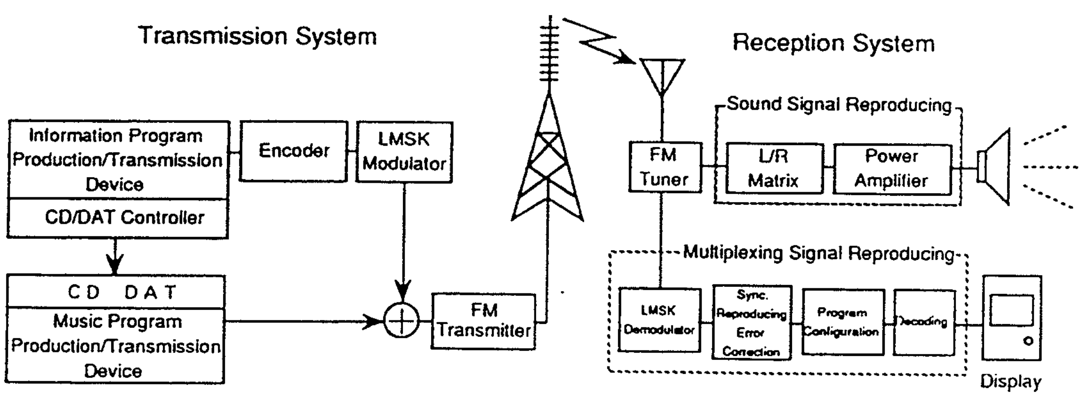

Figure 2. FM multiplex broadcasting system
(Parts of slant lines are that we developed recently)

Overall schemes for FM multiplex broadcasting system is indicated in Figure 2. Transmission system installed at the broadcasting station is indicated on the left of Figure 2. FM music programs are conventionally produced by audio devices such as CD player and tape recorder as well as editing device and mixer to control those audio devices. In order to implement FM multiplex broadcasting, dedicated devices to product and transmit multiplex programs are necessary. The information program is produced, mixed with the music program and transmitted as FM radio wave. The receiver is indicated on the right. The receiver must be able to playback and display multiplex signal in addition to conventional playing back of the music. We shall now describe each of the components in our system.

TRANSMISSION SYSTEM

Transmission system consists of four devices, namely Information Program Production/Transmission Device, CD−DAT Controller, Encoder and LMSK modulator.

INFORMATION PROGRAM PRODUCTION/TRANSMISSION DEVICE − In order to implement FM multiplex broadcasting, a device to produce and transmit program data according to the pre−recorded transmission schedule is necessary. We built this system on an engineering work station. A photo of the system is indicated in Photo 1. Our system makes program production as simple as word processing, by handling characters and graphics using a keyboard, a mouse and a scanner.

For example, text can be input rapidly from the keyboard, and figures can be drawn with a mouse or the scanned image may be traced as a template. Data attributes are specified by selecting parameters indicated on each window with a mouse. Since programs must be offered real time, we particularly paid close attention to creating an effective and easy−to−use user interface in order to reduce production time. The program data is automatically encoded according to the FM multiplex encoding method. The FM multiplex encoding method is based on the hierarchical structure of the OSI (Open Systems Interconnection) used for the Japanese closed caption TV broadcasting. Using the schedule assignment menu, a user can designate each program to be broadcast on schedule. Assigned programs are transmitted to the encoder on schedule. In addition to the regular transmission of programs, our system can also access outside database through a phone line to transmit its data directly or after processing. Our system is capable of simultaneous multi−task processing of program production, transmission schedule designation and data transmission using multi−windows.

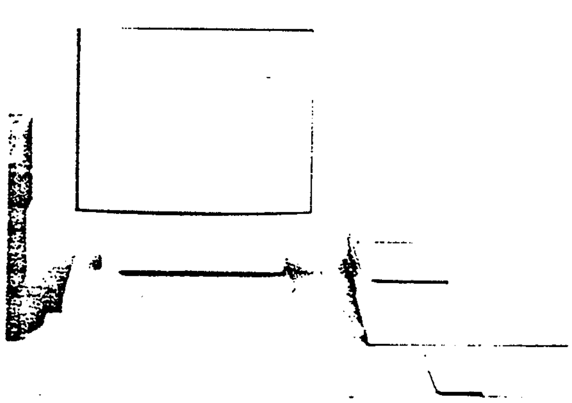

Photo 1. Information Program Production/Transmission Device

CD−DAT CONTROLLER − CD−DAT Controller controls multiple CDs and DATs according the transmission schedule from Information Program Production/Transmission Device. This unit is especially useful when beginning of multiplex signal transmission must be synchronized with the CD playback such as Karaoke broadcasting where the lyric is displayed along with the music. Also, this unit is capable of selecting audio output from multiple CDs and DATs.

ENCODER − Encoder is a device to convert data transmitted by Information Program Production /Transmission Device into transmission format and transmit it in synchronization with LMSK Modulator's 16 kHz clock according to the transmission schedule. Both parallel and serial connections with Information Program Production/Transmission Device are available. RS232C or HDLC are available for serial connection and Centronics connector is available for parallel connection.

Frame configuration for the FM multiplex broadcasting is indicated in Figure 3. Each frame contains 190 blocks of program data at 176 bits per block. Our system adds 14−bit CRC code for error detection, 82 bit horizontal by 82 block vertical two−dimensional (272,190) shortened majority logic decodable code, and BIC (16−bit synchronizing signal) at the beginning of each block to form one frame (288 x 272 bits). The (272,190) shortened majority logic decodable code capable of correcting approximately 11 bit per 272−bit block also used for Japanese closed caption TV broadcasting makes it possible to play back data accurately in areas with weak electric field or

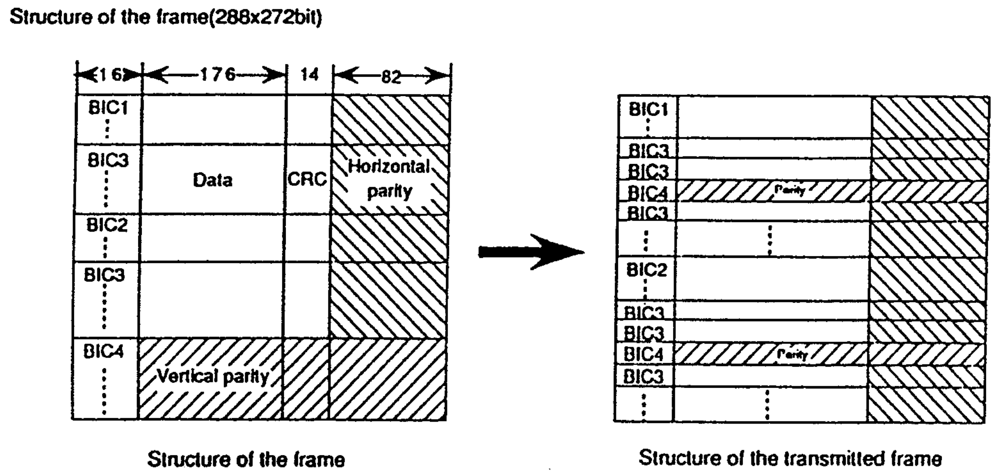

Figure 3. Structure of the frame

excessive noise. Furthermore, by incorporating this powerful error correction code two dimensionally and by changing its transmission order, resistance against both random noise and burst noise has increased considerably making the reception quality suitable even for mobile. We attach PN code (transmission scramble) to all data except BIC in order to simplify clock playback of the receiver by removing direct current element of the data.

Data are transmitted in an order indicated on the right side of Figure 3 in synchronization with the LMSK Modulator's 16 kHz clock. Pseudo–random data may be transmitted from the internal ROM, for example, to transmit "service unavailable" message when the connection with Information Program Production/Transmission Device is cut off.

LMSK MODULATOR – Multiplex signal transmitted from encoder is LMSK modulated in conjunction with music signal level to transmit data to FM modulator. LMSK modulation method is developed for FM multiplex broadcasting to make MSK modulation level variable in conjunction with L–R signal level of stereo sound. When the audio signal level is small, the modulation level is lowered to reduce audio signal interference. When the audio signal level is large, the modulation level is increased to reduce multi–path interference. Addition of this method has little affect over the music broadcasting, while being resistant against multipath interference making it suitable for mobile. With the conventional broadcasting system, it was difficult to maintain sufficient reception quality for mobile due to electric field variance from multipath interference and fading.

RECEIVER

Since FM multiplex broadcasting receiver needs to display texts as well as graphics, it incorporates multiplex signal playback device and a monitor to the conventional FM broadcasting receiver. An example of automobile–mounted receiver is indicated in Photo 2 and screen of traffic information service is indicated in Photo 3. Description of the FM multiplex broadcasting receiver is as the following.

CONFIGURATION – Configuration of FM multiplex broadcasting receiver is indicated in a block diagram in Figure 4. The audio signal is played back through an amplifier and speakers after removing high frequency element with LPF and going through L/R matrix processing. It consists of four blocks as indicated in Figure 4.

The signal output through the tuner is filtered by BPF to remove audio signal and noise ,and to detect LMSK signal multiplexed at 76 kHz. Since the detected multiplex signal level is not consistent, the level variation is removed by the comparator to obtain MSK signal. Digital data is obtained from MSK signal using MSK demodulation. Synchronizing signal is detected from the digital data by synchronization reproduction circuit to find the start of the data block. Then the PN code, initially applied to remove the DC content of the data is removed from the starting position. Error correction circuit corrects errors by using product code of the (272,190) shortened majority logic decodable code. Since this error correction code is capable of correcting approximately 11 bits per 272–bit block, it normally corrects errors sufficiently with the horizontal error correction alone. At this time, CRC code is used to detect any uncorrected error. When there are too many errors to correct with horizontal error correction, vertical error correction is also applied. As indicated on the right side of Figure 3, since data block and parity block are transmitted alternately, one frame is received from the beginning to reshuffle the order as indicated on the left side of Figure 3 before applying vertical error correction. It then applies horizontal error correction again to formulate a truly powerful error correction.

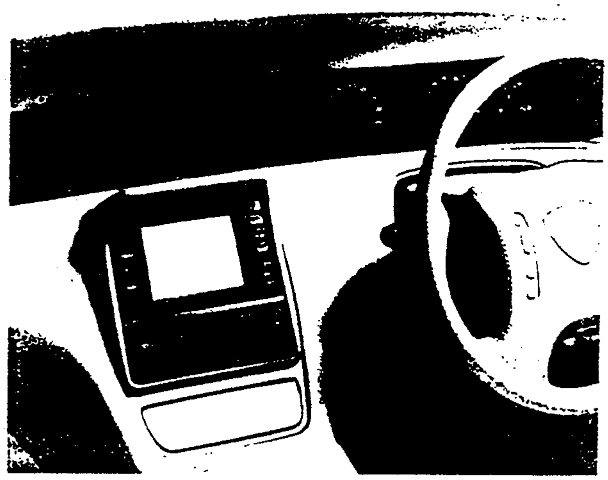

Photo 2. Automobile–mounted receiver

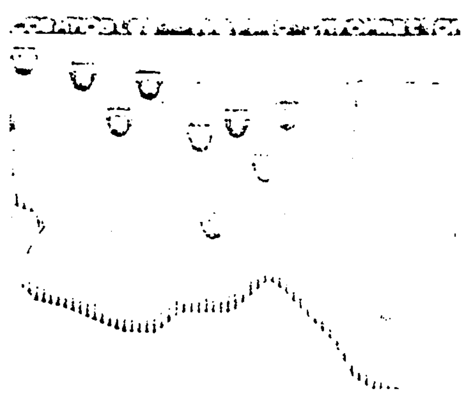

Photo 3. Screen of traffic information service

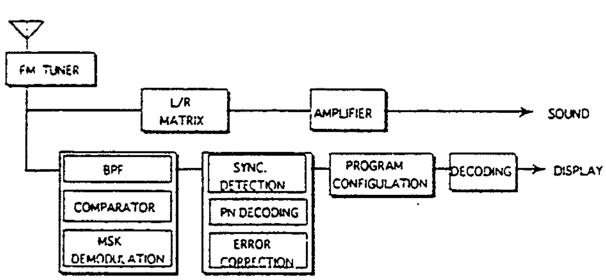

Figure 4. Block diagram of receiver

Because data for each program are not necessarily transmitted consecutively, CPU must reconfigure the corrected data for each program. It then decodes data to be displayed in each screen frame.

DISPLAY FORMATS – There are various possible types of receiver, such as portable, automobile–mounted, component/radio cassette player. However, its implementation depends largely on the monitor size. While there are various display formats for FM multiplex broadcasting, they are all based on three types, level 1, 2, and 3 described below.

LEVEL 1 – Characters and dot patterns are displayed in the 15.5 character by 2.5 line (248 by 60 resolution) area. Since the amount of information displayed is small, the screen can be made compact making it suitable for portable terminals.

LEVEL 2 – Characters and graphics are displayed together in the 15.5 character by 8.5 line (248 by 204 resolution) area. Compared with the level 1, amount of information displayed is considerably larger allowing larger variety of programs to be offered. For example automobiles without a navigation system can access a simple map to work as a map database. Furthermore, traffic information may be transmitted to avoid congested areas.

LEVEL 3 – This level allows superimposed display of information over the navigation system screen. Level 3 utilizes the more detailed map of the navigation system to display its information by linking their data.

LSI INTEGRATION

We have described about circuit to convert transmitted multiplex data with signal processing to visually display text and graphics in the previous section. In order to offer compact and inexpensive receivers, it is essential to integrate circuits into LSI chips. We have integrated LMSK demodulation circuit as well as synchronization reproduction/error correction circuit into LSI chips. They both are fundamental technologies for multiplex broadcasting receiver. The LSIs are indicated in Photo 4. The FM multiplex receiver circuit with the LSIs is indicated in Photo 5. In Photo 5, the LMSK demodulator consisting of the BNC connector on the right and the LSI chip on the top is indicated. The LSI chip on the bottom and the memory

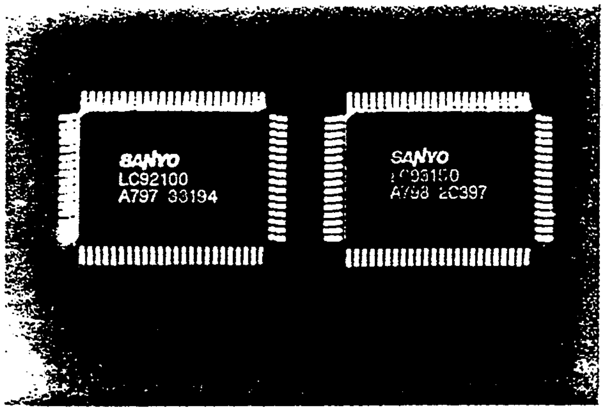

Photo 4. First generation LSI

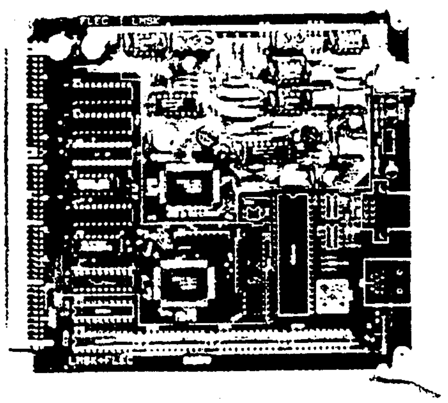

Photo 5. FM multiplex receiver circuit

circuit on its right side comprises the synchronization reproduction and error correction component. The I/F component of the CPU is located at the left edge of the circuit board. The area on the lower right of the circuit board with no installed component is reserved for the communication control device for external data transmission.

LMSK DEMODULATION CIRCUIT LSI – This LSI demodulates MSK signal after removing the level variation and outputs data in synchronization with the 16 kHz clock. Since phase detection method does not require carrier playback, we selected delayed phase detection method suitable for mobile. Also, in terms of MSK method, there is a certain correlation between one–bit delayed phase detection and two–bit delayed phase detection, so we took advantage of this correlation to perform error correction in order to improve demodulation characteristics. Since clock playback is digital, external PLL circuit is not necessary. Also since median of the data is obtained through calculation, accurate clock playback is made possible. The circuit consists of approximately 8,000 gates with 1.5 micron rule and 80–pin flat package for the process.

SYNCHRONIZATION REPRODUCTION/ERROR CORRECTION LSI – This LSI outputs 176–bit data and 14–bit CRC code (190 bit) per block after synchronization reproduction and performing error correction using data output by the LMSK demodulation LSI. The data is output parallel at 8 bits at a time. Hardware automatically executes various controls. The only peripheral component necessary is 32 KB memory. Each parameter for the LSI may be designated arbitrarily by CPU. The circuit consists of approximately 13,000 gates with 1.2 micron rule with 80 pin flat package for the process.

SECOND GENERATION LSI – We have successfully integrated the circuit into LSIs using gate arrays as our first step and already started developing the second generation LSI with superior integration in cooperation with NHK Engineering Services,Inc. LMSK demodulator and error correction component (two LSI chips described above as well as the external memory circuit) are going to be integrated into one LSI. The filter portion of the LMSK demodulator will also be integrated into one IC. Therefore, the receiver circuit shown in Photo 5 will consist of three chips; 2 newly integrated chips and a crystal oscillation chip, to make the receiver circuit more compact and inexpensive. The LSI for LMSK demodulator and error correction components will be a 48–pin QIP or a 28–pin MFP, while the filter IC will be a 14–pin MFP. ES for both chips are scheduled to be shipped in the second quarter of 1994.

APPLICATION

There are various possibilities for application of FM multiplex broadcasting. Range of application is broadened by freely receiving music broadcasting along with digital broadcasting of texts and graphics. For example, by selecting to display lyric synchronized with the music, one can enjoy karaoke (sing–along). It is also possible to find out the music title and artist name even if the listener misses the DJ introduction. By selecting stock information, FM multiplex broadcasting turns into an information terminal. Displaying traffic information and a simple map enables drivers to avoid congestion to arrive at the destination smoothly. Accurate time is always at your fingertip. Possibilities for application are limitless.

Japanese government is considering a traffic information service using FM multiplex broadcasting taking advantage of the features above. In November 1993, a large scale field test was conducted. It proved to be very successful. This service transmits congestion information for particular regions every five minutes using FM multiplex broadcasting. It enabled drivers to access useful information for avoiding traffic congestion through texts and maps. Also the DPGS service system to improve the accuracy of navigation system by sending orientation signal through FM multiplex broadcasting is under development. In addition to personal entertainment, FM multiplex has a high potential to improve the social infrastructure itself.

SUMMARY

We have successfully developed all essential technologies for FM multiplex broadcasting from transmission system to receiver and core LSIs. Based on our achievements, we will proceed further with total development of FM multiplex broadcasting system.

STIC MITRE

STIC System Description

The Subcarrier Transmission Information Channel (STIC) system was developed for the United States Department of Transportation in support of its Intelligent Transportation System (ITS) activities. The system has been optimized for use in broadcasting ITS data to vehicular receivers. It uses a version of DQPSK modulation on a 72.2 kHz subcarrier with a symbol rate of 9025 symbols per second (18050 bits per second). A concatenated Forward Error Correction (FEC) coding approach is used which incorporates convolutional coding with Viterbi decoding, Reed-Solomon coding, and two interleavers. Modulation and coding parameters are summarized in Table 1.

Because of the powerful concatenated code, this system exhibits exceptional robustness in multipath fading and noise, especially for long messages up to 228 bytes in length. The system provides a net throughput of 7600 bits per second, plus some capacity reserved for low latency data, depending on the frame structure selected. (This low latency data path is intended for Differential GPS (DGPS) and/or other high priority messages of an emergency nature). The low latency capability was not tested, but the transmission capacity is reserved for this feature.

The system is compatible with RBDS as well as with the main stereo channel. The system is compatible with, but does not explicitly include, conditional access and receiver addressability features.

Table 1. Summary of STIC Design Characteristics

	Characteristic	Description
1.	Modulation	$\pi/4$ shifted DQPSK
2.	Baseband Center Frequency	72.2 kHz
3.	Baseband Frequency Spectrum	See spectrum analyzer plot below
4.	Subcarrier Injection Levels	Nominally +/- 7.5 kHz
5.	Subcarrier Channel Symbol Rate	9.025 ks/s
6.	Word Synchronization	See frame structure
7.	Error Correction/Detection	Reed-Solomon and convolutional coding with soft decision Viterbi decoding
8.	Latency	Variable depending on interleaver depth and frame size
9.	Information Bit Rate	7.6 kbps plus low latency data

<u>Transmit End Processing</u>

The STIC system provides two data paths: a main data path and a data path reserved for low latency data. The main data path has four optional interleaver depths which correspond to four superframe durations: 46.08, 23.04, 11.52, and 5.76 seconds. These options allow trade-offs between system latency and system robustness in slow fading. As directed by MITRE, only the 11.52 second option was tested.

From the point of view of the signals at the transmitter, the following processes are accomplished for the main data path:

1. An input data rate of 7600 b/s is assumed. This is assumed to be a continuous data stream based on one 228-byte data packet every 240 mS. Each byte consists of 8 bits.
2. The message is block encoded using a (243,228) shortened Reed Solomon 256-ary code.
3. The Reed Solomon coded message is block interleaved by writing 8-bit bytes to a memory with 243 rows and 6 columns. Each cell in the memory contains one 8-bit byte and the message is written by columns and read by rows.
4. The block interleaved message is convolutional encoded using a rate 1/2, constraint length 7 code with generator polynomial coefficients 554 and 744 (octal). The coder runs continuously without flushing.
5. The encoded message is interleaved using a convolutional interleaver with 72 different paths. Each path has a different length shift register with an integer multiple of "J" stages as given in Table 2. Each stage represents one bit. The first path has 71*J stages, the second path has 70*J stages, ... ,and the last path has zero stages. The switch arm changes once for each input bit and at the same time the bits in the shift registers in that path shift one bit.
6. The interleaved message is exclusive-OR'ed with a repeating pseudo-noise (PN) random pattern. The length of the PN pattern is given in Table 2. The PN pattern is synchronized to the interleaving and to the superframe. This process is called covering.
7. The covered message is divided into subframes, frames, and superframes. There are 72 data bits per subframe. The number of subframes per frame is given in Table 2. There are 72 frames per superframe. Framing is synchronized with the interleaver so that the first bit in a subframe comes from the first path in the convolutional interleaver. Four bits are appended as a suffix to each subframe to make each subframe 76 bits long. These four additional bits are called channel state bits.
8. Each frame is provided with a 76-bit synchronization subframe as a prefix. This synchronization subframe consists of a 56-bit "correlation word", a 15-bit frame identification word plus one unused bit, and 4 channel state bits. The 56-bit correlation word is the same for every frame. The 15-bit frame identification word is the encoded frame number using a Bose, Chaudhuri, and Hocquenghem (BCH) (15,7) code. There is always one synchronization subframe per frame.
9. Some subframes are reserved for the low latency data path. The number of subframes reserved in this way depends on the interleaver/superframe option as shown in Table 2. The number of total subframes per frame is also given in Table 2. There are always 72 frames per superframe.
10. The formatted message is modulated on a 72.2 kHz subcarrier using $\pi/4$ shifted differential quadrature phase shift keying (DQPSK). The transmitted symbol rate is 9.025 kb/s.
11. The modulated signal is filtered using square root raised cosine (SRRC) filtering with a roll-off factor of 0.684. This results in a nominal bandwidth of 15.2 kHz (from 64.6 kHz to 79.8 kHz baseband).

Low latency subframes are provided to allow the transmission of data which must be processed quickly for applications which cannot tolerate the delay associated with interleaving. These subframes contain 76 bits and are multiplexed prior to covering as shown in Figure 2. The data rate reserved for the low latency data path is shown in Table 2.

The process described above produces the subcarrier waveform that is frequency division multiplexed with the other signals prior to FM modulation at the broadcast transmitter. An injection level (in terms of the peak amplitude of the subcarrier) of +/- 7.5 kHz is envisioned as typical. Other injection levels are possible with trade-offs in terms of bit error rate (BER) performance and the performance of other subcarriers sharing the transmission.

Table 2. Interleaver and Framing Options

superframe duration (seconds)	5.76	11.52	23.04	46.08
data packets per superframe	24	48	96	192
Convolutional Interleaver, "J" =	18	36	72	144
# stages in m-sequence	17	18	19	20
# bits from m-sequence	93312	186624	3783248	746496
total sub-frames per frame	19	38	76	152
low latency subframes per frame	0	1	3	7
Low latency data rate (bps)	0	475	712.5	831.25
synchronization subframes per frame	1	1	1	1
data sub-frames per frame	18	36	72	144

Figure 1 shows a block diagram of the primary data path processing from the point of view of the transmit end signal processing. As shown in the figure, a 4-byte header could be included in the 228-byte packet. This may be used for identification of the service provider, or for the application and data format that follows in the 224-byte packet payload. This header was not used during the testing.

Figure 2 shows the remainder of the signal processing at the transmit end including multiplexing of the reserved subframe, covering, multiplexing of the synchronization subframe, and modulation.

Figure 3 shows an example frame for the case of the 11.52-second superframe.

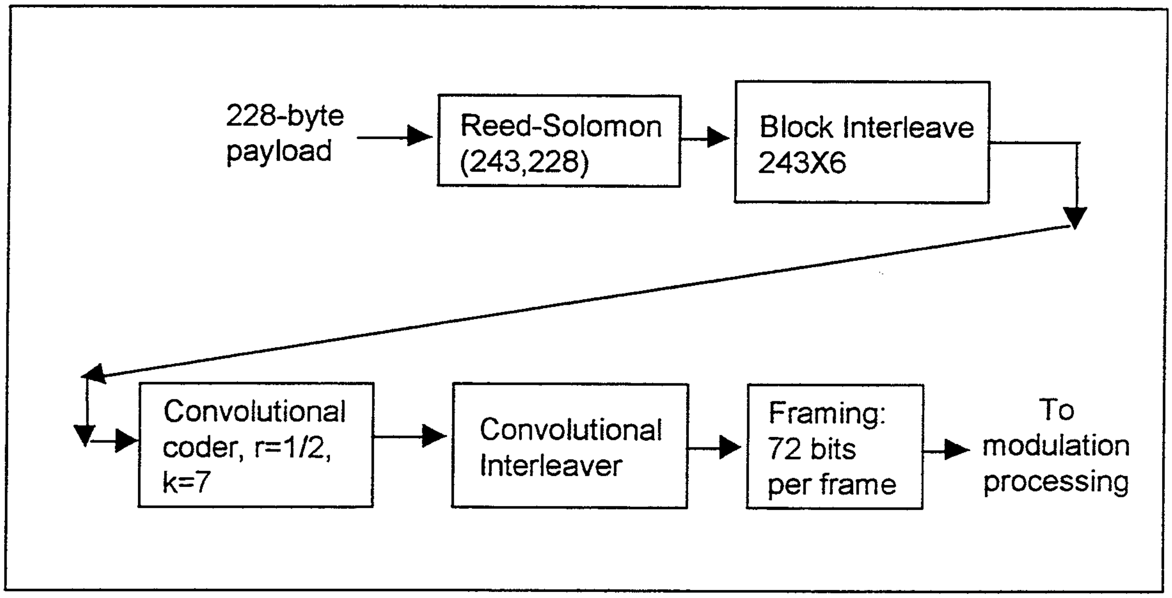

Figure 1. Main Data Path

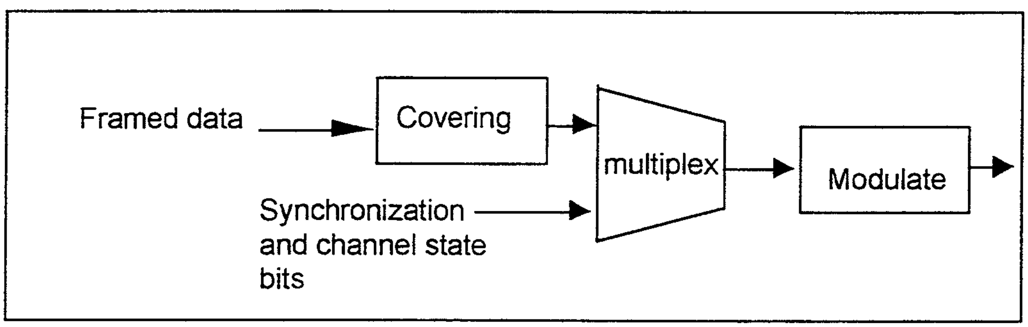

Figure 2. Modulation Signal Processing Overview

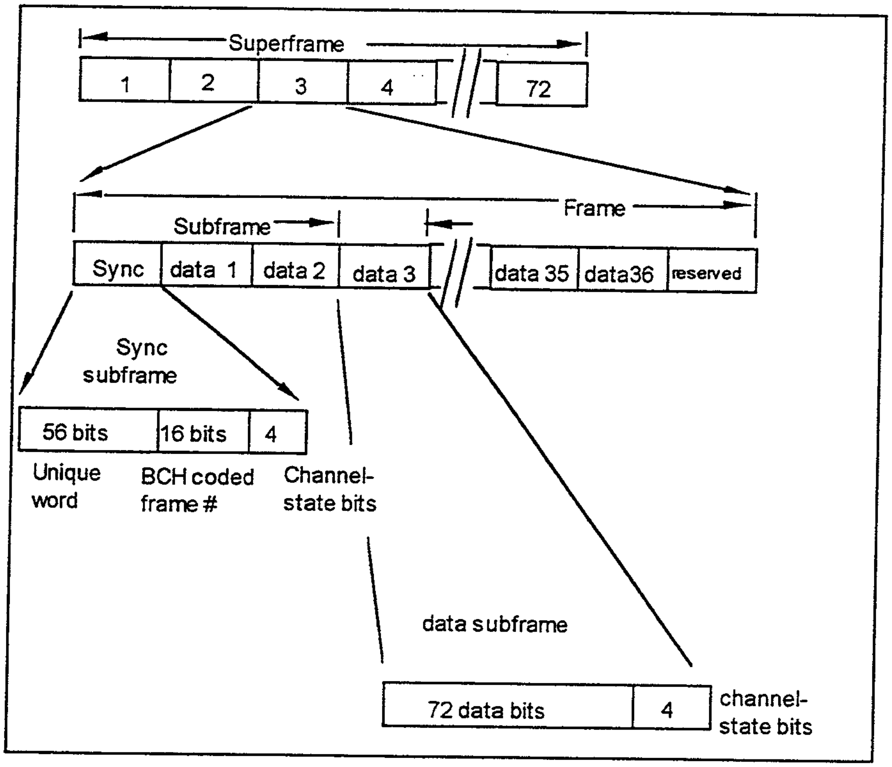

Figure 3. Example Frame Structure

Soft Decision Decoding

The Viterbi algorithm is used for decoding of the convolutional forward error control (FEC) coding. Soft decisions are made in the receiver based on the channel state bits. Soft decision metrics are determined as follows:

1. Each demodulated data bit provides the most significant bit (MSB) for the Viterbi algorithm decoder (VAD) input.

2. Based on the number of errors in the demodulation of the four known channel state bits in each subframe, a soft decision metric is determined using the following mapping:

0	errors maps to the integer value	16
1	error maps to the integer value	8
2	errors maps to the integer value	5
3	errors maps to the integer value	3
4	errors maps to the integer value	1

3. Linear interpolation is done across the subframe using the results of the mapping above, based on channel state bits at both ends of subframe.

4. A soft decision result for the VAD input is determined for each data bit in the subframe (72 data bits per subframe). Assuming a three bit, twos complement format with a half bit offset for the VAD input, the input to the VAD is determined from the following table:

Table 3. Soft Decision Conversion

Interpolated value	data bit = "0"	data bit = "1"
1 to 4	000	111
5 to 8	001	110
9 to 12	010	101
13 to 16	011	100

5. The above soft decision results are deinterleaved in the convolutional deinterleaver, prior to being provided to the VAD.

Note: Certain features of the STIC waveform and system are protected under United States patent law (U.S. Patent No. 5,442,646). The STIC system has been, and will be, licensed to interested users.

Reed Solomon Decoding

The Reed Solomon Code used for the STIC system is capable of correcting as many as 7 symbol errors but can also detect all 8-symbol errors. This feature is used in place of a cyclic redundancy code (CRC) to reliably determine whether a packet has been received correctly.

STIC Bandwidth Occupancy

Figure 4 shows a spectrum analyzer plot of the FM baseband from 50 kHz to 100 kHz. The baseband spectrum in this plot includes a 57 kHz RDS signal, the 72.2 kHz STIC signal injected at ±7.5 kHz, and a 92 kHz analog subcarrier. The 50 dB attenuation at 64 and 81 kHz, is adequate to ensure that the STIC waveform does not impinge on the adjacent 57 kHz RDS or the 92 kHz sub carriers.

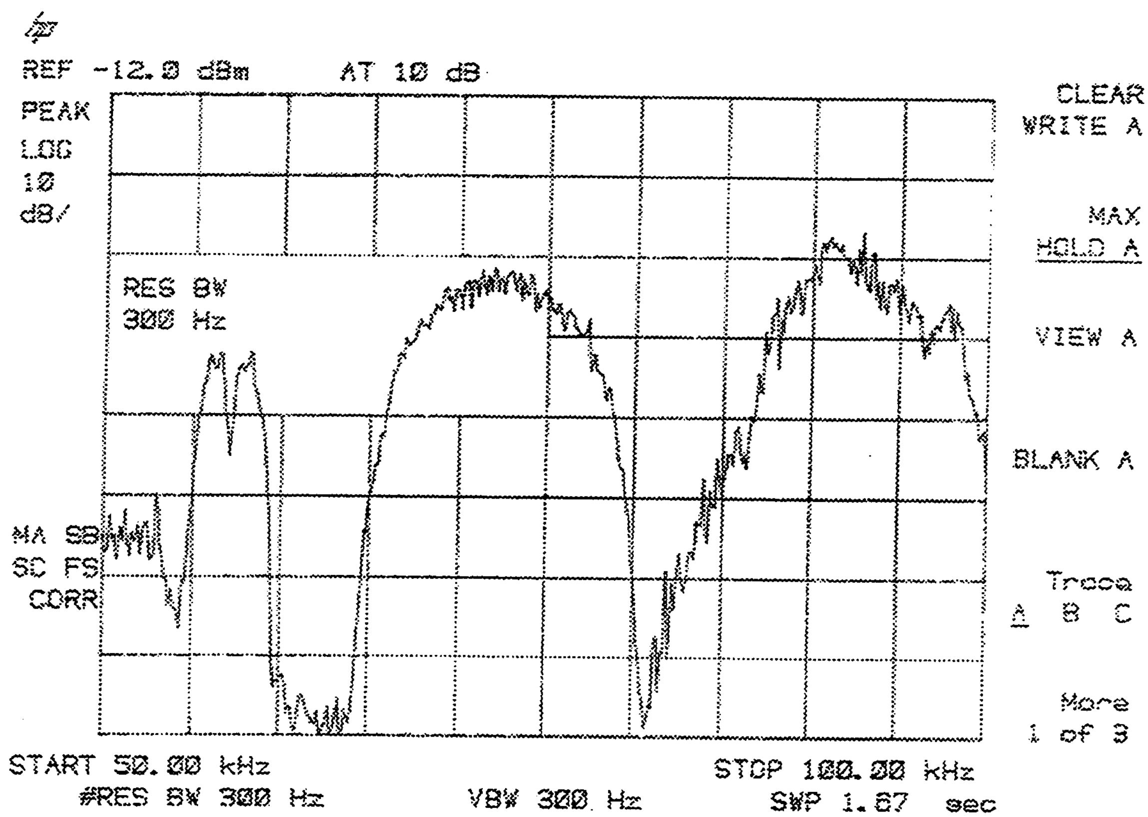

Figure 4. STIC Spectral Characteristics

System Configuration

The complete STIC test configuration which MITRE uses to do performance tests consists of the following items connected together in sequence:

1. TX-end PC
2. STIC modulator
3. Commercial grade FM stereo generator and FM exciter
4. Channel simulation (attenuators and/or HP multipath simulator)
5. Alpine FM receiver
6. STIC demodulator
7. RX-end PC

There is no connection between the TX-end and RX-end PCs. The transmit end PC is used to format the data prior to transmission. The STIC modulator creates the waveform at 72.2 kHz. It does the DQPSK modulation and filtering required to maintain good spectral characteristics. At the receive end, the Alpine receiver accomplishes the tuner function. The output of the FM discriminator of the Alpine receiver is provided to the STIC demodulator. In the demodulator, the 72.2 kHz signal is detected, synchronized, deinterleaved, and decoded. The receive end PC is used for error detection utilities.

Test Utility Description

There are several modes, two of which should be useful to the testing. A "BER" mode is useful for system check-out and troubleshooting. A "packet" mode should be used for the actual performance tests. In the "packet" mode, this is what happens:

1. In the TX-end PC, a binary file is used as the transmit data. Any arbitrary binary file can be used. If the file is shorter than a superframe the data in the file is repeated to fill up the superframe. If the file is longer than a superframe, the file is truncated to exactly fit the superframe. This data is sent repeatedly superframe after superframe.

2. The STIC demodulator passes received data after all error correction to the RX-end PC.

3. A utility in the RX-end PC accepts the received data and develops statistics (on a one sample per superframe basis) of bit error rate, 20-byte message error rate, and 220-byte message error rate. Error rates are displayed by the utility for the current superframe and for the cumulation since the last reset of statistics. A message is counted as being in error if one or more bits in the message is received incorrectly. Loss of synchronization also resets the statistics. In fading, for the x1 interleaver, loss of synchronization occurs about 12 dB below the error rate threshold.

4. The test utility in the RX-end PC has another feature which allows the data actually received to be written to a file. This in combination with the ability of the TX-end PC to send any arbitrary data file allows the independent validation of the test utility. Questions about the utility can be resolved by using an independent comparison of the source data with the received data.

HSDS Seiko

HSDS SYSTEM DESCRIPTION

1. HSDS Overview

The High Speed Data System (HSDS) is a flexible, one-way, communications protocol and permits very small receivers. Receivers, with duty cycles varying from continuously on to duty cycles of less than 0.01%, provide flexibility to select message delay, data throughput and battery life. HSDS can operate as a single or multiple transmitter system. Multiple transmitters are accommodated by frequency-agile receivers, time offset transmission, and lists of alternate frequencies. Reliability can be enhanced through packet retransmission.

The system employs time division multiplexing with a system of master frames, subframes and time slots. Each timeslot contains a single data packet. In multiple transmitter systems, each HSDS master frame is synchronised to Universal Co-ordinated Time (UTC).

The error correction scheme is flexible and varies with the application.

HSDS modulation and encoding provides a high data rate, narrow bandwidth with high spectral efficiency and negligible impact on the main channel. Modulation is Amplitude Modulation Phase Shift Keying (AM-PSK) with duobinary encoding. The channel data rate is 19,000 bits per second.

HSDS deviation can be set from 3.75 to 15 kHz. Sharp transmission filter skirts result in low impact on the main channel in no multipath situations; and pseudo-randomised data reduces impact on the audio even in multipath situations. The narrow bandwidth of HSDS ensures compatibility with RDS, and complies with ITU-R BS.450.

2. Physical Layer

2.1 Modulation

The HSDS modulation scheme satisfies the following criteria:

- Non interference with FM radio receivers
- Compatibility with ITU-R recommendations
- compatible with either a 67 kHz or 92 kHz analogue subcarrier
- Simplicity in IC implementation of the demodulator
- Low-cost mobile receiver with a small form factor
- Adequate Bit Error Rate performance in the presence of noise
- Commercially satisfactory coverage area
- Relatively high data rate.

The HSDS subcarrier frequency is located at either 66.5 kHz. or 85.5 kHz and is phase-locked to the pilot at approximately 63 degrees. Double-sideband suppressed-carrier amplitude modulation with duobinary encoding is used. Duobinary encoding employs controlled inter-symbol interference to achieve 1 bit/sec/Hz efficiency. The duobinary encoding technique achieves this result by using a filter to create inter-symbol interference that combines the current and previous data bit, creating a three level output signal in the demodulator.

2.1.1 Compatibility with main channel audio

HSDS is more than 60 dB below the pilot outside the subcarrier envelope and uses data randomization to 'whiten' any otherwise audible signal elements — avoiding generation of tones in the audio portion of the band.

Figure 1 shows a screen dump of the baseband spectrum of the 66.5 kHz subcarrier in a unfaded situation.

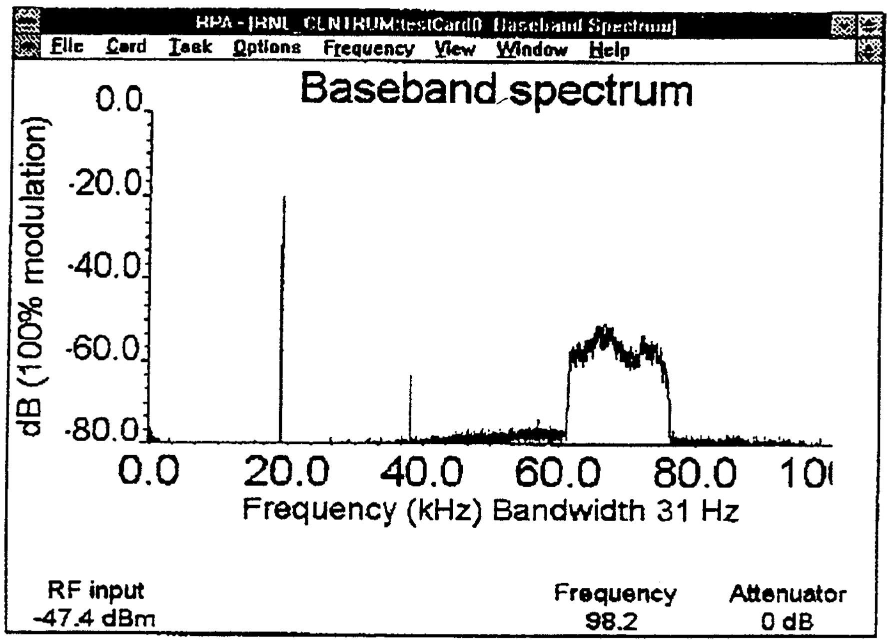

Figure 1 Unfaded Baseband Spectrum

3. Link Layer

The link layer includes features required to make a reliable single transmitter data link and includes the frame and packet structure (size, word synchronisation, error detection and correction).

3.1 Packet Structure

HSDS employs fixed-length packets. The bottom part of Figure 2 illustrates the packet structure used in the HSDS Protocol. Each packet is 260 bits long. Packet format bits in each packet define the packet's structure. A typical packet consists of a word synchronisation flag, Error Correction Code (ECC), information bits and error detection code.

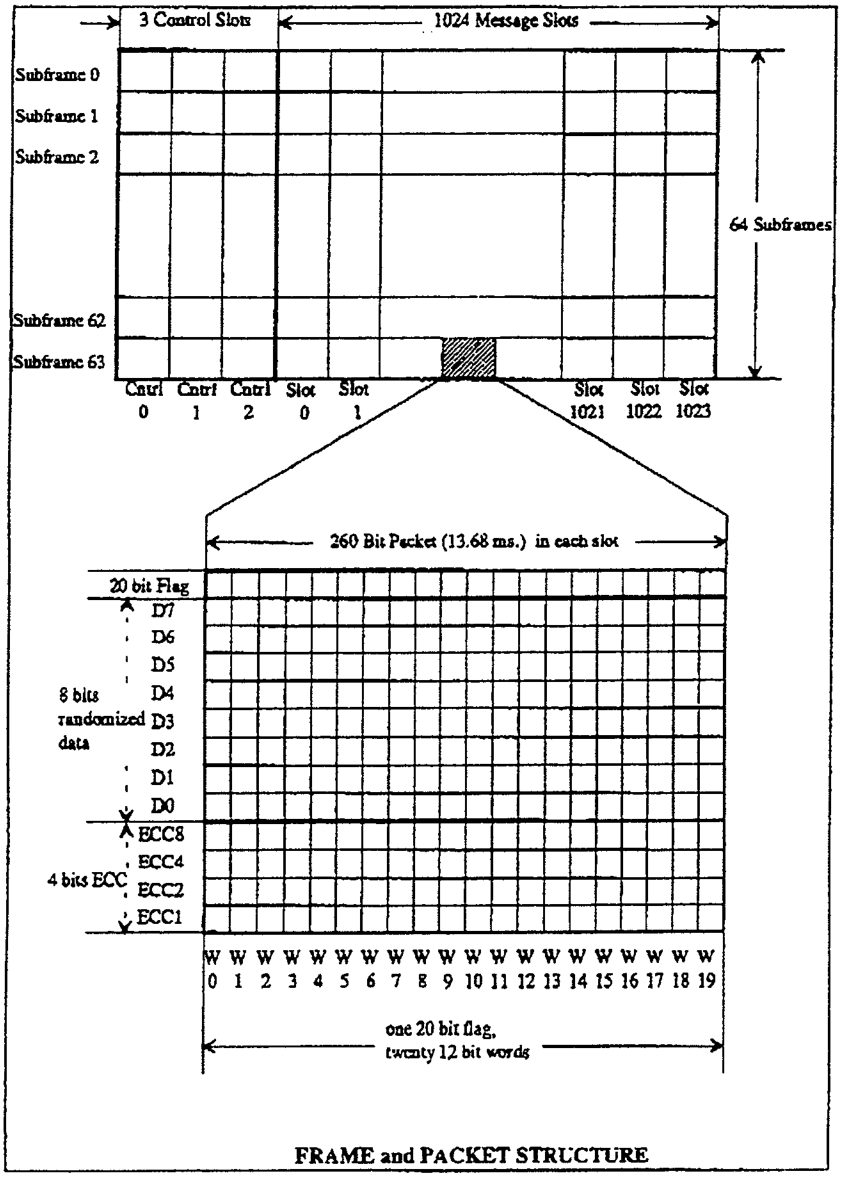

Figure 2 Frame and Packet Structure

For the typical packet format, information bits from higher layers consist of 18 octets (8 bits per octet) per packet. A two octet ITU-T standard 16 bit Cyclic Redundancy Check (CRC) is generated from the 18 octets and appended, thus creating a 20 octet link data unit. The first octet (the incrementing slot number) of the 20 octet data unit is exclusive or'ed with each of the following 19 octets creating pseudo-randomised data to minimise apparent effects of multipath or other distortions to the signal.

Appended to each octet of randomised data is 4 bits of Hamming ECC. This error correction method provides single bit error detection and correction in 12 bits, or 8.3% correction capability, is easy to decode and reasonably efficient. Because of the small size and modular nature of the base error correcting code a variety of packet type can be created for various transport needs.

To increase burst error correction capability, data is interleaved providing immunity to 20 bit error bursts. Word synchronisation is established by a 20 bit flag sequence at the beginning of the packet. Various flags may be used to create multiple networks. Two such flags are defined "A" and "B".

Table 1 shows the steps in the link layer transmitter encoder and the reverse steps performed by the receiver decoder.

Step	Transmit Encoder	Receive Decoder
1	Compute and add CRC	Find flag
2	Randomise data	De-interleave data
3	Add error correction	Apply error correction
4	Interleave data	De-randomise data
5	Add flag	Compute and compare CRC

Table 1: Typical Packet Structure Encode and Decode steps

3.2 Frame Structure

HSDS uses a packet oriented Time Division Multiplexed (TDM) scheme. The top section of Figure 2 illustrates this. The largest structure used by the protocol is a master frame. Each master frame contains 64 subframes. Each subframe is divided into 1027 units called time slots. Each timeslot contains a data packet. The first three timeslots in each subframe are Control Slots, and the remaining 1024 are data timeslots. Control Slot packets carry the time of day and date, and lists of related nearby transmitters also carrying HSDS. Data timeslot packets typically include a slot number, receiver address, data format, packet format, and the message data.

The pilot signal is used as the data clock . The frame structure provides for inaccuracy of the pilot signal through anticipation of bit padding. Since the stereo pilot may not be exactly 19 kHz at the time of transmission, a single bit may be added (pad bit) between packets as required to maintain synchronisation. This occasional addition of a pad bit ensures proper synchronisation between transmitters, and battery savings receivers.

3.3 Small Block Structure

Double error correction on a stream of packets has been designed for applications with less severe power constraints, and with requirements for higher data reliability. There are 15 packets per small block. The first 11 packets of each small block contain information data while the last 4 packets contain ECC on the first 11 packets. The Block ECC uses a (15,11) Hamming Code. The first packet of each small block contains a 10 bit slot number, 6 bit logical channel number, and 8 bit packet format. Packets 2 through 11 contain the slot and channel numbers in the first 2 bytes. The 11th packet contains in the last 2 bytes a CRC on the 218 bytes of data in the small block. For transmission the each subframe is divided into 8 time division multiplexed "physical" channels. Small blocks are typically placed in one of the 8 "physical" channels. Hence each packet of a small block is located 8 slots away from the previous packet.

Below is a diagram of the small block structure.

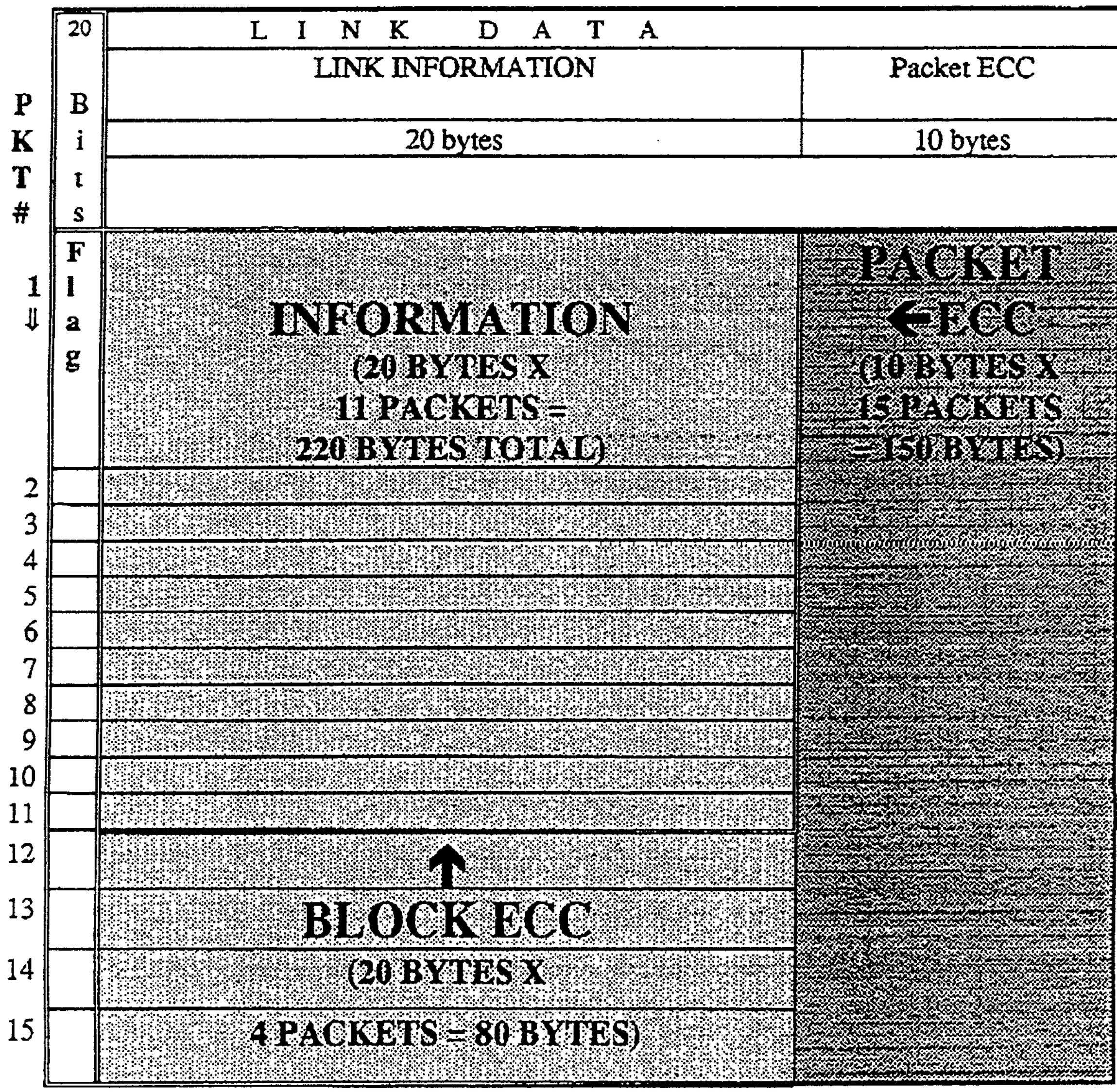

Figure 3 Small Block Structure

4. Network Layer

The network layer includes features required to make a number of individual transmitters act as a single system. This includes:

- receiver addresses
- application multiplexing
- alternative frequency lists
- transmitter time offsets (required for battery savings receivers)
- time synchronisation between transmitters (required for battery savings receivers)

4.1 Multiple Transmitters

When multiple transmitter networks are required, master frames are synchronised and begin at the start of each quarter hour (plus an individual transmitter's time offset). The synchronised, and time offset transmitters provide an opportunity for the receiver to change the tuned frequency and make subsequent packet reception attempts on the alternative frequencies with no loss of data synchronisation.

4.2 System Reliability

While extensive error correction techniques are useful for a moving receiver, they become ineffective when the receiver is stopped in an extremely low signal strength area or moving very slowly through multipath nulls. HSDS addresses multipath and shielding with a combination of frequency, space and time diversity; and in the case of paging, message numbering.

A repetition of packets can result in an effectively higher data quality. If the receiver can receive packets from different transmitters, with different propagation paths, the receiver may receive messages although some packets get lost. The HSDS receiver has the possibility to switch between 'k' time-shifted transmitters, each repeating the same packets 'n' times.

The MCR is calculated by the formula:

$$MCR = PCR_1^{\,n} + PCR_2^{\,n} + ... + PCR_k^{\,n}$$

5. Applications

HSDS implements up to 64 asynchronously multiplexed logical channels at the transport layer. Channels include 3 link packet types: Data Gram Packets, Data Stream Packets, and Data Block Packets.

Data Grams are stand alone packets consisting of 15 bytes of transport data. Data Gram Packets can be delivered in non-sequential order.

Data Streams are continuous streams of transparent data. Any segmentation of transport data is performed at a higher level in this packet type. There are no transport level indications of the beginning or end of Data Stream Packets. Order information is included in Data Stream Packets so that they may be interleaved with other data packets on the same channel. At any one time on a single logical channel, up to 128 Data Stream Packets may be delivered in non-sequential order. Data Stream Packets may include repeats of the same Data Stream Packet for enhanced reliability.

Data Blocks provide capability to send from 1 to 768 bytes of transparent transport data. Transport messages are broken into multiple data blocks. Each data block is broken into multiple DB Packets. Each DB Packet carries up to 12 bytes of transport data. At any one time on a single logical channel, up to 32 Data Blocks may be interleaved. DB Packets may be interleaved with other data packets on the same channel or other logical channels. At any one time on a single logical channel, up to 32 DB Packets may be delivered in non-sequential order. DB Packets may include repeats of the same DB Packet for enhanced reliability."

Summary of System

	HSDS
Parameters	
Subcarrier center frequency	66.5 kHz (mid band) or 85.5 kHz (high band)
Bandwidth	16 kHz @ mid band and 19 kHz @ high band
Channel data Bit rate	19 kbps
Information data rate	Packets - 10.51 kbps Small blocks - 8.3 kbps
Modulation method	double-sideband suppressed-carrier amplitude modulation with duo-binary encoding
Error correction	Packets - interleaved Hamming (12, 8) Small Blocks - time spread packets with additional Hamming (15,11)
Error detection	16 bits of CRC, initial value of 0
Injection level	3.75 kHz to 15 kHz nominally 7.5 kHz
Special Features	
Power saving	Yes, duty cycles from 0.01% to 100%
Receiver addressability	32 bit, 16 bit, 6 bit - flexible
Support of different data types	Data Grams, Data Streams, Data Blocks
Possibility for additional subcarrier services	Yes, RDS and either 67 kHz or 92 kHz analogue
latency	inherent delay 13.6 ms per packet Other delays are transmission system and receiver implementation dependent
Multiple station access	Yes, including time offset transmission for battery savings receivers

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Appendix B

LABORATORY TEST PROCEDURES

Procedures Rev #5

Procedures Changes

HP 11759C MULTIPATH PROFILES

DAR90240.DAT

```
#------------------------------------------ Profile #1
0:TITLE      "AIRPLANE FLUTTER SCENARIO #1 VHF
0:IQDATA_DIR   "C:\CHAN_NEW"
0:CORR_MODE  3X3
0:DELAY_RES   LOW
0:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
0:GROUP_LOSS  0.000000e+00
0:SPECTRUM    PHA  DOP  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF
0:IQFILE      "" "" "" "" "" "" "" "" "" "" "" ""
0:DELAY_US    0.0000  27.5191  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0:DOPPLER_HZ  333.5646 34.8760 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:PHASE_DEG   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:ATTEN_DB    0.0000 8.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------------ Profile #2
1:TITLE      "AIRPLANE FLUTTER SCENARIO #2 VHF
1:IQDATA_DIR   "C:\CHAN_NEW"
1:CORR_MODE  3X3
1:DELAY_RES   LOW
1:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
1:GROUP_LOSS  0.000000e+00
1:SPECTRUM    PHA  DOP  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF
1:IQFILE      "" "" "" "" "" "" "" "" "" "" "" ""
1:DELAY_US    0.0000  13.6761  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
1:DOPPLER_HZ  333.5646 17.4380 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:PHASE_DEG   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:ATTEN_DB    0.0000 6.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------------ Profile #3
2:TITLE      "AIRPLANE FLUTTER SCENARIO #3 VHF
2:IQDATA_DIR   "C:\CHAN_NEW"
2:CORR_MODE  3X3
2:DELAY_RES   LOW
2:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
2:GROUP_LOSS  0.000000e+00
2:SPECTRUM    PHA  DOP  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF  OFF
2:IQFILE      "" "" "" "" "" "" "" "" "" "" "" ""
2:DELAY_US    0.0000  6.8381  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
2:DOPPLER_HZ  333.5646 8.7190 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:PHASE_DEG   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:ATTEN_DB    0.0000 4.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
```

DIGITAL SUBCARRIER LABORATORY TEST OUTLINE
REV #5
January 16, 1996

A. Calibration

1. Check signal injection/power daily
2. Plot RF spectrum daily
3. Noise check daily
4. Weak signal check daily
5. Analog channel proof biweekly
6. Calibrate modulation monitors monthly
7. Proponent self check (optional)
8. Calibrate test bed monthly

B. Characterization of Signal Failure

1. Noise
2. Co-channel
3. Multipath and noise
4. Impulse noise
5. Airplane flutter
6. Weak signal failure

C. Reacquisition

1. Failure due to simulated weak signal
2. Failure due to multipath

D. Digital Subcarrier -> Host Analog

1. Interference to host analog
2. Interference to host analog with multipath

E. Host Analog -> Digital Subcarrier

1. Host analog to digital subcarriers
2. Host analog to digital subcarriers with multipath

F. HS Data -> RBDS, Analog, and 57 kHz Paging Subcarriers

1. HS data to analog subcarriers
2. HS data to RBDS
3. HS data to 57 kHz paging

G Adjacent Channel

1. First adjacent
2. Second adjacent

H. SYSTEM SPECIFIC

1. Phase, digital to 19 kHz pilot
2. Nonstandard injection levels
3. Variable injection

I SUBCARRIER GROUP TABLE

January 16, 1996 REV #5		HIGH SPEED DATA LABORATORY TESTS						
Test Group	Test & Impairment	TEST PROCEDURE	Type of Eval	Sig Lev	System Seiko	System Digital DJ	System MITRE	Test Results Data to be Recorded
A Calibration	1 HS data subcarrier injection (daily)	The injection will be determined by percentage of modulation and peak deviation.	Objective	As needed	X 10%	X 4-10%	X 10%	Injection
	2 Spectrum (daily)	An RF plot of each system will be taken daily. Baseband spectrum analyzer settings: Sweep 100 kHz, rez. band width 300 Hz, Video 30 Hz, and 30 sec sweep. RF spectrum analyzer settings: Sweep 200 kHz or 500 kHz, rez. band width 1000 Hz, and video 30 Hz. Subcarrier group A & B will be used for this test.	Objective	M	X 10%	X 10%	X 10%	Spectrum record
	3 Noise (daily)	Gaussian noise will be added to the signal in 0.25 dB steps until the onset of message errors is observed. Subcarrier group A & B will be used for this test.	Objective	M	X 10%	X 4& 10%	X 10%	Noise level at the onset of message errors
	4 Weak signal (daily)	Starting with a medium signal level, the signal will be reduced until the onset of message errors is observed. Subcarrier group A & B will be used for this test.	Objective	M	X 10%	X 4& 10%	X 10%	Signal level at the onset of message errors
	5 Proof host transmitters (weekly)	During the compatibility tests, an automated proof of performance will be conducted weekly on the analog transmitters. The test will include the analog system performance with and without the subcarrier groups A & B. A high quality demodulator will be used for the test.	Objective	M	NA	NA	NA	Record of frequency response, separation, and distortion
	6 Monitor calibration (monthly)	The FM analog modulation monitors will be calibrated monthly.	Objective	NA	NA	NA	NA	Calibration record in lab log
	7 Proponent self check	This test will use the proponent self certification routine to determine if the system is operating within specified limits.	Objective	System need				Note in lab log
	8 Test bed calibration (monthly)	All of the critical components in the test bed including the multipath simulator, attenuators, combiners, filters, generators, and measuring instruments will be calibrated on a monthly schedule.	Objective	NA	NA	NA	NA	Calibration record in lab log

January 16, 1996 REV #5 HIGH SPEED DATA LABORATORY TESTS

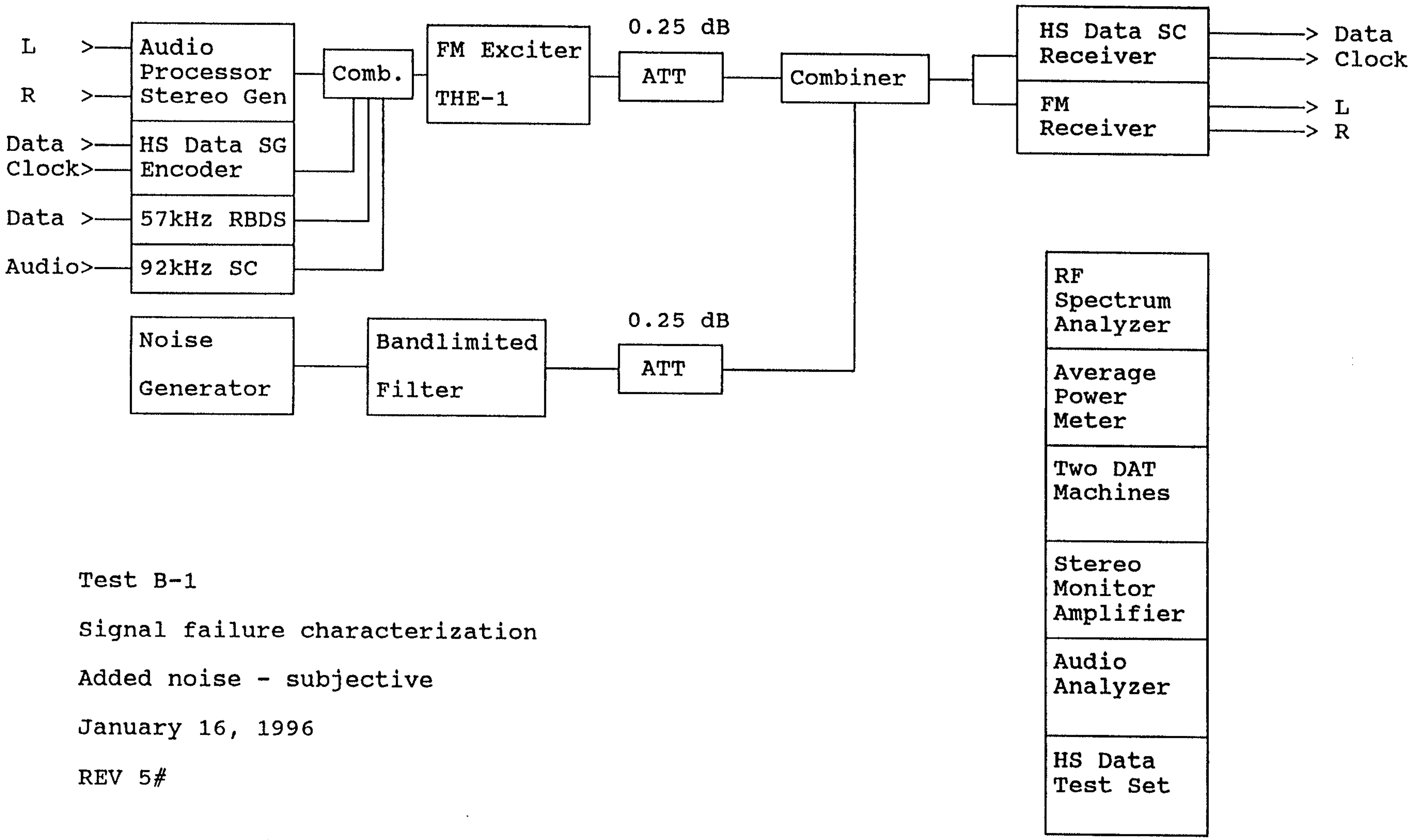
Test Group	Test & Impairment	TEST PROCEDURE Note: 1. The co-channel undesired transmitter will be modulated by clipped pink noise with two subcarriers, 67 kHz and 92 kHz, each set for 10% injection. 2. To minimize possible measurement variations caused by hysteresis, the noise and co-channel will be increased rather than decreased when finding HS data errors.	Type of Eval	Sig Lev dBm	System			Test Results Data to be Recorded
					Seiko	D/DJ	MITRE	
B Character-ization of HS digital subcarrier signal failure	1 Noise	1. Using clipped pink noise for main channel modulation and only the HS subcarrier under test, the gaussian noise will be added to the signal and increased to a level that produces the onset of message errors. 2. Subcarrier groups A & B will be individually added to the signal, and any change in HS data errors will be noted. 3. The 92 kHz analog subcarrier channel audio S/N will be measured with no noise added to the RF channel and with the noise added that produced message errors in step #1. Audio recordings for subjective audio evaluation will be made of the analog subcarrier. 4. Noise will be added to the signal until un-correctable RBDS block errors are observed (Subcarrier Group A).	Objective & Lab EO&C	M	X 10%	X Auto	X 10%	Noise level at the onset of message errors Analog S/N at the onset of message errors Noise level at onset of RBDS block errors
	2 Co-channel	1. Using the undesired transmitter signal modulated with clipped pink noise and the two reference subcarriers (110%), the co-channel interference will be increased until an audio S/N of 45 dB is observed on the desired channel without modulation. 2. The HS subcarrier, subcarrier group A, and subcarrier group B will be added to the undesired transmitter. Any further changes in the desired channel's stereo or subcarrier S/N will be recorded. 3. With the HS data channel the desired path, the undesired co-channel signal will be increased until the onset of message errors on the HS data channel. The D/U will be recorded at this point. 4. The Delco 16192463 and Pioneer SX-201 receivers will be used.	Objective & Lab EO&C	M	X 10%	X 4& 10%	X 10%	D/U at 45 dB S/N Any changes caused by subcarrier groups D/U with message errors
	3 Multipath with noise	1. This test will be conducted four times, each with a different multipath scenario. The scenarios will be those used by the EIA DAR Subcommittee for testing DAR systems. 2. Using subcarrier group A and without noise added, each of the multipath scenarios will be assessed for impairment. 3. If impairments are observed, the message error and BER will be recorded. 4. For those multipath tests where no impairments are observed, noise will be added to the signal in 0.5 dB steps until an increase in message errors and BER is observed.	Objective & Lab EO&C	M	X 10%	X Auto	X 10%	HS system error with each multipath or Noise level with multipath at the onset of errors

January 16, 1996 REV #5 — HIGH SPEED DATA LABORATORY TESTS

Test Group	Test & Impairment	TEST PROCEDURE	Type of Eval	Sig Lev	System			Test Results Data to be Recorded
					Seiko	D/DJ	MITRE	
B Character-ization of HS digital subcarrier signal failure	4 Impulse noise	1. A 10 nanosecond pulse will be used for this test. Starting with a pulse rate of 100 Hz, the pulse rate will be increased until an increase in message error is observed. 2. The pulse generator output will be mixed with the DAR signal. 3. The pulse amplitude will be 1 volt. If HS message errors are detected with the 1 volt signal, the voltage will be reduced until errors discontinue. 4. Subcarrier group A will be used for this test.	Objective & Lab EO&C	M	X 10%	X Auto	X 10%	Pulse rate that causes an increase in system errors Pulse amplitude in Volts P-P that causes an increase in errors
	5 Airplane flutter	1. Tests will be conducted with the three airplane flutter scenarios used in the DAR laboratory tests by WG-B of the EIA DAR Subcommittee. 2. If an increase in message error rate is not observed with multipath, the attenuation for the delayed signal will be reduced until an increase message error rate is observed. 3. Subcarrier group A will be used for this test.	EO&C or objective	W & M	X 10%	X Auto	X 10%	Multipath scenario & noise level that cause increase in system errors
	6 Weak signal	1. Starting with the medium signal level, the signal level will be reduced until the onset of message errors is observed (0.25 dB steps). 2. Subcarrier group A, B, and Off, will be used for this test.	Objective	Varying	X 10%	X Auto	X 10%	Signal level at increase in errors Any change caused by the addition of subcarriers

Air Multipath Scenarios (Each of these tests will include a path without delay or attenuation.)

Scenario	Speed KPH	Delay usec.	Attenuation dB
#1	400	8.25	16.0
#2	200	4.12	12.0
#3	100	2.06	8.0



Test B-1

Signal failure characterization

Added noise - subjective

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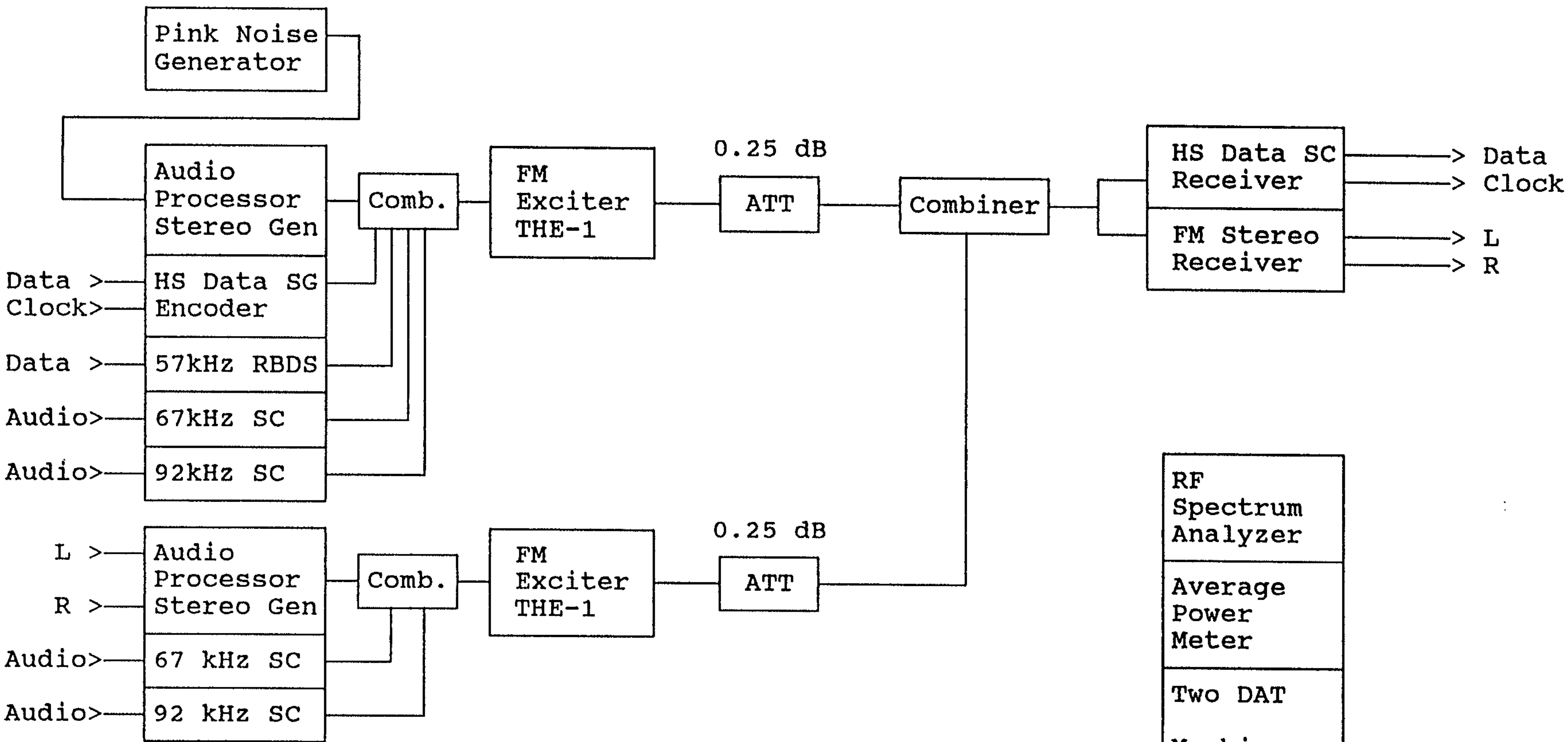
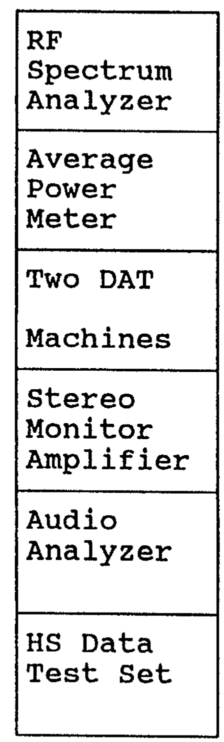


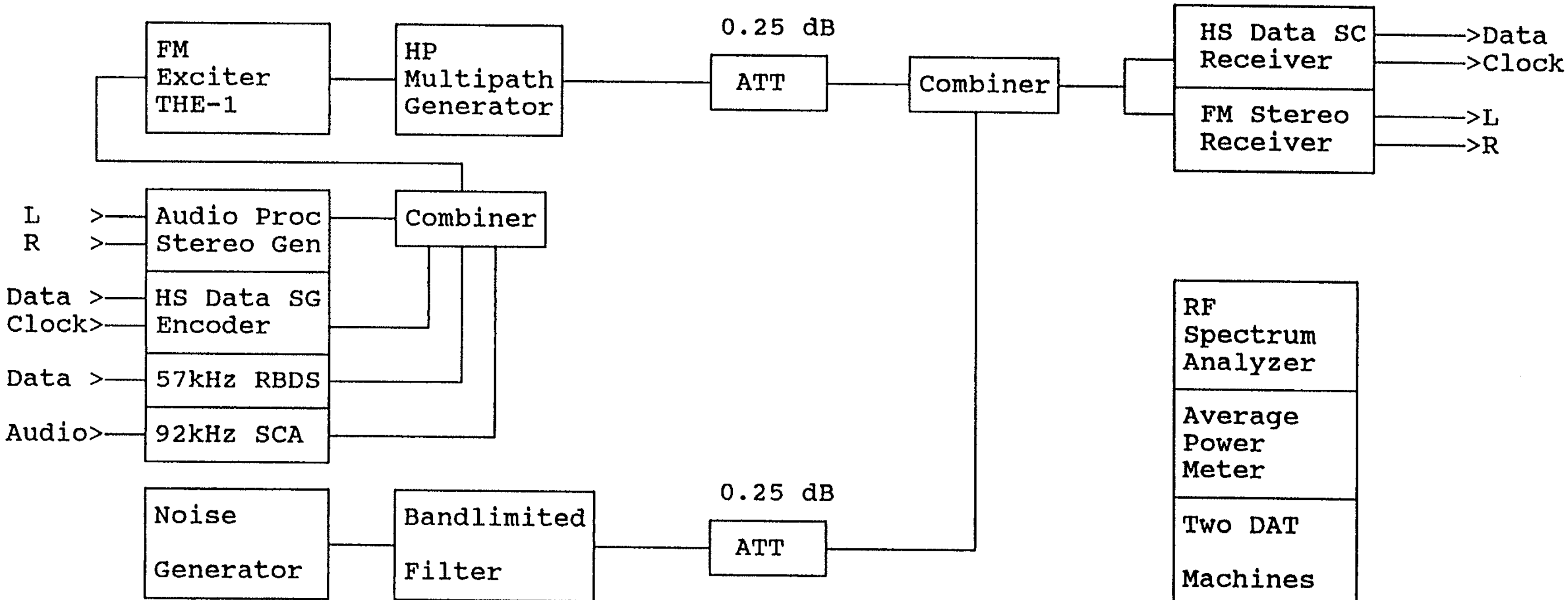


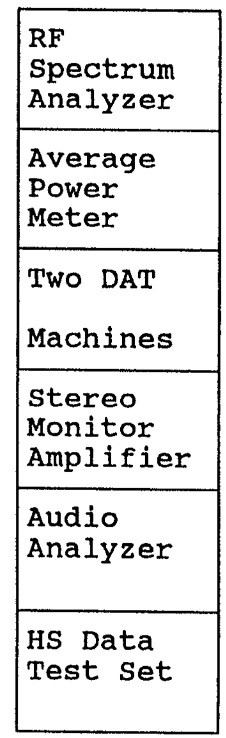
Test B-2

Co-Channel

January 16, 1996

REV #5





Test B-3

Signal failure characterization

Multipath and noise

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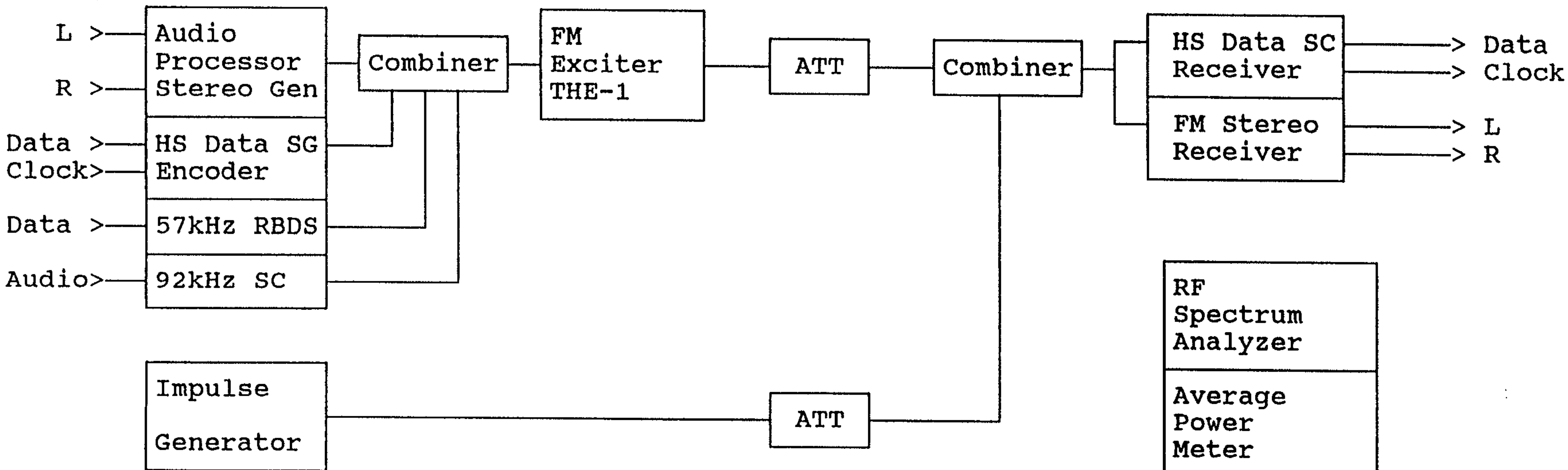
REV #5



TEST EQUIPMENT

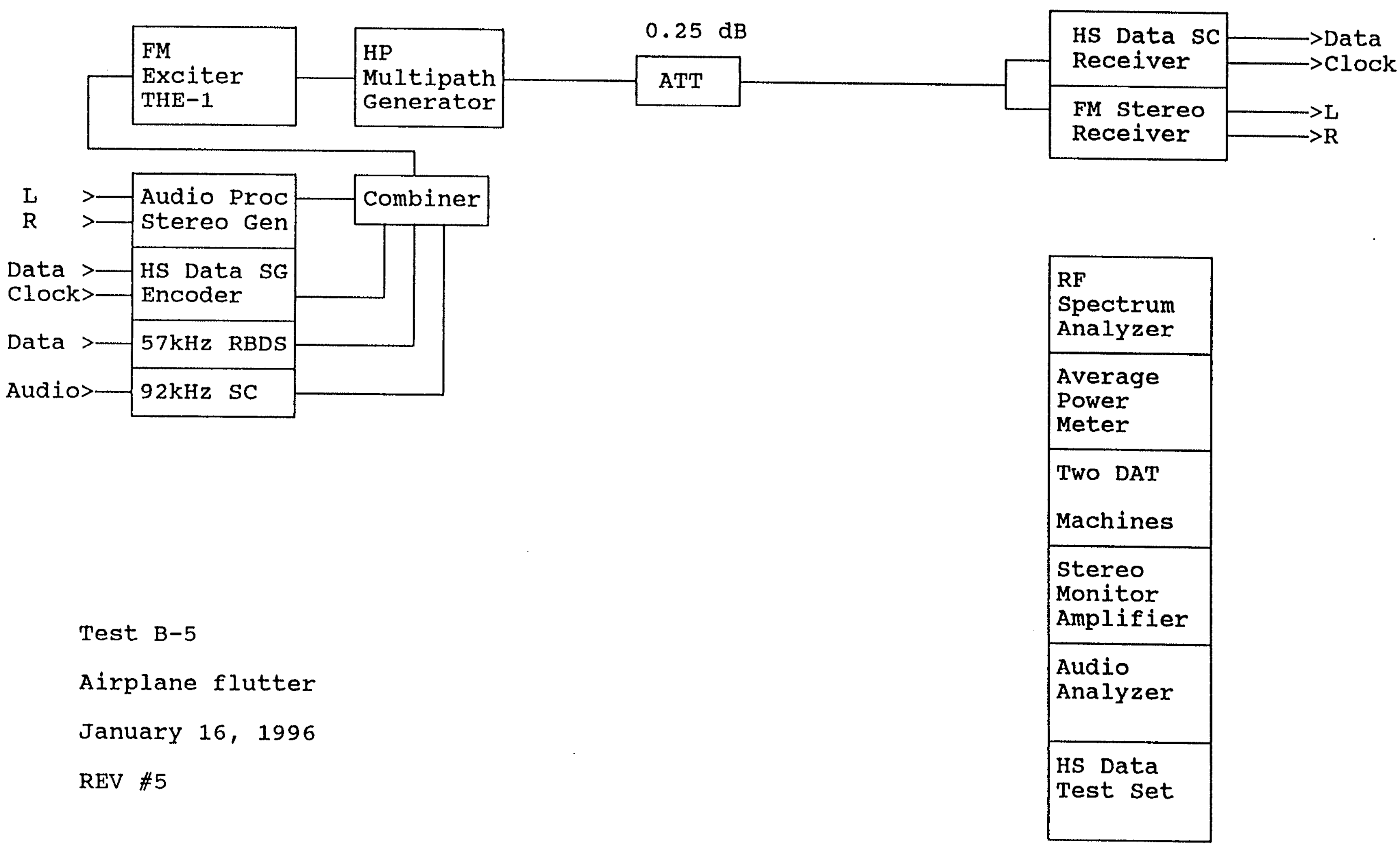
RF Spectrum Analyzer
Average Power Meter
Two DAT Machines
Stereo Monitor Amplifier
Audio Analyzer
Wide Band Oscilloscope

Test B-4

Impulse noise EO&C

January 16, 1996

REV #5



Test B-5

Airplane flutter

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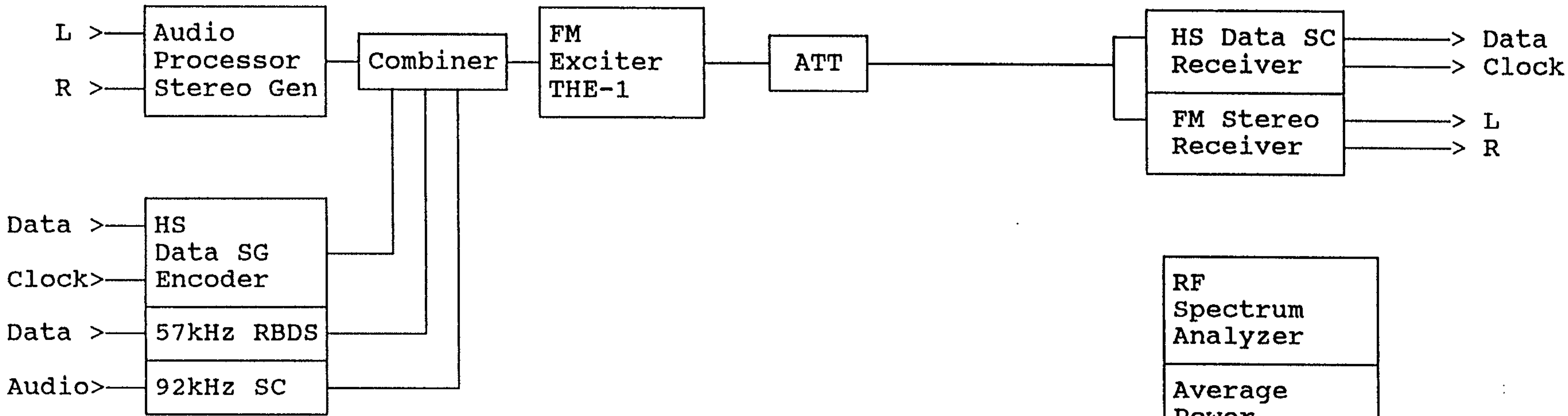
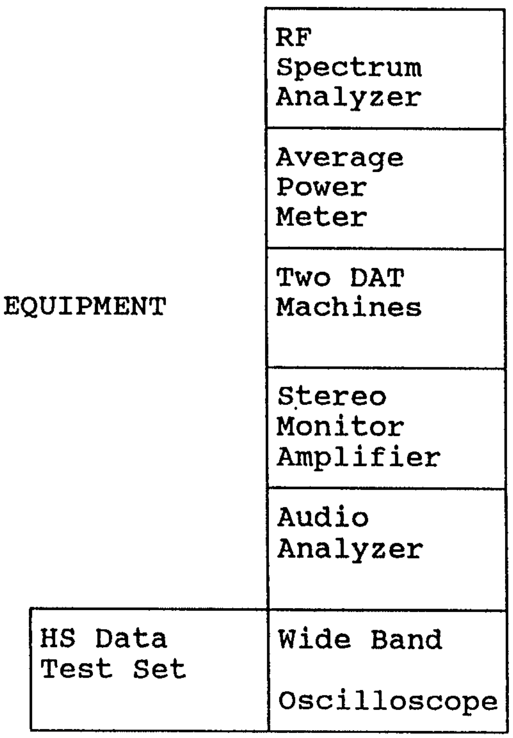
REV #5



TEST EQUIPMENT



Test B-6

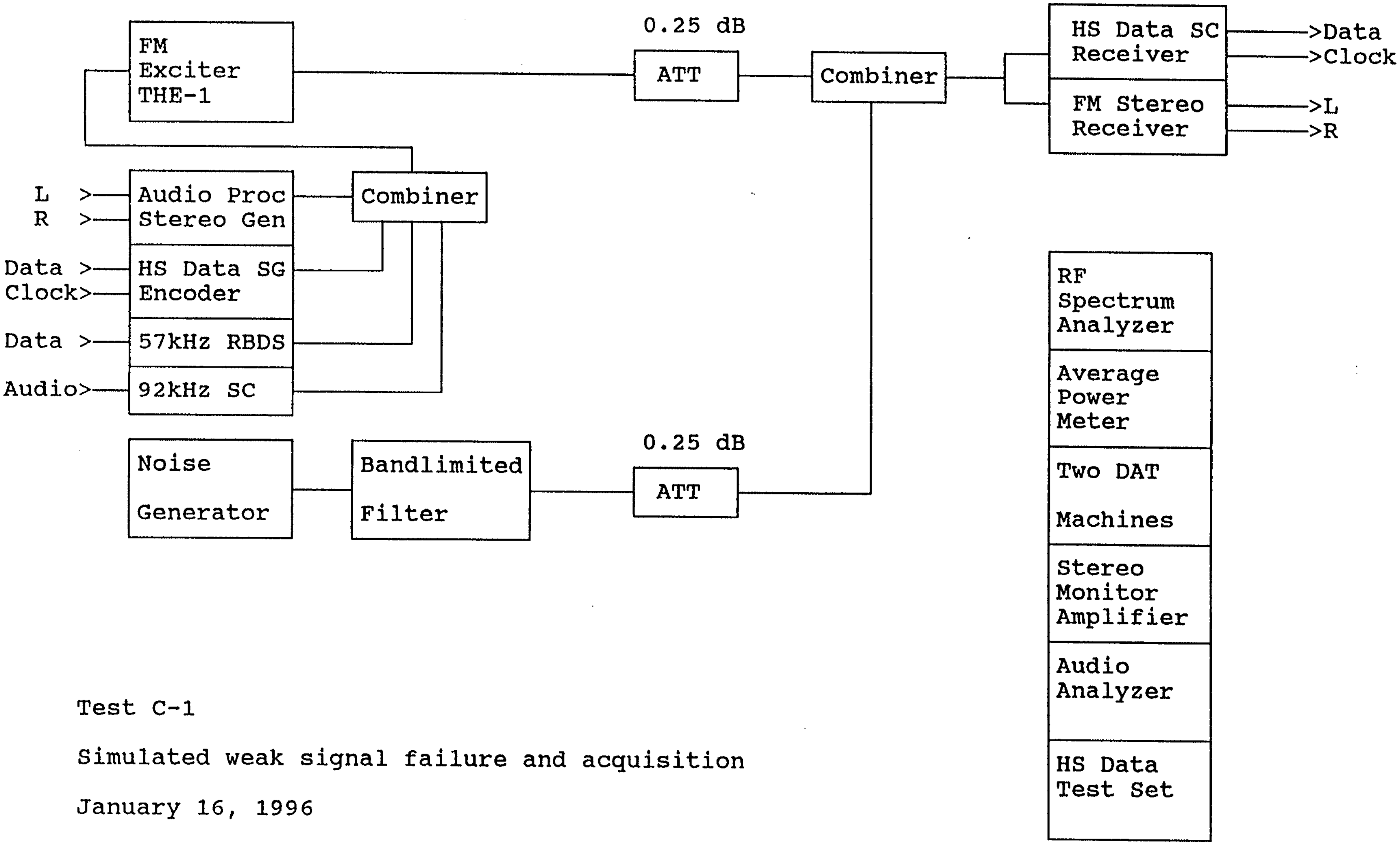
Weak Signal

January 16, 1996

REV #5

January 16, 1996 REV #5 — HIGH SPEED DATA LABORATORY TESTS

Test Group	Test Number and Impairment	TEST PROCEDURE Note: 1. Continuous music will be used for the FM audio modulation. 2. These tests will be conducted using subcarrier group A.	Type of Eval	Signal Level dBm	System: Seiko	System: D/DJ	System: MITRE	Test Results & Data to be Recorded
C Acquisition and reacquisition tests	1 Simulated weak signal failure and acquisition	1. Noise will be added to the signal in 0.25 dB steps until a complete loss of message is observed. 2. The FM transmitter with subcarrier group A will be disconnected from the receiver to assure loss of lock. 3. Three tests will be conducted with the noise reduced in 2.0 dB, 4.0 dB, & 6.0 dB steps below message failure for each test. 4. The signal will be reconnected to the HS data receiver and acquisition time recorded for each noise level. 5. EO&C comments will be recorded by the laboratory specialists.	EO&C in Lab	M	X 10%	X Auto	X 10%	Acquisition time at each noise level Any sign of hysteresis
	2 Simulated acquisition with multipath and noise	1. This test will be conducted four times, each with a different multipath scenario. The scenarios will be those used by the EIA DAR Subcommittee for testing DAR systems. 2. Noise will be added until the signal fails. 3. The FM transmitter with the subcarriers will be disconnected from the receiver to assure loss of lock. 4. A different scenario will be selected. 5. For each of the multipath scenarios, three tests will be conducted with the noise reduced to 2.0 dB, 4.0 dB, & 6.0 dB below packet failure. 6. The signal will be reconnected to the HS data receiver at 5, 10, 15, & 20 seconds into the multipath scenario and the acquisition time recorded for each of the test parameters in step #5.	EO&C in Lab	M	X 10%	X Auto	X 10%	Acquisition time for each multipath scenario, noise level, and MP start time.



Test C-1

Simulated weak signal failure and acquisition

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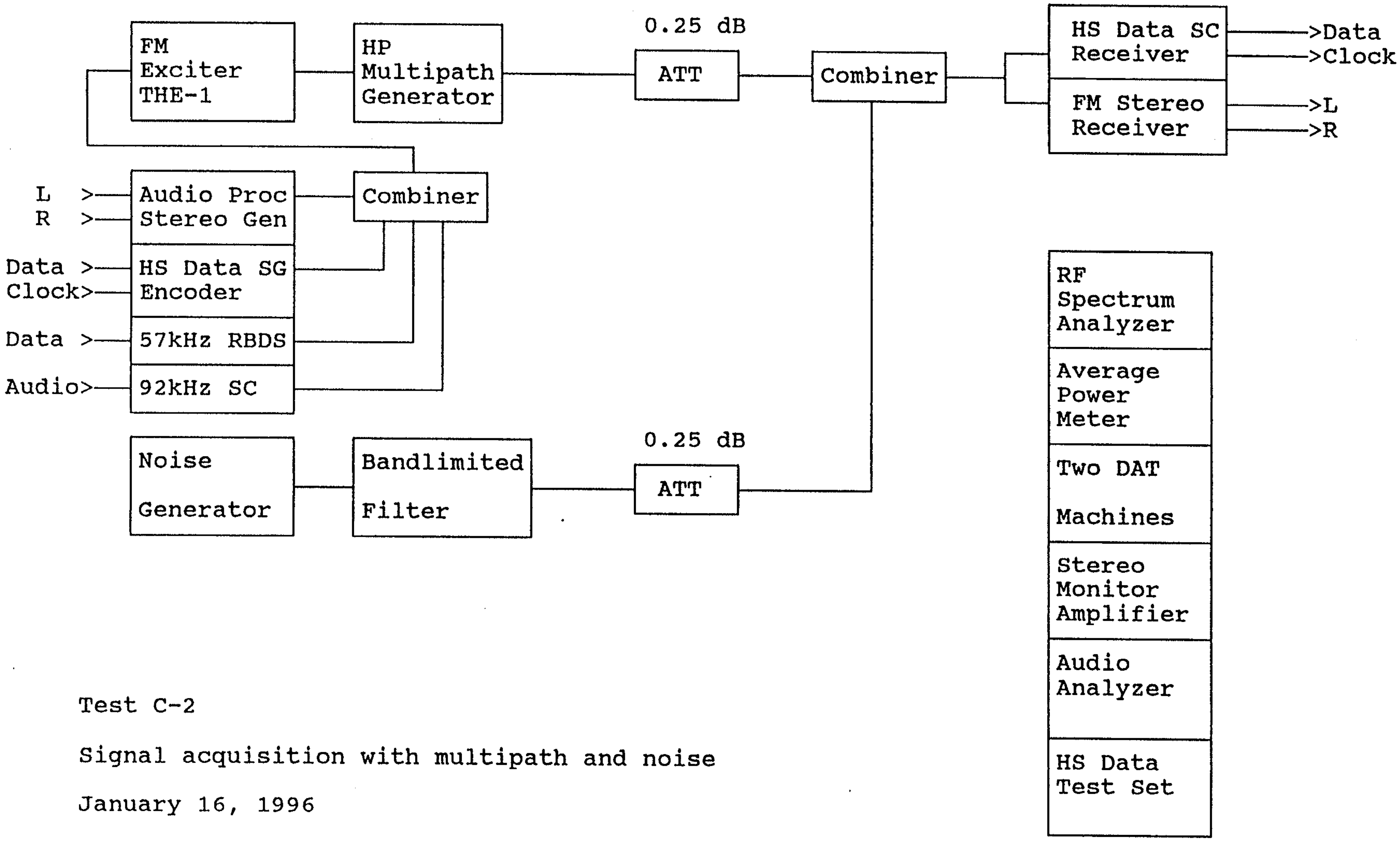
REV #5



Test C-2

Signal acquisition with multipath and noise

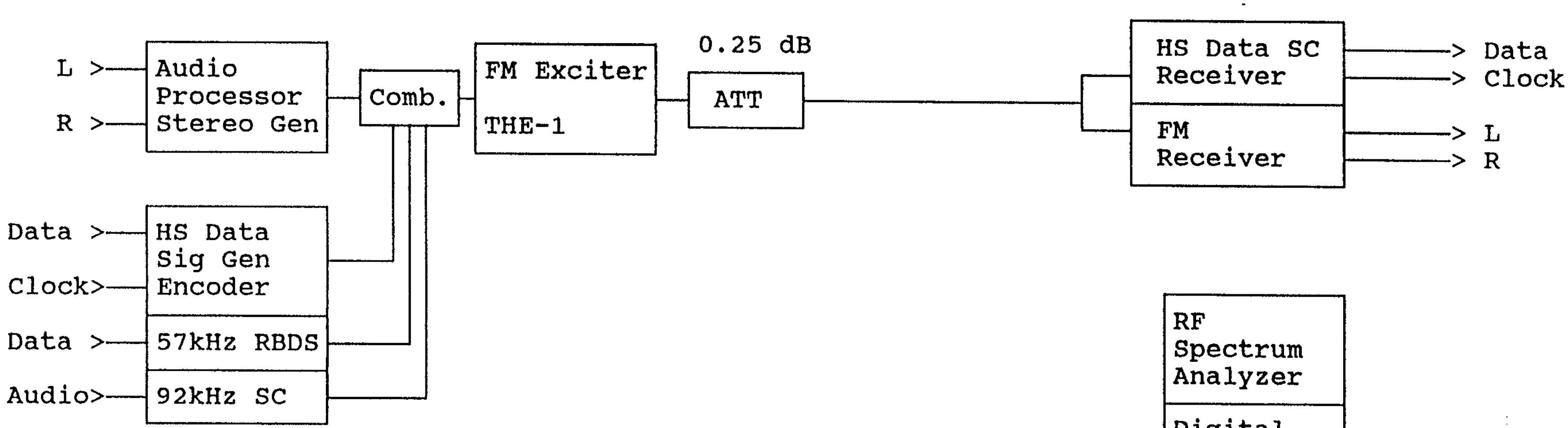
January 16, 1996

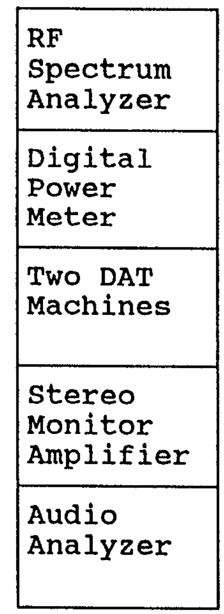
REV #5

January 16, 1996 REV #5

HIGH SPEED DATA LABORATORY TESTS

Test Group	Test	TEST PROCEDURE	Type of Evaluation	Desired Signal Level dBm	System			Test Results & Data to be Recorded
					Seiko	D/DJ	MITRE	
D HS data subcarrier -> host analog	1 HS data subcarrier to host analog	1. Five consumer receivers will be used for the tests: two auto, one portable, one high end home Hi-Fi, and one home HI-Fi FM receiver. The high end Hi-Fi receiver will have a built in RBDS decoder. A 92 kHz analog subcarrier receiver will be available for these tests. The performance of these receivers has been characterized by the EIA DAR Subcommittee Working Group B. 2. The main audio channel S/N will be first measured with no subcarriers. 3. The main audio channel S/N will then be measured with the HS data subcarrier turned on. 4. The subcarriers group A and B will be turned on, and the noise contribution to the main audio channel will be measured. 5. With moderate processed audio on the program channel, the HS data channel will be alternately switched on and off, and the program channel audio recorded on digital audio tape. The RBDS and analog subcarriers will also be separately switched on and off, and the results recorded on DAT.	Objective, EO&C, and subjective	M & W	X 10%	X Auto	X 10%	Program channel audio S/N for each receiver: without subcarriers with HS data subcarrier with subcarrier group A with subcarrier group B
	2 HS data to host analog with multipath	1. The receivers used in test D-1 will be used for this test. 2. This test will be conducted four times, each with a different multipath scenario. The multipath scenarios will be those used by the EIA DAR Subcommittee for testing DAR systems. 3. The desired audio signal will be modulated with classical music, rock music, silence, and spoken voice. Moderate audio processing will be used. 4. With each multipath scenario and each subcarrier group, the quality of the program channel will be compared to a program channel operating without subcarriers. 5. A separate EO&C report will be written for each multipath scenario and subcarrier combinations. 6. Audio recordings will be made of the test combinations for the further subjective assessment.	EO&C and subjective	M	X 10%	X Auto	X 10%	Effect of the HS data subcarrier & MP on the main audio: without subcarriers with HS data subcarrier with subcarrier group A with subcarrier group B



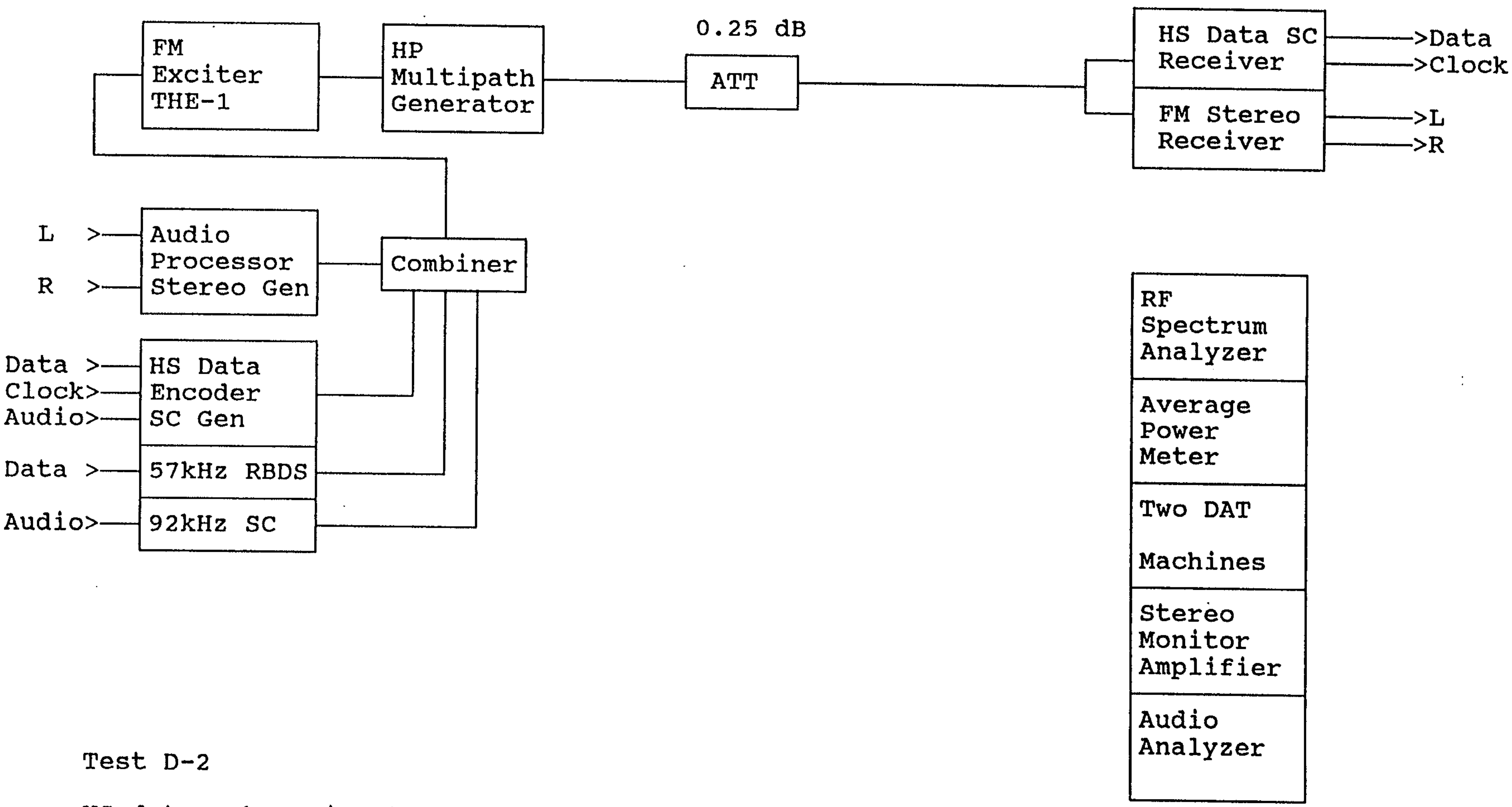


Test D-1

HS data to host analog

January 16, 1996

REV #5



Test D-2

HS data subcarrier to host analog with multipath

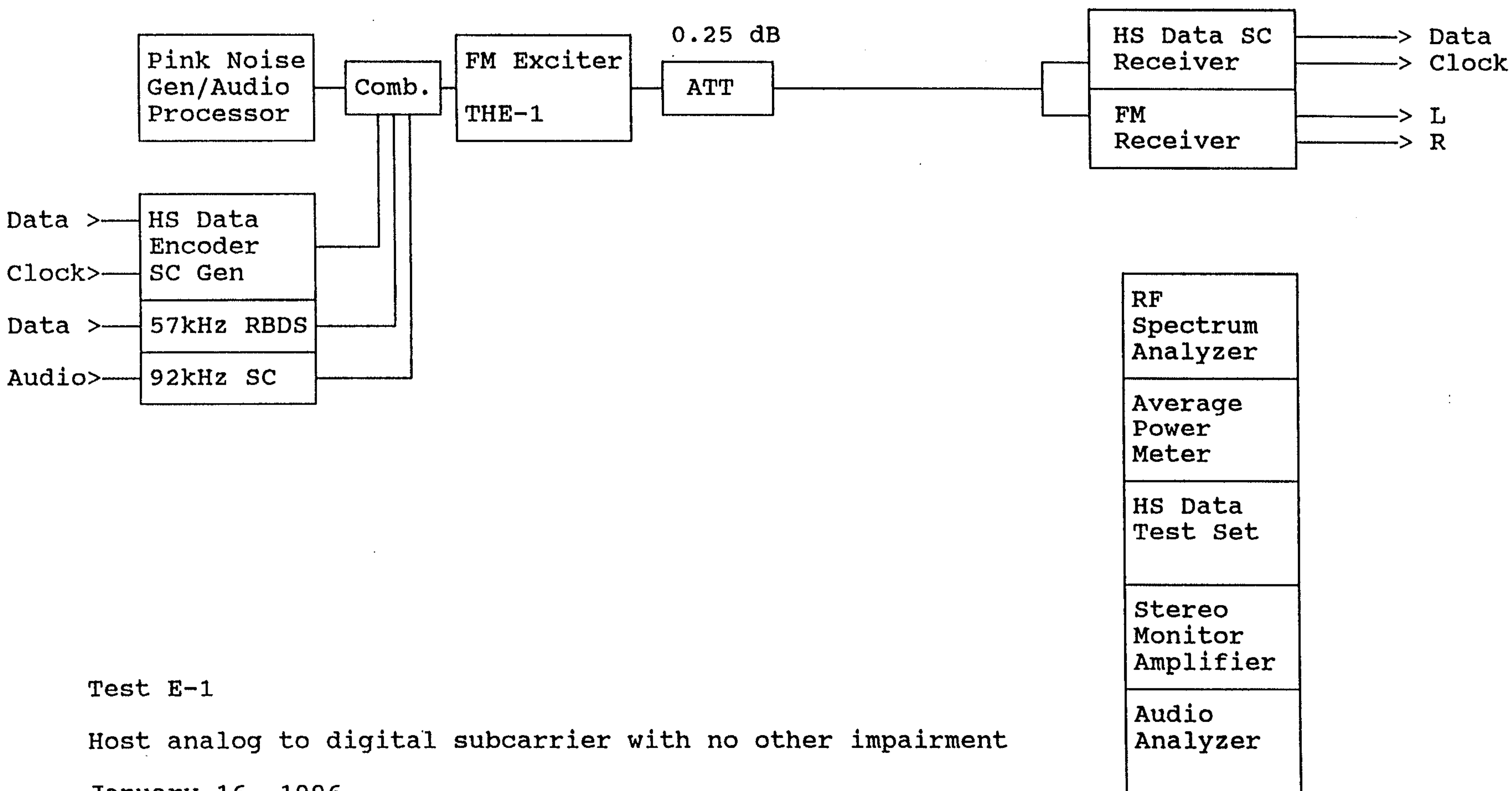
January 16, 1996

REV #5

January 16, 1996 REV #5

HIGH SPEED DATA LABORATORY TESTS

Test Group	Test	TEST PROCEDURE Note: 1. The FM stereo audio modulation will be set for 9O% and the combined subcarriers for 20% for a total of 110% .	Type of Eval	Desired Signal Level dBm	System			Test Results & Data to be Recorded
					Seiko	D/DJ	MITRE	
E Analog program -> high speed digital subcarrier	1 Host analog to digital subcarrier with no other impairments	1. The FM analog modulation will be alternately switched on and off while observing the high speed data channel for impairments. This test will be conducted with clipped pink noise modulating the program channel. Subcarrier group A and B will be used for this test. 2. If impairments are observed, the analog FM and 57 kHz subcarriers will be switched off, and any changes in HS data errors noted. 3. The above procedures (step 1&2) will be repeated with the main FM audio channel heavily modulated with processed stereo rock music.	Objective	M	X 10%	X Auto & 10%	X 10%	HS data errors: No audio modulation Pink noise modulation Compressed audio modulation Possible impairments caused by main channel modulation and subcarrier group A or B.
	2 Host analog to digital subcarrier with multipath	1. This test will be conducted four times, each with a different multipath scenario. The scenarios will be those used by the EIA DAR Subcommittee for testing DAR systems. Clipped pink noise will be used for the program channel audio modulation. 2. The audio modulation will be alternately switched on and off while observing the high speed data channel for errors.	Objective or EO&C	M	X 10%	X Auto & 10%	X 10%	Changes in errors caused by main channel modulation with multipath



Test E-1

Host analog to digital subcarrier with no other impairment

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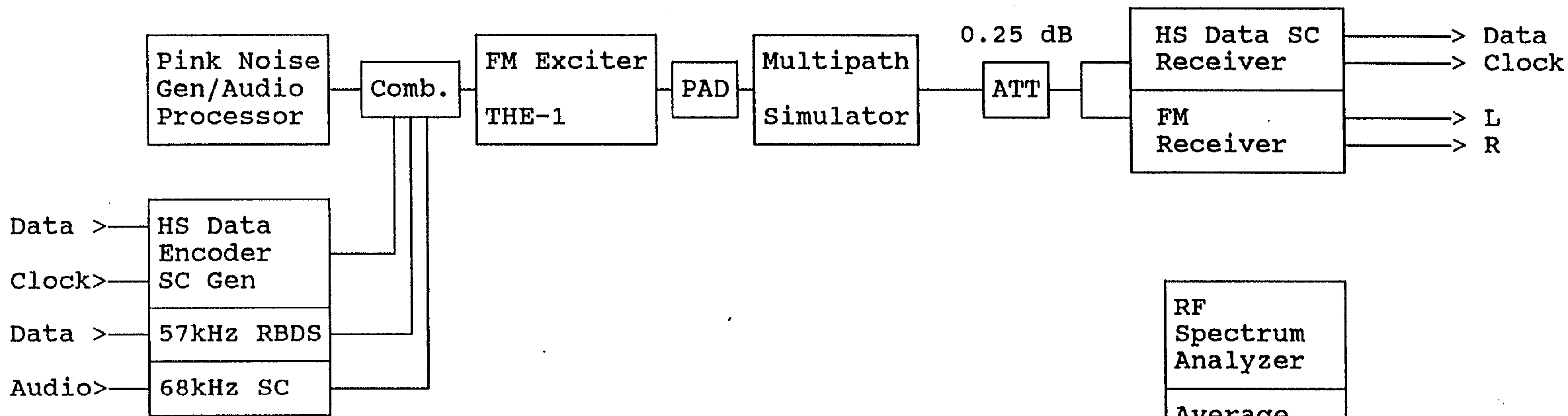
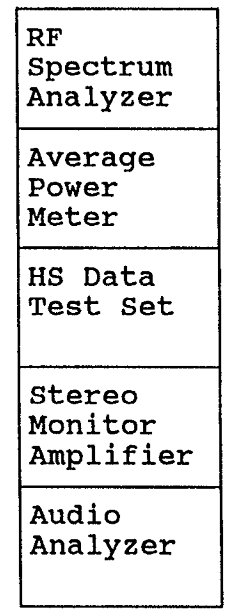




Test E-2

Host analog to digital subcarrier with multipath

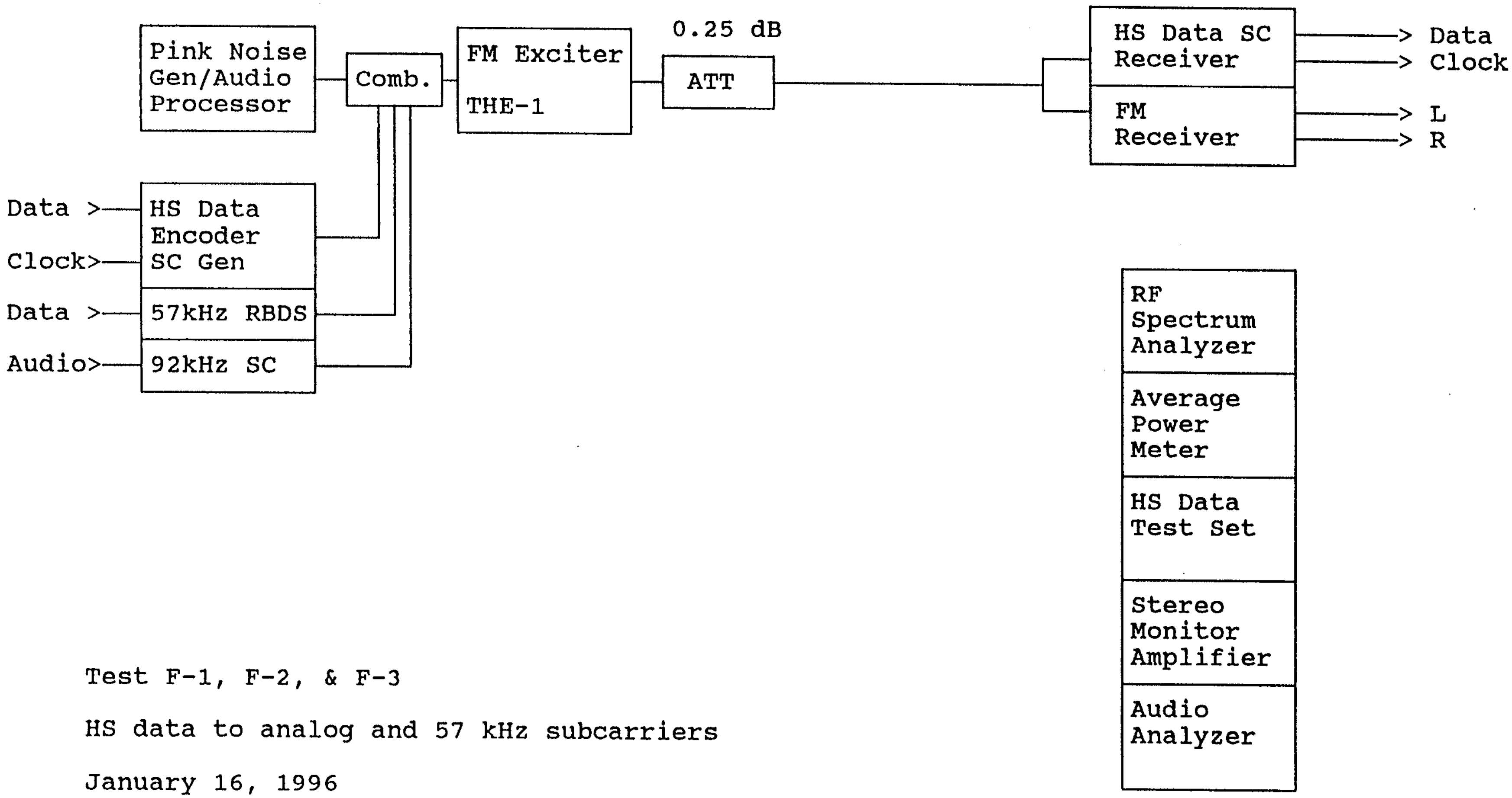
January 16, 1996

REV #5

January 16, 1996 REV #5

HIGH SPEED DATA LABORATORY TESTS

Test Group	Test	TEST PROCEDURE Note: Clipped pink noise will be used for the FM program channel modulation.	Type of Evaluation	Desired Signal Level dBm	System			Test Results & Data to be Recorded
					Seiko	D/DJ	MITRE	
F HS Data subcarrier -> RBDS and analog subcarriers	1 HS data subcarrier to analog SC	1. Subcarrier group A will be used for this test. 2. With all the subcarriers in group A operating, the audio S/N for the 92 kHz analog subcarrier channel will be measured. 3. The HS data and the RBDS subcarriers will be alternately turned on and off. Any change in audio S/N on the analog subcarriers will be noted. 4. Recordings will be made of the 92 kHz analog signal tests for subjective assessment.	Objective & subjective	M & W	X 10%	NA	X 10%	Changes in analog subcarrier audio S/N with the presence of the HS data and RBDS Subjective changes in the analog subcarrier with the presence of HS data and RBDS
	2 HS data to RBDS	1. Subcarrier group A will be used for this test. 2. With all the subcarriers is group A operating, noise will be added to the signal until errors are observed. 3. The HS data and the analog subcarriers will be alternately turned on and off. Any change in RBDS errors will be noted.	Objective	M & W	X 10%	X Auto	X 10%	Changes in RBDS errors with HS data or the analog subcarrier
	3 HS data to 57 kHz paging	1. Subcarrier group B will be used for this test. 2. With all the subcarriers is group B operating, noise will be added to the signal until errors are observed.	Objective	M & W	X 10%	X Auto	X 10%	Changes in 57 kHz paging errors with the HS data



Test F-1, F-2, & F-3

HS data to analog and 57 kHz subcarriers

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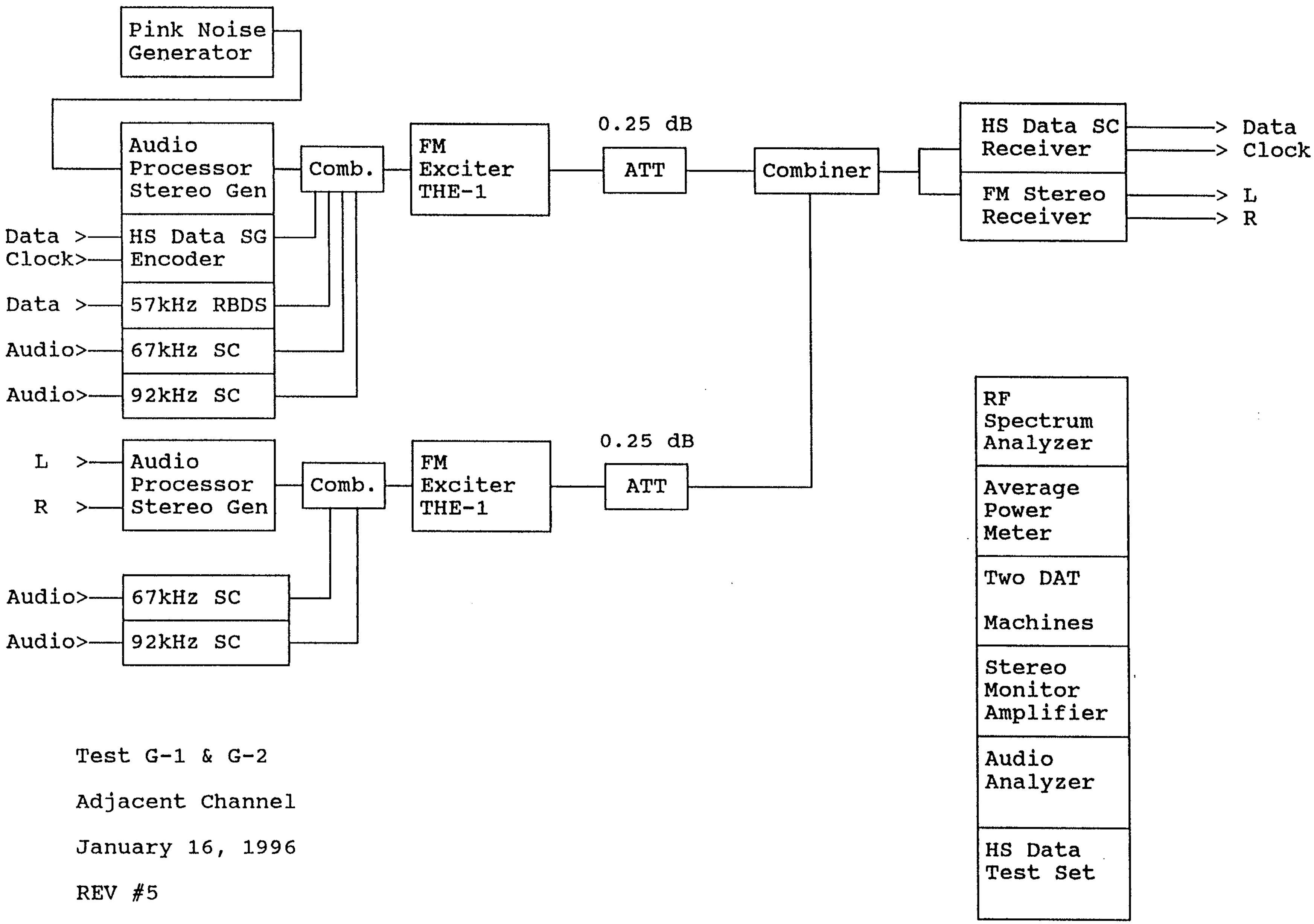
January 16, 1996 REV #5 HIGH SPEED DATA LABORATORY TESTS

Test Group	Test & Impairment	TEST PROCEDURE Note: 1. The undesired adjacent channel signal will be modulated by clipped pink noise. 2. The desired transmitter will have a stereo generator, 67 kHz subcarrier generator set for 10% injection, and 92 kHz subcarrier generator set for 10% injection. 3. The Delco Model 16192463 and Pioneer Model SX-201 receivers used for the DAR compatibility tests will be used for the stereo 45 dB S/N measurement.	Type of Eval	Sig Lev dBm	System			Test Results Data to be Recorded
					Seiko	D/DJ	MITRE	
G Adjacent channel interference	1 First adjacent	1. With the first adjacent channel transmitter modulated with clipped pink noise, 67 kHz analog subcarrier, and 92 kHz subcarrier, the first adjacent signal will be increased (0.5 dB steps) until an audio S/N of 45 dB is observed on the desired stereo channel. At this D/U the subcarrier S/N will also be measured. 2. Subcarrier groups A and B will be substituted for the two analog subcarriers on the undesired first adjacent channel transmitter. Changes in the desired channel stereo audio S/N, or subcarrier S/N will be noted. 3. With the HS data channel the desired path, the undesired first adjacent signal will be increased until the onset of message errors on the HS data channel. The D/U will be recorded at this point.	Objective & Lab EO&C	M	X 10%	X Auto	X 10%	D/U at 45 dB S/N Changes in program audio or analog subcarrier S/N caused by the addition of adjacent channel HS subcarriers D/U with message errors
	2 Second adjacent	1. With the second adjacent channel transmitter modulated with clipped pink noise, 67 kHz analog subcarrier, and 92 kHz subcarrier, the second adjacent signal will be increased (0.5 dB steps) until an audio S/N of 45 dB is observed on the desired stereo channel. At this D/U the subcarrier S/N will also be measured. 2. Subcarrier groups A and B will be substituted for the two analog subcarriers on the undesired second adjacent channel transmitter. Changes in the desired channel stereo audio S/N, or subcarrier S/N will be noted. 3. With the HS data channel the desired path, the undesired second adjacent signal will be increased until the onset of message errors on the HS data channel. The D/U will be recorded at this point.	Objective & Lab EO&C	M	X 10%	X Auto	X 10%	D/U at 45 dB S/N Changes in program audio or analog subcarrier S/N caused by the addition of adjacent channel HS subcarriers D/U with message errors



Test G-1 & G-2

Adjacent Channel

January 16, 1996

REV #5

January 16, 1996 REV #5

HIGH SPEED DATA LABORATORY TESTS

Test Group	Test	TEST PROCEDURE	Type of Evaluation	Desired Signal Level dBm	System: Seiko	System: D/DJ	System: MITRE	Test Results & Data to be Recorded
H System specific	1 Phase, digital to 19 kHz pilot	The following tests will be conducted with the HS data system not locked to the stereo 19 kHz pilot. B-1 Noise D-1 Interference to host analog	Objective & EO&C	M	X 10%			Changes caused by the loss of lock to noise performance and compatibility
	2 Nonstandard injection levels	The following tests will be conducted with 17% injection level and 3% RBDS. With some of the systems this injection level will exceed the restrictions of Part 73.319 of the FCC Rules. B-1 Noise B-2 Co-channel B-6 Weak signal failure D-1 Interference to host analog G Adjacent channel	Objective & EO&C	M	X 17%		X 17%	Possible performance improvements or changes in interference or compatibility
	3 Variable injection	The following tests will be conducted on the system (Digital DJ) that uses the stereo level to control the HS data injection level. Each of the tests listed below will be conducted with low and high audio signal levels. The low audio (low injection) program material will be classical music, and for the high level program material, (high injection) processed rock music will be used. B-1 Noise B-2 Co-channel B-3 Multipath and noise B-4 Impulse Noise B-6 Weak signal failure C Reacquisition D-1 Interference to host analog	Objective & EO&C	M		X Auto		Changes from previous tests

I. SUBCARRIER GROUPS January 16, 1996 REV #5		
Group A RBDS		
System #1 Seiko	System #2 Digital DJ	System #3 MITRE
RBDS 57.0 kHz 3%	RBDS 57.0 kHz 3%	RBDS 57.0 kHz 3%
Data 66.5 kHz 10%	Data 76.0 kHz 10%	Data 72.2 kHz 10%
FM 92.0 kHz 7%	FM 92.0 kHz 7%	FM 92.0 kHz 7%
Group B 57 kHz Paging		
System #1 Seiko	System #2 Digital DJ	System #3 MITRE
Paging 57.0 kHz 10%	Paging 57.0 kHz 10%	Paging 57.0 kHz 10%
Data 66.5 kHz 10%	Data 76.0 kHz 10%	Data 72.2 kHz 10%

General

Test Signal Levels

W	Weak	-75 dBm
M	Moderate	-65 dBm
S	Strong	-50 dBm

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HSSC LABORATORY TEST PROCEDURES REVISION #5 January 16, 1996

FURTHER CHANGES

Test

B.2.4 Denon TU-380 RD Receiver replaced Pioneer SX-201.

B.2 S/N measured at OME.

B.5 Airplane flutter should read:

Air Multipath Scenarios (Each of these tests will include a path without delay and attenuation.)

Scenario	Speed KPH	Delay usec.	Attenuation dB
#1	400	27.5	8.0
#2	200	13.7	6.0
#3	100	6.8	4.0

D.1 Subjective (EO&C) only at moderate signal level (-65 dBm).

E.1 CBN added.

D.1/H.1 Receivers used for tests: Ford, Pioneer, and Denon.

H-1 Digital DJ was added.

H.2/D.1 & G All five receivers were used for tests.

DDJ used 92% injection.

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Appendix C

MULTIPATH

Summary of Channel Multipath Characterization Report

Multipath Profiles

SUMMARY OF:
THE FINAL REPORT OF THE CHANNEL CHARACTERIZATION TASK GROUP; THE DERIVATION AND RATIONAL FOR MULTIPATH SIMULATION PARAMETERS FOR THE EIA-DAR LABORATORY TESTING

NOTE: This is a condensed version of the above titled report. It follows different section headings but with the same appendix reference as the full report. Only Appendix J is attached to this summary. The full report is available as a separate document.

MULTIPATH CHARACTERIZATION AND CHANNEL SIMULATION BACKGROUND

At the January 22, 1992 meeting of the EIA-DAR Committee, the "Digital Audio Radio Technical Performance and Service Objectives" were discussed and adopted. The requirement for multipath performance testing was set.

The candidate laboratory channel simulator could be directly programmed using time domain values; the relative attenuations, doppler frequencies (or relative phases) and time delays. Searching the literature for channel characteristics in the time domain for direct application to the simulator revealed very little information. A source of direct information on time domain parameters, the characterization test, was required.

In early 1993 the Delco channel test plan system was disclosed. The Delco system description evolves over a number of months as detailed in the series of memoranda and reports in Appendix A. The Channel Characterization data would be collected and then processed to extract the time domain parameters that would then be applied to the laboratory channel simulation. The processing plans are described in Appendix B.

The Hewlett Packard simulator, model No. 11759C was chosen for the laboratory testing. It can be programmed in the Direct mode with the individual channel parameters to simulate a multipath condition. Use of this technique to achieve a dynamic simulation at fixed steps along a path (sequential snapshots) was discussed and the direct control of the simulator based on the actual measured channel characteristics was pursued.

CHANNEL TEST NEEDS; EQUIPMENT, VENUE, ETC.

The channel test program is summarized in Appendix C. Only one city could reasonably be used for channel characteristic testing because of cost and time limits, therefore the test venue should contain many areas that represent as many "difficult" environments as possible.

By May 1993, plans were underway for conducting a channel characterization test in Charlotte, N.C. Those early tests revealed system and operational limitations in conducting such tests, detailed in the July Subcommittee meeting and in a report in Appendix D. Plans were made to revise the equipment and test at another venue.

Bonneville Broadcasting, a long time participant in the EIA-DAR test program, offered its transmitter site in Salt Lake City on Farnsworth Mountain. The site was investigated and the equipment was delivered and set up at the site with testing beginning in late September and continuing to early October of 1993.

CHANNEL TEST DATA COLLECTED; FINDINGS; ENVIRONMENTS, SPEED, DATA, VOLUME COLLECTED, PROCESSING, ETC.

In early October 1993 the actual Salt Lake City channel characterization test data was collected over approximately one week. Appendix E is a description of the measurements and the data collected. As data was collected along each path, the environment around the area was described. Four major "Environments" quickly emerged: Urban, Suburban, Rural and Terrain Obstructed. Appendix F is a March 7, 1994 memorandum discussing the data collected, its analysis and the certification of the test method.

The data extraction strategy was studied and modified from its initial frequency domain dependent version to one which selected reflections based on time domain values in order of the strongest reflections with their accompanying delay and relative phases.

By April 1994 the VHF Channel Characterization data had been analyzed, providing the overall range of reflection magnitudes verses time delay for the four significant environments in Salt Lake City as shown in Appendix G. Further analysis then extracted the individual channel reflection vs. time information on a file by file basis as explained in the memorandum report dated April 17, 1994 in Appendix H.

The measured VHF reflection time vs. magnitude information was studied to arrive at the range of data appropriate for challenging multipath Environments. Information from other sources was also compared to the measured VHF channel data so that the simulation could include the 1.4 GHz UHF channel DAR system as well. The Canadian CRC investigation relating to L-Band characterization lead to the exchange of several documents, a selection of which are included in Appendix I.

The listings of time delays and magnitudes with appropriate doppler velocities and Rayleigh file parameters for each of the three environments (four tests), as adopted by the EIA-DAR test laboratory and is indicated in the **attached Appendix J.**

SIMULATOR LIMITATIONS; ATTENUATOR RATE OF CHANGE & "ARTIFACTS"

The direct control method, described in the Simulator operating manual, was tested in early 1994 and limitations quickly appeared. The simulator attenuator control circuits have a significantly slow time constant which will allow only slow changes in the simulation channels, far slower than were measured. This was implemented and found to function properly.

Tests were run on the simulator using sample direct control data and observing the simulator effect in the frequency domain. Upon close observation it could be seen that artifacts were being generated. Appendix K is a memorandum and report of July 12, 1994 describing the findings. The report and attachments indicate that the frequency domain artifacts are generated by the step changes in the simulator channels.

In an attempt to resolve the Frequency Domain artifacts the data was "smoothed", as indicated in Appendix K, by limiting the rate of change of some of the parameters and approximating missing data between data files. The artifacts decreased but still remained. It was decided, not knowing the impact of the artifacts on the systems under test, that the direct control of the simulator was not possible.

IMPLEMENTING SIMULATION MODE; MAINTAINING VARIABILITY

The Simulation or "sim" mode of operation allows for two variations. The first is the "Doppler" mode, a fixed parameter mode with a fixed cyclical simulation, and the second applies a Rayleigh variation characteristic on the "Doppler" control parameters. This Rayleigh characteristic will restore some of the channel variability lost in going from the Direct to the Sim mode of channel simulation.

The Rayleigh fading characteristic is imparted on the simulator action by a control file that is generated by the HP program IQMAKE. The Rayleigh fading values are oriented about the basic channel parameters, those which were measured in Salt Lake City, not any other parameters associated with any standard Cellular or Land Mobile system. The resulting simulation has the overall characteristic of the measured control values but with the Rayleigh variation characteristics specific for the frequency and velocity of interest for the test, impressed on each of the control channels. This effect on each of the individual channels then generates a combined effect on the overall variation of the combined R.F. channel output.

DISCUSSION OF APPROPRIATENESS OF DOPPLER VS. RAYLEIGH CHARACTERISTICS

Much discussion centered about the proper use of the Doppler or Rayleigh simulation modes. Objections were raised citing the HP instruction manual with various references to the Rayleigh model defined for mobile cellular radio. Concerns were expressed relative to whether or not a Rayleigh faded channel was appropriate for the mobile environment. The use of particular sections of the Salt Lake City measured channel characteristics and then only that one venue was questioned.

Many individual experts in mobile communications reviewed the questions and concerns and have supported this simulation concept as appropriate for the laboratory testing. Appendix L contains the observations, comments and responses regarding the Rayleigh and Doppler simulations.

As a result of the questions regarding the use of Rayleigh simulation a decision was made to incorporate both Doppler and Rayleigh simulations in an expanded laboratory test.

CHANNEL TEST AND SIMULATION; LESSONS LEARNED

This channel characterization project and the channel simulation in the laboratory has again confirmed the immense variability that exists in an R.F. propagation path which can not be carried to and totally duplicated in laboratory simulation. For laboratory purposes, however, capturing all that variability would be counter-productive. For example, in an average environment, much of the time the R.F. channel may be quite benign with few if any interesting and stressful multipath conditions. The laboratory testing is meant to be a critical test of the systems. It is the relatively rare but stressful conditions that need to be reliably and rapidly repeated in the laboratory. This goal guided the extraction of "significant" multipath segments from the four environments to concentrate on those areas that generally would yield harsh tests.

Ideally, the original laboratory test would have used the actual channel parameters measured in the field, complete with their variability along the measurement path, to control the channel simulator as if driving along that same path. Hardware limitations prohibited this. The same general channel characteristics for the difficult path segments were used but with the parameter variability now supplied by the Rayleigh fading profile applied to those characteristics.

The channel simulation testing has been applied uniformly to all of the proponent systems, even to the extent of testing in both Rayleigh and Doppler modes. The systems individual relative performances will be determined by the systems themselves, not by the design of the testing. If the testing were designed so that all systems were to fail the test, or where all were to easily pass the simulation test, the results would be useless. The only valid test is one that spans the range of performance from perfect to failed for all systems under test and hence determines a threshold of actual performance. The laboratory simulation provides such a test.

HP 11759C MULTIPATH PROFILES

DAR90100.PRO

```
#------------------------------------------ Profile #1
0:TITLE      "URBAN SLOW RAYLEIGH
0:IQDATA_DIR  "C:\chan_new"
0:CORR_MODE  3X3
0:DELAY_RES  LOW
0:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
0:GROUP_LOSS  0.000000e+00
0:SPECTRUM    RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  OFF  OFF  OFF
0:IQFILE     "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "RAY2.IQ" "" "" ""
0:DELAY_US    0.0000  0.2000  0.5000  0.9000  1.2000  1.4000  2.0000  2.4000  3.0000  0.0000  1.0000  2.0000
0:DOPPLER_HZ 0.1744 0.1744 0.1744 0.1744 0.1744 0.1744 0.1744 0.1744 0.1744 0.0000 2.0000 1.5000
0:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:ATTEN_DB   2.0000 0.0000 3.0000 4.0000 2.0000 0.0000 3.0000 5.0000 10.0000 0.0000 2.0000 2.0000
0:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------------ Profile #2
1:TITLE      "URBAN FAST RAYLEIGH
1:IQDATA_DIR  "C:\chan_new"
1:CORR_MODE  3X3
1:DELAY_RES  LOW
1:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
1:GROUP_LOSS  0.000000e+00
1:SPECTRUM    RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  OFF  OFF  OFF
1:IQFILE     "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "" "" ""
1:DELAY_US    0.0000  0.2000  0.5000  0.9000  1.2000  1.4000  2.0000  2.4000  3.0000  0.0000  1.0000  2.0000
1:DOPPLER_HZ 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 0.0000 2.0000 1.5000
1:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:ATTEN_DB   2.0000 0.0000 3.0000 4.0000 2.0000 0.0000 3.0000 5.0000 10.0000 0.0000 2.0000 2.0000
1:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------------ Profile #3
2:TITLE      "RURAL FAST RAYLEIGH "
2:IQDATA_DIR  "C:\chan_new"
2:CORR_MODE  3X3
2:DELAY_RES  LOW
2:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
2:GROUP_LOSS  0.000000e+00
2:SPECTRUM    RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  OFF  OFF  OFF
2:IQFILE     "RAY131.IQ" "RAY131.IQ" "RAY131.IQ" "RAY131.IQ" "RAY131.IQ" "RAY131.IQ" "RAY131.IQ" "RAY131.IQ"
"RAY131.IQ" "" "" ""
2:DELAY_US    0.0000  0.3000  0.5000  0.9000  1.2000  1.9000  2.1000  2.5000  3.0000  0.0000  1.0000  2.0000
2:DOPPLER_HZ 13.0785 13.0785 13.0785 13.0785 13.0785 13.0785 13.0785 13.0785 13.0785 0.0000 2.0000 1.5000
2:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:ATTEN_DB   4.0000 8.0000 0.0000 5.0000 16.0000 18.0000 14.0000 20.0000 25.0000 0.0000 2.0000 2.0000
2:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------------ Profile #4
3:TITLE      "TERRAIN OBSTRUCTED FAST RAYLEIGH
3:IQDATA_DIR  "C:\chan_new"
3:CORR_MODE  3X3
3:DELAY_RES  LOW
3:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
3:GROUP_LOSS  0.000000e+00
3:SPECTRUM    RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  RAY  OFF  OFF  OFF
3:IQFILE     "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "RAY52.IQ" "" "" ""
3:DELAY_US    0.0000  1.0000  2.5000  3.5000  5.0000  8.0000  12.0000  14.0000  16.0000  0.0000  1.0000  2.0000
3:DOPPLER_HZ 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 5.2314 0.0000 2.0000 1.5000
3:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
3:ATTEN_DB   10.0000 4.0000 2.0000 3.0000 4.0000 5.0000 2.0000 8.0000 5.0000 0.0000 2.0000 2.0000
3:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
```

HP 11759C MULTIPATH PROFILES

DAR90240.DAT

```
#------------------------------------ Profile #1
0:TITLE     "AIRPLANE FLUTTER SCENARIO #1 VHF
0:IQDATA_DIR  "C:\CHAN_NEW"
0:CORR_MODE  3X3
0:DELAY_RES  LOW
0:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
0:GROUP_LOSS  0.000000e+00
0:SPECTRUM   PHA DOP OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
0:IQFILE     "" "" "" "" "" "" "" "" "" "" "" ""
0:DELAY_US    0.0000 27.5191 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:DOPPLER_HZ 333.5646 34.8760 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:ATTEN_DB  0.0000 8.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------ Profile #2
1:TITLE     "AIRPLANE FLUTTER SCENARIO #2 VHF
1:IQDATA_DIR  "C:\CHAN_NEW"
1:CORR_MODE  3X3
1:DELAY_RES  LOW
1:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
1:GROUP_LOSS  0.000000e+00
1:SPECTRUM   PHA DOP OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
1:IQFILE     "" "" "" "" "" "" "" "" "" "" "" ""
1:DELAY_US    0.0000 13.6761 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:DOPPLER_HZ 333.5646 17.4380 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:ATTEN_DB  0.0000 6.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
1:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

#------------------------------------ Profile #3
2:TITLE     "AIRPLANE FLUTTER SCENARIO #3 VHF
2:IQDATA_DIR  "C:\CHAN_NEW"
2:CORR_MODE  3X3
2:DELAY_RES  LOW
2:CHAN_ATTEN  0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
2:GROUP_LOSS  0.000000e+00
2:SPECTRUM   PHA DOP OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
2:IQFILE     "" "" "" "" "" "" "" "" "" "" "" ""
2:DELAY_US    0.0000 6.8381 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:DOPPLER_HZ 333.5646 8.7190 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:PHASE_DEG  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:ATTEN_DB  0.0000 4.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
2:CORRELATION 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
```

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Appendix D

COMPATIBILITY RECEIVER CHARACTERIZATION REPORTS

Receiver #1 Delco ← NEW to NSSC

Receiver #2 Denon

Receiver #3 Panasonic

Receiver #4 Pioneer

From DAB tests.

Receiver #5 Ford ← NEW to NSSC

Delco

#1

Engineers: RMc/DL
Date: 8/16/96
Print Date: 1/6/97

PROJECT: RECEIVER CHARACTERIZATION

Radio Mfg.: Delco Electronics RX # 7
Model No.: 16192463
Serial No.: 1000703

FM TESTS (TEST FREQ. 94.1MHz)

TEST SET-UP
Ant. Net: Delco/JFW AM/FM composite Dummy Antenna Insertion loss = -6dB
Audio Ref: 2.0Vrms Load Imp = 4 ohms
Rec. set up: Graphic EQ - Flat, Loudness - Off, Fader & Bal.- Centered

Test bed: Test Bed, W/Orban Stereo Gen & Harris Exciter as Signal Source
Meas.: Audio measurements made with Audio Precision as rms unweighted

S/N RATIO - 1KHZ, 100% MOD
MAX 62 dB (mono)

THD - 1KHZ, 100% MOD (-50dBm)

MONO	0.51 %
STEREO	0.67 %

LIMITING THRESHOLD (Audio -1dB)
-96 dBm

HIGH CUT THRESHOLD
Audio: 10KHZ, L+R, 100% Mod, Pilot off
-3dB = -86 dBm

SEPARATION @ -62dBm

Freq.	L->R	R->L

1KHZ 31dB (W/O Pre-Emph)
10KHZ 21.6dB (W/O Pre-Emph)

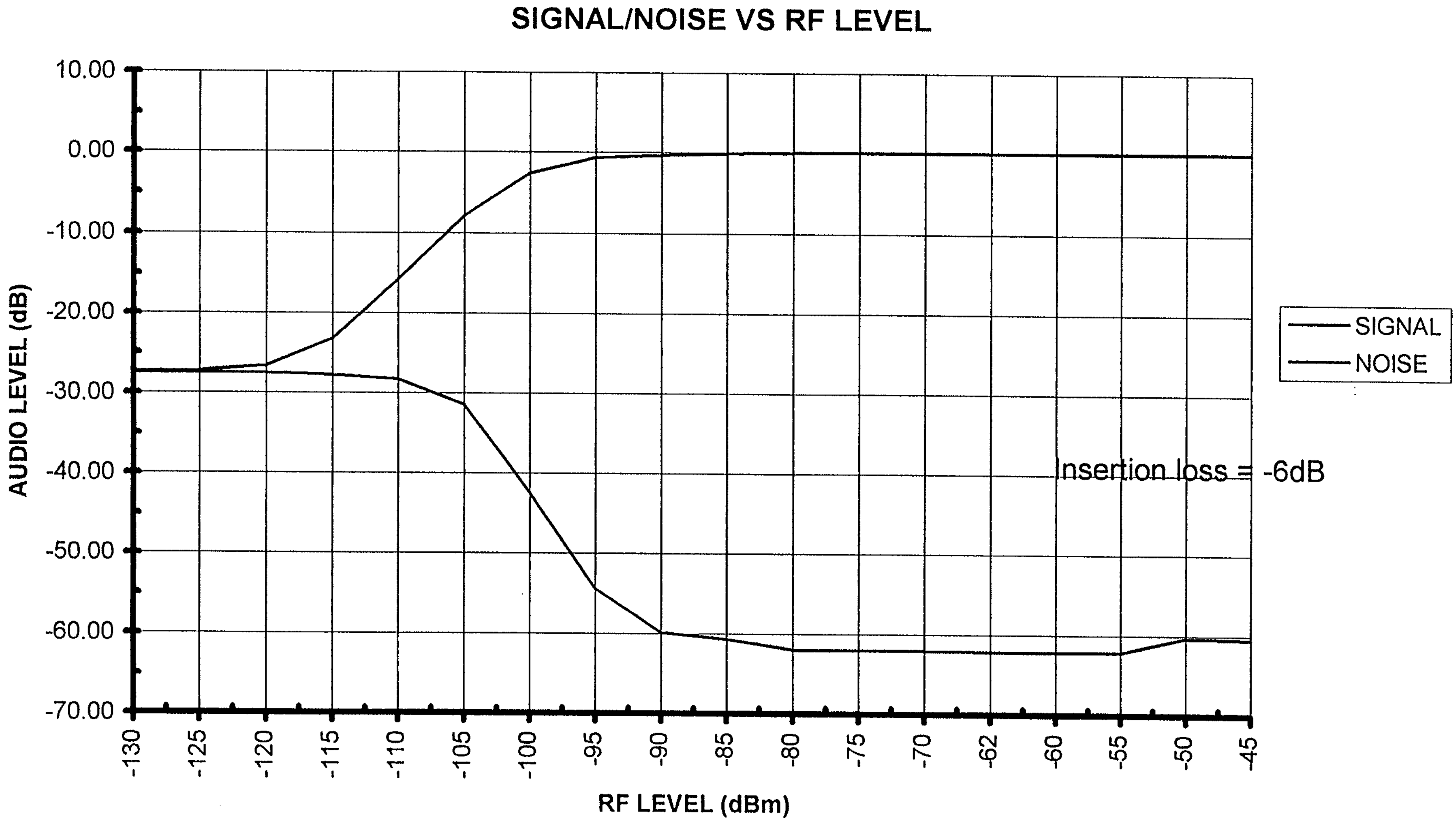
SIGNAL, NOISE & SEPARATION VS RF LEVEL

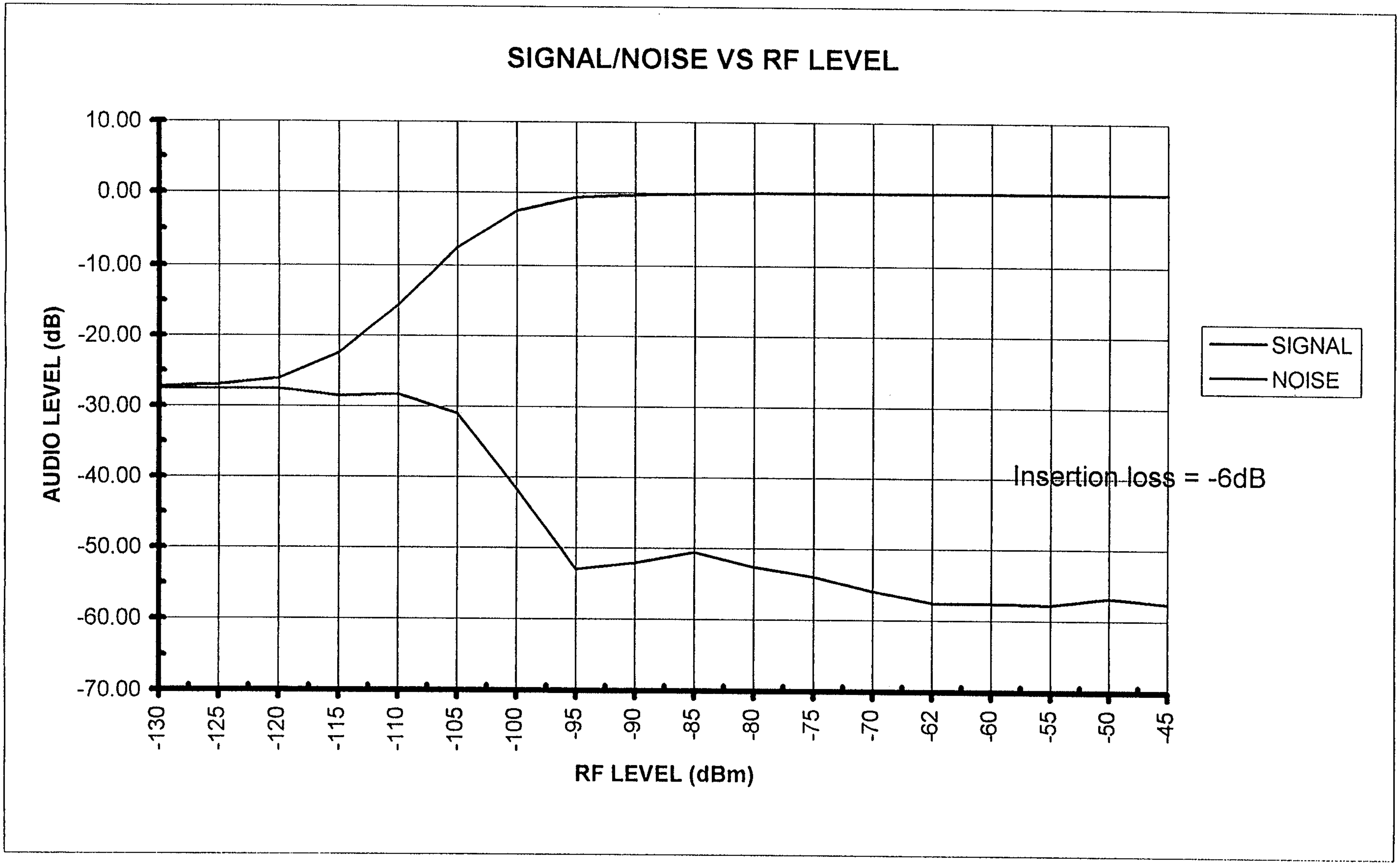
* Left channel used as the measurement channel for Signal and Noise data
* Left channel driven (L only) for separation data
* Audio test frequency = 1KHZ
* RF levels represent power into the dummy antenna
* Filt. Noise figures represent noise measurements made with a 15khz low pass filter to reject the pilot

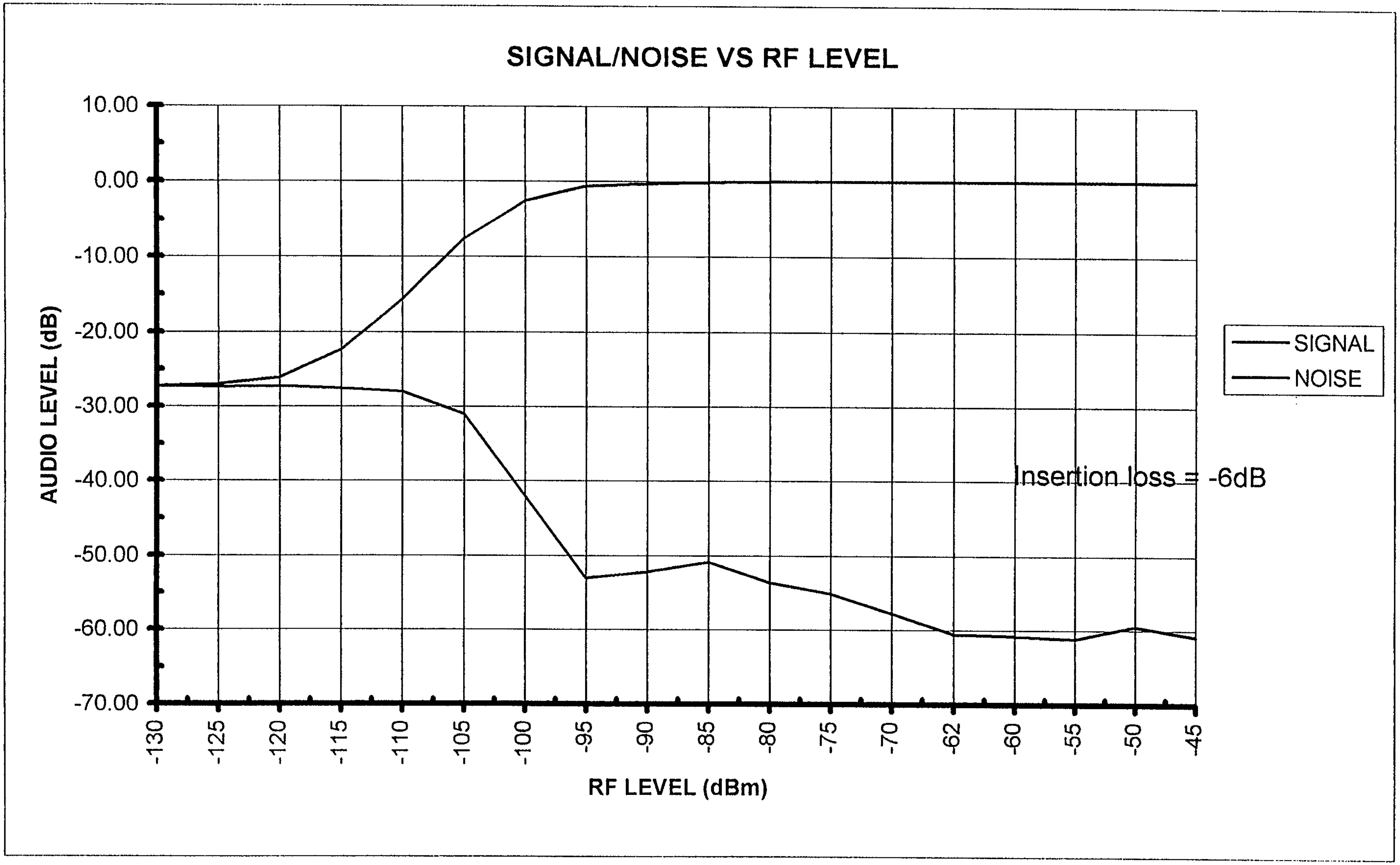
CURVE DATA

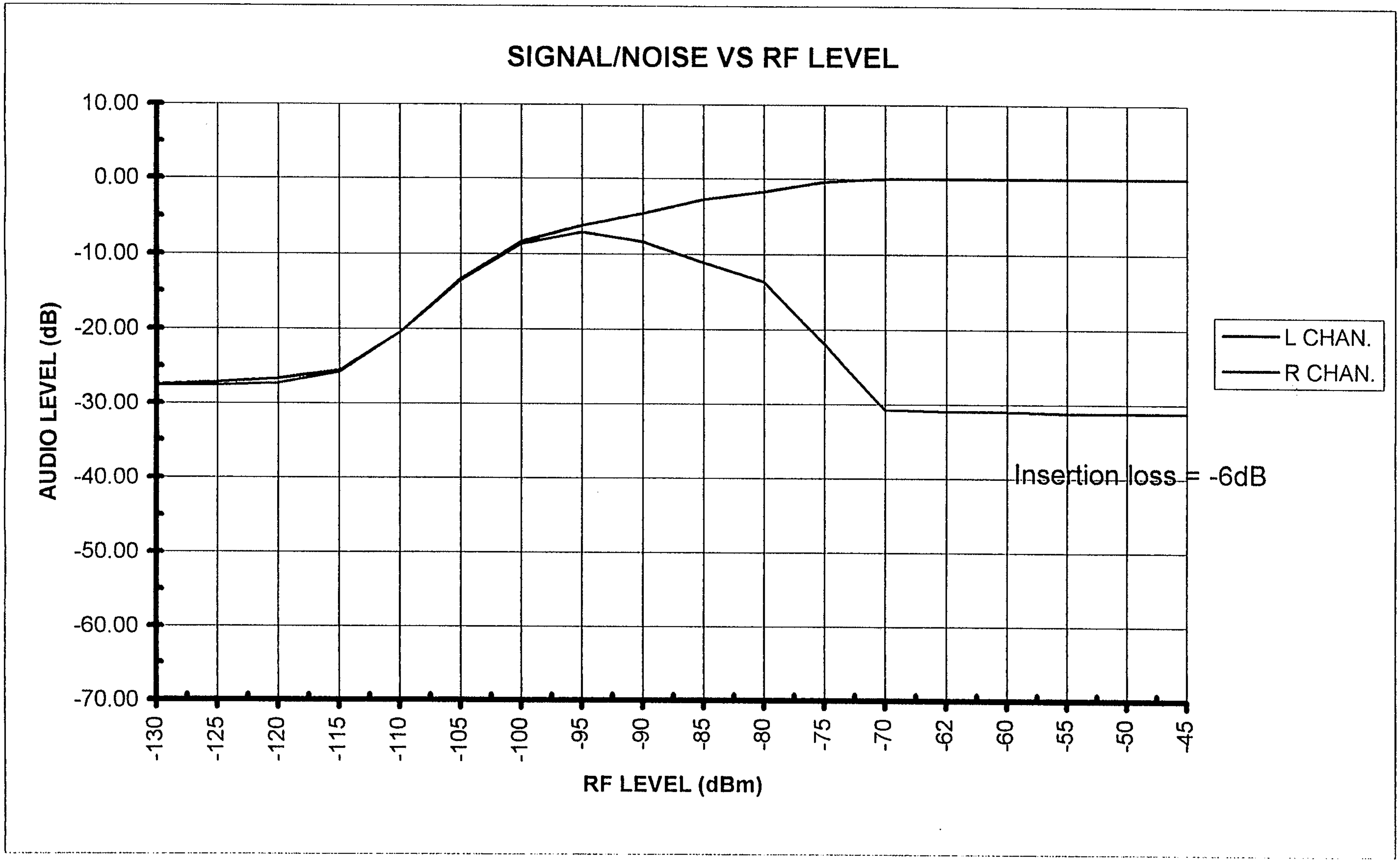
SIGNAL, NOISE & SEPARATION VS RF LEVEL

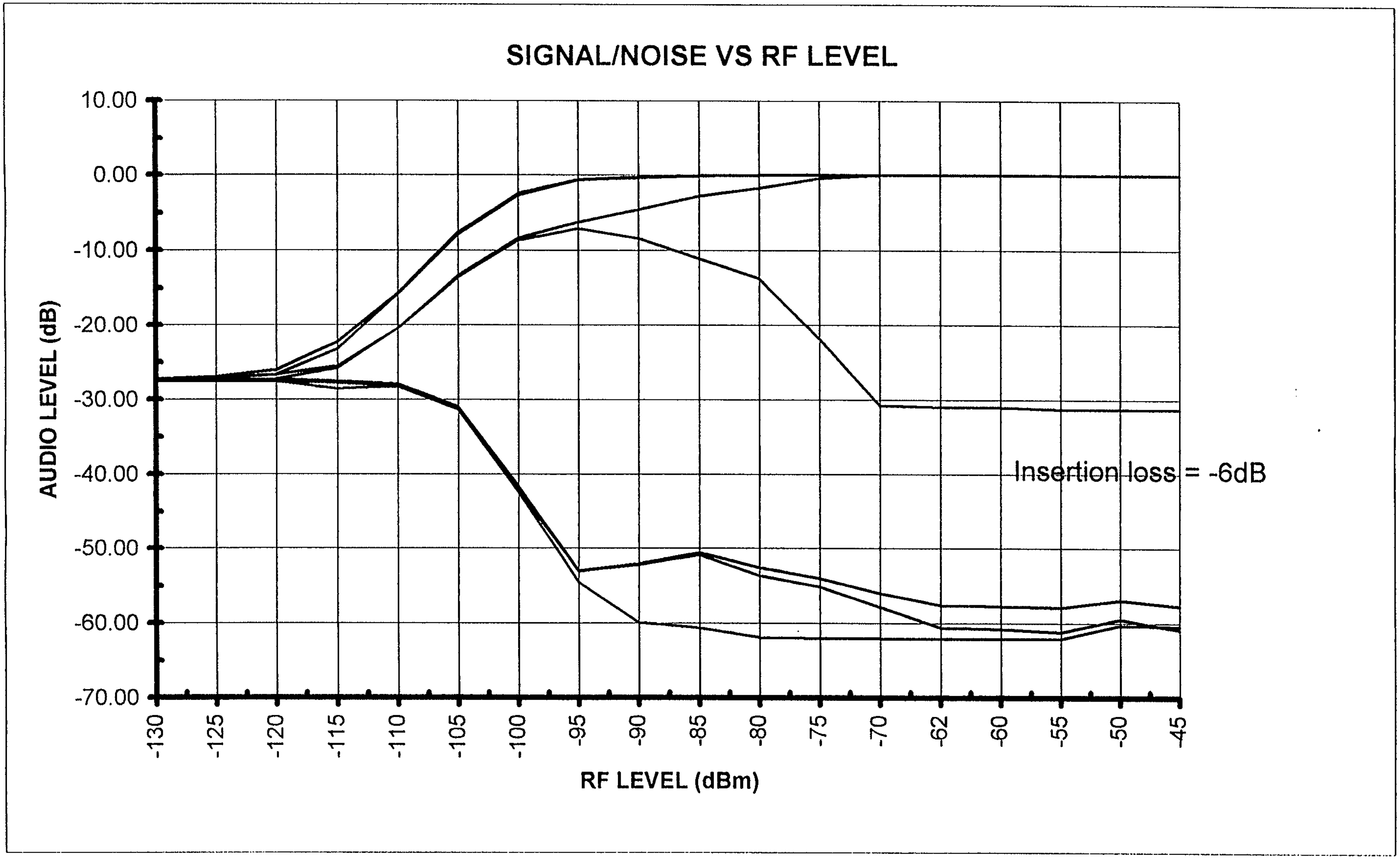
	mono (L)		Stereo (L)				Separation L->R	
RF Level dBm	Signal dB	Noise dB	Signal dB	Filt. Noise dB	Noise dB	RF Level dBm	Left dB	Right dB
-130	-27.40	-27.60	-27.30	-27.30	-27.60	-130	-27.50	-27.60
-125	-27.30	-27.60	-27.00	-27.40	-27.60	-125	-27.20	-27.60
-120	-26.70	-27.60	-26.10	-27.30	-27.60	-120	-26.70	-27.30
-115	-23.30	-27.80	-22.40	-27.60	-28.60	-115	-25.60	-25.80
-110	-15.80	-28.30	-15.70	-28.00	-28.30	-110	-20.50	-20.50
-105	-7.90	-31.40	-7.60	-31.00	-31.00	-105	-13.35	-13.60
-100	-2.70	-42.40	-2.50	-42.00	-41.60	-100	-8.39	-8.72
-95	-0.69	-54.50	-0.60	-53.10	-53.00	-95	-6.24	-7.10
-90	-0.38	-59.90	-0.30	-52.20	-52.10	-90	-4.60	-8.38
-85	-0.15	-60.70	-0.10	-50.90	-50.60	-85	-2.77	-11.10
-80	0.00	-61.90	0.00	-53.60	-52.60	-80	-1.74	-13.70
-75	0.00	-62.00	0.00	-55.10	-54.00	-75	-0.44	-21.90
-70	0.00	-62.00	0.00	-57.80	-56.00	-70	0.00	-30.80
-62	0.00	-62.10	0.00	-60.60	-57.60	-62	0.00	-31.00
-60	0.00	-62.10	0.00	-60.80	-57.70	-60	0.00	-31.00
-55	0.00	-62.10	0.00	-61.20	-57.90	-55	0.00	-31.30
-50	0.00	-60.30	0.00	-59.50	-56.90	-50	0.00	-31.30
-45	0.00	-60.50	0.00	-60.90	-57.70	-45	0.00	-31.30


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
SIGNAL
NOISE
Insertion loss = -6dB


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
SIGNAL
NOISE
Insertion loss = -6dB


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
SIGNAL
NOISE
Insertion loss = -6dB


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
L CHAN.
R CHAN.
Insertion loss = -6dB


SIGNAL/NOISE VS RF LEVEL
AUDIO LEVEL (dB)
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
Insertion loss = -6dB

Engineers: RMc/DL
Date: 8/16/96
Print Date: 1/6/97

PROJECT: RECEIVER CHARACTERIZATION

Mfg.: Delco
Model No.: 16192463
Serial No.: 1000703

AM TESTS (TEST FREQ. 1660KHz) (No data taken due to generator failure)

TEST SET-UP
Ant. Network: JFW composite antenna dummy
Audio Ref.: 2.0Vrms (0dB)
Rec. set up: Loudness off, graphic EQ flat, balance & fade centered

Test Bed: Test Bed: Boonton RF generator used as signal source
Meas.: Audio measurements made with Audio Precision as rms unweighted

THD - 400HZ, 80% MOD (-47dBm)

MONO	%
STEREO	%

Selectivity (RF level = -105dBm)

Narrow	Wide	Narrow	Wide
+ 10KHz =	+ 10KHz =	+20KHz = NA	+20KHz = NA
- 10KHz =	- 10KHz =	-20KHz =	-20KHz =
Average =	Average =	Average =	Average =

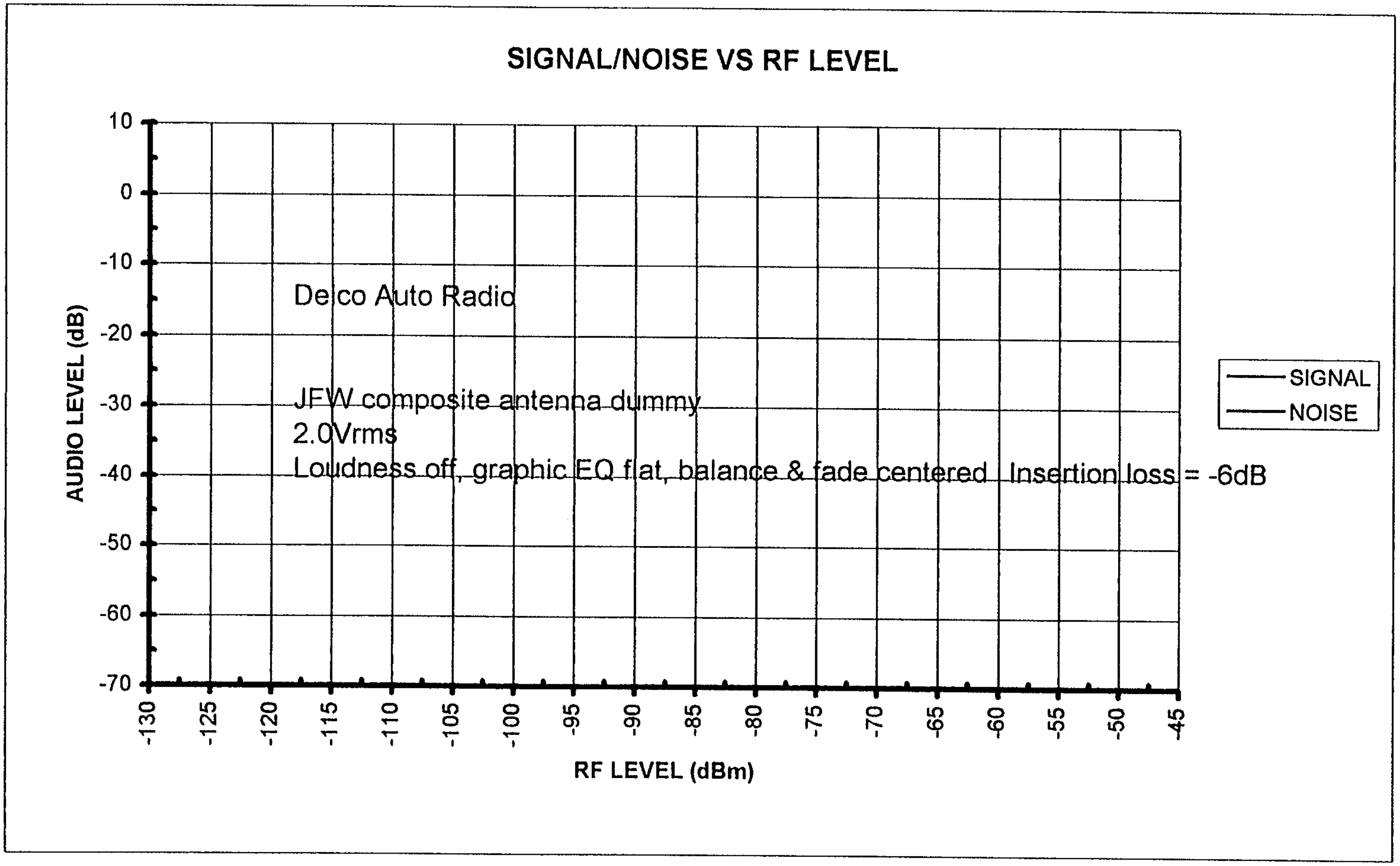
* Left channel used as the measurement channel for Signal and Noise data

* Audio test frequency = 400HZ
* "Signal" mo 35.3dB
* "Wide Band" refers to "Am-St" selected
* "Narrow Band" refers to "Am-St" off

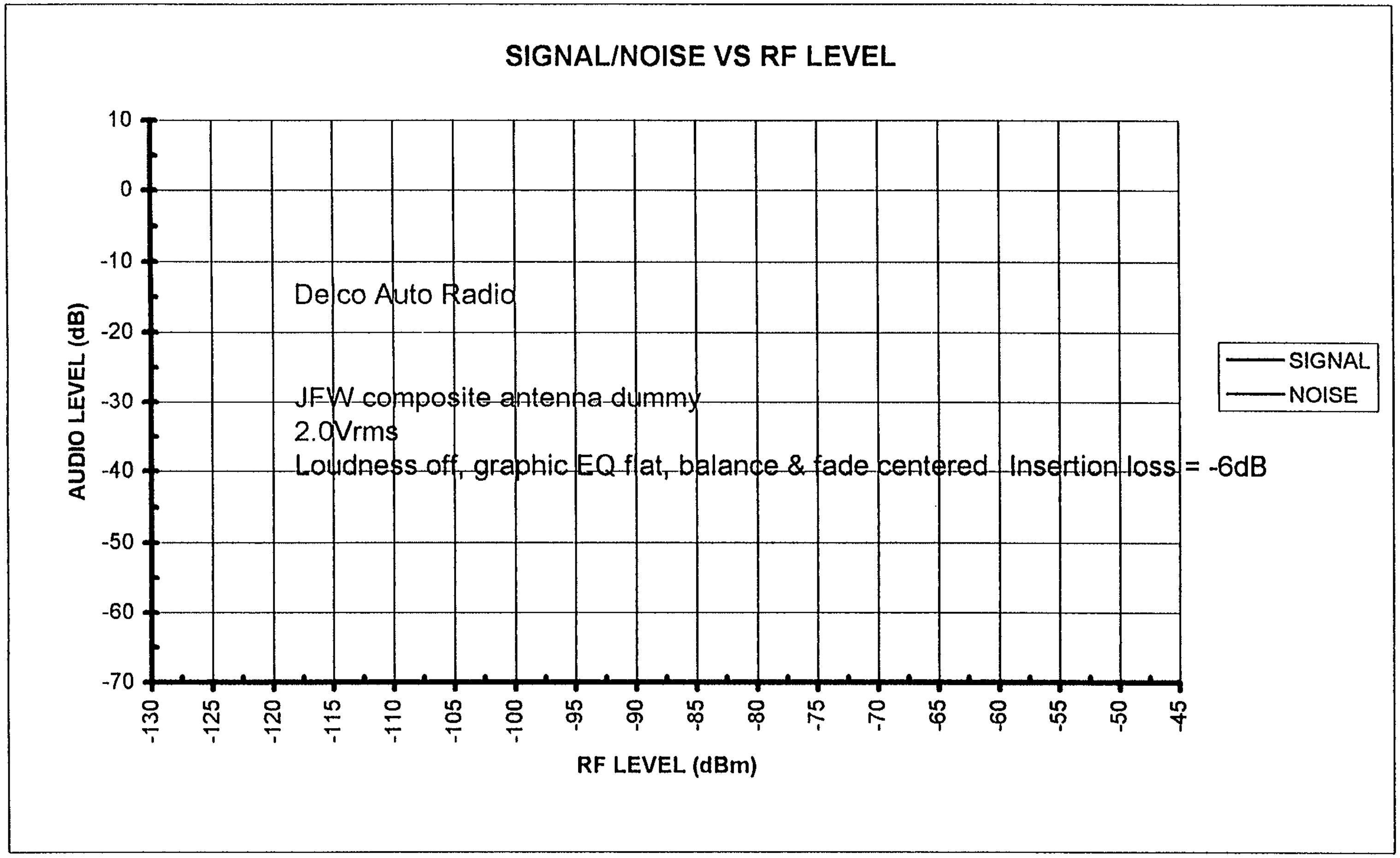
CURVE DATA

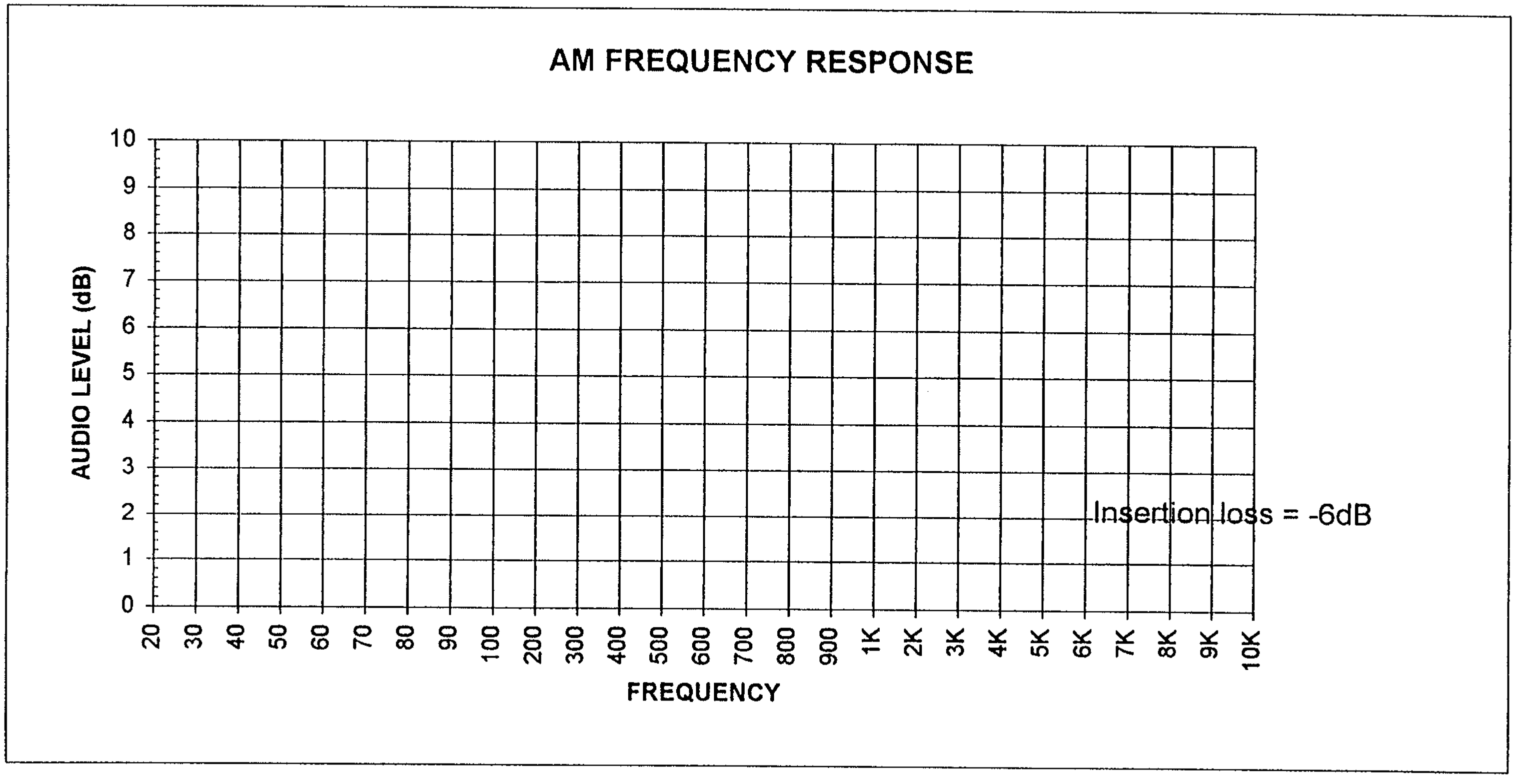
Audio VS RF Level

RF Level	Wide Band		Narrow Band					
	Signal	Noise	Signal	Noise	Signal	Noise	Left	Right
nt power into t	dB	dB	dB	dB	dB	dB	dB	dB
-130								
-125								
-120								
-115								
-110								
-105								
-100								
-95								
-90								
-85								
-80								
-75								
-70								
-65								
-60								
-55								
-50								
-45								



SIGNAL/NOISE VS RF LEVEL
10
0
-10
-20
-30
-40
-50
-60
-70
AUDIO LEVEL (dB)
Delco Auto Radio
JFW composite antenna dummy
2.0Vrms
Loudness off, graphic EQ flat, balance & fade centered Insertion loss = -6dB
SIGNAL
NOISE
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-65
-60
-55
-50
-45
RF LEVEL (dBm)


SIGNAL/NOISE VS RF LEVEL
10
0
-10
-20
-30
-40
-50
-60
-70
AUDIO LEVEL (dB)
Delco Auto Radio
JFW composite antenna dummy
2.0Vrms
Loudness off, graphic EQ flat, balance & fade centered. Insertion loss = -6dB
SIGNAL
NOISE
-130 -125 -120 -115 -110 -105 -100 -95 -90 -85 -80 -75 -70 -65 -60 -55 -50 -45
RF LEVEL (dBm)


AM FREQUENCY RESPONSE
AUDIO LEVEL (dB)
10
9
8
7
6
5
4
3
2
1
0
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1K
2K
3K
4K
5K
6K
7K
8K
9K
10K
FREQUENCY
Insertion loss = -6dB

EIA Digital Audio Radio Test Laboratory

DAR Lab
8/16/96
RMc/DL

Delco First Adjacent Channel Characteristics

Desired Frequency:	94.1MHz
Operating Level:	-62dBm
Lower First Freq.:	93.9MHz

Note:

* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).
* SCAs were added, as a second test, at 20% (67kHz@10%, 92kHz@10%) to clipped pink noise. While this represents overmodulation of 10%, it demonstrates the impact of SCA signals in an adjacent situation.

UNDES. ATTEN.	S/N (dB)	W/SCAs S/N (dB)	D/U (dB)
50.00	49.50	49.50	22.0
49.00	49.50	49.50	21.0
48.00	49.50	49.50	20.0
47.00	49.50	49.50	19.0
46.00	49.50	49.50	18.0
45.00	49.50	49.50	17.0
44.00	49.50	49.30	16.0
43.00	49.50	49.20	15.0
42.00	49.50	49.00	14.0
41.00	49.50	48.90	13.0
40.00	49.50	48.90	12.0
39.00	49.50	48.70	11.0
38.00	49.50	48.50	10.0
37.00	38.50	37.90	9.0
36.00	26.10	26.10	8.0
35.00	24.00	23.70	7.0
34.00	23.00	23.00	6.0
33.00	22.90	22.60	5.0
32.00	22.70	22.50	4.0
31.00	22.60	22.50	3.0
30.00	22.60	22.40	2.0
29.00	22.50	22.40	1.0
28.00	22.40	22.20	0.0
27.00	22.40	22.20	-1.0
26.00	22.30	22.10	-2.0
25.00	22.30	22.00	-3.0
24.00	22.20	21.90	-4.0
23.00	22.10	21.80	-5.0
22.00	22.00	21.50	-6.0

0dB D/U Calibration Details

Output Attenuator:	17 dB	
Input Attenuator:	2.4 dB	(Desired sig.)
Co-Chan." Attenuator:	28 dB	(Undesired sig.)
red Ch. Output Level:	-62 dBm	
Key Point Meas.	-6.86 dBm	(Desired sig.)

Desired Signal
-62 dBm
at Receiver

EIA Digital Audio Radio Test Laboratory

DAR Lab
8/16/96
RMc/DL

Delco First Adjacent Channel Characteristics

Desired Frequency: 94.1MHz
Operating Level: -62dBm
Upper First Freq.: 94.3MHz

Note:

* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).
* SCAs were added, as a second test, at 20% (67kHz@10%, 92kHz@10%) to clipped pink noise. While this represents overmodulation of 10%, it demonstrates the impact of SCA signals in an adjacent situation.

UNDES. ATTEN.	S/N (dB)	W/SCAs S/N (dB)	D/U (dB)
50.00	49.50	49.50	22.0
49.00	49.50	49.50	21.0
48.00	49.50	49.50	20.0
47.00	49.50	49.50	19.0
46.00	49.50	49.50	18.0
45.00	49.50	49.50	17.0
44.00	49.50	49.50	16.0
43.00	49.50	49.50	15.0
42.00	49.50	49.00	14.0
41.00	49.50	48.90	13.0
40.00	49.50	48.90	12.0
39.00	49.50	48.60	11.0
38.00	49.50	48.90	10.0
37.00	49.50	48.30	9.0
36.00	49.50	47.90	8.0
35.00	49.50	47.50	7.0
34.00	49.50	46.90	6.0
33.00	49.50	46.50	5.0
32.00	49.50	45.60	4.0
31.00	49.40	45.00	3.0
30.00	49.40	44.30	2.0
29.00	48.80	40.40	1.0
28.00	**36.30**	**31.80**	**0.0**
27.00	27.50	26.50	-1.0
26.00	23.90	23.50	-2.0
25.00	22.90	22.70	-3.0
24.00	22.70	22.50	-4.0
23.00	22.60	22.20	-5.0
22.00	22.50	22.00	-6.0

0dB D/U Calibration Details

Output Attenuator:	17 dB	
Input Attenuator:	2.4 dB	(Desired sig.)
Co-Chan." Attenuator:	28 dB	(Undesired sig.)
red Ch. Output Level:	-62 dBm	
Key Point Meas.	-6.86 dBm	(Desired sig.)

-62 dBm

Delco Second Adjacent Channel Characteristics

Desired Frequency:	94.1MHz
Operating Level:	-62dBm
Lower Second Freq.:	93.7MHz

Note:

* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).
* SCAs were added, as a second test, at 20% (67kHz@10%, 92kHz@10%) to clipped pink noise. While this represents overmodulation of 10%, it demonstrates the impact of SCA signals in an adjacent situation.

		W/SCAs	
UNDES. ATTEN.	RADIO S/N (dB)	RADIO S/N (dB)	
40	49.6	49.6	2
39	49.6	49.6	1
38	49.6	49.6	0
37	49.6	49.6	-1
36	49.6	49.6	-2
35	49.6	49.6	-3
34	49.6	49.6	-4
33	49.6	49.6	-5
32	49.6	49.6	-6
31	49.6	49.6	-7
30	49.6	49.6	-8
29	49.6	49.6	-9
28	49.6	49.6	-10
27	49.3	49.3	-11
26	49	49	-12
25	48.6	48.6	-13
24	48.5	48.5	-14
23	48.3	48.3	-15
22	48	48	-16
21	47.6	47.6	-17
20	47.1	47.1	-18
19	49.9	49.9	-19
18	46.7	46.7	-20
17	46.7	46.7	-21
16	46.9	46.9	-22
15	47	47	-23
14	47	47	-24
13	46.9	46.9	-25
12	46.7	46.7	-26
11	46.5	46.5	-27
10	46.3	46.3	-28
9	46	46	-29
8	46	46	-30
7	46	46	-31
6	46.2	46.2	-32
5	46.3	46.3	-33
4	46.5	46.5	-34
3	46.8	46.8	-35
2	47.1	47.1	-36
1	47.3	47.3	-37
0	47.7	47.7	-38

0dB D/U Calibration Details

Output Attenuator:	7 dB	
Input Attenuator:	12.4 dB	(Desired sig.)
"Co-Chan." Attenuator:	38 dB	(0dB D/U)
ired Ch. Output Level:	-62 dBm	
Key Point Meas.	-16.88 dBm	(Desired sig.)

Note: Various test levels were re-tested with SCAs on/off to verify that the inclusion of SCA signals had no effect.

EIA Digital Audio Radio Test Laboratory

DAR Lab
8/18/96
RMc/DL

Delco Second Adjacent Channel Characteristics

Desired Frequency:	94.1MHz
Operating Level:	-62dBm
Upper First Freq.:	94.5MHz

Note:
The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).
SCAs were added, as a second test, at 20% (67kHz@10%, 92kHz@10%) to clipped pink noise.
While this represents overmodulation of 10%, it demonstrates the impact of SCA signals in an adjacent situation.

UNDES. ATTEN.	RADIO S/N (dB)	W/SCAs RADIO S/N (dB)	D/U (dB)
40	49.6	49.6	2
39	49.6	49.6	1
38	49.6	49.6	0
37	49.6	49.6	-1
36	49.6	49.6	-2
35	49.6	49.6	-3
34	49.6	49.6	-4
33	49.6	49.6	-5
32	49.6	49.6	-6
31	49.6	49.6	-7
30	49.6	49.6	-8
29	49.6	49.6	-9
28	49.6	49.6	-10
27	49.6	49.6	-11
26	49.6	49.6	-12
25	49.6	49.6	-13
24	49.6	49.6	-14
23	49.6	49.6	-15
22	49.3	49.3	-16
21	49.1	49.1	-17
20	49	49	-18
19	48.8	48.8	-19
18	48.5	48.5	-20
17	48.4	48.4	-21
16	48.1	48.1	-22
15	47.8	47.8	-23
14	47.5	47.5	-24
13	47.2	47.2	-25
12	46.9	46.9	-26
11	46.6	46.6	-27
10	46.5	46.5	-28
9	46.7	46.7	-29
8	46.8	46.8	-30
7	46.9	46.9	-31
6	46.8	46.8	-32
5	46.5	46.5	-33
4	46.3	46.3	-34
3	46	46	-35
2	45.7	45.7	-36
1	45.8	45.8	-37
0	45.9	45.9	-38

0dB D/U Calibration Details

Output Attenuator:	7 dB	
Input Attenuator:	12.4 dB	(Desired sig.)
"Co-Chan." Attenuator:	38 dB	(0dB D/U)
ired Ch. Output Level:	-62 dBm	
Key Point Meas.	-16.88 dBm	(Desired sig.)

Note: Various test levels were re-tested with SCAs on/off to verify that the inclusion of SCA signals had no effect.

DAR Lab
6-Jan-97
RMc

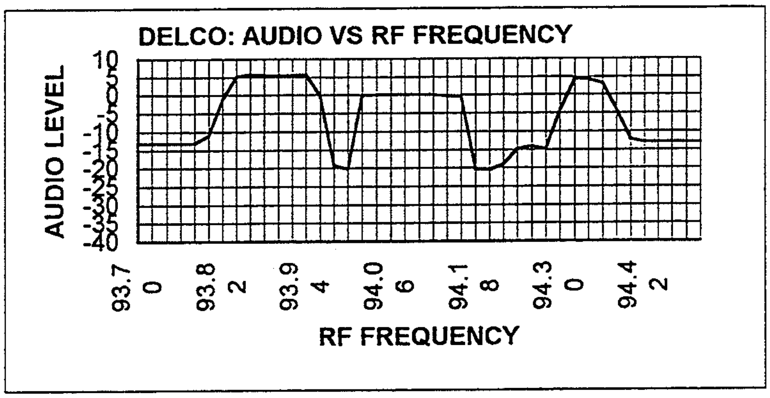
DELCO2.XLS

DELCO Channel Characteristics **94.1MHZ**

Audio VS RF Frequency

Note:
* The results here represent a chacteristic receiver input signature based on sweeping the RF signal through the desired channel
* The test signal is modulated with 1khz @ 100%
* The measurements are made using 15khz low pass and CCIR filters with quasi-peak detection
* RF level is -62dBm

RF FREQ.	AUDIO LEVEL	
93.70	-13.2	
93.72	-13.2	
93.74	-13.2	
93.76	-13.2	
93.78	-13.2	
93.80	-11.1	
93.82	-1	
93.84	5.14	
93.86	5.8	
93.88	5.64	
93.90	5.5	
93.92	5.52	
93.94	5.87	
93.96	-0.3	
93.98	-19.1	
94.00	-20.3	
94.02	-0.15	
94.04	0	
94.06	0	
94.08	0	
94.10	0	Tuning Frequency
94.12	0	
94.14	-0.22	
94.16	-0.42	
94.18	-20.37	
94.20	-20.57	
94.22	-18.92	
94.24	-14.9	
94.26	-14.06	
94.28	-14.97	
94.30	-4.3	
94.32	4.2	
94.34	4.35	
94.36	3.16	
94.38	-3.9	
94.40	-12.3	
94.42	-13.1	
94.44	-13.1	
94.46	-13.1	
94.48	-13.1	
94.50	-13.1	



DAR FM TEST RECEIVER DATA

Receiver Lab #2

Type High End Home Hi-Fi

Index

FM -> FM Laboratory Measurements for the Denon Model TU-380 RD

Laboratory Receiver #2

Type: High end home Hi-Fi

Measurements were made at a moderate signal level of -62 dBm.

The signal to noise ratio was set at 45 dB and this measurement was made using a 15kHz low pass and a CCIR filter with quasi-peak detection.

Test Results:

Co-Channel	D/U	43.39 dB
Lower First Adjacent	D/U	23.61 dB
Upper First Adjacent	D/U	12.46 dB
Lower Second Adjacent	D/U	-24.67 dB
Upper Second Adjacent	D/U	-33.18 dB

ELECTRONIC INDUSTRIES ASSOCIATION
Digital Audio Radio Laboratory
Engineers: RMc/DL
DATE: 2/21/95

PROJ.: RADIO CHARACTERIZATION/CONFIRMATION

* Key point measurements for comparison to Grossjean data
* Additional data with regard to audio performance VS RF level

TEST SET-UP

* Receiver: Denon TU-380RD
* Ant. Net: 50/75 ohm resistive pad (-7.8dB insertion loss)
* Audio Ref: 724mVrms
* Receiver in "Auto" Mode for stereo tests
* Receiver in manual mode for mono tests
* Test Bed, W/Orban Stereo Gen & Harris Exciter as Signal Source
* Audio measurements made with Audio Precision as rms unweighted

FM TESTS (TEST FQ. 94.1MHZ)

S/N RATIO - 1KHZ, 100% MOD

MAX	70dB	-62dBm	(mono)

THD - 1KHZ, 100% MOD (-50dBm)

MONO	0.17 %
STEREO	0.24 %

LIMITING THRESHOLD (Audio -1dB)

-106dBm

HIGH CUT THRESHOLD

Audio: 10KHZ, L+R, 100% Mod, Pilot off
NA due to mute

SEPARATION @ -62dBm

Freq.	L->R	R->L	
1KHZ	-38dB	-37dB	(W/O Pre-Emph)
10KHZ	-35dB	-34dB	(W/O Pre-Emph)

SIGNAL, NOISE & SEPARATION VS RF LEVEL

* Left channel used as the measurement channel for Signal and Noise data
* Left channel driven (L only) for separation data
* Audio test frequency = 1KHZ
* Receiver in "Manual" mode for Mono measurements, "Auto" mode for stereo measurements
* RF levels represent power into the receiver after 50/75 ohm conversion

CURVE DATA

SIGNAL, NOISE & SEPARATION VS RF LEVEL

RF Level	mono (L)		Stereo (L)			RF Level	Separation L->R	
	Signal	Noise	Signal	Filt. Noise	Noise		Left	Right
dBm	dB	dB	dB	dB	dB	dBm	dB	dB
-130	-12	-12	-73	-73	-73	-130	-73	-73
-125	-12	-12	-73	-73	-73	-125	-73	-73
-120	-12	-12	-73	-73	-73	-120	-73	-73
-115	-9	-12	-73	-73	-73	-115	-73	-73
-110	-3.7	-21	-73	-73	-73	-110	-73	-73
-105	-0.6	-33	-73	-73	-73	-105	-73	-73
-100	-0.05	-44	-73	-73	-73	-100	-73	-73
-95	0	-47	0	-33	-33	-95	0	-29
-90	0	-52	0	-38	-38	-90	0	-33
-85	0	-57	0	-43	-43	-85	0	-36
-80	0	-62	0	-48	-48	-80	0	-37
-75	0	-66	0	-53	-53	-75	0	-38
-70	0	-68	0	-57	-57	-70	0	-38
-62	0	-70	0	-62	-62	-62	0	-38
-57	0	-70	0	-64	-64	-57	0	-38

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SIGNAL & FILTERED NOISE VS RF LEVEL

DENON TU-380RD

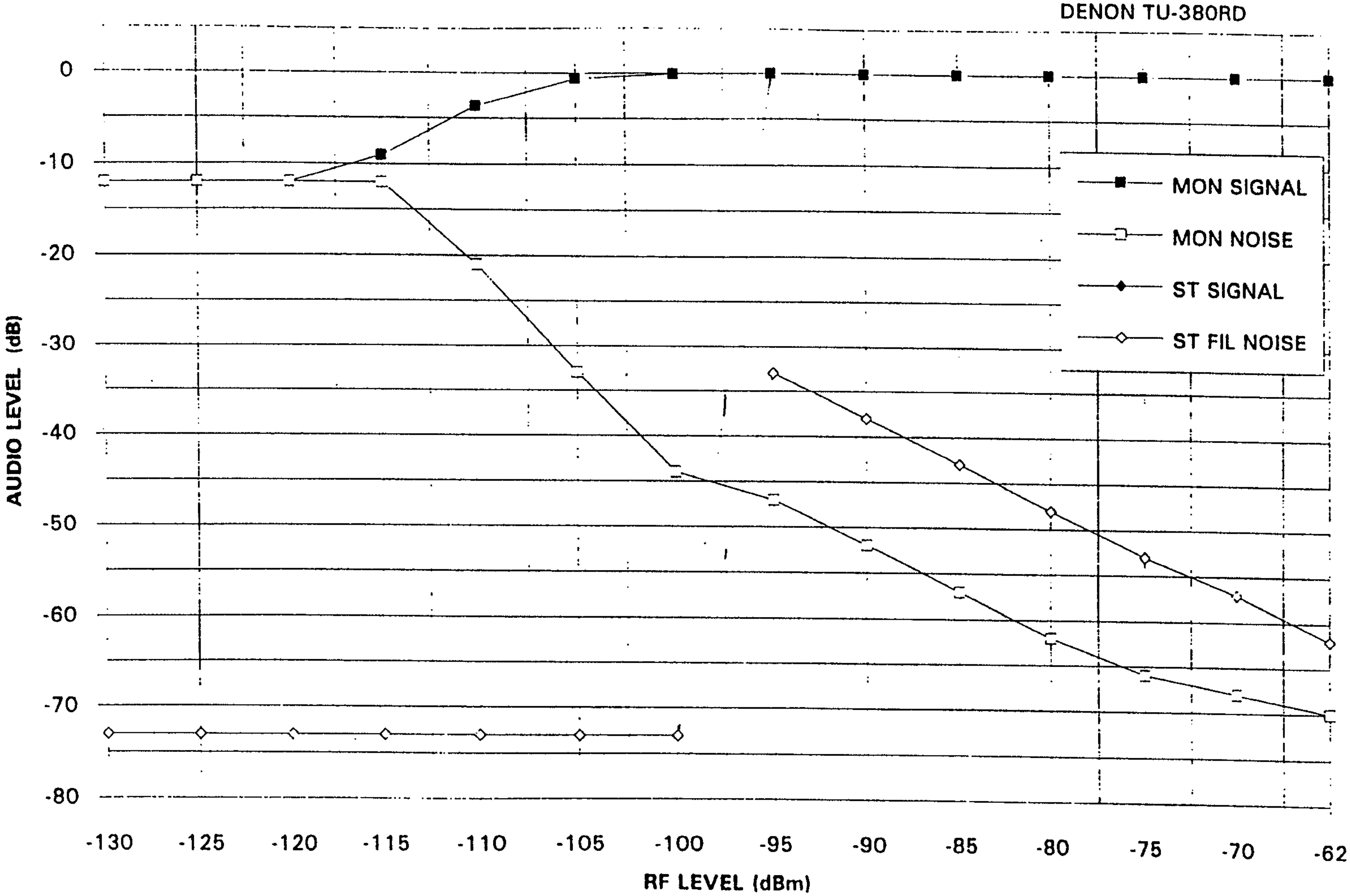

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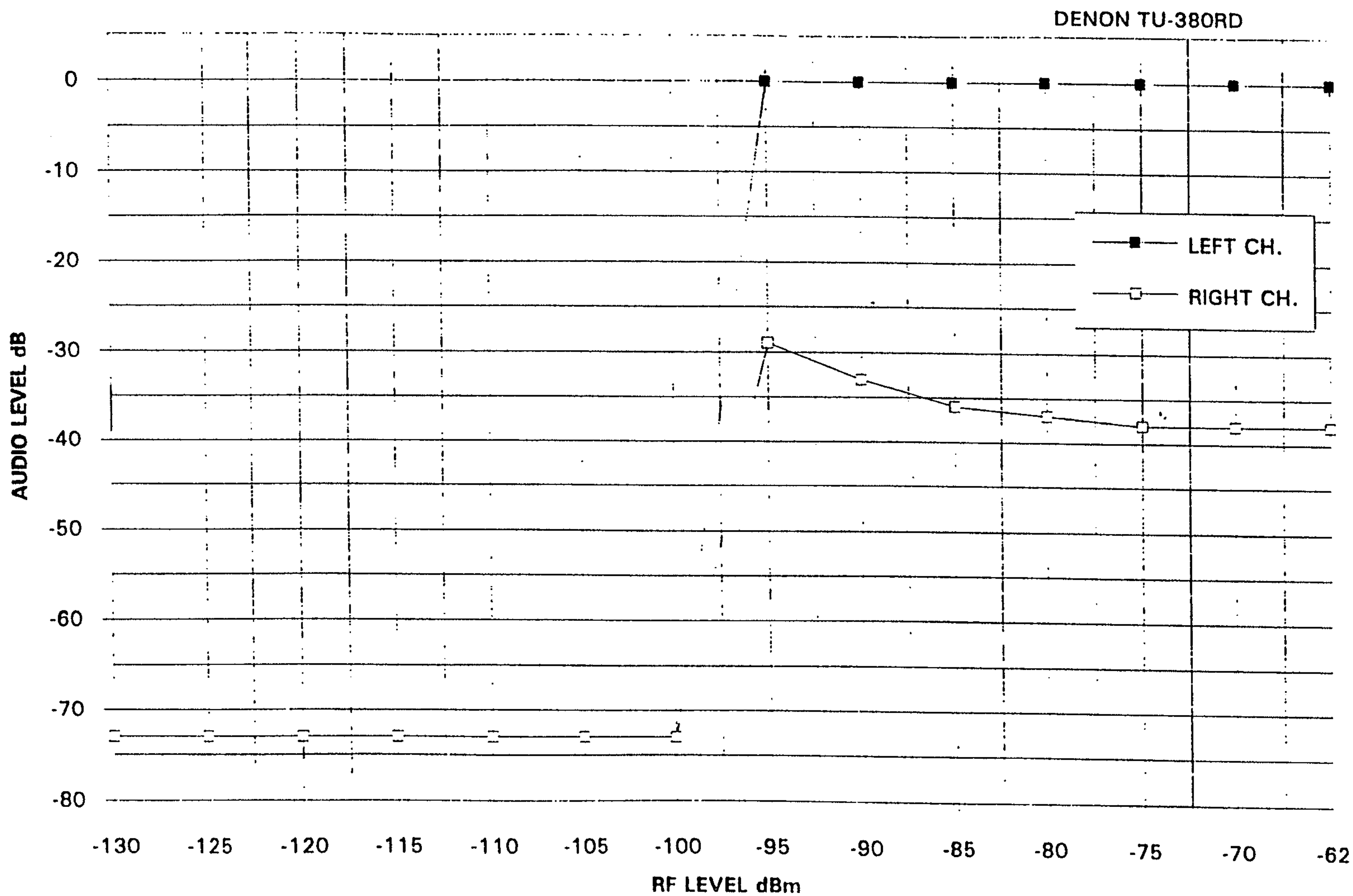
Chart 1 of 3

EIA DAR LAB

SEPARATION VS RF LEVEL



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Cha... 2 of 3

404

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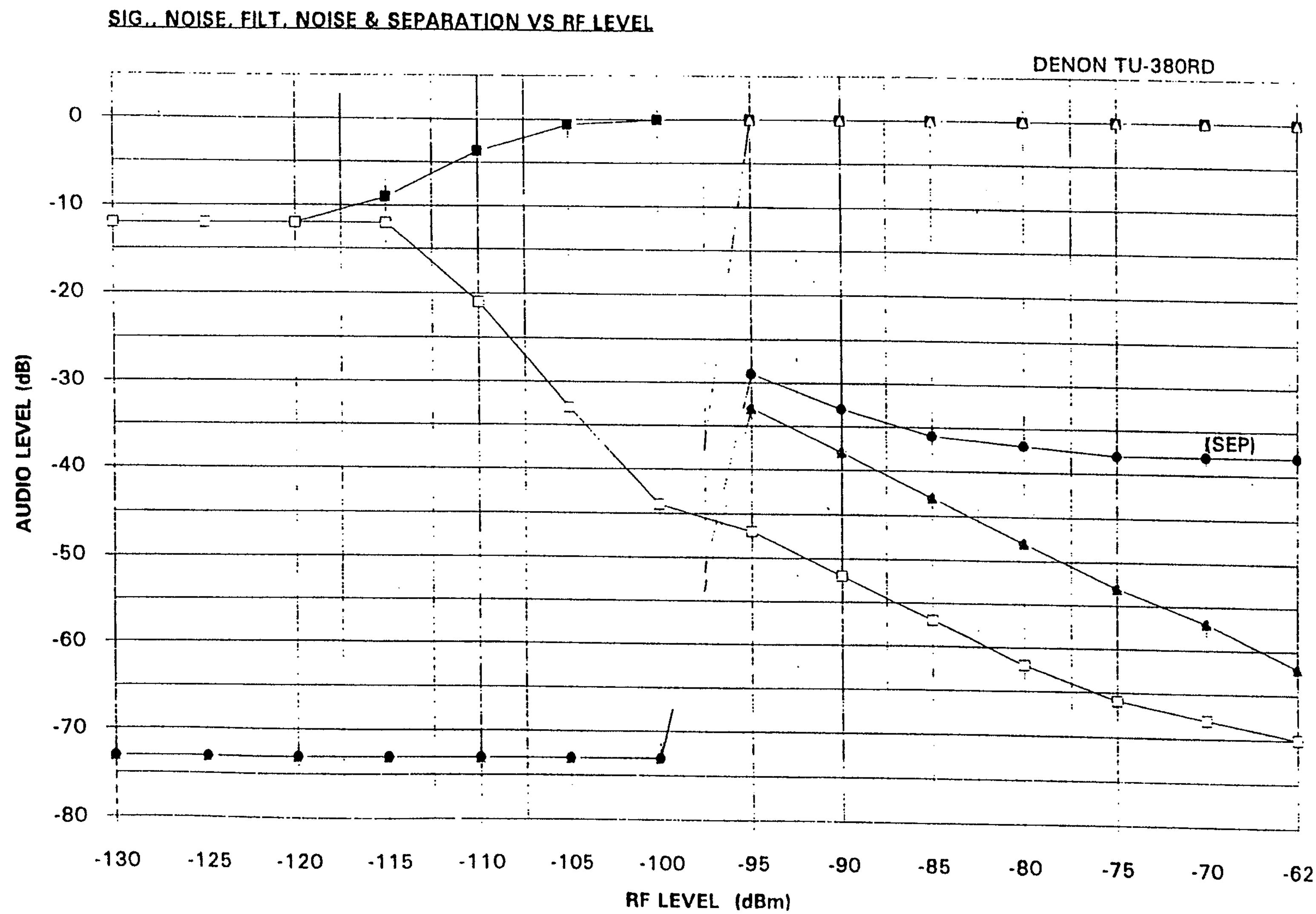

SIG., NOISE, FILT. NOISE & SEPARATION VS RF LEVEL
DENON TU-380RD
AUDIO LEVEL (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
(SEP)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
RF LEVEL (dBm)

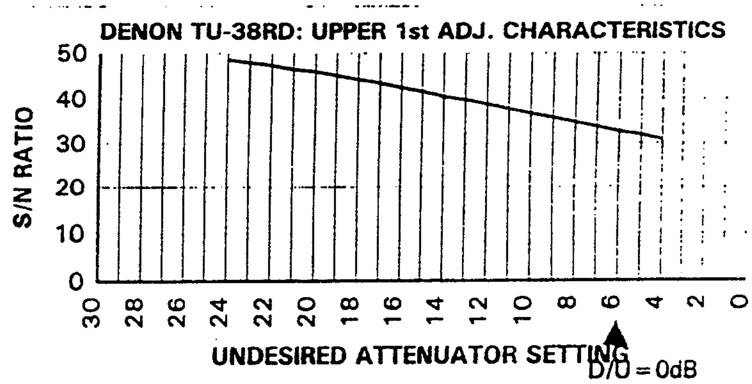
	GEN	RCVR		RCVR
TUNER TEST DATA				
Manufacturer:	Denon			
Model Number:	TU-380RD			
Serial Number:	(4056301149)			
Type:	High End Home Hi-Fi			
	Using IEEE/EIA 10Ω,10Ω,45Ω matching pad			
FM 30% modulation(98.1MHz)				
20 dB S/N	2.2	1.1 µV	12.1 dBf	-106.2 dBm
30 dB S/N	3.2	1.6 µV	15.2 dBf	-103.0 dBm
50 dB S/N	25.2	12.6 µV	33.3 dBf	-85.0 dBm
Interstation Noise	-3.0	dB		
Mute start Level	10.0	5.0 µV	25.2 dBf	-93.0 dBm
High cut at 10KHz	none			
Fo+½IF rejection	16.0	8.0 mV	77.2 dB	-88.9 dBm
Image rejection	794.0	397.0 µV	51.1 dB	-55.0 dBm
FM 100% MODULATION MONO				
Usable Sensitivity	4.0	2.0 µV	17.3 dBf	-101.0 dBm
50dB S/N	11.0	5.5 µV	26.1 dBf	-92.2 dBm
Maximum S/N	78.0	dB		
THD %	0.2			
AM Rejection at 1mV	55.2	dB		
FM 100% MODULATION STEREO				
Usable Sensitivity	mutes			
50dB S/N	80.0	40.0 µV	43.3 dBf	-74.9 dBm
Maximum S/N	66.0	dB		
THD %	0.2			
1KHz separation	55.0	dB		
10KHz separation	37.0	dB		
Stero Blend action:	none			
Separation at 25µV receiver input		dB	39.2 dBf	-73.0 dBm
67KHz SCA Rejection	-66.0	dB		
δF=5KHz				
19 and 38KHzproducts	-53.0	dB		
FM TWO SIGNAL TESTS(98.1 MHz)				
708µV (-50dBm)				
Capture Ratio	2.3	dB		
Selectivity@ 200KHz				
for 30dB S/N	11.0	dB		
for 50dB S/N	9.5 –	dB		
Selectivity@ 400KHz				
for 30dB S/N	67.0	dB		
for 50dB S/N	46.5 –	dB		
IM Rejection	3.5	1.8 mV	76.1 dBf	-42.1 dBm
(98.9 and 99.7)				
2MHz IM rejection	4.0	2.0 mV	77.3 dBf	-41.0 dBm
(99.1 and 100.1)				
IF mix rejection	4.0	2.0 mV	77.3 dBf	-41.0 dBm
(96.4 and 107.2)				
AM 30% MODULATION MONO				
DUMMY ANTENNA:	50Ω generator to AM ANT terminals			
20dB S/N	3.0	3.0 µV	-97.4 dBm	
Max S/N	53.0	dB		
THD at max S/N	0.3	%		
THD at 80% mod	0.8	%		
-3dB Audio Response				
600KHz	1945.0	Hz		
1400KHz	1945.0	Hz		
±10KHz Selectivity	33.0	dB		
±20KHz Selectivity	52.0	dB		
Local AGC action:				
level for -3dB 600KHz	desired signal reduction			
1400KHz	none			
10MHz				
27MHz				
IF mix rejection				
(1400 & 945 or 950)	2.5	1.8 mV	-39.0 dBm	

DAR Lab
Mar 8/95 DENUP1.XLS
RMc
Denon TU-380RD Adjacent Channel Characteristics

Upper first adj. channel 94.3mhz

Note:
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
* The interfering signal is modulated with clipped pink noise
* SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35		
34		
33		
32		
31		
30		
29		
28		
27		
26		
25		
24	48.6	
23	48	
22	47.4	
21	46.5	
20	46	
19	45.2	
18	44.2	
17	43.4	
16	42.5	
15	41.6	
14	40.5	
13	39.7	
12	38.8	
11	37.8	
10	36.8	
9	35.8	
8	34.8	
7	33.8	
6	32.7	D/U=0dB
5	32	
4	30.9	
3		
2		
1		
0		



DAR Lab
Mar 8/95 DENLOW2.XLS

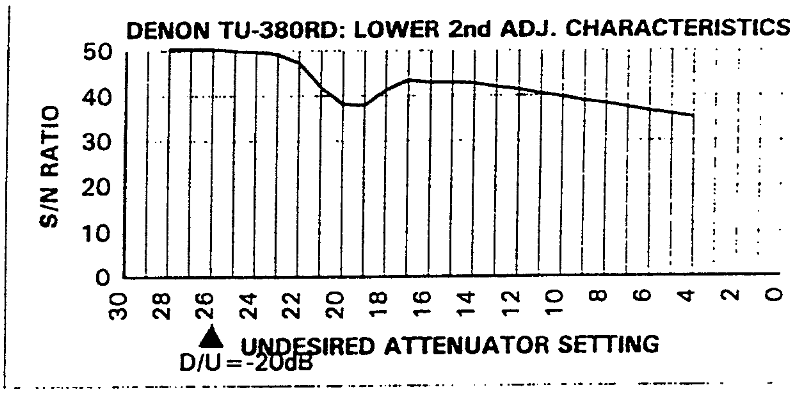
Denon Adjacent Channel Characteristics

Lower second adj. channel 93.7mhz

Note:

- The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
- The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
- The interfering signal is modulated with clipped pink noise
- SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35		
34		
33		
32		
31		
30		
29		
28	50.5	
27	50.5	
26	50.5	D/U=-20dB
25	50	
24	49.8	
23	49.3	
22	47.4	
21	41.9	
20	38.2	
19	37.9	
18	41.3	
17	43.5	
16	43	
15	43	
14	42.8	
13	42	
12	41.4	
11	40.5	
10	39.8	
9	38.9	
8	38.3	
7	37.5	
6	36.6	
5	36	
4	35.2	
3		
2		
1		
0		



DAR Lab
Mar 13/95

DENUP2.XLS

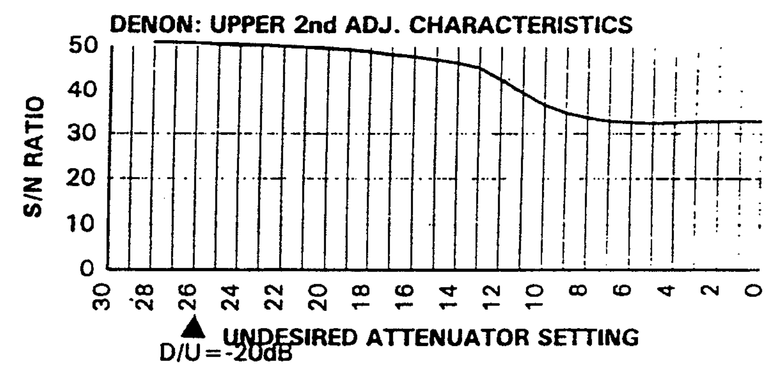
Denon TU-380RD Adjacent Channel Characteristics

Upper second adj. channel 94.5mhz

Note:

- The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
- The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
- The interfering signal is modulated with clipped pink noise
- SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40	51.2	
39		
38		
37		
36		
35		
34		
33		
32		
31		
30	51.9	
29		
28	51	
27	50.9	
26	50.8	D/U=-20dB
25	50.6	
24	50.5	
23	50.3	
22	50	
21	49.8	
20	49.5	
19	49.2	
18	48.8	
17	48.2	
16	47.7	
15	47	
14	46.3	
13	45.2	
12	42.5	
11	39.4	
10	36.6	
9	34.8	
8	33.7	
7	32.9	
6	32.6	
5	32.4	
4	32.5	
3	32.8	
2	32.8	
1	32.9	
0	32.9	



DAR FM TEST RECEIVER DATA

Receiver Lab #3

Type Portable

Index

FM -> FM Laboratory Measurements for the Panasonic Model RX-FS430

Laboratory Receiver #3

Type: Portable (Blaster)

Measurements were made at a moderate signal level of -62 dBm.

The signal to noise ratio was set at 45 dB and this measurement was made using a 15kHz low pass and a CCIR filter with quasi-peak detection.

Test Results:

Co-Channel	D/U	40.94 dB
Lower First Adjacent	D/U	27.33 dB
Upper First Adjacent	D/U	27.19 dB
Lower Second Adjacent	D/U	-22.41 dB
Upper Second Adjacent	D/U	2.16 dB

ELECTRONIC INDUSTRIES ASSOCIATION
Digital Audio Radio Laboratory
Engineers: RMc/DL
DATE: 2/21/95

PROJ.: RADIO CHARACTERIZATION/CONFIRMATION

- Key point measurements for comparison to Grossjean data
- Additional data with regard to audio performance VS RF level

TEST SET-UP

- Receiver: Panasonic Portable stereo
- Ant. Net: 50/75 ohm resistive pad (-7.8dB insertion loss)
- Audio Ref: 1.0Vrms
- Test Bed, W/Orban Stereo Gen & Harris Exciter as Signal Source
- Audio measurements made with Audio Precision as rms unweighted except stereo noise.

FM TESTS (TEST FQ. 94.1MHZ)

S/N RATIO - 1KHZ, 100% MOD

MAX	-61dB	-62dBm	(mono)

THD - 1KHZ, 100% MOD (-50dBm)

MONO	0.54 %	
STEREO	1.10 %	(Increase due to pilot content)

LIMITING THRESHOLD (Audio -1dB)

-96dBm

HIGH CUT THRESHOLD

Audio: 10KHZ, L+R, 100% Mod, Pilot off
NA

SEPARATION @ -62dBm

Freq.	L->R	R->L	
1KHZ	30.8dB	29dB	(W/O Pre-Emph)
10KHZ	25dB	24dB	(W/O Pre-Emph)

SIGNAL, NOISE & SEPARATION VS RF LEVEL

- Left channel used as the measurement channel for Signal and Noise data
- Left channel driven (L only) for separation data
- Audio test frequency = 1KHZ
- RF levels represent power into the receiver after 50/75 ohm conversion

CURVE DATA

SIGNAL, NOISE & SEPARATION VS RF LEVEL

RF Level	mono (L)		Stereo (L)			RF Level	Separation L->R	
	Signal	Noise	Signal	Filt. Noise	Noise		Left	Right
dBm	dB	dB	dB	dB	dB	dBm	dB	dB
-130	-27.8	-27.8	-28	-27	-28	-130	-27.5	-27.5
-125	-27.7	-27.8	-28	-27	-28	-125	-27.5	-27.5
-120	-27.3	-27.9	-28	-27	-28	-120	-27.5	-27.5
-115	-24.6	-28.2	-25.4	-25	-29	-115	-26.2	-26.7
-110	-18	-29	-18.4	-24	-29.7	-110	-21.5	-22
-105	-9.8	-31.5	-10.2	-21.5	-32	-105	-14.1	-14.8
-100	-3.46	-37	-3.8	-22	-28	-100	-3.2	-22
-95	-0.6	-46.5	-0.6	-29.6	-32.3	-95	-0.5	-26.3
-90	0	-55.4	0	-34.4	-36	-90	0	-28.3
-85	0	-61	0	-39.5	-38.6	-85	0	-29.4
-80	0	-64.5	0	-46	-40	-80	0	-30
-75	0	-66	0	-51	-40.5	-75	0	-30.6
-70	0	-66	0	-55.7	-40.7	-70	0	-30.7
-62	0	-66	0	-61	-40.7	-62	0	-30.8
-57						-57		

EIA DAR LAB

SIGNAL & FILTERED NOISE VS RF LEVEL

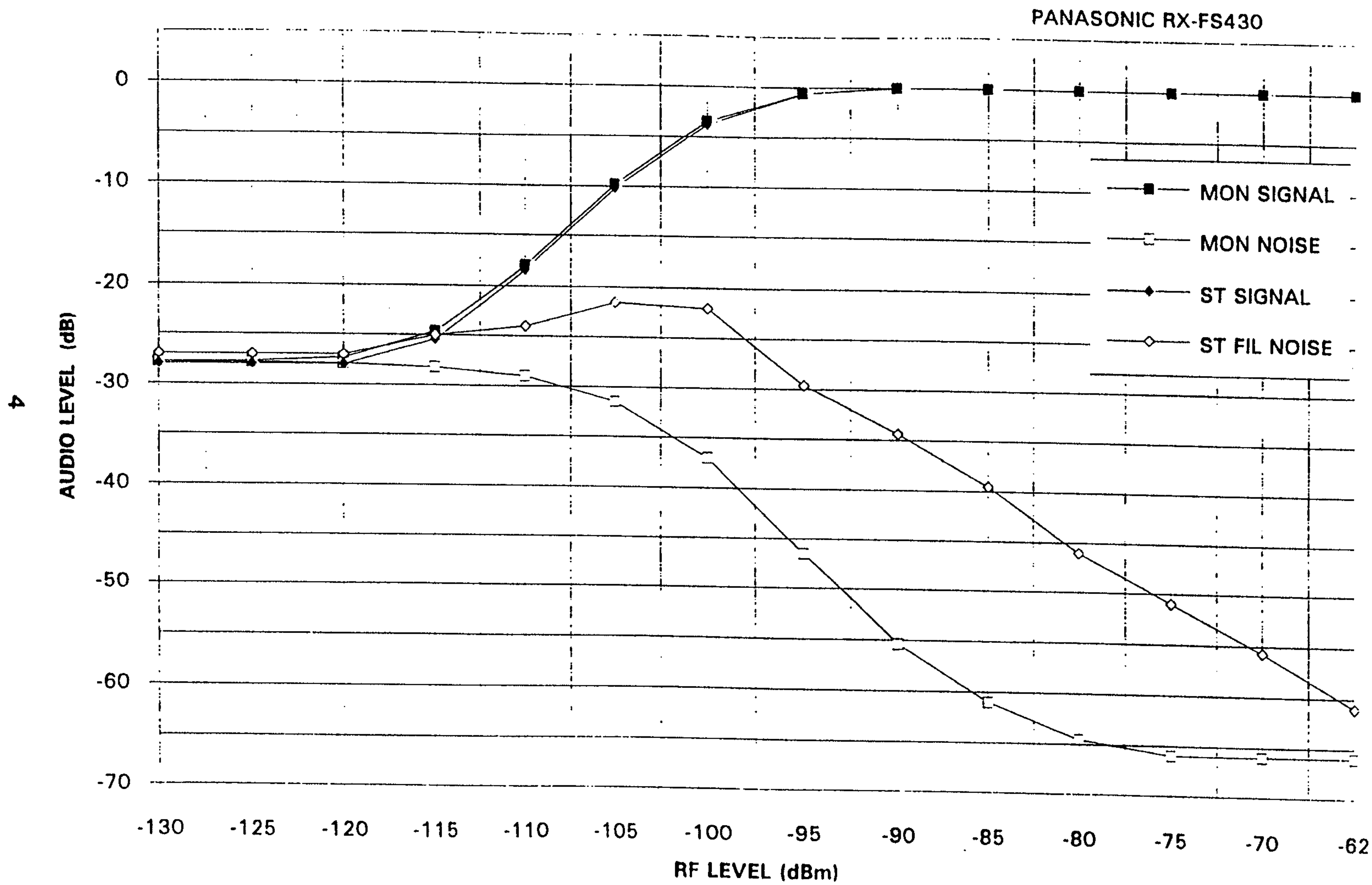


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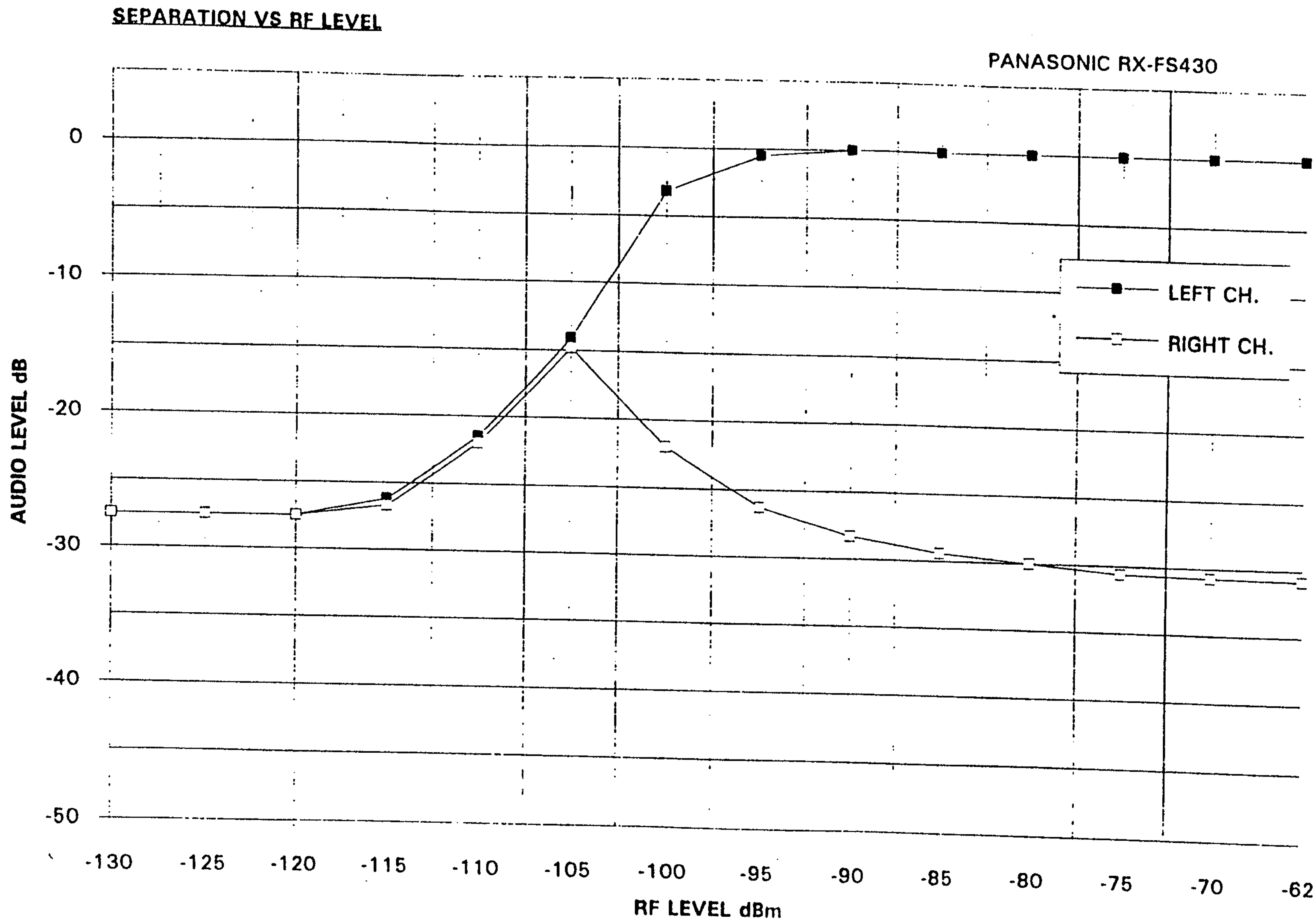
Chart 1 of 3

EIA DAR LAB


SEPARATION VS RF LEVEL
PANASONIC RX-FS430
AUDIO LEVEL dB
0
-10
-20
-30
-40
-50
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
RF LEVEL dBm
LEFT CH.
RIGHT CH.

5

EIA DAR LAB

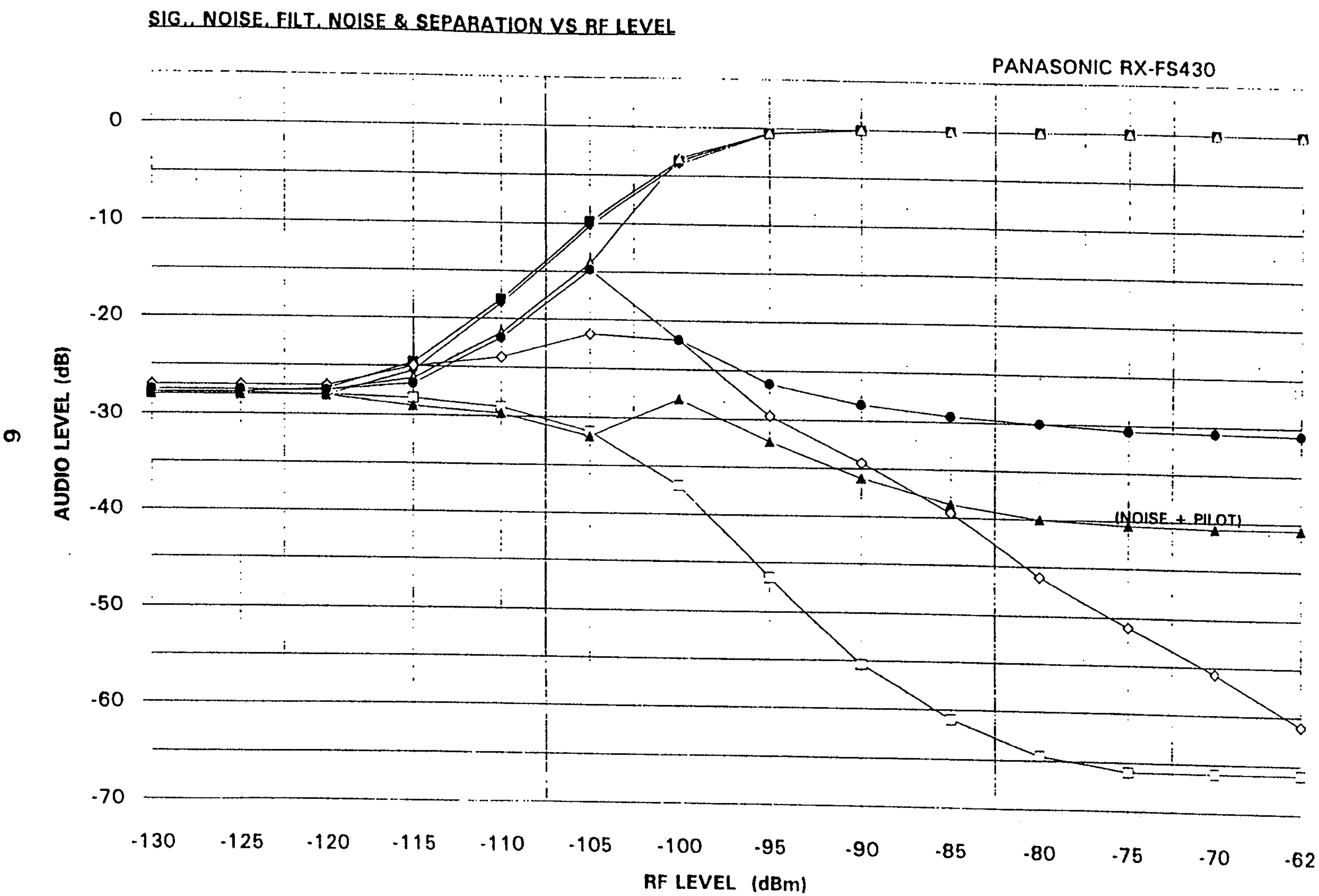


Chart 3 of 3

FM TUNER TEST DATA

Manufacturer: Panasonic
Model Number: RX-FS430
Serial Number: GR3JA01184
Type: Personal Portable
using IEEE/IHF 10Ω,10Ω,45Ω resistive pad
external antenna disconnected

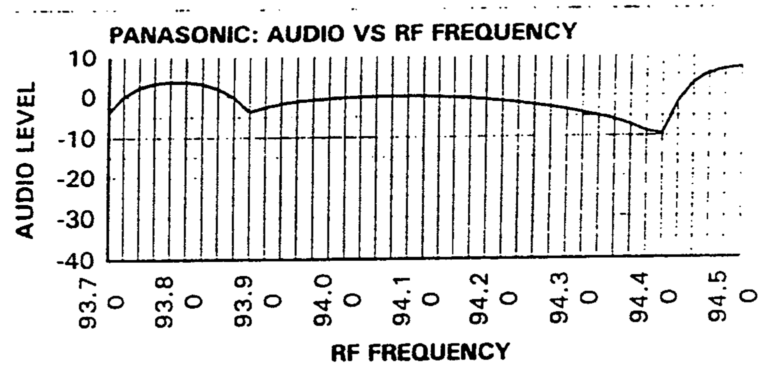
	GEN	RCVR		RCVR
FM 30% modulation(98.1MHz)				
20 dB S/N	4.3	2.15 μV	17.9 dBf	-100.3 dBm
30 dB S/N	6.8	3.4 μV	21.9 dBf	-96.4 dBm
50 dB S/N	80	40 μV	43.3 dBf	-74.9 dBm
Interstation Noise	-15	dB		
Mute start Level		μV	dBf	dBm
High cut at 10KHz		dB at	μV	
Fo+½IF rejection	8	4 mV	65.4 dB	
Image rejection	36	18 μV	18.5 dB	
FM 100% MODULATION MONO				
Usable Senditivity	6	3 μV	20.8 dBf	-97.4 dBm
50dB S/N	14	7 μV	28.1 dBf	-90.1 dBm
Maximum S/N	61	dB		
THD %	0.34			
AM Rejection at 1mV	48	dB		
FM 100% MODULATION STEREO				
Usable Sensitivity	9	4.5 μV	24.3 dBf	-93.9 dBm
50dB S/N	100	50 μV	45.2 dBf	-73.0 dBm
Maximum S/N	60	dB		
THD %	0.35			
1KHz separation	35	dB		
10KHz separation	38.5	dB		
Stero Blend action:	none			
Separation at 50μV		dB	39.0 dBf	-81.0 dBm
67KHz SCA Rejection δF=5KHz	54	dB		
19 and 38KHzproducts	-40	dB		
FM TWO SIGNAL TESTS(98.1 MHz) 708μV (-50dBm)				
Capture Ratio	1.4	dB		
Selectivity@ 200KHz				
for 30dB S/N	5.5	dB		
for 50dB S/N	2	dB		
Selectivity@ 400KHz				
for 30dB S/N	29	dB		
for 50dB S/N	23.5	dB		
IM Rejection (98.9 and 99.7)	4	2 mV	77.3 dBf	-41.0 dBm
2MHz IM rejection (99.1 and 100.1)	4	2 mV	77.3 dBf	-41.0 dBm
IF mix rejection (96.4 and 107.2)	4	2 mV	77.3 dBf	-41.0 dBm
AM 30% MODULATION MONO				
DUMMY ANTENNA:	50Ω gem to 5.6μH in series with ferrite antenna			
20dB S/N	16	16 μV	-82.9 dBm	
Max S/N	51	dB		
THD at max S/N	0.7	%		
THD at 80% mod	1.1	%		
-3dB Audio Response		%		
600KHz	1570			
1400KHz	1680	Hz		
±10KHz Selectivity	14	dB		
±20KHz Selectivity	28.5	dB		
Local AGC action:		μV	dBm	
level for -3dB 600KHz desired signal reduction				
1400KHz		mV	dBm	
10MHz	141	141 mV	-4.0 dBm	
27MHz		mV	dBm	
IF mix rejection (1400 & 945 or 950)	NM	mV	dBm	
	local AGC prevents measurement			

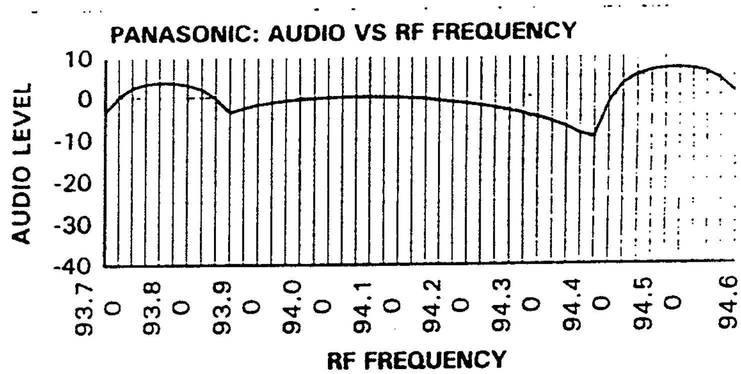
DAR Lab
Mar 15/95 PANAVRF.XLS
Panasonic Channel Characteristics **94.1MHZ**

Audio VS RF Frequency

Note:
- The results here represent a chacteristic receiver input signature based on sweeping the RF signal through the desired channel
- The test signal is modulated with 1khz @ 100%
- The measurements are made using 15khz low pass and CCIR filters with quasi-peak detection
- RF level is -62dBm
- Manual tuned radio - tuned for lowest distortion for center tuning

RF FREQ.	AUDIO LEVEL	
93.70	-3.6	
93.72	0.12	
93.74	2.31	
93.76	3.36	
93.78	3.72	
93.80	3.65	
93.82	3.15	
93.84	2.03	
93.86	-0.14	
93.88	-3.67	
93.90	-2.66	
93.92	-1.77	
93.94	-1.22	
93.96	-0.83	
93.98	-0.56	
94.00	-0.34	
94.02	-0.17	
94.04	-0.03	
94.06	0.05	
94.08	0.07	
94.10	**0**	**Tuning**
94.12	-0.09	
94.14	-0.29	
94.16	-0.54	
94.18	-0.85	
94.20	-1.21	
94.22	-1.63	
94.24	-2.12	
94.26	-2.69	
94.28	-3.34	
94.30	-4.09	
94.32	-4.95	
94.34	-5.94	
94.36	-7.18	
94.38	-8.82	
94.40	-9.56	
94.42	-1.51	
94.44	3.06	
94.46	5.32	
94.48	6.36	
94.50	6.89	





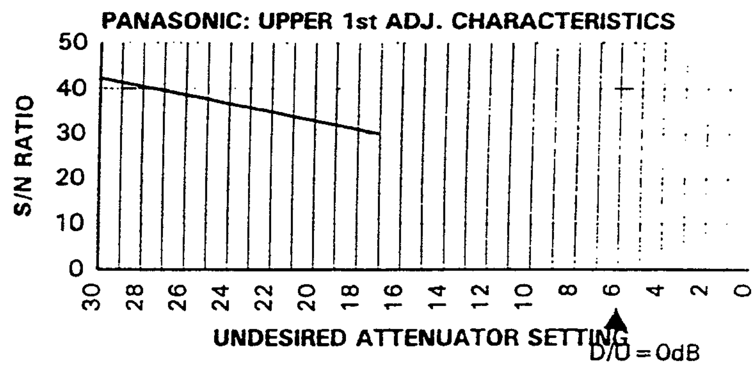
DAR Lab
Mar 8/95 PANUP1.XLS
RMc

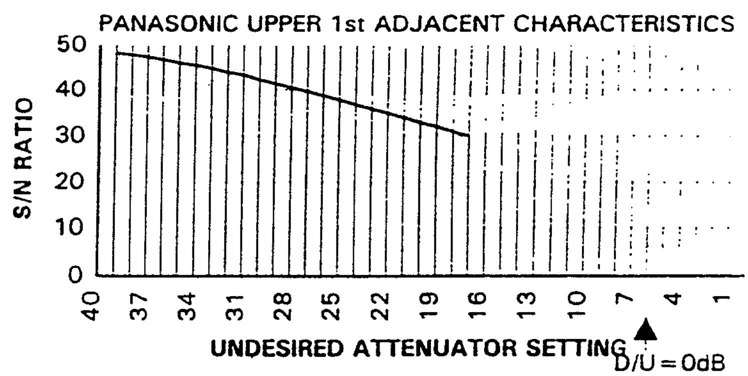
Panasonic Adjacent Channel Characteristics

Upper first adj. channel 94.3mhz

Note:
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
* The interfering signal is modulated with clipped pink noise
* SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39	48.2	
38	47.8	
37	47.3	
36	46.7	
35	46	
34	45.5	
33	44.8	
32	43.9	
31	43.3	
30	42.3	
29	41.4	
28	40.5	
27	39.6	
26	38.7	
25	37.8	
24	36.7	
23	35.8	
22	34.9	
21	33.9	
20	32.9	
19	32	
18	31	
17	30	
16		
15		
14		
13		
12		
11		
10		
9		
8		
7		
6		D/U=0dB
5		
4		
3		
2		
1		
0		





DAR Lab
Mar 8/95

PANLOW2.XLS

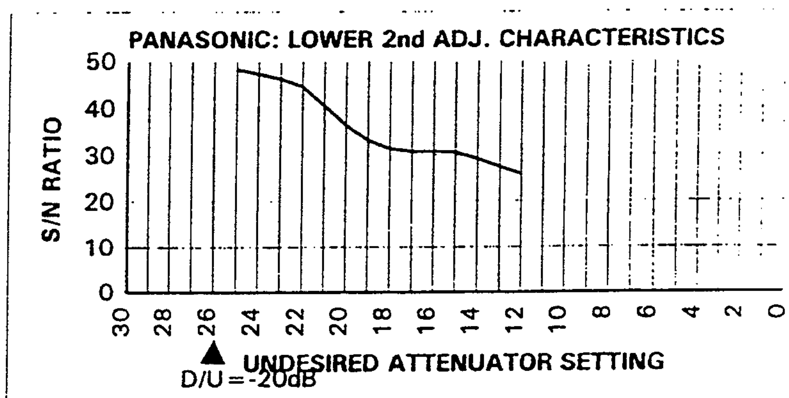
Panasonic Adjacent Channel Characteristics

Lower second adj. channel 93.7mhz

Note:

- The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
- The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
- The interfering signal is modulated with clipped pink noise
- SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35		
34		
33		
32		
31		
30		
29		
28		
27		
26		D/U=-20dB
25	48.3	
24	47.3	
23	46.2	
22	44.6	
21	40.6	
20	36.5	
19	33.2	
18	31.4	
17	30.8	
16	30.8	
15	30.6	
14	29.2	
13	27.5	
12	25.8	
11		
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		

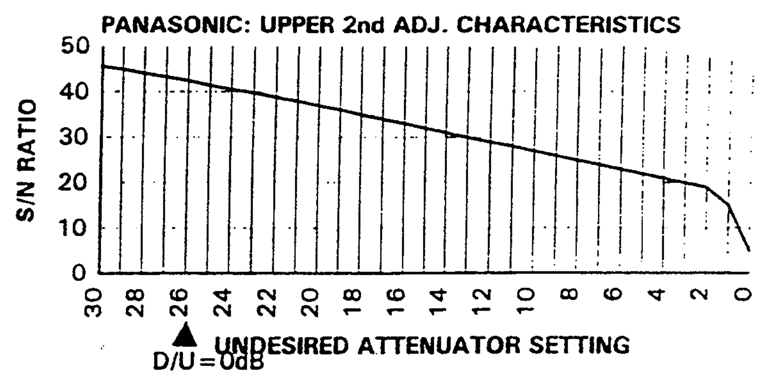


Panasonic Portable Radio Adjacent Channel Characteristics

Upper second adj. channel 94.5mhz

Note:
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
* The interfering signal is modulated with clipped pink noise
* SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40	47.9	
39	49.7	
38	49.5	
37	48.7	
36	48.8	
35	47.5	
34	48	
33	47.5	
32	46.8	
31	46.1	
30	45.6	
29	45	
28	44.1	
27	43.3	
26	42.5	D/U=0dB
25	41.4	
24	40.6	
23	39.8	
22	38.8	
21	38	
20	37	
19	36.1	
18	35	
17	34	
16	33	
15	32	
14	31	
13	30	
12	29	
11	28	
10	27	
9	26	
8	25	
7	24	
6	23	
5	22	
4	21	
3	20	
2	19	
1	15	
0	5	



DAR FM TEST RECEIVER DATA

Receiver Lab #4

Type Home Hi-Fi

Index

FM -> FM Laboratory Measurements for the Pioneer Model SX-201

Laboratory Receiver #4

Type: Home Hi-Fi

Measurements were made at a moderate signal level of -62 dBm.

The signal to noise ratio was set at 45 dB and this measurement was made using a 15kHz low pass and a CCIR filter with quasi-peak detection.

Test Results:

Co-Channel	D/U 44.18 dB
Lower First Adjacent	D/U 31.87 dB
Upper First Adjacent	D/U 21.22 dB
Lower Second Adjacent	D/U -15.16 dB
Upper Second Adjacent	D/U -14.92 dB

ELECTRONIC INDUSTRIES ASSOCIATION
Digital Audio Radio Laboratory
Engineers: RMc/DL
DATE: 2/21/95

PROJ.: RADIO CHARACTERIZATION/CONFIRMATION

* Key point measurements for comparison to Grossjean data
* Additional data with regard to audio performance VS RF level

TEST SET-UP

* Receiver: Pioneer SX-201
* Ant. Net: 50/75 ohm resistive pad (-7.8dB insertion loss)
* Audio Ref: 580mV
* Receiver in "Manual Tuning" Mode for all measurements
* Test Bed, W/Orban Stereo Gen & Harris Exciter as Signal Source
* Audio measurements made with Audio Precision as rms unweighted

FM TESTS (TEST FQ. 94.1MHZ)

S/N RATIO - 1KHZ, 100% MOD

MAX	-65dB	-62dBm	(mono)

THD - 1KHZ, 100% MOD (-50dBm)

MONO	0.64 %	
STEREO	1.37 %	(Increase due to pilot content)

LIMITING THRESHOLD (Audio -1dB)

-108dBm

HIGH CUT THRESHOLD

Audio: 10KHZ, L+R, 100% Mod, Pilot off
NA

SEPARATION @ -62dBm

Freq.	L->R	R->L	
1KHZ	-33.4dB	-34.5dB	(W/O Pre-Emph)
10KHZ	-23dB	-24.4dB	(W/O Pre-Emph)

SIGNAL, NOISE & SEPARATION VS RF LEVEL

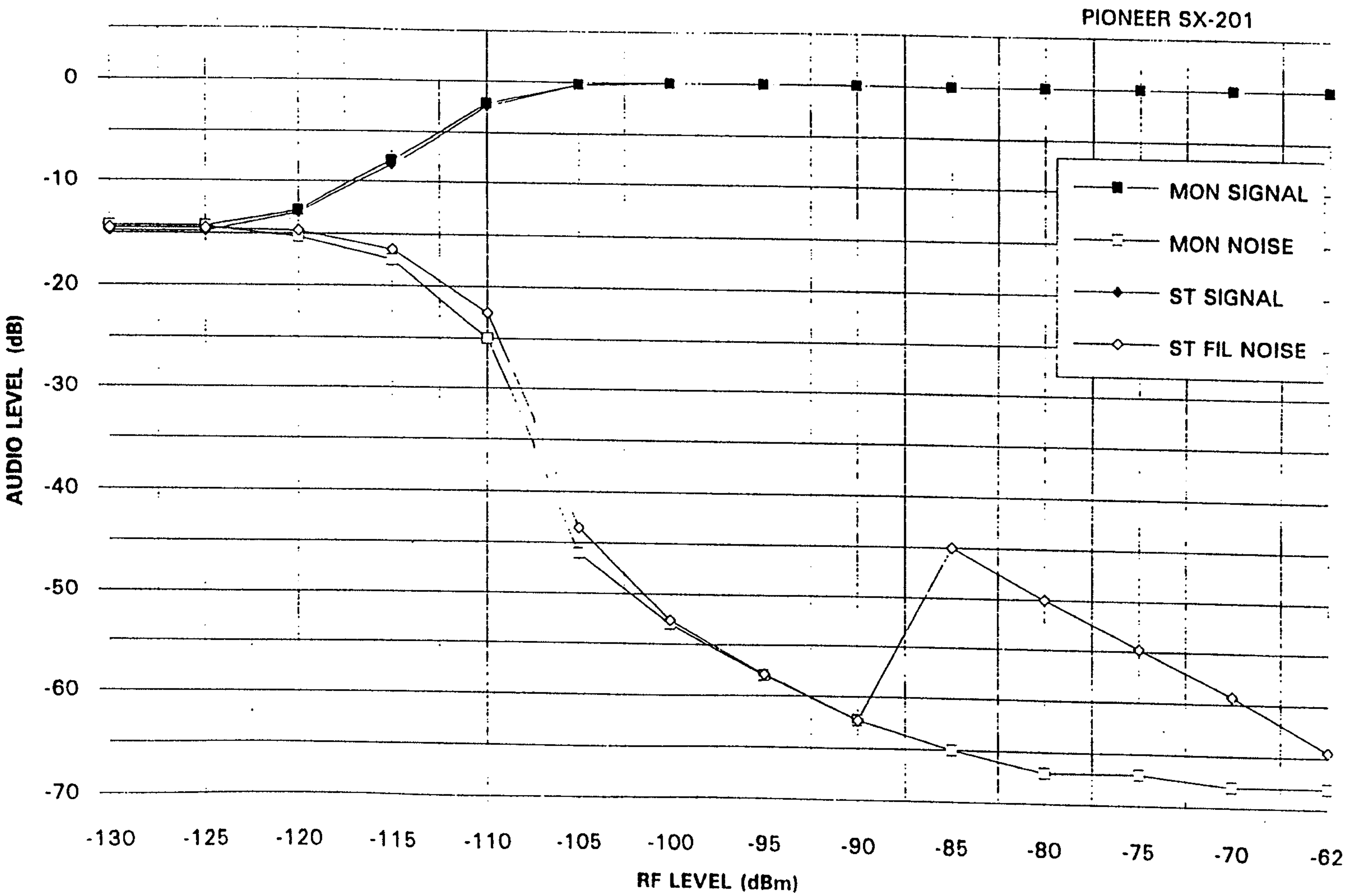
* Left channel used as the measurement channel for Signal and Noise data
* Left channel driven (L only) for separation data
* Audio test frequency = 1KHZ
* Receiver in "Manual Tuning" Mode for all measurements
* RF levels represent power into the receiver after 50/75 ohm conversion
* Filt. Noise figures represent noise measurements made with a 15khz low pass filter to reject the pilot

CURVE DATA

SIGNAL, NOISE & SEPARATION VS RF LEVEL

RF Level	mono (L)		Stereo (L)			RF Level	Separation L->R	
	Signal	Noise	Signal	Filt. Noise	Noise		Left	Right
dBm	dB	dB	dB	dB	dB	dBm	dB	dB
-130	-14.3	-14.3	-14.8	-14.5	-14.8	-130	-15	-15
-125	-14.3	-14.3	-14.8	-14.5	-14.8	-125	-15	-15
-120	-12.8	-15.3	-13	-14.7	-15	-120	-15	-14
-115	-7.8	-17.5	-8.3	-16.5	-17	-115	-13.5	-8.7
-110	-2.2	-25	-2.5	-22.5	-24	-110	-8.6	-6
-105	-0.2	-46	-0.23	-43.5	-40	-105	-6	-6
-100	0	-53	0	-52.6	-41.5	-100	-6	-6
-95	0	-58	0	-57.9	-42	-95	-6	-6
-90	0	-62.3	0	-62.3	-42	-90	-6	-6
-85	0	-65	0	-45	-39	-85	0	-33.1
-80	0	-67	0	-50	-39.8	-80	0	-33.4
-75	0	-67	0	-54.8	-40	-75	0	-33.4
-70	0	-68	0	-59.3	-40	-70	0	-33.4
-62	0	-68	0	-64.5	-40	-62	0	-33.4
-57						-57		

SIGNAL & FILTERED NOISE VS RF LEVEL



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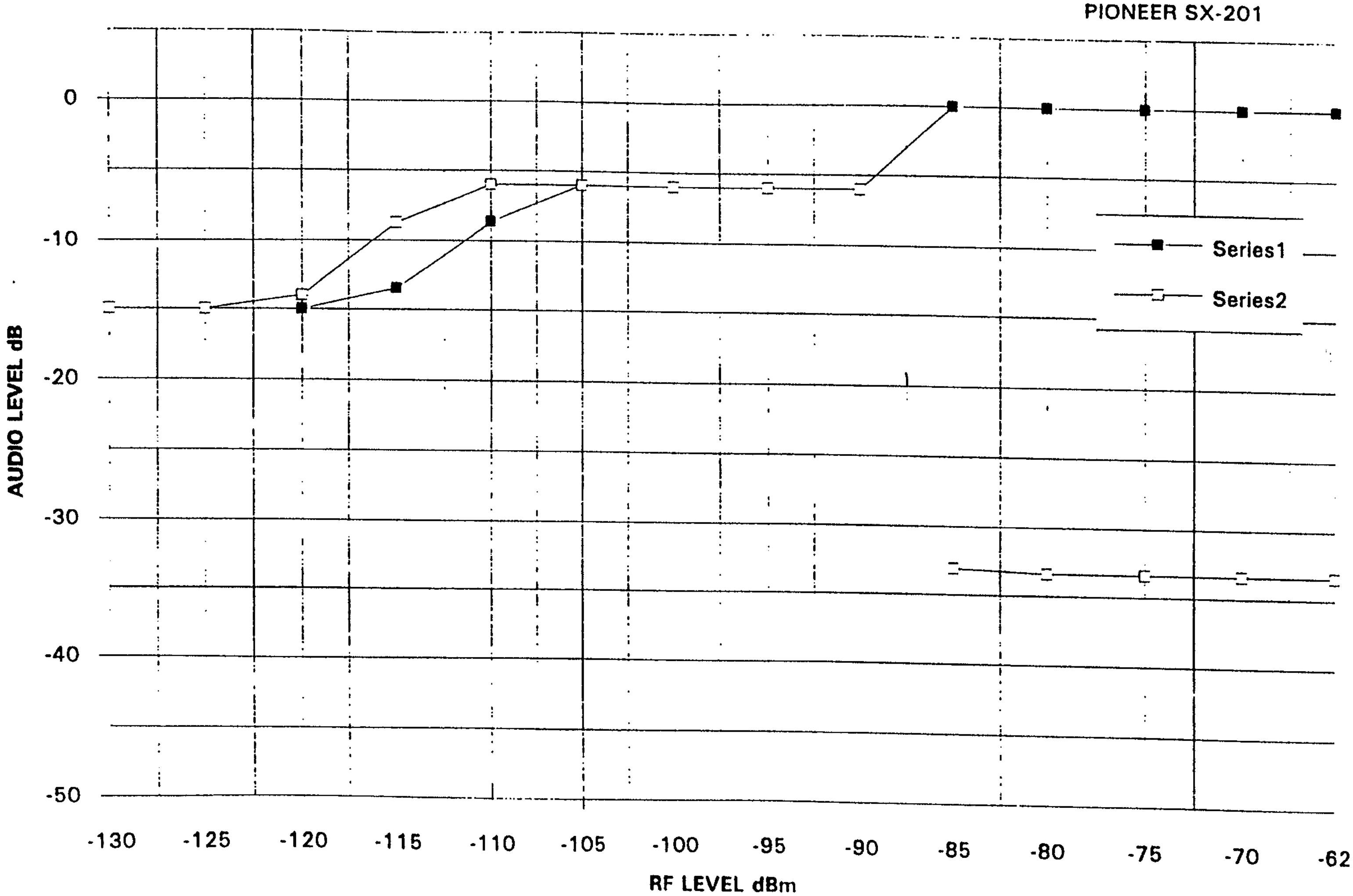
SEPARATION VS RF LEVEL



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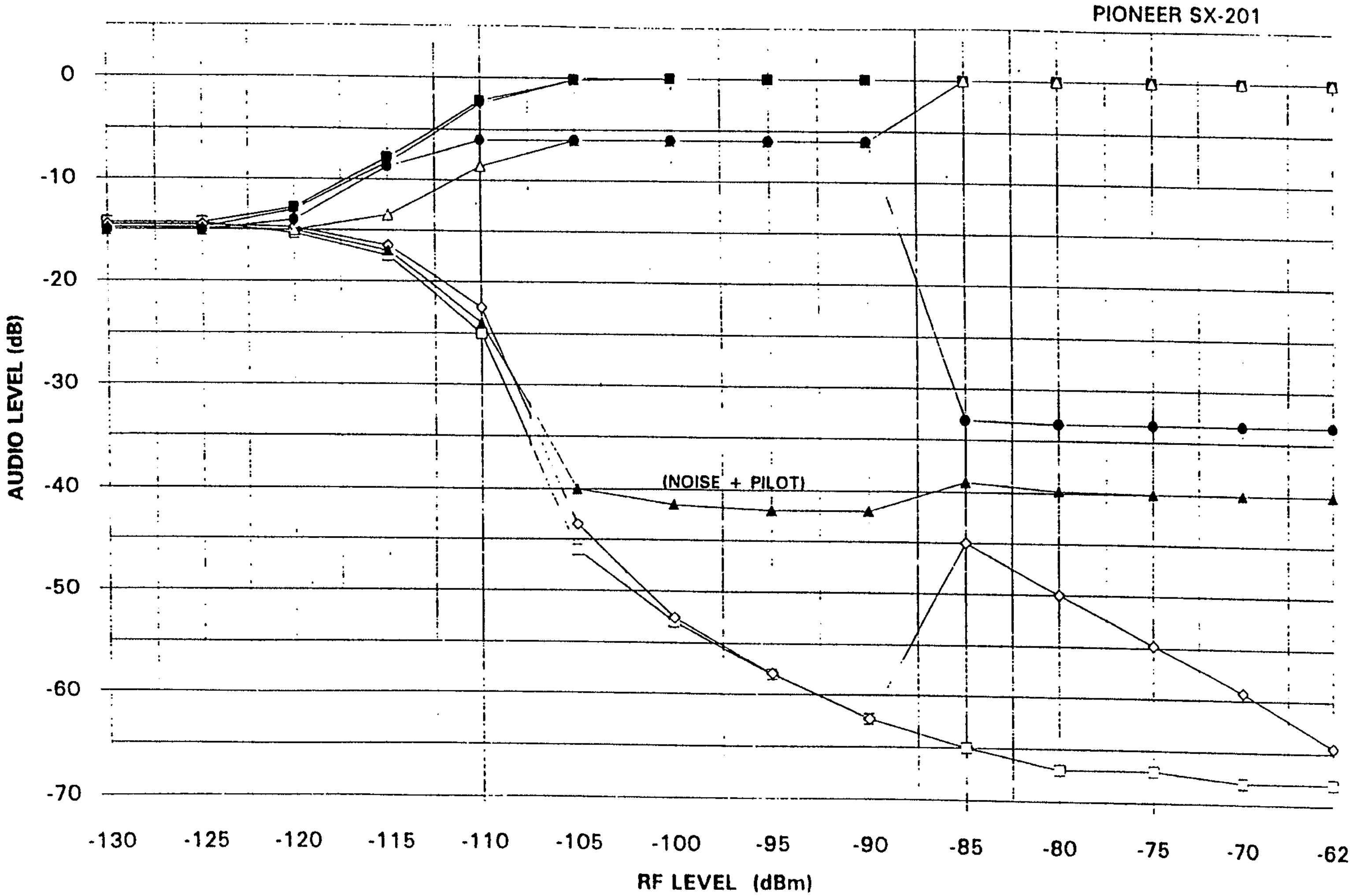
SIG., NOISE, FILT. NOISE & SEPARATION VS RF LEVEL



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FM TUNER TEST DATA

	GEN	RCVR 300Ω		RCVR
Manufacturer:	Pioneer			
Model Number:	SX-201			
Serial Number:	OA3965843C			
Type:	Home Hi-Fi			

using IEEE/IHF 10Ω,10Ω,45Ω resistive pad and balun transformer

FM 30% modulation(98.dBm levels are 300Ω balanced output level

	GEN	RCVR 300Ω		RCVR
20 dB S/N	3	3 μV	14.8 dBf	-97.4 dBm
30 dB S/N	4.4	4.4 μV	18.1 dBf	-94.1 dBm
50 dB S/N	7	7 μV	22.1 dBf	-90.1 dBm
Interstation Noise	-2	dB		
Mute start Level		μV	dBf	dBm
High cut at 10KHz	0	dB at	μV	
Fo+½IF rejection	5	5 mV	64.4 dB	
Image rejection	224	224 μV	37.5 dB	

FM 100% MODULATION MONO

Usable Senditivity	4.4	2.2 μV	18.1 dBf	-100.1 dBm
50dB S/N	14	7 μV	28.1 dBf	-90.1 dBm
Maximum S/N	75	dB		
THD %	0.33			
AM Rejection at 1mV	56	dB		

FM 100% MODULATION STEREO

Usable Sensitivity	switches to mono		dBf	dBm
50dB S/N	70	35 μV	42.1 dBf	-76.1 dBm
Maximum S/N	66	dB		
THD %	0.8			
1KHz separation	39	dB		
10KHz separation		dB		
Stero Blend action:				
separation at 50μVrec	37	dB	39.2 dBf	-73.0 dBm
67KHz SCA Rejection δF=5KHz	65	dB		
19 and 38KHzproducts	-21	dB		

FM TWO SIGNAL TESTS(98.1 MHz)

Capture Ratio	1.5	dB		
Selectivity@ 200KHz				
for 30dB S/N	6	dB		
for 50dB S/N	2.5	dB		
Selectivity@ 400KHz				
for 30dB S/N	51	dB		
for 50dB S/N	46.5	dB		
IM Rejection (98.9 and 99.7)	3	3 mV	74.8 dBf	-37.4 dBm
2MHz IM rejection (96.4 and 100.1)	8	8 mV	83.3 dBf	-28.9 dBm
IF mix rejection (96.4 and 107.1)	1.4	1.4 mV	68.1 dBf	-44.1 dBm

AM 30% MODULATION MONO

DUMMY ANTENNA: 50Ω generator replacing loop

20dB S/N	15	15 μV	-83.5 dBm
Max S/N	51	dB	
THD at max S/N	0.1	%	
THD at 80% mod	0.5	%	
-3dB Audio Response		%	
600KHz	1484		
1400KHz	1484	Hz	
±10KHz Selectivity	26	dB	
±20KHz Selectivity	38	dB	
Local AGC action:		μV	dBm
level for -3dB 600KHz desired signal reduction			
1400KHz			
10MHz		mV	dBm
27MHz		mV	dBm
IF mix rejection (1400 & 945 or 950)	10	10 mV	-26.98 dBm

DAR Lab
~~Mar 8/95~~ 15/95 PIONAVRF.XLS

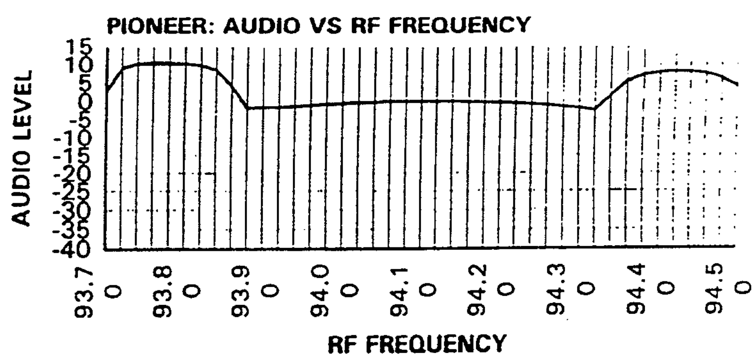
Pioneer Channel Characteristics **94.1MHZ**

Audio VS RF Frequency

Note:

- The results here represent a chacteristic receiver input signature based on sweeping the RF signal through the desired channel
- The test signal is modulated with 1khz @ 100%
- The measurements are made using 15khz low pass and CCIR filters with quasi-peak detection
- RF level is -62dBm

RF FREQ.	AUDIO LEVEL	
93.70	2.75	
93.72	9	
93.74	10.4	
93.76	10.66	
93.78	10.63	
93.80	10.4	
93.82	9.88	
93.84	8.52	
93.86	4.12	
93.88	-1.76	
93.90	-1.62	
93.92	-1.52	
93.94	-1.3	
93.96	-1.05	
93.98	-0.81	
94.00	-0.6	
94.02	-0.41	
94.04	-0.26	
94.06	0	
94.08	0	
94.10	**0**	**Tuning Frequency**
94.12	0	
94.14	0	
94.16	-0.13	
94.18	-0.24	
94.20	-0.39	
94.22	-0.57	
94.24	-0.78	
94.26	-1.07	
94.28	-1.43	
94.30	-1.88	
94.32	-2.5	
94.34	1.54	
94.36	5.32	
94.38	7	
94.40	7.7	
94.42	8	
94.44	7.9	
94.46	7.5	
94.48	6.2	
94.50	4	



DAR Lab
Mar 8/95 PIONUP1.XLS
RMc

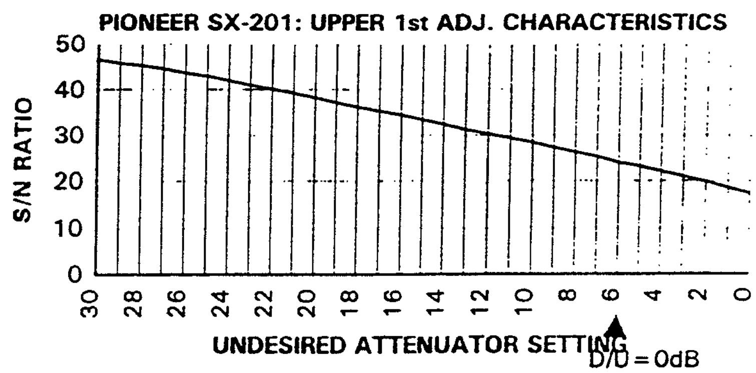
Pioneer Adjacent Channel Characteristics

Upper first adj. channel 94.3mhz

Note:

* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
* The interfering signal is modulated with clipped pink noise
* SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35		
34		
33		
32		
31		
30	46.6	
29	45.8	
28	45.3	
27	44.6	
26	43.7	
25	43	
24	42	
23	41	
22	40.2	
21	39.3	
20	38.3	
19	37.3	
18	36.3	
17	35.4	
16	34.5	
15	33.5	
14	32.5	
13	31.3	
12	30.4	
11	29.4	
10	28.4	
9	27.3	
8	26.3	
7	25.3	
6	24	D/U=0dB
5	23.2	
4	22.1	
3	21	
2	19.9	
1	18.6	
0	17.4	



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Mar 8/95

PIONLOW2.XLS

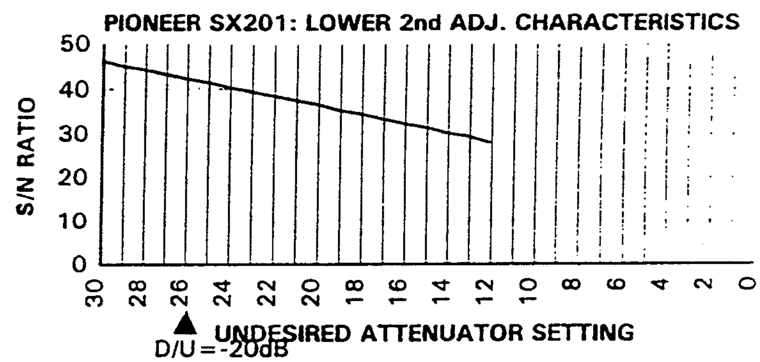
Pioneer SX201 Adjacent Channel Characteristics

Lower second adj. channel 93.7mhz

Note:

- The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
- The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
- The interfering signal is modulated with clipped pink noise
- SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35	49.9	
34	49.2	
33	48.5	
32	47.8	
31	47	
30	46.2	
29	45	
28	44.3	
27	43.3	
26	**42.3**	**D/U=-20dB**
25	41.5	
24	40.4	
23	39.4	
22	38.5	
21	37.5	
20	36.6	
19	35.3	
18	34.5	
17	33.4	
16	32.3	
15	31.4	
14	30.2	
13	29.3	
12	27.9	
11		
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		
0		



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DAR Lab
Mar 13/95

PIONUP2.XLS

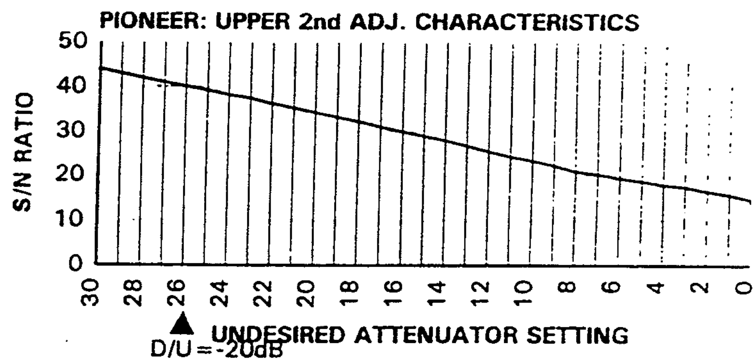
PIONEER SX-201 Adjacent Channel Characteristics

Upper second adj. channel 94.5mhz

Note:

- The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
- The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection
- The interfering signal is modulated with clipped pink noise
- SCA's (group B) are employed on both the desired and the undesired signals.

UNDES. ATTEN.	RADIO S/N (dB)	
40		
39		
38		
37		
36		
35	47.5	
34	46.9	
33	46.1	
32	45.3	
31	44.6	
30	44	
29	43	
28	42	
27	41	
26	**40.1**	**D/U=-20dB**
25	39.3	
24	38.2	
23	37.5	
22	36.3	
21	35.4	
20	34.3	
19	33.3	
18	32.3	
17	31.1	
16	30	
15	29	
14	28	
13	26.8	
12	25.5	
11	24.3	
10	23.3	
9	22.2	
8	20.9	
7	20.2	
6	19.3	
5	18.6	
4	17.8	
3	17.3	
2	16.3	
1	15.6	
0	14.6	



Ford

#5

Digital Radio Test Laboratory

ngineer(s): DML
Date: 8/27/96
Print Date: 1/6/97

PROJECT: RECEIVER CHARACTERIZATION

Radio Mfg.: Ford RX # 8
Model No.: F5XF-19B132-CA
Serial No.: VFCH 108443

FM TESTS (TEST FREQ. 94.1MHz)

TEST SET-UP
Ant. Net: None
Audio Ref: 2.0Vrms Load Imp = 8 Ω
Rec. set up: Fader & Balance-Centered

Test bed: Test Bed, W/Orban Stereo Gen & Harris Exciter as Signal Source
Meas.: Audio measurements made with Audio Precision as rms unweighted

S/N RATIO - 1KHZ, 100% MOD (-50 dBm)

MAX	68.5 dB	(mono)
	66.0 dB	(stereo)

THD - 1KHZ, 100% MOD (-50dBm)

	0.84 %	(mono)
	0.70 %	(stereo)

LIMITING THRESHOLD (Audio -1dB)
-83 dBm

HIGH CUT THRESHOLD
Audio: 10KHZ, L+R, 100% Mod, Pilot off
-3dB = -79 dBm

SEPARATION @ -62dBm

Freq.	L->R	
1KHZ	dB	(W/O Pre-Emph)
10KHZ	dB	(W/O Pre-Emph)

SIGNAL, NOISE & SEPARATION VS RF LEVEL
* Left channel used as the measurement channel for Signal and Noise data
* Left channel driven (L only) for separation data
* Audio test frequency = 1KHZ
* RF levels represent power into the dummy antenna
* Filered Noise represents noise measurements made with a 15 kHz low pass filter to reject the pilot

CURVE DATA

SIGNAL, NOISE & SEPARATION VS RF LEVEL

	mono (L)		Stereo (L)				Separation L->R	
RF Level	Signal	Noise	Signal	Filt. Noise	Noise	RF Level	Left	Right

Digital Radio Test Laboratory

dBm	dB	dB	dB	dB	dB	dBm	dB	dB
-130	-32.50	-33.00	-32.50	-33.00	-33.00	**-130**	-32.00	-32.00
-125	-32.70	-33.00	-32.50	-33.00	-33.00	**-125**	-32.20	-32.20
-120	-33.00	-33.00	-33.00	-33.00	-33.00	**-120**	-32.20	-32.00
-115	-32.50	-33.00	-32.50	-33.00	-33.00	**-115**	-32.00	-32.00
-110	-28.00	-34.00	-28.00	-34.00	-34.00	**-110**	-29.90	-30.00
-105	-18.20	-37.50	-18.50	-37.50	-37.30	**-105**	-21.50	-21.50
-100	-5.30	-45.00	-5.50	-45.00	-44.70	**-100**	-8.80	-8.90
-95	-2.10	-54.00	-2.14	-55.20	-54.00	**-95**	-7.05	-7.10
-90	-1.54	-58.20	-1.57	-59.40	-58.00	**-90**	-6.56	-6.64
-85	-1.15	-61.70	-1.18	-62.70	-61.50	**-85**	-6.13	-6.33
-80	-0.81	-64.20	-0.84	-64.50	-63.50	**-80**	-5.70	-6.15
-75	-0.55	-66.10	-0.57	-65.50	-64.30	**-75**	-5.22	-6.20
-70	-0.34	-67.00	-0.37	-65.50	-63.70	**-70**	-4.60	-6.50
-62	-0.13	-67.50	-0.15	-65.50	-60.00	**-62**	-3.00	-8.60
-60	-0.10	-67.70	-0.12	-65.50	-58.80	**-60**	-2.50	-9.60
-55	0.00	-67.40	0.00	-66.00	-56.50	**-55**	-1.22	-13.20
-50	0.00	-67.40	0.00	-66.00	-54.80	**-50**	-0.43	-17.10
-45	0.00	-67.40	0.00	-65.50	-52.60	**-45**	0.00	-20.40

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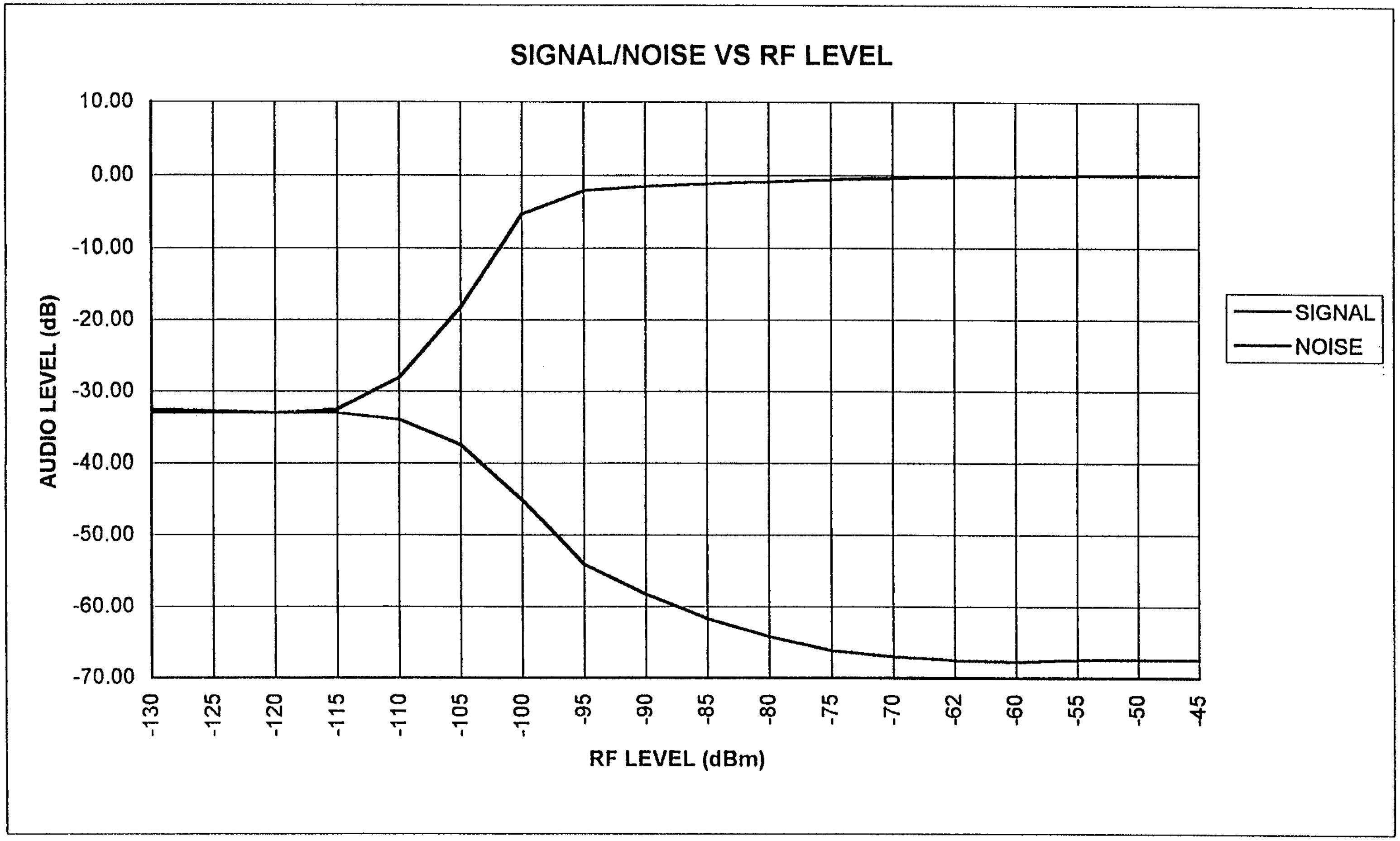
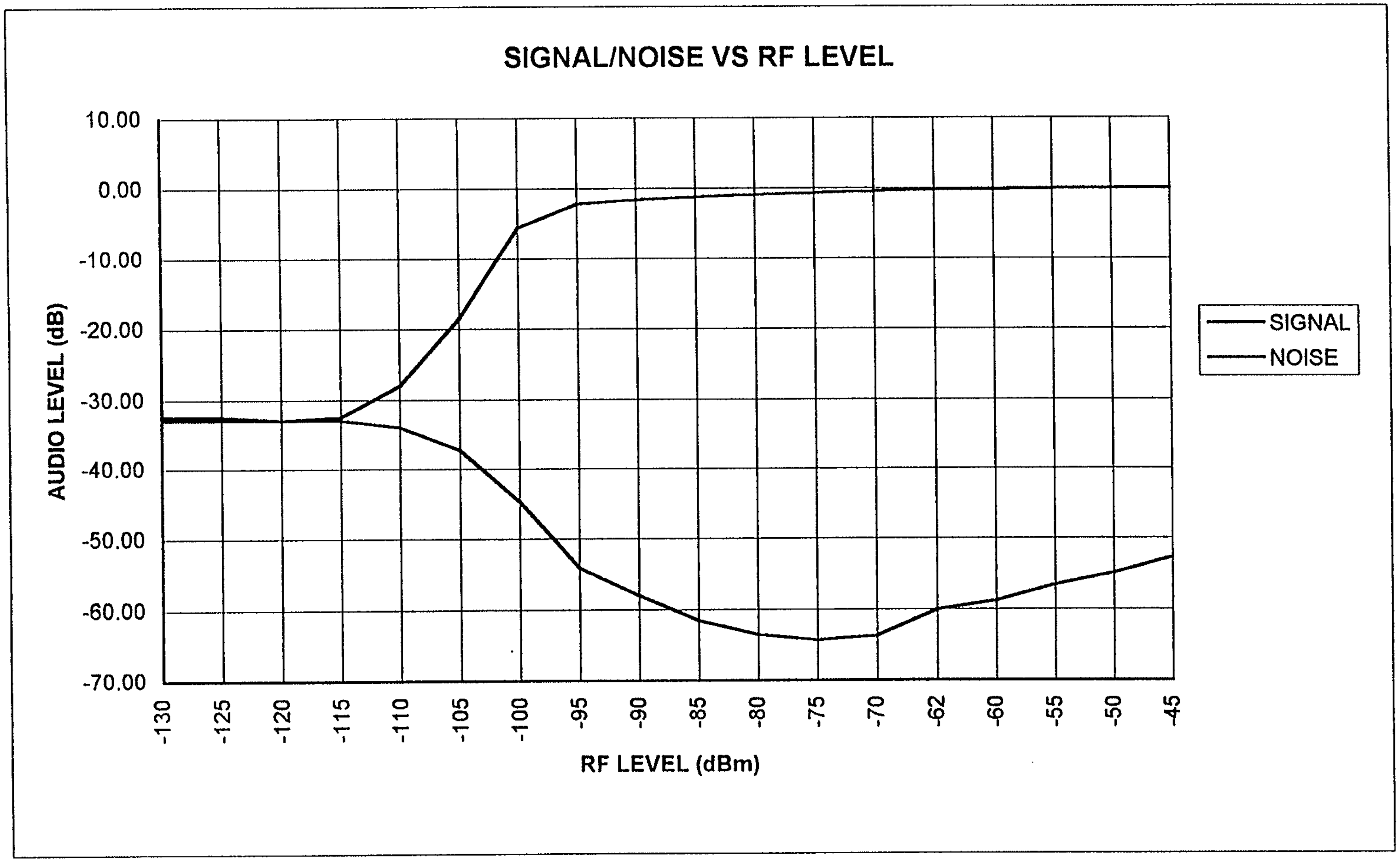
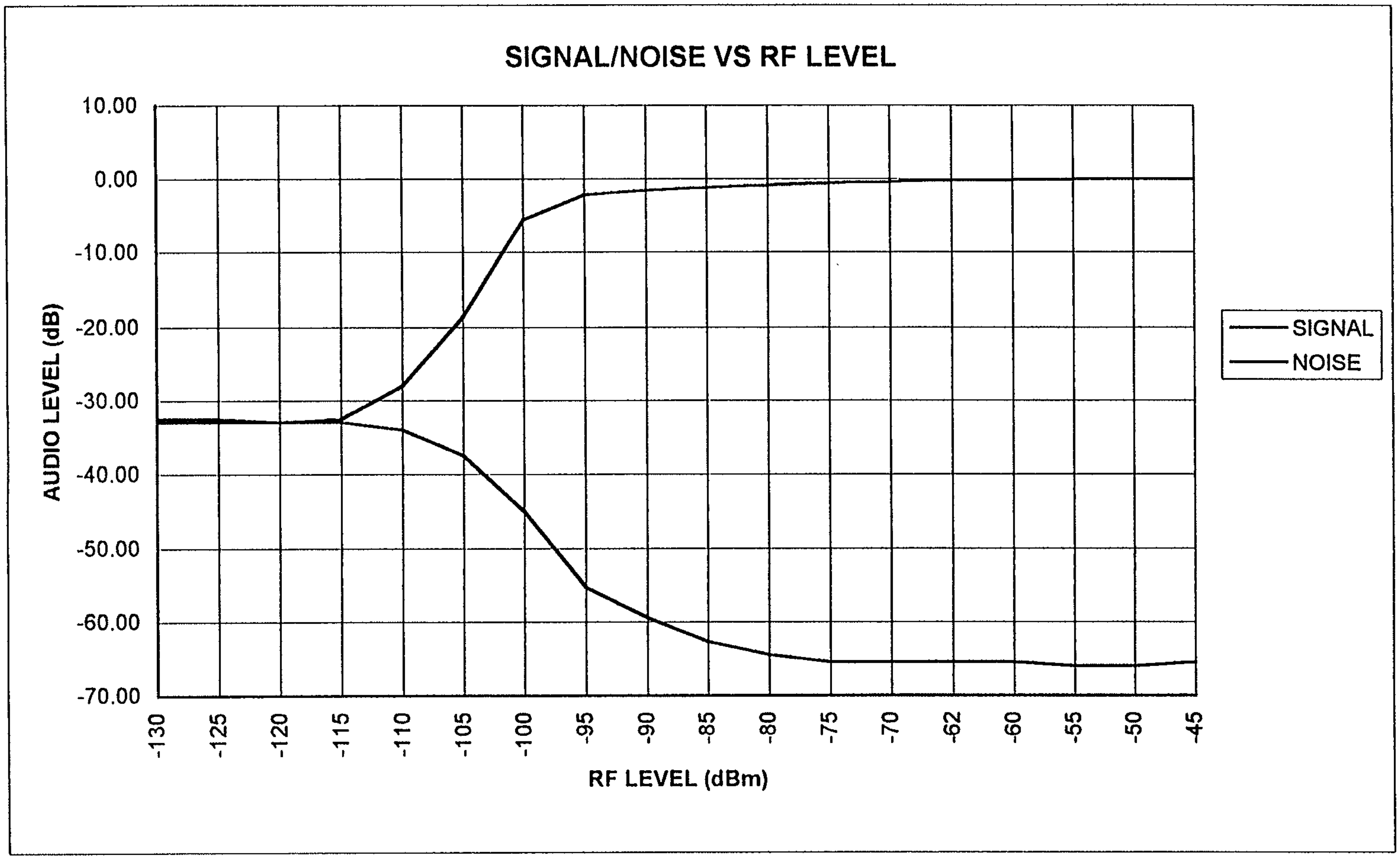
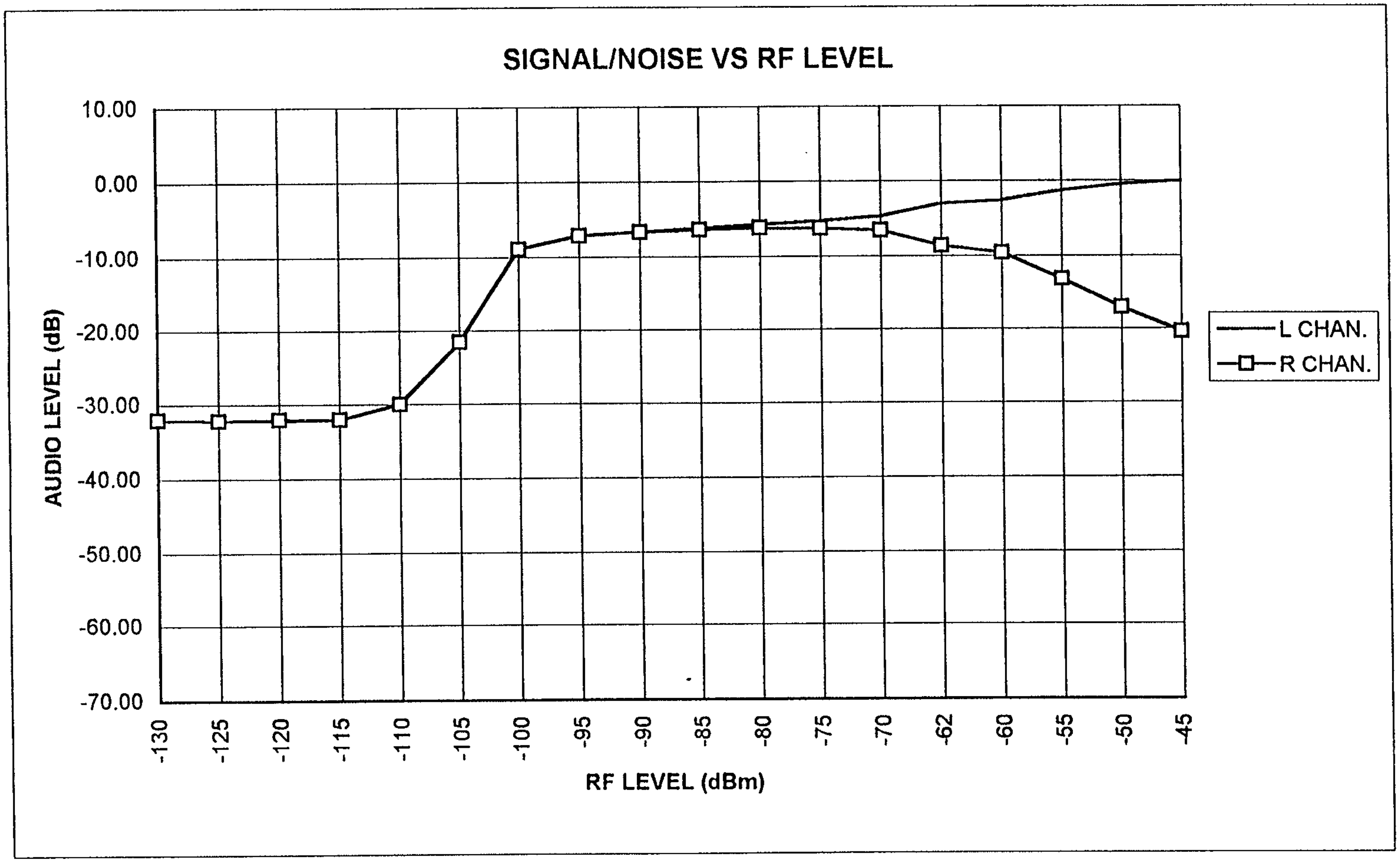
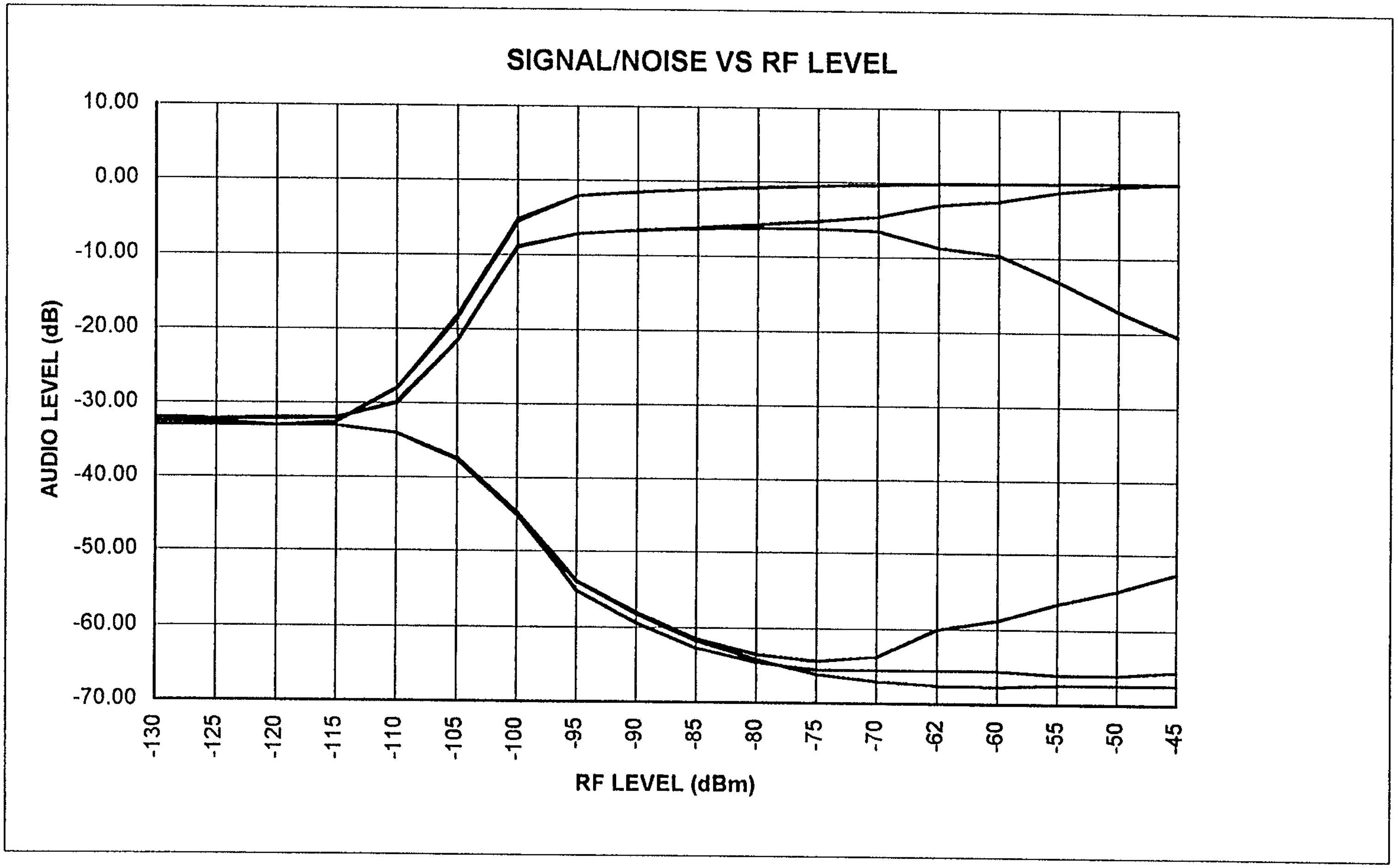



SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
SIGNAL
NOISE


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
SIGNAL
NOISE


SIGNAL/NOISE VS RF LEVEL
AUDIO LEVEL (dB)
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)
L CHAN.
R CHAN.


SIGNAL/NOISE VS RF LEVEL
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
AUDIO LEVEL (dB)
-130
-125
-120
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
-62
-60
-55
-50
-45
RF LEVEL (dBm)

Digital Radio Test Laboratory

First Adjacent Channel Characteristics

Date: 8/27/96
Engineer(s): DML

Desired Frequency: 94.1 MHz
Operating Level: 62.0 dBm
Lower First Adjacent: 93.9 MHz

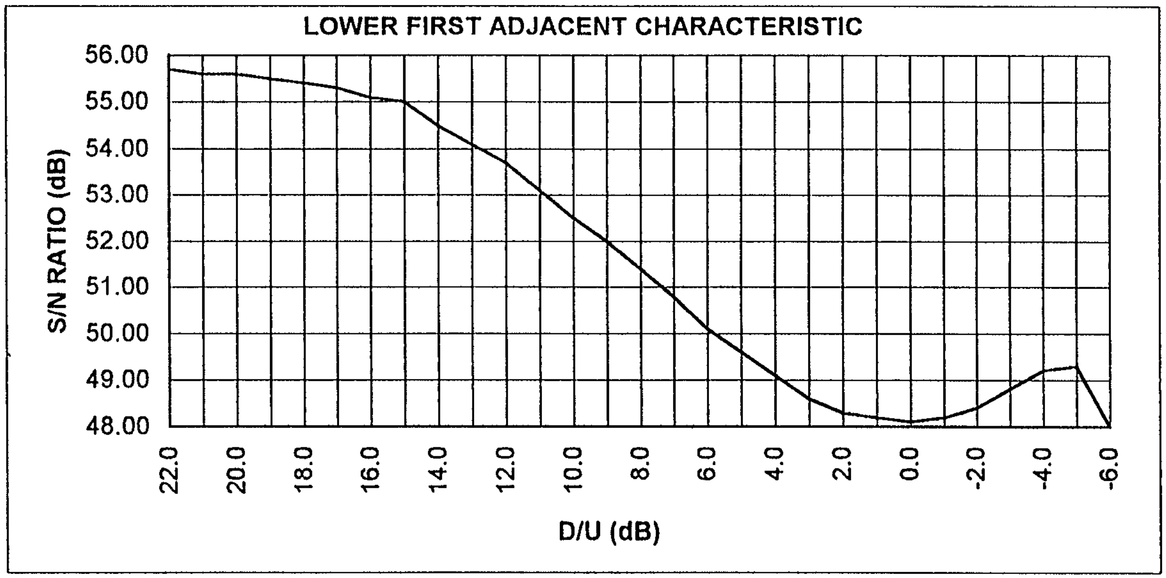
Note:
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).

D/U (dB)	S/N (dB)	Undesired ttenuation
22.0	55.70	50.00
21.0	55.60	49.00
20.0	55.60	48.00
19.0	55.50	47.00
18.0	55.40	46.00
17.0	55.30	45.00
16.0	55.10	44.00
15.0	55.00	43.00
14.0	54.50	42.00
13.0	54.10	41.00
12.0	53.70	40.00
11.0	53.10	39.00
10.0	52.50	38.00
9.0	52.00	37.00
8.0	51.40	36.00
7.0	50.80	35.00
6.0	50.10	34.00
5.0	49.60	33.00
4.0	49.10	32.00
3.0	48.60	31.00
2.0	48.30	30.00
1.0	48.20	29.00
0.0	48.10	28.00
-1.0	48.20	27.00
-2.0	48.40	26.00

0dB D/U Calibration Details

Output Attenuator:	17 dB
Input Attenuator:	2.5 dB (Desired sig.)
"Co-Chan." Attenuator:	28 dB (Undesired sig.)
Desired Ch. Output Level:	-62 dBm
Key Point Meas.	-6.99 dBm (Desired sig.)

-3.0	48.80	25.00
-4.0	49.20	24.00
-5.0	49.30	23.00
-6.0	48.00	22.00



Digital Radio Test Laboratory

First Adjacent Channel Characteristics

Date: 8/27/96
Engineer(s): DML

Desired Frequency: 94.1 MHz
Operating Level: 62.0 dBm
Upper First Adjacent: 94.3 MHz

Note:

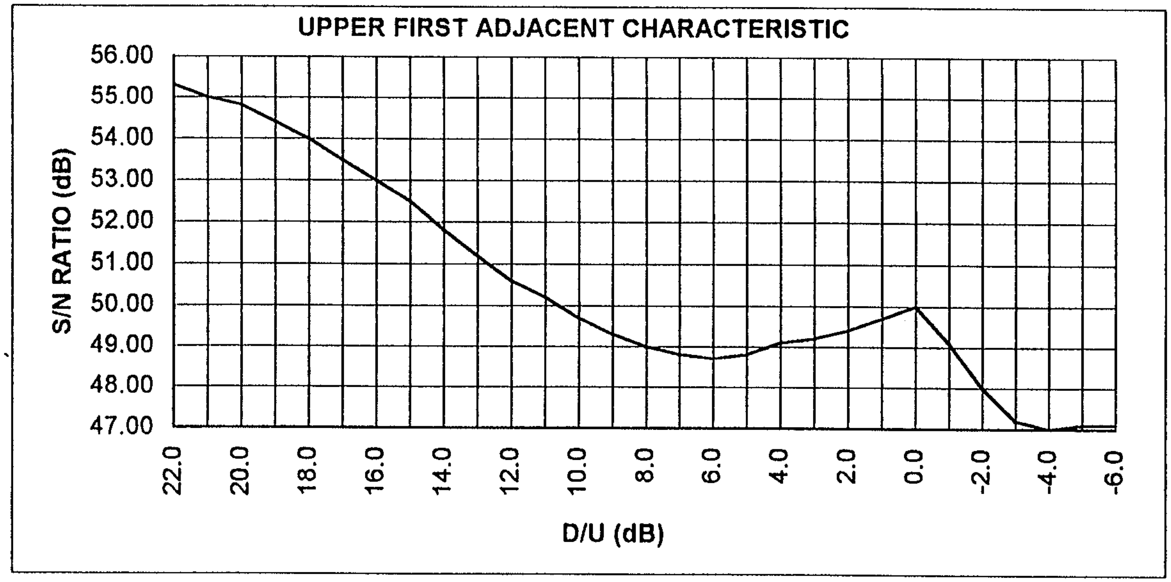
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).

D/U (dB)	S/N (dB)	Undesired ttenuation
22.0	55.30	50.00
21.0	55.00	49.00
20.0	54.80	48.00
19.0	54.40	47.00
18.0	54.00	46.00
17.0	53.50	45.00
16.0	53.00	44.00
15.0	52.50	43.00
14.0	51.80	42.00
13.0	51.20	41.00
12.0	50.60	40.00
11.0	50.20	39.00
10.0	49.70	38.00
9.0	49.30	37.00
8.0	49.00	36.00
7.0	48.80	35.00
6.0	48.70	34.00
5.0	48.80	33.00
4.0	49.10	32.00
3.0	49.20	31.00
2.0	49.40	30.00
1.0	49.70	29.00
0.0	50.00	28.00
-1.0	49.10	27.00
-2.0	48.00	26.00

0dB D/U Calibration Details

Output Attenuator:	17 dB	
Input Attenuator:	2.5 dB	(Desired sig.)
"Co-Chan." Attenuator:	28 dB	(Undesired sig.)
Desired Ch. Output Level:	-62 dBm	
Key Point Meas.	-6.99 dBm	(Desired sig.)

-3.0	47.20	25.00
-4.0	47.00	24.00
-5.0	47.10	23.00
-6.0	47.10	22.00



Second Adjacent Channel Characteristics

Date: 8/27/96
Engineer(s): DML

Desired Frequency: 94.1 MHz
Operating Level: 62.0 dBm
Lower Second Adjacent: 93.7 MHz

Note:

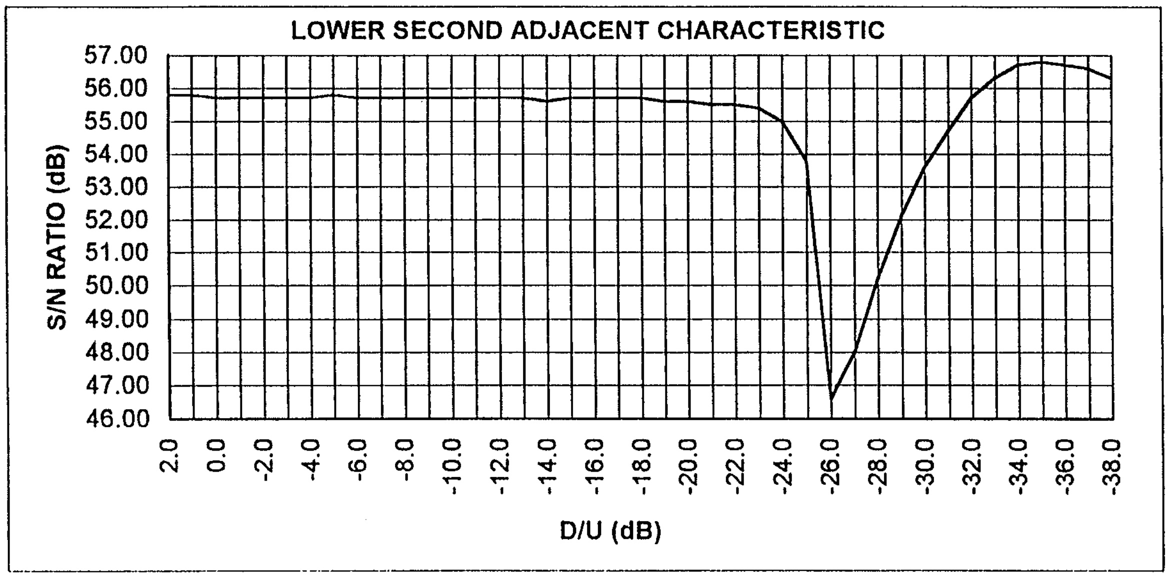
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).

D/U (dB)	S/N (dB)	Undesired ttenuation
2.0	55.80	40.00
1.0	55.80	39.00
0.0	55.70	38.00
-1.0	55.70	37.00
-2.0	55.70	36.00
-3.0	55.70	35.00
-4.0	55.70	34.00
-5.0	55.80	33.00
-6.0	55.70	32.00
-7.0	55.70	31.00
-8.0	55.70	30.00
-9.0	55.70	29.00
-10.0	55.70	28.00
-11.0	55.70	27.00
-12.0	55.70	26.00
-13.0	55.70	25.00
-14.0	55.60	24.00
-15.0	55.70	23.00
-16.0	55.70	22.00
-17.0	55.70	21.00
-18.0	55.70	20.00
-19.0	55.60	19.00
-20.0	55.60	18.00
-21.0	55.50	17.00
-22.0	55.50	16.00

0dB D/U Calibration Details

Output Attenuator:	7 dB	
Input Attenuator:	12.5 dB	(Desired sig.)
"Co-Chan." Attenuator:	38 dB	(Undesired sig.)
Desired Ch. Output Level:	-62 dBm	
Key Point Meas.	-17 dBm	(Desired sig.)

-23.0	55.40	15.00
-24.0	55.00	14.00
-25.0	53.80	13.00
-26.0	46.60	12.00
-27.0	48.00	11.00
-28.0	50.20	10.00
-29.0	52.10	9.00
-30.0	53.60	8.00
-31.0	54.70	7.00
-32.0	55.70	6.00
-33.0	56.30	5.00
-34.0	56.70	4.00
-35.0	56.80	3.00
-36.0	56.70	2.00
-37.0	56.60	1.00
-38.0	56.30	0.00



Second Adjacent Channel Characteristics Date: 8/27/96

Desired Frequency: 94.1 MHz Engineer(s): DML
Operating Level: 62.0 dBm
Upper Second Adjacent: 94.5 MHz

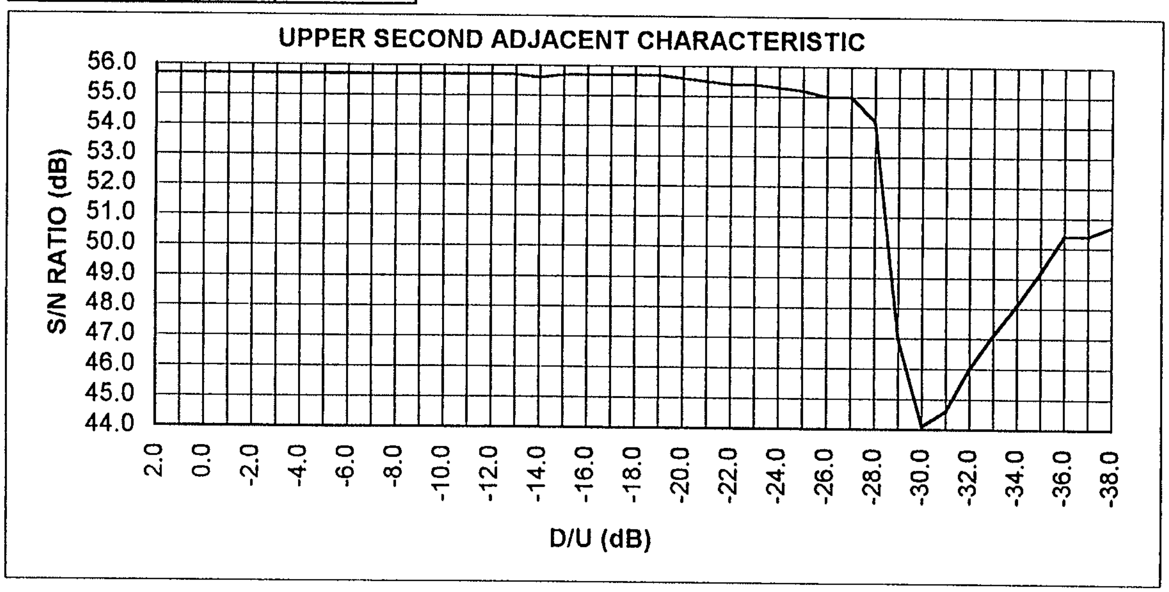
Note:
* The results here represent a chacteristic receiver input signature based on ramping the undesired signal up in 1dB increments and recording the signal to noise ratio.
* The measurements are made using a 15khz low pass and CCIR filters with quasi-peak detection.
* The interfering signal is modulated with clipped pink noise at 100% modulation (no pilot).

D/U (dB)	S/N (dB)	Undesired ttenuation
2.0	55.7	40.00
1.0	55.7	39.00
0.0	55.7	38.00
-1.0	55.7	37.00
-2.0	55.7	36.00
-3.0	55.7	35.00
-4.0	55.7	34.00
-5.0	55.7	33.00
-6.0	55.7	32.00
-7.0	55.7	31.00
-8.0	55.7	30.00
-9.0	55.7	29.00
-10.0	55.7	28.00
-11.0	55.7	27.00
-12.0	55.7	26.00
-13.0	55.7	25.00
-14.0	55.6	24.00
-15.0	55.7	23.00
-16.0	55.7	22.00
-17.0	55.7	21.00
-18.0	55.7	20.00
-19.0	55.7	19.00
-20.0	55.6	18.00
-21.0	55.5	17.00
-22.0	55.4	16.00

0dB D/U Calibration Details

Output Attenuator:	7 dB	
Input Attenuator:	12.5 dB	(Desired sig.)
"Co-Chan." Attenuator:	38 dB	(Undesired sig.)
Desired Ch. Output Level:	-62 dBm	
Key Point Meas.	-17 dBm	(Desired sig.)

-23.0	55.4	15.00
-24.0	55.3	14.00
-25.0	55.2	13.00
-26.0	55.0	12.00
-27.0	55.0	11.00
-28.0	54.2	10.00
-29.0	47.0	9.00
-30.0	44.1	8.00
-31.0	44.6	7.00
-32.0	46.0	6.00
-33.0	47.1	5.00
-34.0	48.1	4.00
-35.0	49.2	3.00
-36.0	50.4	2.00
-37.0	50.4	1.00
-38.0	50.7	0.00

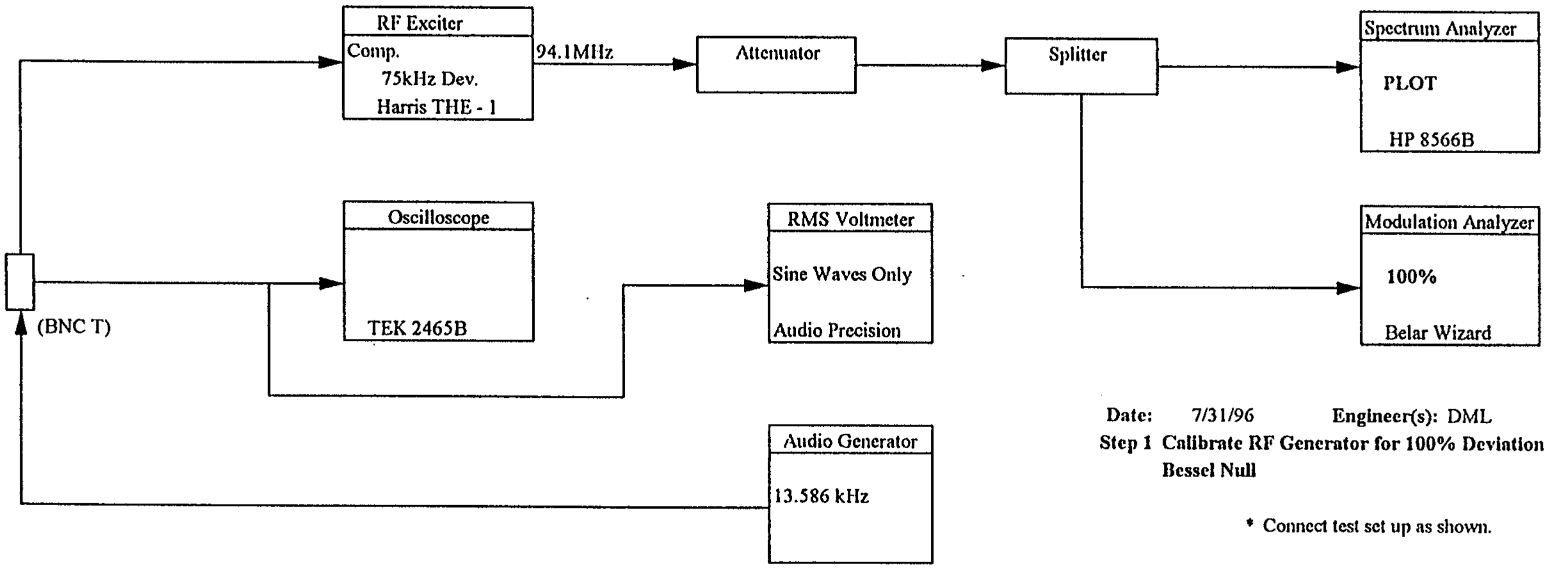


450

Appendix E

SUBCARRIER INJECTION CALIBRATION

Digital Radio Test Laboratory



Date: 7/31/96 **Engineer(s):** DML

Step 1 Calibrate RF Generator for 100% Deviation Bessel Null

* Connect test set up as shown.
* Set audio generator to 13.586KHz.
* If applicable, fix RF generator modulation input sensitivity to known state (Boonton).
* Set audio generator output level for second null (100%) 11 significant sidebands.
* Measure and record the signal voltage levels both as Vpp and RMS.
* Measure and record modulation meter reading
* Plot spectrum analyzer display.

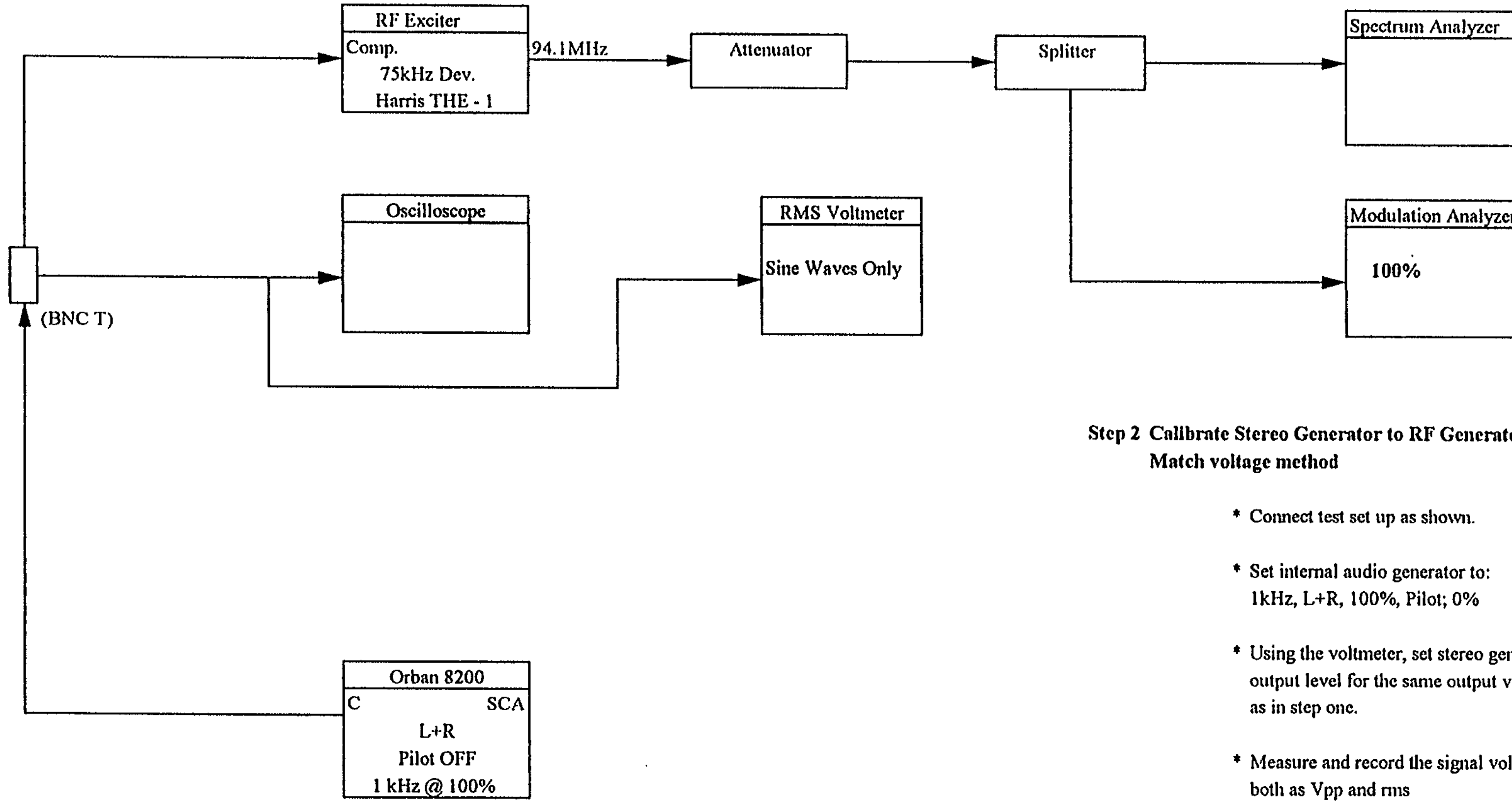
Establishes 100% reference and basic Modulation Monitor accuracy

MEASUREMENTS

Composite

STEP	Vpp	Vrms	Mod.%	Notes
1	2.85	0.994	100	This step includes plot

Digital Radio Test Laboratory



Step 2 Calibrate Stereo Generator to RF Generator for 100%
Match voltage method

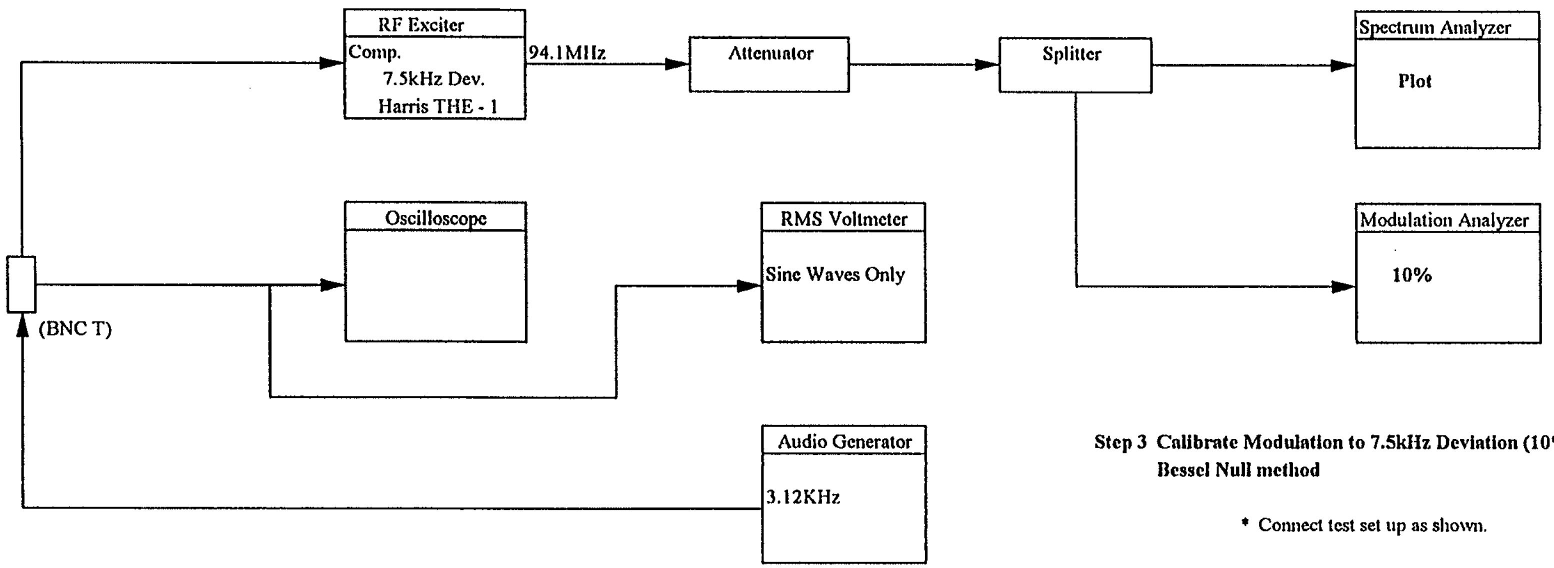
* Connect test set up as shown.
* Set internal audio generator to:
  1kHz, L+R, 100%, Pilot; 0%
* Using the voltmeter, set stereo generator output level for the same output voltage as in step one.
* Measure and record the signal voltage levels both as Vpp and rms
* Measure and record modulation meter reading

Calibrates Stereo Generator for 100% traceable to Bessel null

MEASUREMENTS

Composite

STEP	Vpp	Vrms	Mod.%	Notes
1	2.85	0.994	100	This step includes plot
2	2.85	0.998	100	



Step 3 Calibrate Modulation to 7.5kHz Deviation (10%)
Bessel Null method

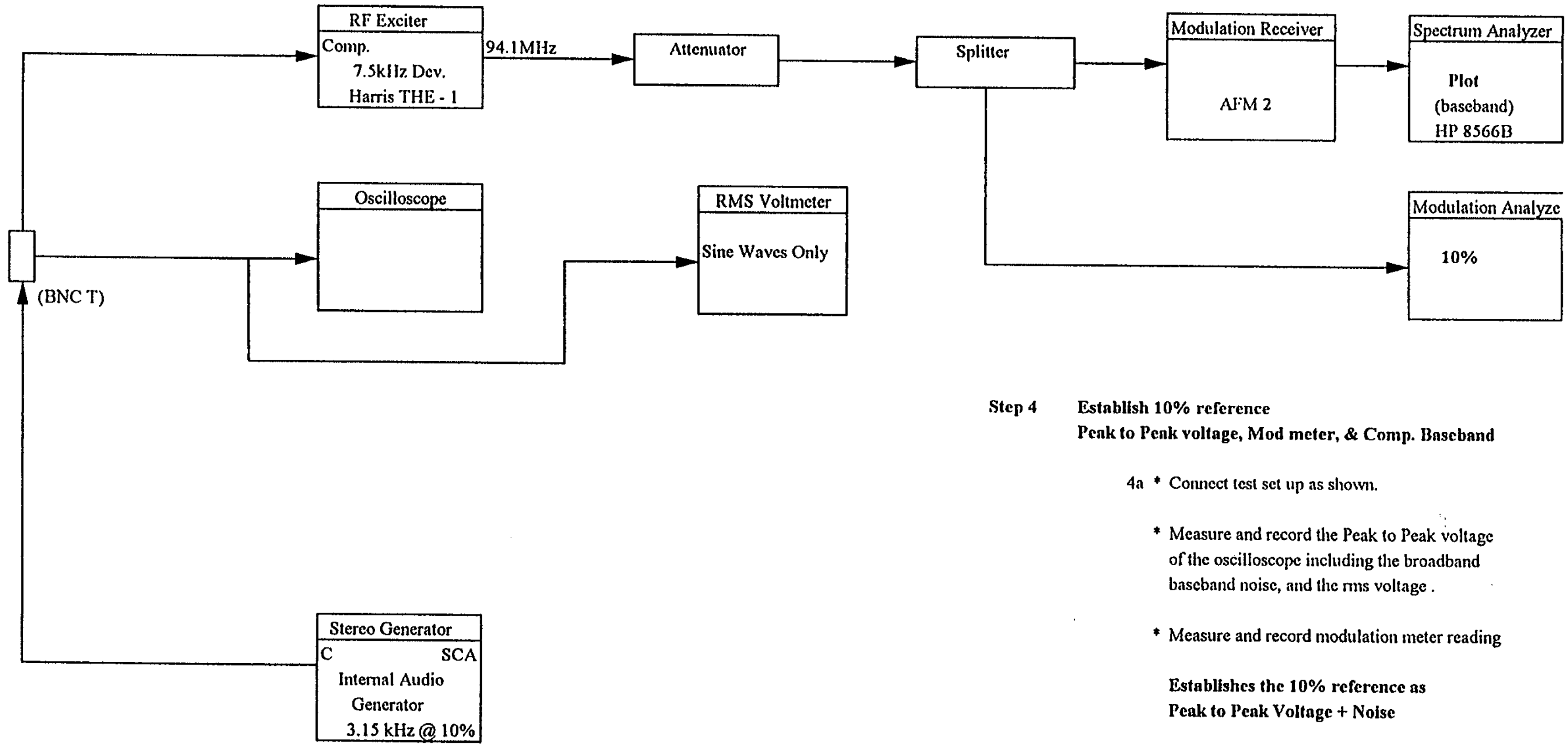
- Connect test set up as shown.
- Set audio generator to 3.119 kHz.
- Adjust audio generator output level for first null (10%).
- Measure and record the signal voltage levels both as Vpp and rms
- Measure and record modulation meter reading
- Plot spectrum analyzer display.

Ensures modulation monitor linearity

MEASUREMENTS

Composite

STEP	Vpp	Vrms	Mod.%	Notes
1	2.850	0.994	100	This step includes plot
2	2.850	0.998	100	
3	0.285	0.1008	11	This step includes plot



Step 4 Establish 10% reference
Peak to Peak voltage, Mod meter, & Comp. Baseband

4a * Connect test set up as shown.

* Measure and record the Peak to Peak voltage of the oscilloscope including the broadband baseband noise, and the rms voltage .

* Measure and record modulation meter reading

Establishes the 10% reference as Peak to Peak Voltage + Noise

4b * Increase 3.15 kHz level to 100% and calibrate 0dB on spectrum analyzer baseband signal

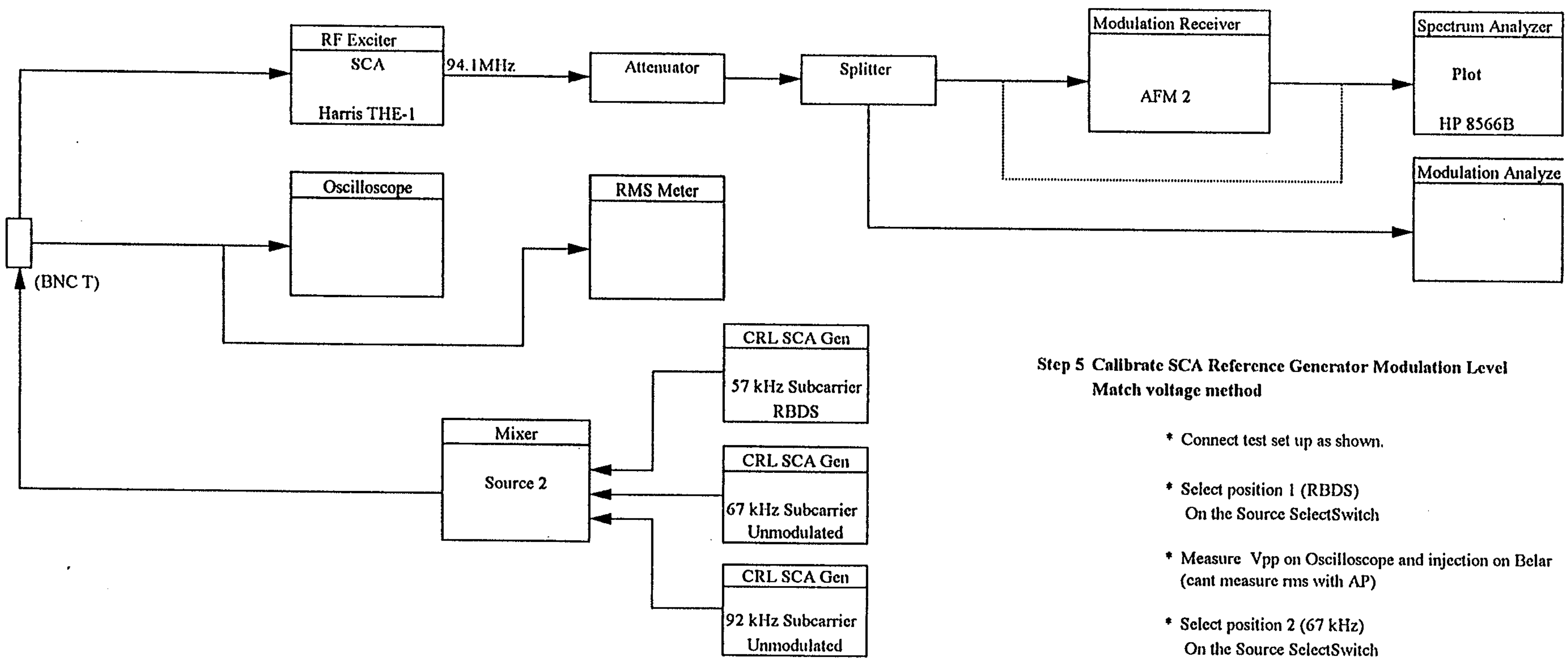
* Turn off 3.15 kHz signal and turn on Pilot at 9%
Measure and record modulation level
Plot baseband spectrum

Establishes the Pilot signal as a spectral reference

MEASUREMENTS

Composite

STEP	Vpp	Vrms	Mod.%	Notes
1	2.850	0.994	100	This step includes plot
2	2.850	0.998	100	
3	0.285	0.1008	11	This step includes plot
4a	0.285	0.100	11	3.15 kHz Vpp reading is: Vpp + noise
4b	0.275	0.080	10	19 kHz Vpp reading is: Vpp + noise



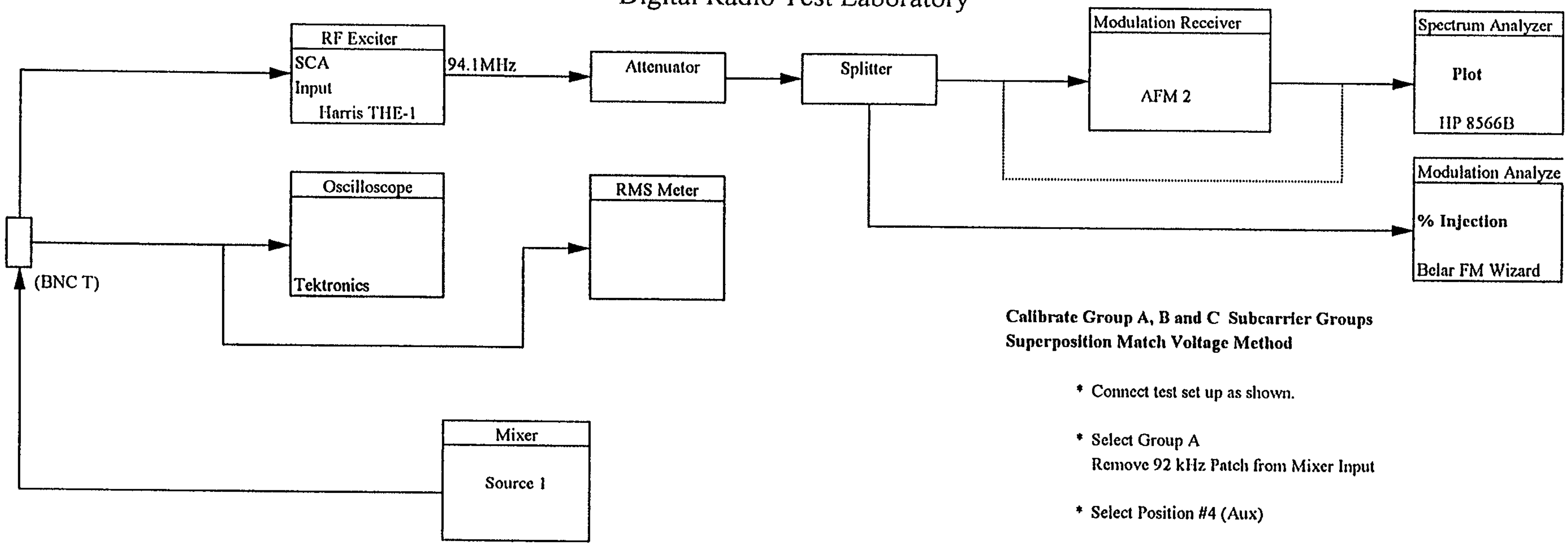
Step 5 Calibrate SCA Reference Generator Modulation Level
Match voltage method

* Connect test set up as shown.
* Select position 1 (RBDS)
  On the Source SelectSwitch
* Measure Vpp on Oscilloscope and injection on Belar
  (cant measure rms with AP)
* Select position 2 (67 kHz)
  On the Source SelectSwitch
* Measure Vpp on Oscilloscope, injection on Belar
  and Vrms on AP
  (must select Low Pass with fc=500 kHz)
* Repeat last 2 steps with position 3 (92 kHz)
* Plot baseband spectrum

MEASUREMENTS

	Composite			Harris SCA IN		
STEP	Vpp	Vrms	Mod.%	Vpp	Vrms	Notes
1	2.85	0.994	100	NA	NA	This step includes plot
2	2.85	0.998	100	NA	NA	
3	0.285	0.1008	11	NA	NA	This step includes plot
4a	0.285	0.100	11	NA	NA	3.15 kHz Vpp reading is: Vpp + noise
4b	0.275	0.0804	10	NA	NA	19 kHz Vpp reading is: Vpp + noise
5a	NA	NA	11	0.285	NA	57 kHz
5b	NA	NA	11	0.285	0.100	67 kHz
5c	NA	NA	10	0.285	0.100	92 kHz

Digital Radio Test Laboratory



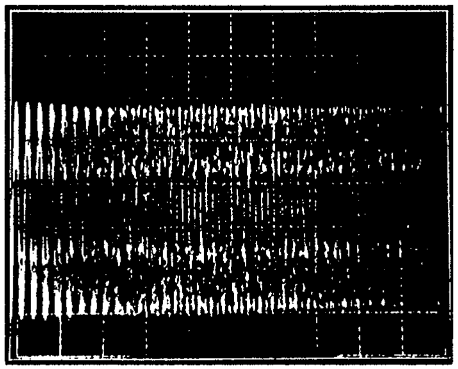
Calibrate Group A, B and C Subcarrier Groups
Superposition Match Voltage Method

* Connect test set up as shown.
* Select Group A
  Remove 92 kHz Patch from Mixer Input
* Select Position #4 (Aux)
* Verify 3% RBDS Injection, Vpp on Oscilloscope and injection on Belar
* Switch to Group B and verify 10 % 57 kHz Injection
* Select Group A
  Remove 57 kHz Patch from Mixer Input
* Connect 92kHz Patch to Mixer Input
* Verify 7% 92kHz Injection, Vpp
* Remove 92 kHz Patch from Mixer Input
* Select Position #1 (Seiko)
* Verify 10% Proponent Injection, Vpp
* Select Position #2 (DDJ) Verify 10% Injection, Vpp
* Select Position #3 (MITRE) Verify 10% Injection, Vpp

Measurements

	Harris THE-1 Composite Input			Harris THE-1 SCA Input		
STEP	Vpp	Vrms	Mod.%	Vpp	Vrms	Notes
1	2.88	1.018	100	NA	NA	This step includes plot
2	2.85	1.007	100	NA	NA	
3	0.288	0.102	10.7	NA	NA	This step includes plot
4a	0.285	0.101	10.6	NA	NA	3.15 kHz Vpp reading is: Vpp + noise
4b	0.262	0.0926	9.8	NA	NA	19 kHz Vpp reading is: Vpp + noise
5a	NA	NA	11	0.285	NA	57 kHz
5b	NA	NA	11	0.285	0.100	67 kHz
5c	NA	NA	10	0.285	0.100	92 kHz
6a	NA	NA	11	0.280	NA	Seiko
6b	NA	NA	11	0.280	NA	DDJ
6c	NA	NA	11	0.280	NA	MITRE
7a	NA	NA	4	0.092	NA	57 kHz 3% Group A
7b	NA	NA	11	0.285	NA	57 kHz 10% Group B
7c	NA	NA	8	0.190	0.074	92 kHz 7% Group A

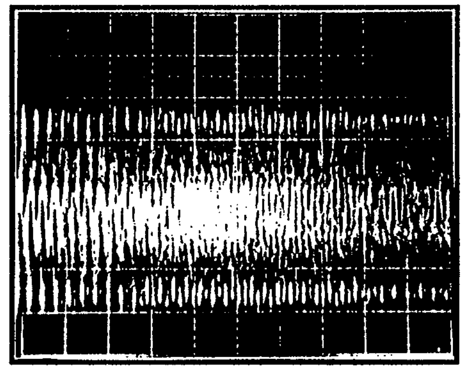
(AT SCA input to exciter)



100 mV, 50µsec / Division

MITRE

17%



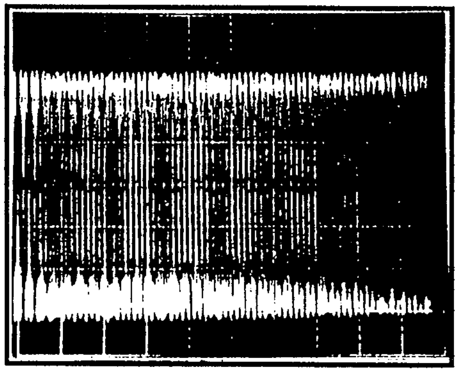
100 mV, 50µsec / Division

SEIKO

17%

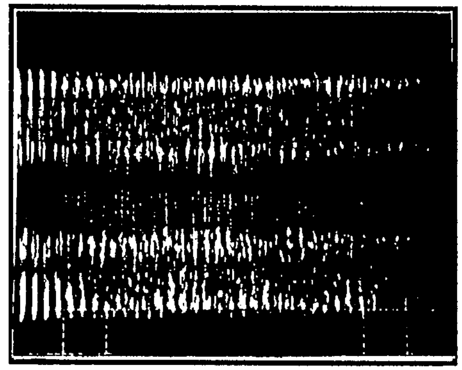
(At SCA input to exciter)

Digital Radio Test Laboratory



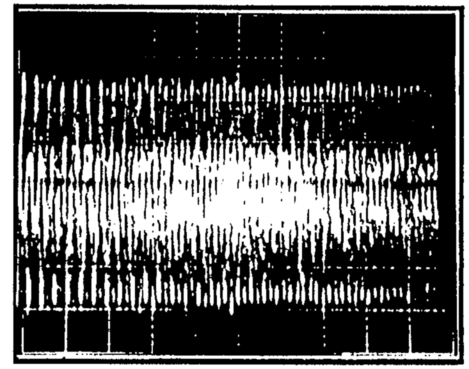
50 mV, 50μsec / Division

DIGITAL DJ



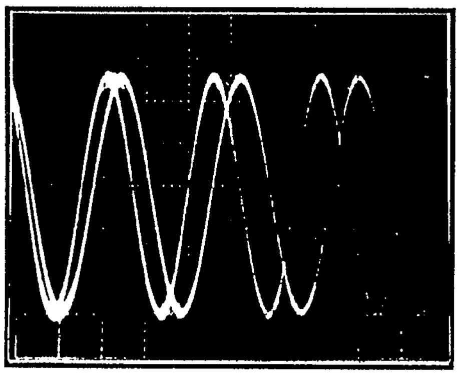
50 mV, 50μsec / Division

MITRE



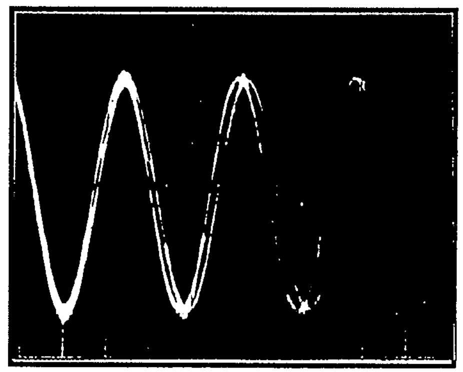
50 mV, 50μsec / Division

SEIKO



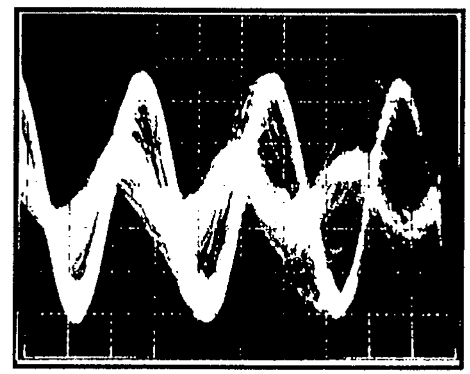
50 mV, 5μsec / Division

DIGITAL DJ



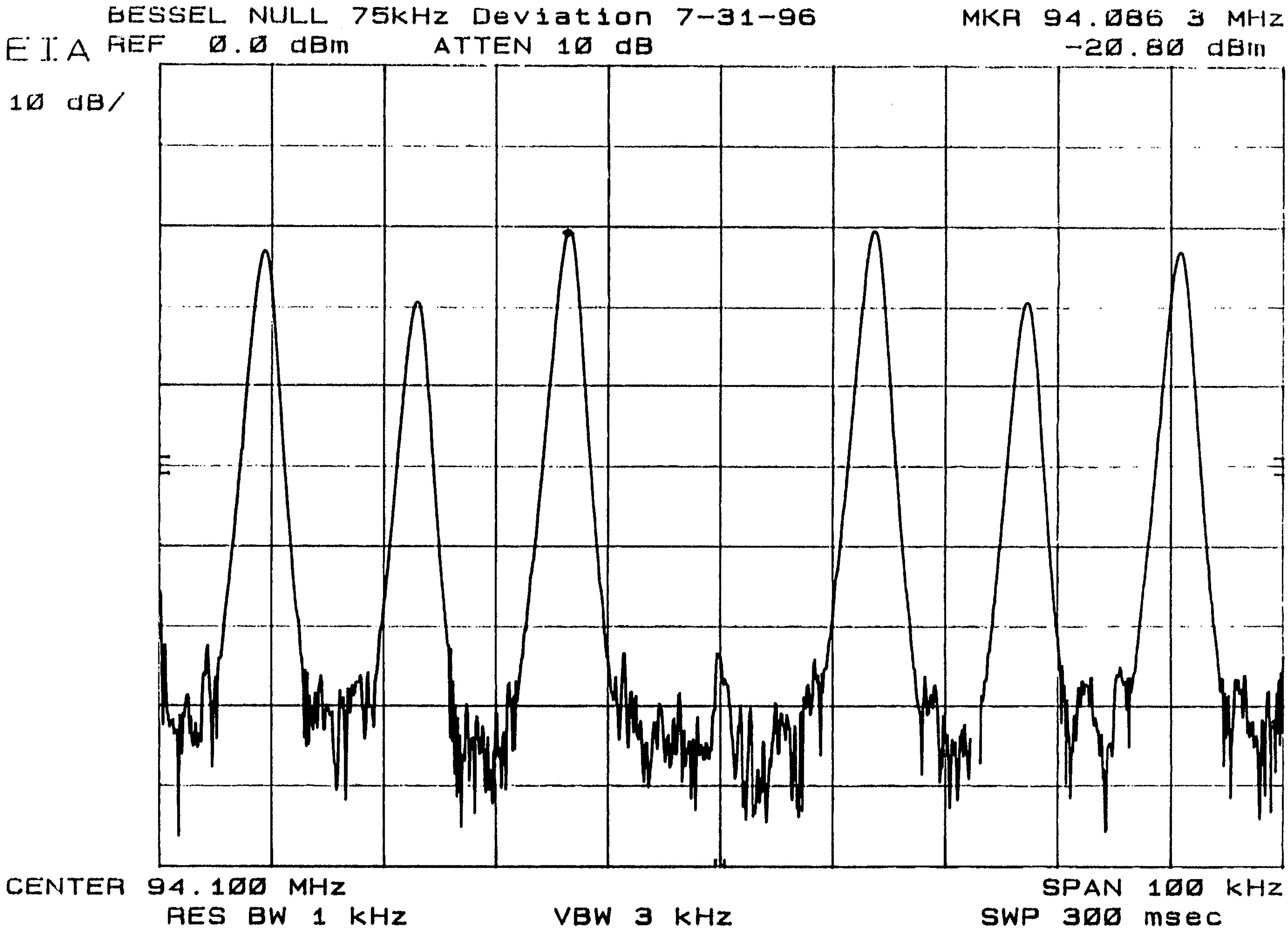
50 mV, 5μsec / Division

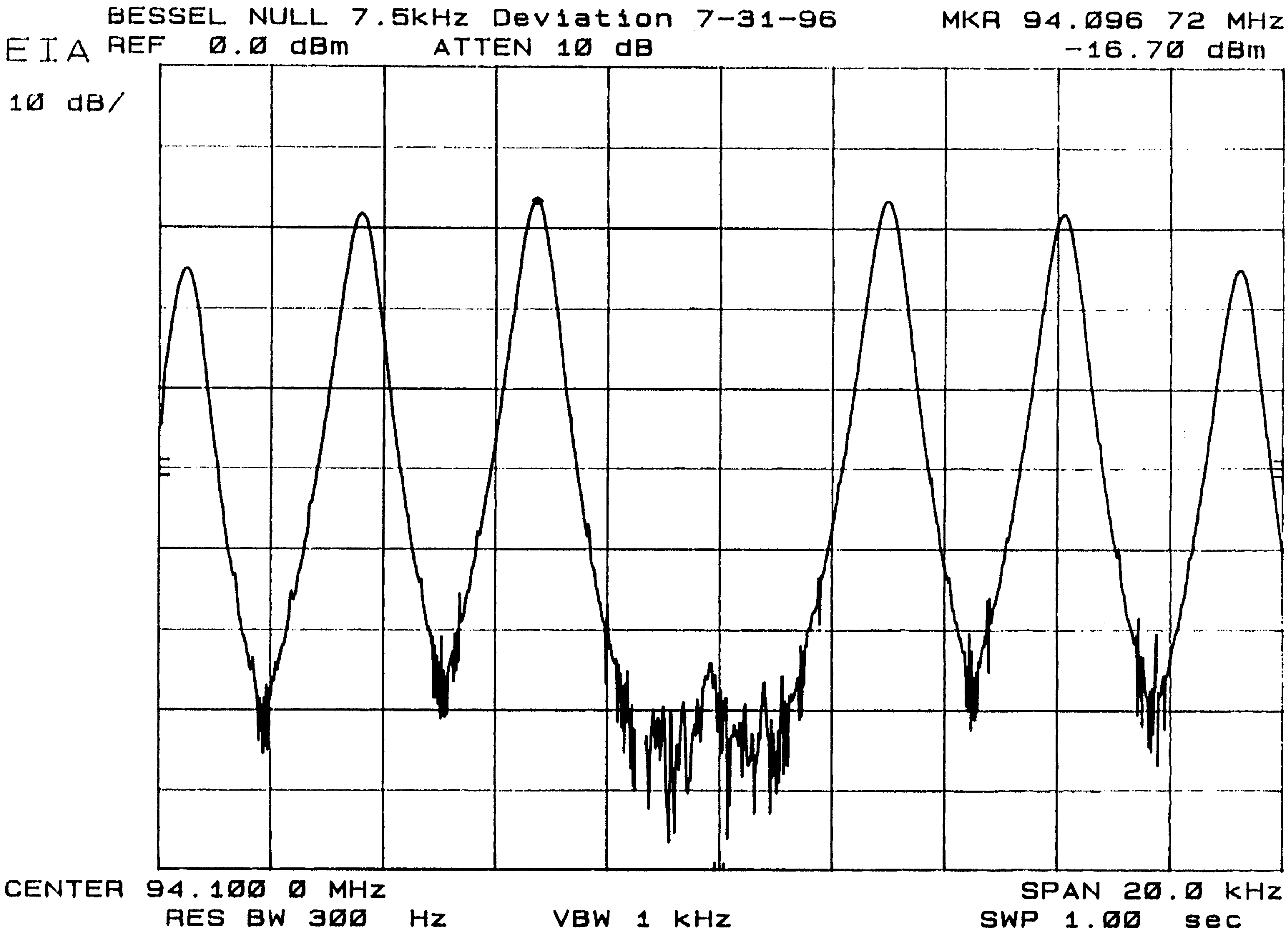
MITRE



50 mV, 5μsec / Division

SEIKO

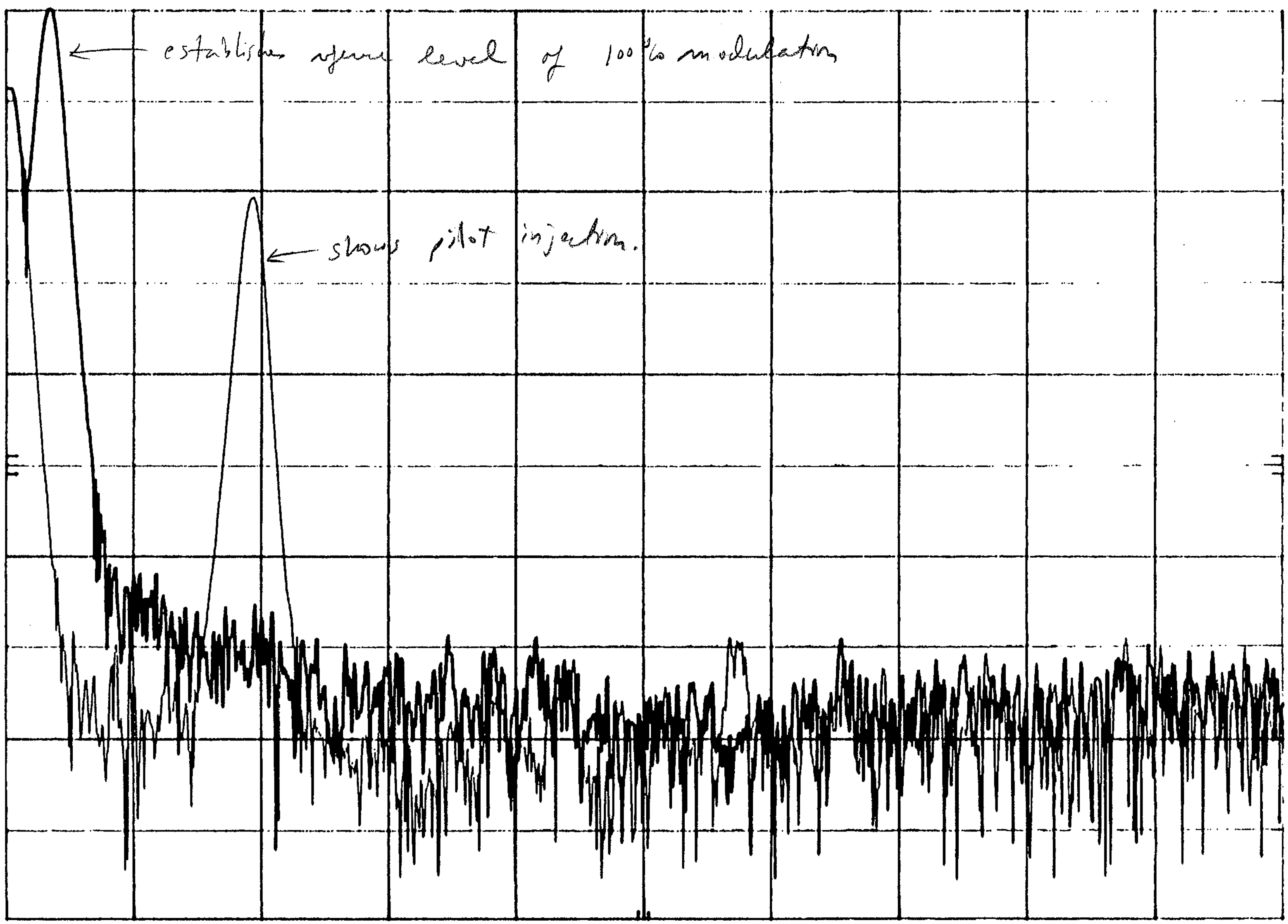

BESSEL NULL 75kHz Deviation 7-31-96
MKR 94.086 3 MHz
-20.80 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
SPAN 100 kHz
RES BW 1 kHz
VBW 3 kHz
SWP 300 msec


BESSEL NULL 7.5kHz Deviation 7-31-96
MKR 94.096 72 MHz
-16.70 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 0 MHz
SPAN 20.0 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 1.00 sec

BASEBAND 3.15kHz at 75kHz Deviation + Pilot 7-31-96

EIA REF -15.1 dBm ATTEN 10 dB

10 dB/

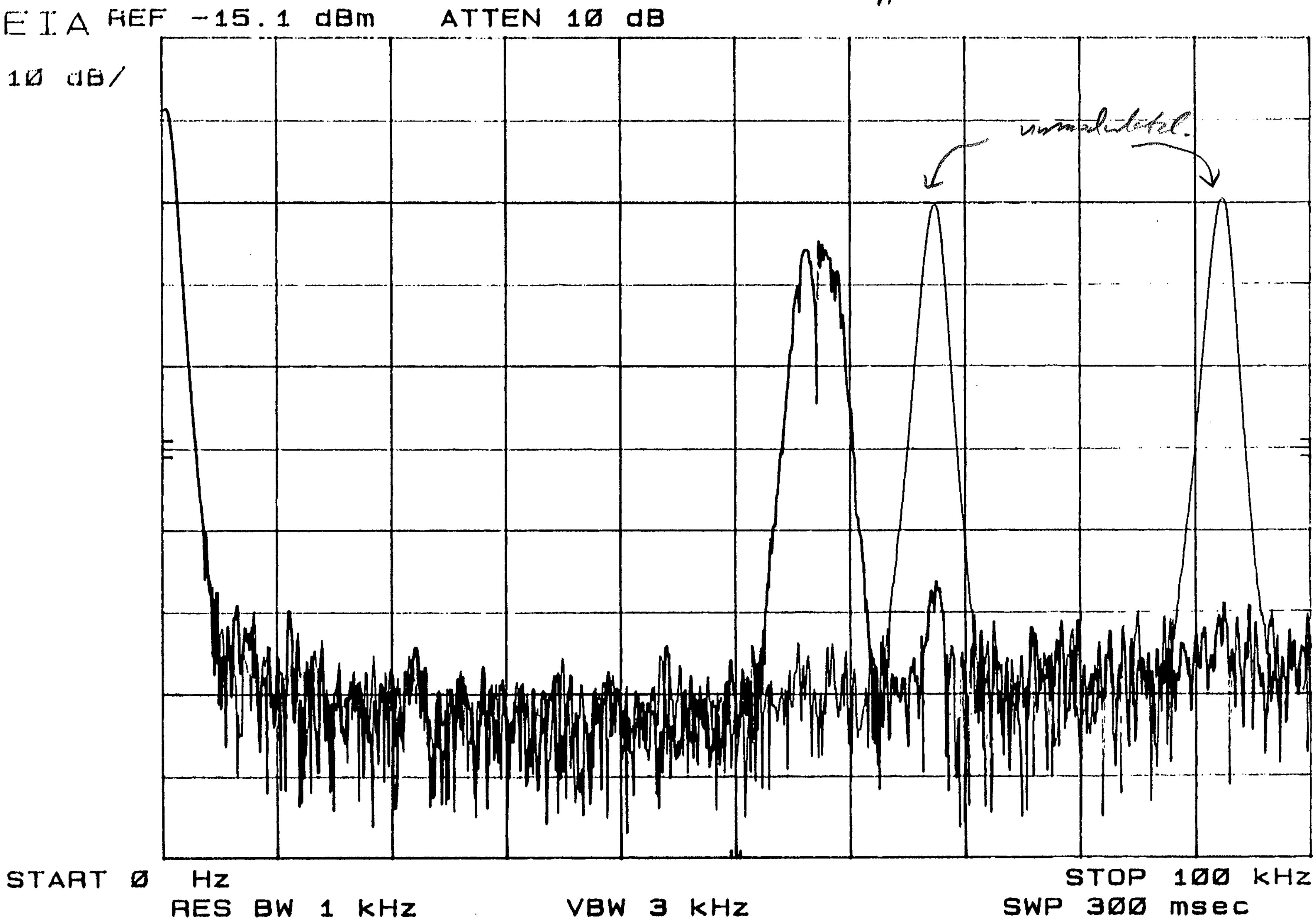


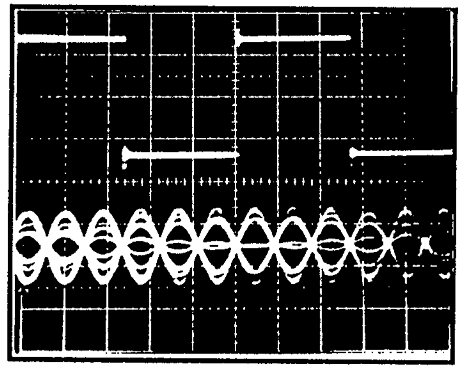
START 0 Hz STOP 100 kHz

RES BW 1 kHz VBW 3 kHz SWP 300 msec

all at 10%.

57, 67 and 92 kHz Subcarrier Baseband 7-31-96





CH 1: 2.0 V, 10μsec / Division

CH 2: 0.5 V, 10μsec / Division

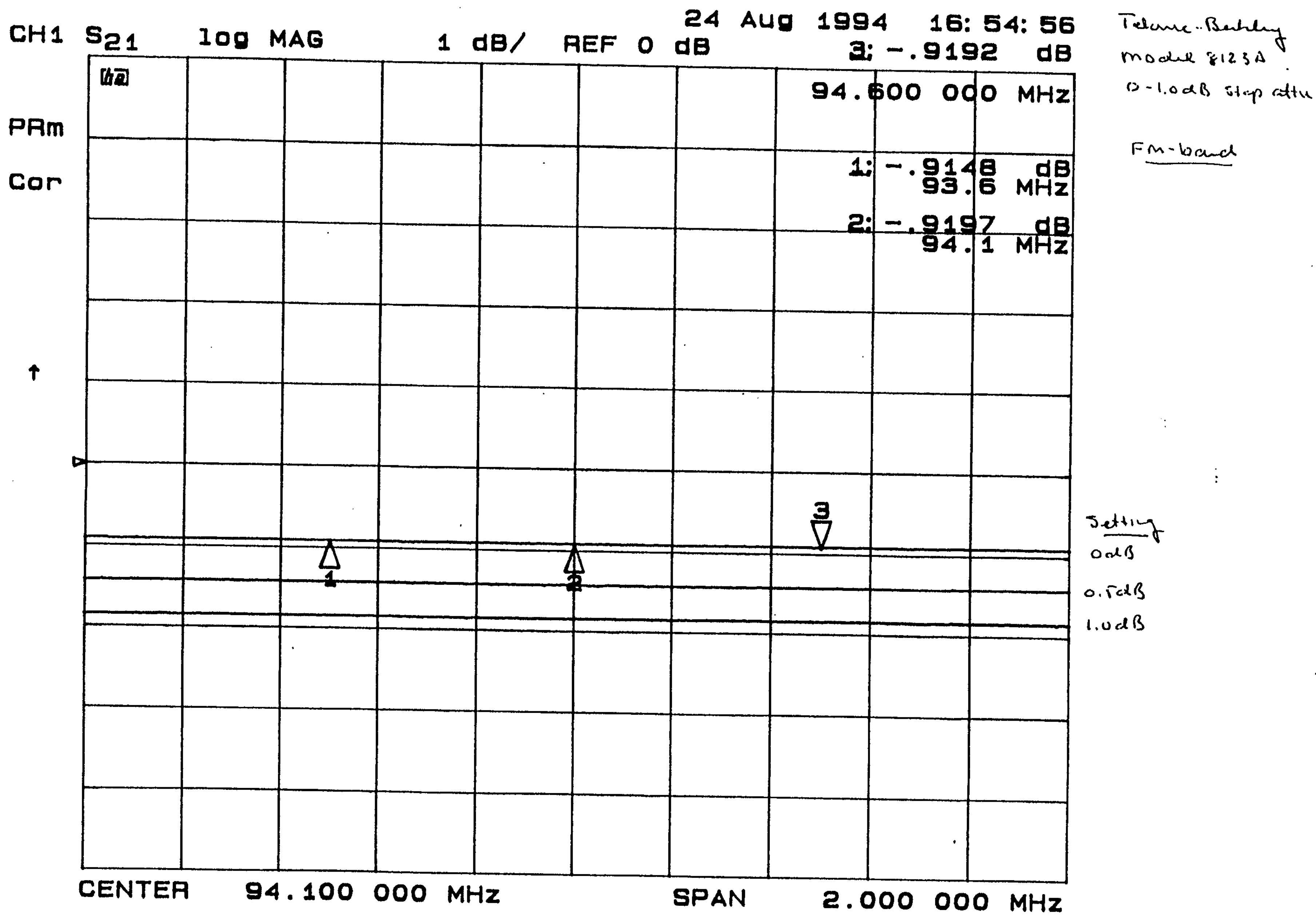
Pilot vs 57kHz

Zero Crossings Aligned

464

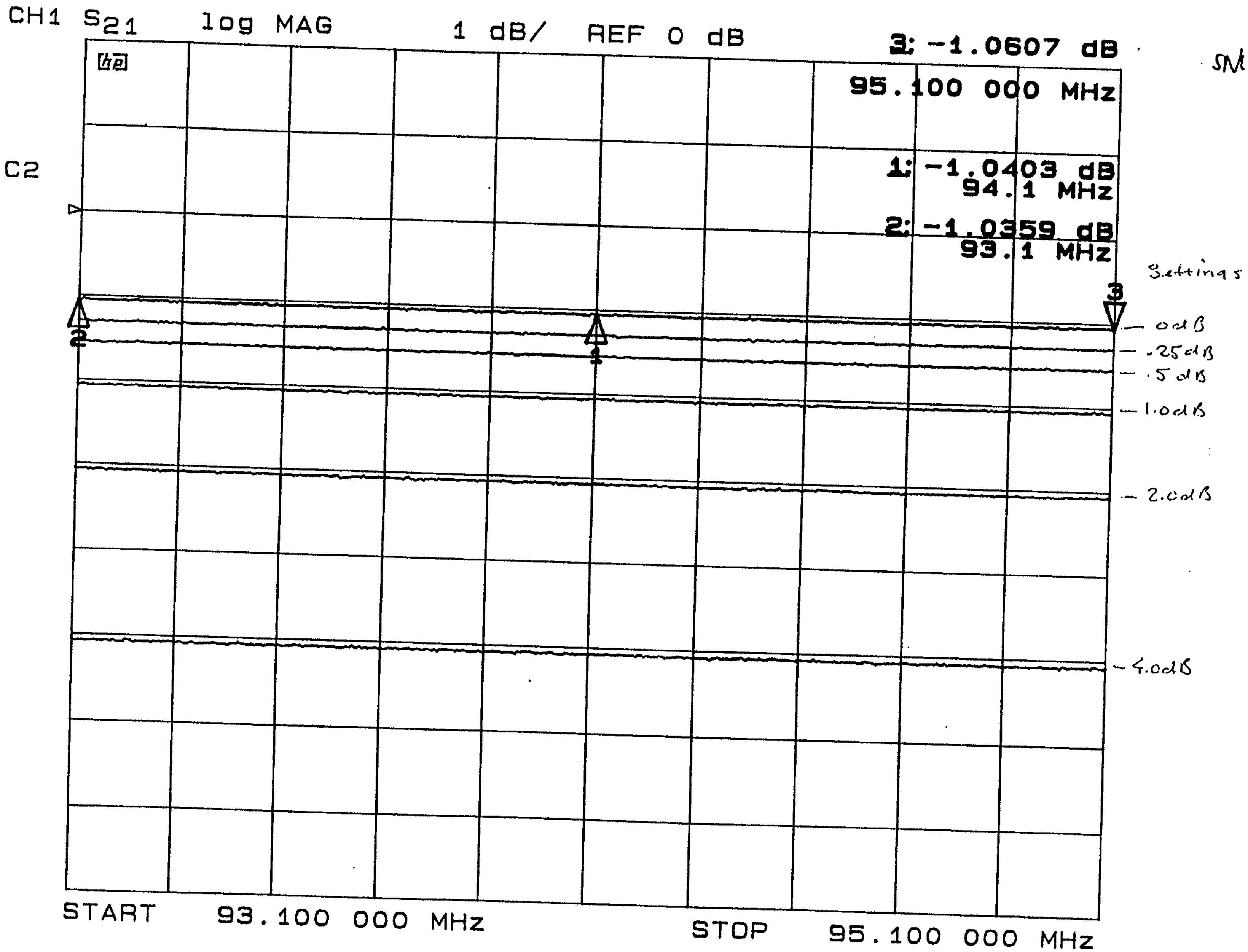
Appendix F

RF COMPONENT CALIBRATION


CH1 S21 log MAG 1 dB/ REF 0 dB
24 Aug 1994 16: 54: 56
3: -.9192 dB
94.600 000 MHz
PRm
Cor
1: -.9148 dB
93.6 MHz
2: -.9197 dB
94.1 MHz
CENTER 94.100 000 MHz
SPAN 2.000 000 MHz
Telonic-Berkeley
model 8123A
0-1.0dB step attn.
FM-band
Setting
0dB
0.5dB
1.0dB

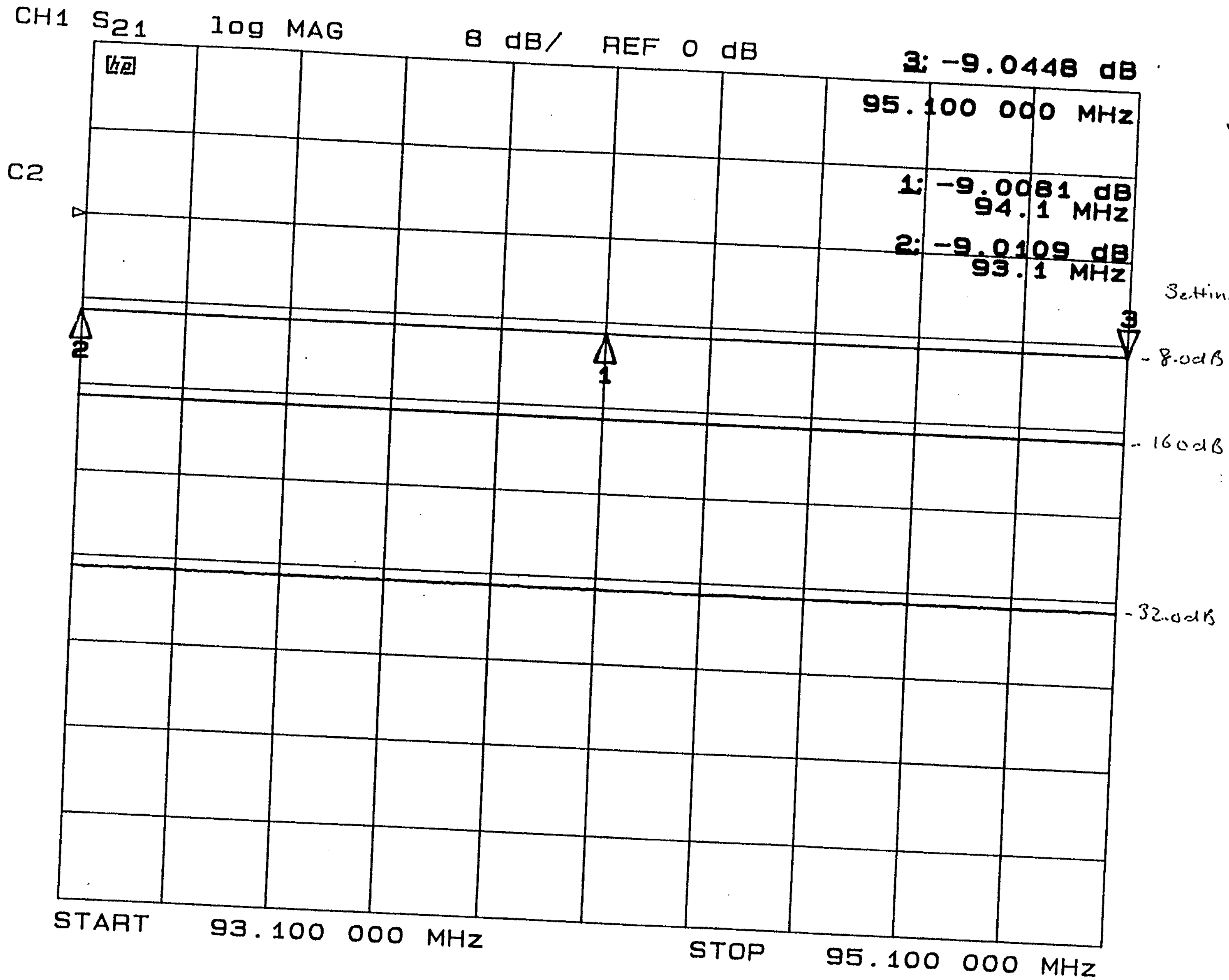
1/94

SM5767


CH1 S_{21} log MAG 1 dB/ REF 0 dB
3: -1.0607 dB
95.100 000 MHz
C2
1: -1.0403 dB
94.1 MHz
2: -1.0359 dB
93.1 MHz
Settings
0 dB
.25 dB
.5 dB
1.0 dB
2.0 dB
4.0 dB
START 93.100 000 MHz
STOP 95.100 000 MHz

194

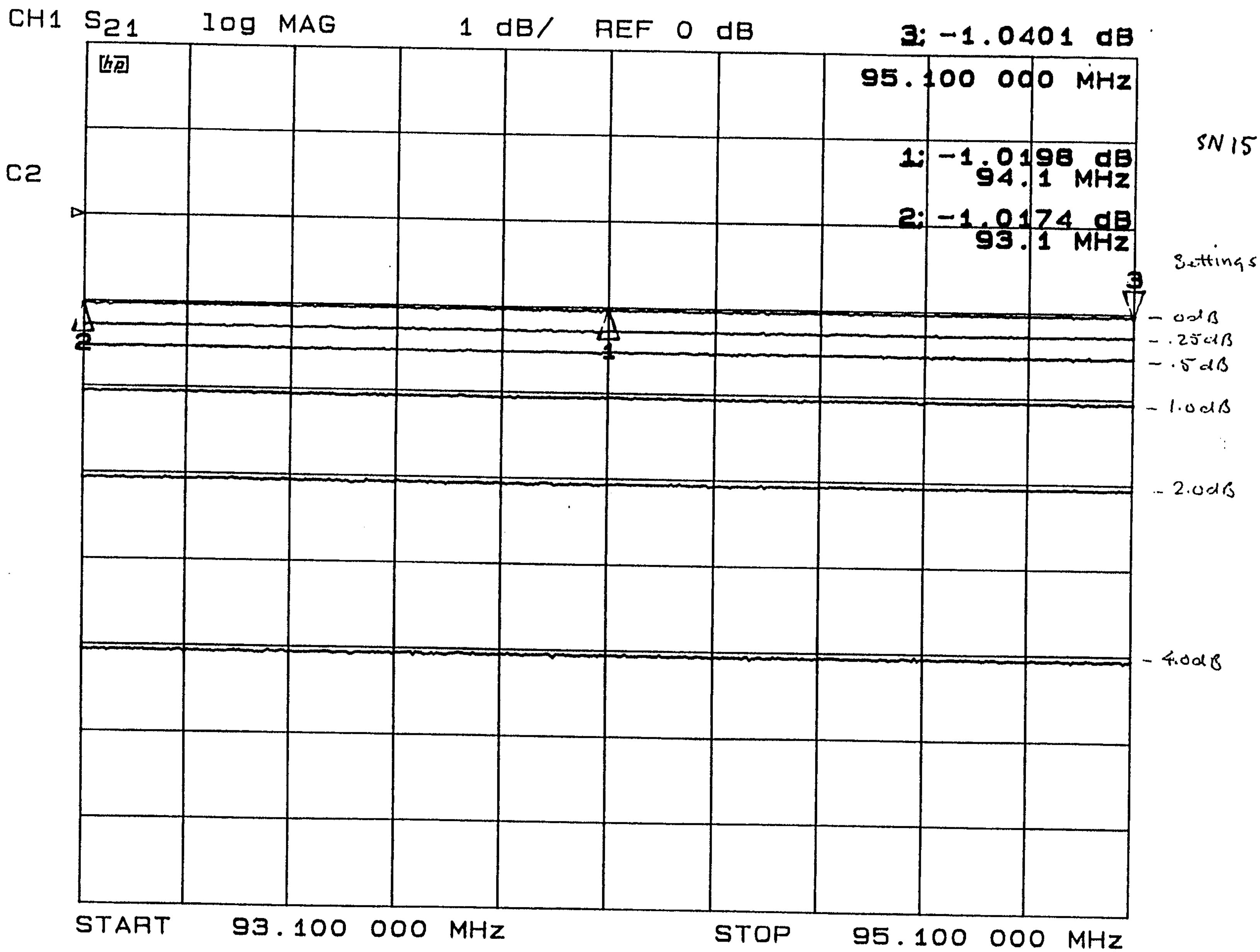
SN 15767



CH1 S21 log MAG 8 dB/ REF 0 dB
3: -9.0448 dB
95.100 000 MHz
C2
1: -9.0081 dB
94.1 MHz
2: -9.0109 dB
93.1 MHz
Settings
-8.0dB
-16.0dB
-32.0dB
START 93.100 000 MHz
STOP 95.100 000 MHz

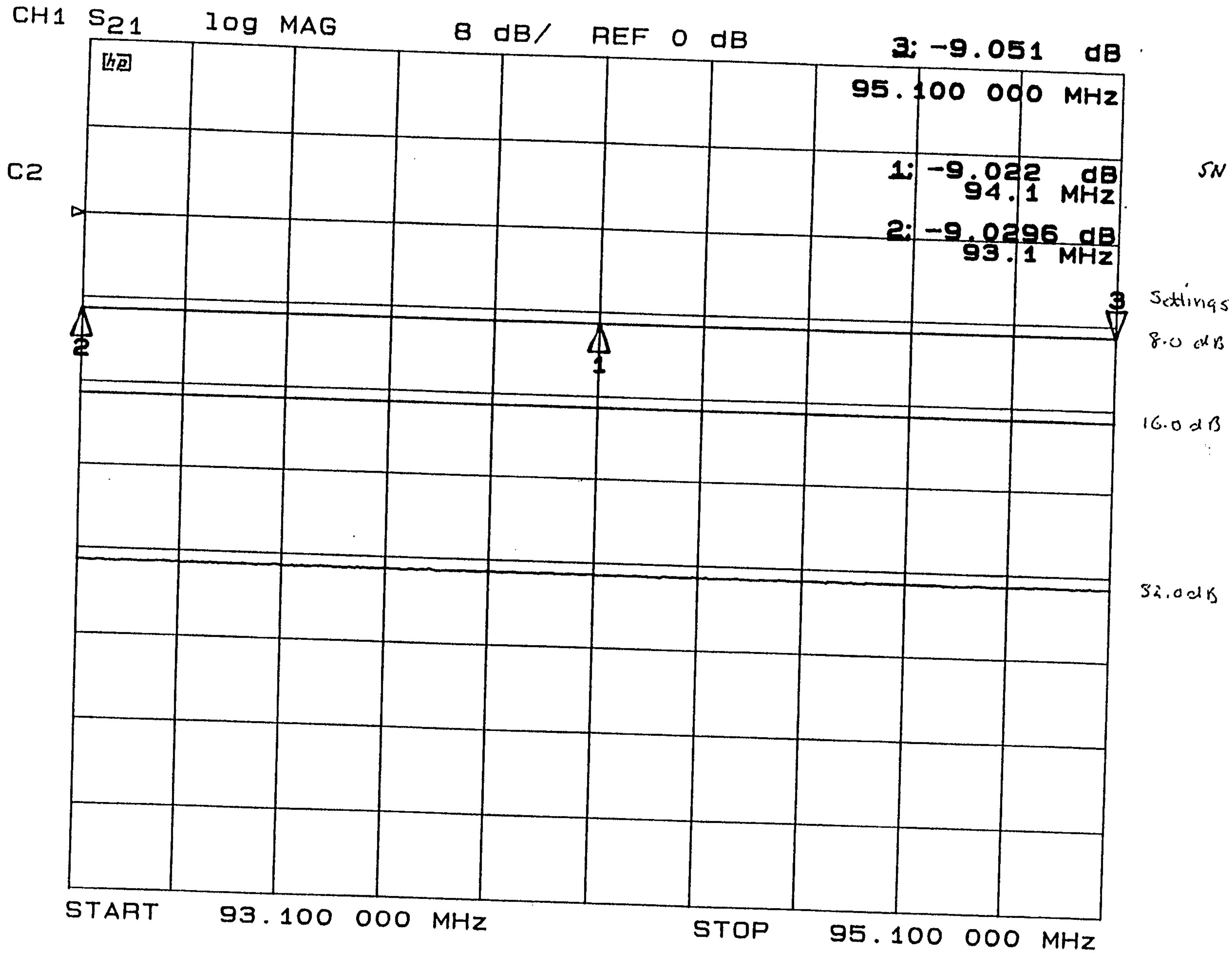
SN1576

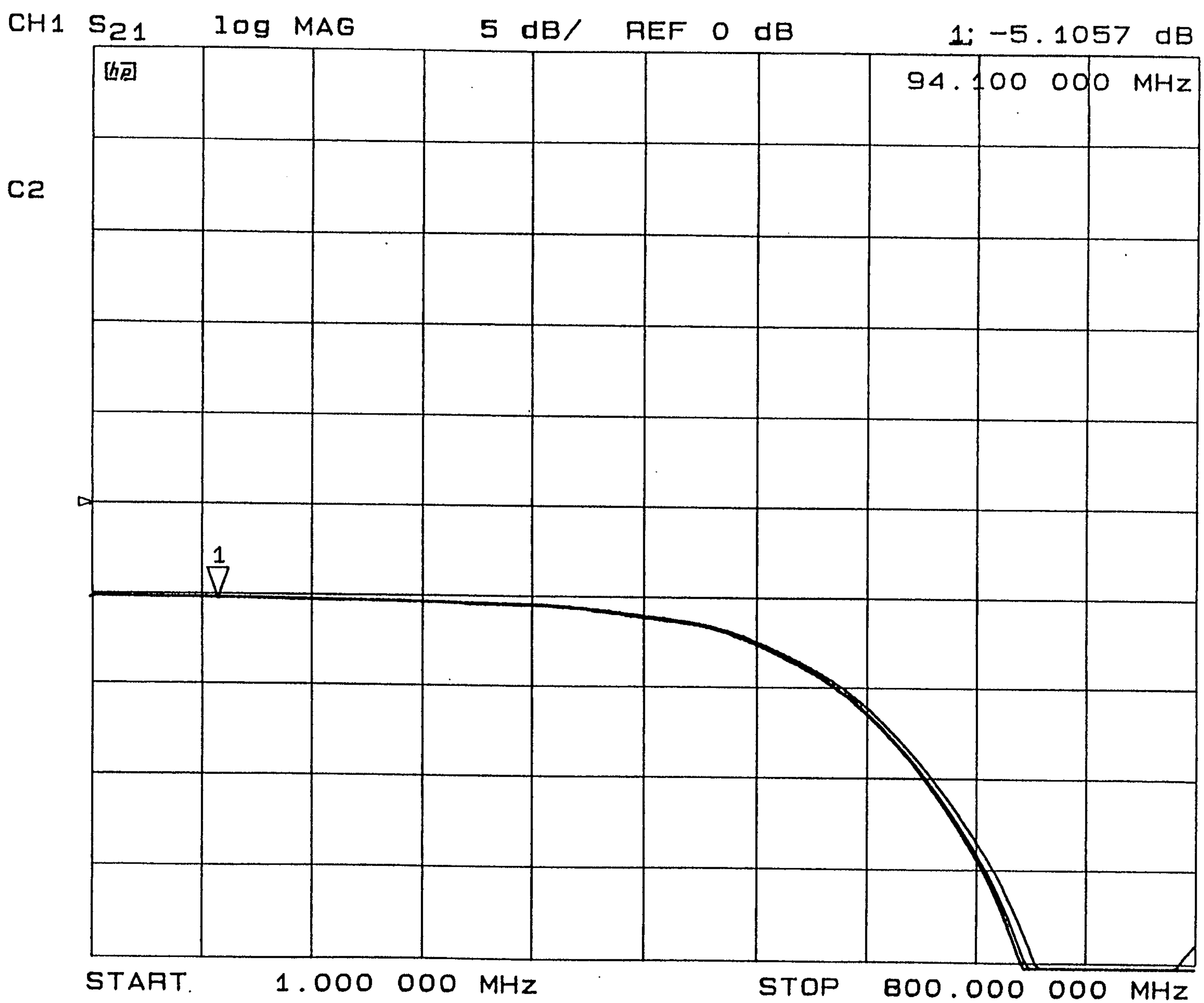
4/1/94


CH1 S21 log MAG 1 dB/ REF 0 dB
3: -1.0401 dB
95.100 000 MHz
1: -1.0198 dB
94.1 MHz
2: -1.0174 dB
93.1 MHz
C2
SN15766
Settings
0 dB
.25 dB
.5 dB
1.0 dB
2.0 dB
4.0 dB
START 93.100 000 MHz
STOP 95.100 000 MHz

SN15766

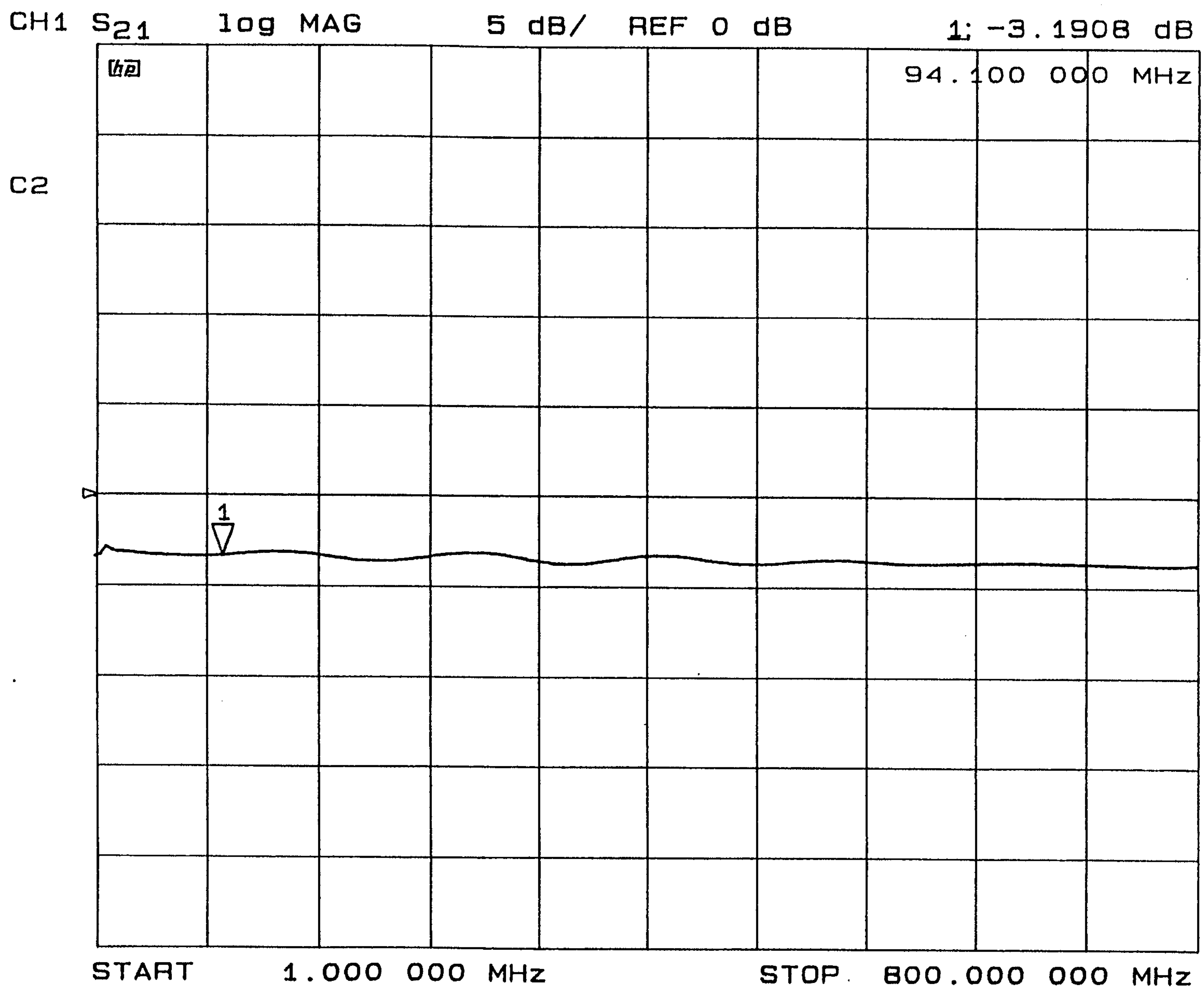
4/1/94



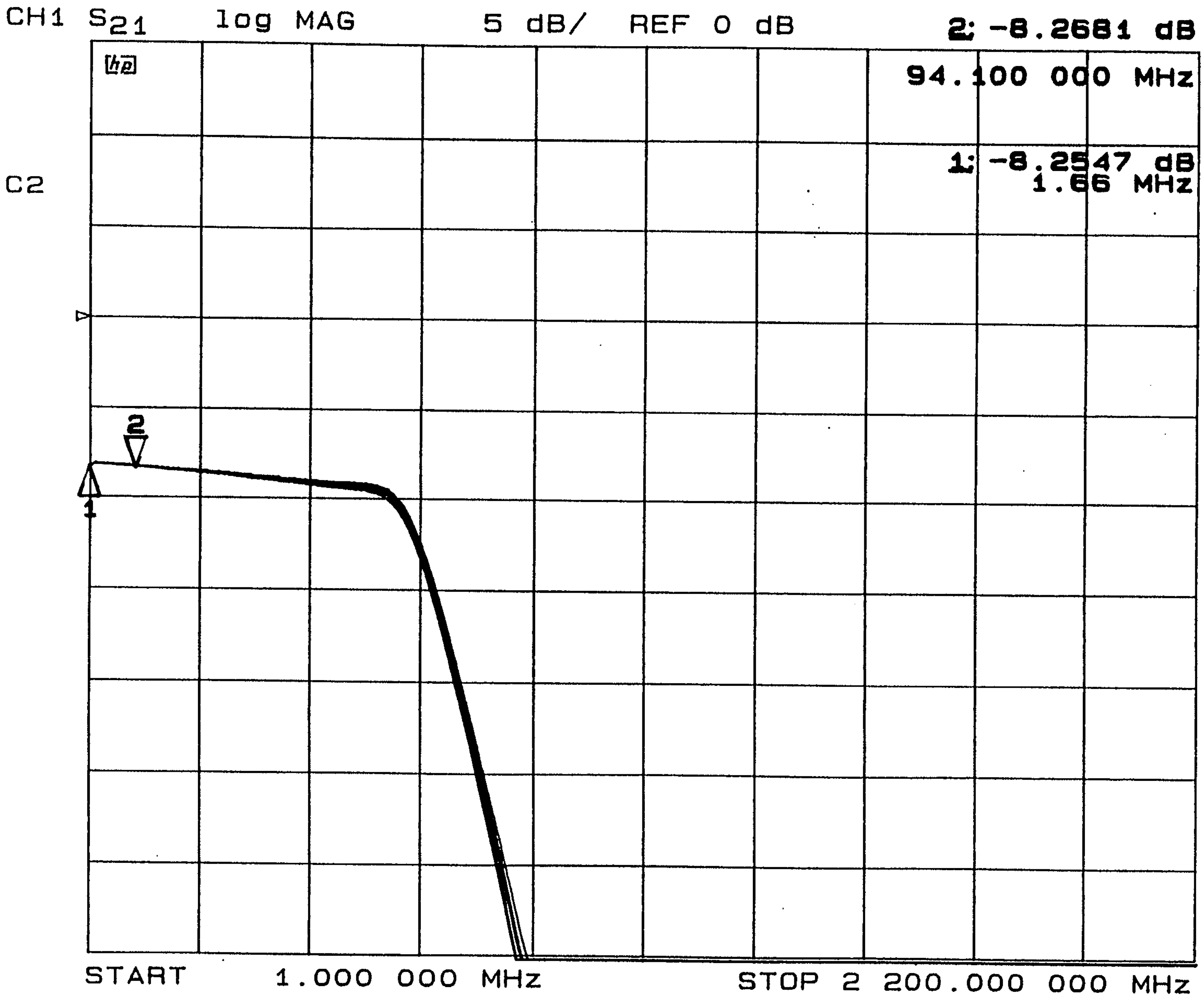


5/19/99
ZFSC-3-13
|S21|
all ports in one plot

470



5/13/94
2FSC-2-1W
#2
|S21|
Both plots in one plot



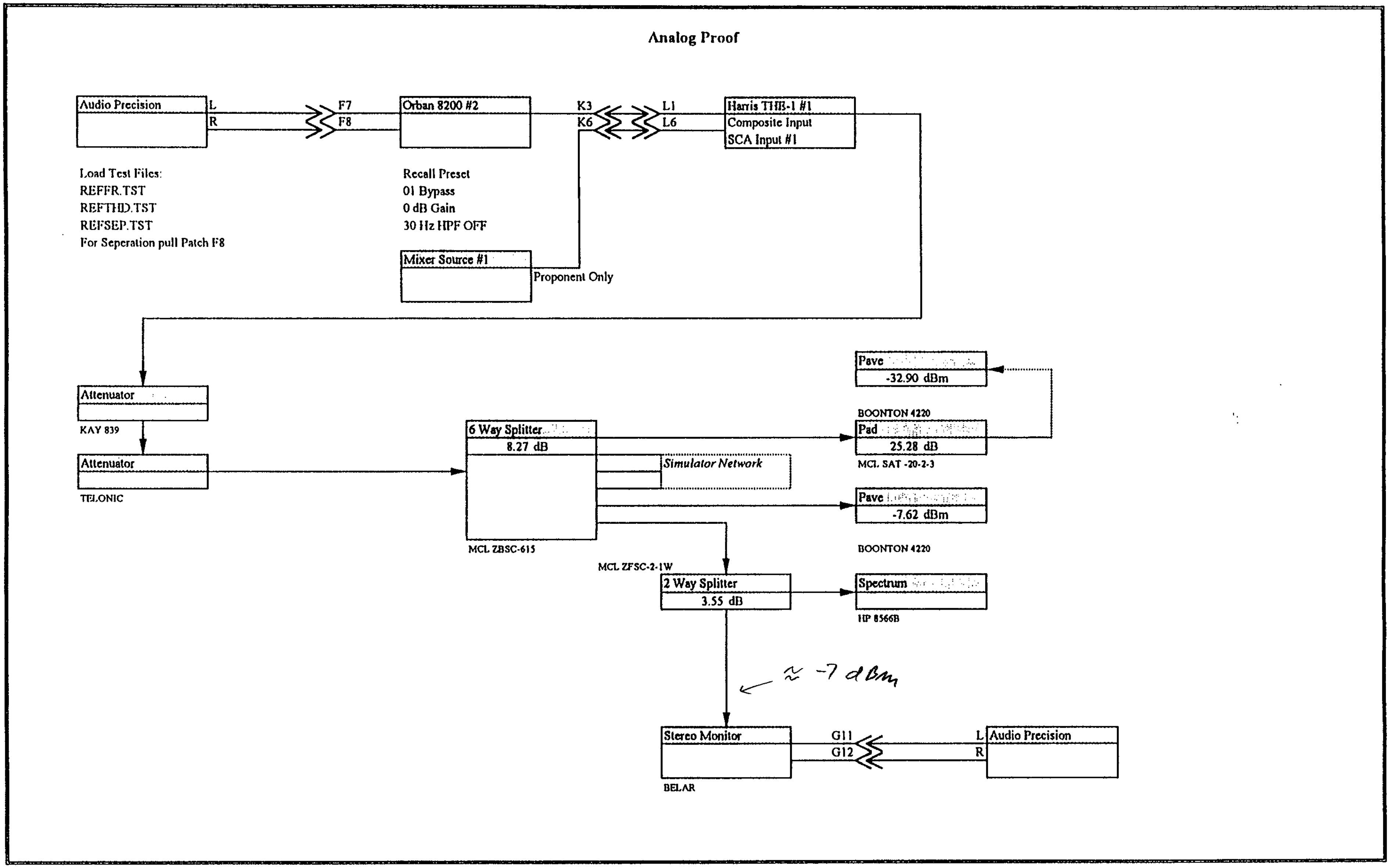
4/26/99

ZBSC-615
6-way splitter
ports to ref
(overlay)
unused ports
terminated

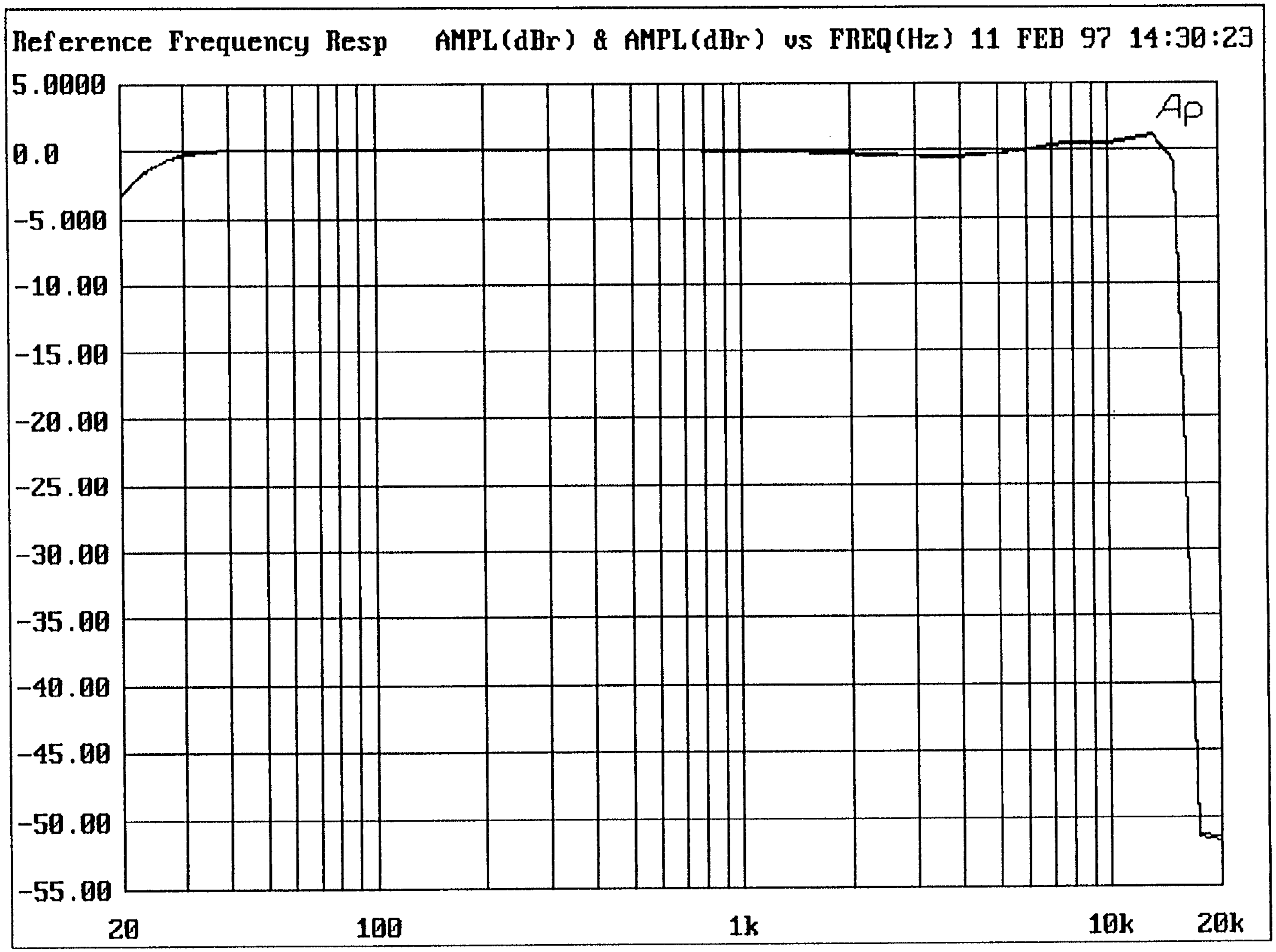
473

Appendix G

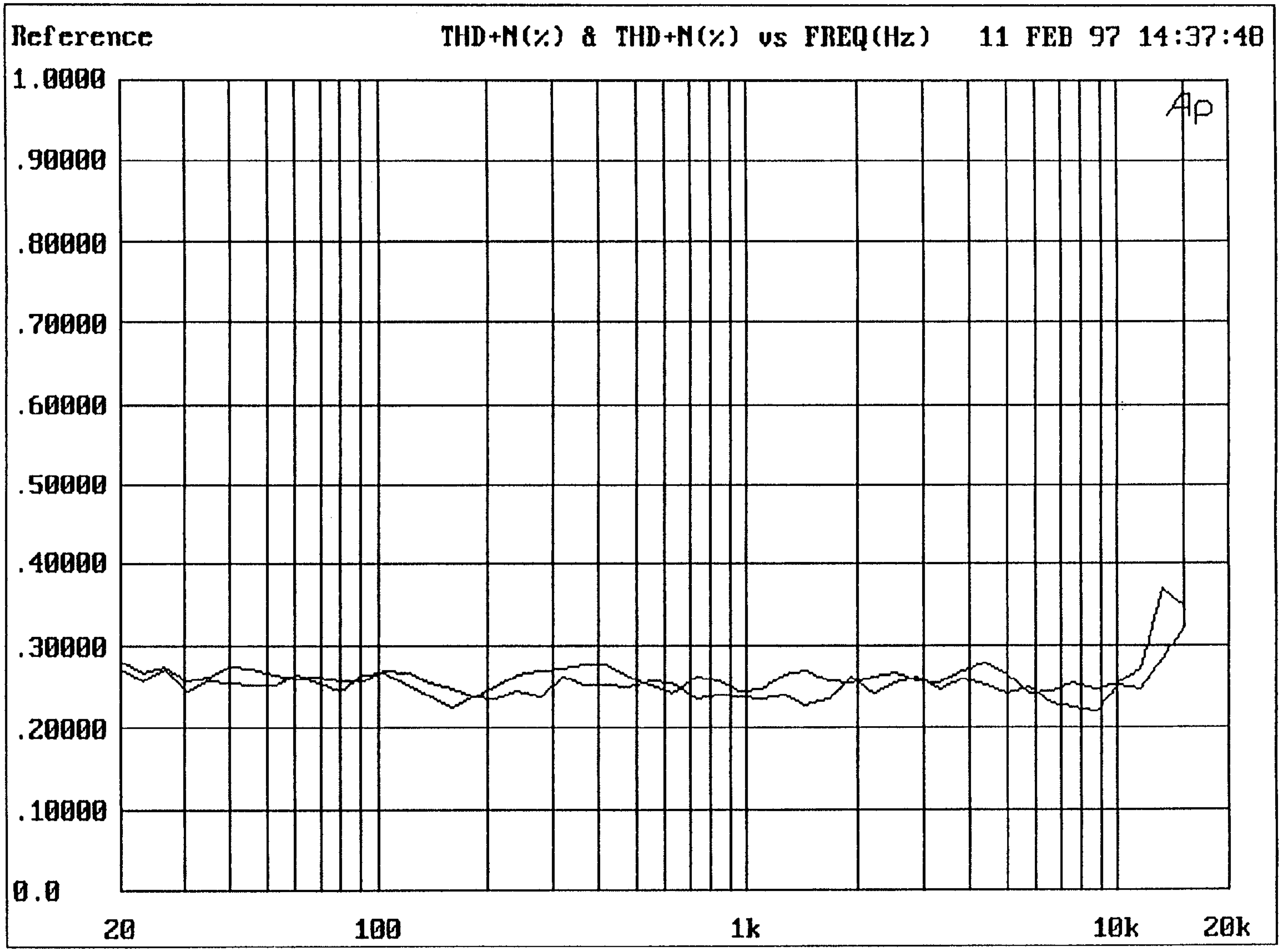
ANALOG TRANSMITTER TESTS

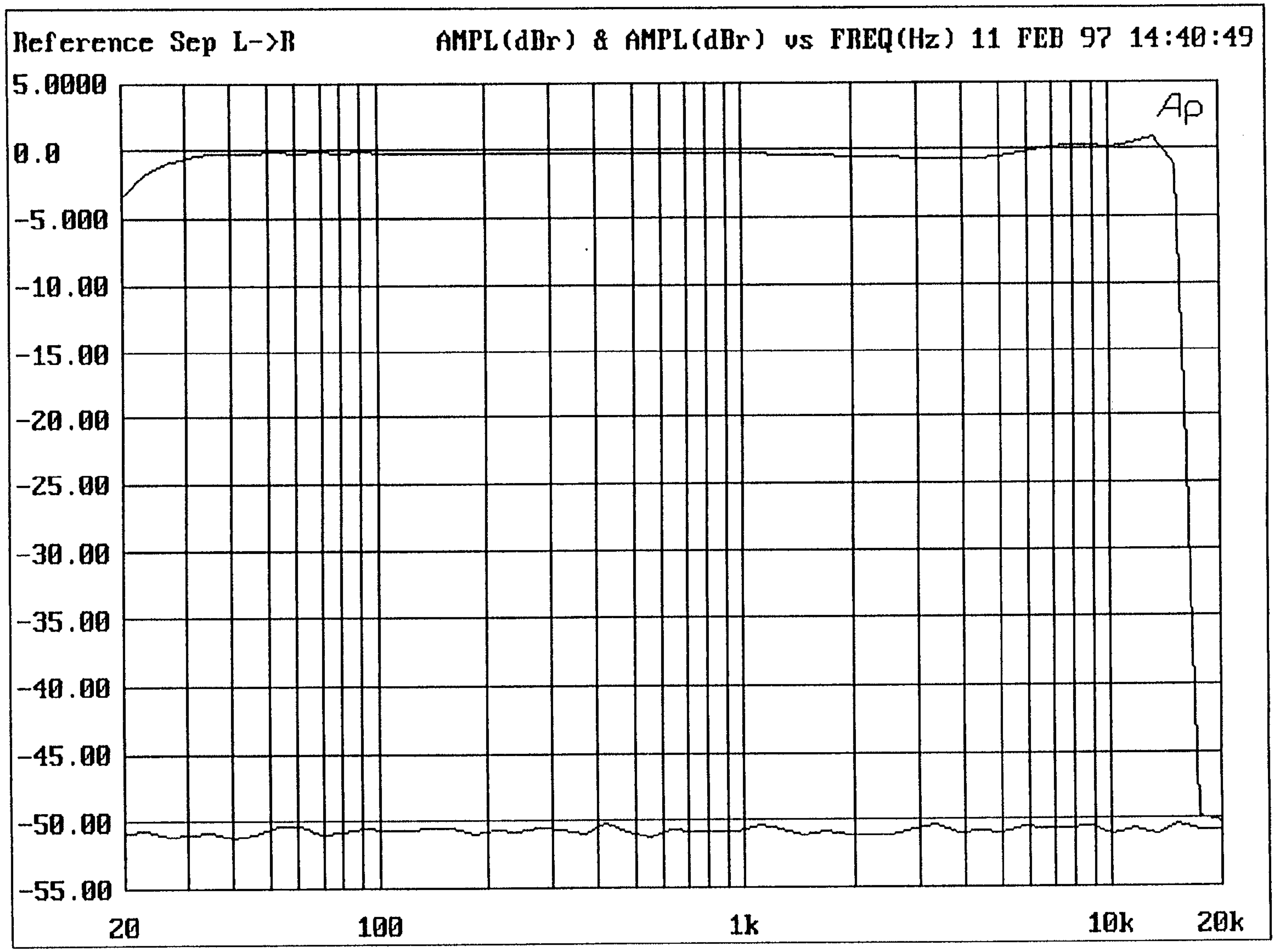


(setup for plots which follow)



Reference Frequency Resp
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 11 FEB 97 14:30:23
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap


Reference
THD+N(%) & THD+N(%) vs FREQ(Hz)
11 FEB 97 14:37:48
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap


Reference Sep L->R
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 11 FEB 97 14:40:49
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap

Clipped pink noise

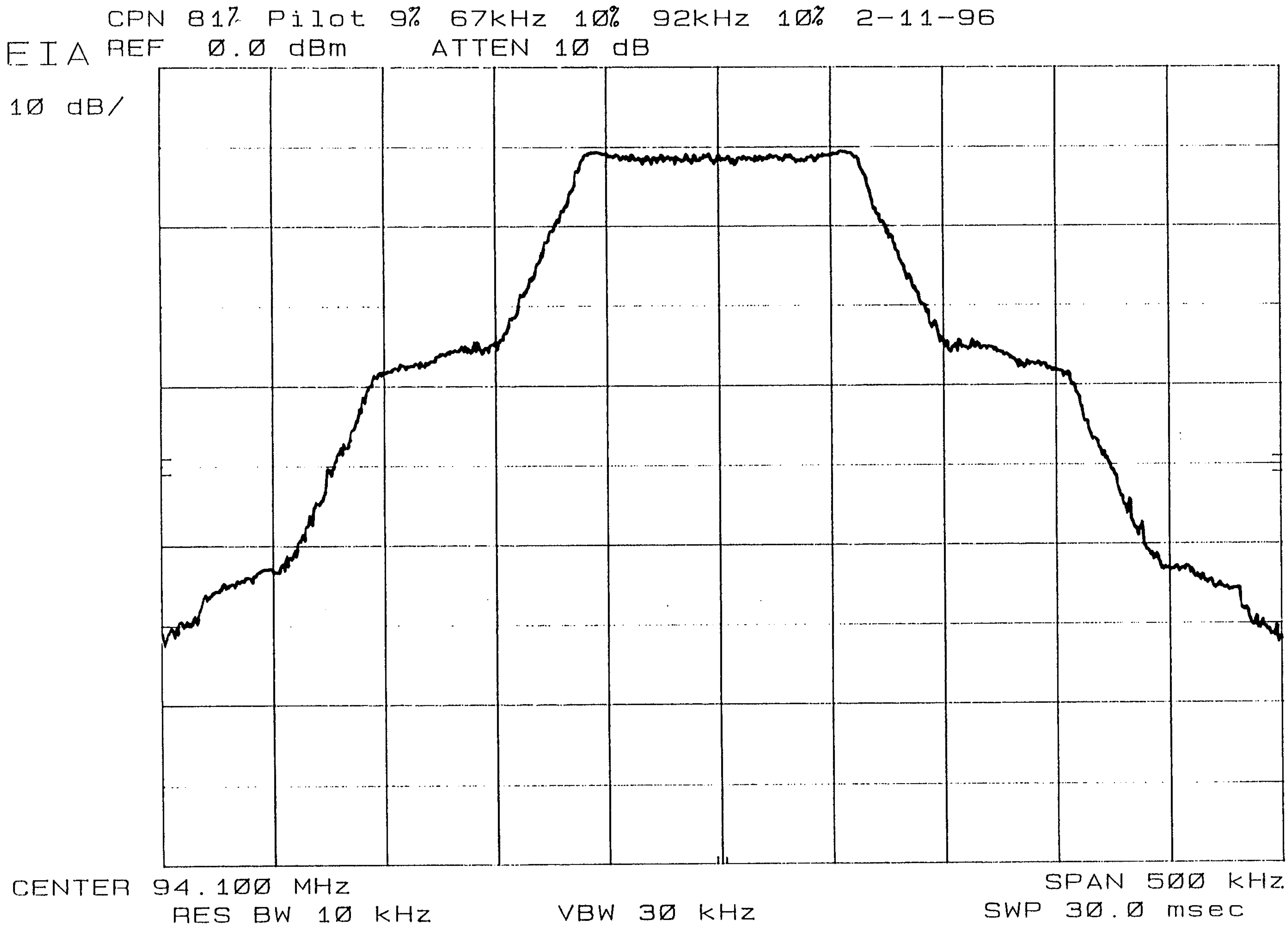
CPN 91% Pilot 9% RBDS 10% 2-11-96 (Max Hold)

EIA REF 0.0 dBm ATTEN 10 dB

10 dB/

CENTER 94.100 MHz SPAN 500 kHz

RES BW 10 kHz VBW 30 kHz SWP 30.0 msec



CPN 81% Pilot 9% 67kHz 10% 92kHz 10% 2-11-96
EIA REF 0.0 dBm ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
RES BW 10 kHz
VBW 30 kHz
SPAN 500 kHz
SWP 30.0 msec

(Pages 480 – 499 left blank)

500

Appendix H

CUSTOM LABORATORY EQUIPMENT

Subcarrier Mixer

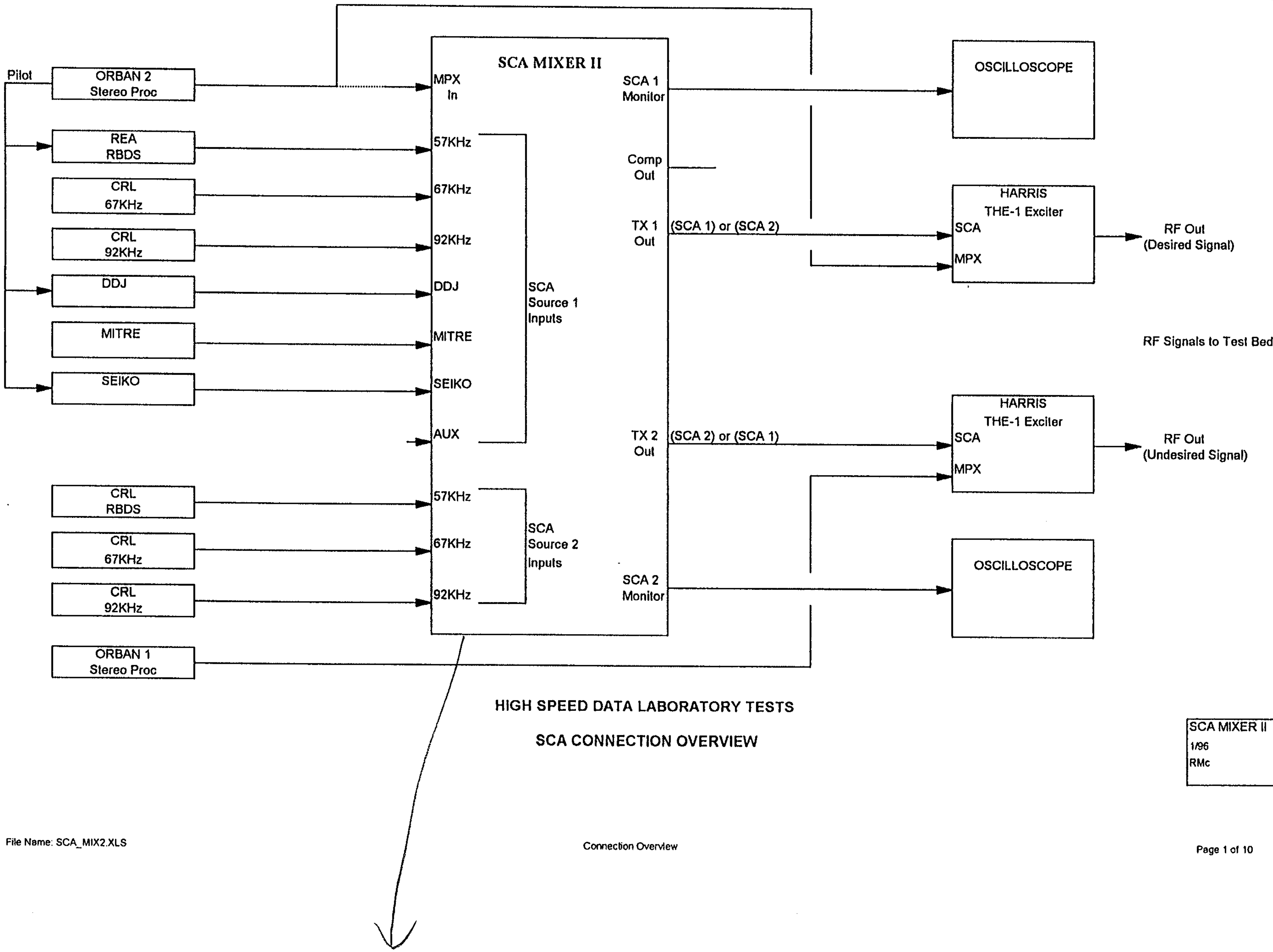
Remote Control System

Pilot LP Filter

Dummy Antenna

Subcarrier Mixer

DIGITAL RADIO TEST LABORATORY

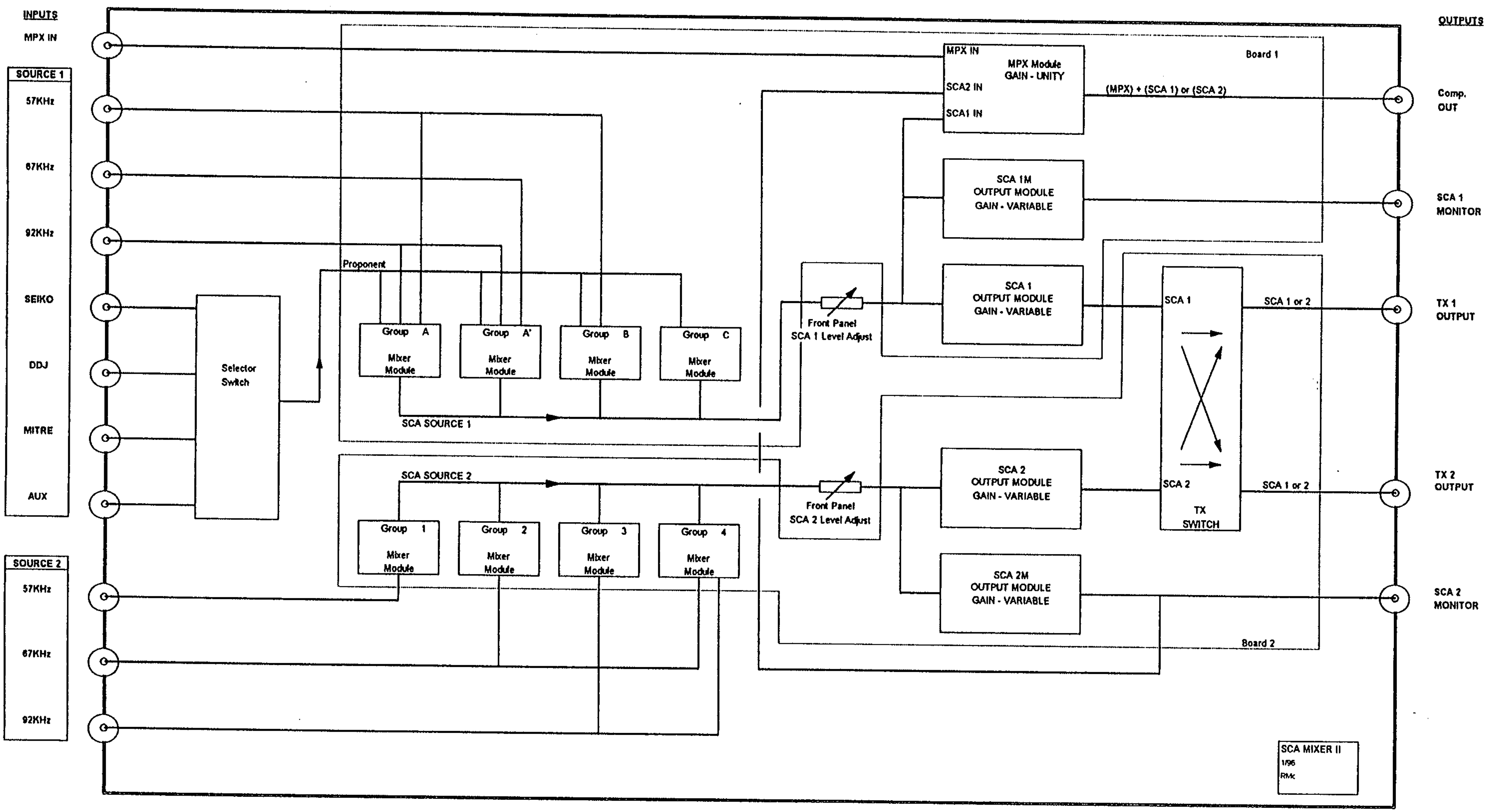


HIGH SPEED DATA LABORATORY TESTS

SCA CONNECTION OVERVIEW

SCA MIXER II
1/96
RMc

DIGITAL RADIO TEST LABORATORY



DIGITAL RADIO TEST LABORATORY

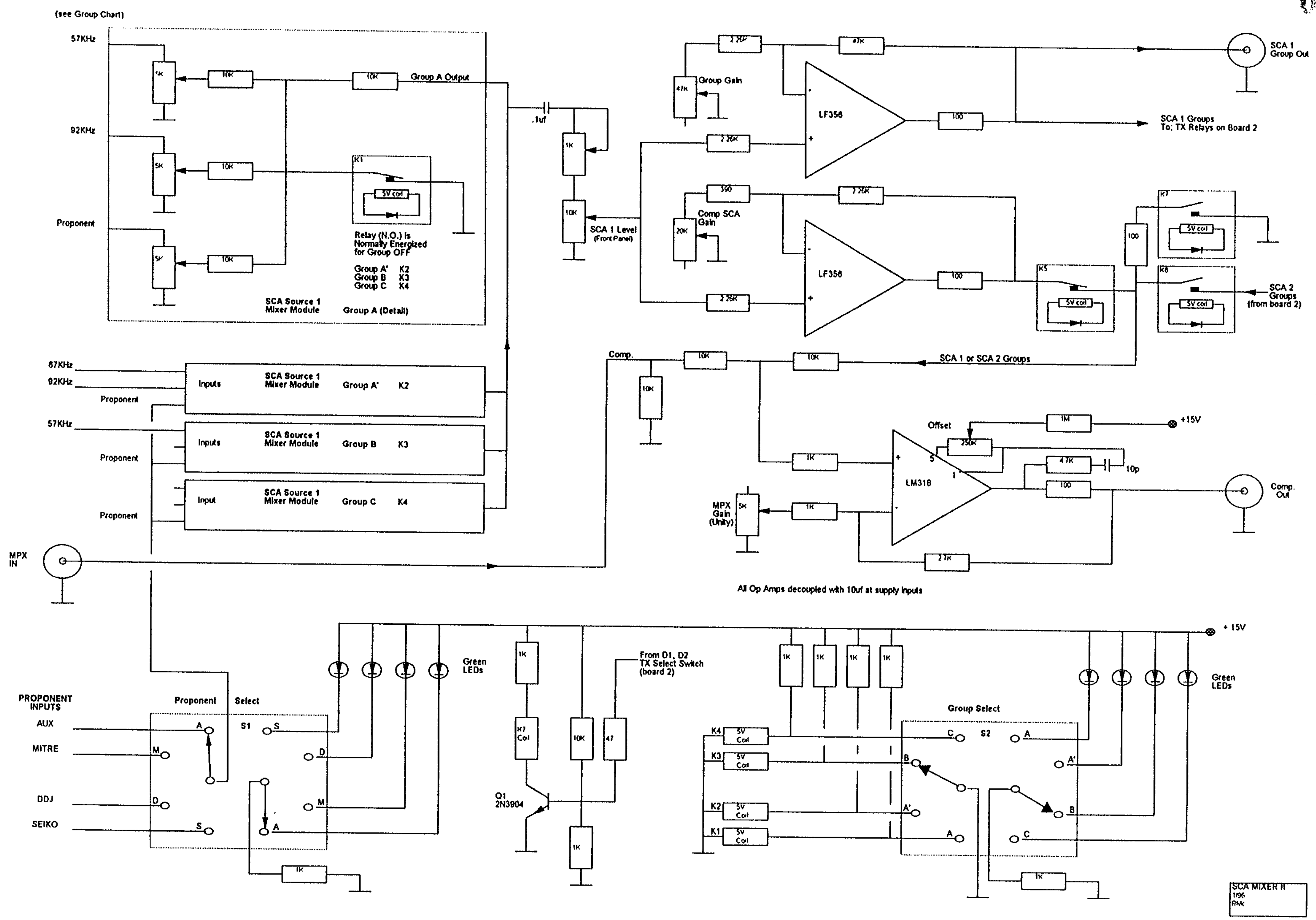
EIA SCA MIXER II

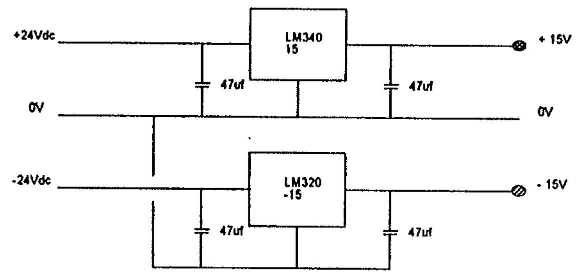
RMc

SCA Group Chart

INPUT	GROUP A SCA	GROUP A Inject (%)	GROUP A' SCA	GROUP A' Inject (%)	GROUP B SCA	GROUP B Inject (%)	GROUP C SCA	GROUP C Inject (%)
1	Proponent	10	Proponent	0	Proponent	10	Proponent	10
2	57KHz RBDS	3	67KHz	10	57KHz RBDS	10		
3	92KHz	7	92KHz	10				

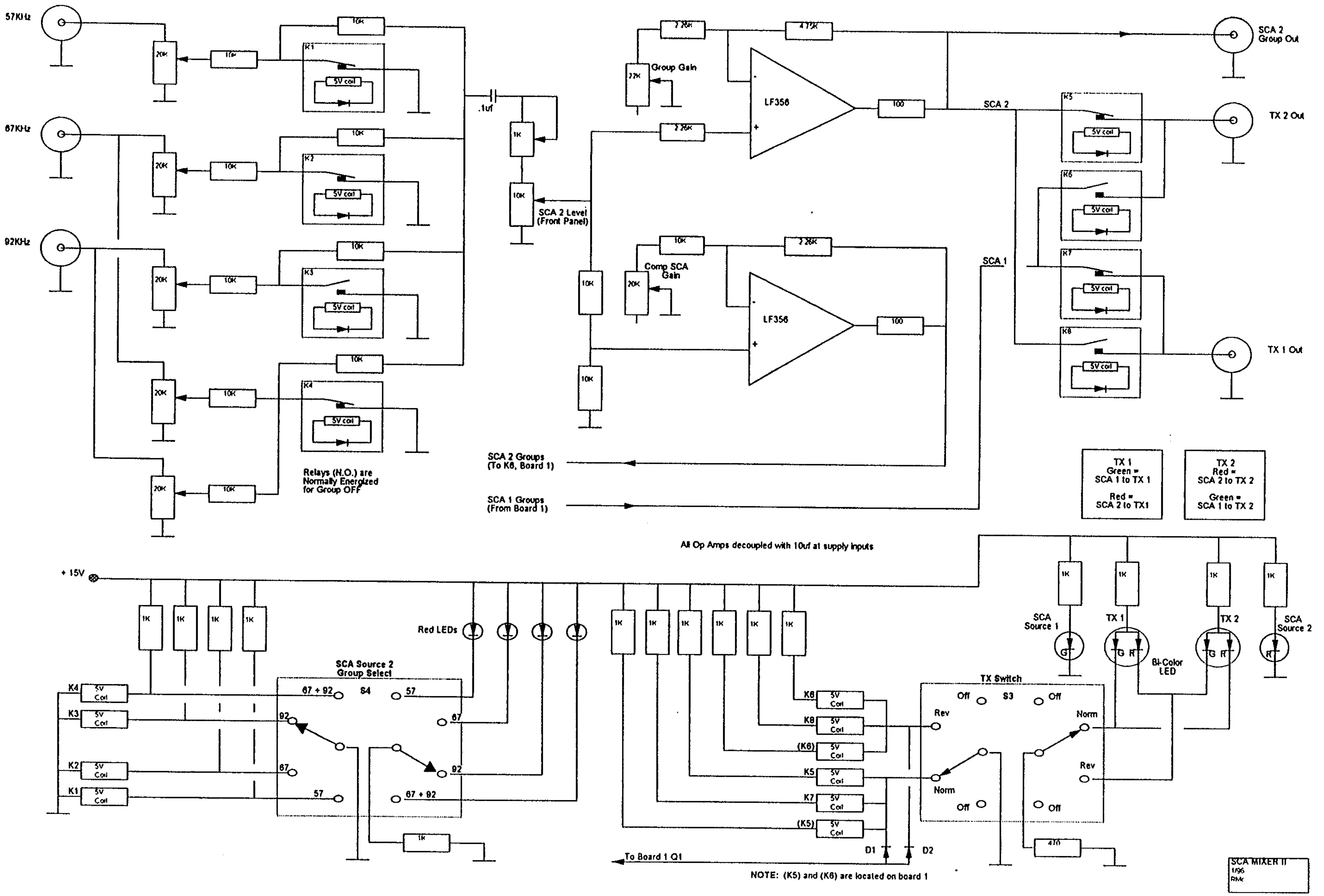
DIGITAL RADIO TEST LABORATORY

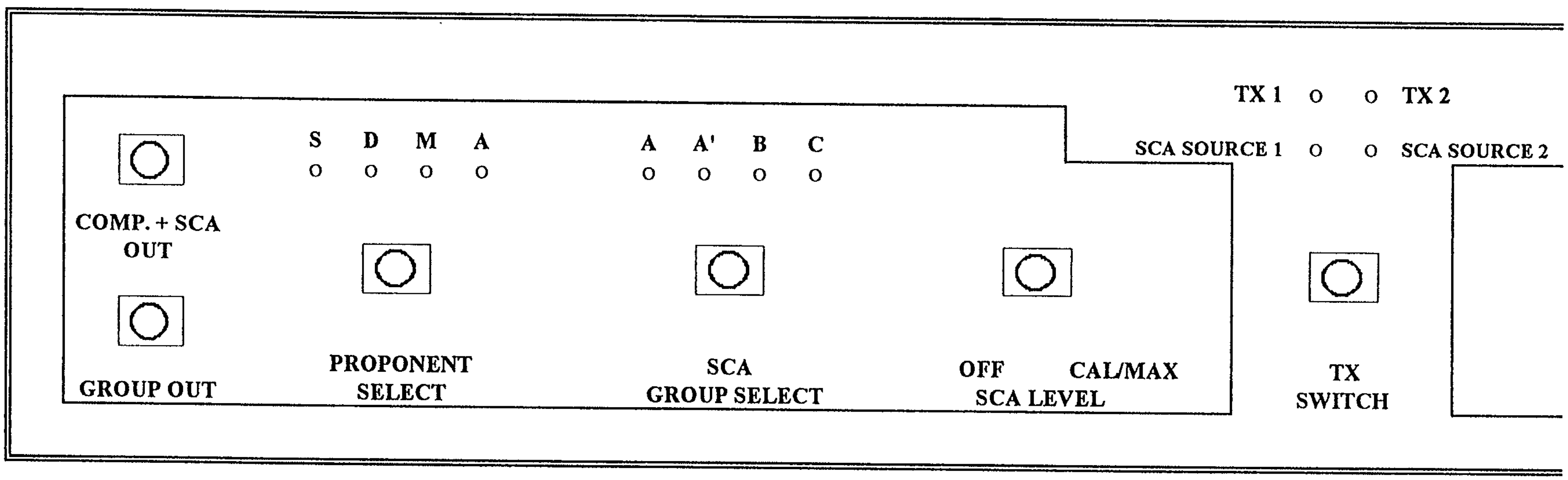




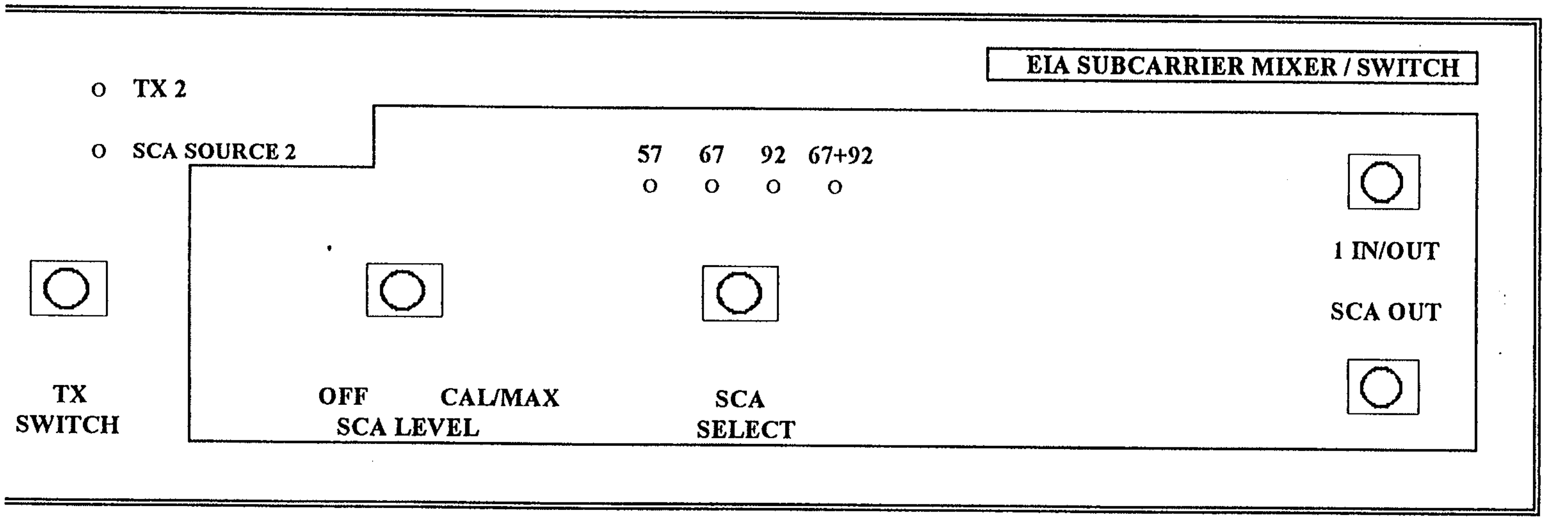
Power Supply

DIGITAL RADIO TEST LABORATORY



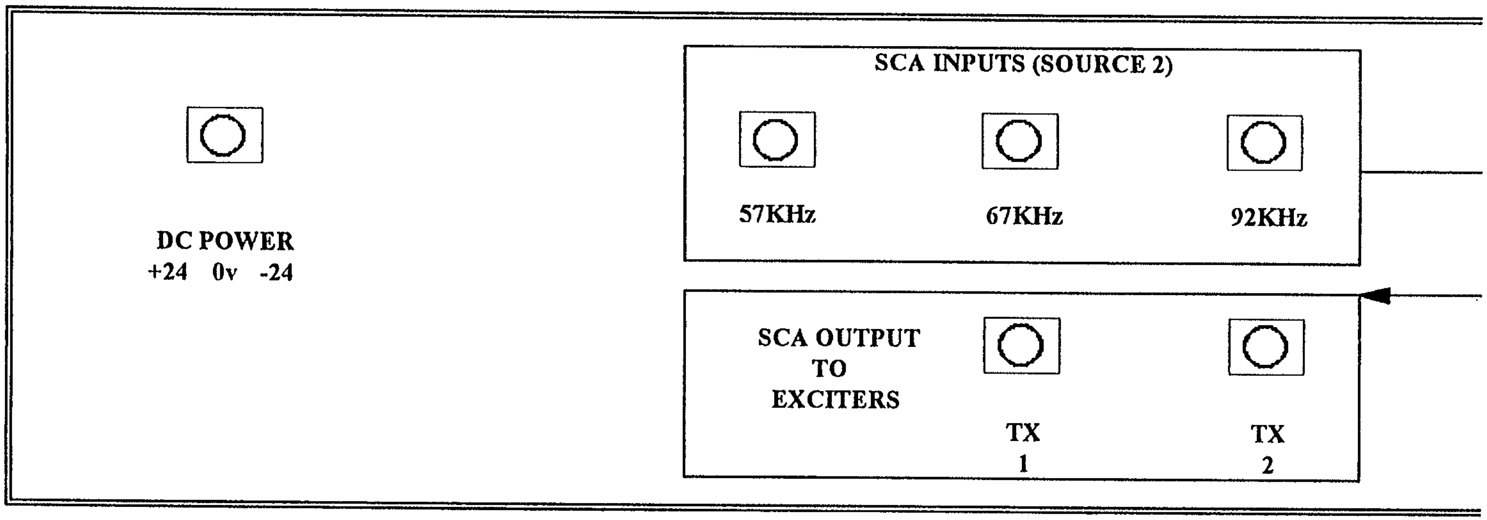

TX 1
TX 2
SCA SOURCE 1
SCA SOURCE 2
S D M A
A A' B C
COMP. + SCA OUT
GROUP OUT
PROPONENT SELECT
SCA GROUP SELECT
OFF
CAL/MAX
SCA LEVEL
TX SWITCH

LEFT FRONT



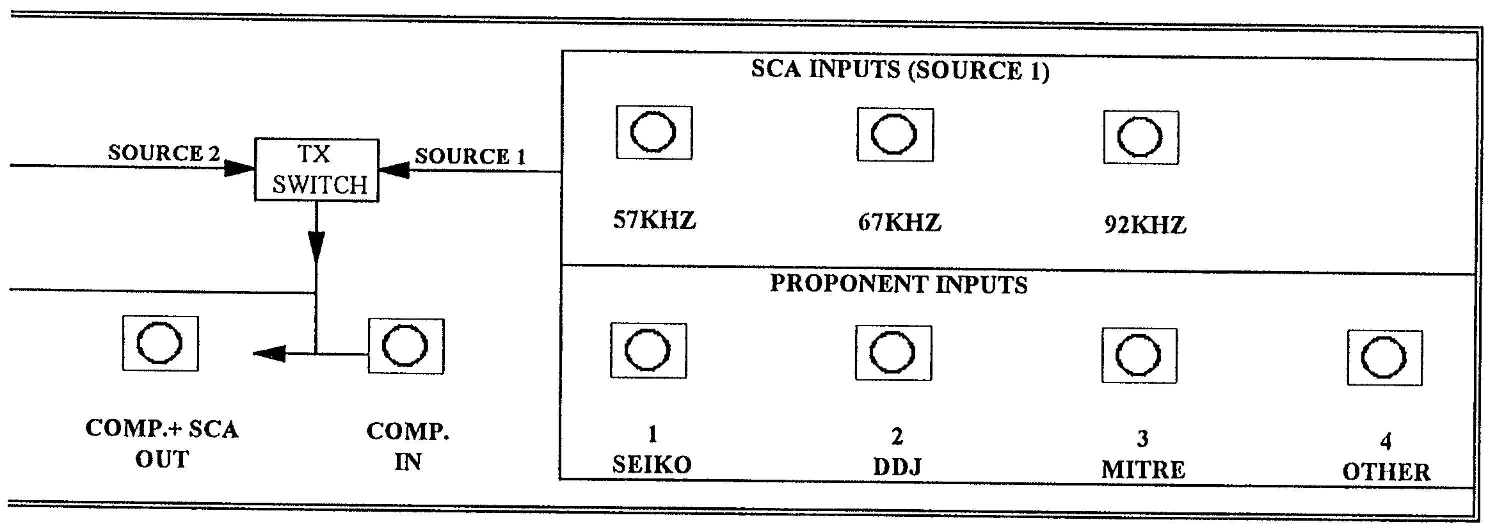
EIA SUBCARRIER MIXER / SWITCH
o TX 2
o SCA SOURCE 2
57 67 92 67+92
1 IN/OUT
SCA OUT
TX
SWITCH
OFF CAL/MAX
SCA LEVEL
SCA
SELECT

RIGHT FRONT


SCA INPUTS (SOURCE 2)
DC POWER
+24 0v -24
57KHz
67KHz
92KHz
SCA OUTPUT
TO
EXCITERS
TX
1
TX
2

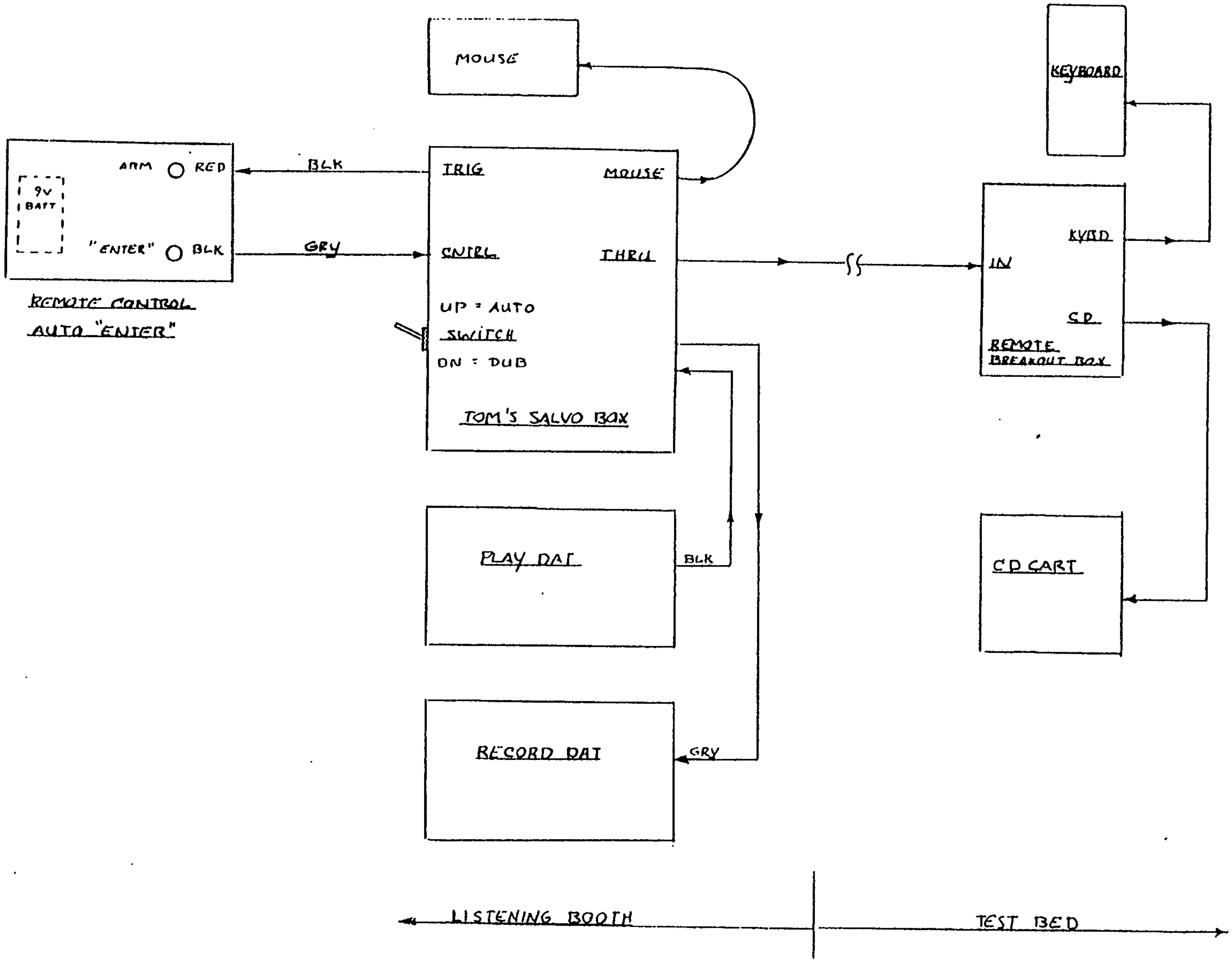
LEFT REAR

DIGITAL RADIO TEST LABORATORY

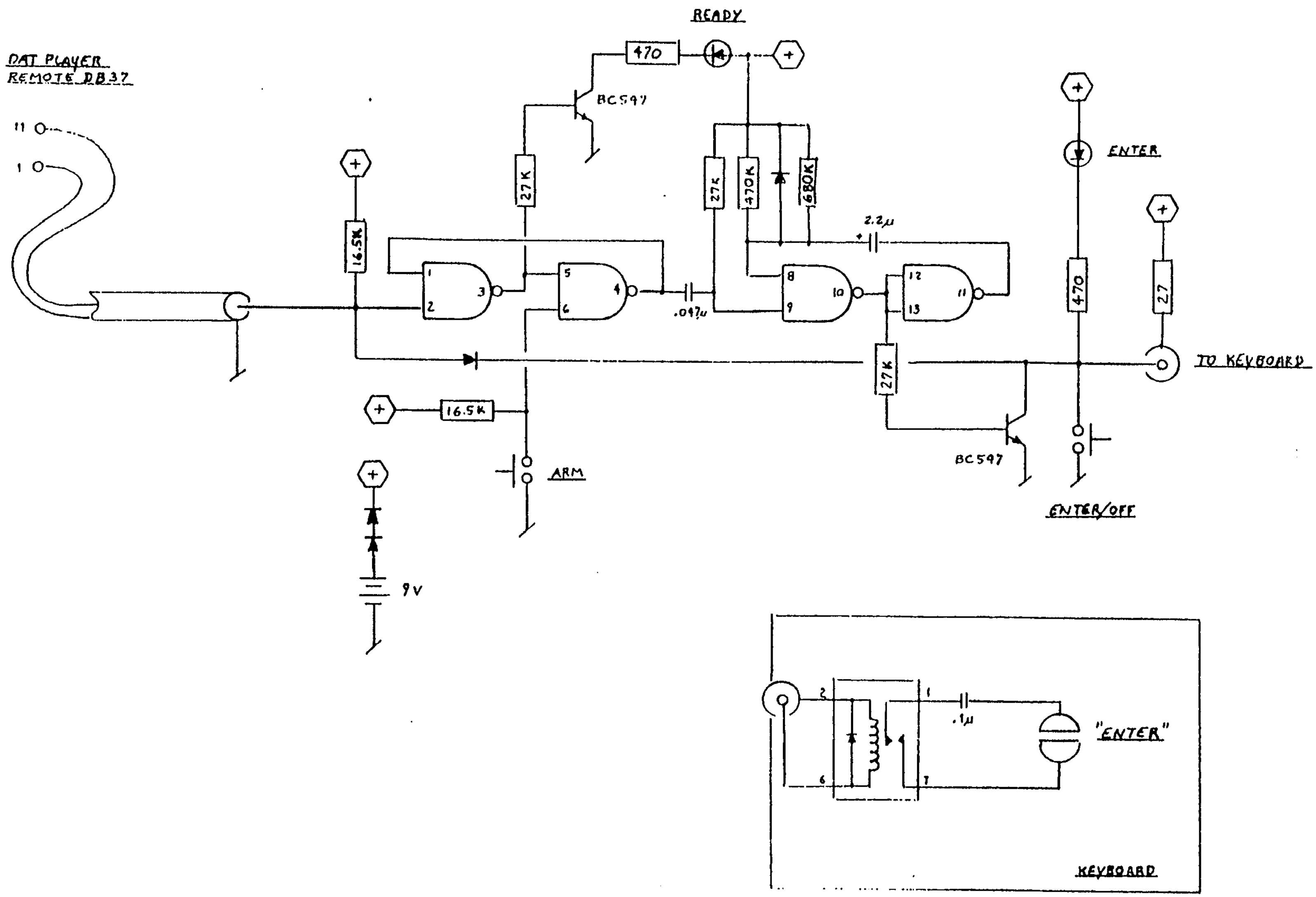


RIGHT REAR

Remote Control System



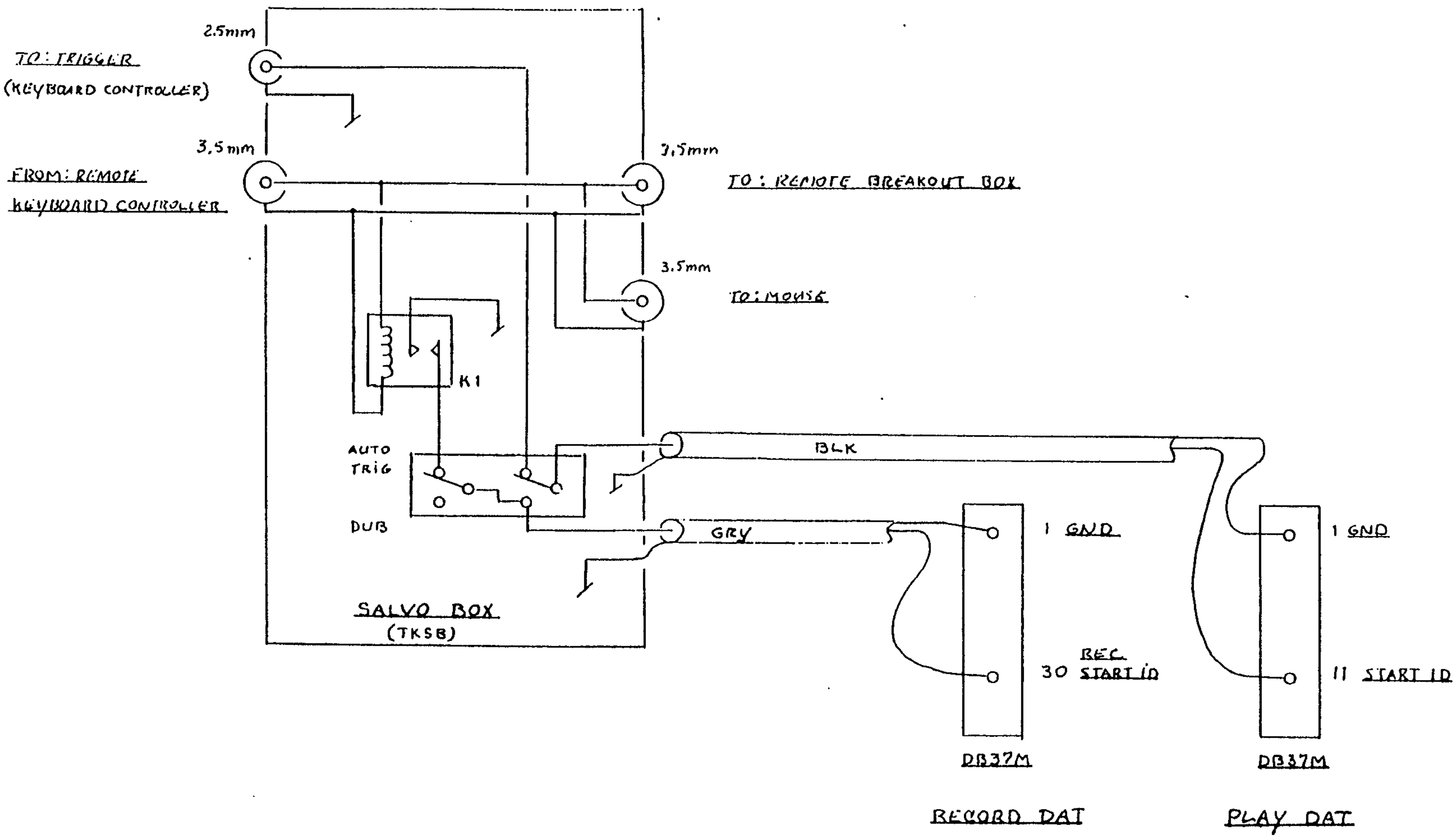
2/95 RMS
REMOTE CONTROL
CONNECTION DIA.



11/94 RMc

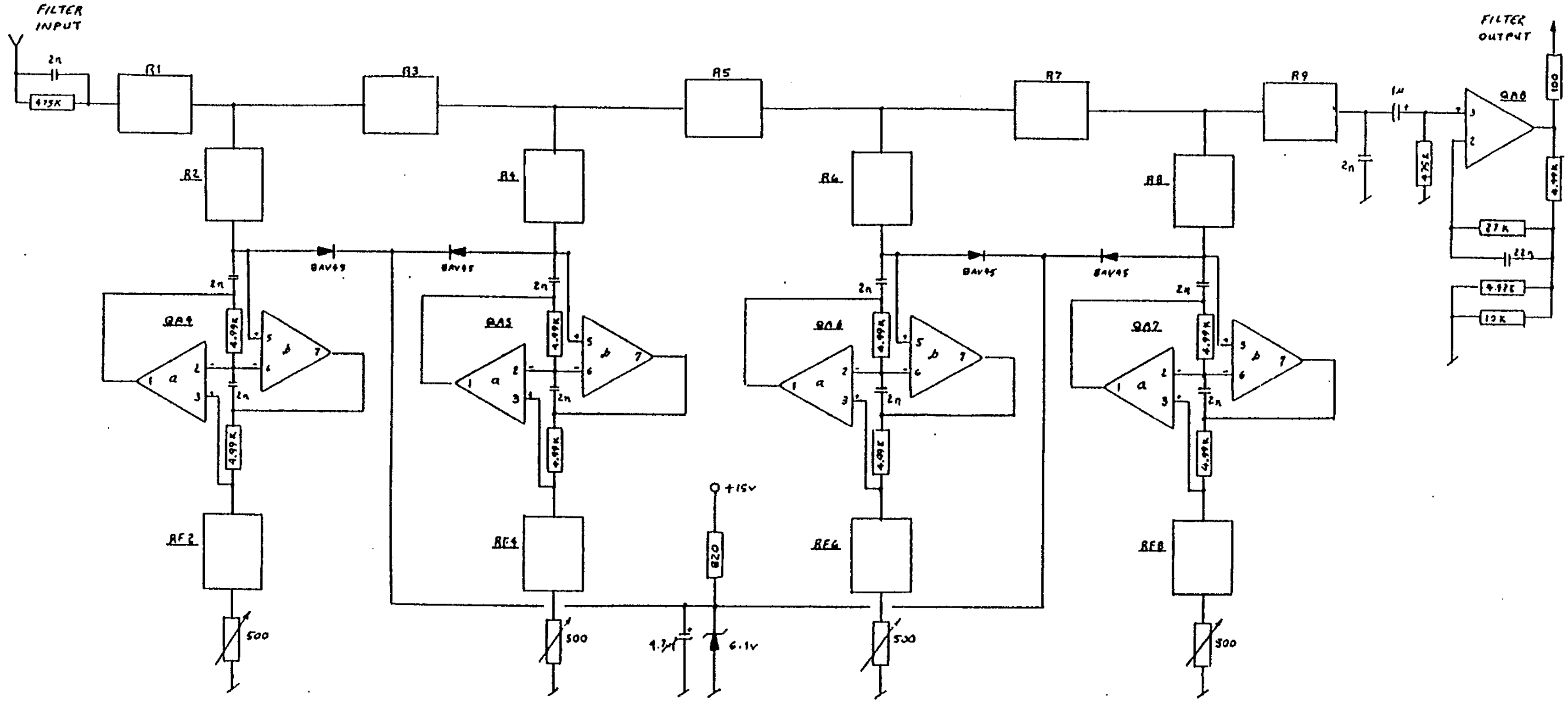
EIA

REMOTE KEYBOARD CONTROLLER



2/95
TOM'S SALVO CONTROL BOX

Pilot LP Filter

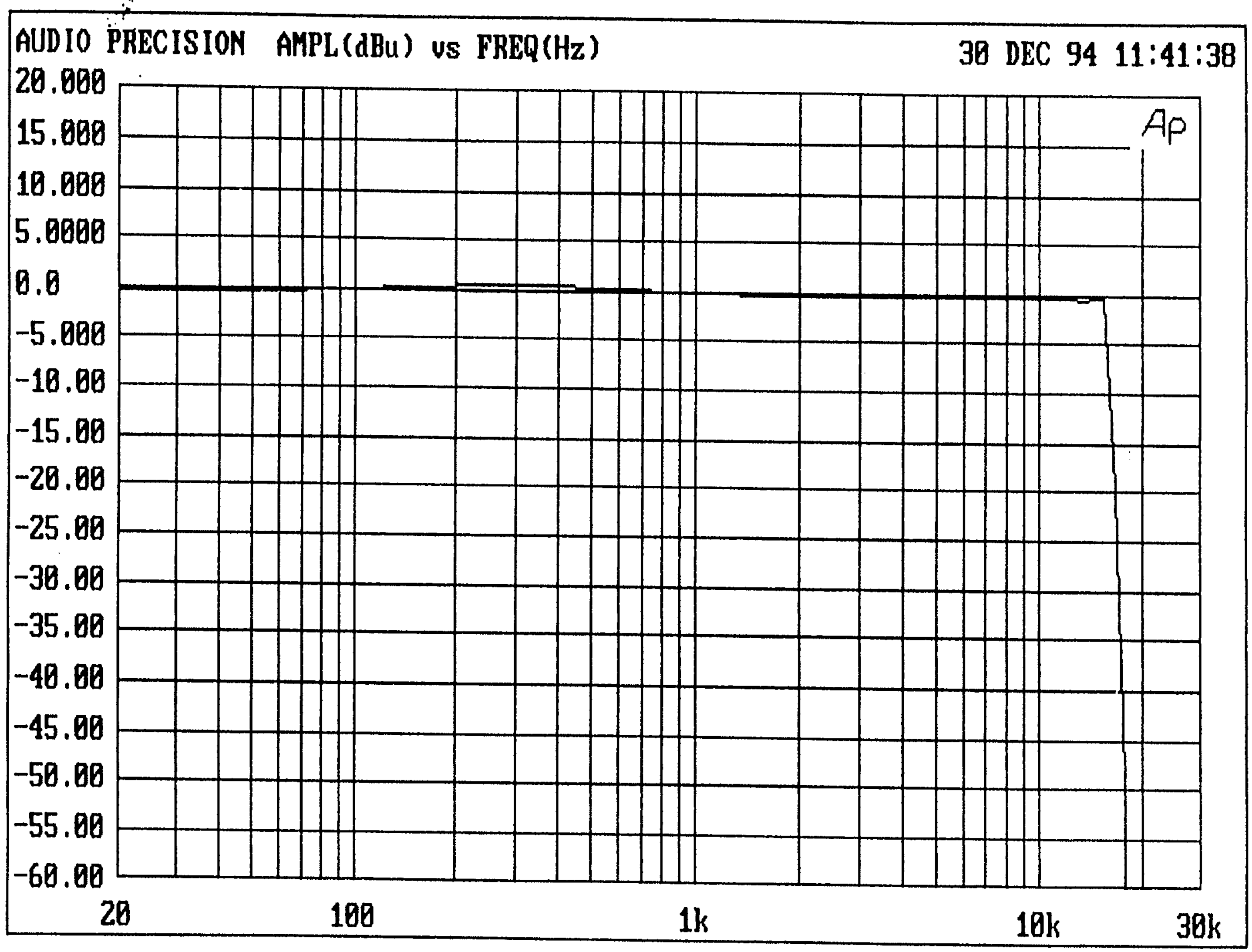


QA4 - 7   NE5532

QA8   NE5534

ALL IC'S DECOUPLED WITH 0.1uF CER CAPACITORS

9 POLE ELLIPTICAL FILTER


AUDIO PRECISION AMPL(dBu) vs FREQ(Hz)
30 DEC 94 11:41:38
Ap
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15.000
10.000
5.0000
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-10.00
-15.00
-20.00
-25.00
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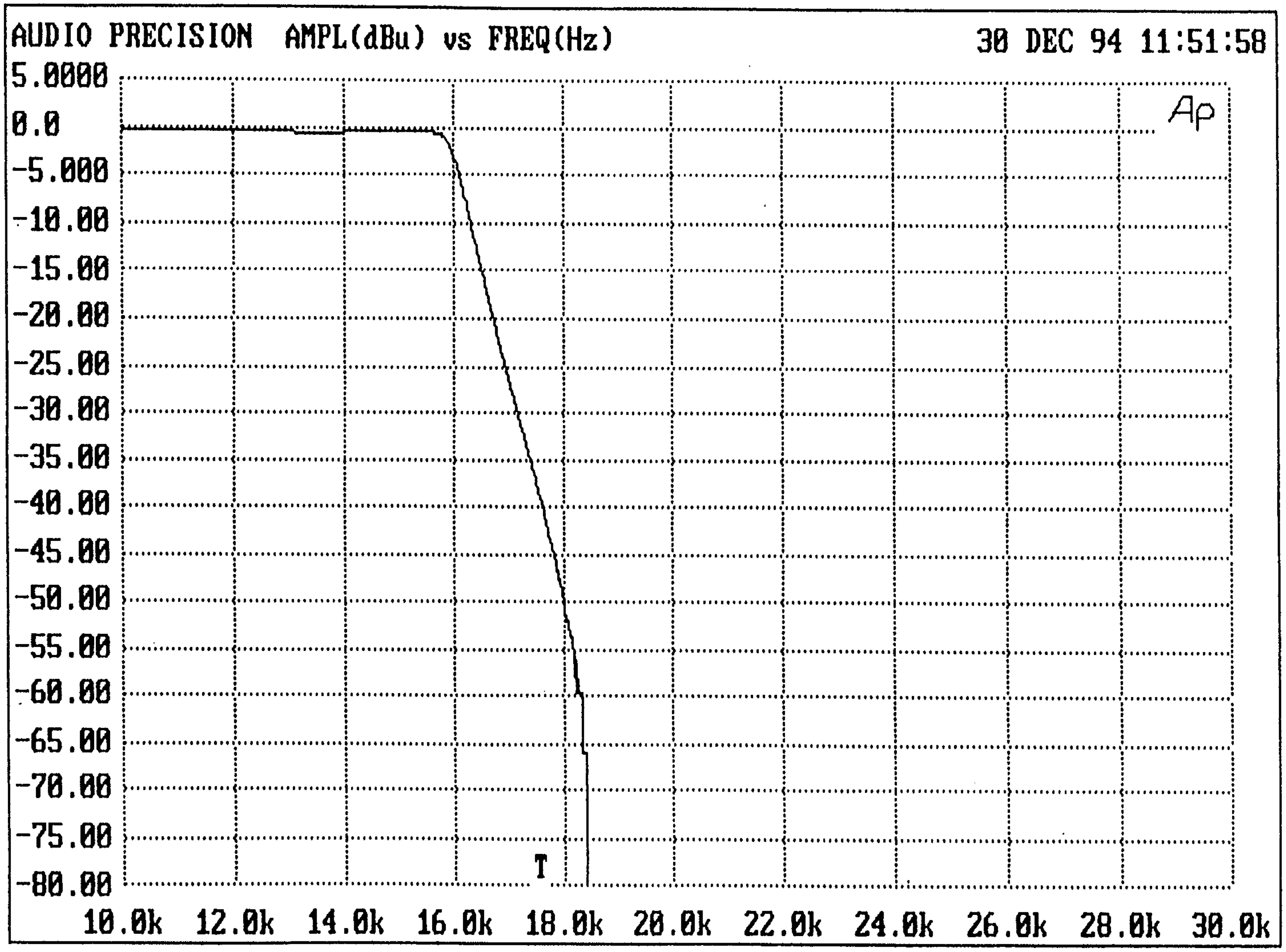
-60.00
20
100
1k
10k
30k


AUDIO PRECISION AMPL(dBu) vs FREQ(Hz)
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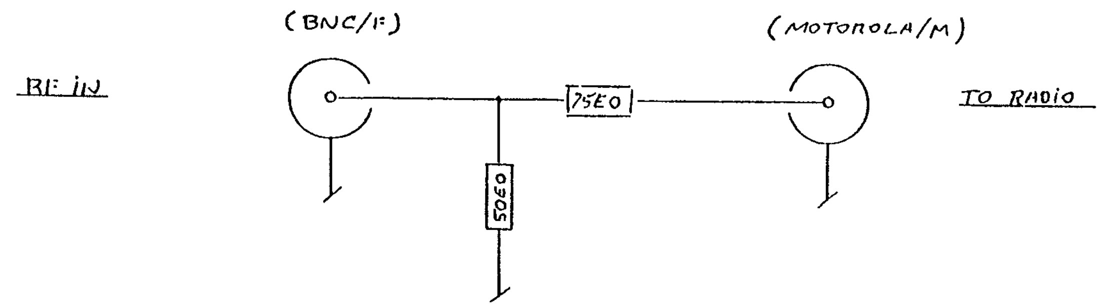
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
-70.00
-75.00
-80.00
T
10.0k 12.0k 14.0k 16.0k 18.0k 20.0k 22.0k 24.0k 26.0k 28.0k 30.0k

Dummy Antenna



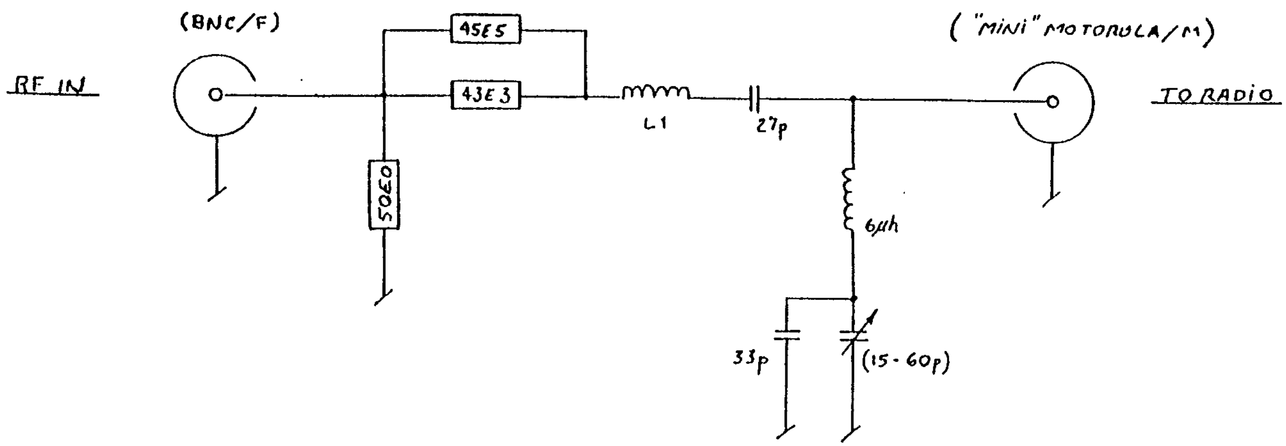
NOTES: * RF "TIGHT" ENCLOSURE

* INSERTION LOSS: 4.88dB W/ PAC/MIDLINE RADIOS (100Ω IMP)

EIA/DAR LAB

FORD FM DUMMY ANTENNA

1/95 RMS



NOTES:
- * L1 HAND WOUND - 14 T/24GA/0.125 DIA./0.75 L
- * RF "TIGHT" ENCLOSURE
- * "MINI" MOTOROLA: MALE "MOTOROLA" STYLE, SMALLER DIA.
- * INSERTION LOSS: FM/6dB
  AM/ VARIABLE W/FREQ.
- * MFG: JFW

EIA/DAR LAB

DELCO AM/FM DUMMY ANTENNA

1/95 RMC

Appendix I

EQUIVALENT NOISE BANDWIDTH CALCULATION

Noise Equivalent Bandwidth Calculation by the Method of Least Squares Approximation

Introduction

If white noise with a two-sided power spectral density of $N_0/2$ is passed through a band-pass filter with a transfer function H(f), the average noise power at the filter output is given by

$$P_{NO} = \int_{-\infty}^{\infty} |H(f)|^2 (N_0/2)\,df = N_0 \int_{0}^{\infty} |H(f)|^2 df \qquad (1)$$

If the filter were ideal (i.e. a "brick-wall" magnitude response), with a bandwidth B_N and a mid-band gain (or point of minimum insertion loss) H_0, the output average noise power would be

$$P_{NO} = N_0 B_N H_0^2 \qquad (2)$$

By equating the expressions in equations (1) and (2), it is possible to determine the noise equivalent bandwidth of a real filter as

$$B_N = (1/H_0)^2 \int_{-\infty}^{\infty} |H(f)|^2 df \qquad (3)$$

where the mid-band, or maximum gain of the real filter has been adjusted to an amplitude of H_0. Note that only the filter's magnitude response is involved here. By means of equation (3) a band-pass filter's noise equivalent bandwidth may be determined if the band-pass filter's transfer function is known analytically, or can be determined experimentally.

While the analytic expressions for band-pass filters are well known, they do not take into account the de-tuning effects of lossy components or the parasitic coupling between various components and between components and the enclosure. Therefore, while it would be easier to integrate an analytical expression for H(f), it would not properly include the effects of the real filter that is being used. Consequently it was decided to obtain the filter transfer function experimentally and evaluate equation (3) using numerical methods.

A network analyzer is a natural choice for obtaining these type of measurements since it evaluates the frequency response (offering both magnitude and phase information) of devices under test. The analysis band can be easily adjusted and proper calibration can be done to place the analyzer's reference planes at the input and output of the filter to be characterized. Thus, only the filter's response is obtained, including the parasitic and package effects. Data may be obtained in linear magnitude format, which is the natural choice for use with equation (3). An HP 8753D automatic vector network analyzer was used for data collection.

There are several limitations involved in obtaining an accurate representation of H(f) which must be considered and compensated for before it is certain that the B_N value obtained in equation (3) is correct. These limitations are-

(1) the expression for H(f) thus obtained is truncated in frequency, that is, H(f) information is not obtained for all frequencies, $0 \le f \le \infty$, but rather over a finite range $f_L \le f \le f_U$.

(2) The analyzer provides a discrete representation of H(f) in the frequency domain, i.e. it is not a continuous response. The analyzer used could provide up to 1601 calibrated data points across any desired frequency band.

(3) The amplitude information thus obtained is subject to errors due to noise and numerical round-off.

(4) As a result of (2) and (3) above, the filter's actual shape, specifically it maximum transmission gain (minimum insertion loss) location, could be missed if proper care is not taken in obtaining the data.

To ensure that the filters are properly characterized given the above limitations, the following steps are taken-

(1) Each filter was characterized on the 8753D to find its minimum insertion loss point (H_0 in equations (2) and (3)), which was chosen as the filter's center frequency. The upper and lower frequencies, f_u and f_l respectively, over which the filter

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characterization would occur were chosen as the frequency(s) at which the magnitude response was 5% of the filter's minimum insertion loss; i.e., $0.05H_0$. Since the integral in equation (3) involves $|H(f)|^2$ this choice ensures that 99.5% of the area under the filter's response curve is accounted for. The validity of this choice was ascertained by checking the $0.025H_0$ frequency band as well; the resulting B_N values were practically unchanged (<~0.1% difference) from the $0.05H_0$ interval.

Each filter's transmission maximum was normalized to 1.0, and the rest of the data points scaled accordingly. The magnitude response of each filter as obtained from the network analyzer appears at the end of this appendix. Note that the scale used is linear, not logarithmic.

It is the area under this curve which must be evaluated so that the equivalent "brick-wall" filter bandwidth may be obtained. Note that by normalizing the filter's insertion loss to 1.0, the $(1/H_0)^2$ term appearing in equation (3) is absorbed into the expression for $|H(f)|^2$.

(2) To verify that the transmission peak H_0, was the proper one, the frequency band, defined as f_u-f_l was shifted by an amount $f_\Delta/2$, where

$$f_\Delta = (f_u-f_l)/1600 \qquad (4)$$

where 1600 is the maximum number of intervals between the 1601 data points that the 8753D can display. This frequency shift also verified that the filter response in question had no spurious responses in the region of interest.

(3) and (4) To account for the HP 8753D's finite resolution and frequency step size, it was decided that rather than performing a Simpson's rule integration on the raw data, a curve fitting procedure would be employed using polynomial functions, as follows

$$|H(f_i)|^2 \approx \sum_{n=0}^{N} a_n\phi_i(n) \qquad (5)$$

for i=0,1,2,...Imax, where Imax is the number of data points obtained from the 8753D and the $\phi_i(n)$ represent the polynomial functions that will be used to fit the filter transfer function over the interval from f_l to f_u. The maximum polynomial order, N, is chosen based on a convergence criterion to be discussed later. The $H(f_i)$ are the filter transfer function data points as obtained from the 8753D using the linear scale at the discrete frequencies f_i. The $H(f_i)$ are normalized so that the filter's minimum insertion loss is 1.0. The coefficients a_n will be determined using the method of least squares so as to minimize the error in a mean square sense. Thus, the polynomial expansion on the right hand side of equation (5) will represent the best approximation to the actual filter transfer function.

To guarantee an accurate representation of H(f) over the interval from f_l to f_u, three sets of data points were taken, the first set consisting of 1601 points, the second consisting of 3201 points, and the third set consisting of 6401 data points taken over the interval from f_l to f_u. Since the 8753D can only generate 1601 calibrated data points over any one interval, the interval from f_l to f_u was sub-divided into two and then four sections to obtain 3201 and 6401 data points respectively. The sub-sections were combined to re-create the original interval of f_l to f_u in the computer program which performed the curve fit technique. Thus, in equation (5), Imax1=1601, Imax2=3201 and Imax3=6401 points respectively.

The choice of polynomial functions on the right hand side of equation (5) is appropriate since they form a linearly independent set of functions on an interval [a,b], and because the analytical expressions for the actual band-pass filter transfer functions, in both the pass-band and in the skirt regions can ultimately be expressed in terms of polynomial functions. Thus the use of polynomial functions to fit the data represent a "natural" choice.

To avoid numeric overflow that would inevitably occur if the curve fit was attempted in the region of the filter's center frequency, the filter's response was shifted from f_0, its original center frequency, down to zero frequency. Thus, f_l and f_u are shifted to f_l-f_0 and f_u-f_0, respectively. Finally the band of interest, namely f_u-f_l was re-defined to be the interval [-1,1], and this interval was subdivided into the appropriate number of sections corresponding to the appropriate f_Δ in equation (4). Once the unknown coefficients, the a_n, have been obtained, the noise equivalent bandwidth, B_n, is re-normalized to the band f_u-f_l.

It should be noted that there is no loss of accuracy introduced by re-defining the bandwidth of the frequency shifted filter response to the interval [-1,1], even though this process will shift the filter's minimum insertion loss point (i.e. which was defined as f_0 and then shifted to zero frequency) away from zero (unless of course it just so happens that f_0 also corresponds to the midpoint defined as $(f_u+f_l)/2$). This is not a problem since the method of least squares, which is used here, will fit the best curve to the data regardless whether the general shape of the data to be fit is symmetric about the ordinate or not. Since our purpose is to obtain the equivalent "brick-wall" filter response whose area is the same as that of the actual filter being characterized, maintaining the filter shape with respect to its position along an abscissa is not critical, maintaining the area under that filter shape is.

With the filter's band-pass so defined, there is no loss of accuracy if the abscissa is re-defined from a frequency scale to the x-axis, and the ordinate is now referred to as the y-axis. We now have a set of data points described in the x-y coordinate system. The expression in equation (5) may now be expressed as

$$f(x_i) \approx \sum_{n=0}^{N} a_n \phi_n(x_i) \qquad (6)$$

where i=0,1,2,...Imax as before. the coefficients a_n are obtained by applying the method of least squares (a brief description of which appears at the end of this section) to equation (6) followed by Gauss elimination to invert the resulting square matrix. The coefficients resulting from the application of this technique provide the best fit of the expansion function $\phi_n(x_i)$ to the data points. Once coefficients of the polynomial function have been obtained, the area under the curve may be obtained by an analytical integration of this function. Thus, the expression for B_n, the equivalent noise bandwidth of the filter given in equation (3) has been obtained.

The calculated noise equivalent bandwidth for the filters are presented below, along with the frequency band over which the filter data was obtained (the frequencies between which the filter response is $\geq 0.05H_0$) the resulting step size, f_Δ given in equation (4) and the filter's minimum insertion loss, H_0 as obtained from the network analyzer.

Filter Type	$f_u - f_l$ (MHz)	f_Δ (kHz)	H_0 (dB)	B_n (MHz)
AM #1	2.72	1.700	-0.29	1.04400
FM #1	20.00	12.500	-2.72	6.44868
FM #2	20.00	12.500	-2.80	6.41530
L-Band	24.00	15.000	-1.03	11.58017
S-Band	36.00	22.500	-0.90	17.82766

Table 1. Band-pass filter data.

Remarks on the Accuracy of the Expression for B_n

There are two main questions regarding the accuracy of the technique used that must be properly addressed so as to have a high confidence level in the numerical results obtained by this method. They are-

(1) Have sufficient data points in frequency been obtained for the filter, and

(2) is the polynomial order of the $\phi_n(x)$ in equation (6) sufficiently high to ensure the expression for B_n thus obtained has converged to its limiting value.

To ensure that sufficient data points (1601) were obtained for the filter response, three things were done, they are-

1a) The band $f_u - f_l$ was divided into two, then four sections so that the overall band was represented by 3201 and 6401 points, respectively. This was done by taking 1601 data points per band and properly joining the data together in the program to fill the entire band $f_u - f_l$ with data.

1b) The start and stop frequencies, f_l and f_u respectively, where shifted by one half of the frequency step, f_Δ, for the case of 6401 data points for each filter. This was done to verify that there were no spurious transmission peaks between data points, i.e., the data was smooth. It should be noted that the frequency steps given in Table 1 are so fine relative to each filter's center frequency (frequency of minimum insertion loss) that any transmission anomalies, resulting from spurious resonances, would naturally appear in the data as measured. This procedure also improved the possibility that the point of minimum insertion loss was obtained for each filter.

1c) A Simpson's rule integration of the data was performed for each of the three sets of data (1601, 3201, and 6401 points). The resulting values of B_n thus obtained were checked for convergence using the criterion that $\Delta B_n \leq 1.0\%$, where ΔB_n = B_n(3201 points)-B_n(1601 points) and B_n(6401 points)-B_n(3201 points). By doing this, it was ascertained that 1601 data points would be sufficient to characterize the filters listed in Table 1.

For the filter designated FM #1, 801 data points were taken as well, as a check to see if using fewer points increased ΔB_n. In this case, $B_n(1601)-B_n(801)$ produced a larger difference (~1.0%) than $B_n(3201)-B_n(1601)$ did, however, it still met our criterion of $\Delta B_n \leq 1.0\%$ and so 801 data points could have been used. We decided to stay with 1601 data points because it gave better accuracy and cost very little extra run time in the program.

It should be noted here that in terms of the B_n obtained by this method, a 1% error in B_n represents a worst case error of <0.05 dB. This value, 0.05 dB, is well within the accuracy level of the rest of the components and test equipment used in the test bed in the DAR lab.

Performing a Simpson's rule integration on the raw data also provided a check on the values obtained for B_n obtained by the least squares curve fit approach. This ensured us that no gross error was made in obtaining the final values of B_n.

A final check on the B_n values was to perform the rather crude but reliable technique of graphically computing the area under the filter's response curve on the spectrum analyzer. This technique is fully described in a Hewlett Packard application note AN-150-4, (April 1974) and the description will not be repeated here. In each case where this technique was used as a check, the results were within 10% to 15% of those obtained by the method of least squares.

To ensure that an adequate order was used for the approximating polynomial, the B_n calculation was performed for each filter using several different values of N, the highest order of polynomial used, along with a criterion that $\Delta B_n \leq 0.01\%$ is achieved before the iteration in N is terminated. In this case

ΔB_n is defined as B_n(Ncur.)-B_n(Ncur.-2) where Ncur. is the current order of the polynomial and only an even polynomial order was used in the procedure. In practice it was found that N=28 easily met this criterion. The difference between N=28 and N=30 was never more than 0.007% for any filter listed in Table 1. Using N>30 produced no significant improvement or change in the B_n values obtained for any filter beyond one part in 10^4.

Appendix: The Method of Least Squares

Let us consider a linear space of real functions f, g, h, ... which are defined on a set of points, x, (which can be continuous or discrete) on a closed interval [a,b] on the real axis. A scalar product can be defined in this space if, to any pair of elements defined in this space, there corresponds a real number, designated (f,g), which is called the scalar product of f and g. The scalar product must also satisfy the following properties-

(a) $(f,g)=(g,f)$ (A1a)

(b) $(f,f)\geq 0;\ (f,f)=0 \text{ iff } f\equiv 0$ (A1b)

(c) $(\alpha f,g)=\alpha(f,g)$; were α is real (A1c)

(d) $(f_1+f_2,g)=(f_1,g)+(f_2,g)$ (A1d)

For continuous functions on the interval [a,b] the scalar product may be defined as

$$(f,g)=(1/(b-a))\int_a^b f(x)g(x)\,dx \tag{A2}$$

While for functions defined on a finite set of discrete points on the interval [a,b], the scalar product my be defined as

$$(f,g)=(1/(N+1))\sum_{n=0}^{N} f(x_n)g(x_n) \tag{A3}$$

In this case, these functions are defined to exist on a N+1 dimensional linear space, and the function f may be considered as a (N+1) dimensional vector $f=(f_0, f_1, f_2, \ldots f_N)$ on this space. Thus the scalar product as defined on equation (A3) may be considered as a projection of the vector f onto a basis function, or along a principal co-ordinate, of the space.

The norm of a scalar product may be defined as

$$|f|=(f,f)^{1/2} \tag{A4}$$

and a distance in the linear space as follows

$$d(f,g)=|f-g|=(f-g,f-g)^{1/2} \tag{A5}$$

Using the above terminology and definitions, we may now define a function consisting of elements of a linear space as follows

$$\Phi_n(x)=a_0\phi_0(x)+a_1\phi_1(x)+ \ldots +a_N\phi_N(x)=\sum_{n=0}^{N} a_n\phi_n(x) \tag{A6}$$

where the a_n are real numerical coefficients, as a generalized polynomial with respect to the system of functions $\phi_n(x)$. If an arbitrary function f(x) belongs to a linear space E on which the $\phi_n(x)$ are defined, the problem of choosing the coefficients a_n in (A6) such that the mean square error is minimized can be stated as a problem in which the distance $d(f,\Phi_n)$ is minimized. Using the concept of distance in the linear space as given in equation (A4), we can define $d(f,\Phi_n)$ as

$$d(f,\Phi_n)=|f-\Phi_n|=(f-\Phi_n, f-\Phi_n)^{1/2} \tag{A7}$$

The polynomial that satisfies the property of minimizing $d(f,\Phi_n)$ is the polynomial which minimizes the mean square error between f(x) and $\Phi_n(x)$ over the interval [a,b]. In this way, the generalized polynomial defined in (A6) represents the "best fit" to the data points.

To see that an appropriate choice of the coefficients a_j can minimize the distance function $d(f,\Phi_n)$ in equation (A7) we may proceed as follows. Inserting the generalized polynomial defined in equation (A6) into (A7) and squaring the resulting expression we can write

$$d^2(f,\Phi_n)=|f-\Phi_n|=(f-\Phi_n,f-\Phi_n)$$

$$=(f,f)+\sum_{j,k=0}^{N} a_j a_k(\phi_j,\phi_k)-2\sum_{j=0}^{N} a_j\ (f,\phi_j) \qquad \text{(A8)}$$

The quantity $d^2(f,\Phi_n)$ in equation (A8) is a quadratic form relative to the coefficients a_j, and consequently for any a_j, $d^2(f,\Phi_n)\geq 0$. The quantity $d^2(f,\Phi_n)$ will reach its non-negative minimum when the distance, $d(f,\Phi_n)=(d^2(f,\Phi_n))^{1/2}$, reaches its minimum.

To obtain the coefficients a_j for which this minimum occurs, we can take the partial derivatives of equation (A8) with respect to the a_j's and set them equal to zero. This will produce the following set of linear equations

$$a_0(\phi_0,\phi_0)+a_1(\phi_1,\phi_0)+a_2(\phi_2,\phi_0)+\ldots+a_n(\phi_n,\phi_0)=(f,\phi_0)$$

$$a_0(\phi_0,\phi_1)+a_1(\phi_1,\phi_1)+a_2(\phi_2,\phi_1)+\ldots+a_n(\phi_n,\phi_0)=(f,\phi_1)$$

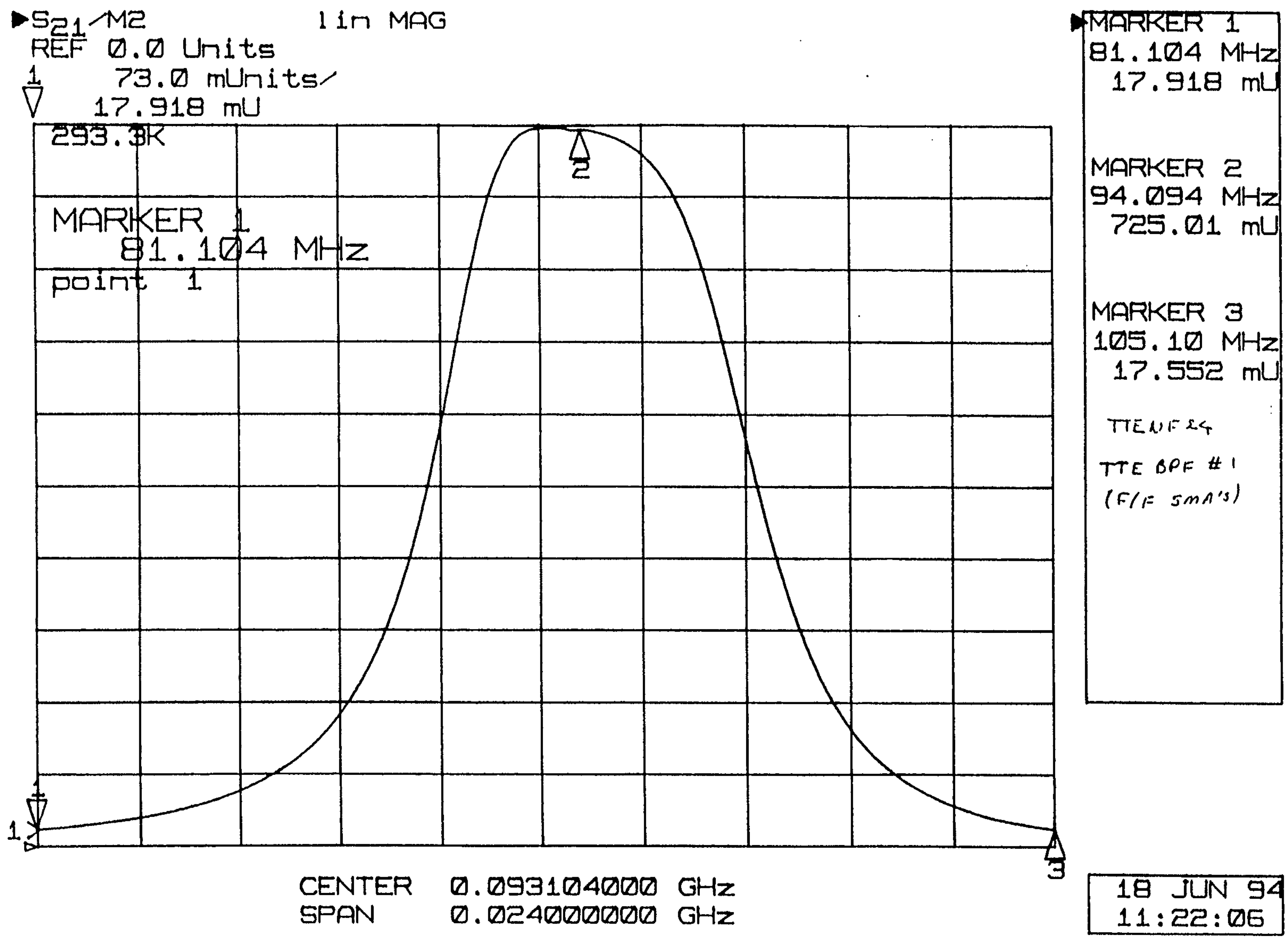
$$\ldots \qquad \ldots \qquad \text{(A9)}$$

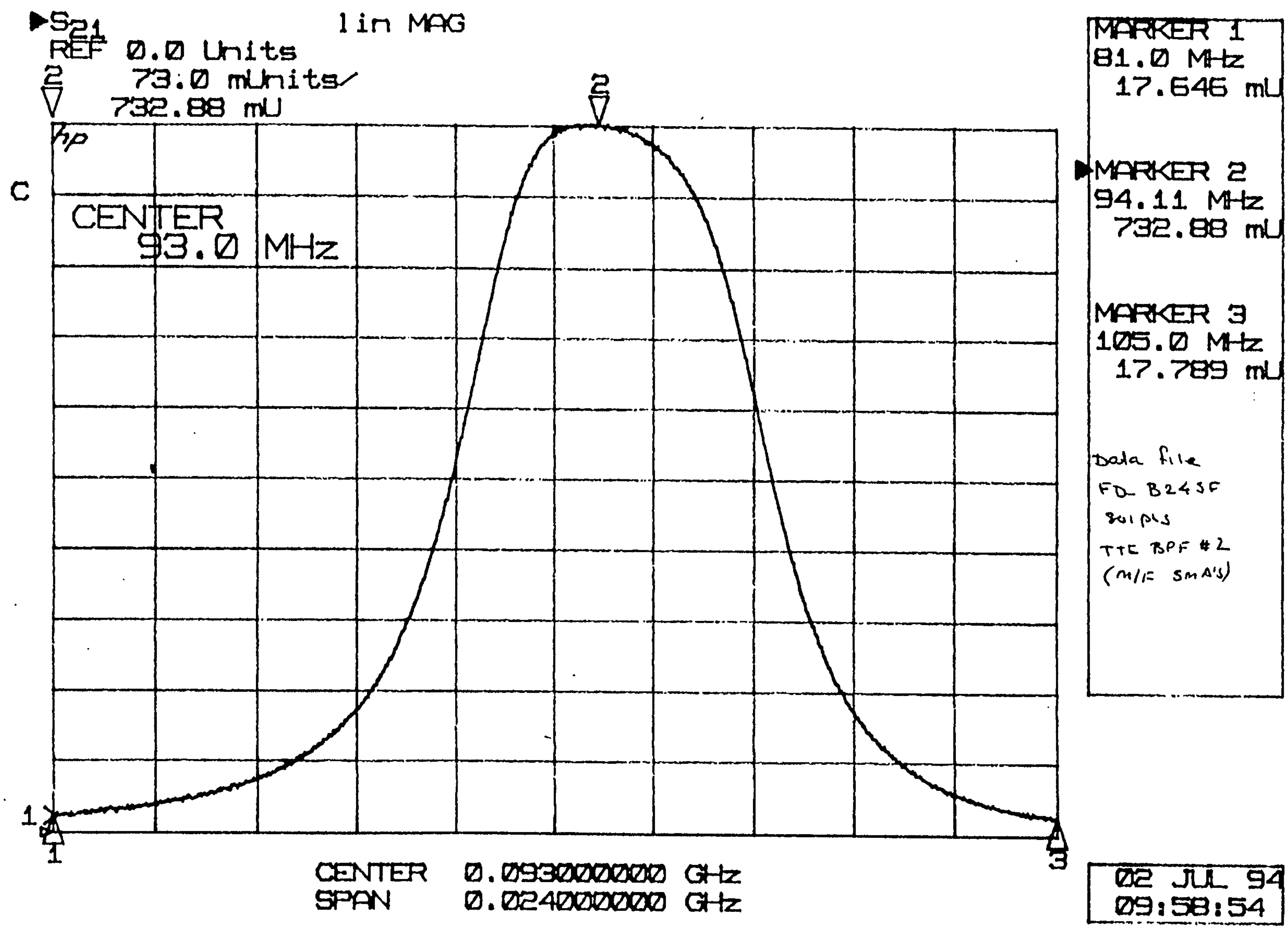
$$\ldots \qquad \ldots$$

$$a_0(\phi_0,\phi_n)+a_1(\phi_1,\phi_n)+a_2(\phi_2,\phi_n)+\ldots+a_n(\phi_n,\phi_n)=(f,\phi_n)$$

The scalar products (ϕ_i,ϕ_j) in equation (A9) form an (N by N) array. Since the functions ϕ_n are linearly independent, this array will have a non-vanishing determinant and consequently it may be inverted. Gauss elimination is used to invert the array, and so equation (A9) can be solved for the a_n which will provide a minimum value for the $d(f,\Phi_n)$. This is the technique used to find the proper coefficients a_i in equation (5). The functions $\phi_n(x)$ are chosen to be polynomial functions, i.e. $\phi_n(x)=x^n$, for the reasons given in the main body of this paper. Note that with 1601 data points and N=30, the system of equations described in equation (4) is over specified, and that the method of least squares described above reduces this system of equations to one of N equations with N unknowns.

The program to evaluate the noise equivalent bandwidth of the filters was written in HP BASIC. Data on each filter was obtained from the HP 8753D using the linear scale. The program found the maximum amplitude of the data , normalized the data to this value, then squared it to create $|H(f_i)/H_0|^2$. The program then evaluated the appropriate scalar products as defined in equation (A9). Gauss elimination was used to invert the matrix and thus solve for the unknown a_n's. The corresponding value for B_n was obtained by integration of the resulting polynomial. A Simpson's rule integration was also performed on the raw data and the results displayed for B_n obtained in this fashion as a check on the least squares technique. The user may choose the order of the polynomial function used in the curve fit, as well as the number of data points to be used in the analysis.


S21/M2
lin MAG
REF 0.0 Units
73.0 mUnits/
17.918 mU
293.3K
MARKER 1
81.104 MHz
point 1
MARKER 1
81.104 MHz
17.918 mU
MARKER 2
94.094 MHz
725.01 mU
MARKER 3
105.10 MHz
17.552 mU
TTE BPF #1
(F/F SMA's)
CENTER 0.093104000 GHz
SPAN 0.024000000 GHz
18 JUN 94
11:22:06



S21
lin MAG
REF 0.0 Units
73.0 mUnits/
732.88 mU
CENTER
93.0 MHz
MARKER 1
81.0 MHz
17.646 mU
MARKER 2
94.11 MHz
732.88 mU
MARKER 3
105.0 MHz
17.789 mU
Data file
FD-B245F
801 pts
TTC BPF #2
(M/F SMA's)
CENTER 0.093000000 GHz
SPAN 0.024000000 GHz
02 JUL 94
09:58:54

Appendix J

SUBJECTIVE ASSESSMENT

LABORATORY SUBJECTIVE TESTS

The EO&C rating scale is the impairment rating scale used by the laboratory staff for the evaluation of increase or decrease in interference to the desired signal caused by the HSSC signal or other signals. The ratings were made in comparison to a reference. The test is called Expert Observation and Commentary (EO&C).

EO&C Rating Scale

-3	Much Worse
-2	Worse
-1	Slightly Worse
0	The Same
1	Slightly Better
2	Better
3	Much Better

Appendix K

IMPULSE NOISE

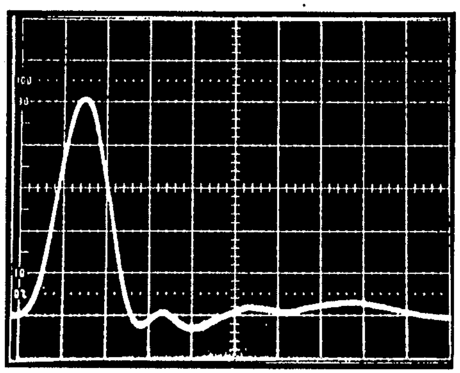
Page 1 of 1 Oscilloscope Photos

Spectrum Analyzer Plots

1. 100 Hz pulse at 94.1 MHz
2. 200 Hz pulse at 94.1 MHz
3. 300 Hz pulse at 94.1 MHz
4. 600 Hz pulse at 94.1 MHz
5. 1 kHz pulse at 94.1 MHz

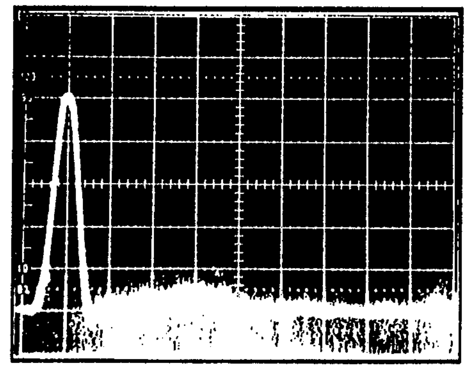
Digital Radio Test Laboratory

Interstate P25 Pulse generator.



0.2 V, 5 nsec / Division

at Receiver Input



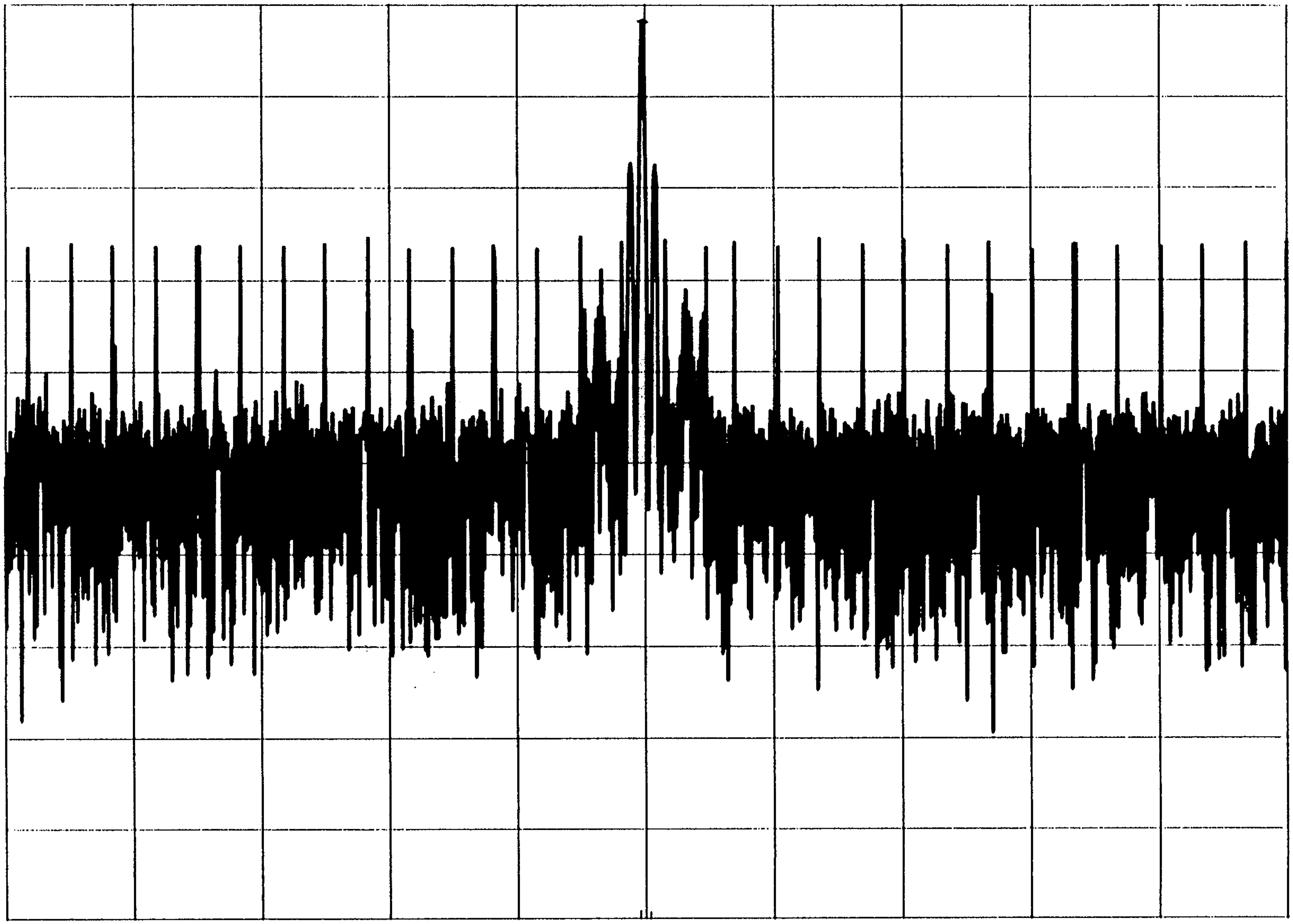
0.2 V, 10 nsec / Division

at Receiver Input

B-4: RR=100Hz: ATTN=0dB: 11-7-96 MKR 94.096 MHz

EIA REF -55.0 dBm ATTEN 10 dB -56.80 dBm

10 dB/



CENTER 94.10 MHz SPAN 2.00 MHz

RES BW 3 kHz VBW 10 kHz SWP 600 msec

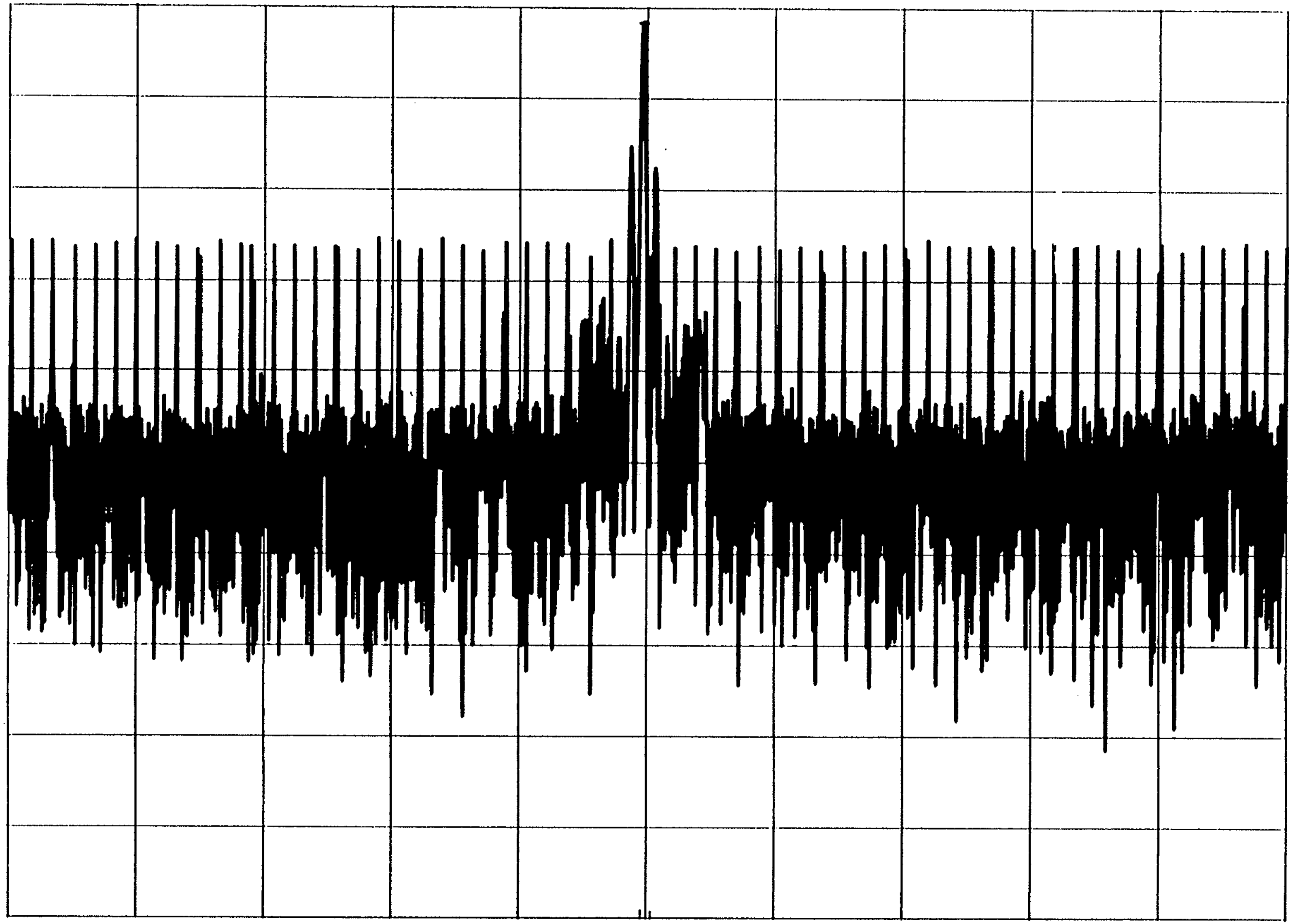
#1

B-4: RR=200Hz: ATTN=0dB: 11-7-96

EIA REF -55.0 dBm ATTEN 10 dB

MKR 94.094 MHz
-56.70 dBm

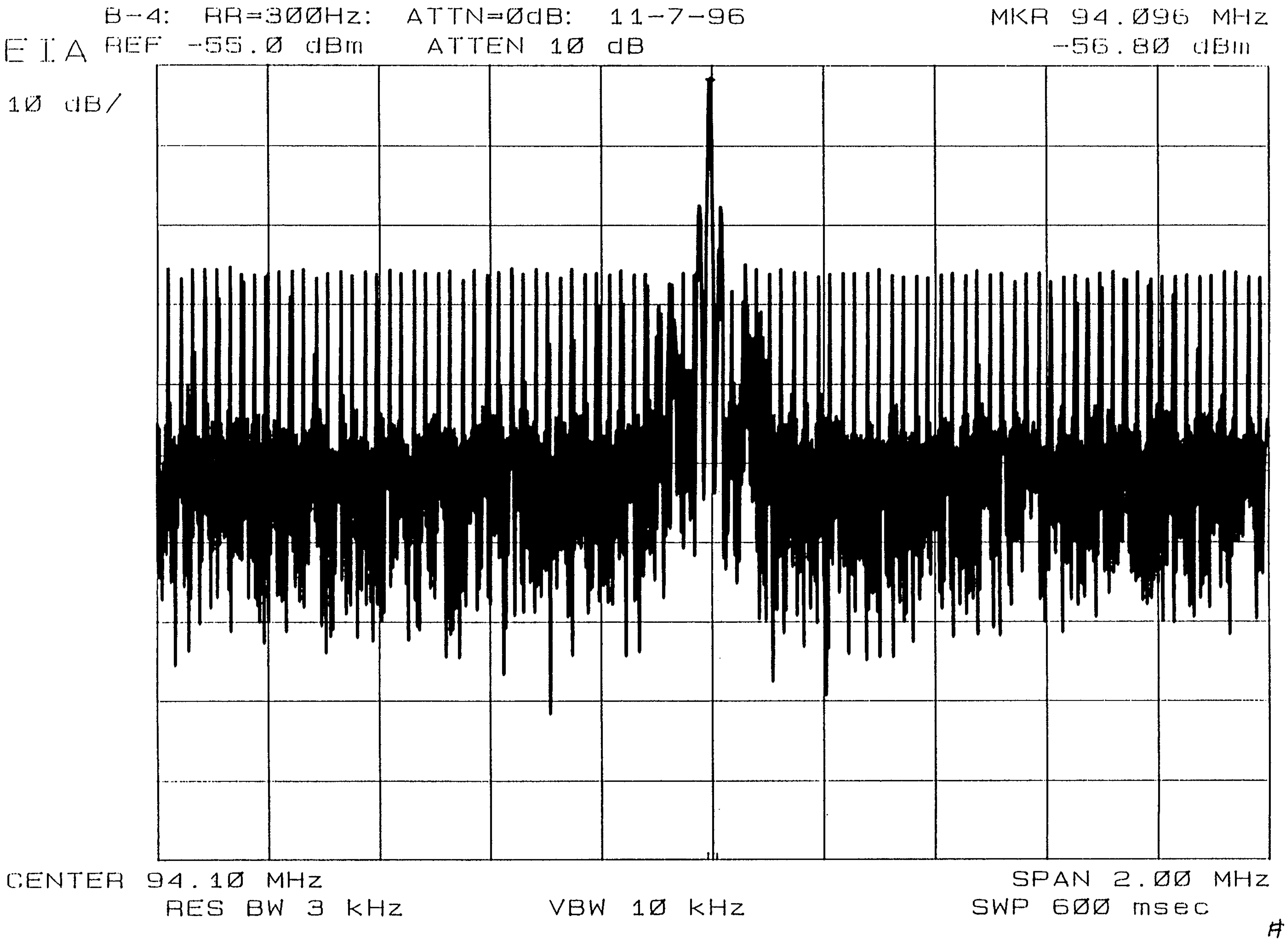
10 dB/



CENTER 94.10 MHz
RES BW 3 kHz VBW 10 kHz

SPAN 2.00 MHz
SWP 600 msec

#2


B-4: RR=300Hz: ATTN=0dB: 11-7-96
MKR 94.096 MHz
EIA
REF -55.0 dBm
ATTEN 10 dB
-56.80 dBm
10 dB/
CENTER 94.10 MHz
SPAN 2.00 MHz
RES BW 3 kHz
VBW 10 kHz
SWP 600 msec
#3

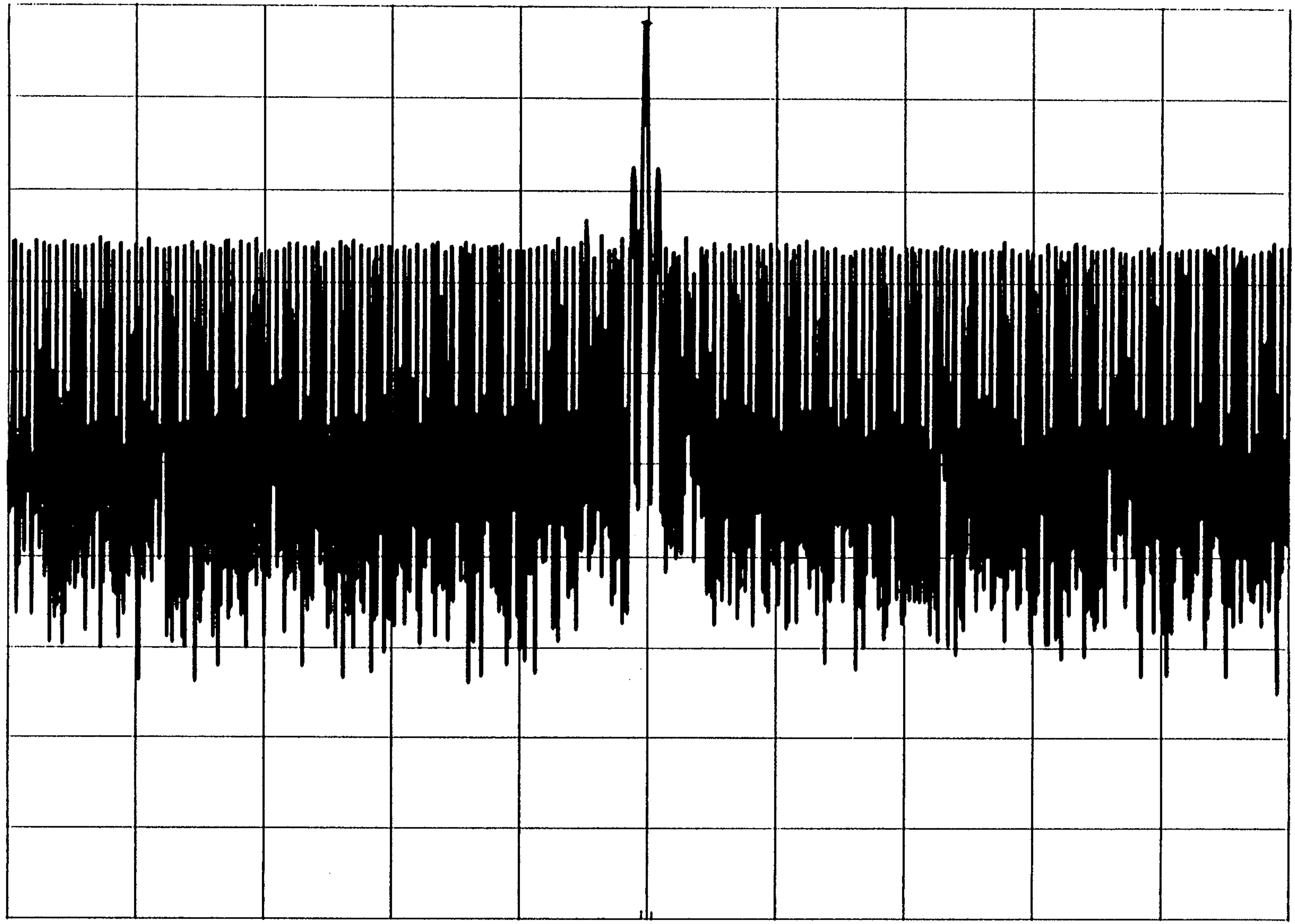
B-4: RR=600Hz: ATTN=0dB: 11-7-96

MKR 94.096 MHz

E.I.A REF -55.0 dBm ATTEN 10 dB

-56.80 dBm

10 dB/

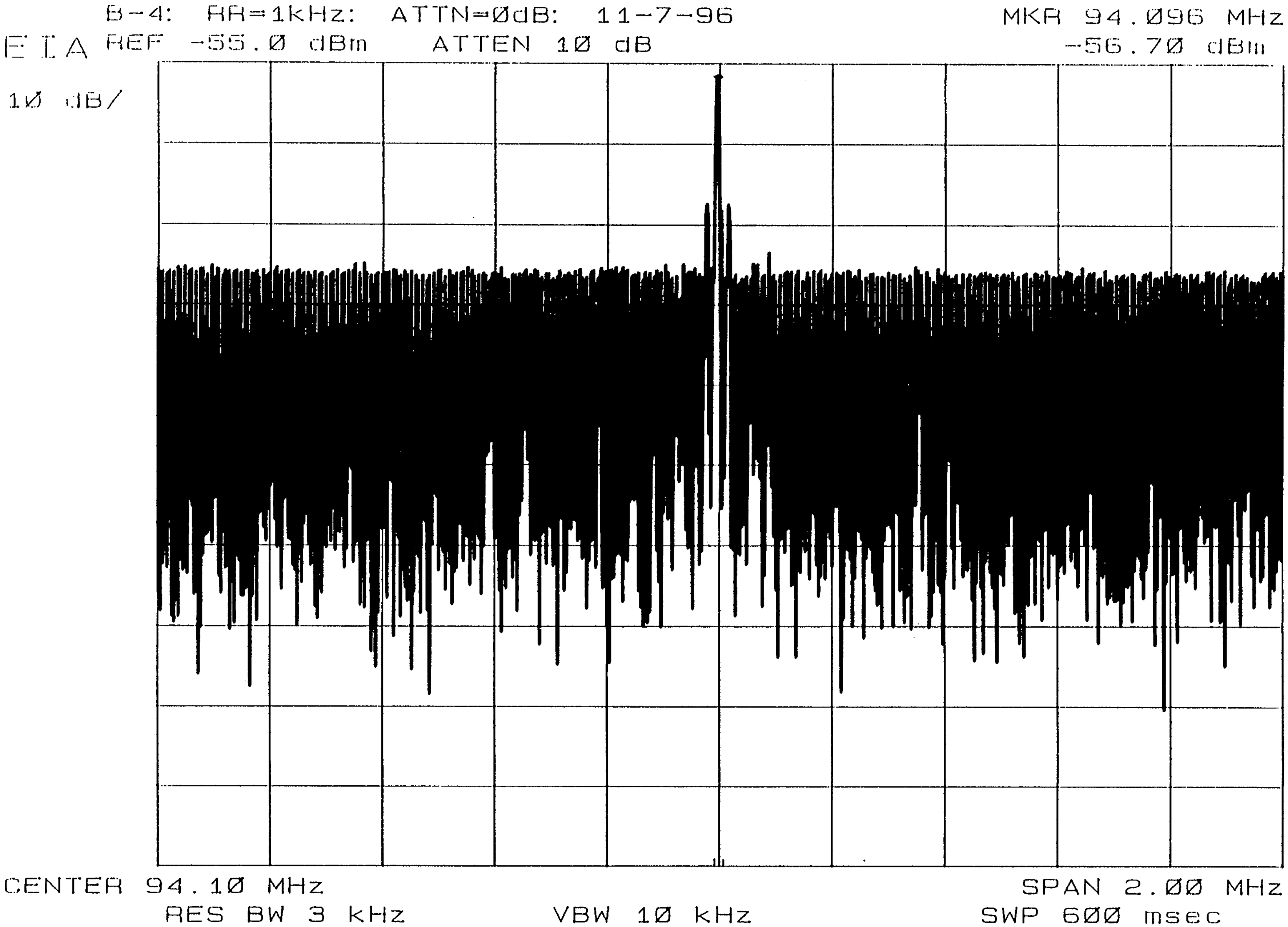


CENTER 94.10 MHz

SPAN 2.00 MHz

RES BW 3 kHz VBW 10 kHz SWP 600 msec

#4


B-4: RR=1kHz: ATTN=ØdB: 11-7-96
MKR 94.Ø96 MHz
-56.7Ø dBm
EIA
REF -55.Ø dBm
ATTEN 1Ø dB
1Ø dB/
CENTER 94.1Ø MHz
SPAN 2.ØØ MHz
RES BW 3 kHz
VBW 1Ø kHz
SWP 6ØØ msec

#5

546

Appendix L

MULTIPATH SIMULATION POWER

547

Hewlett Packard 11759C VHF Multipath Simulation Characterization:

Urban, Rural and Obstructed Environment Instantaneous and Mean Average Power

prepared for:

NRSC HSSC Subcommittee

February 10, 1997

by

David M. Londa, RF Test Manager

Table of Contents

1.0 Introduction

The High Speed Subcarrier (HSSC) subcommittee of the National Radio Systems Committee (NRSC) has initiated tests on HSSC systems. Tests which use simulated multipath are included in the test procedures. The simulated multipath environments used in the test procedures are detailed in this report.

2.0 Methods

The two HP 11759C multipath simulators are connected as detailed in Figure 1.

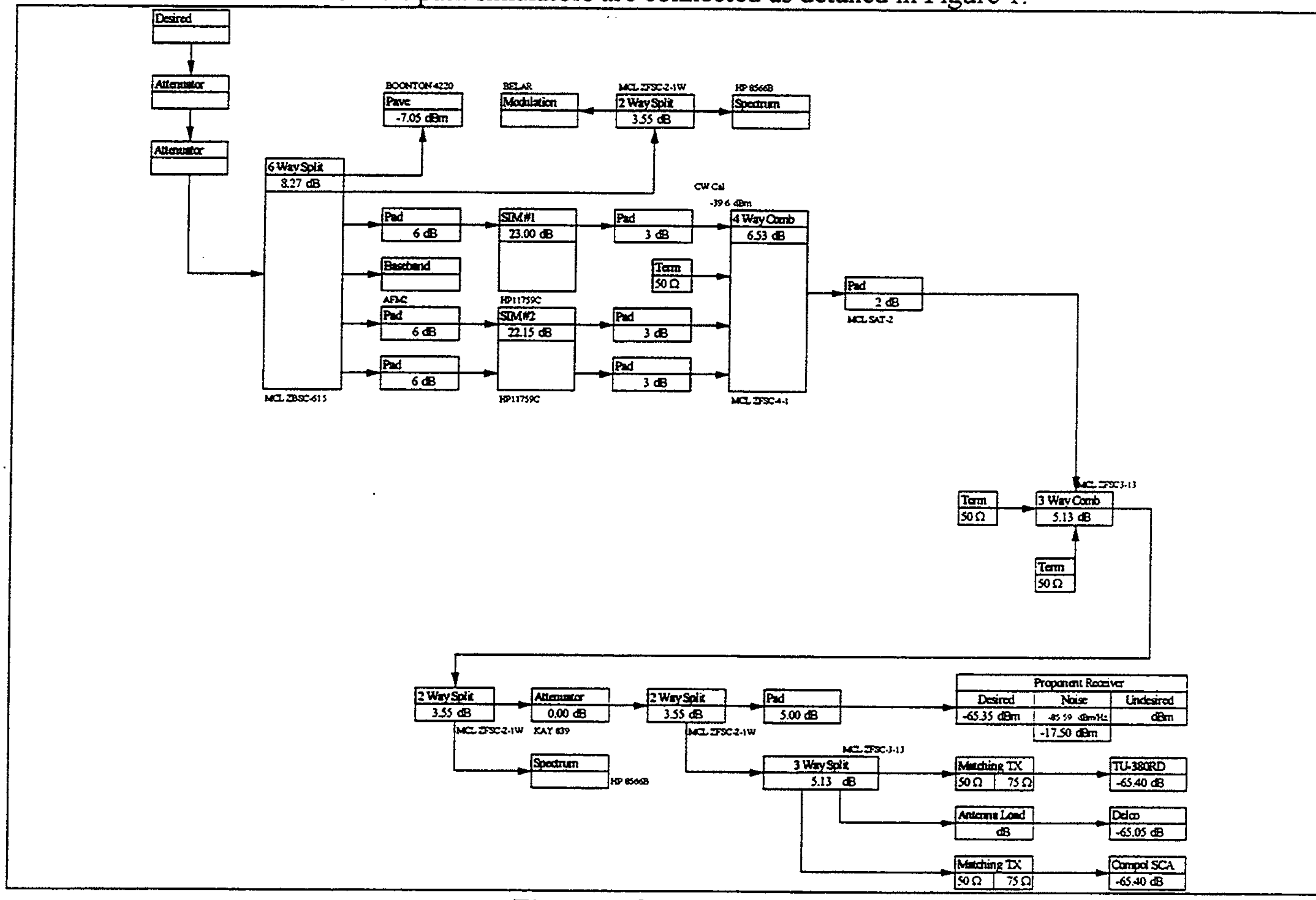


Figure 1: Simulator Connection

A CW signal at 94.1 MHz is input to the simulator network. The simulations are run with 2 km per hour Doppler shifts to ensure measurement convergence. A spectrum analyzer (HP8566B) is connected to the network where the proponent receiver is indicated in Figure 1.

2.1 Spectrum Analyzer Settings

The spectrum analyzer settings are as follow:

Center Frequency	94.1 MHz
Span	500 kHz
Resolution Bandwidth	30 kHz
Video Bandwidth	10 kHz
Sweep Time	20 ms

2.2 Computer Control

A computer program controls the spectrum analyzer. The program instructs the analyzer to make 20 ms sweeps then reads the average power into array variables. This process is repeated until two periods of waveform data are collected. The waveform arrays are then scanned and written to hard disk. While scanning the arrays the instantaneous average power in dBm is converted to Watts and accumulated. After the accumulation is complete the mean of the instantaneous average power is calculated and converted back to dBm.

3.0 Collected Data

The instantaneous average power arrays are plotted in Figures 2, 3 and 4.

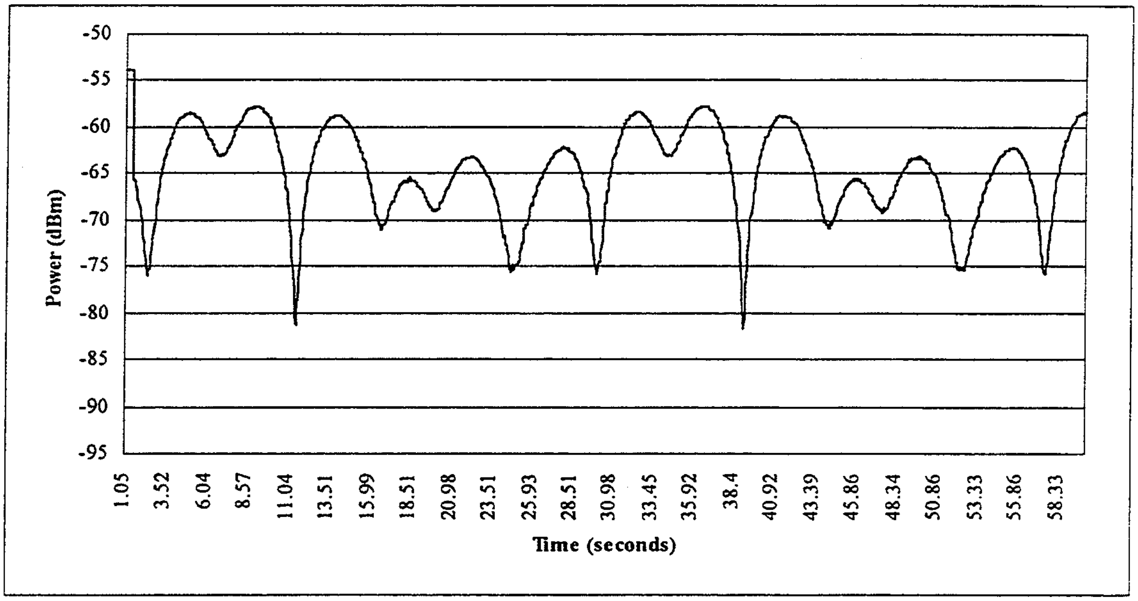


Figure 2: Urban Environment

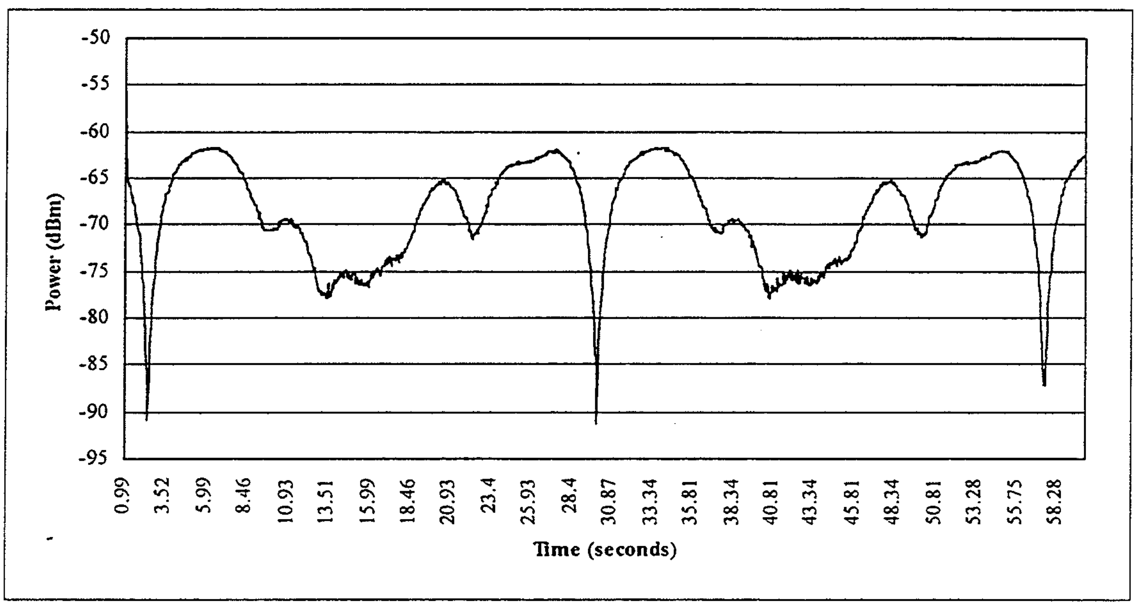


Figure 3: Rural Environment

Consumer Electronics Manufacturers Association
a sector of the
Electronic Industries Association

NRSC Digital Radio Test Laboratory
NASA Lewis Research Center
21000 Brookpark Rd MS 54-2
Cleveland , OH 44135

National Association of Broadcasters

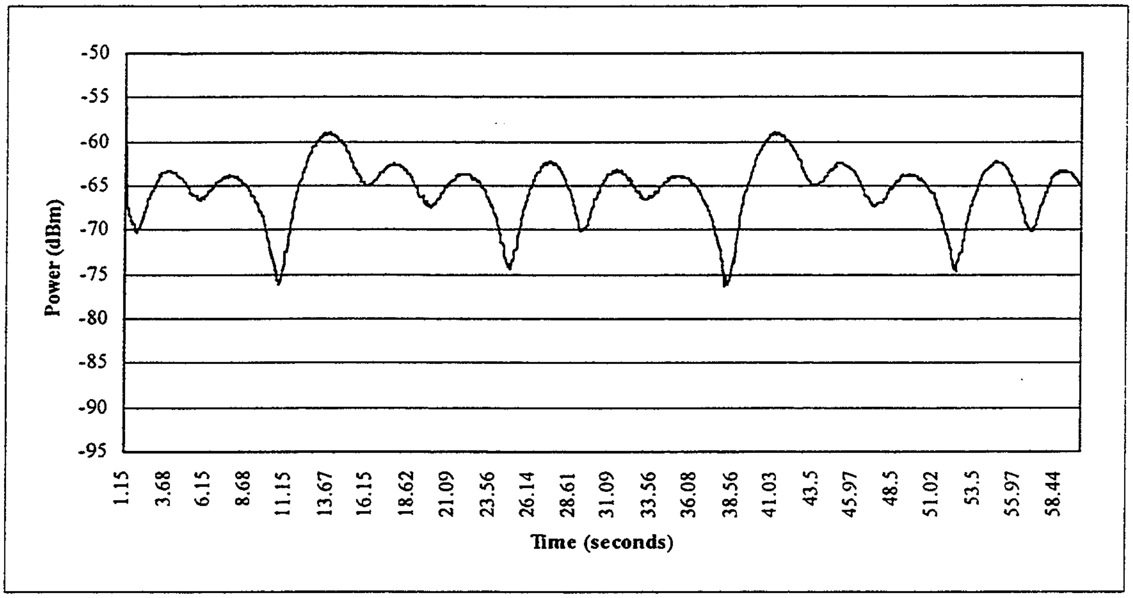


Figure 4: Obstructed Environment

3.1 Offsets

The offsets from the one path zero phase reference power are listed in Table 1.

Environment	Offset (dB)
Urban	-2.45
Rural	-5.53
Obstructed	-4.00

Table 1: Offsets

slowed down simulation to calculate offsets. (2 km/hr)

4.0 Conclusion

The mean average power of the Urban, Rural and Obstructed Environments has been calculated. The offsets from the one path zero phase reference are listed in Table 1.

4.1 Applying Offsets

The offsets can be applied to the C_o/N_o parameter in the B-3 test. The C_o/N_o listed in the results of these tests is based on an average power which was higher than expected by the offset amount. Subtracting the absolute value of the offset from the listed C_o/N_o will yield a parameter consistent with the mean average power of the respective simulation.

(Page 555 left blank)

Appendix M

PROPONENT COMMENTS

557

DIGITAL DJ
THE POWER TO SEE WHAT YOU HEAR

February 7, 1996

Tom Keller
Consultant/CEMA
Springfield, VA
via fax (703) 569-3370

Re: Digital DJ Comments on Lab Test Results

Dear Tom:

The Digital DJ system was tested under a number of different scenarios. The following comments address concerns that may influence comparisons of the various data.

It is difficult to interpret the Composite Signal Descriptions. It is unclear when Orban 1 and Orban 2 are used. It is also unclear when Comp Out 1 and 2 are used. The reference diagrams available are HS_G_DDJ.XLS and the diagram in the test outline. It is unclear that the subcarrier was locked to the appropriate Orban during co- and adjacent channel tests.

It is unspecified that the s/n measurements and DAT recordings were taken from the left channel of the receivers except in D-1. The test outline generally calls for the stereo s/n

left only used.

D series tests which include subcarrier group A and B suffer an immediate 0.9 dB rise in the noise floor as the main channel reference drops from 91% to 81% modulation. This could be incorrectly considered as subcarrier crosstalk.

Please provide peak deviation and modulation specifications for the 92 kHz subcarrier. As our system was not particularly designed to be compatible with 92 kHz, comparison of these tests with and without group A would serve to document DDJ 92 kHz compatibility as well as the other proponents 92 kHz compatibility. It is unknown what impact the 92 kHz subcarrier in group A had on BER and re-acquisition data.

Tests B-1 with pilot unlocked and with variable injection enabled should not be directly compared to the first B-1 test with the pilot locked. Subcarrier group A has been added. The initial B-1 test was conducted with the proponent subcarrier only.

specifically Ford radio

The H series D-1 "Proponent Variable and Pilot" tests do not represent the DDJ subjective performance. Subjectively, the 4% figures are more accurate. When taking host analog s/n measurements, the main channel should be quiet and the injection is minimum, not varying from 4-10% via an external audio source.

Because the 10% fixed tests are available as a reference, the H series tests should be conducted under the same conditions. All tests performed with the DDJ system operating at fixed injection may not accurately reflect the performance of the intended application.

It should also be taken into consideration that these tests do not reflect the effects of transmission system non-linear group delays, bandwidth limitations and synchronous AM components which vary among typical FM facilities and can affect particular subcarrier waveforms differently, principally in the presence of multipath.

Digital DJ will authorize the early release of the supplemental lab data delivered on January 28, 1997.

Sincerely,

Philip Moore

cc: J. Schwartz, T. Takahisa, S Azhar, D. Layer

MITRE

February 6, 1997
W096-L-011

Shazia Azhar
EIA/CEMA
2500 Wilson Boulevard
Arlington, VA 22201-3834

Subject: High Speed Subcarrier Test Results

Ms. Azhar:

In accordance with paragraph # 11 of the Contract for Testing between EIA/CEMA and the Federal Highway Administration (FHWA), this letter describes some issues and errors in the preliminary test data provided on January 16 and January 28, 1997 to MITRE, in its role supporting FHWA.

In general, it appears from the preliminary data package, that a complete and thorough test plan has been implemented carefully and with great attention to accuracy. It is clear that Tom Keller, Dave Londa, and Bob McCutcheon have done an outstanding job. However, there are several issues with the data and its presentation which must be disclosed. In general, these issues are relatively minor, are related to specific tests, and are not meant to place the whole test report in a negative light. The issues of concern are enumerated below:

(1) For test B4, an Interstate impulse generator, model # P25 was used. According to Tom Keller, this generator has a frequency stability of about 1 Hz, as measured in the lab. Also, Tom indicated that the pulse repetition rate was manually set with an accuracy of about 1 Hz. This implies that the test was done with a source which may have been accurate to within +/- 1 or 2 Hz. For systems with channel interleaving, a small change in frequency, possibly as small as 0.1 Hz, could make a large difference in performance. For example, tests with pulse repetition rates which are multiples of 100 Hz are synchronous with the STIC interleaver, and performance differences between 300 Hz and 301 Hz could be drastic. This test should be run with a more stable and accurate impulse generator. Also, repetition rates should be tested on a finer scale, with attention to potential problem areas for each proponent.

(2) In some places in the test report, the acronym HSDS was used to refer generically to proponent systems in general. The HSDS acronym is specifically associated with the SEIKO system and should not be used in any other way. The term High Speed SubCarrier (HSSC) is preferable for reference to proponent systems in general.

The MITRE Corporation
Washington C³ Center
7525 Colshire Drive, McLean, Virginia 22102-3481
Telephone (703) 883-6000/Telex 248923

(3) For test G1, the tabular results for the upper first adjacent channel rejection for the Pioneer radio do not match the graphical plot of these results.

(4) The airplane flutter parameters listed in the test data package do not match those in the latest test plan dated January 16, 1996. Tom Keller explained that the values in the test data report are correct and he recalls mentioning the error in the test plan during one of the HSSC subcommittee meetings.

(5) For test D1, using the Pioneer Radio, with no multipath, and group B subcarriers, the spectral plot shows an increased noise floor. This test was recorded on tape # HS40400, track ID # 12. Notes on the spectral plot indicate a noise buzz. Discussions with Tom Keller indicated that this buzz was caused by a problem with the tape. Tom faxed me another spectral plot which exhibited the buzz alone and also showed the spectrum when the buzz was avoided. The original plot and the plot provided by Tom are attached here as Figures 1 and 2 respectively. I do not believe that the buzz is caused by the STIC signal. CCIR grading of this segment was -0.2 (very small degradation).

(6) For test D2, using the Pioneer Radio, in urban slow multipath, and using only the STIC subcarrier, the spectral plot shows a spiked noise floor and a tone at about 3 kHz. This test was recorded on tape # HS40400, track ID # 18. Discussions with Tom Keller indicated that this also was caused by a problem with the tape. Tom faxed me another spectral plot which exhibited the buzz alone and also showed the spectrum when the buzz was avoided. The original plot and the plot provided by Tom are attached here as Figures 3 and 4 respectively. I do not believe that the STIC signal caused either the spiked noise floor or the tone or any buzz. CCIR grading of this segment was 0 (no degradation).

In conclusion, the test results, in general, appear to be very accurate and reliable. With the exceptions noted above, these test results should be considered a good starting point from which decisions regarding waveform standardization can proceed.

Finally, as you requested in your letter dated January 28, I am willing to waive the three week review period for the second data set. However, in order to simplify distribution of the data, I urge you to provide data for all the proponents together, for any give set of tests. In other words, I recommend that you hold the second data set until the February 20th meeting if other proponents are not willing to waive the three week review period.

Sincerely,

Jim Marshall
Associate Center Manager
Signal Processing Center

Enclosures

cc: Tom Keller
Dave Layer
Jim Arnold
Gene McHale
Bill Jones
Mike Rau
Dave Kelley

Client:

NRSC Digital Radio

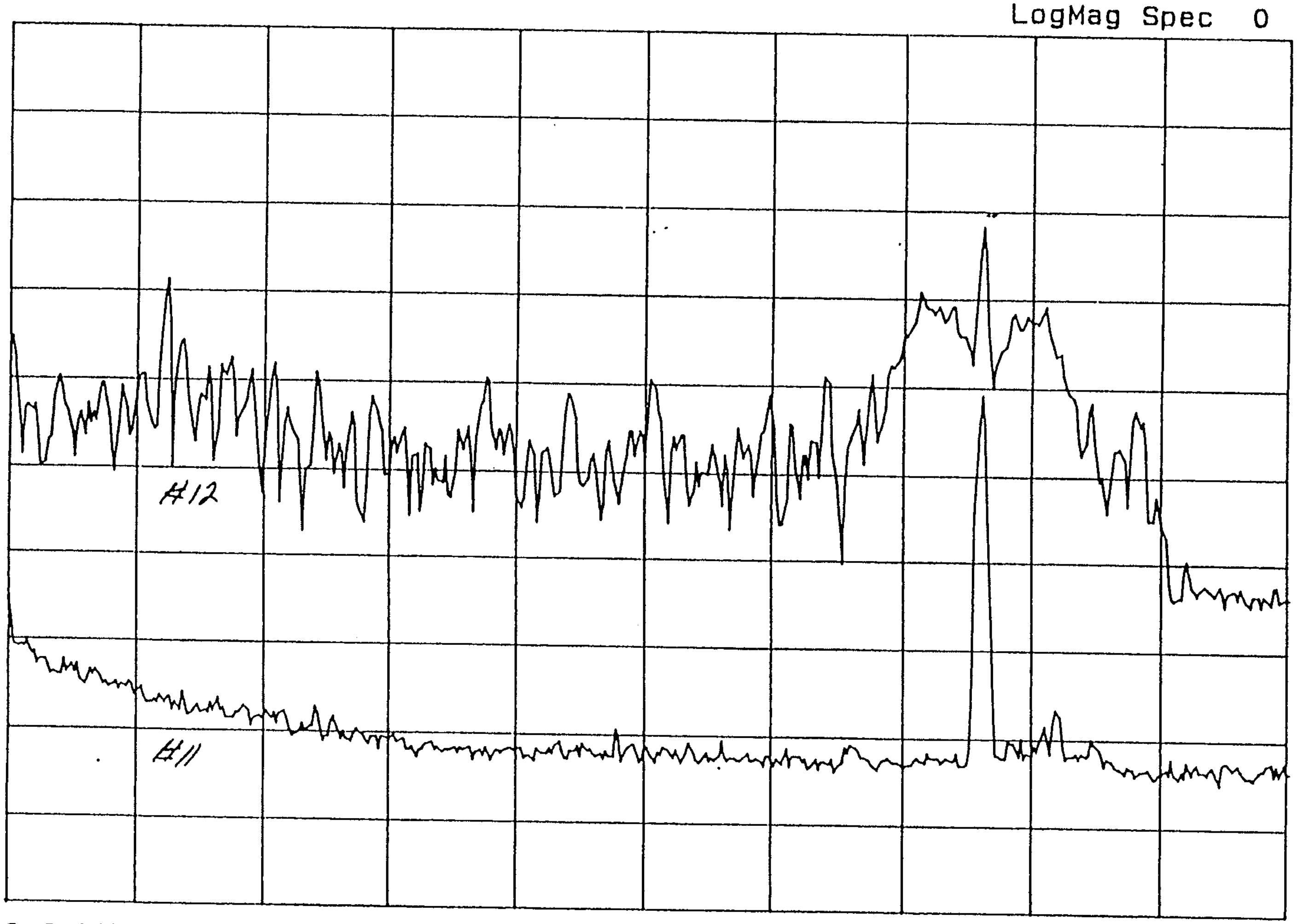
Test Laboratory

(High Speed FM

SubCarrier SubCommittee)

HS 40400 FIGURE 1

LogMag Spec 0



0.0 kHz 12.5000 kHz 25.0000 kHz

Top = 0 dbV 10 dB/div Wndo: BMH

File= Live

Report & Test Plan: #1

No Formal SCSC Plan,
Dig Radio Test Lab Plan

Test Squence

Reference Point ________

Operator Comments

NO MP.
GROUP B

#12 HAS NOISE
.BUZZ; SEE NEXT
PLOTS

#12 MITRE

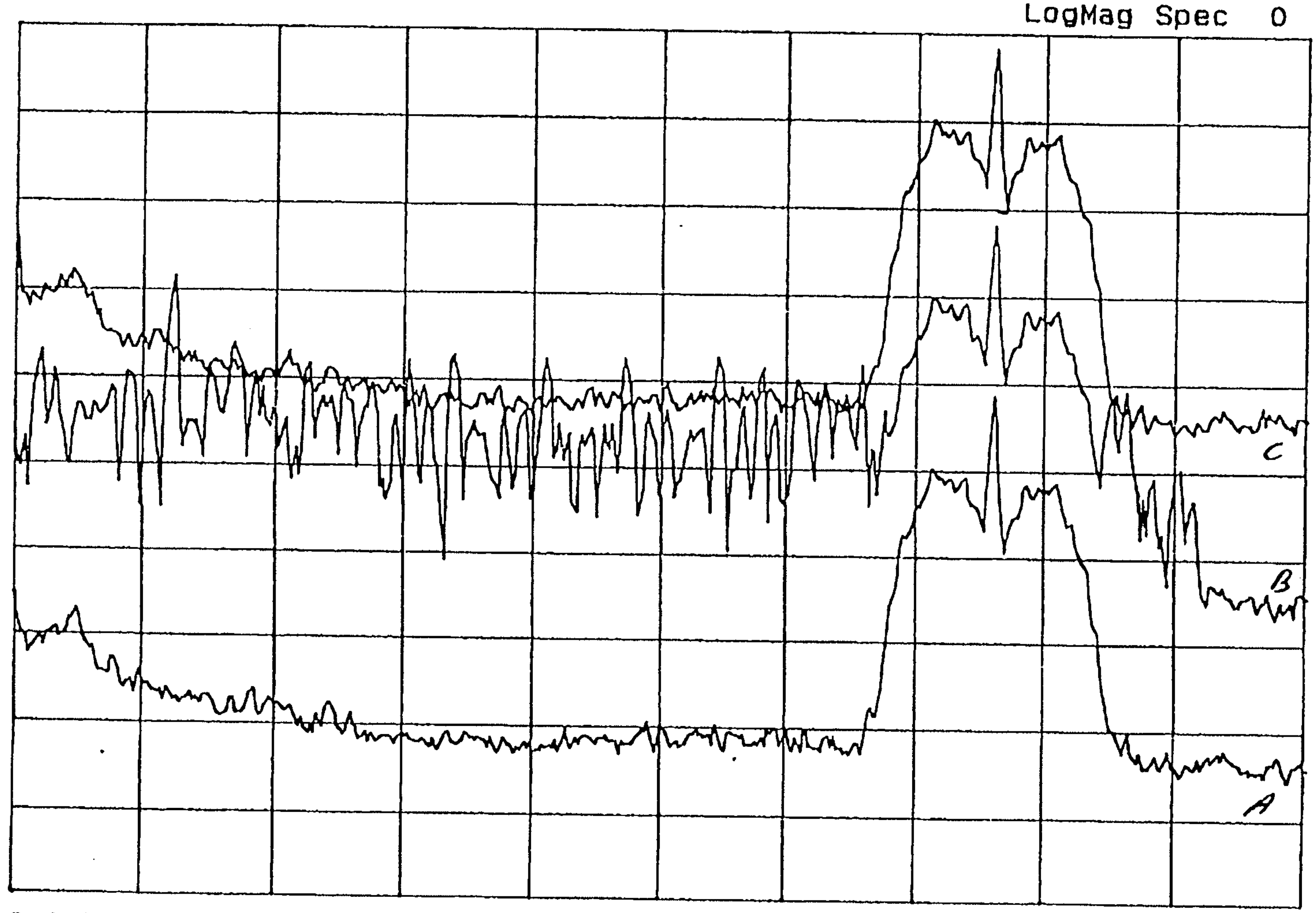
#11 REF
PIONEER
D-1

Analog Baseband Frequency Spectrum

1/11/97 22: 03: 54

SubCarrier Systems Corporation

FIGURE 2



Client:
NRSC Digital Radio
Test Laboratory
(High Speed FM
SubCarrier SubCommit

Report & Test Plan: #1
No Formal SCSC Plan,
Dig Radio Test Lab P

Test Squence HS 409
Reference Point
ID # 12

Operator Comments

A: PRE BUZZ

B: BUZZ ~ 21:45

C: POST BUZZ

IF BUZZ IS EQUIP ERROR; USE PLOT A FOR COMPARISIONS

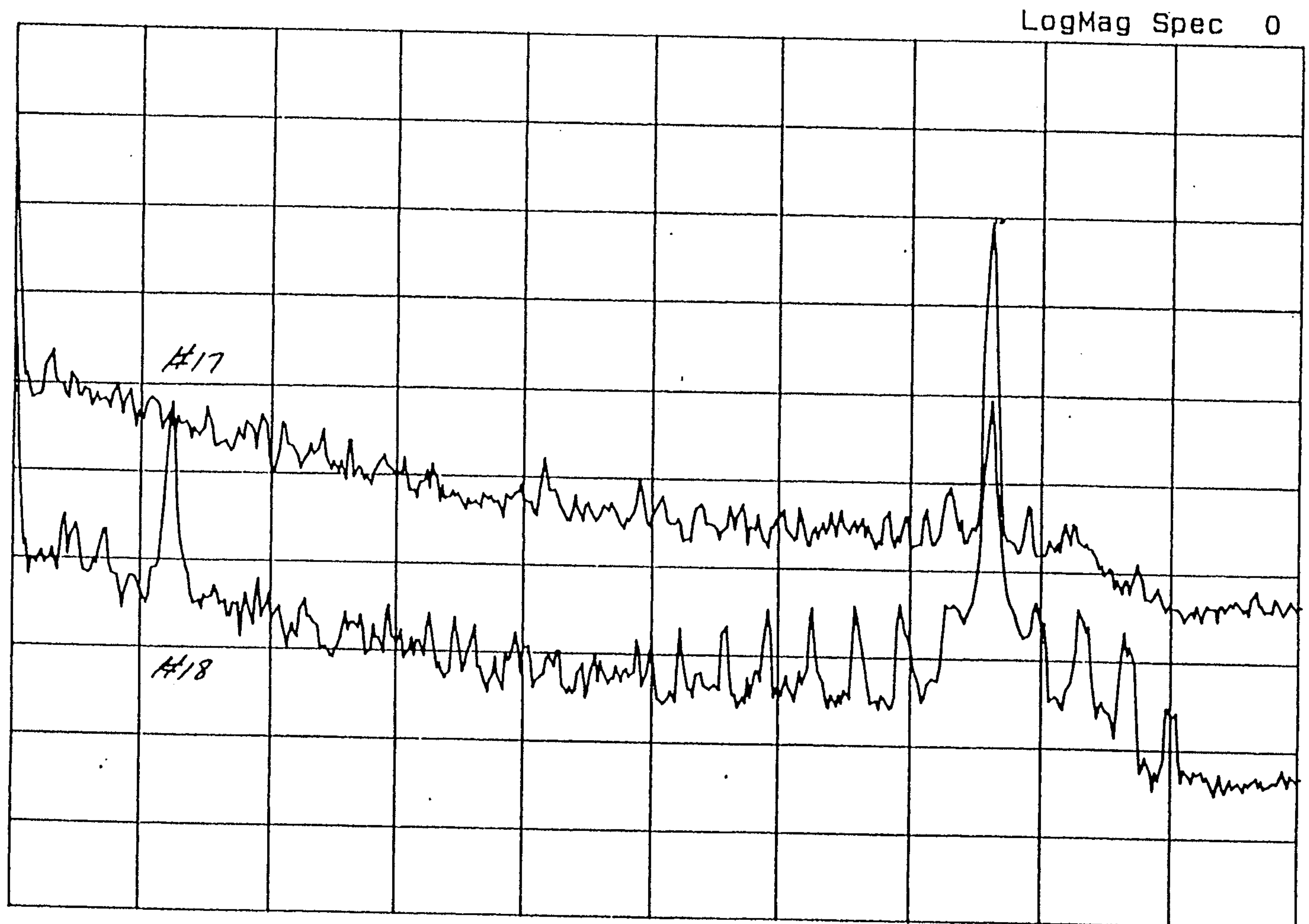
Analog Baseband Frequency Spectrum

1/11/97 22: 08: 07

SubCarrier Systems Corporation

FIGURE 3

Client:
NRSC Digital Radio
Test Laboratory
(High Speed FM
SubCarrier SubCommittee)



Top = -20 dbV 10 dB/div
Wndo: BMH
File= Live

Report & Test Plan: #1
No Formal SCSC Plan,
Dig Radio Test Lab Plan

Test Squence HS 40400
Reference Point ______

Operator Comments
URBAN SLOW
NO SCA

#18 - [redacted] MITRE

[redacted]

PIONEER
D-2

Analog Baseband Frequency Spectrum

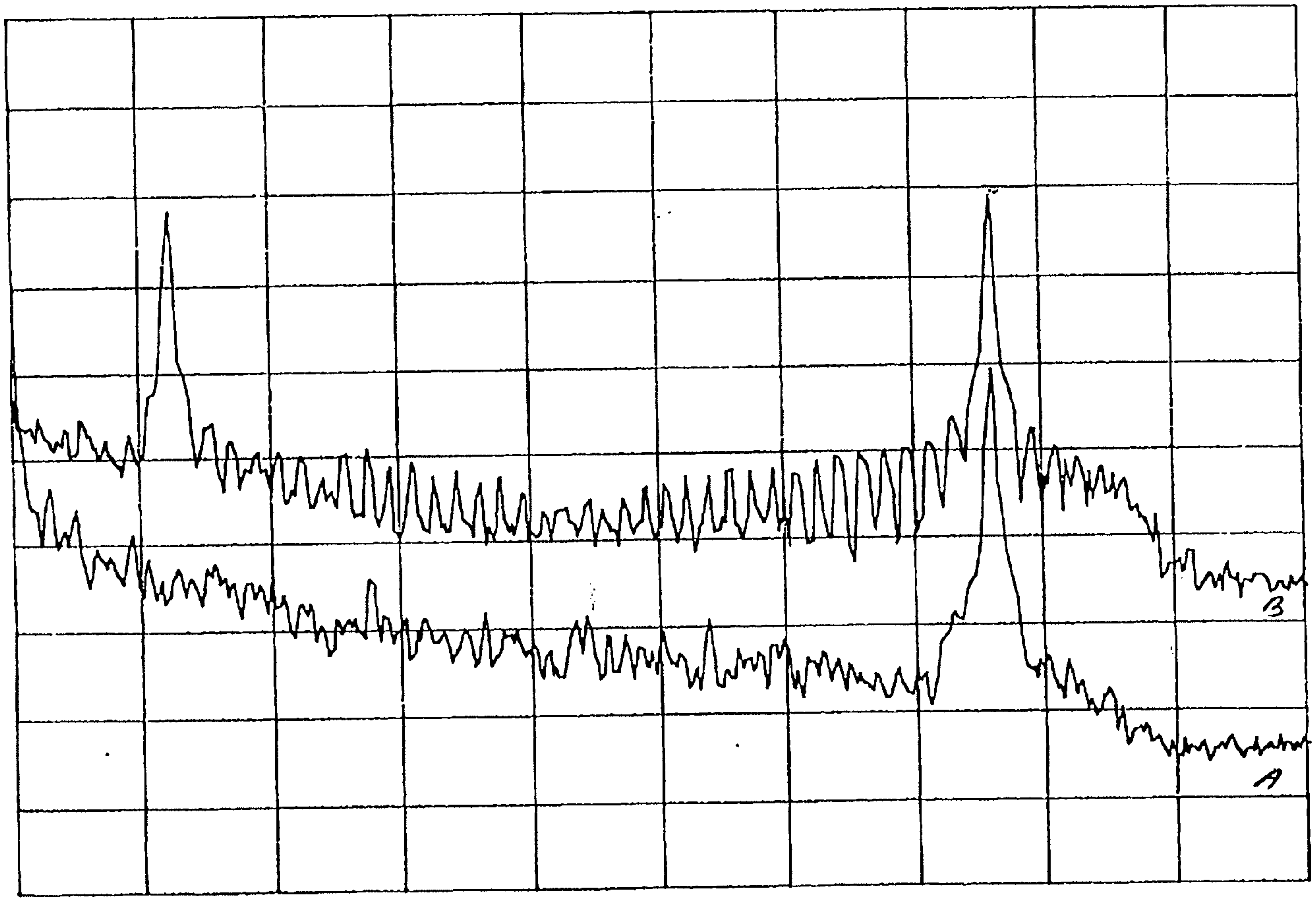
1/11/97 22: 37: 38

SubCarrier Systems Corporation

FIGURE 4

Client:
NRSC Digital Radio
Test Laboratory
(High Speed FM
SubCarrier SubCommitt

LogMag Spec 0



0.0 kHz 12.5000 kHz 25.0000 kHz

Top = 0 dbV 10 dB/div Wndo: BMH

File= Live

Report & Test Plan: #1
No Formal SCSC Plan,
Dig Radio Test Lab Pl

Test Squence HS409
Reference Point ______
Run id 18

Operator Comments

A: Pre Buzz

B: Moment of Bu
~34.23

Rest of Run like

Analog Baseband Frequency Spectrum

1/11/97 22: 41: 06

SubCarrier Systems Corporation

SEIKO Communications Systems, Inc.

Comments on NRSC - HSSC Lab Test Results and Report

Seiko objects to three primary areas of the NRSC - HSSC Lab test results and report. Those are:

1. impact of 10% RDS injection on HSDS performance
2. multipath testing
3. limited report of 20 byte error rate

Regarding the impact of 10% RDS injection (Group B):
The tests do not reflect the results obtained by Seiko Communications Systems (SCS) in our labs. The results suggest that the phase relationship between the RDS signal and the HSDS was not set or was not set optimally. HSDS operates successfully with several stations operating RDS at 10% injection. Attached are results from 1992 tests by SCS Engineers regarding compatibility with RDS at various phases. This setup issue shows up in the following test cases:

- B1.2 Group B -> HS Digital Subcarrier
- B6 Weak Signal -> HS Digital Subcarrier
- E1 Analog Program -> HS Digital Subcarrier

In each case a RDS signal with similar injection to HSDS made the HSDS unable to operate in an error free mode. The lab has agreed to perform some re-tests in this area, but at this time it is not clear whether the results in the report will reflect the re-test or not.

Regarding Multipath Testing:
Testing only for error free performance only is not a good measure of the HSDS system, since repeats of data are expect on other frequencies and or at later times. HSDS is designed for paging and traffic information to operate as low as 50% of 20 byte packets successful from any one station Performance at much lower carrier to noise levels would probably yield similar results to the high carrier to noise ratio - i.e. greater than 50% with 20 byte packets success in all cases except obstructed and urban fast in 220 byte blocks. It would have been more representative of actual performance to test the systems over a range of carrier to noise levels in multipath environments not at just the Onset of Message Errors.

Regarding limited reporting of 20 byte error rate:
The final report should include all 20 byte error rate data for HSDS. In actual commercial operation of HSDS, all ITS and paging information currently utilize the 20 byte packet. Reporting only 220 byte block does not accurately reflect the typical operational mode of HSDS.

Gary Gaskill
Gary Gaskill
Feb. 6, 1997

1625 NW AmberGlen Court, Suite 140, Beaverton, Oregon 97006 Telephone: (503) 531-3450 Facsimile: (503) 531-1700

HSDS
C.3. COMPATIBILITY OF ~~RECEPTOR~~ TO RDS

Since at least a portion of the RDS signal occupies some of the RECEPTOR reception bandwidth, an interference mechanism exists that can degrade the performance of the RECEPTOR decoder when RDS signals are present. The amount of interference can be quantified in terms of subcarrier injection levels of each subcarrier signal.

Since the RDS subcarrier and RECEPTOR subcarrier are both phase locked to the 19kHz pilot signal, an optimum phase relationship relative to the pilot exists for RDS that will provide minimum interference to RECEPTOR. This minimum interference RDS to pilot phase has been observed to be 64° (this should not be confused with the RECEPTOR data to pilot phase).

The following table is experimental data that was taken at STS. The table lists the necessary injection level of an RDS subcarrier causing a 1dB degradation in sensitivity to RECEPTOR.

Injection level of RDS necessary to cause a 1dB degradation in sensitivity to RECEPTOR.			
RECEPTOR INJECTION LEVEL	RDS Injection level RDS to pilot phase=64°	RDS Injection level RDS to pilot phase=0°	RDS Injection level RDS to pilot phase=90°
10%	20.0%	11.2%	15.9%
9%	17.8%	7.1%	14.2%
8%	11.2%	6.3%	11.2%
7%	8.9%	5.6%	7.1%
6%	7.1%	4.5%	7.1%
5%	5.6%	4.0%	5.6%

C.4. RDS TO RECEPTOR INJECTION LEVEL RECOMMENDATIONS

The following recommendations are suggested when picking RECEPTOR and RDS injection levels in situations when both services are in use.

- RECEPTOR subcarrier should be at least 7.5%.

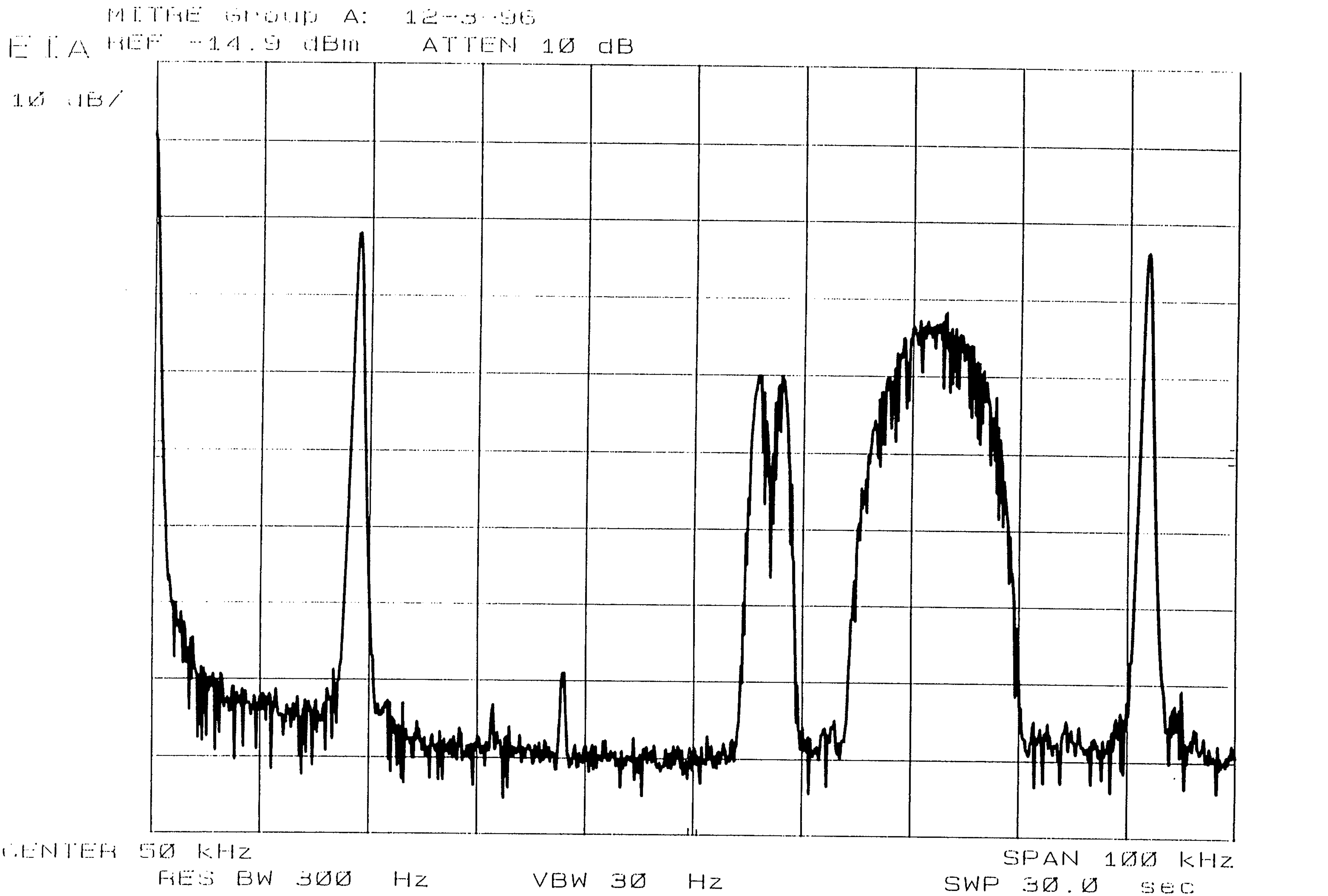
Appendix N

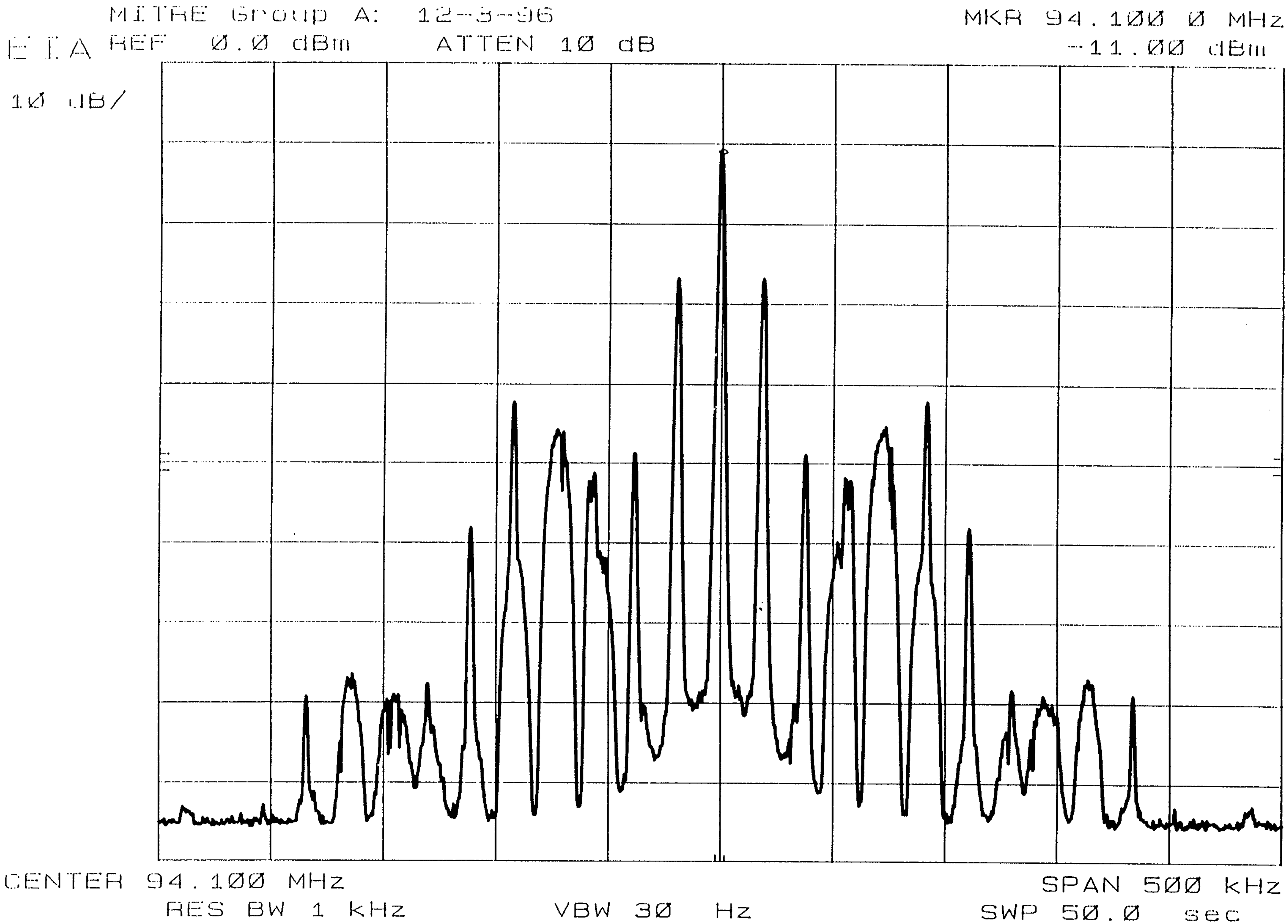
SYSTEM PLOTS

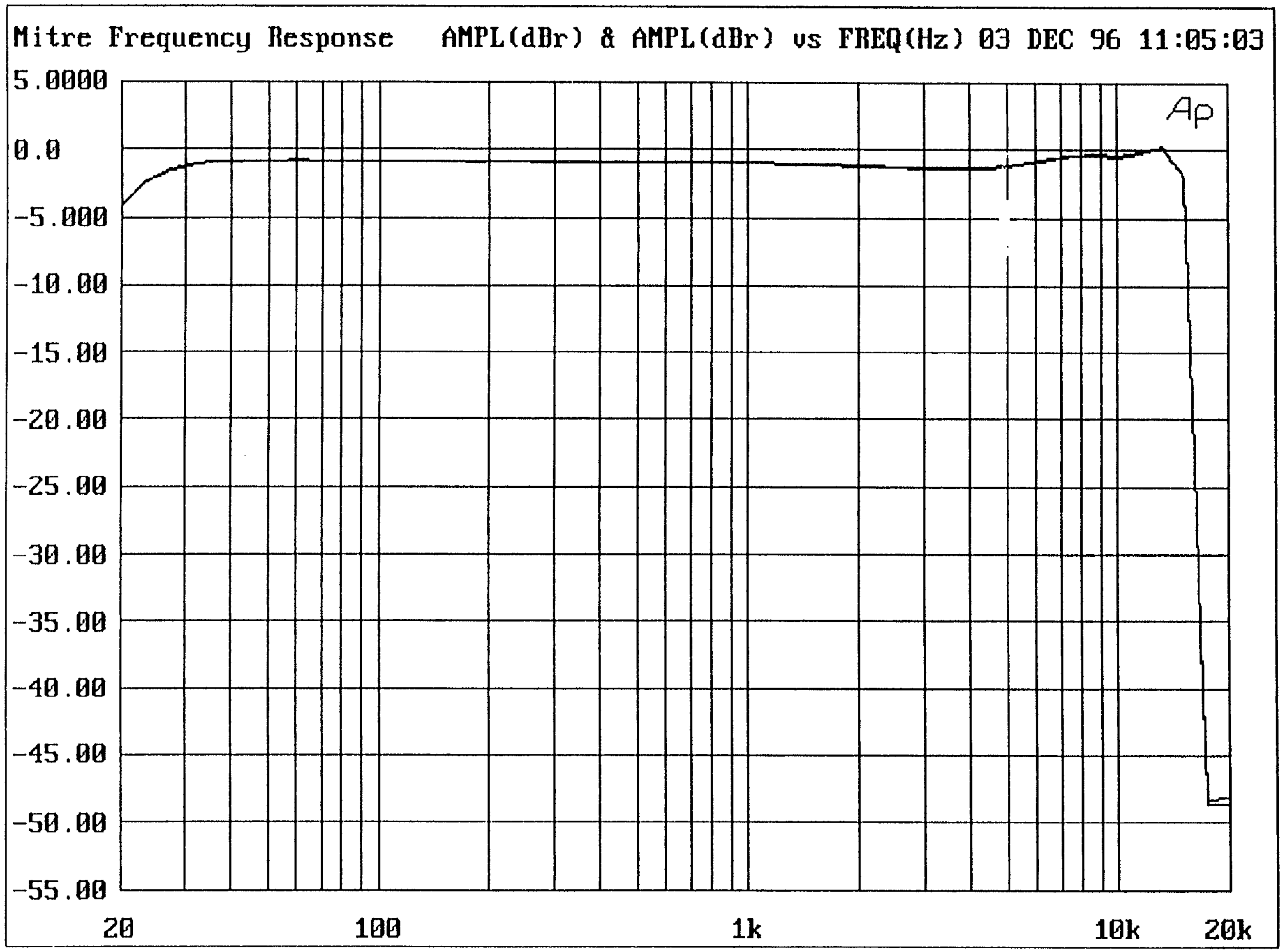
MITRE

System Plots

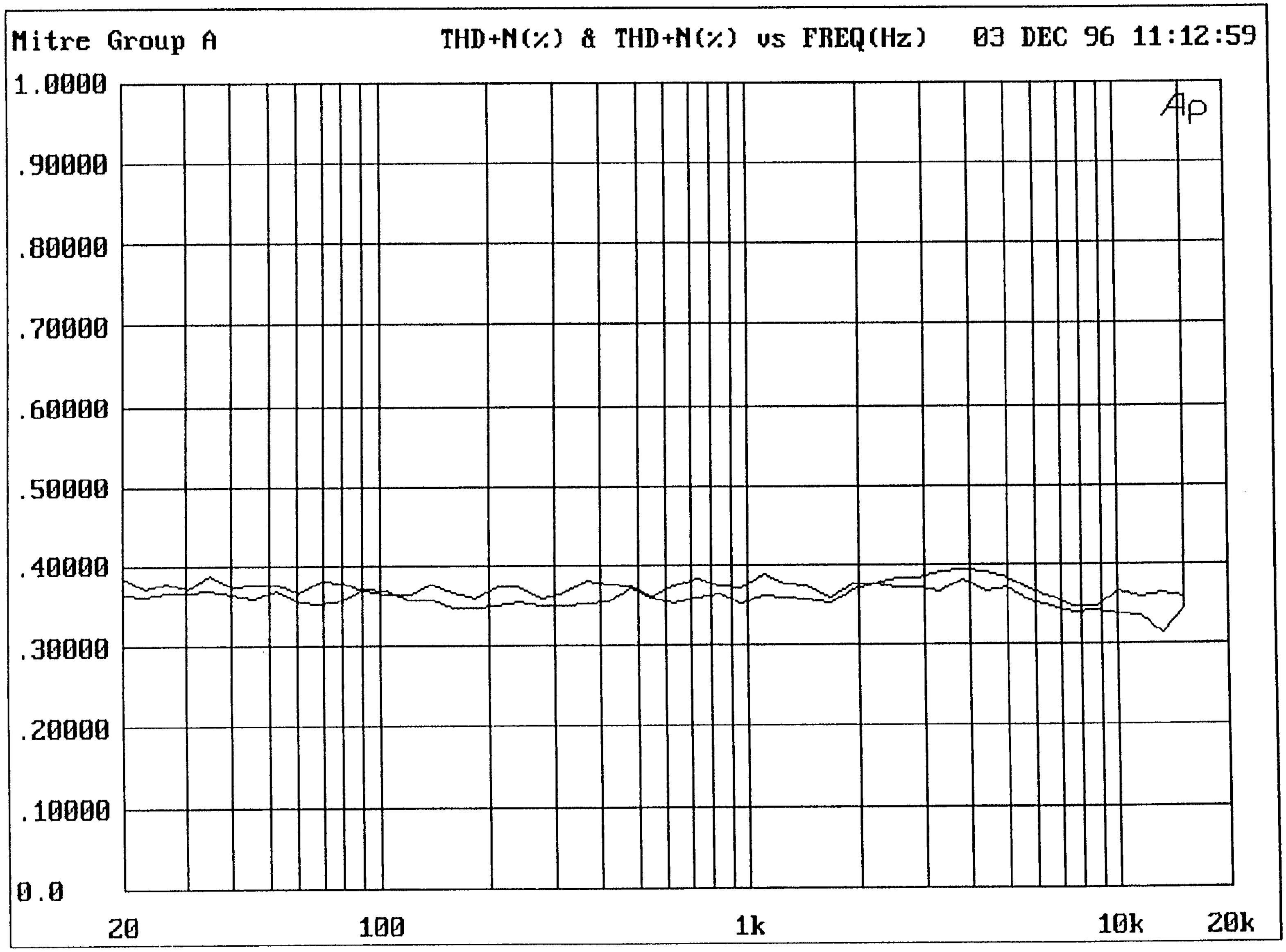
(see add'l plots at end of Appendix)


MITRE Group A: 12-3-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

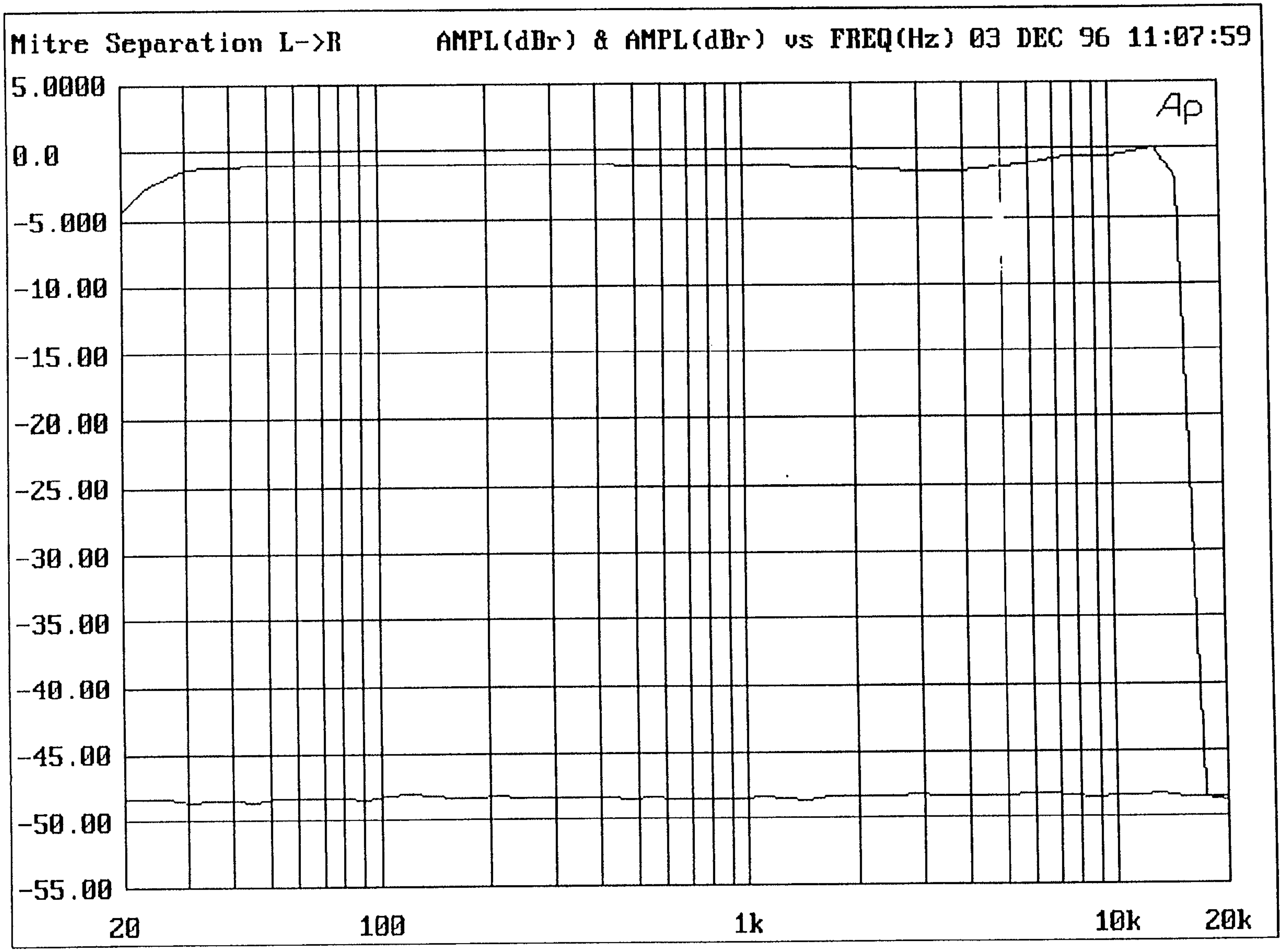

MITRE Group A: 12-3-96
EIA
REF 0.0 dBm
ATTEN 10 dB
MKR 94.100 0 MHz
-11.00 dBm
10 dB/
CENTER 94.100 MHz
RES BW 1 kHz
VBW 30 Hz
SPAN 500 kHz
SWP 50.0 sec

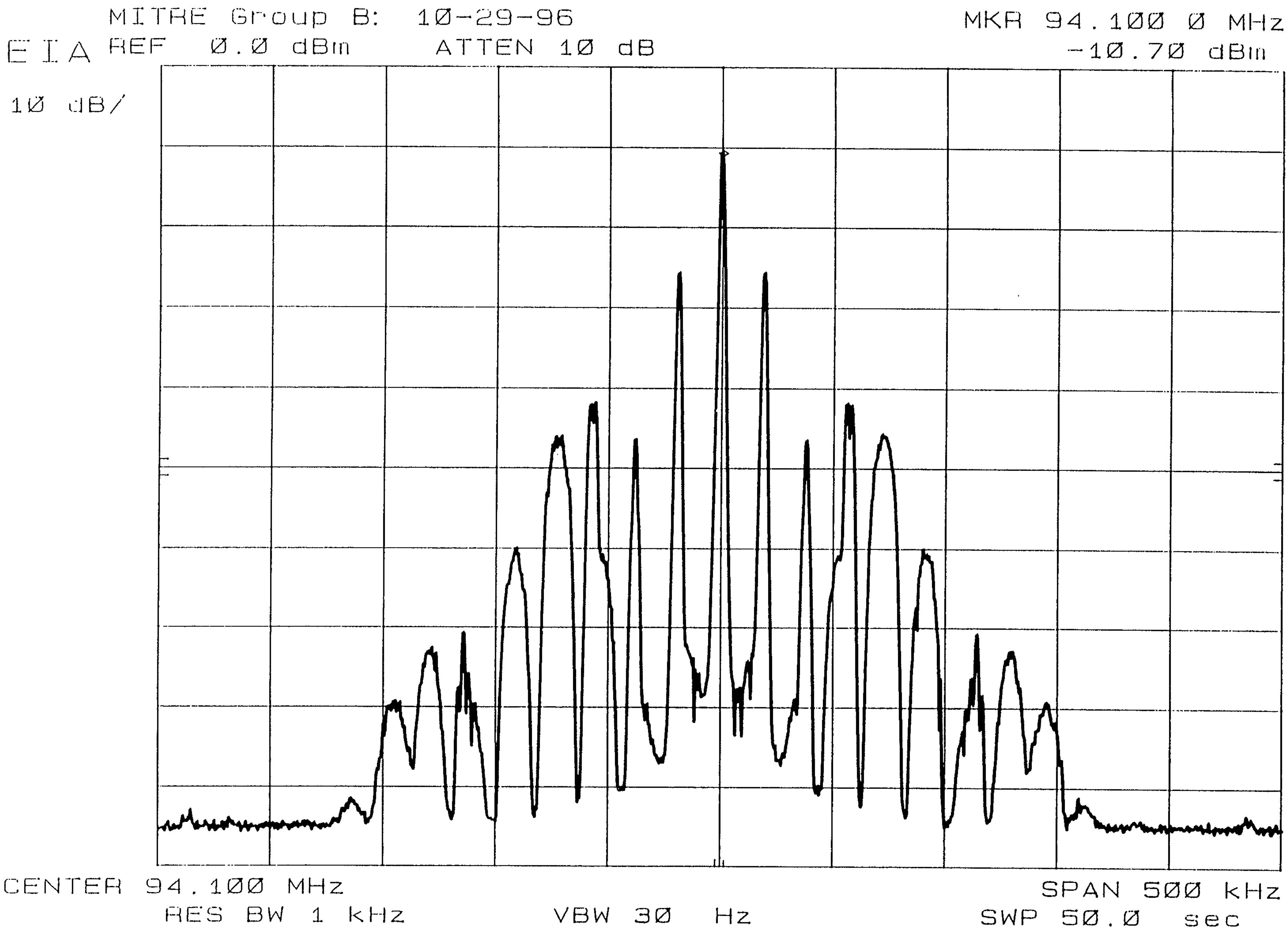


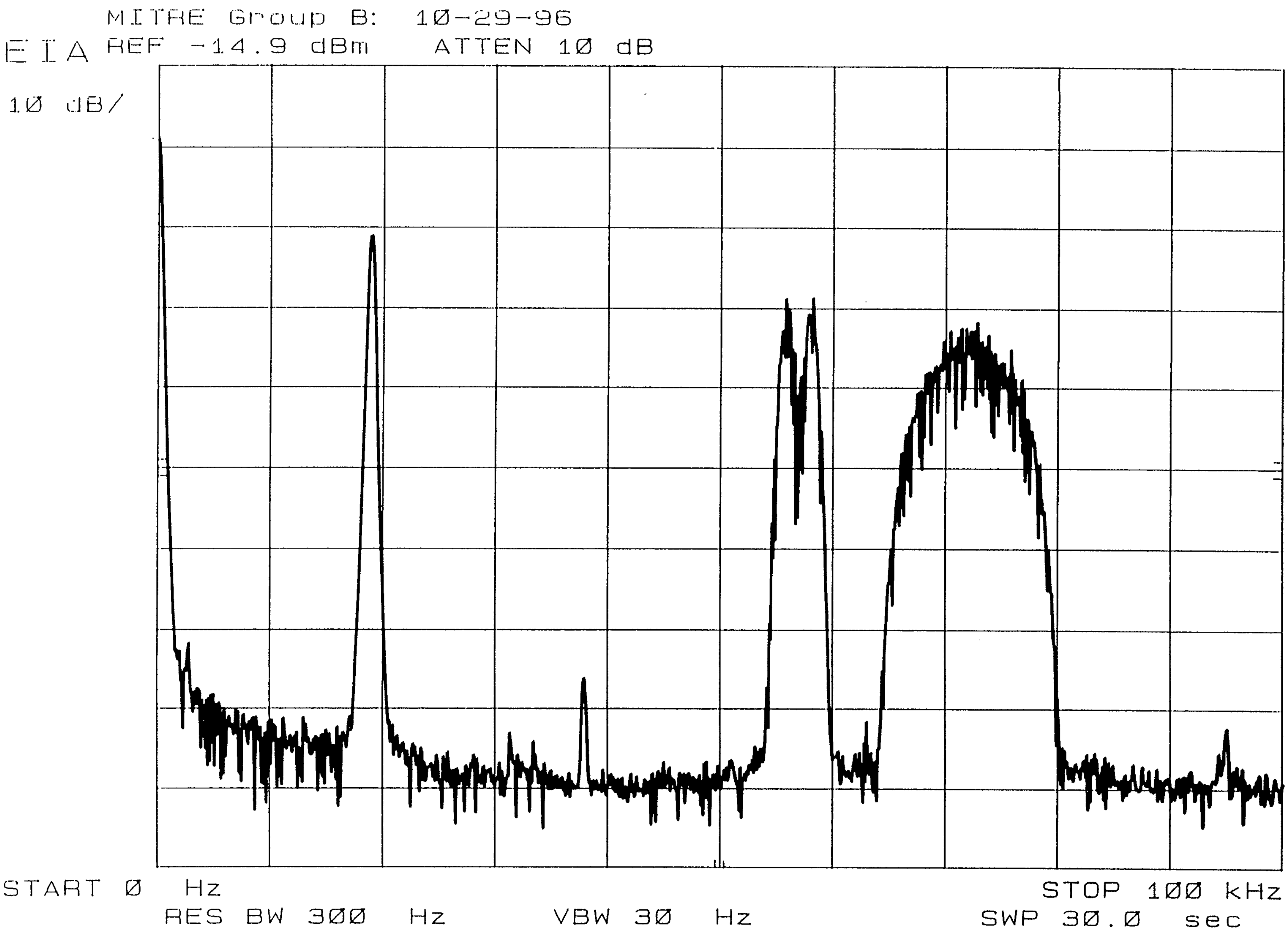
Mitre Frequency Response AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 11:05:03
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap

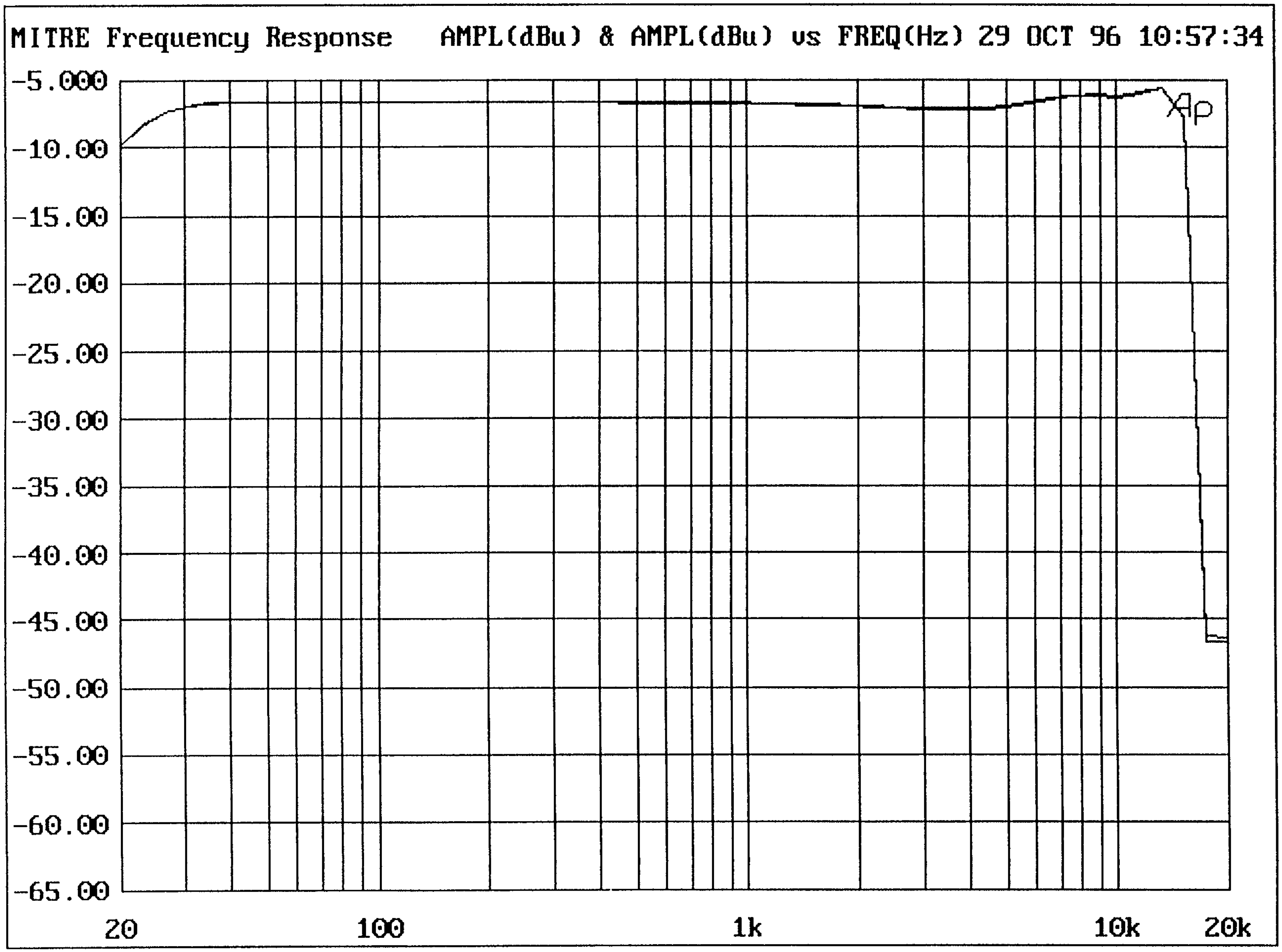


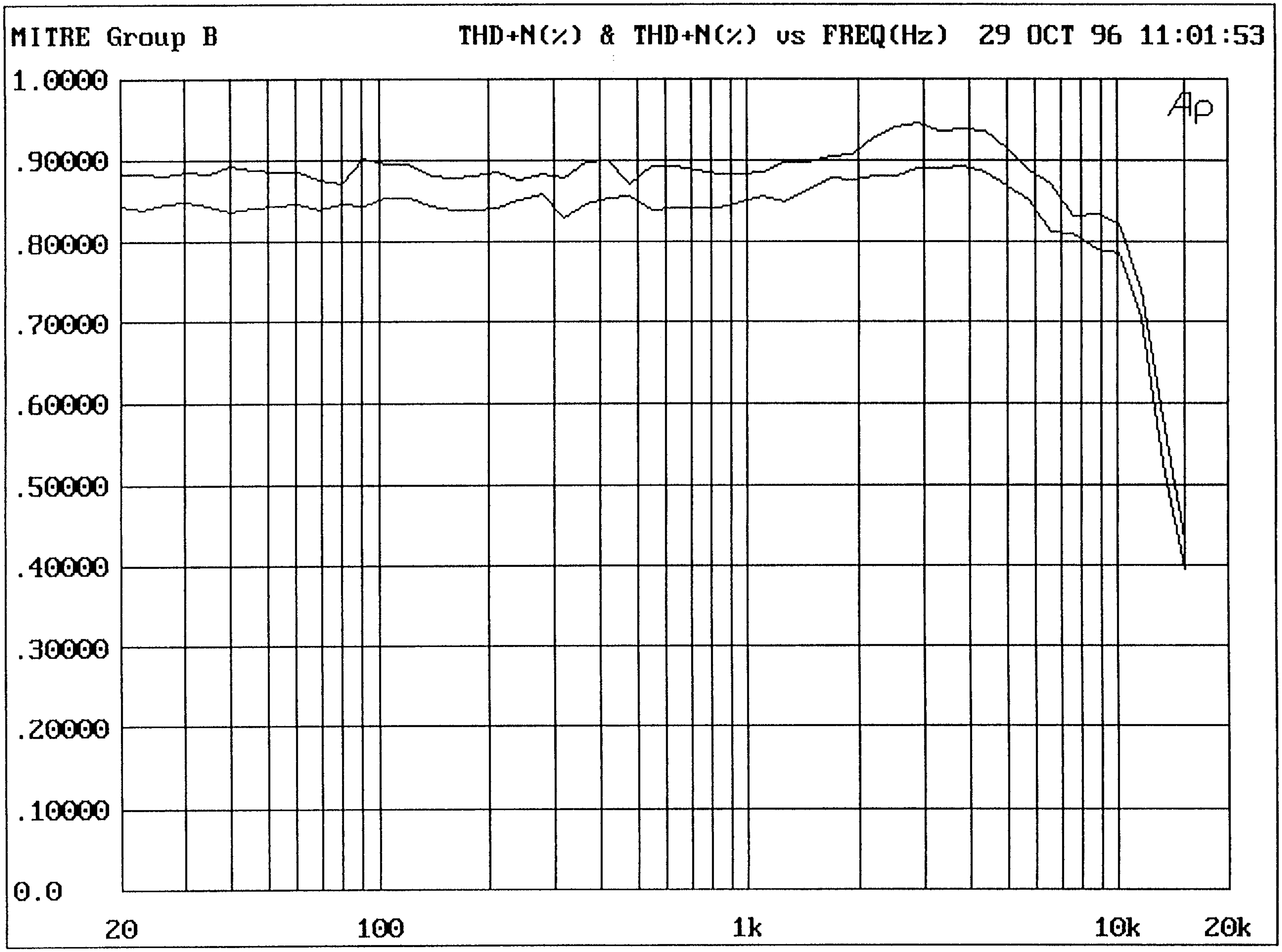
Mitre Group A
THD+N(%) & THD+N(%) vs FREQ(Hz)
03 DEC 96 11:12:59
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap

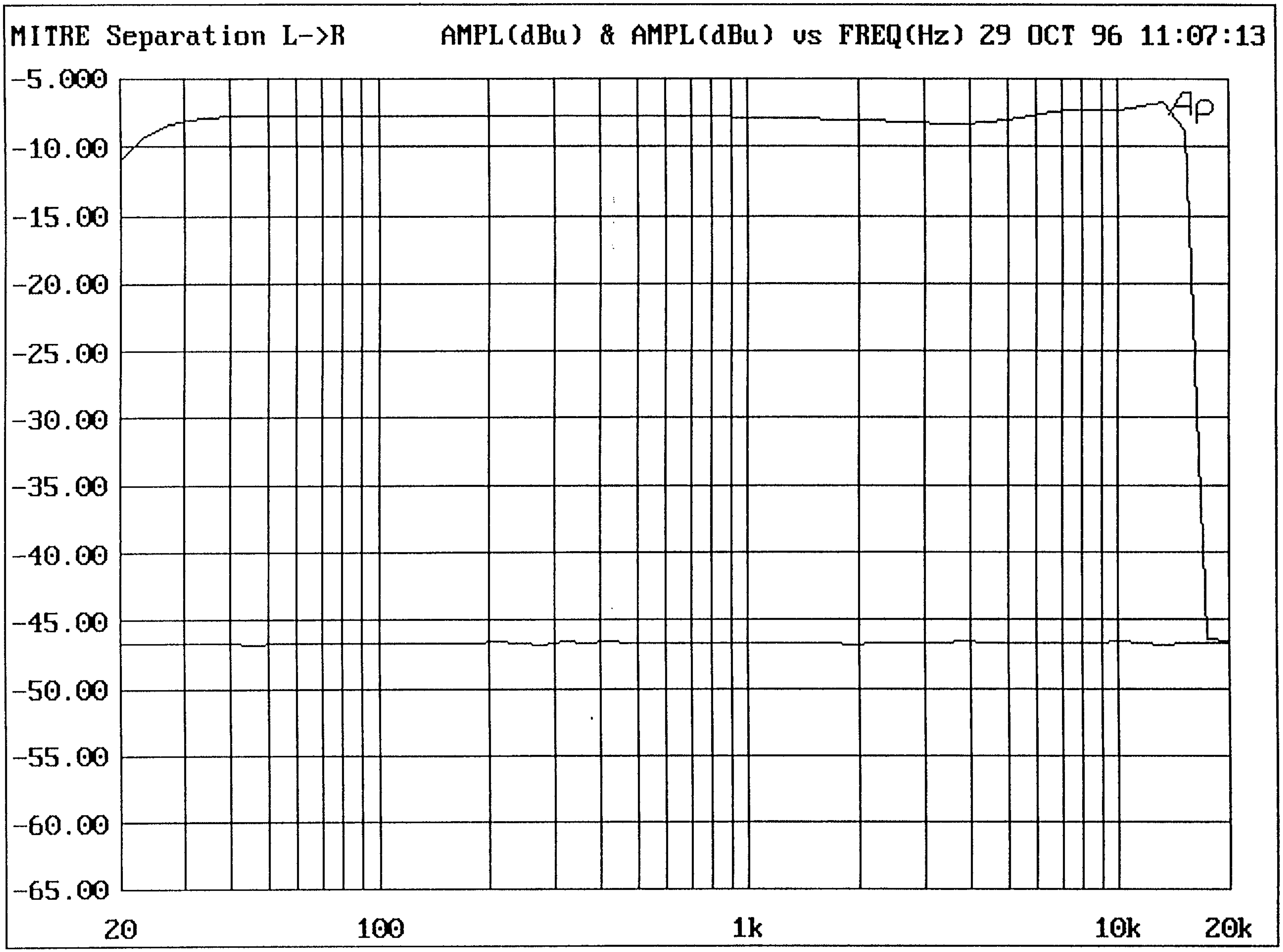

Mitre Separation L->R
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 11:07:59
Ap
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k

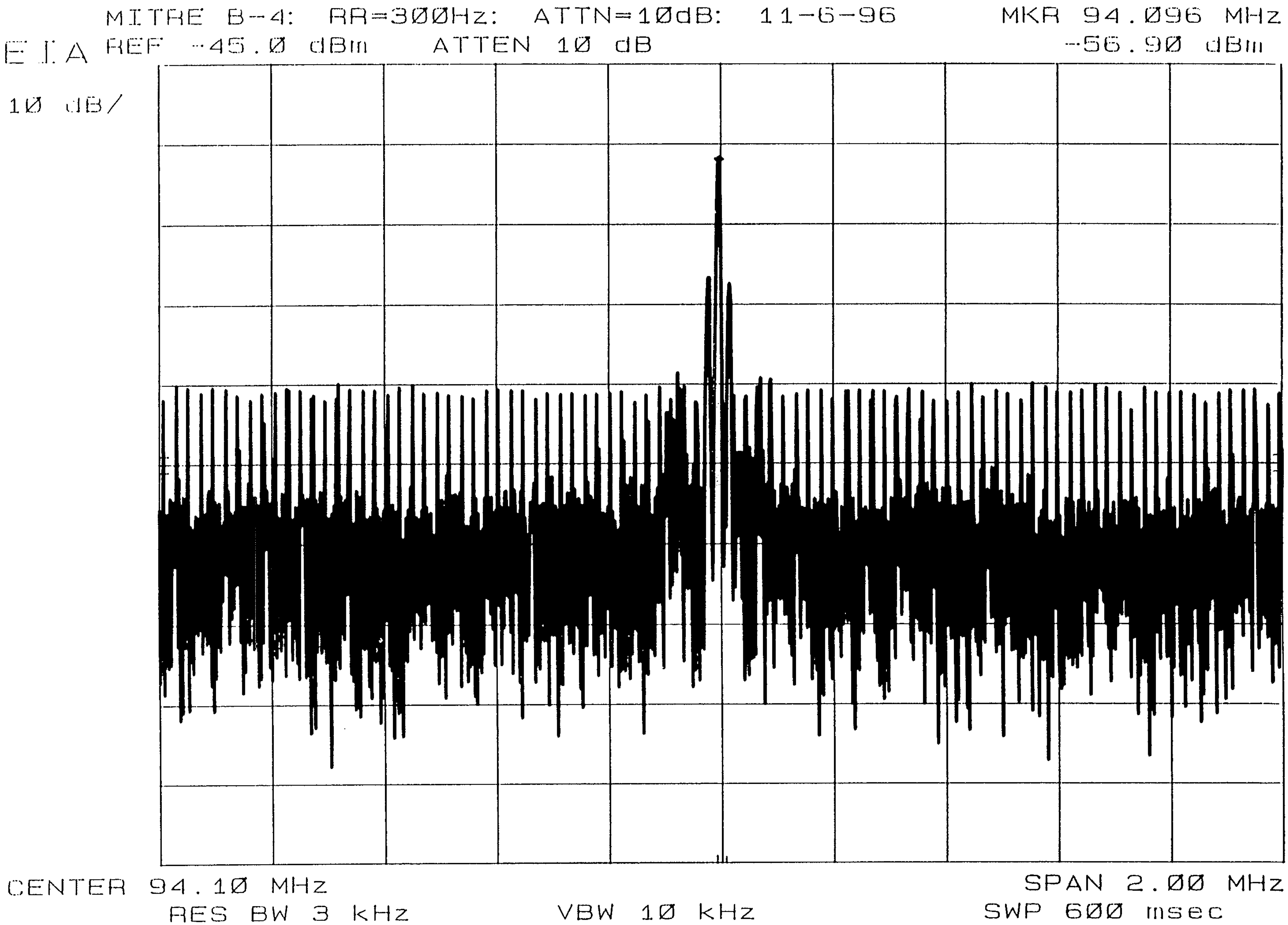

MITRE Group B: 10-29-96
EIA
REF 0.0 dBm
ATTEN 10 dB
MKR 94.100 0 MHz
-10.70 dBm
10 dB/
CENTER 94.100 MHz
RES BW 1 kHz
VBW 30 Hz
SPAN 500 kHz
SWP 50.0 sec


MITRE Group B: 10-29-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
START 0 Hz
STOP 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec


MITRE Frequency Response
AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 29 OCT 96 10:57:34
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap

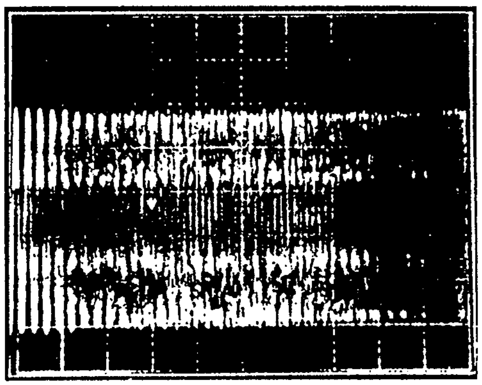

MITRE Group B
THD+N(%) & THD+N(%) vs FREQ(Hz) 29 OCT 96 11:01:53
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap


MITRE Separation L->R
AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 29 OCT 96 11:07:13
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap


MITRE B-4: RR=300Hz: ATTN=10dB: 11-6-96
MKR 94.096 MHz
EIA
REF -45.0 dBm ATTEN 10 dB
-56.90 dBm
10 dB/
CENTER 94.10 MHz
SPAN 2.00 MHz
RES BW 3 kHz
VBW 10 kHz
SWP 600 msec

Non-Standard Injection

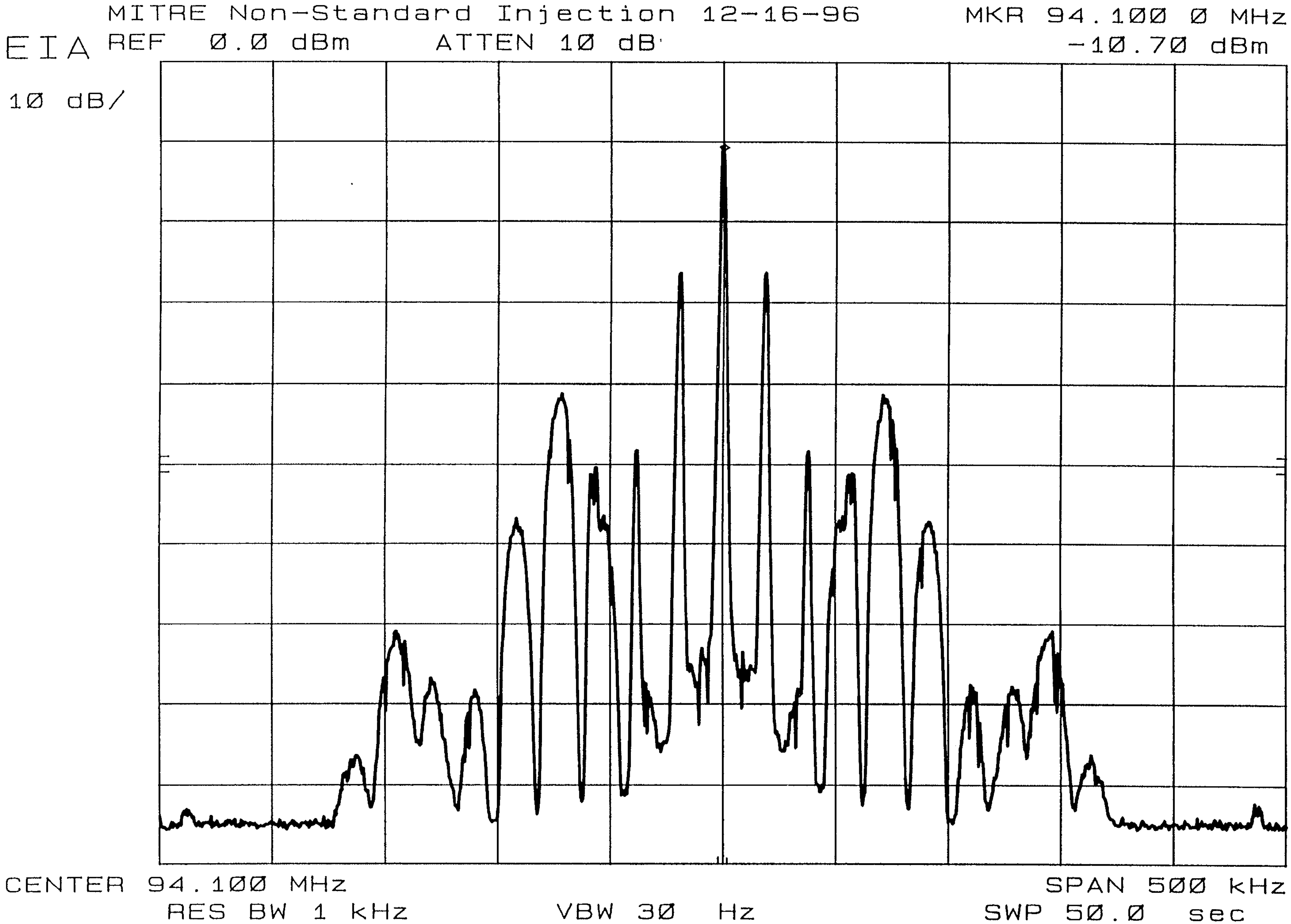
MITRE

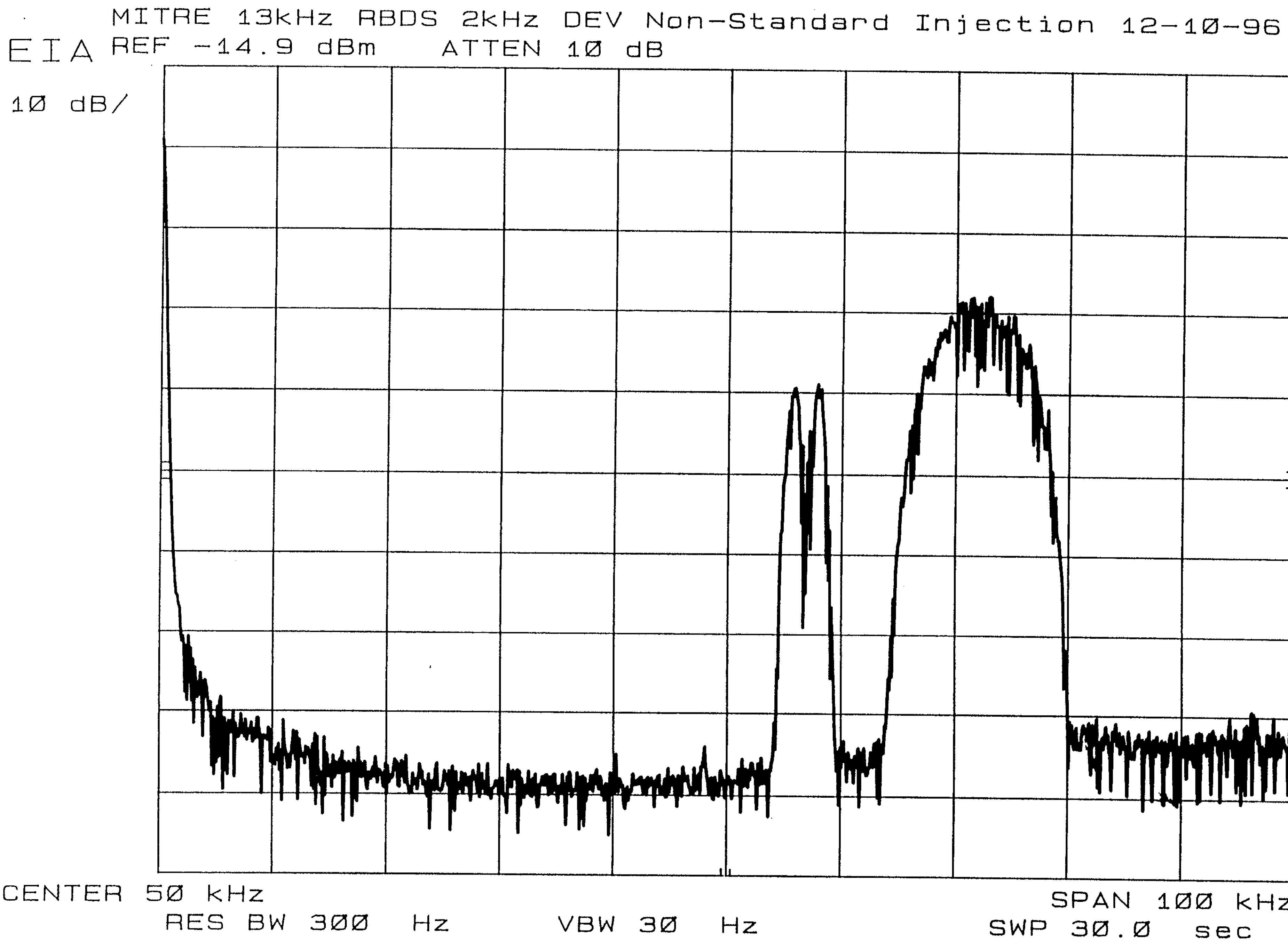


100 mV, 50μsec / Division

MITRE

17%

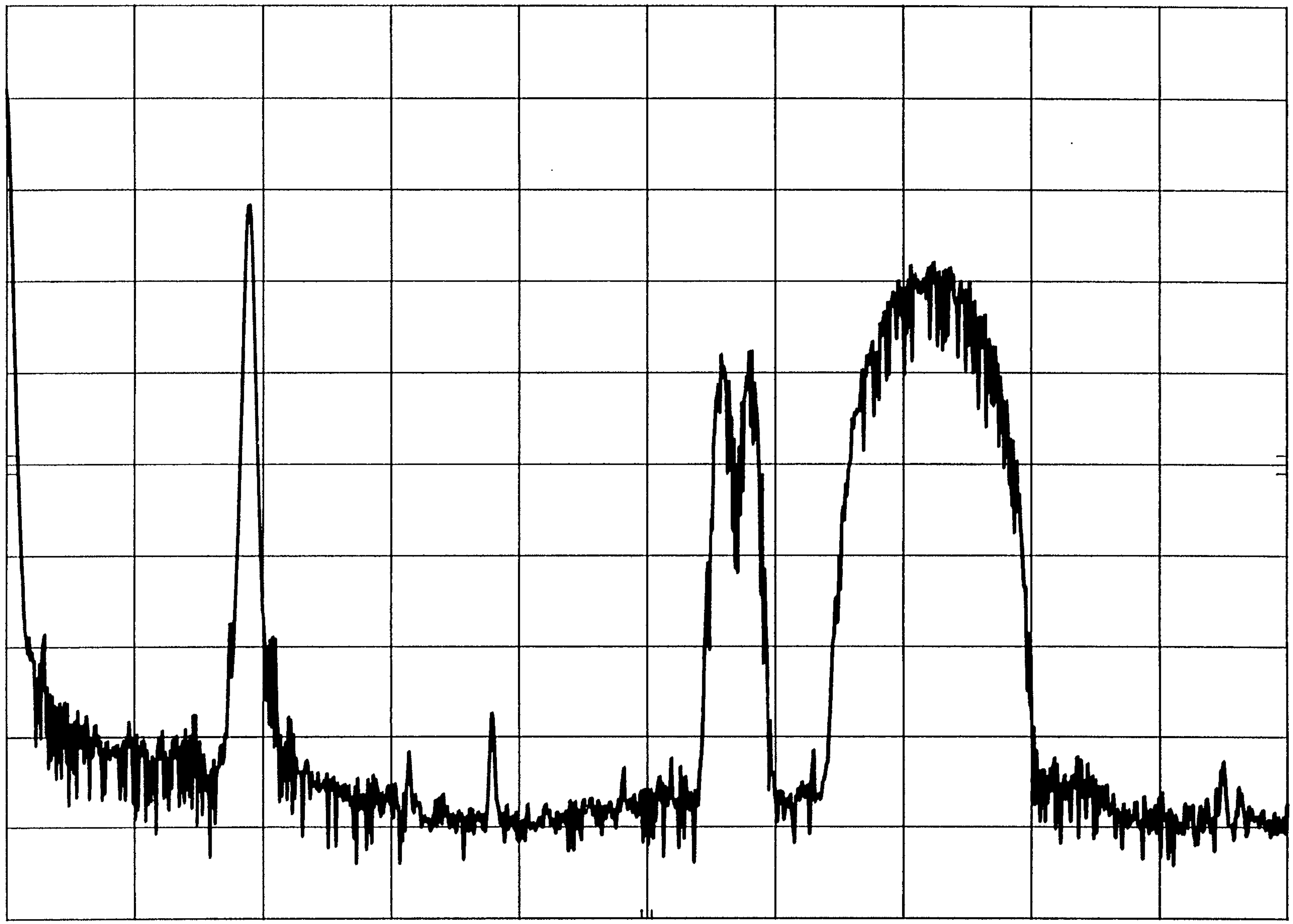

MITRE Non-Standard Injection 12-16-96
MKR 94.100 Ø MHz
EIA
REF Ø.Ø dBm
ATTEN 1Ø dB
-1Ø.7Ø dBm
1Ø dB/
CENTER 94.1ØØ MHz
SPAN 5ØØ kHz
RES BW 1 kHz
VBW 3Ø Hz
SWP 5Ø.Ø sec


MITRE 13kHz RBDS 2kHz DEV Non-Standard Injection 12-10-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

MITRE Non-Standard Injection 12-16-96

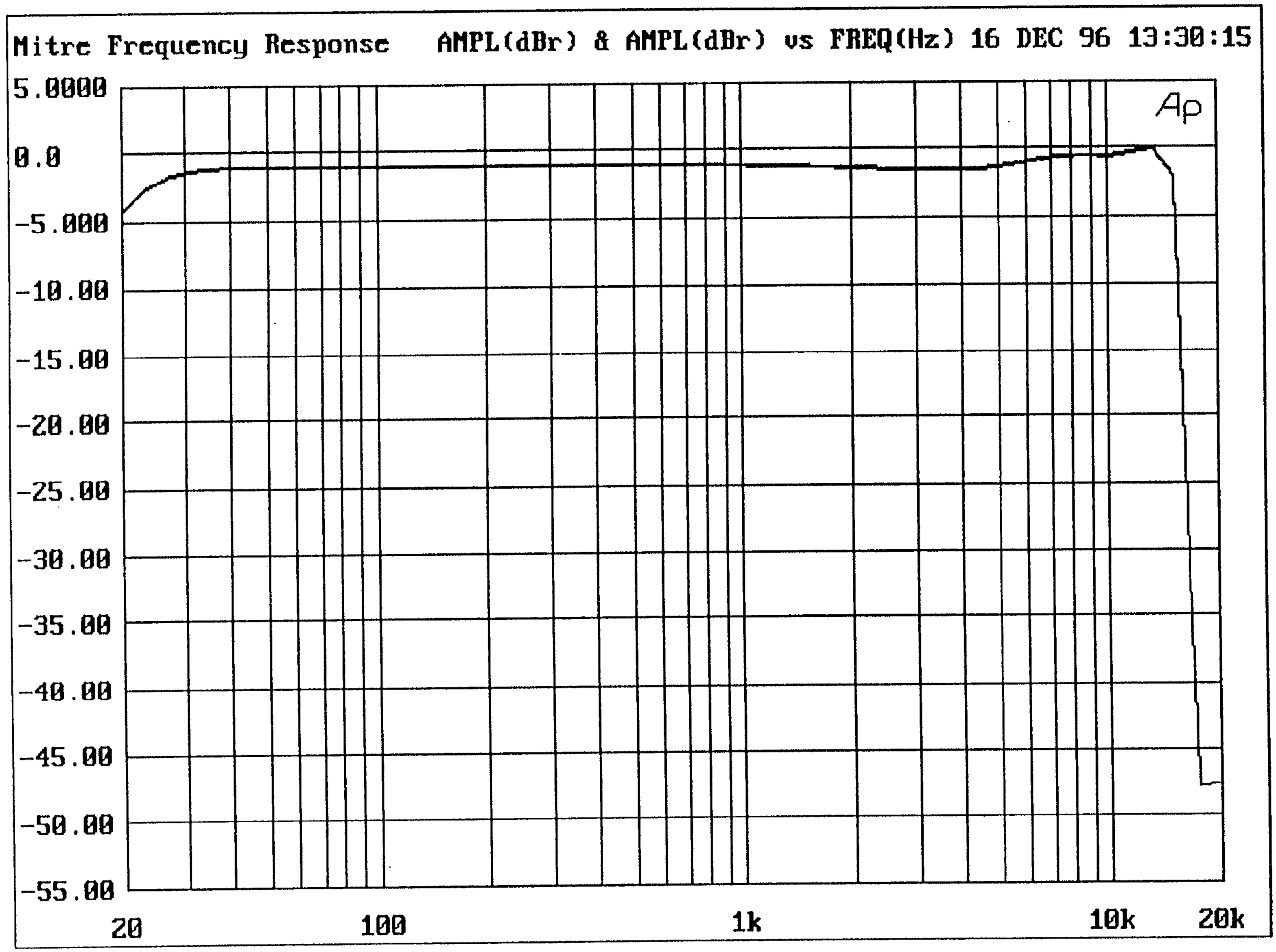
EIA REF -14.9 dBm ATTEN 10 dB

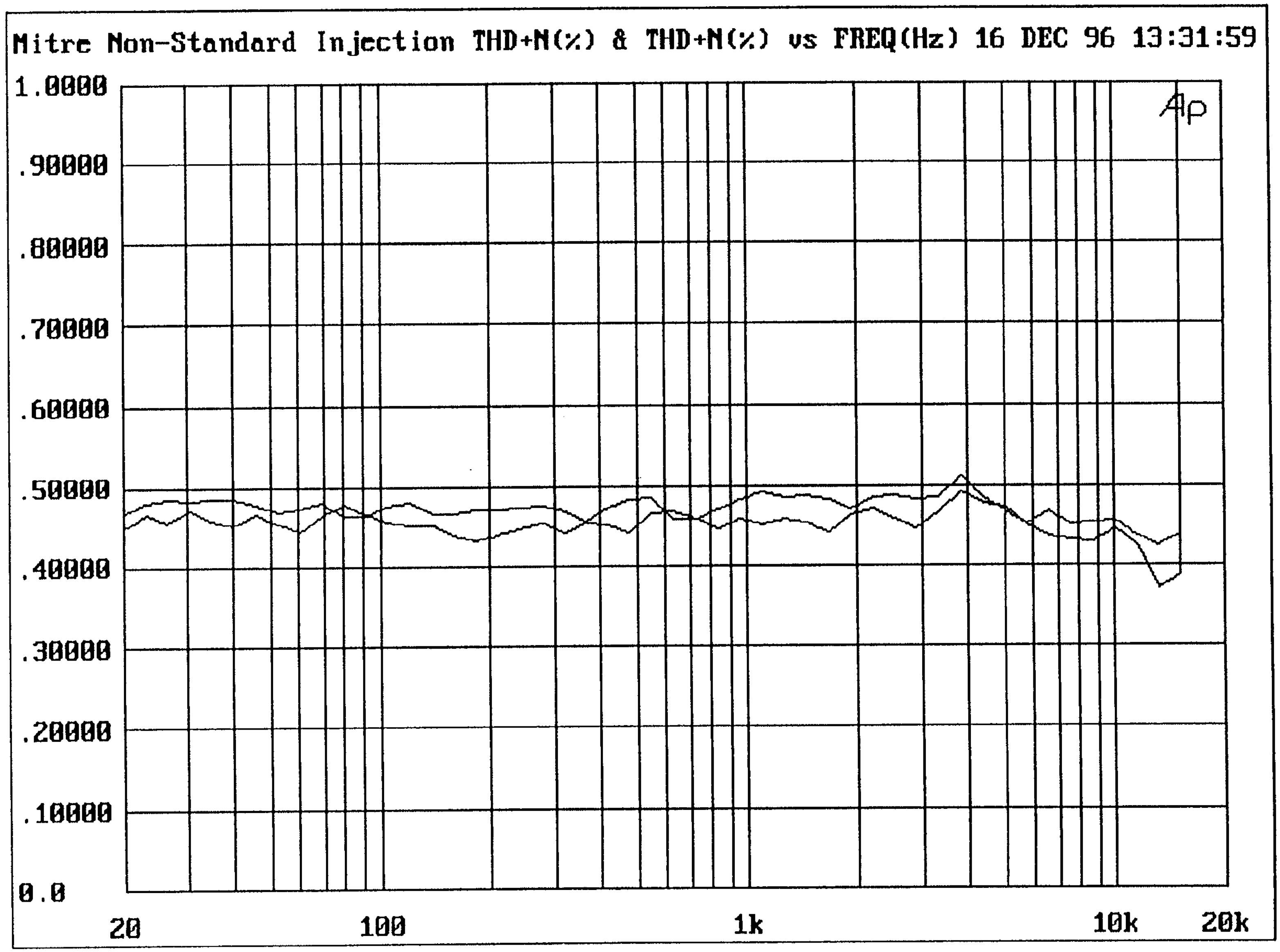
10 dB/

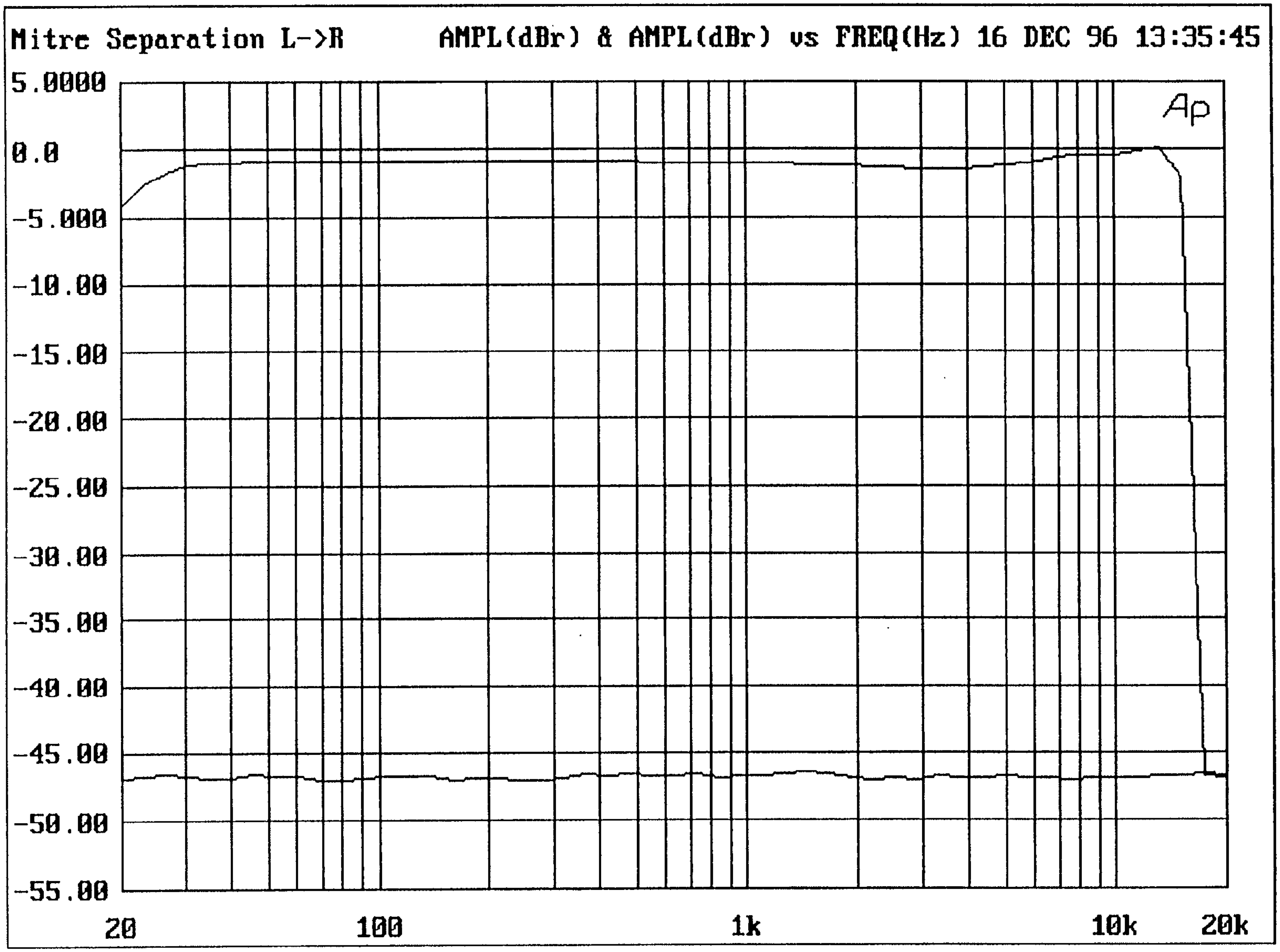


START 0 Hz STOP 100 kHz

RES BW 300 Hz VBW 30 Hz SWP 30.0 sec


Mitre Frequency Response AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 16 DEC 96 13:30:15
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap


Mitre Non-Standard Injection THD+N(%) & THD+N(%) vs FREQ(Hz) 16 DEC 96 13:31:59
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap

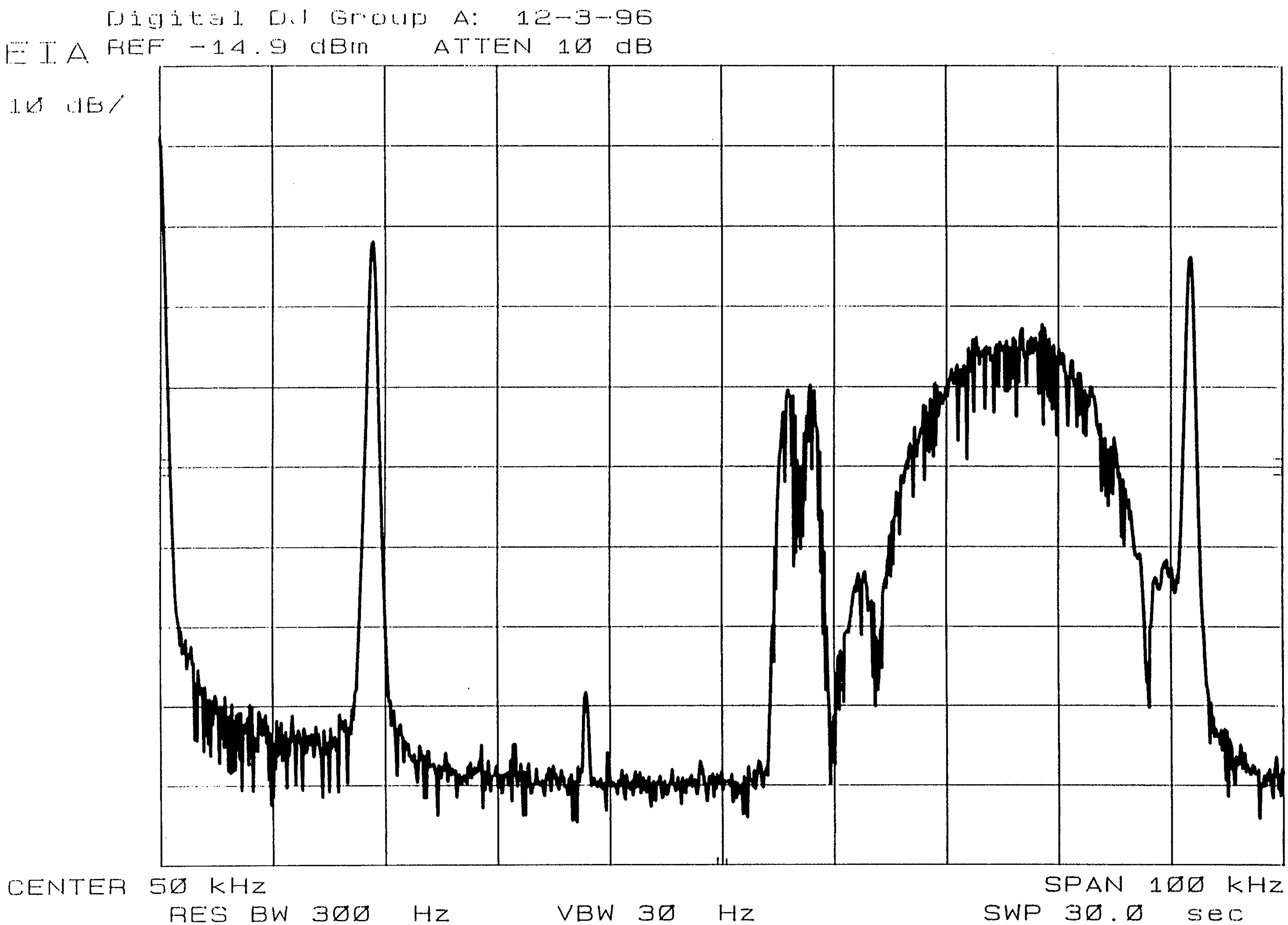


Mitre Separation L->R
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 16 DEC 96 13:35:45
Ap
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k

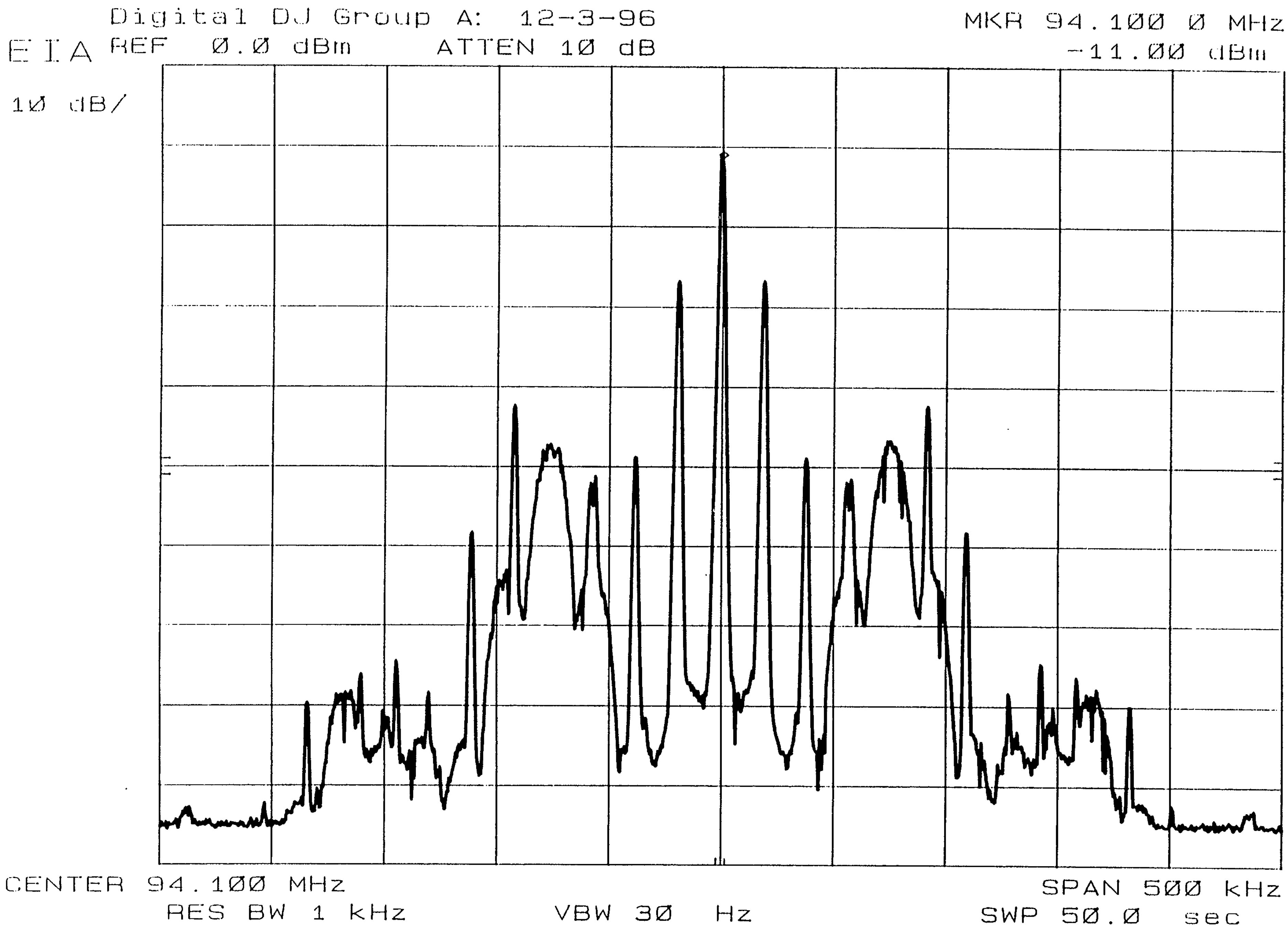
DDJ

System Plots

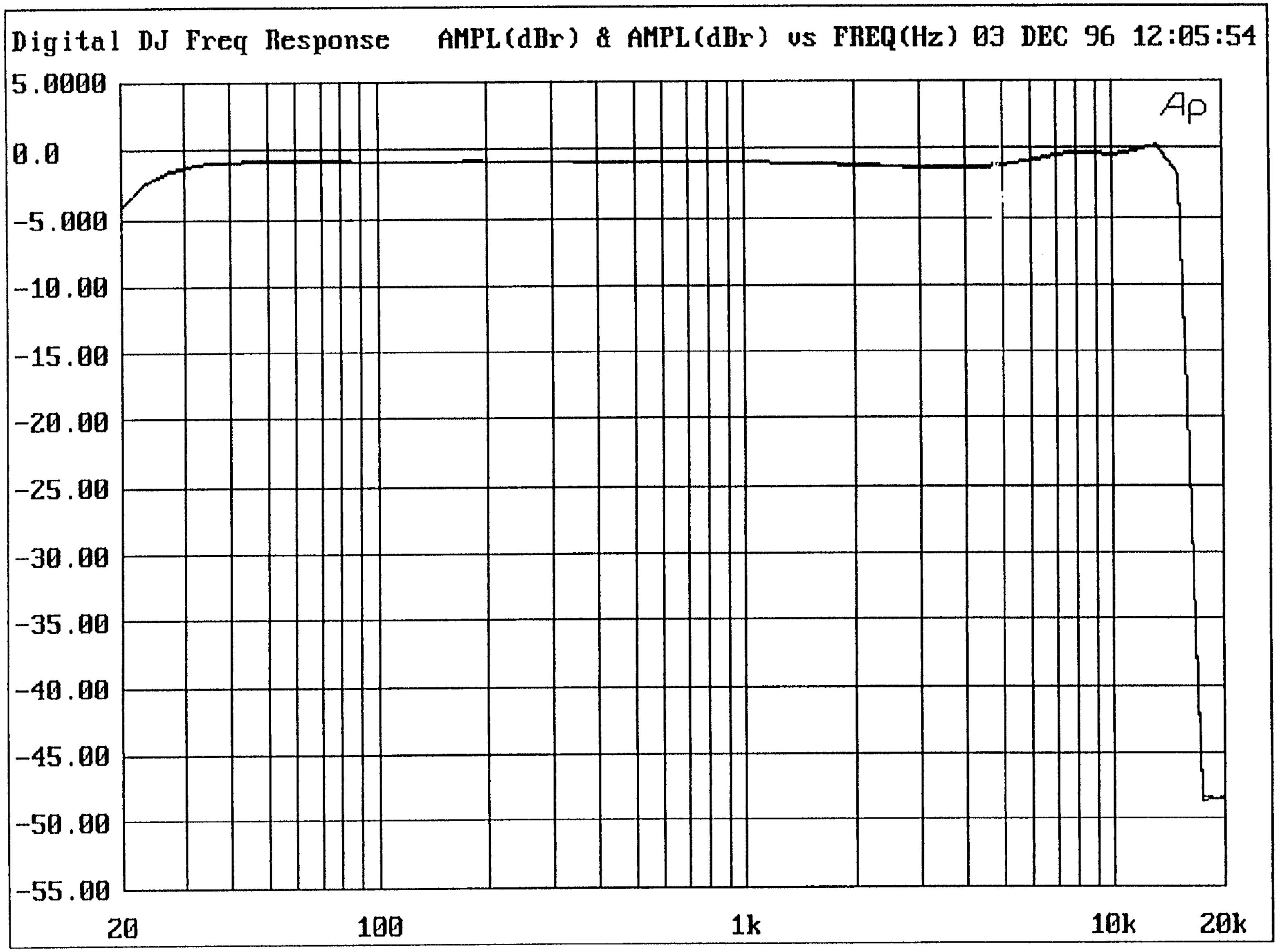
(see additional plots at end of appendix)

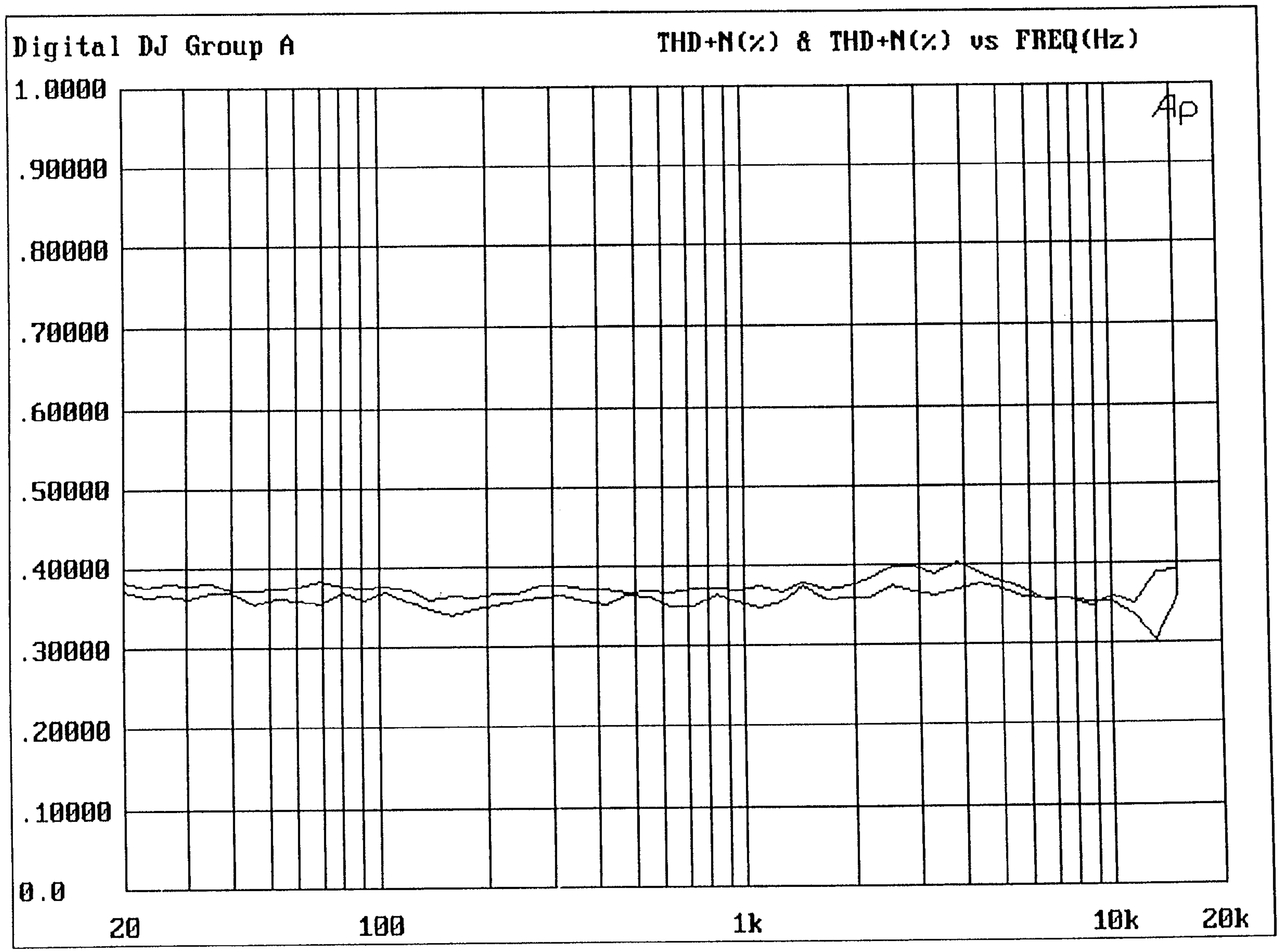


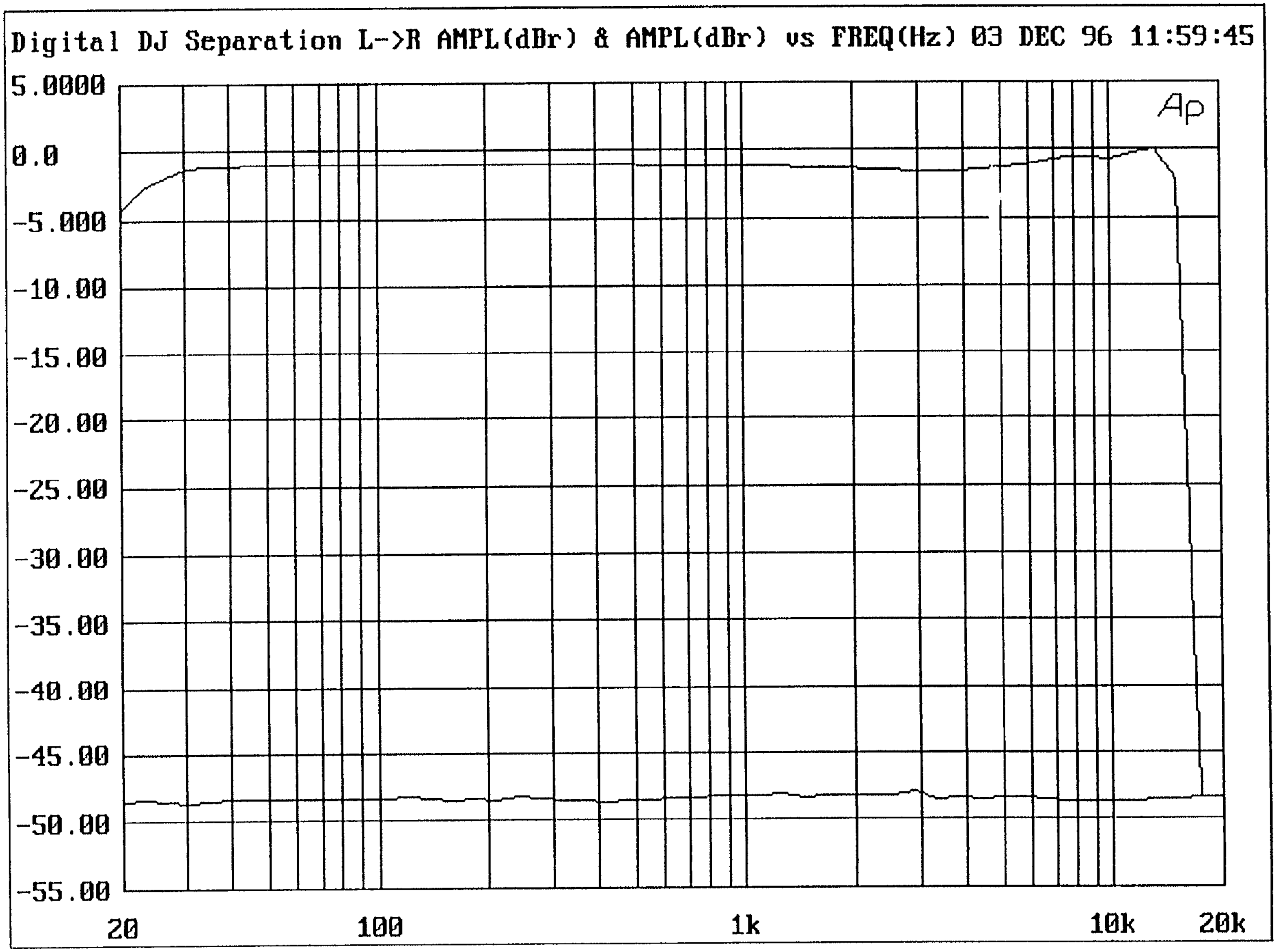
Digital DJ Group A: 12-3-96
EIA
REF -14.9 dBm
ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec



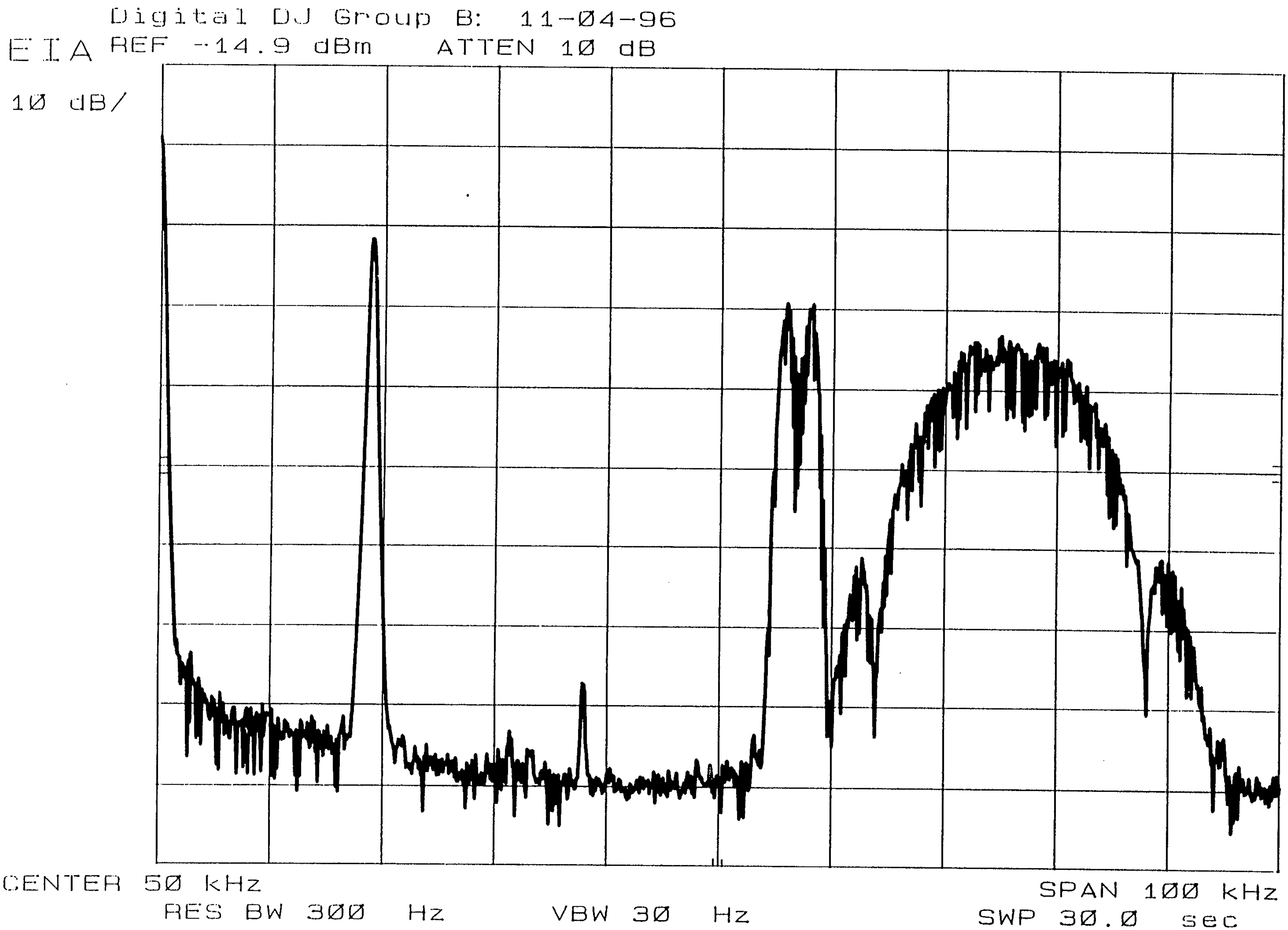
Digital DJ Group A: 12-3-96
EIA
REF 0.0 dBm ATTEN 10 dB
MKR 94.100 0 MHz
-11.00 dBm
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec

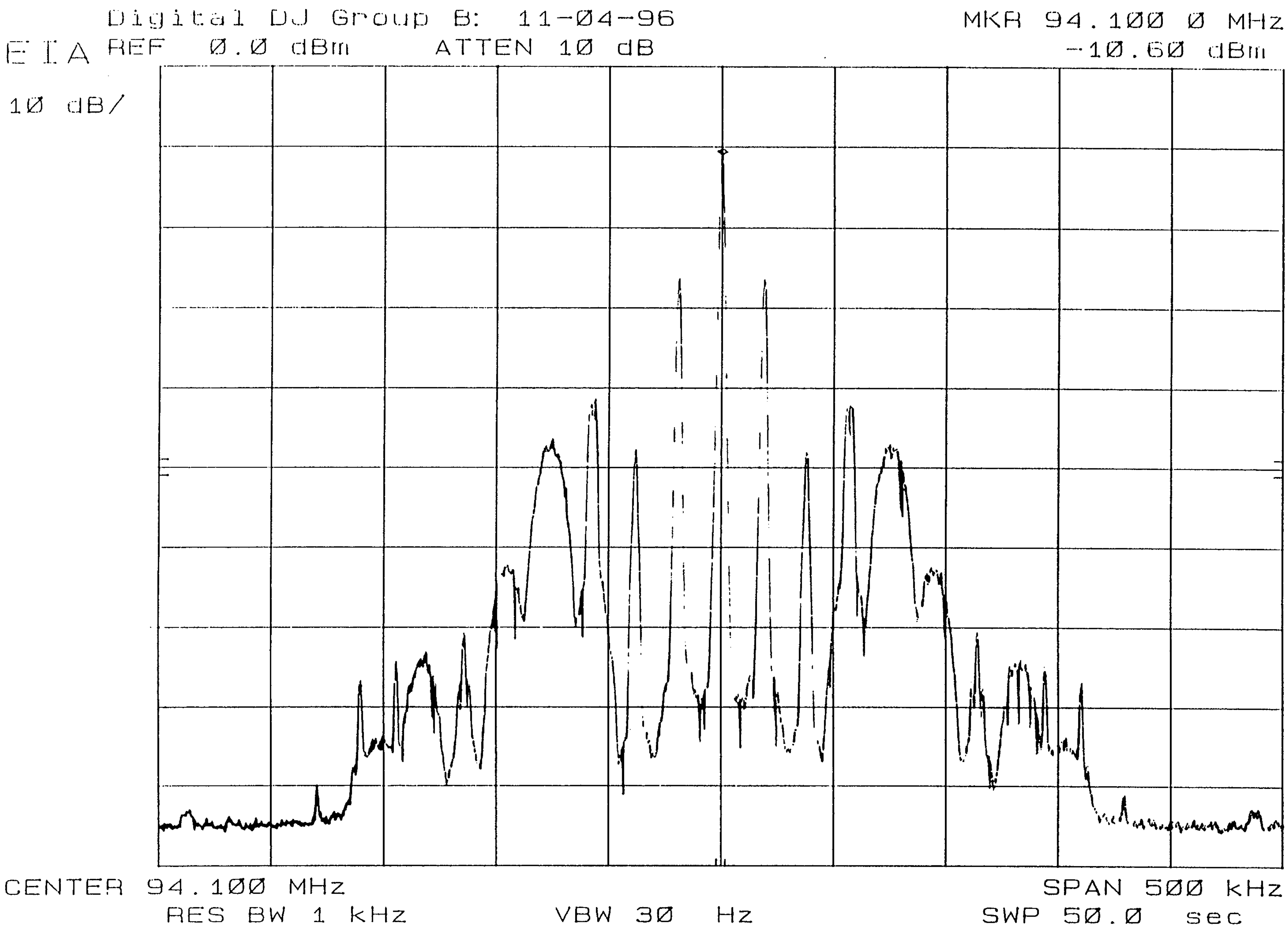

Digital DJ Freq Response
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 12:05:54
Ap
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k


Digital DJ Group A
THD+N(%) & THD+N(%) vs FREQ(Hz)
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap

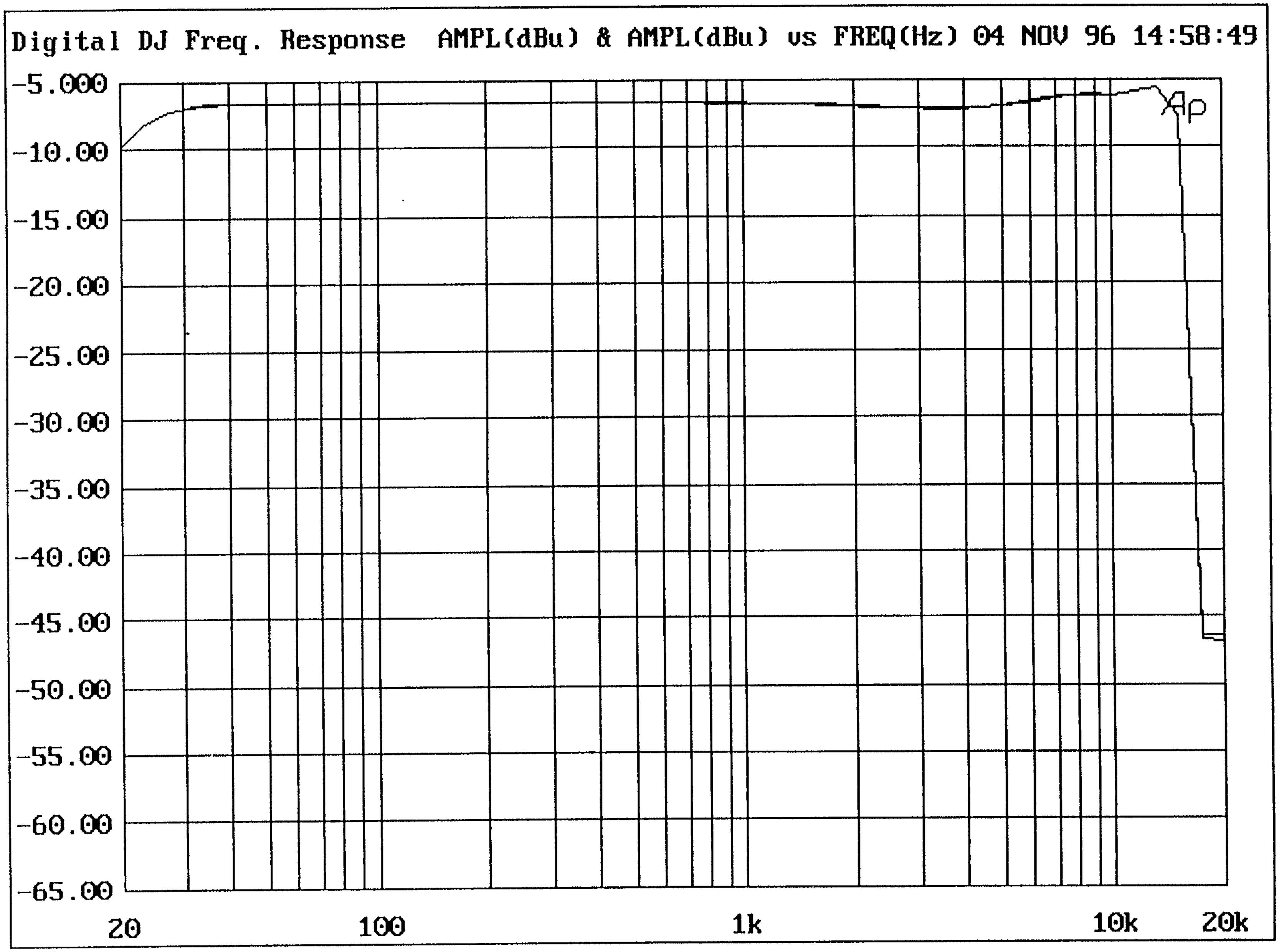


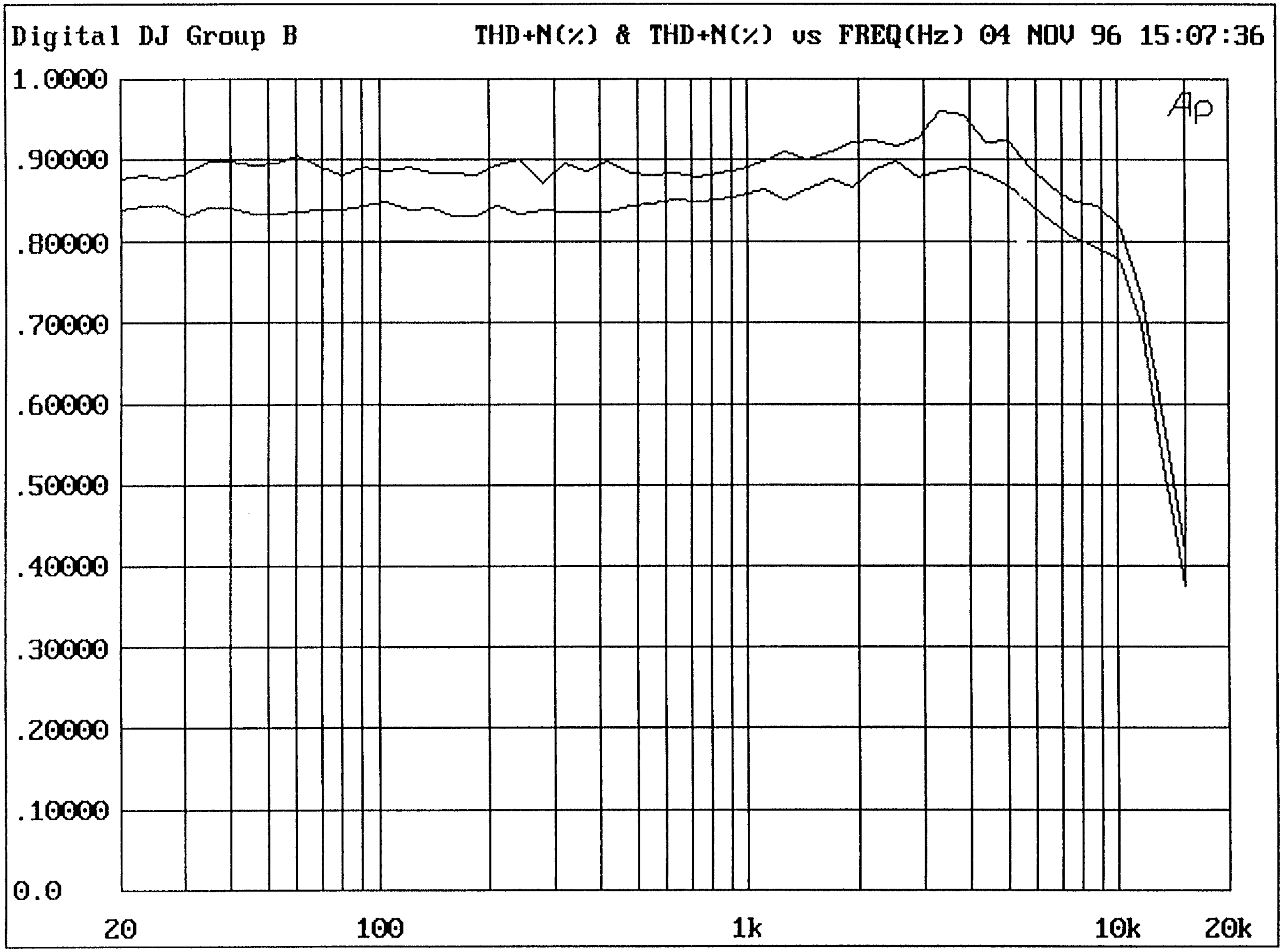
Digital DJ Separation L->R AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 11:59:45
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap


Digital DJ Group B: 11-04-96
EIA REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz VBW 30 Hz
SWP 30.0 sec

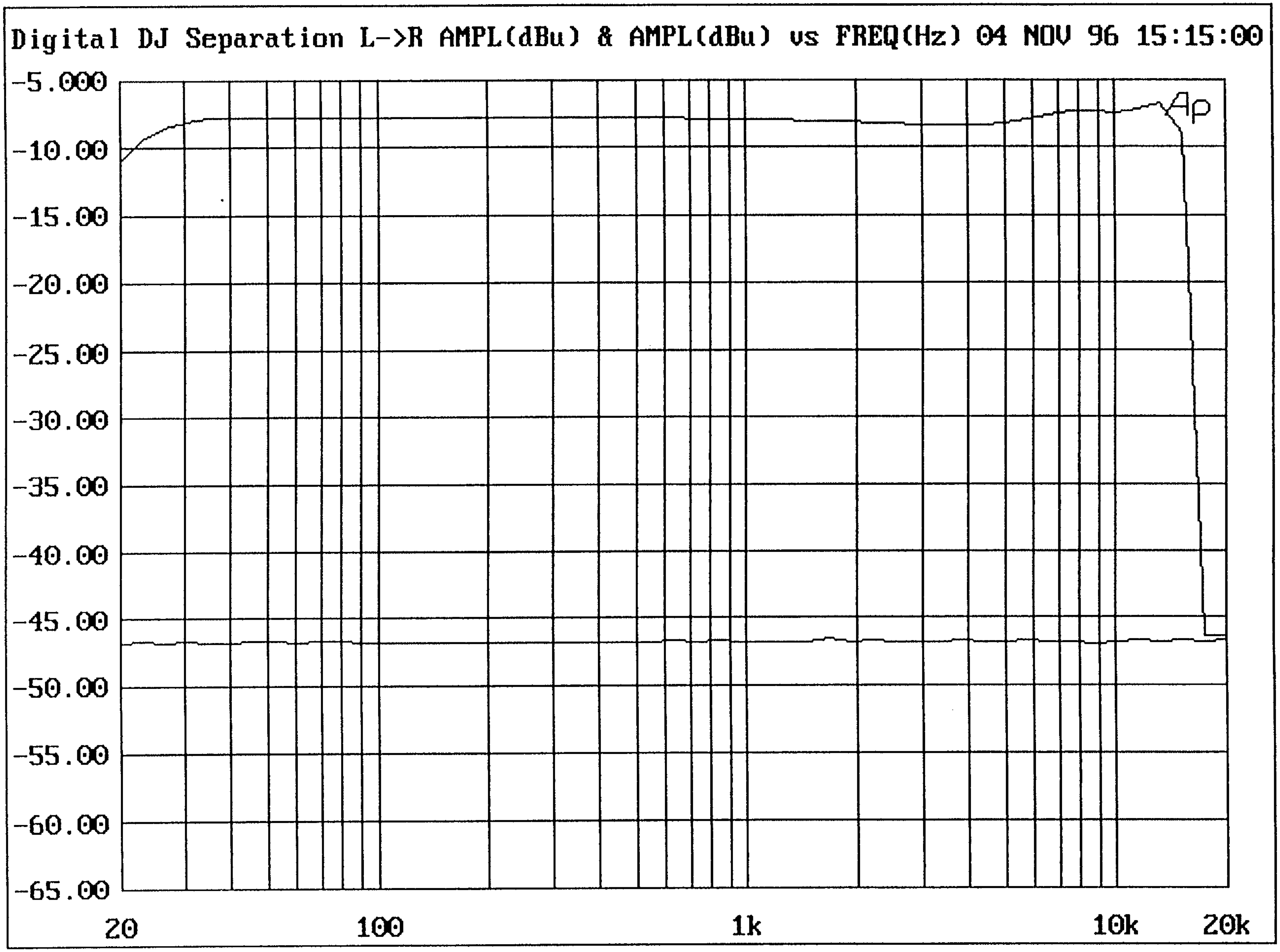


Digital DJ Group B: 11-04-96
MKR 94.100 0 MHz
EIA REF 0.0 dBm ATTEN 10 dB
-10.60 dBm
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec


Digital DJ Freq. Response AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 04 NOV 96 14:58:49
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap



Digital DJ Group B
THD+N(%) & THD+N(%) vs FREQ(Hz) 04 NOV 96 15:07:36
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap

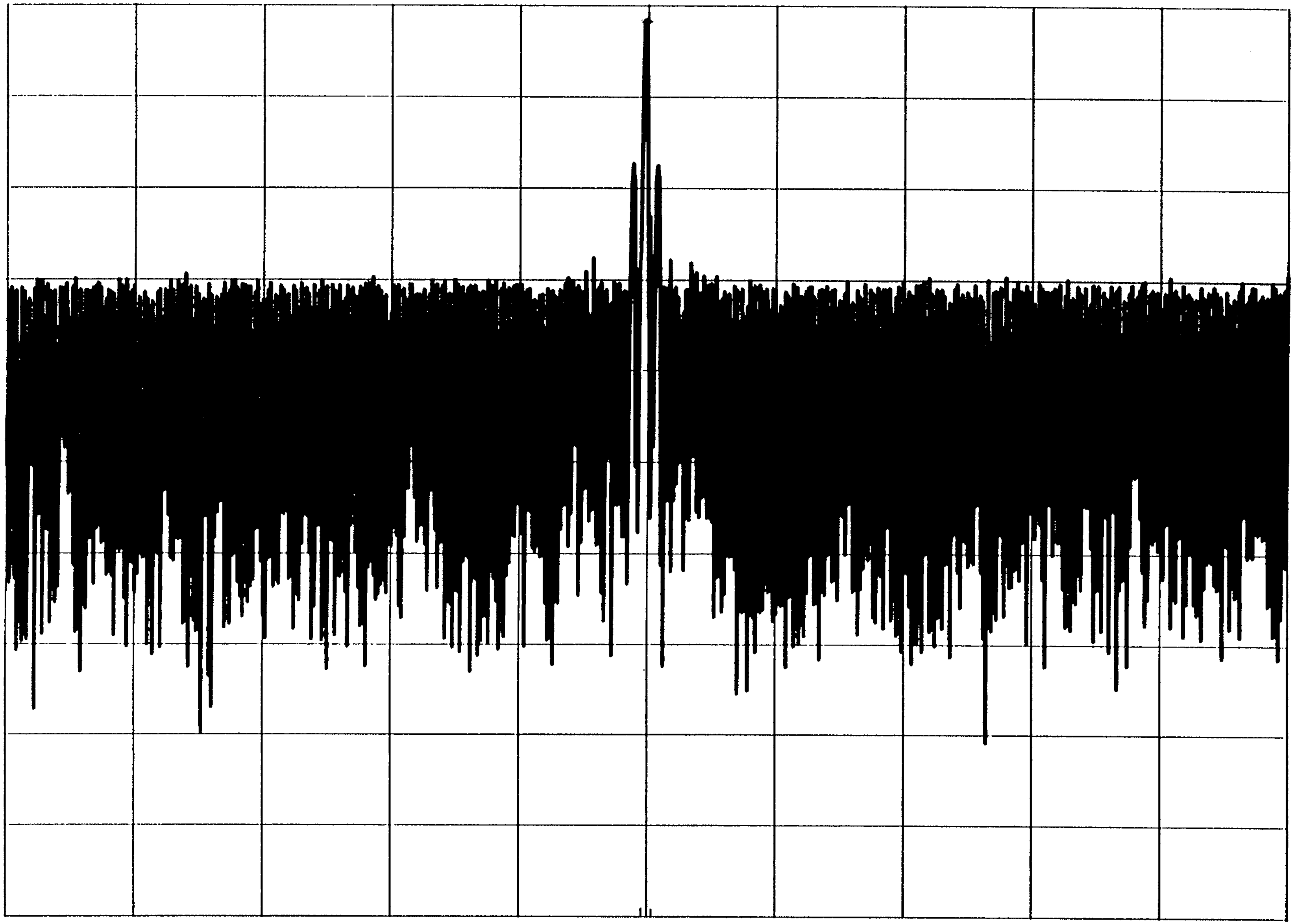


Digital DJ Separation L->R AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 04 NOV 96 15:15:00
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap

Digital DJ B-4: RR=1kHz: ATTN=10dB: 11-7-96 MKR 94.096 MHz

EIA REF -55.0 dBm ATTEN 10 dB -56.80 dBm

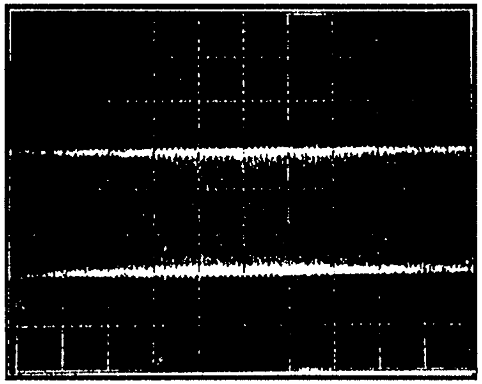
10 dB/



CENTER 94.10 MHz SPAN 2.00 MHz

RES BW 3 kHz VBW 10 kHz SWP 600 msec

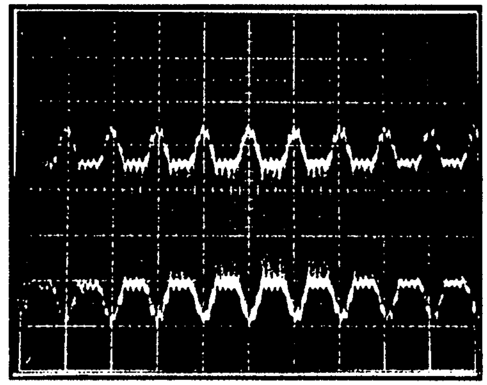
Variable Injection



50 mV, 500μsec / Division

DIGITAL DJ

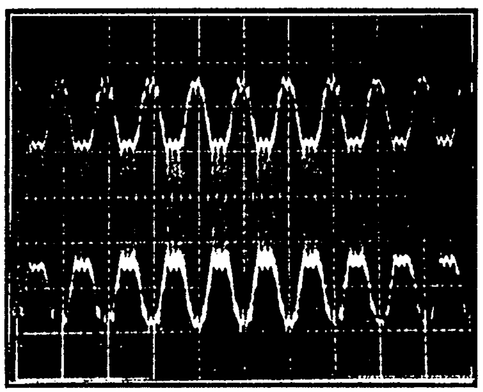
1 kHz @ %0



50 mV, 500μsec / Division

DIGITAL DJ

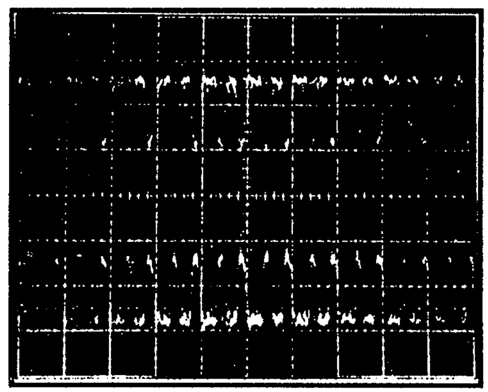
1 kHz @ 4%



50 mV, 500μsec / Division

DIGITAL DJ

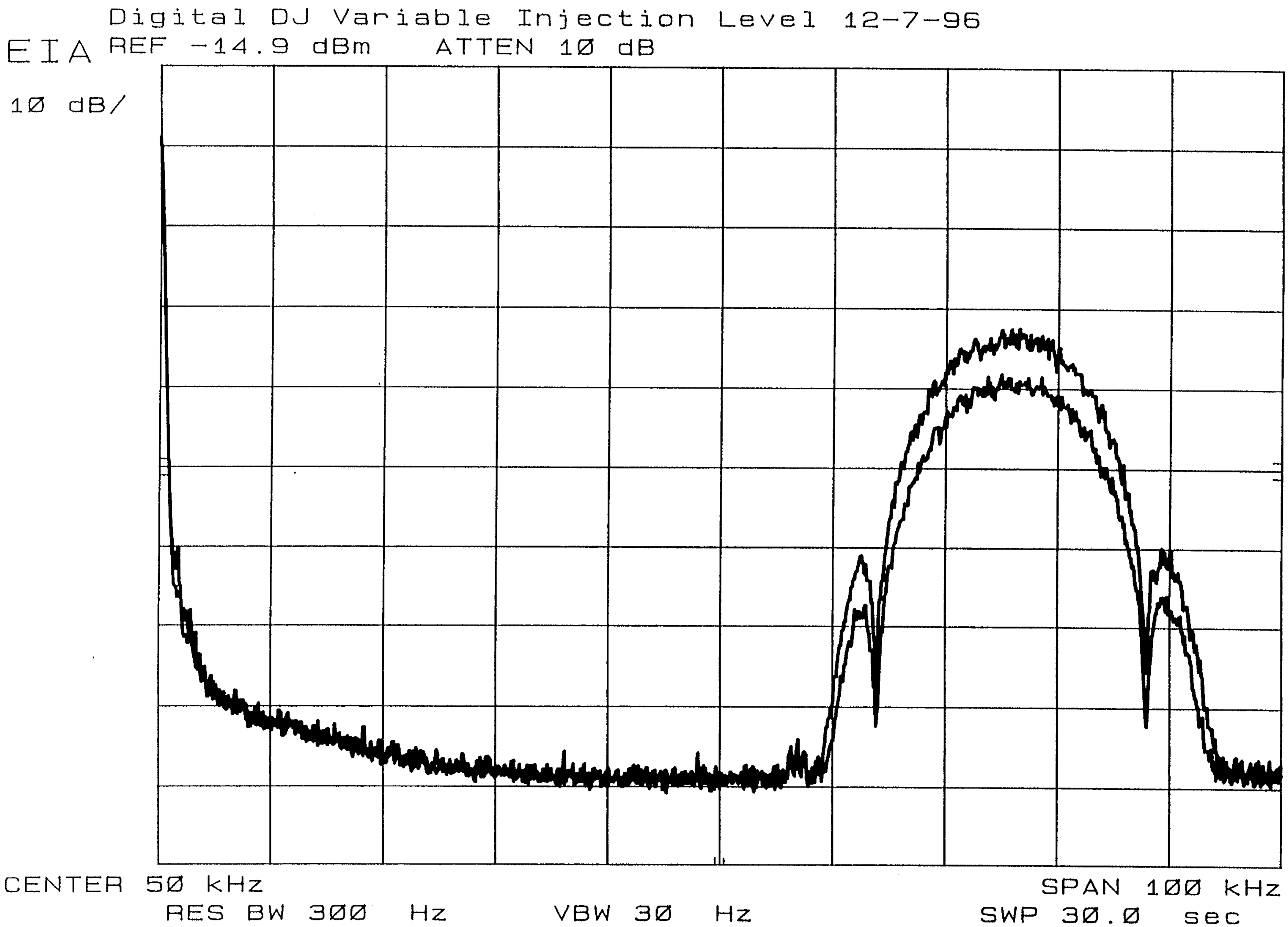
1 kHz @ 5%

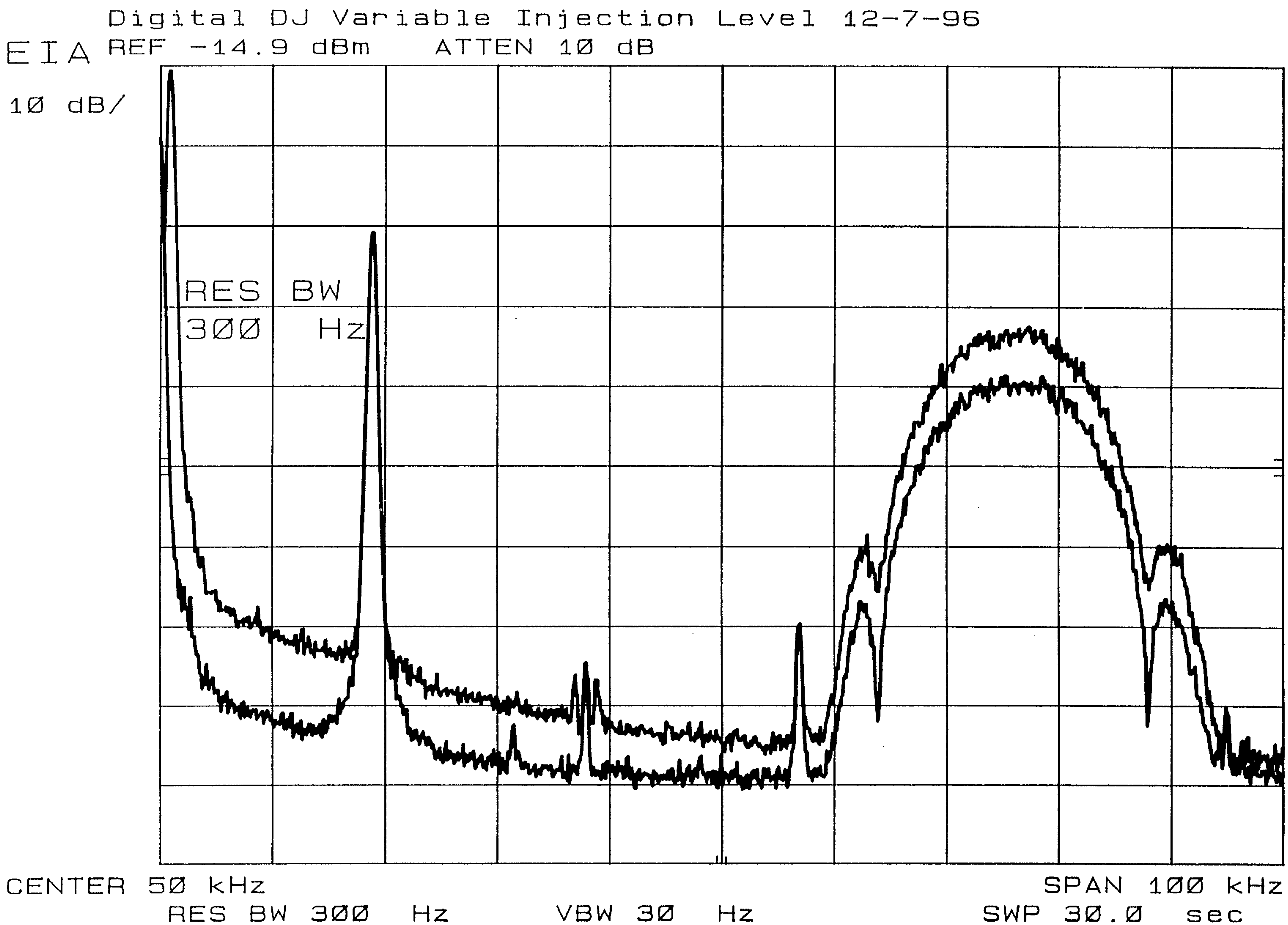


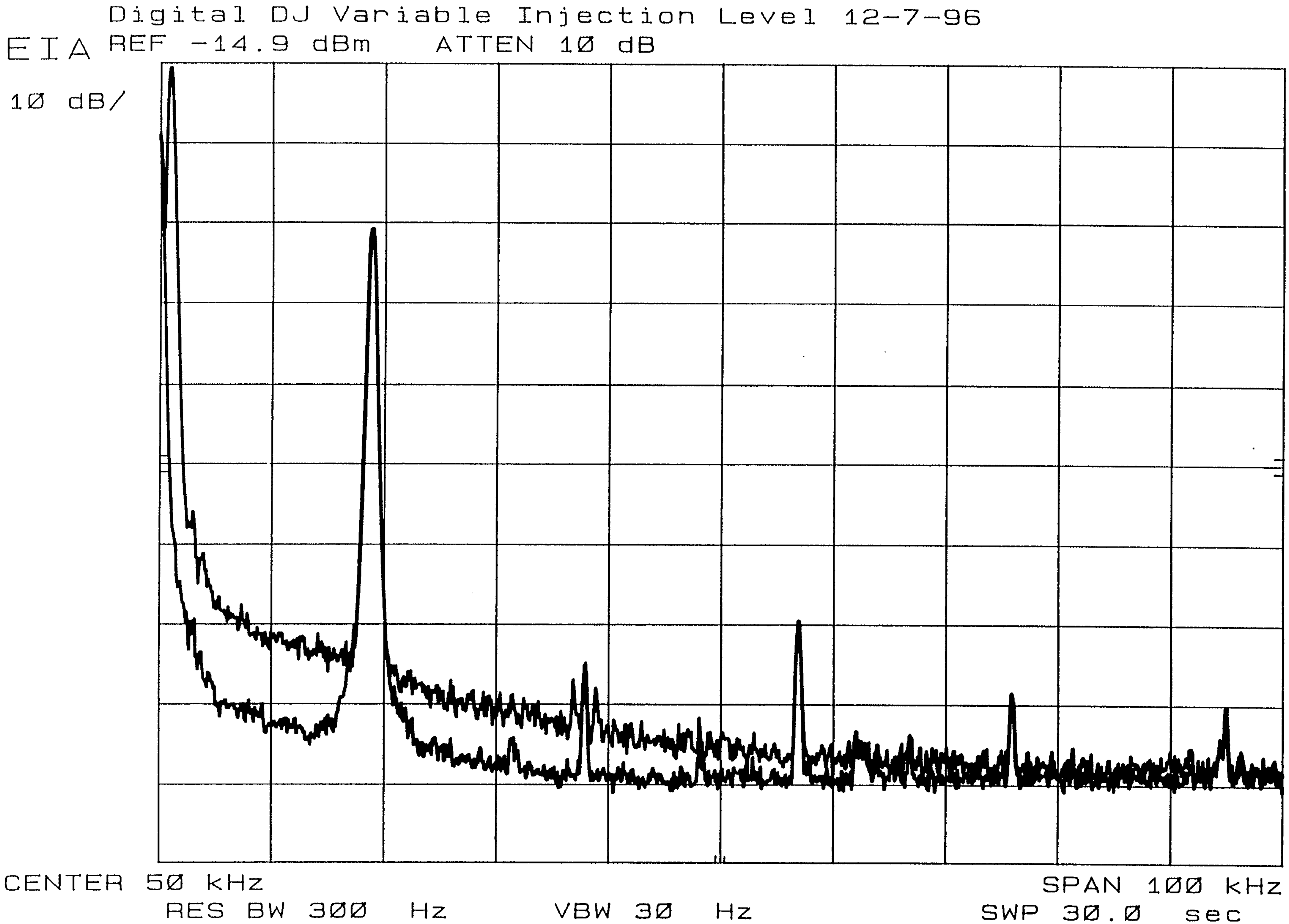
50 mV, 500μsec / Division

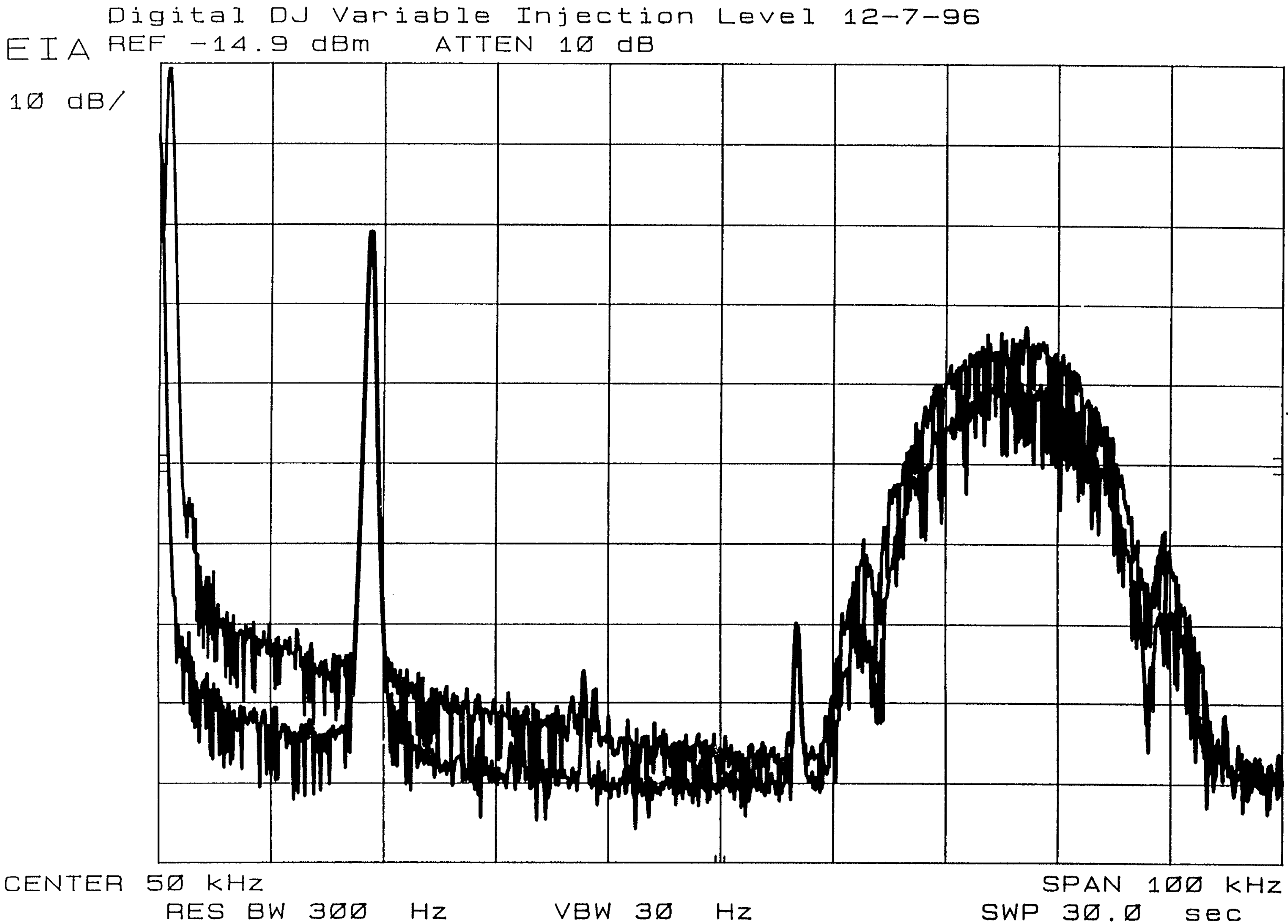
DIGITAL DJ

1 kHz @ 10%

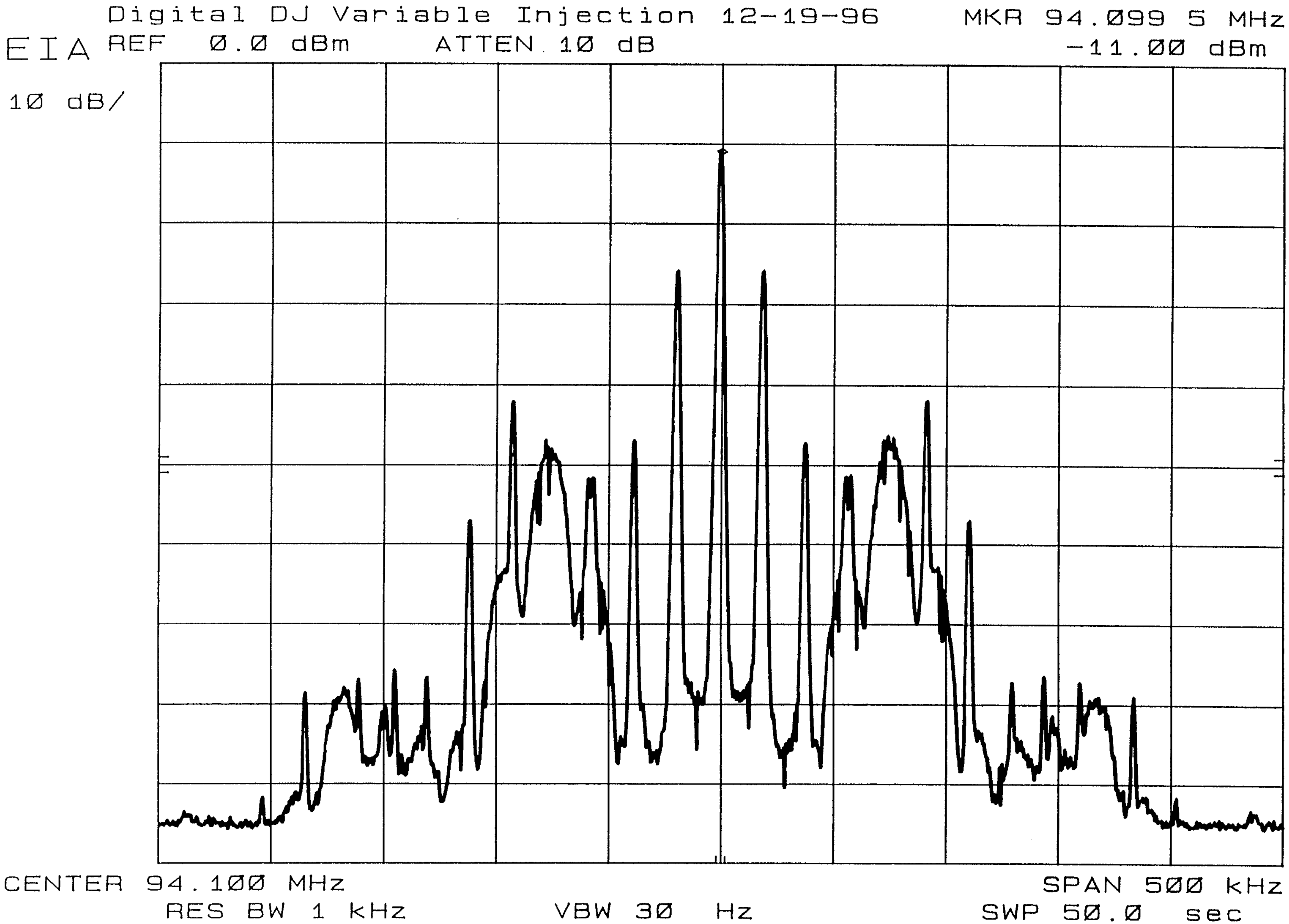

Digital DJ Variable Injection Level 12-7-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec


Digital DJ Variable Injection Level 12-7-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
RES BW
300 Hz
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

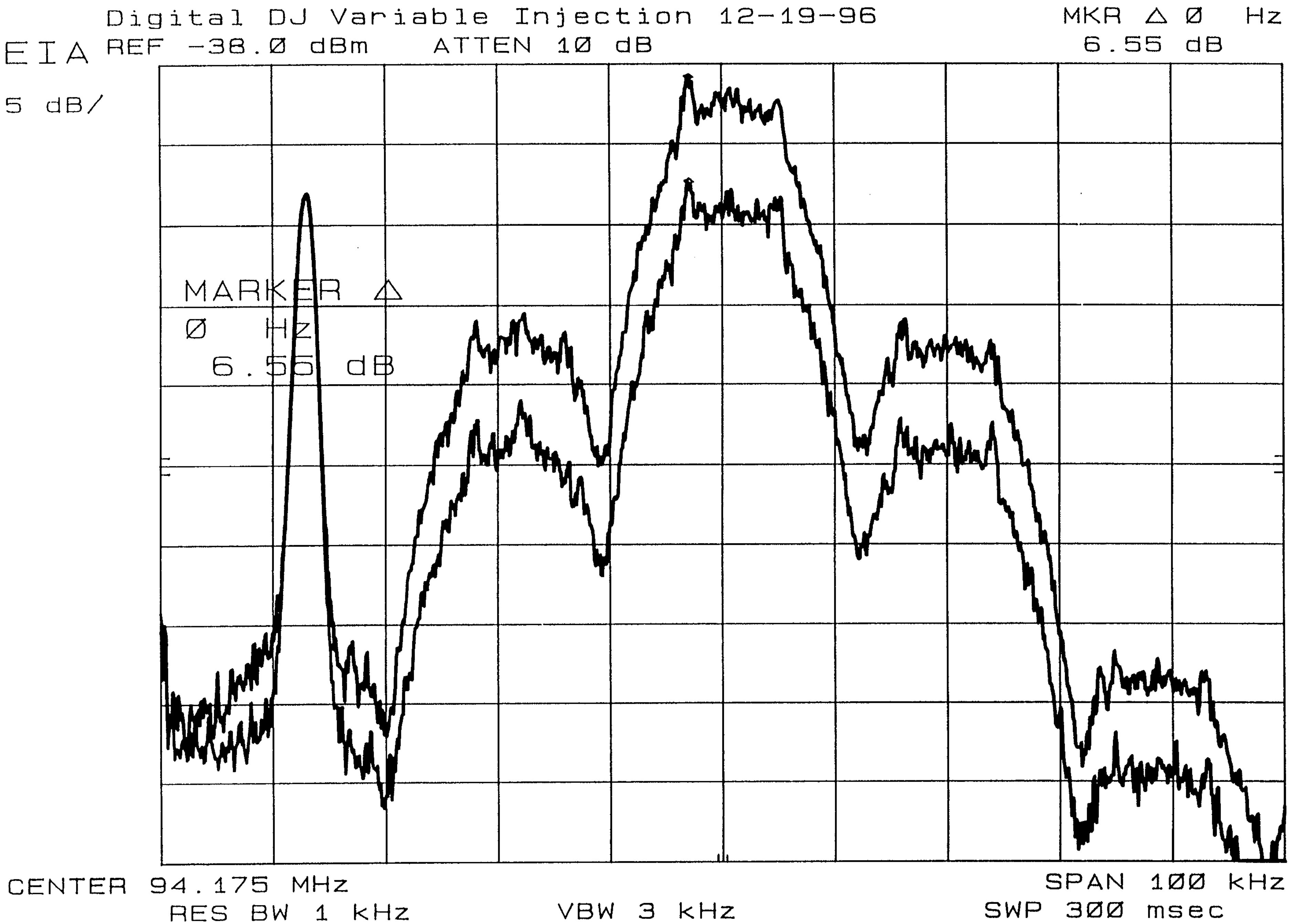

Digital DJ Variable Injection Level 12-7-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

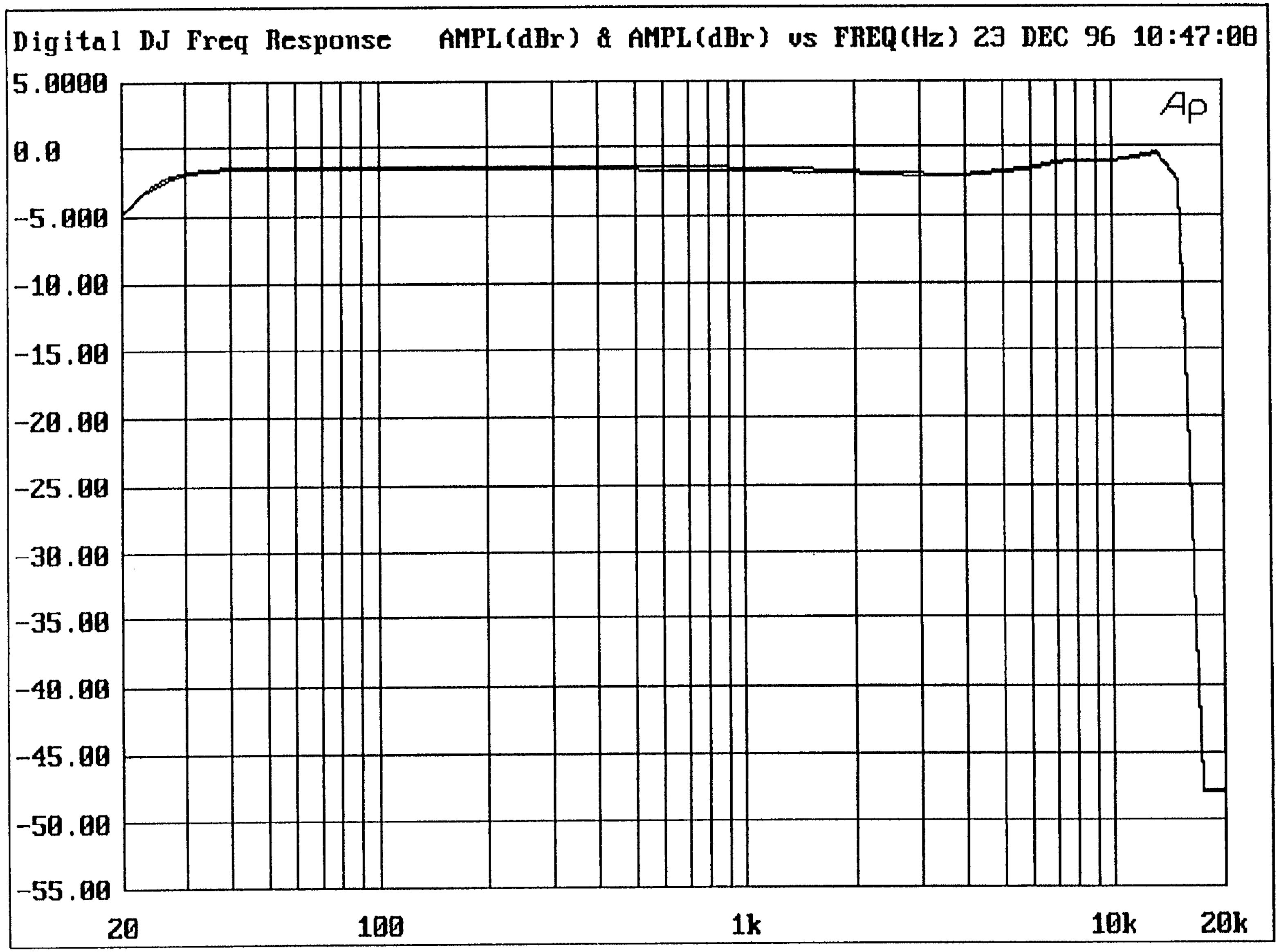


Digital DJ Variable Injection Level 12-7-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

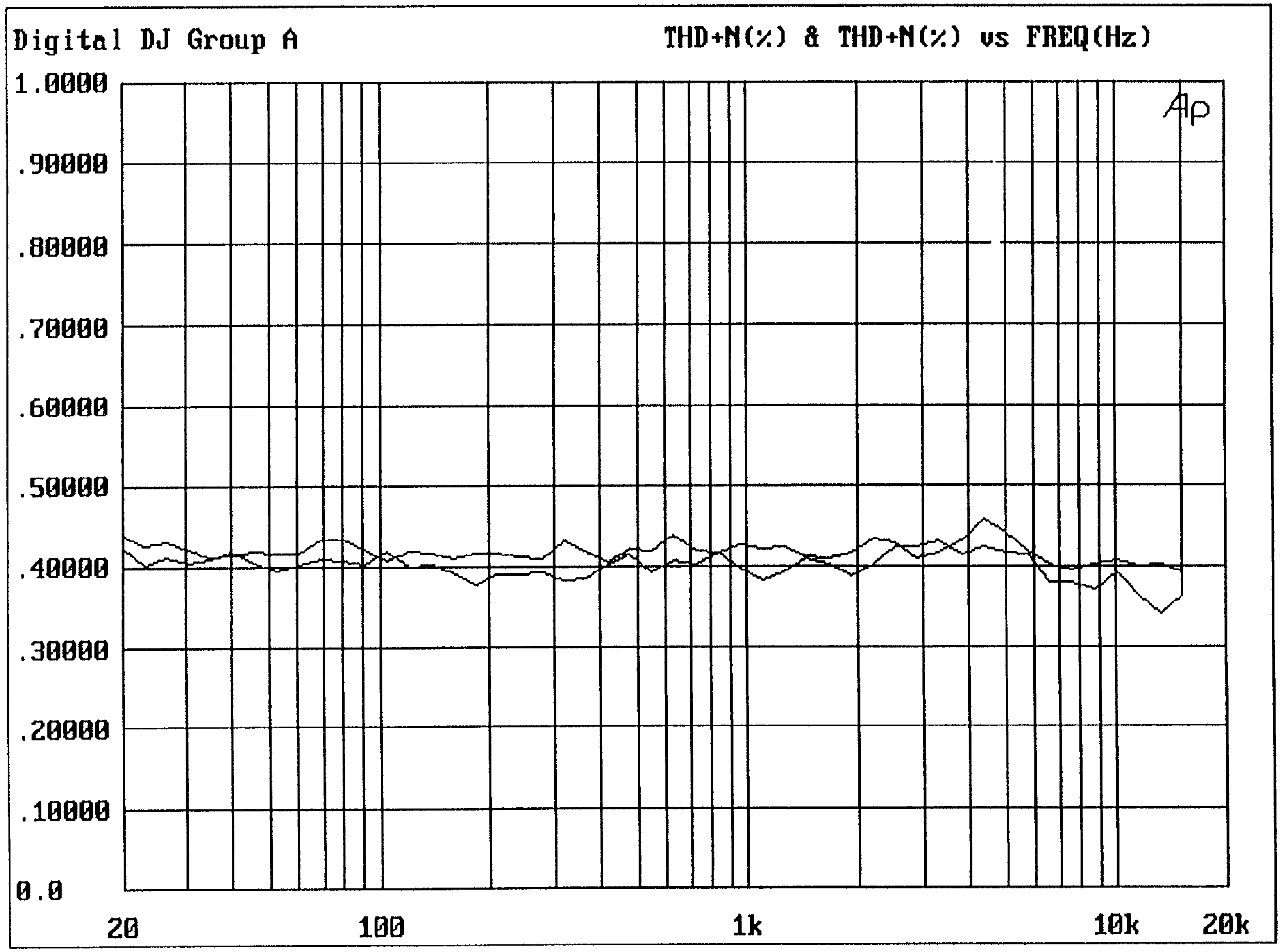


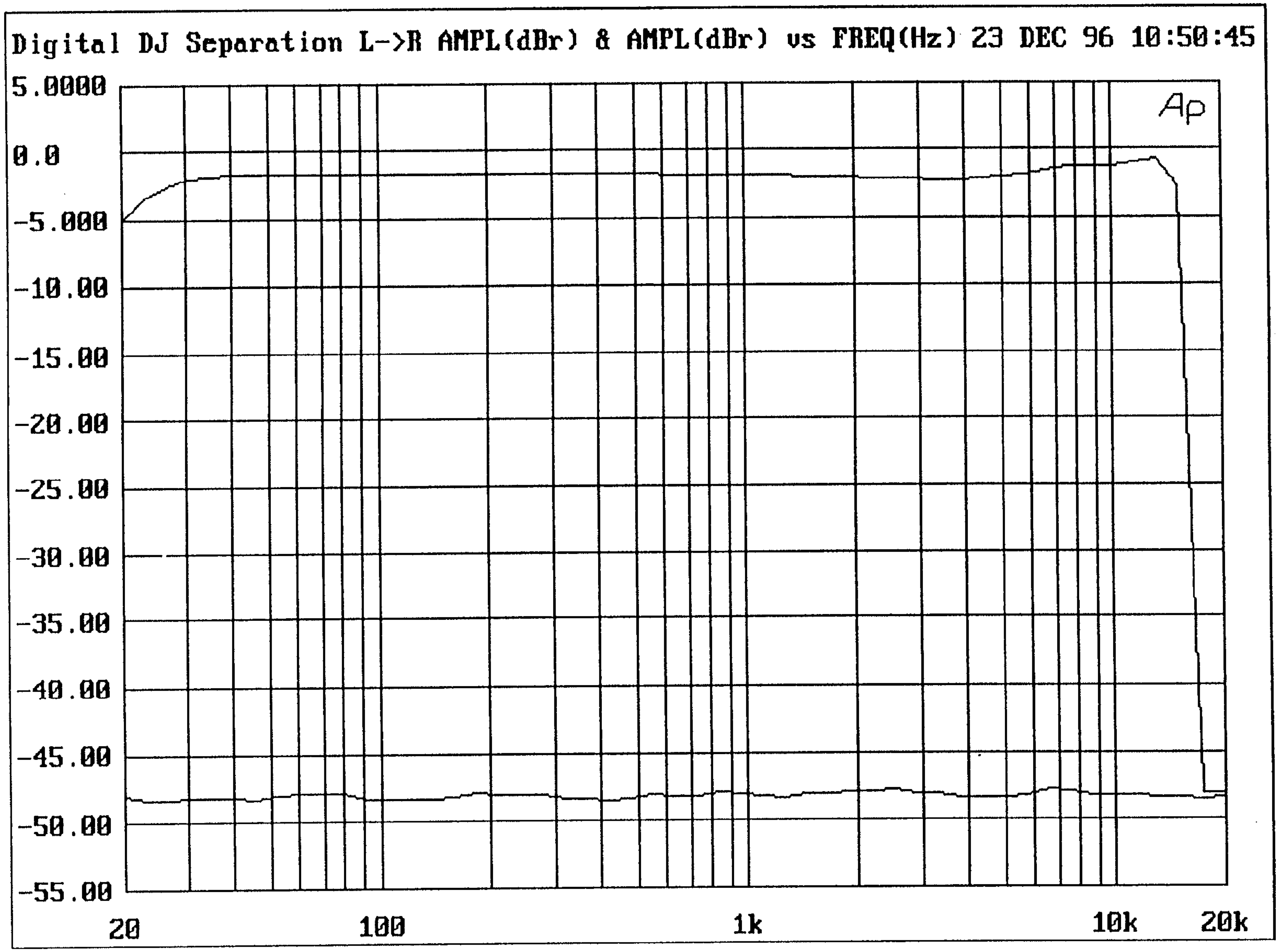
Digital DJ Variable Injection 12-19-96
MKR 94.099 5 MHz
-11.00 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec


Digital DJ Variable Injection 12-19-96
MKR △ Ø Hz
6.55 dB
EIA
REF -38.Ø dBm ATTEN 1Ø dB
5 dB/
MARKER △
Ø Hz
6.55 dB
CENTER 94.175 MHz
SPAN 1ØØ kHz
RES BW 1 kHz
VBW 3 kHz
SWP 3ØØ msec

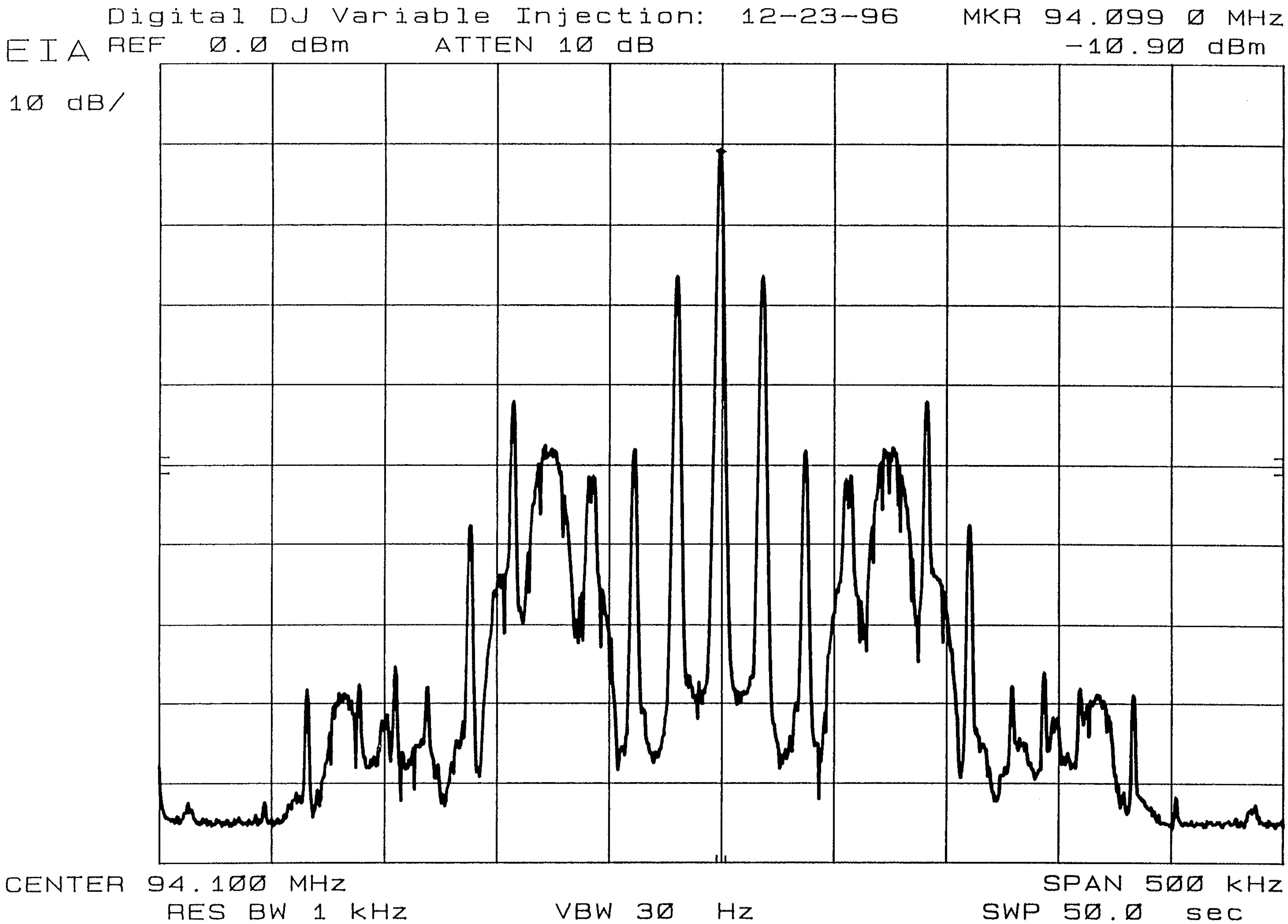


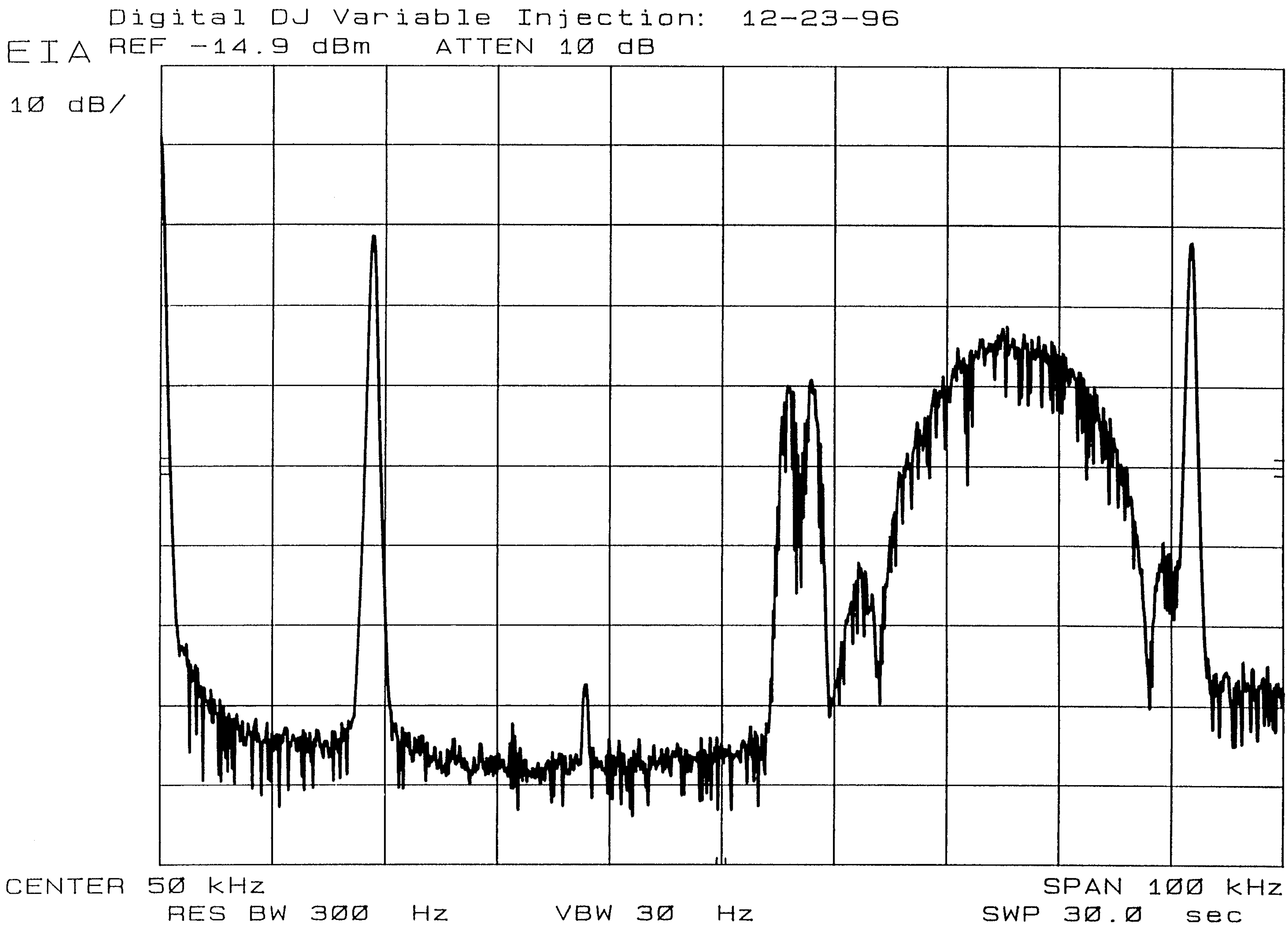
Digital DJ Freq Response AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 23 DEC 96 10:47:00
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap


Digital DJ Group A
THD+N(%) & THD+N(%) vs FREQ(Hz)
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap



Digital DJ Separation L->R AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 23 DEC 96 10:50:45
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap

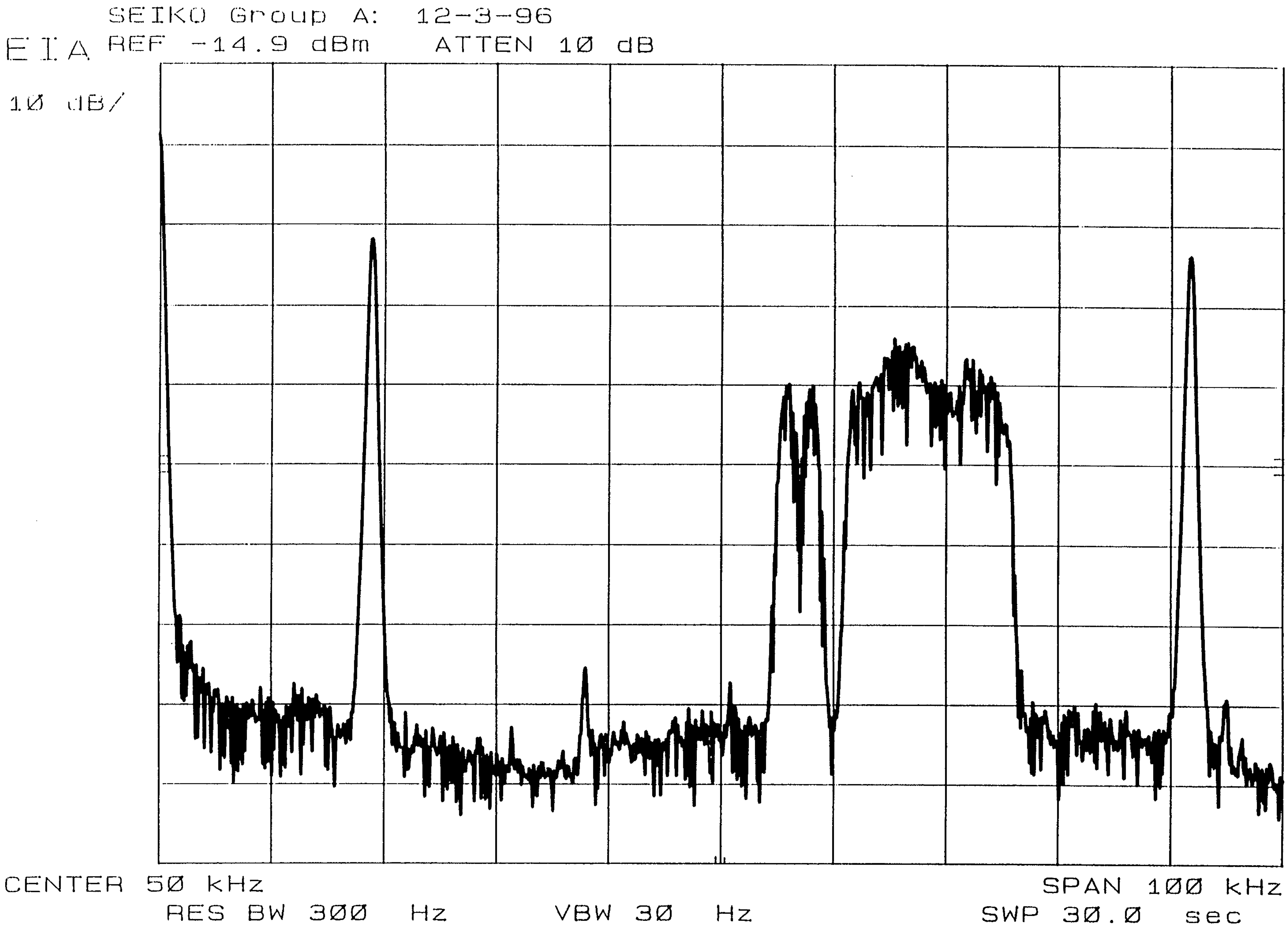

Digital DJ Variable Injection: 12-23-96
MKR 94.099 0 MHz
-10.90 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec


Digital DJ Variable Injection: 12-23-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

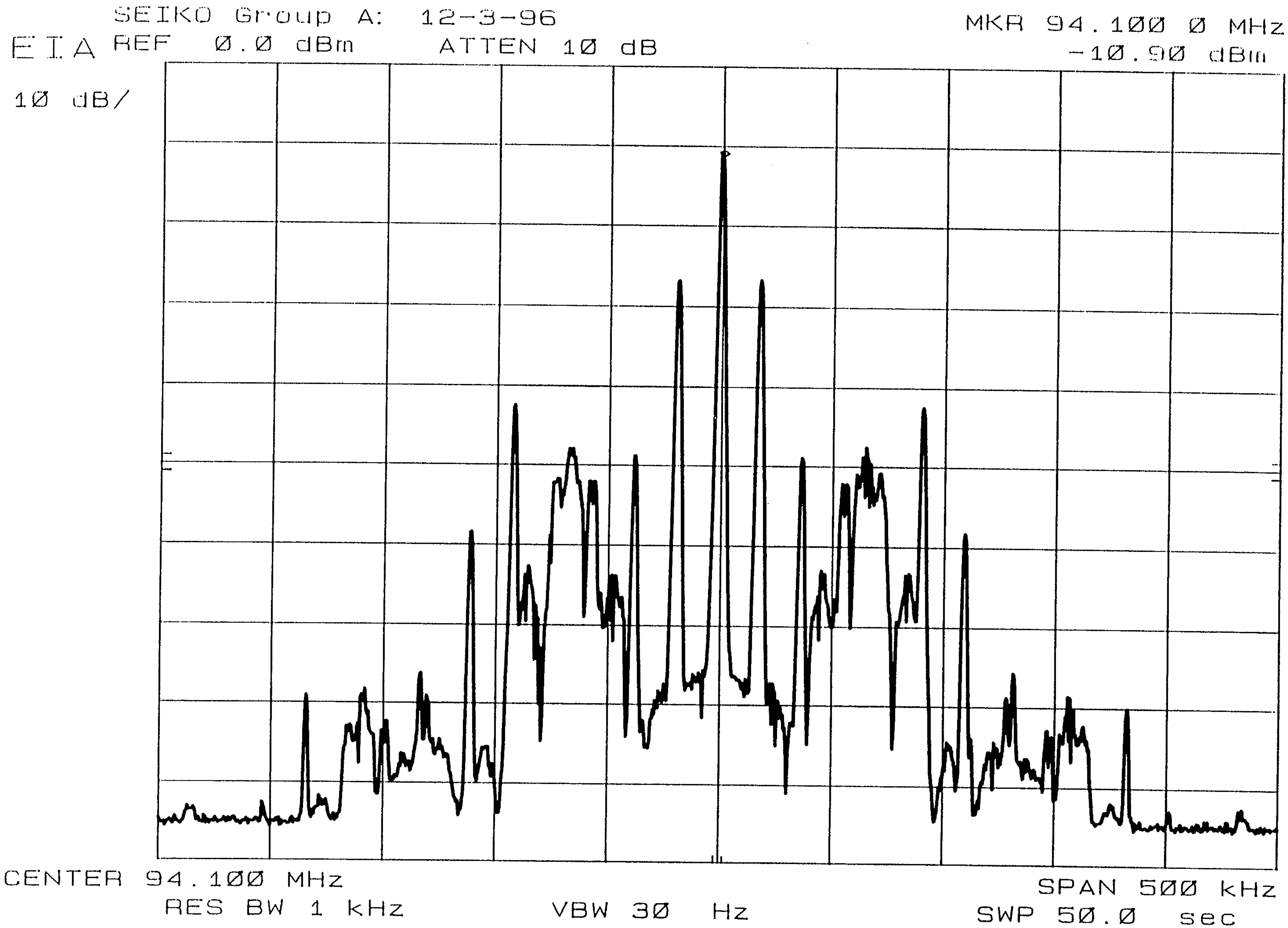
Seiko

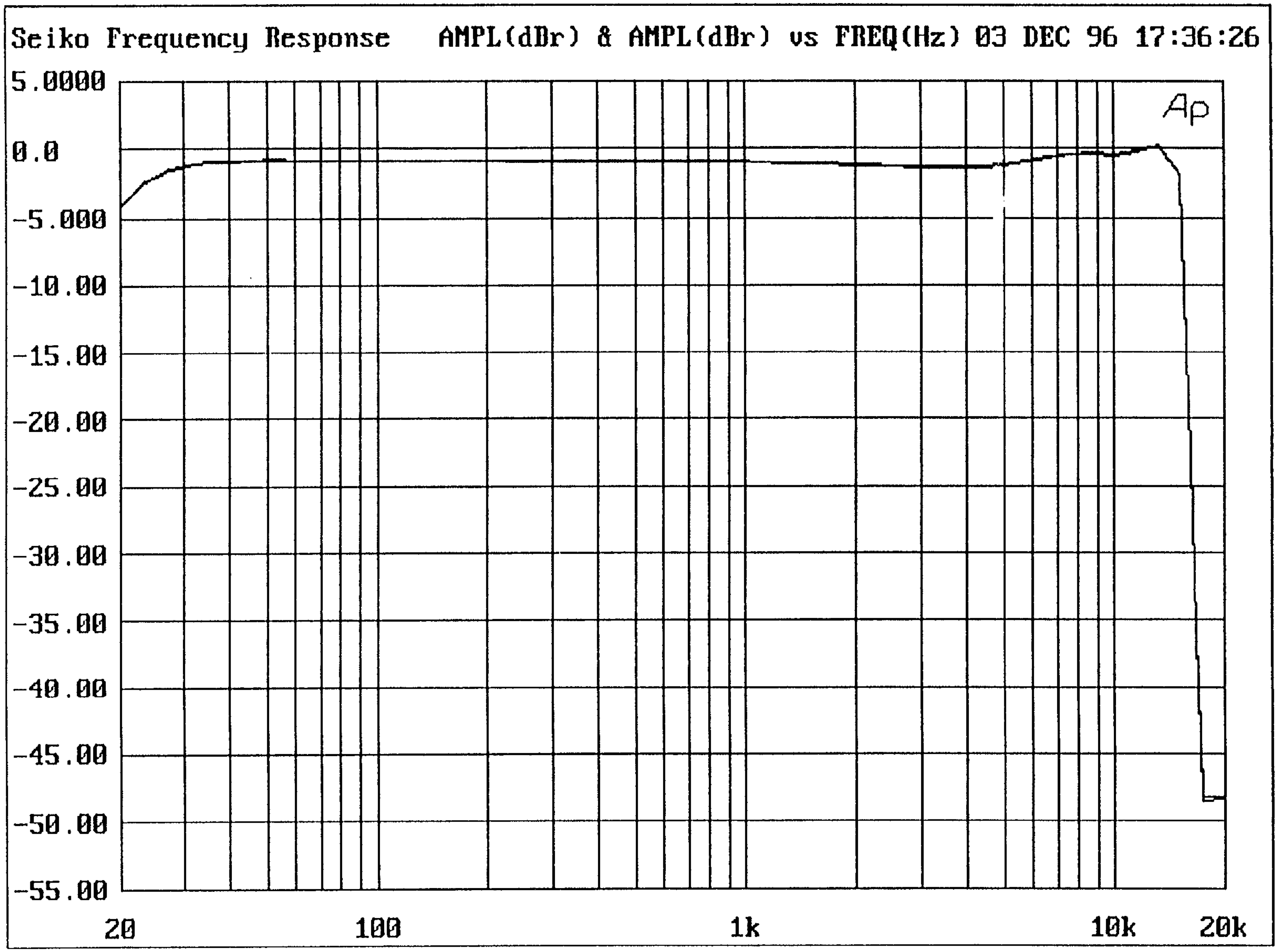
System Plots

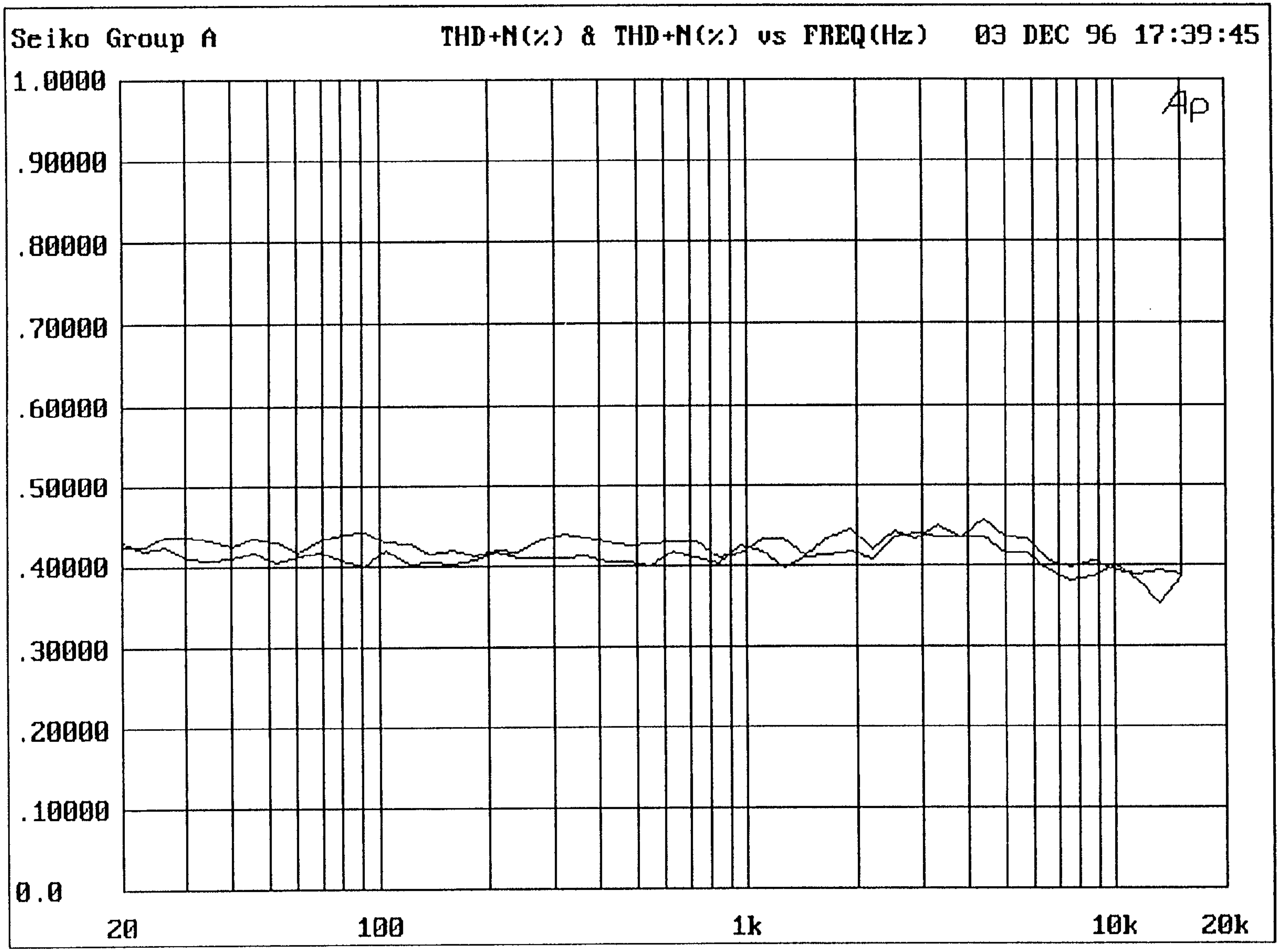
(see additional plots at end of appendix)



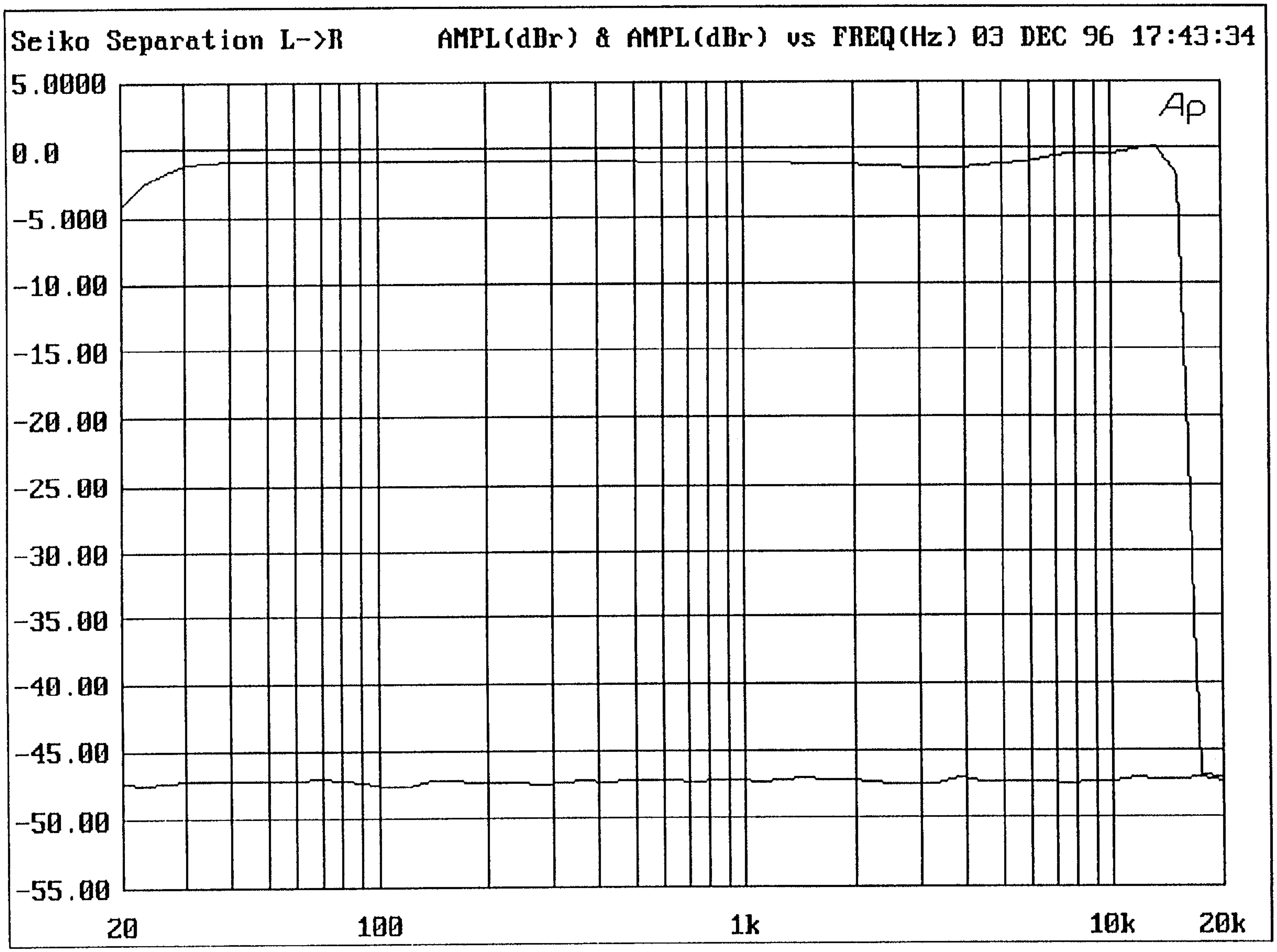
SEIKO Group A: 12-3-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

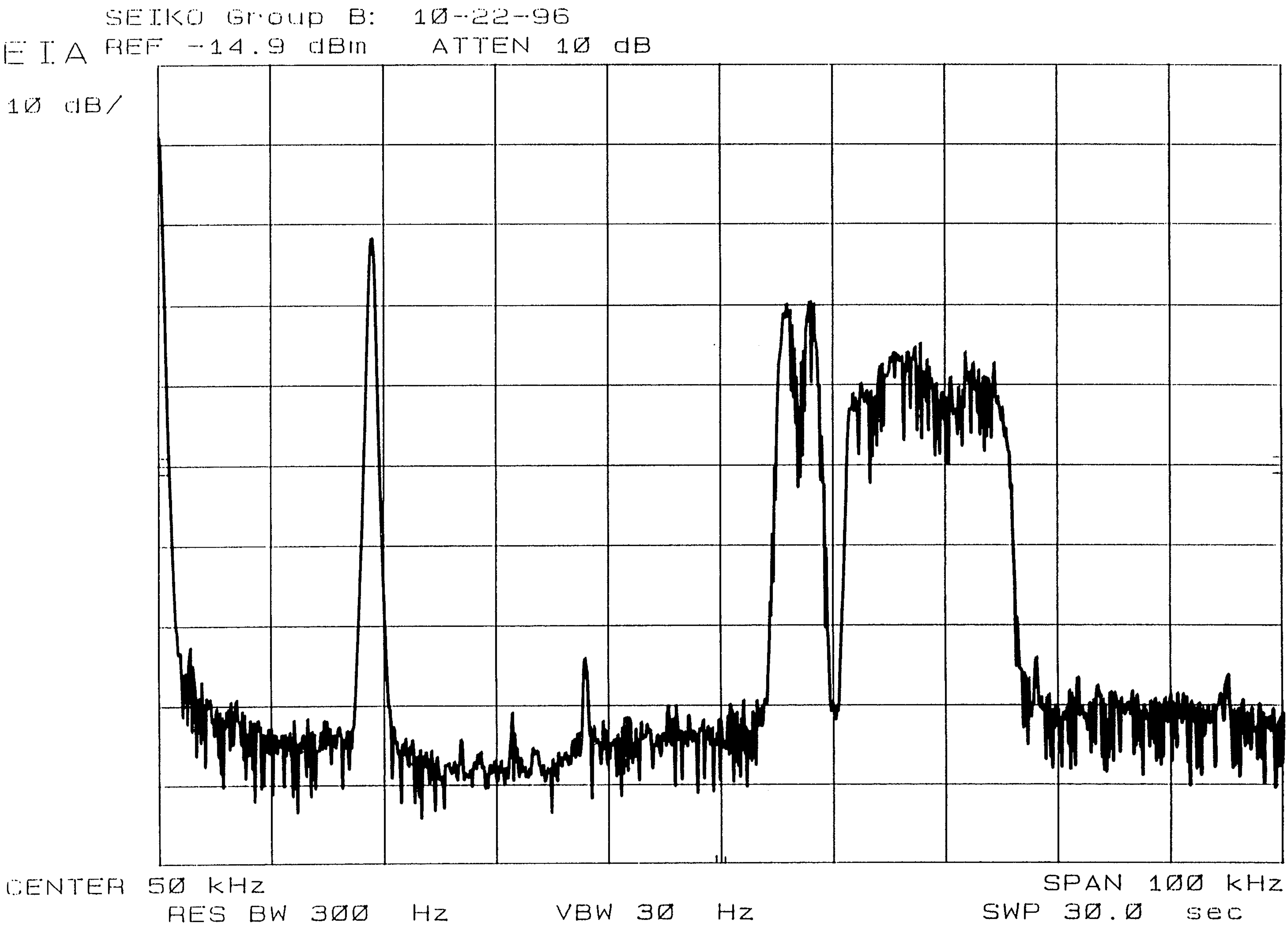

SEIKO Group A: 12-3-96
EIA
REF 0.0 dBm
ATTEN 10 dB
MKR 94.100 0 MHz
-10.90 dBm
10 dB/
CENTER 94.100 MHz
RES BW 1 kHz
VBW 30 Hz
SPAN 500 kHz
SWP 50.0 sec

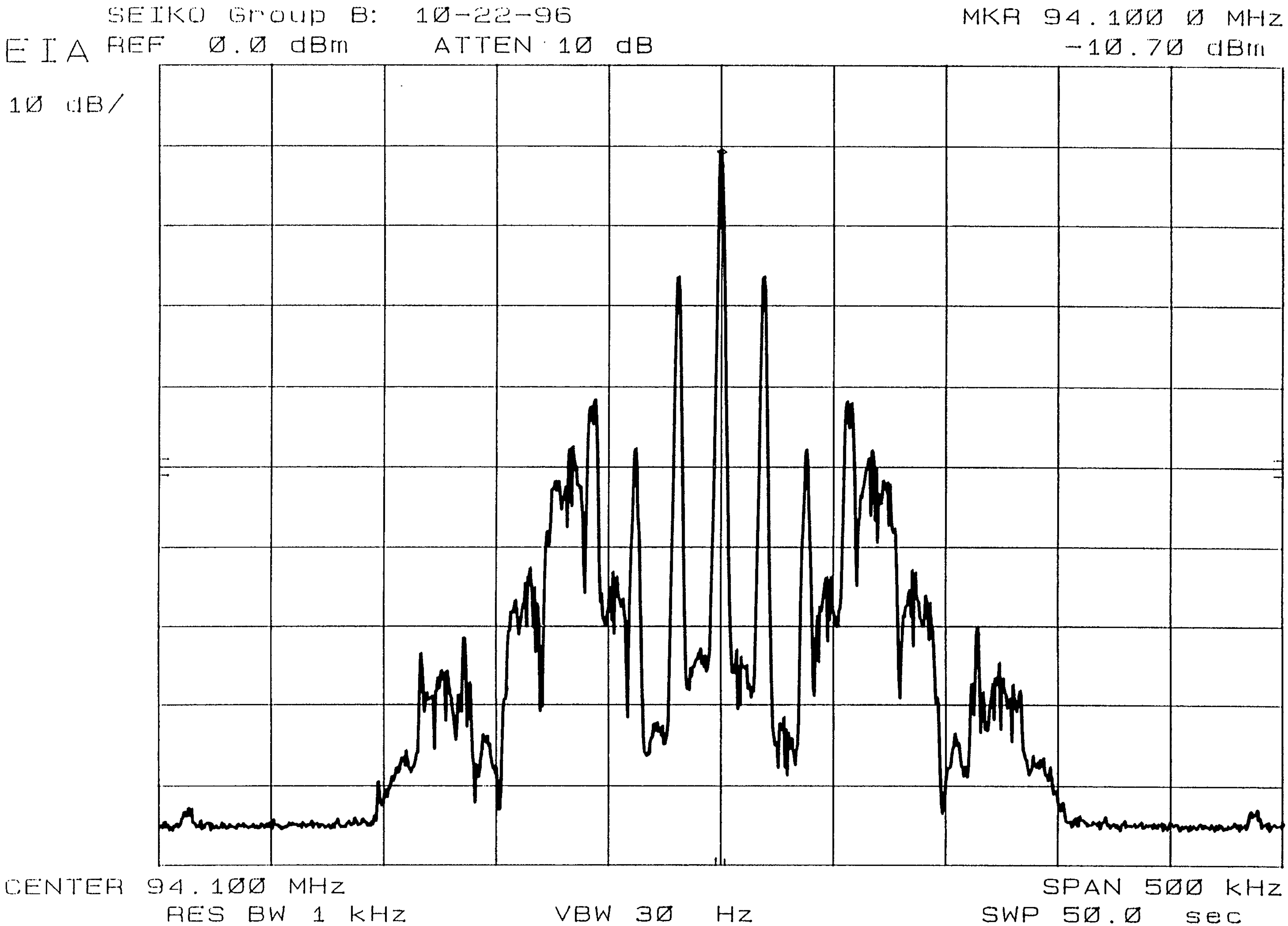

Seiko Frequency Response AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 17:36:26
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap

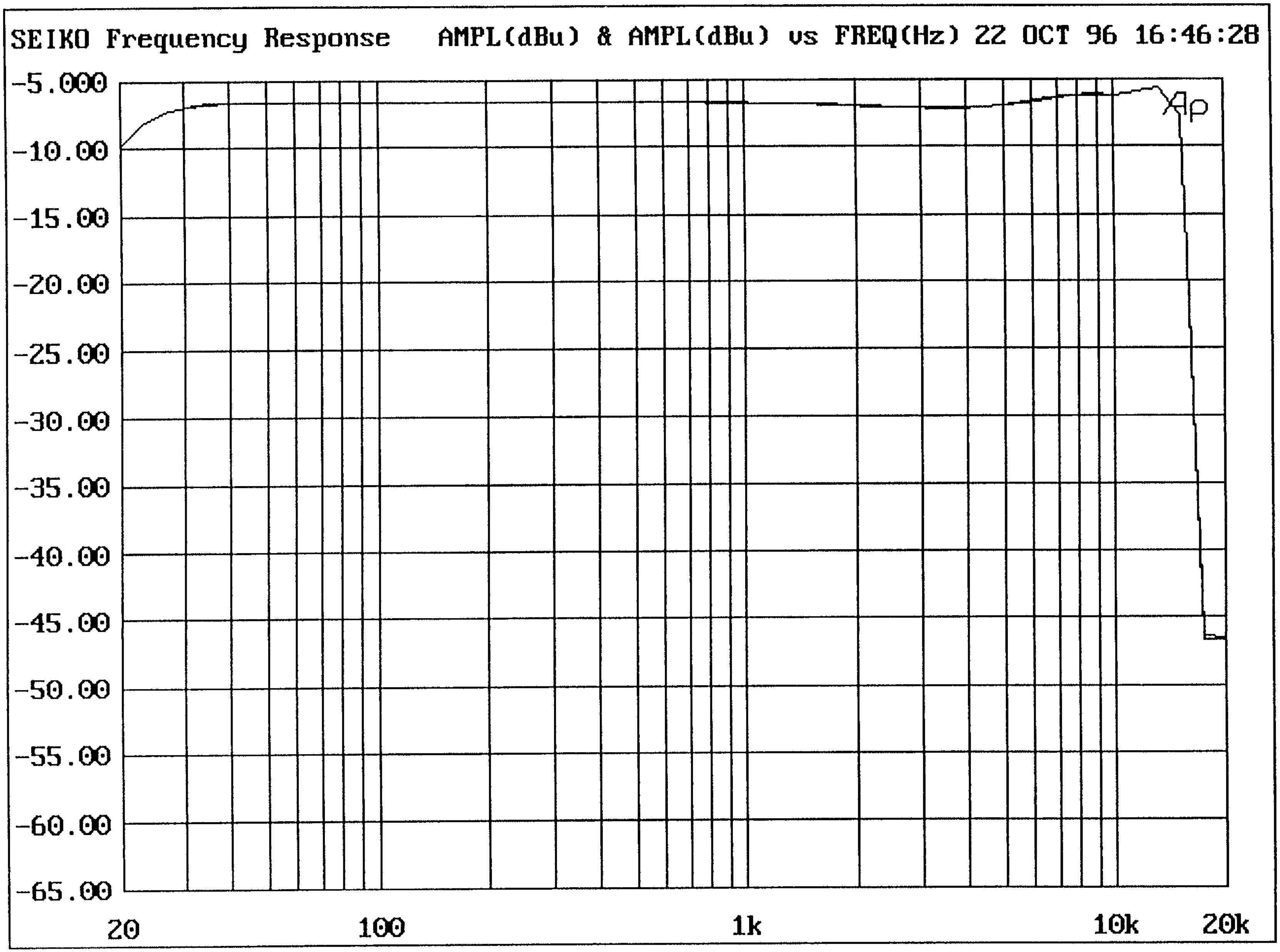


Seiko Group A
THD+N(%) & THD+N(%) vs FREQ(Hz)
03 DEC 96 17:39:45
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap

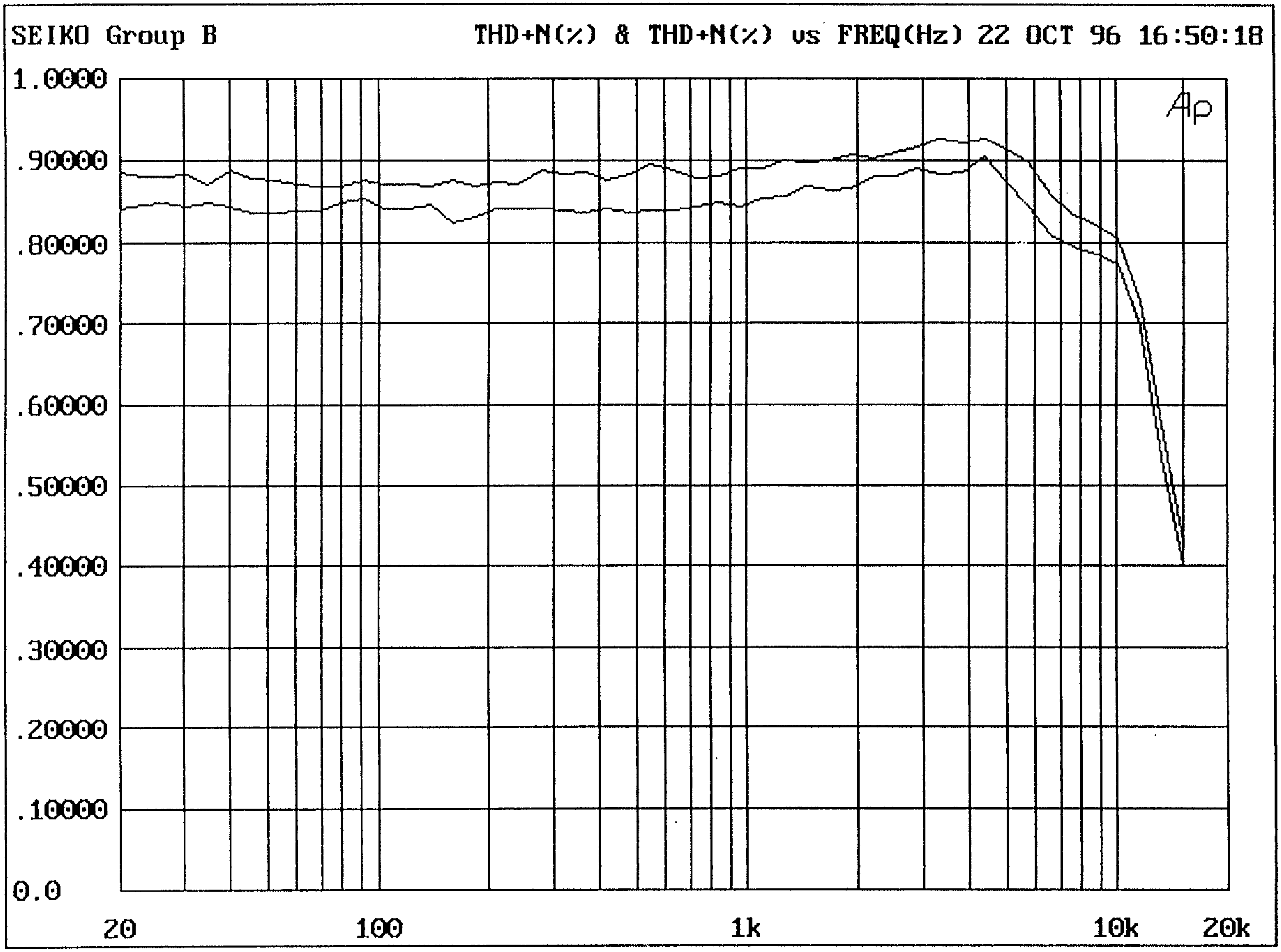

Seiko Separation L->R
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 03 DEC 96 17:43:34
Ap
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k

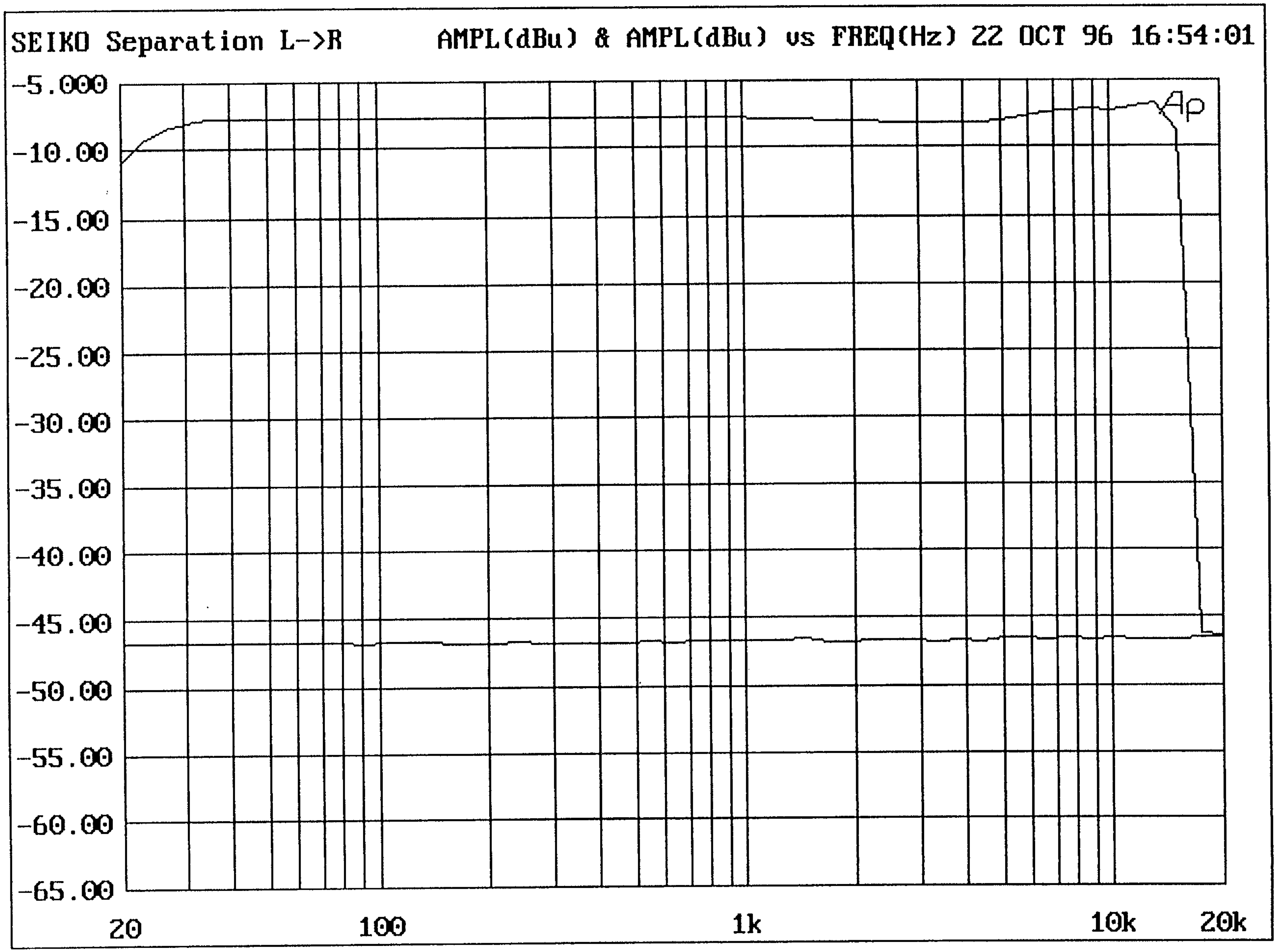

SEIKO Group B: 10-22-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec


SEIKO Group B: 10-22-96
MKR 94.100 0 MHz
-10.70 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec



SEIKO Frequency Response AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 22 OCT 96 16:46:28
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap

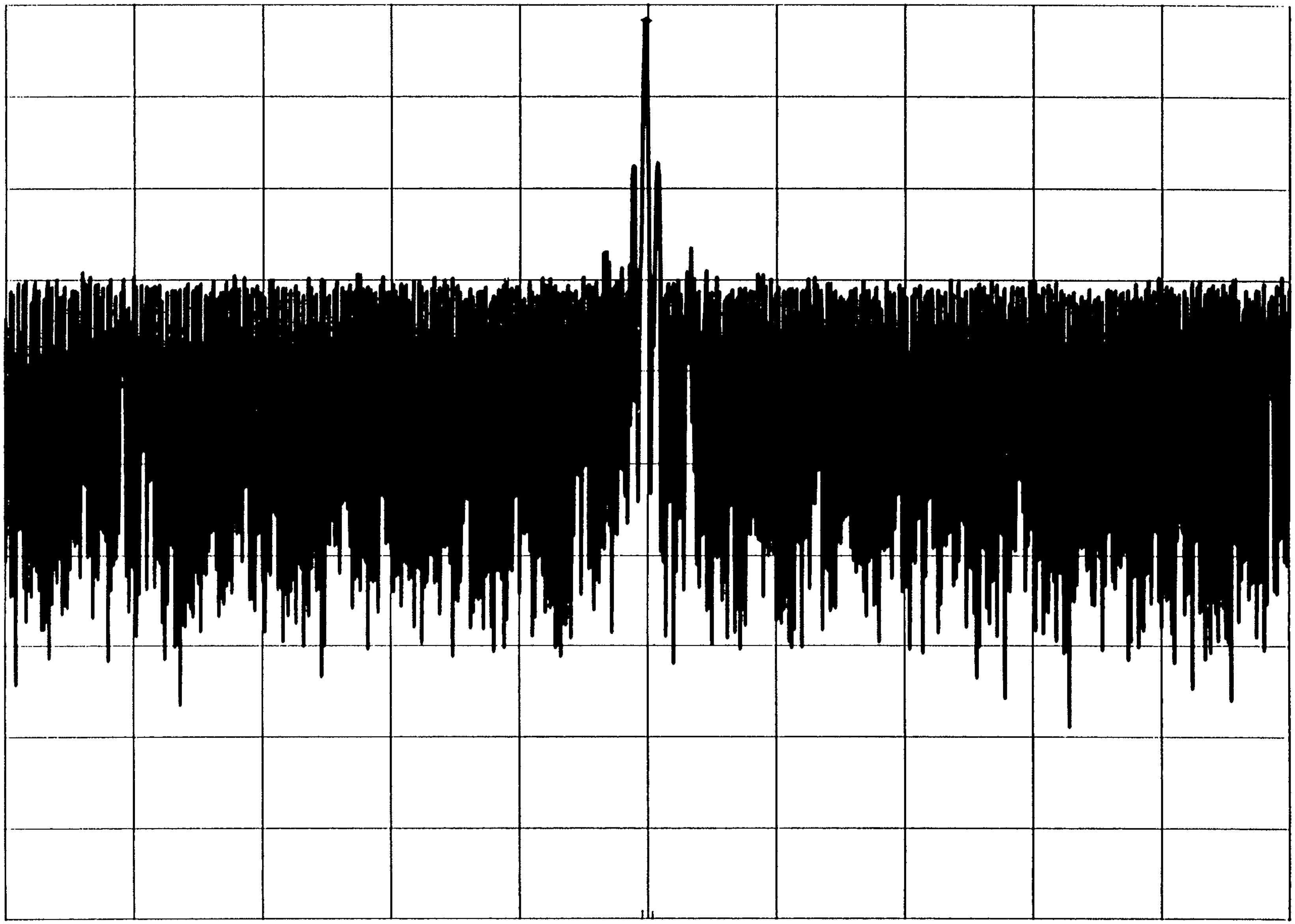

SEIKO Group B
THD+N(%) & THD+N(%) vs FREQ(Hz) 22 OCT 96 16:50:18
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap


SEIKO Separation L->R
AMPL(dBu) & AMPL(dBu) vs FREQ(Hz) 22 OCT 96 16:54:01
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
20
100
1k
10k
20k
Ap

SEIKO B-4: RR=1kHz: ATTN=10dB: 11-7-96 MKR 94.096 MHz

EIA REF -55.0 dBm ATTEN 10 dB -56.70 dBm

10 dB/

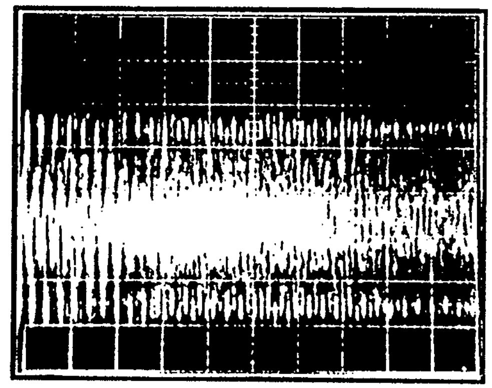


CENTER 94.10 MHz SPAN 2.00 MHz

RES BW 3 kHz VBW 10 kHz SWP 600 msec

Non-Standard Injection

SEIKO



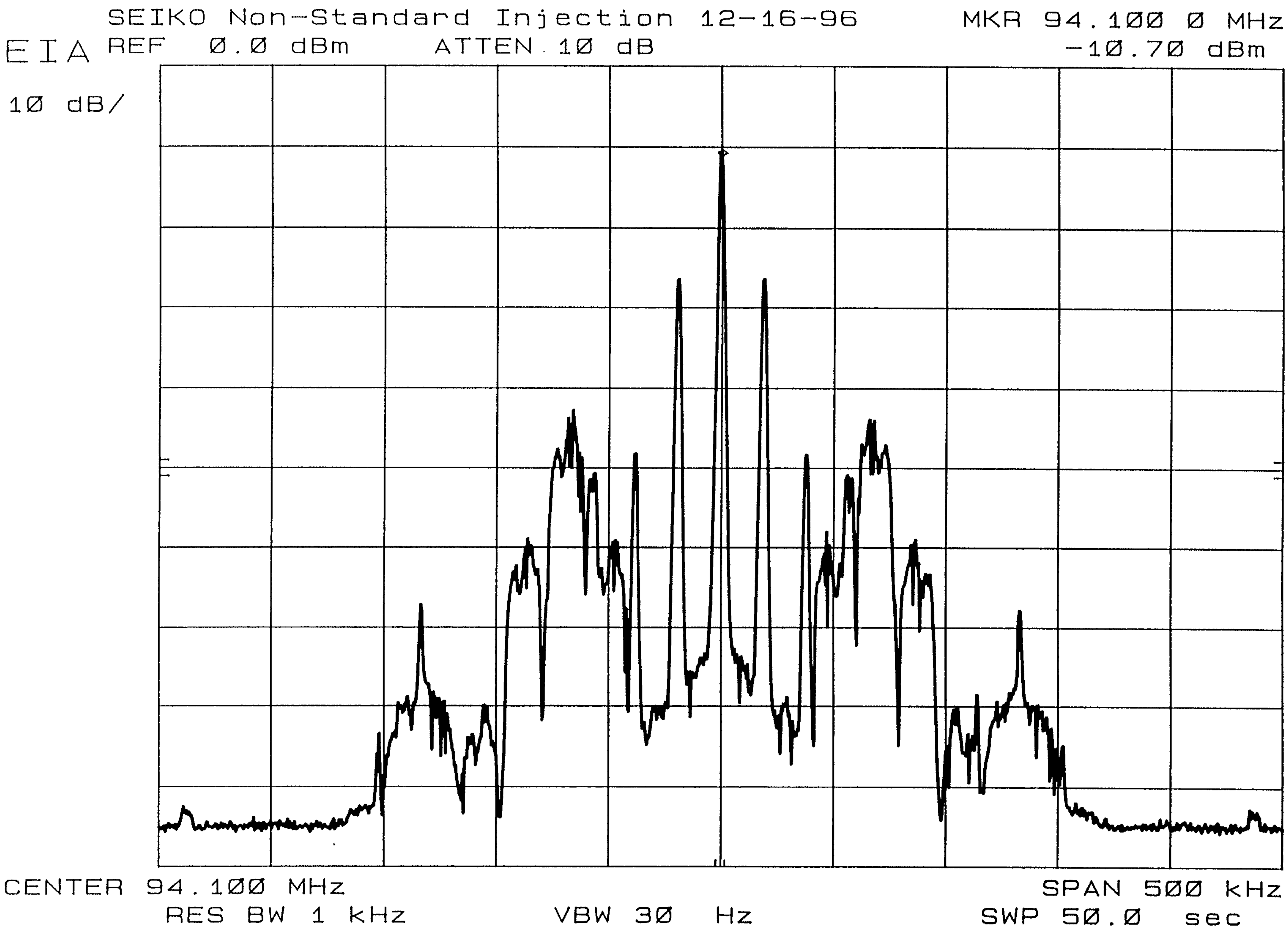
100 mV, 50µsec / Division

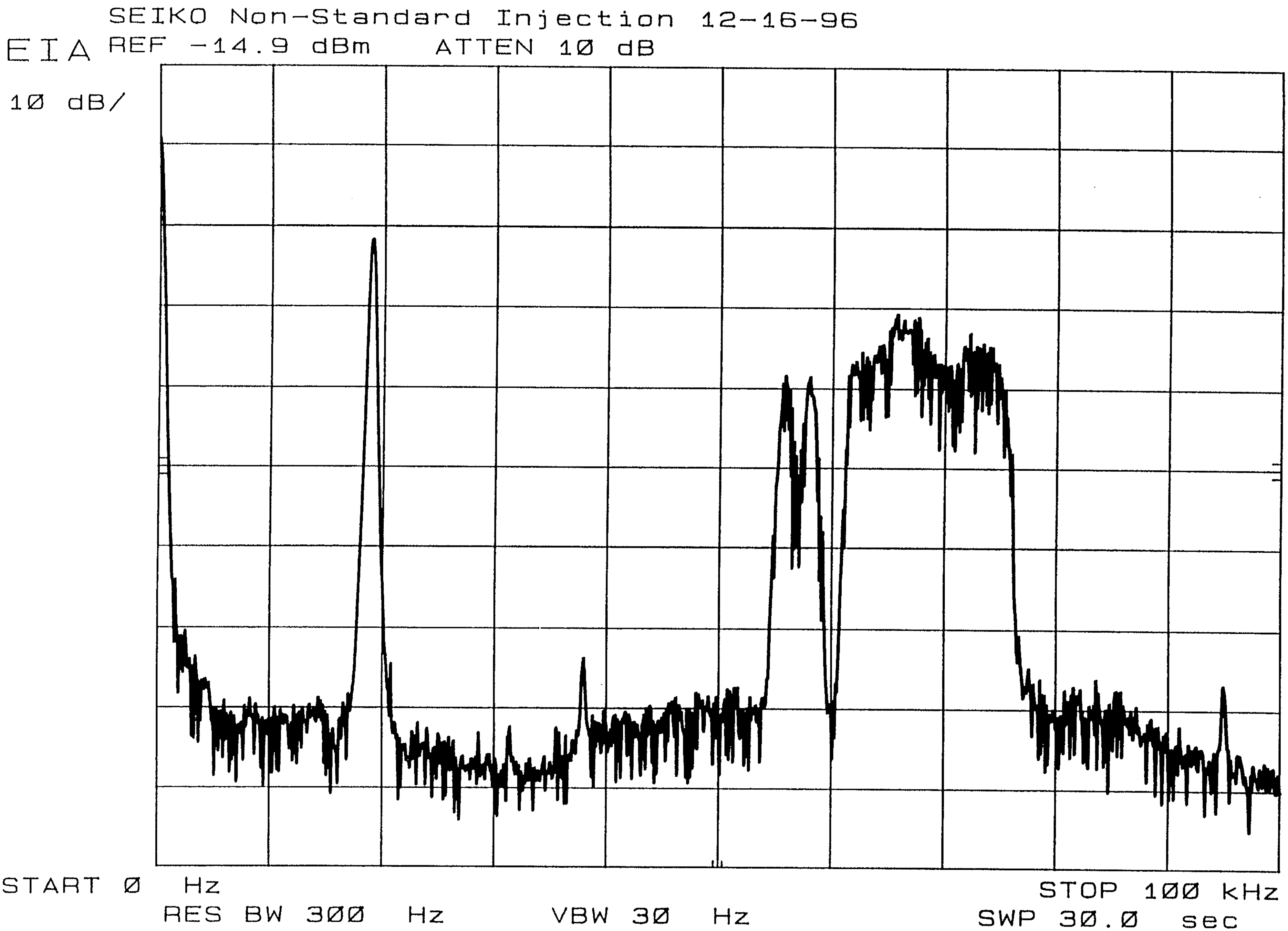
SEIKO

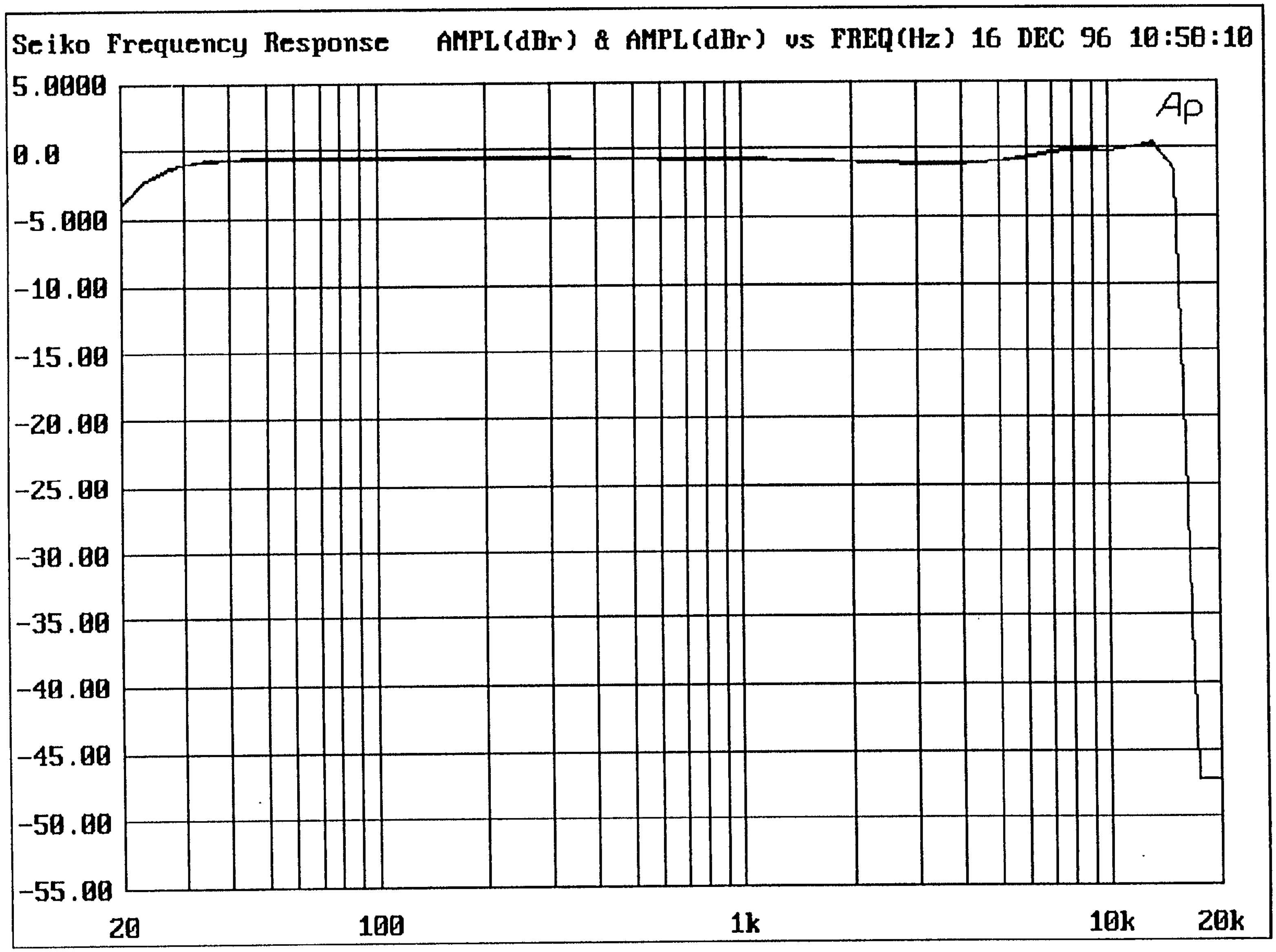
17%

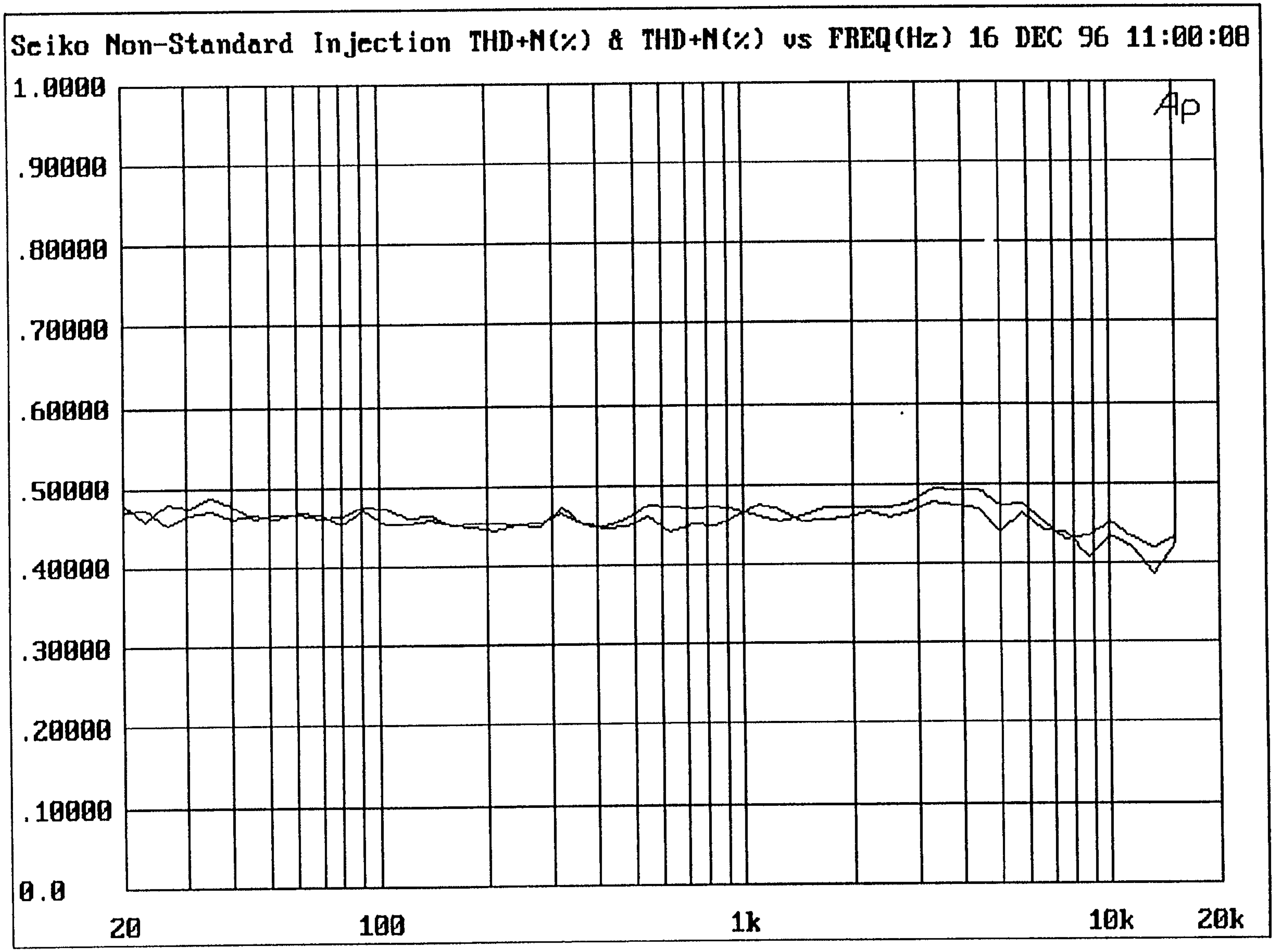
17%

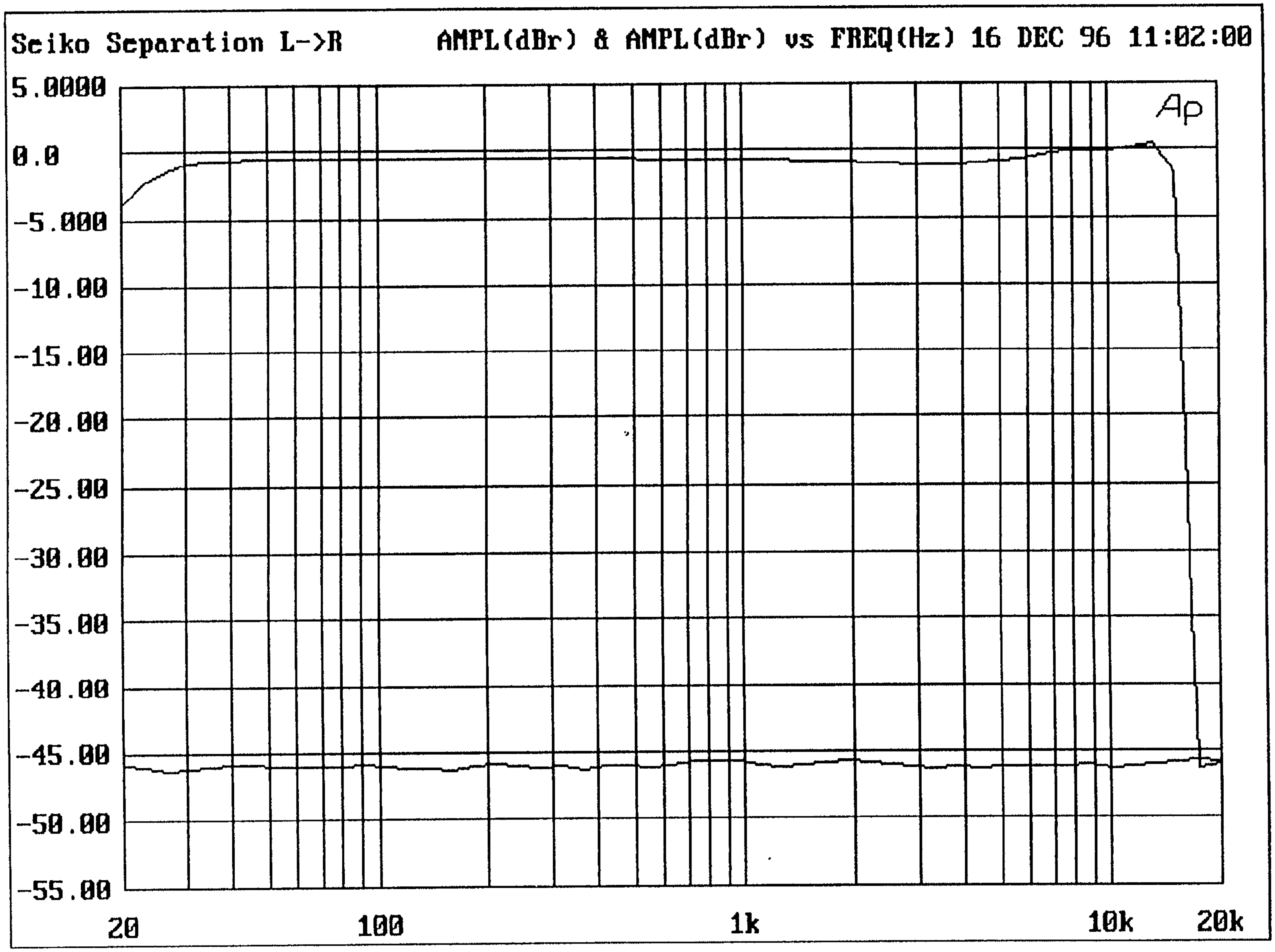
Non-Standard Injection

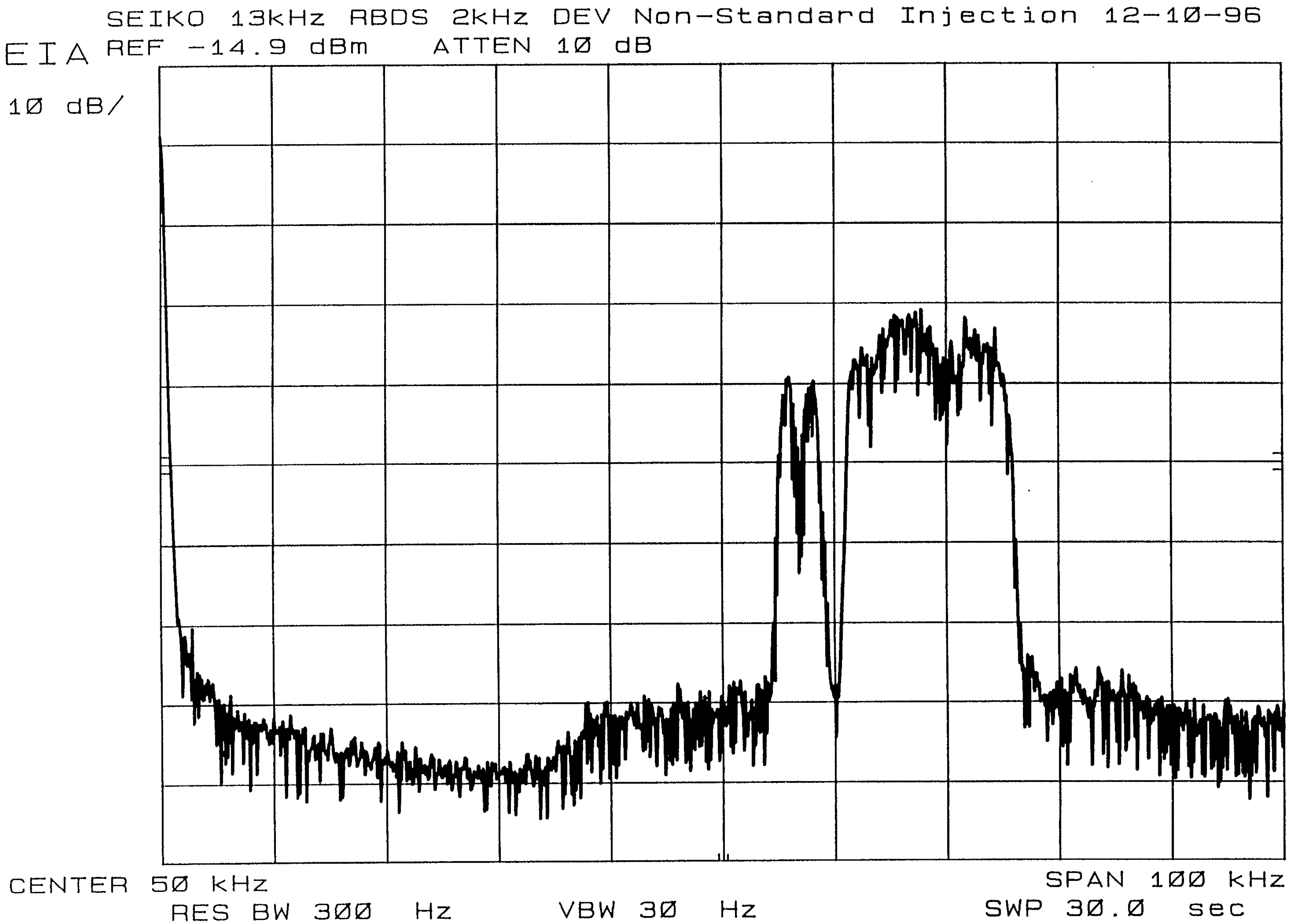

SEIKO Non-Standard Injection 12-16-96
MKR 94.100 0 MHz
-10.70 dBm
EIA
REF 0.0 dBm
ATTEN 10 dB
10 dB/
CENTER 94.100 MHz
SPAN 500 kHz
RES BW 1 kHz
VBW 30 Hz
SWP 50.0 sec


SEIKO Non-Standard Injection 12-16-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
START 0 Hz
STOP 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec


Seiko Frequency Response
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 16 DEC 96 10:58:10
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k
Ap


Seiko Non-Standard Injection THD+N(%) & THD+N(%) vs FREQ(Hz) 16 DEC 96 11:00:08
1.0000
.90000
.80000
.70000
.60000
.50000
.40000
.30000
.20000
.10000
0.0
20
100
1k
10k
20k
Ap


Seiko Separation L->R
AMPL(dBr) & AMPL(dBr) vs FREQ(Hz) 16 DEC 96 11:02:00
Ap
5.0000
0.0
-5.000
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
20
100
1k
10k
20k


SEIKO 13kHz RBDS 2kHz DEV Non-Standard Injection 12-10-96
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 30 Hz
SWP 30.0 sec

(Attachment 7)
(to 5/27/97 Minutes)

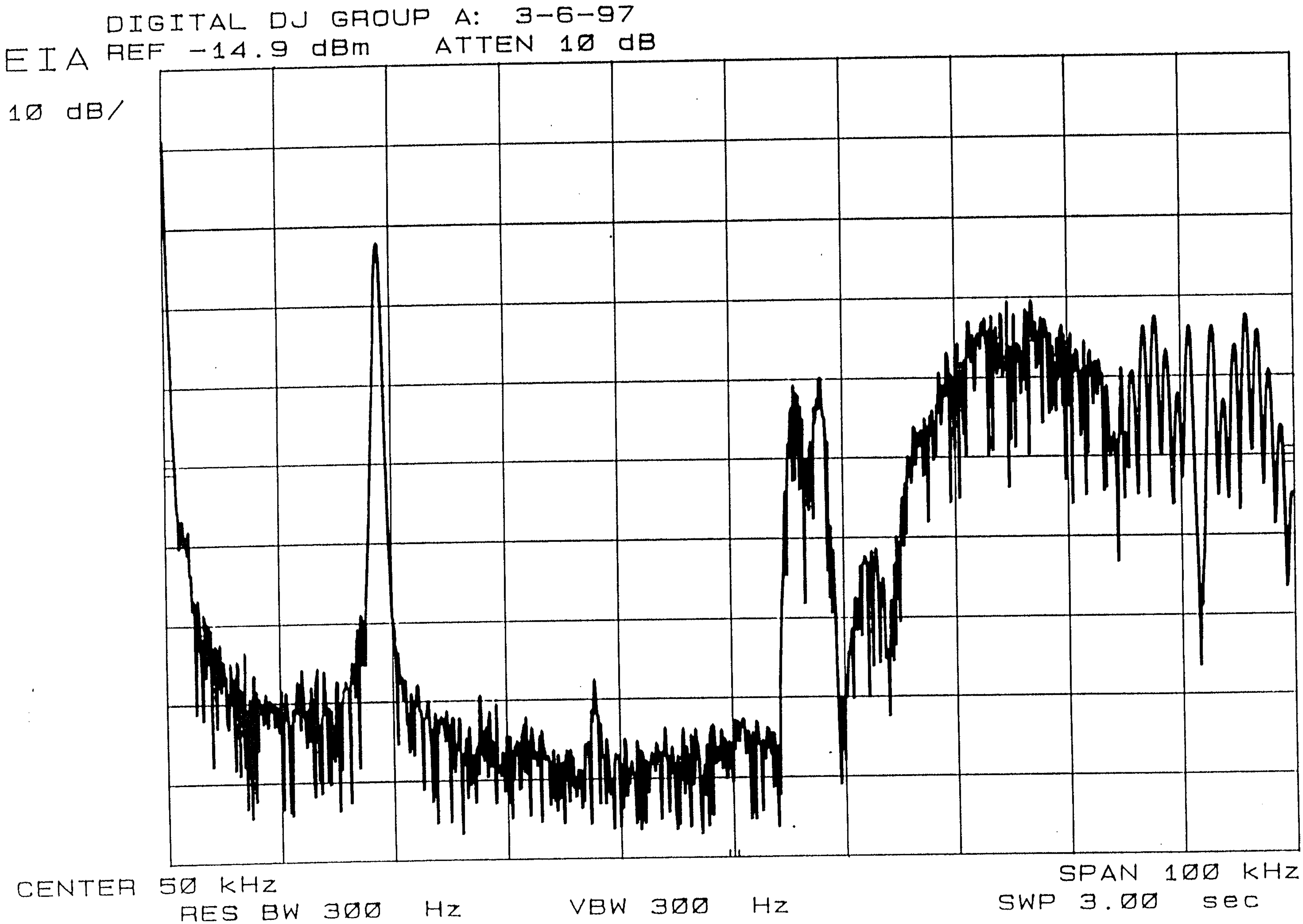
ADDITIONAL SYSTEM PLOTS

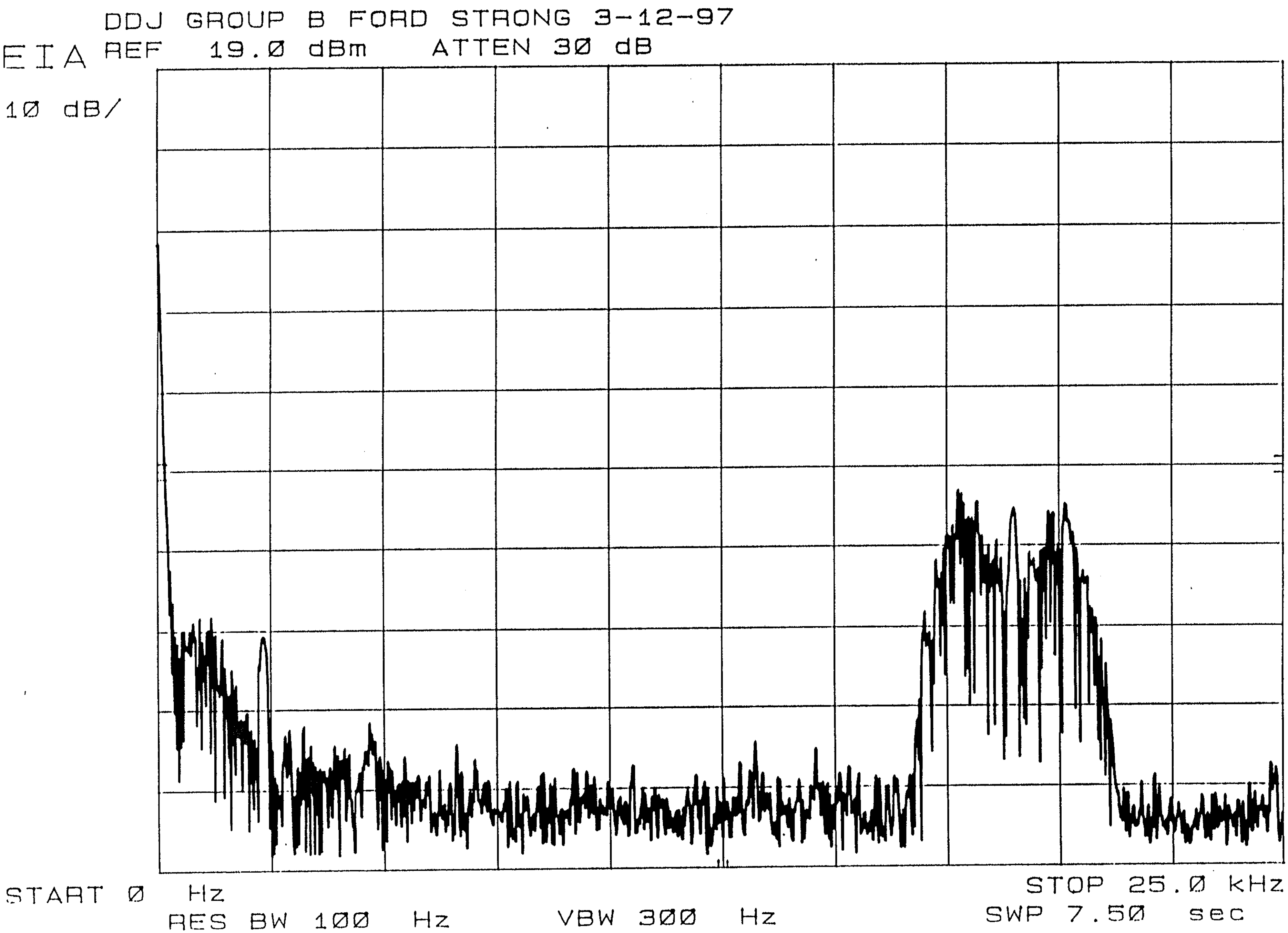
- DigitalDJ Group A: 3-6-97 (shows DDJ and 92 kHz analog SCA)

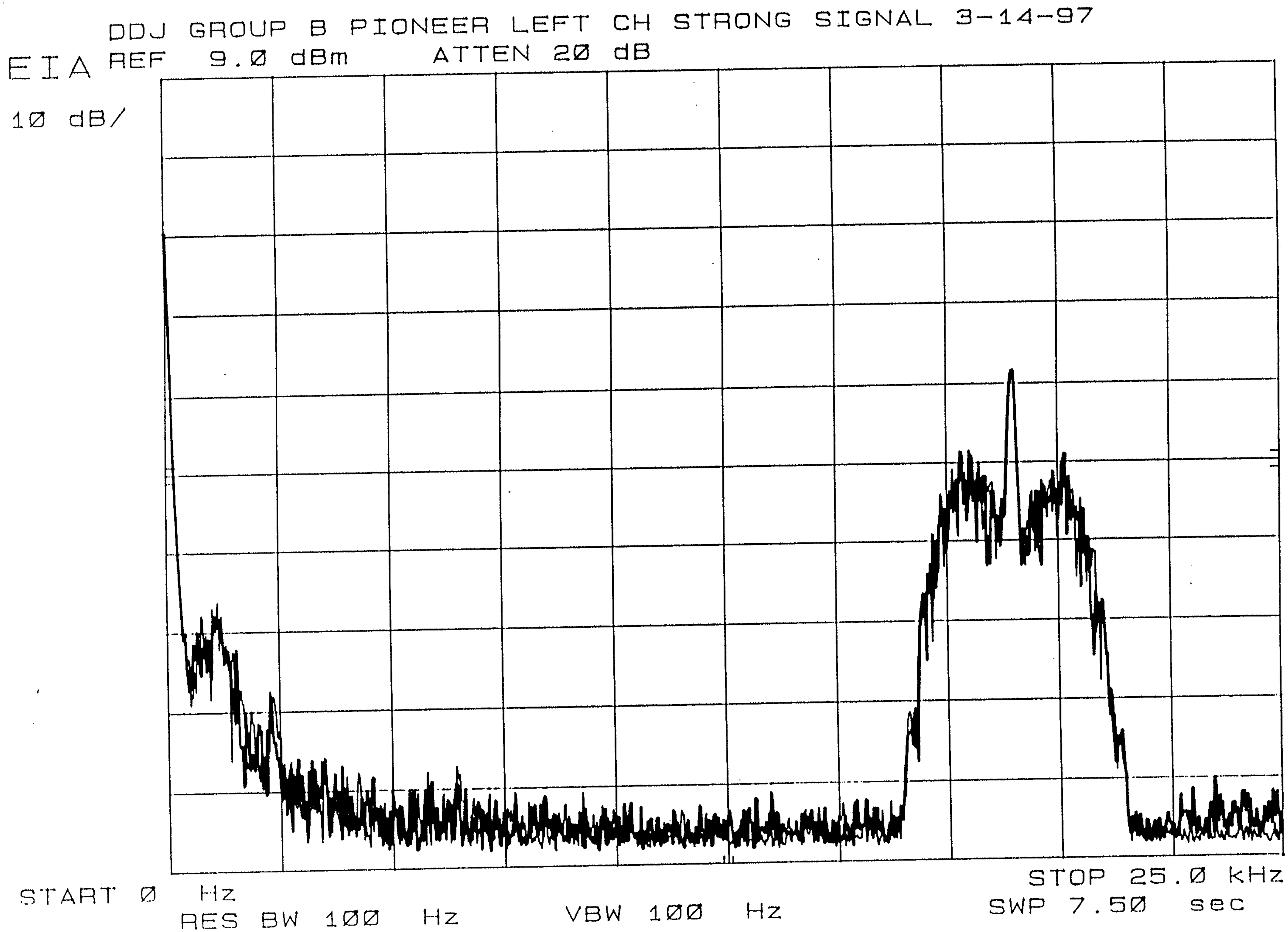
- DigitalDJ Group B Ford Strong 3-12-97
- DigitalDJ Group B Pioneer Left Ch. Strong Signal 3-14-97
- DigitalDJ Group B Pioneer Strong 3-14-97

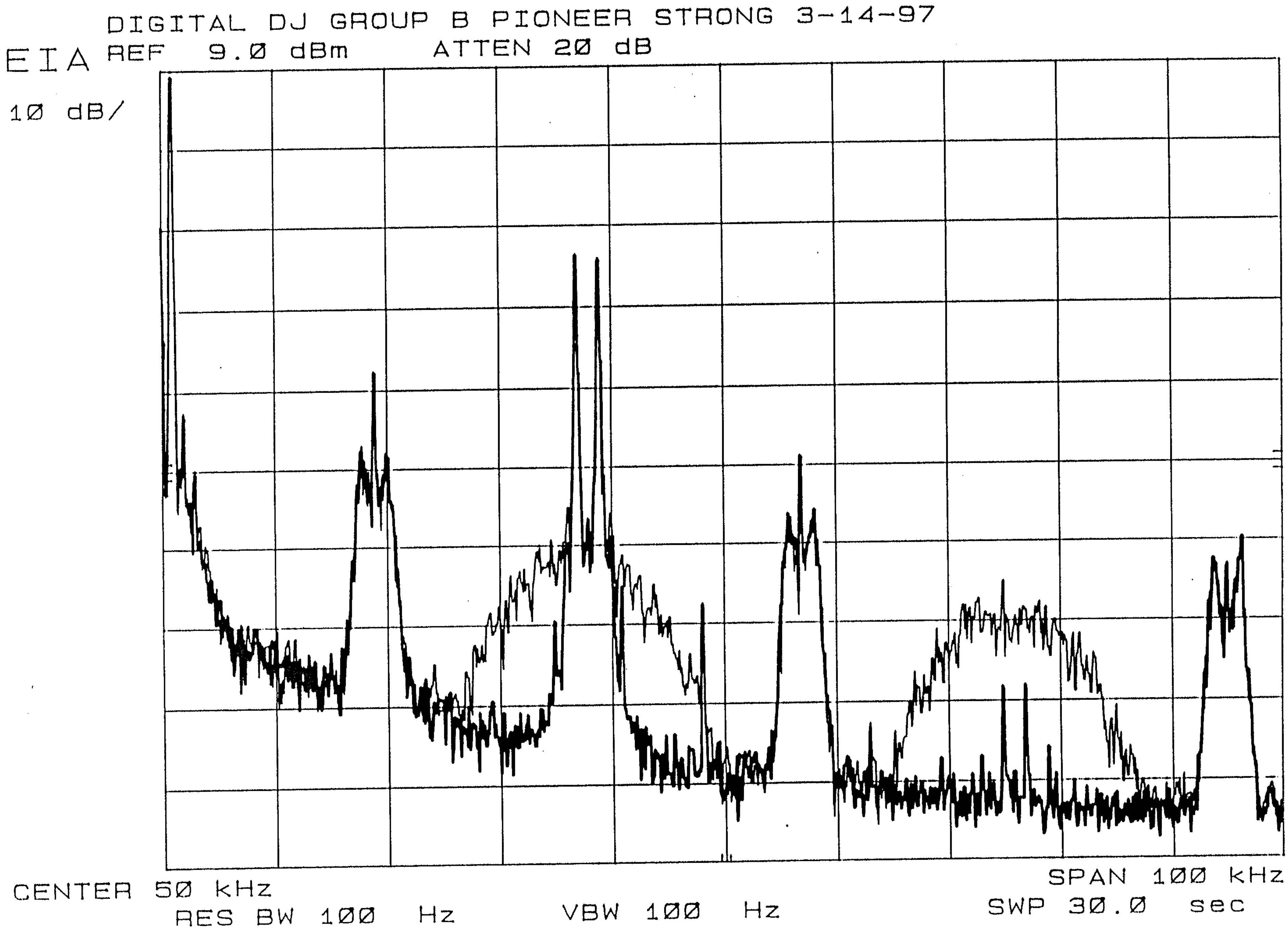
- Mitre Group B Ford Strong 3-12-97
- Mitre Group B Pioneer Left Ch. Strong Signal 3-14-97
- Mitre Group B Pioneer Strong 3-14-97

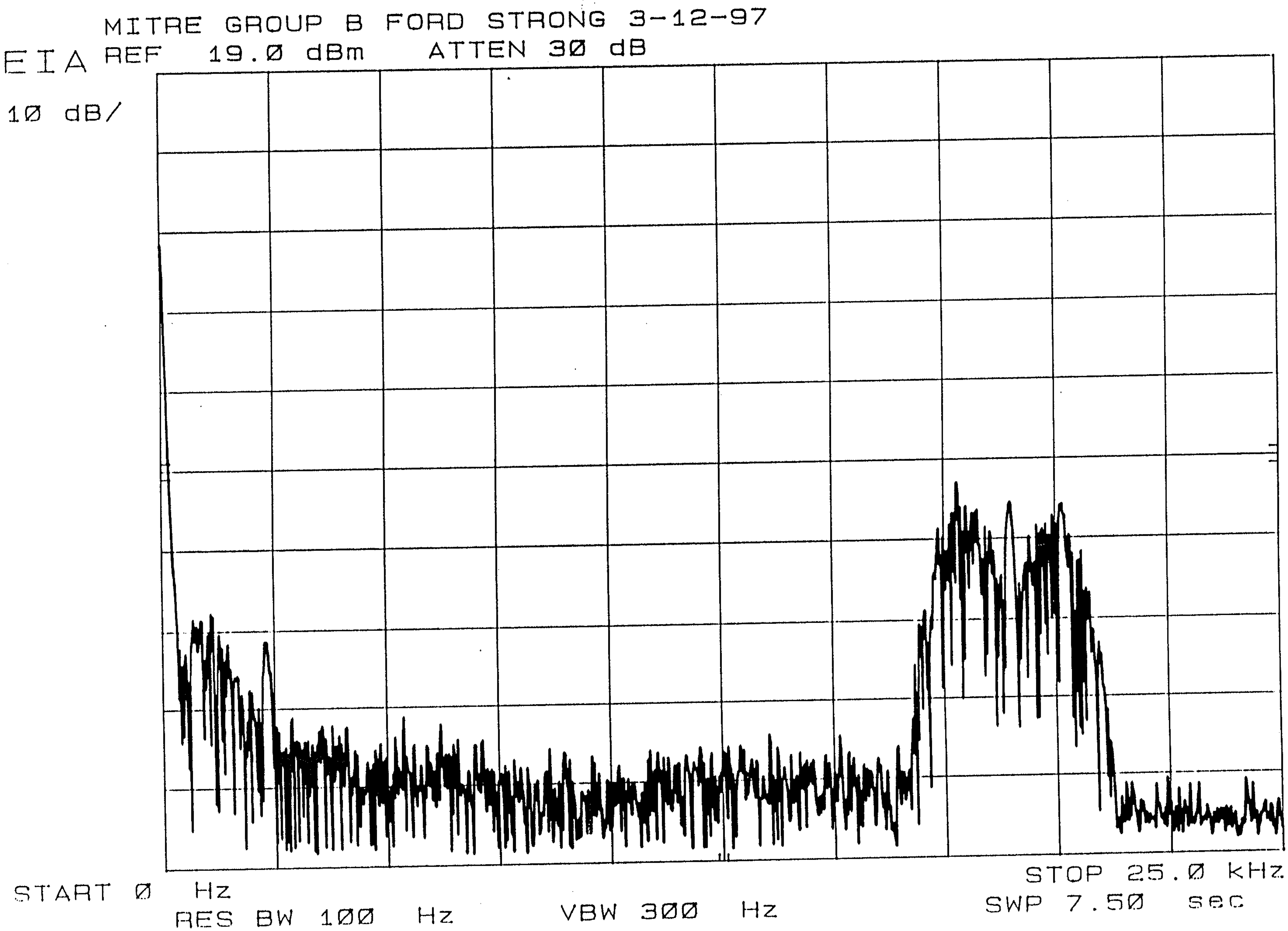
- Seiko Group B Ford Strong 3-12-97
- Seiko Group B Pioneer Left Ch. Strong Signal 3-14-97
- Seiko Group B Pioneer Strong 3-14-97

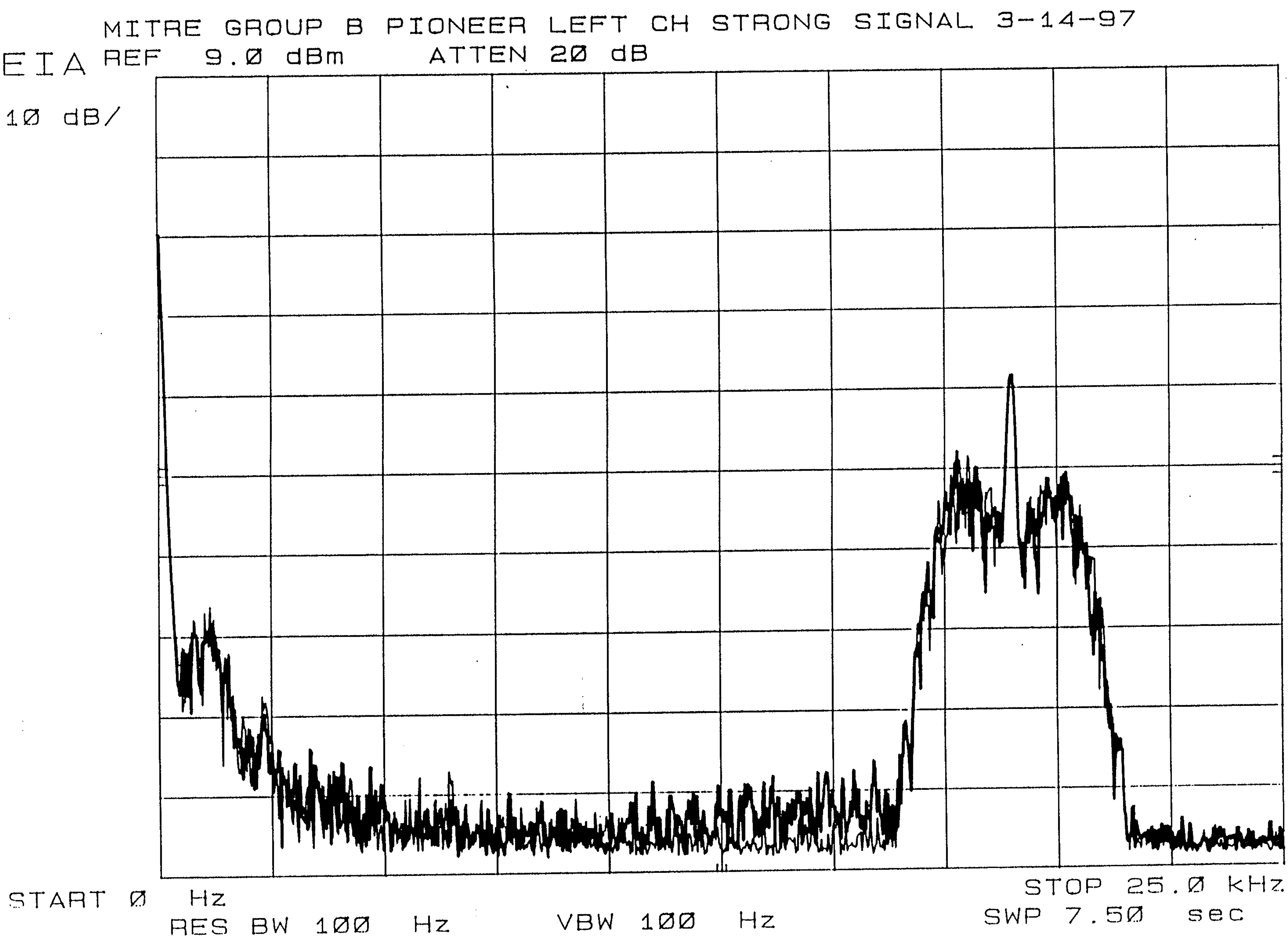

DIGITAL DJ GROUP A: 3-6-97
EIA
REF -14.9 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
RES BW 300 Hz
VBW 300 Hz
SPAN 100 kHz
SWP 3.00 sec


DDJ GROUP B FORD STRONG 3-12-97
EIA
REF 19.Ø dBm ATTEN 3Ø dB
1Ø dB/
START Ø Hz
STOP 25.Ø kHz
RES BW 1ØØ Hz
VBW 3ØØ Hz
SWP 7.5Ø sec

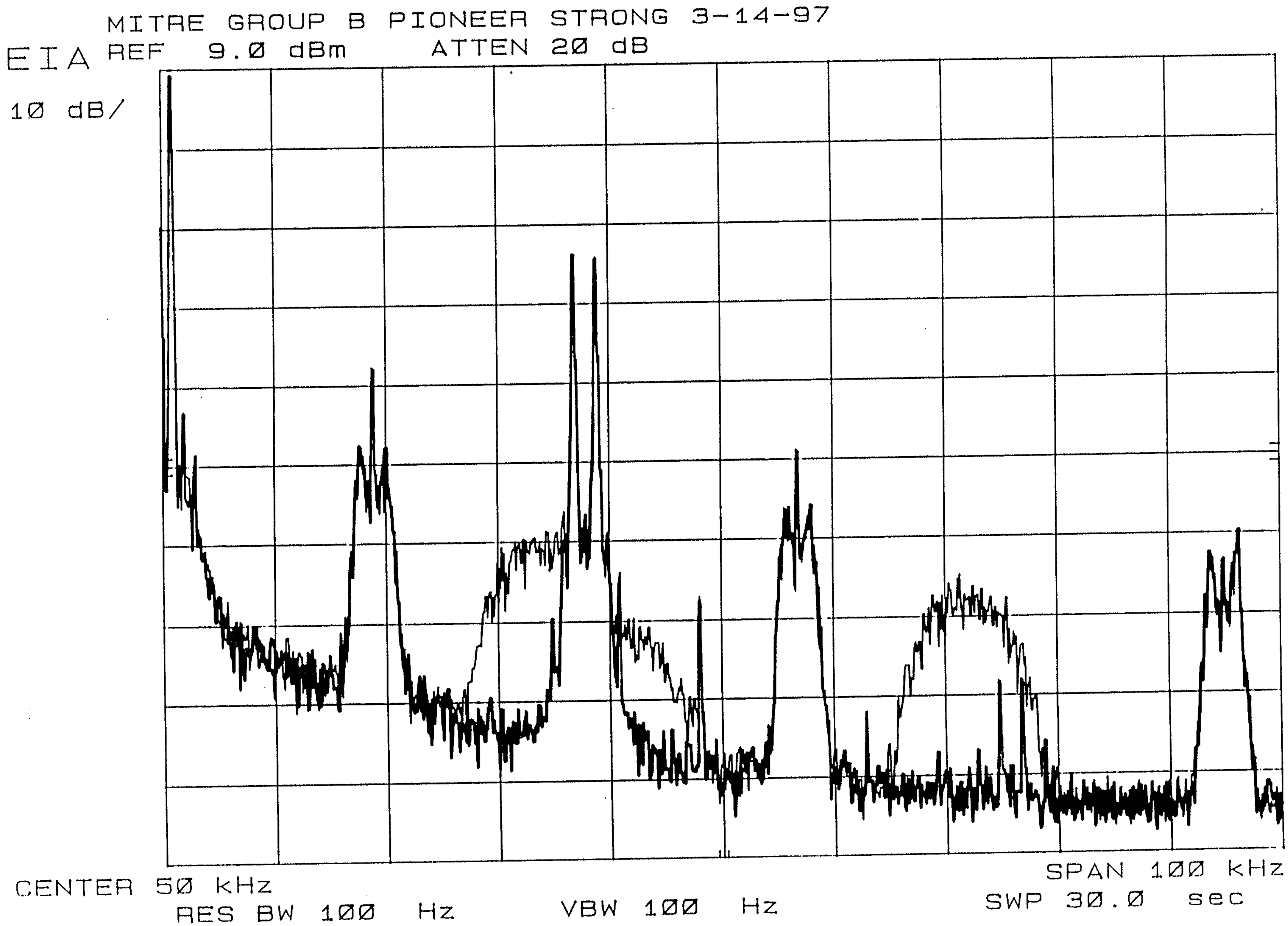

DDJ GROUP B PIONEER LEFT CH STRONG SIGNAL 3-14-97
EIA
REF 9.0 dBm ATTEN 20 dB
10 dB/
START 0 Hz
STOP 25.0 kHz
RES BW 100 Hz
VBW 100 Hz
SWP 7.50 sec

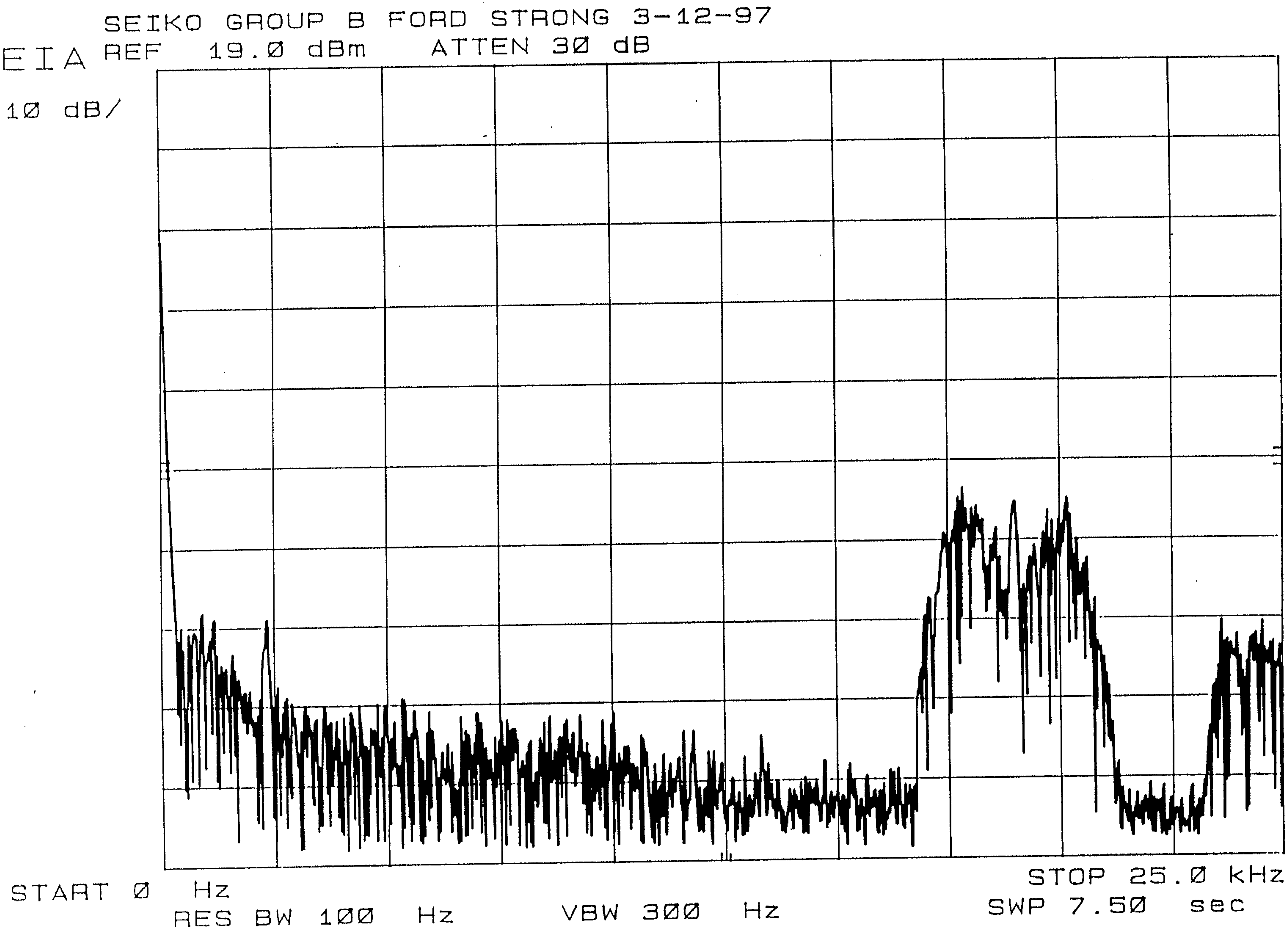

DIGITAL DJ GROUP B PIONEER STRONG 3-14-97
EIA
REF 9.0 dBm ATTEN 20 dB
10 dB/
CENTER 50 kHz
RES BW 100 Hz
VBW 100 Hz
SPAN 100 kHz
SWP 30.0 sec


MITRE GROUP B FORD STRONG 3-12-97
EIA
REF 19.0 dBm ATTEN 30 dB
10 dB/
START 0 Hz
STOP 25.0 kHz
RES BW 100 Hz
VBW 300 Hz
SWP 7.50 sec



MITRE GROUP B PIONEER LEFT CH STRONG SIGNAL 3-14-97
EIA
REF 9.0 dBm ATTEN 20 dB
10 dB/
START 0 Hz
RES BW 100 Hz
VBW 100 Hz
STOP 25.0 kHz
SWP 7.50 sec

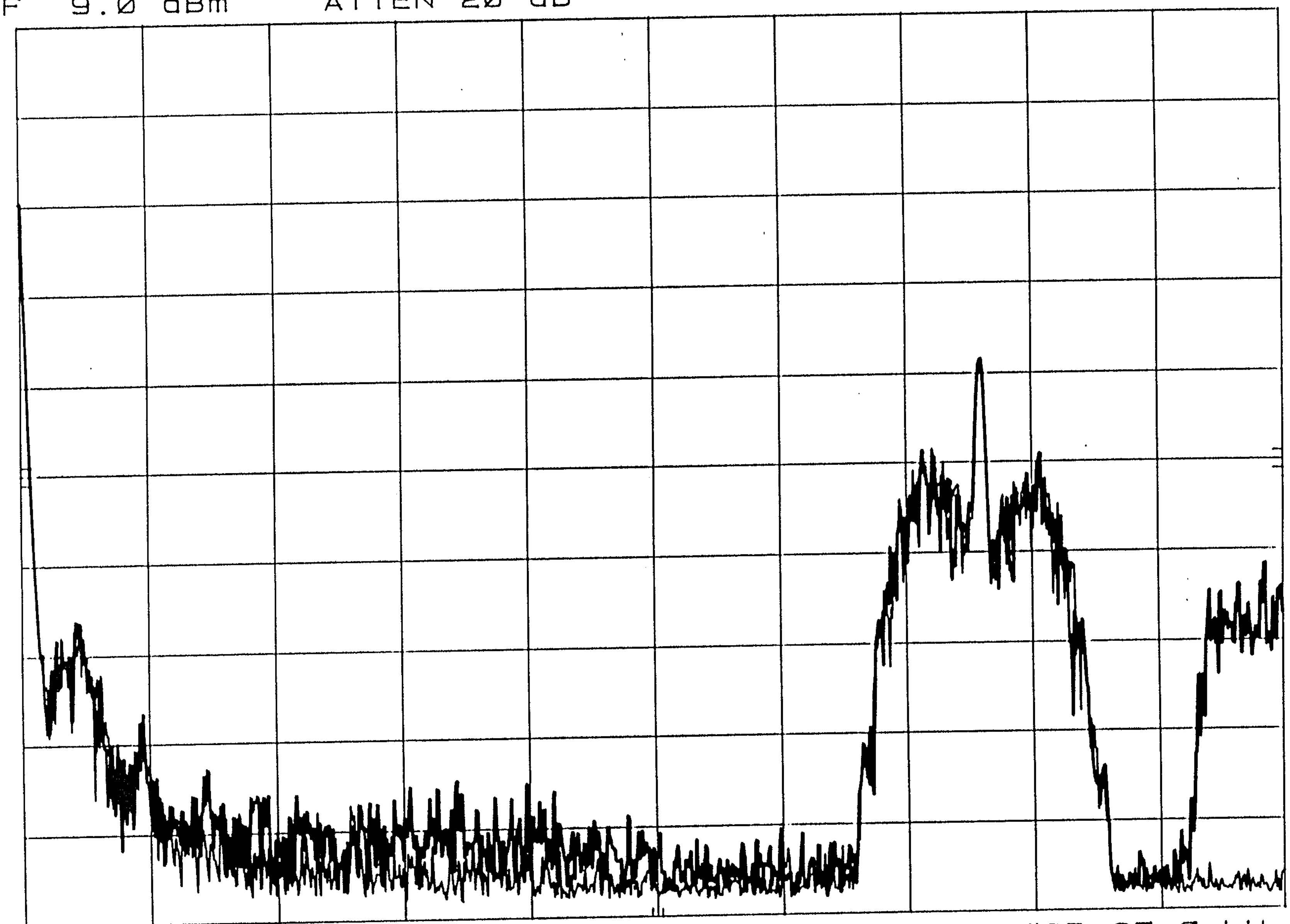

MITRE GROUP B PIONEER STRONG 3-14-97
EIA
REF 9.0 dBm ATTEN 20 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 100 Hz
VBW 100 Hz
SWP 30.0 sec


SEIKO GROUP B FORD STRONG 3-12-97
EIA
REF 19.0 dBm ATTEN 30 dB
10 dB/
START 0 Hz
RES BW 100 Hz
VBW 300 Hz
STOP 25.0 kHz
SWP 7.50 sec

SEIKO GROUP B PIONEER LEFT CH STRONG SIGNAL 3-14-97

EIA REF 9.Ø dBm ATTEN 2Ø dB

10 dB/

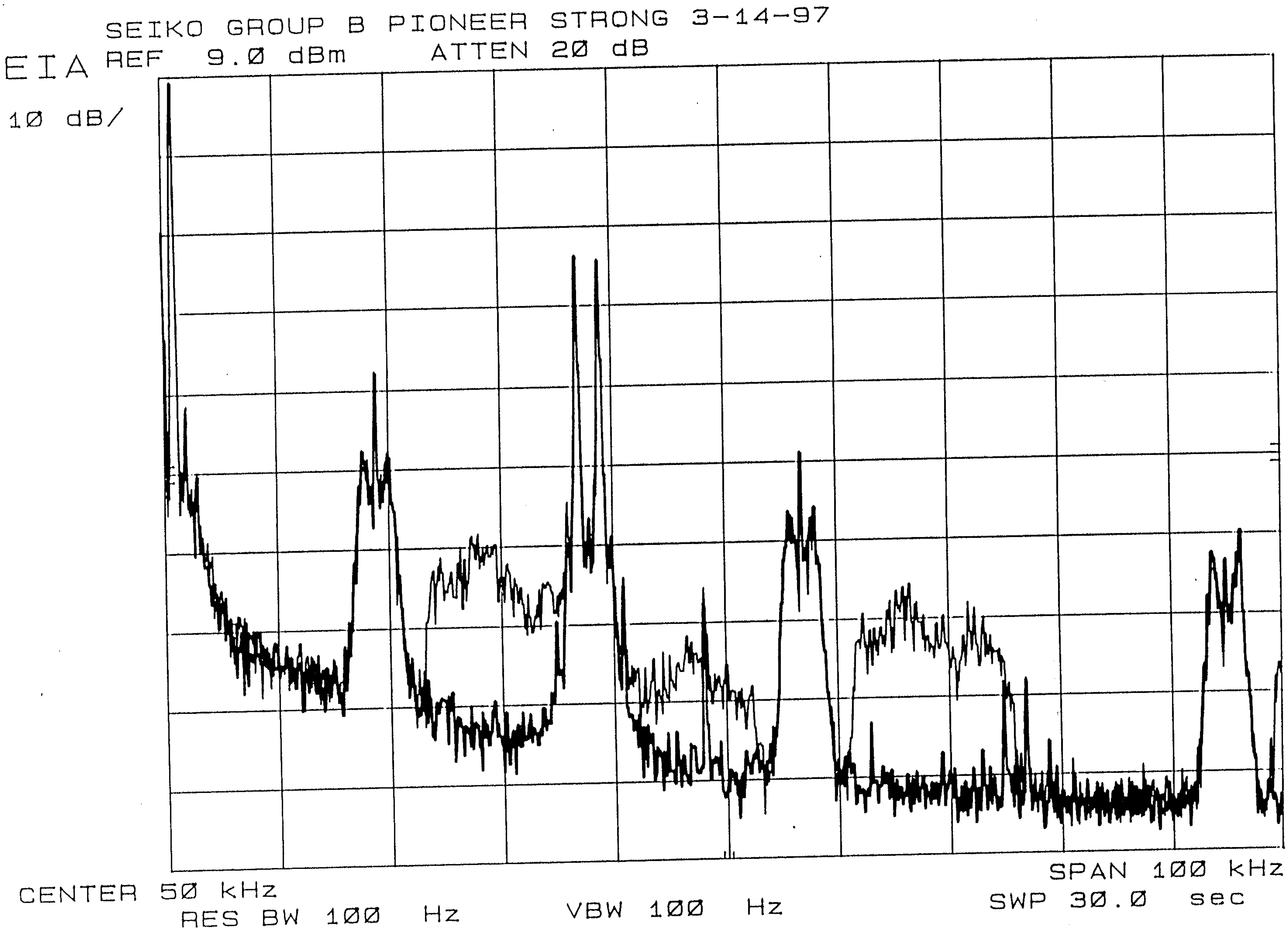


START Ø Hz

RES BW 1ØØ Hz VBW 1ØØ Hz

STOP 25.Ø kHz

SWP 7.5Ø sec


SEIKO GROUP B PIONEER STRONG 3-14-97
EIA
REF 9.0 dBm ATTEN 20 dB
10 dB/
CENTER 50 kHz
RES BW 100 Hz
VBW 100 Hz
SPAN 100 kHz
SWP 30.0 sec

(5)

HSSC Proponent Receiver Characterization

Date(s): 2/13-2/17/1997
Engr(s): **DML, RMc**

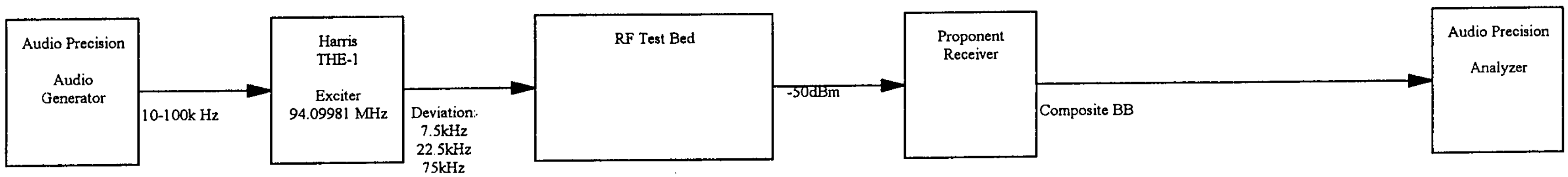
TEST	DEVICE		Modulation	Injection	RESULTS	
Frequency Response:	Proponent RX		10-100k Hz	100, 30 & 10%	AP Graph	
THD vs Frequency:	Proponent RX		10-100k Hz	100, 30 & 10%	AP Graph	HP Composite Plot
Limiting Threshold:	Proponent RX		1kHz	100%	Tabular Data / Plot	
First Adj. Upper/Lower (6dB D/U)	Proponent RX	**D**	Proponent Center	10%	HP Spectrum Plots	
		U	CPN	100%		
Second Adj. Upper/Lower (-40dB D/U)	Proponent RX	**D**	Proponent Center	10%	HP Spectrum Plots	
		U	CPN	100%		

Note: Clipped Pink Noise (CPN)

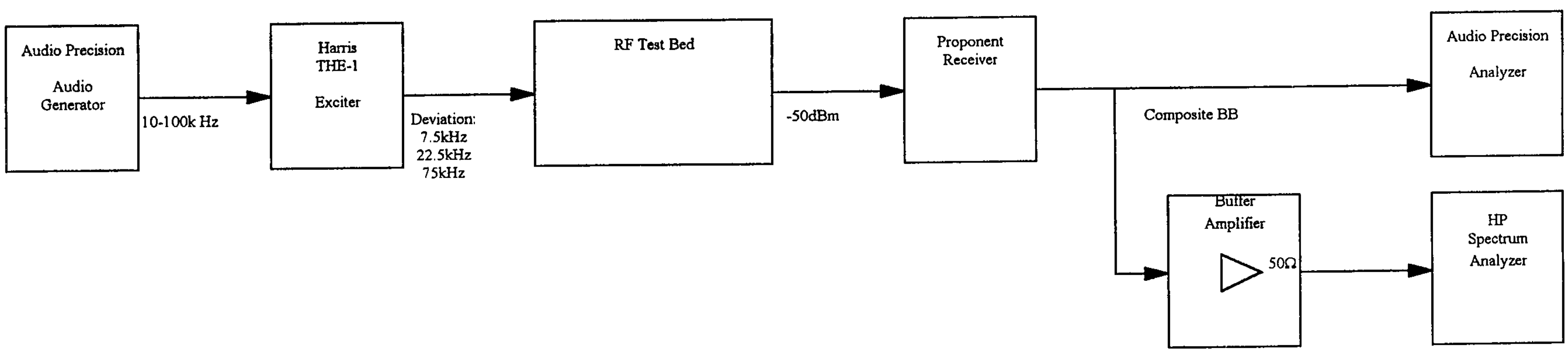
APPENDIX O

(Handed out at tutorial)

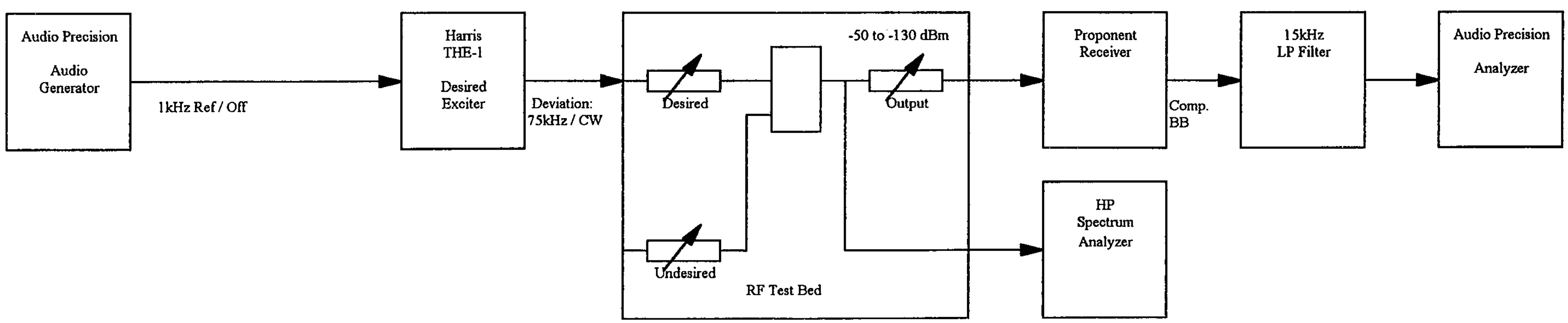
Frequency Response



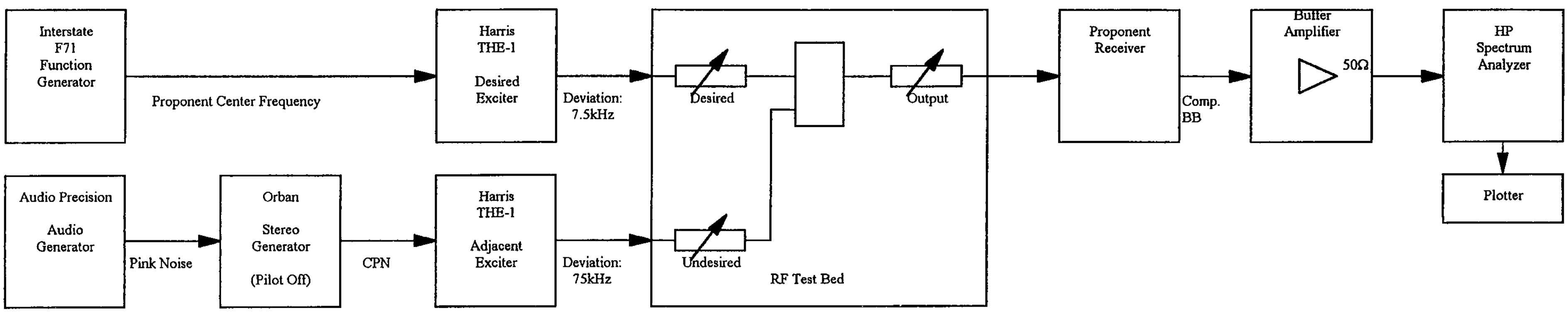
Distortion + Noise



Limiting Threshold / Sensitivity

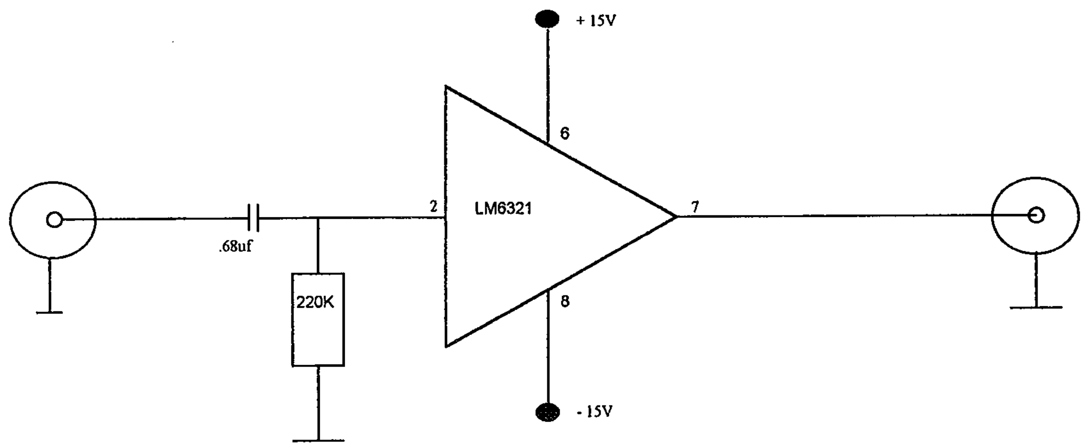


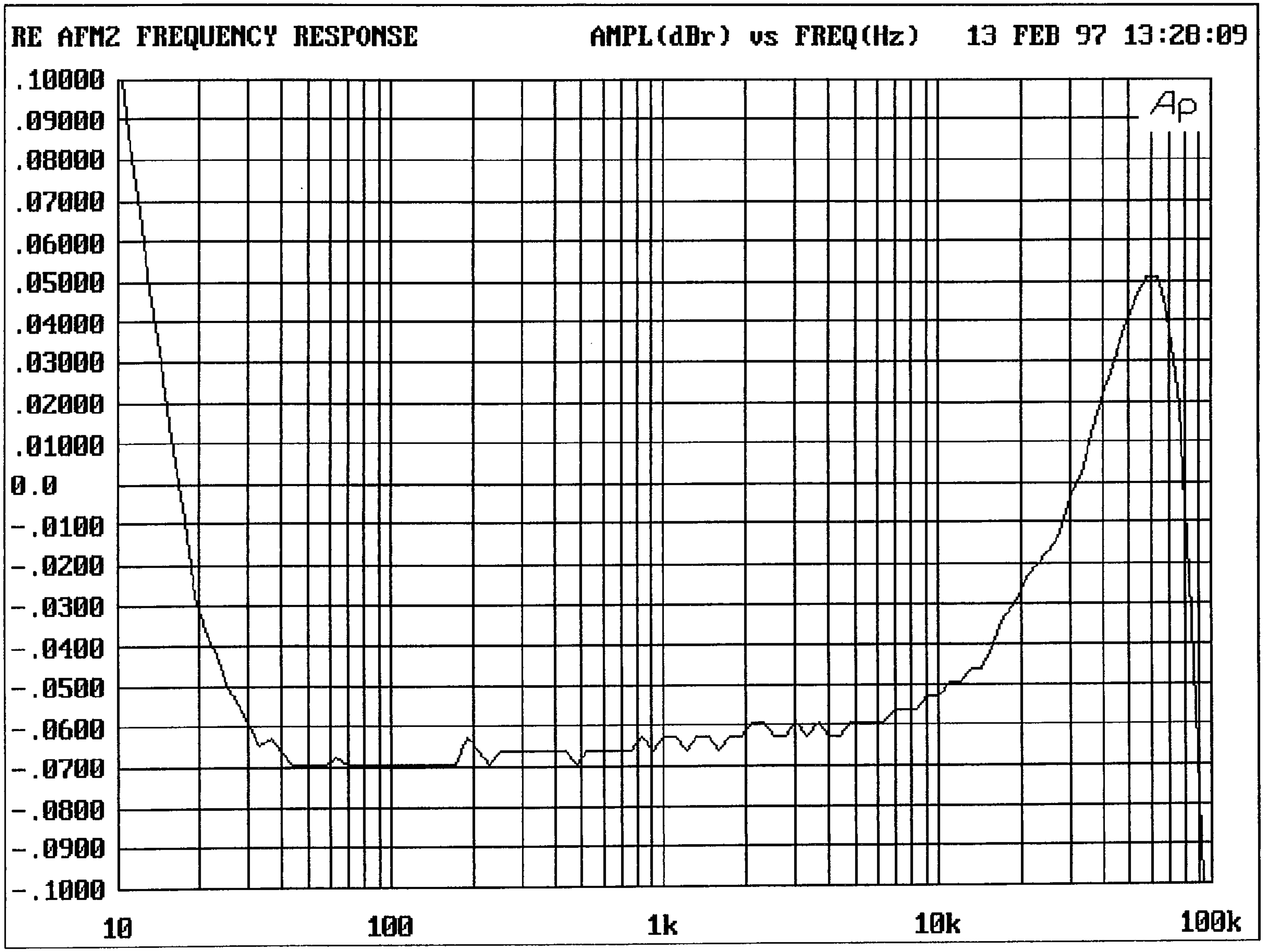
Selectivity



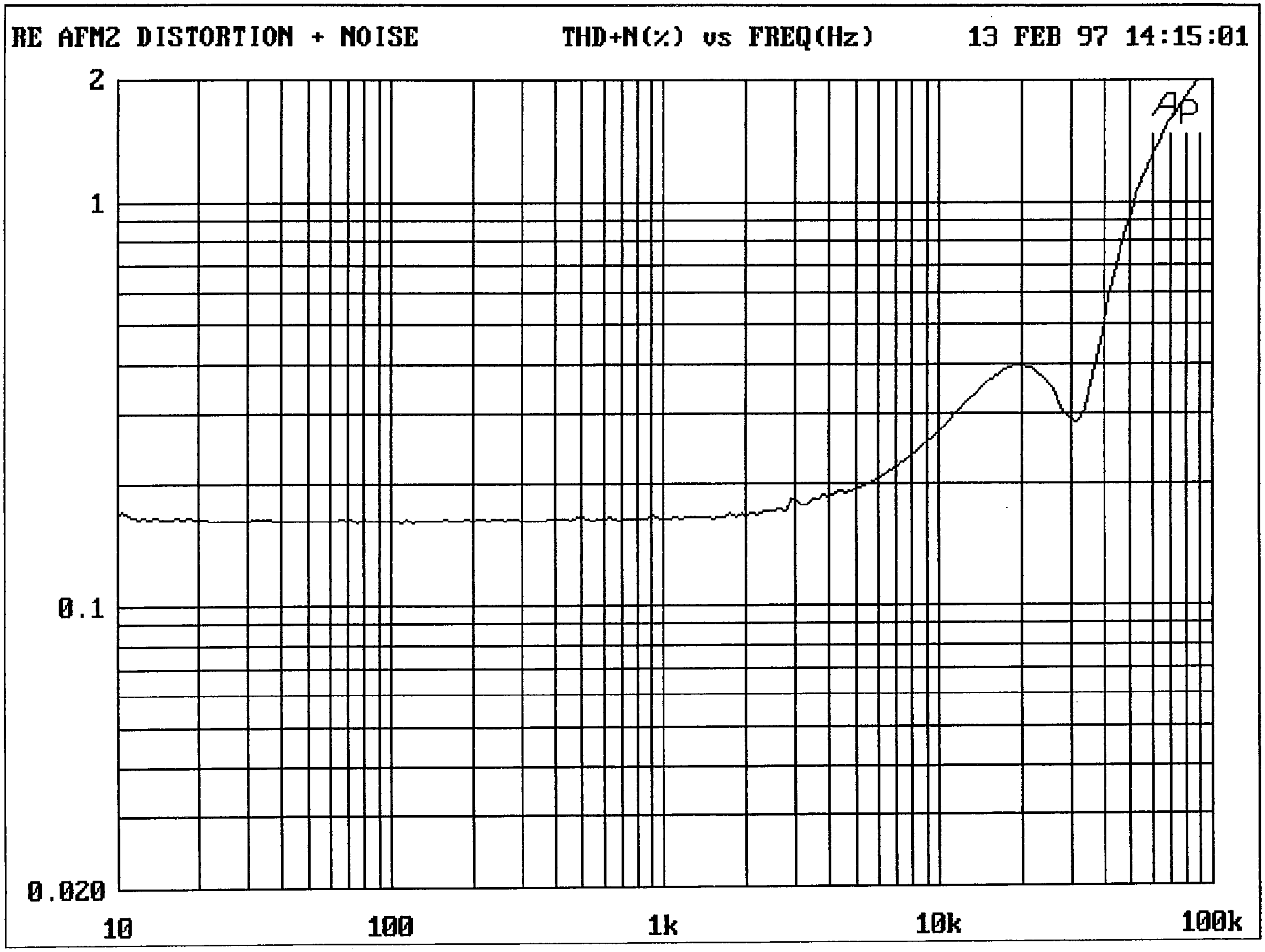
HSSC Proponent Receiver Characterization

Buffer Amplifier Interface to HP Spectrum Analyzer

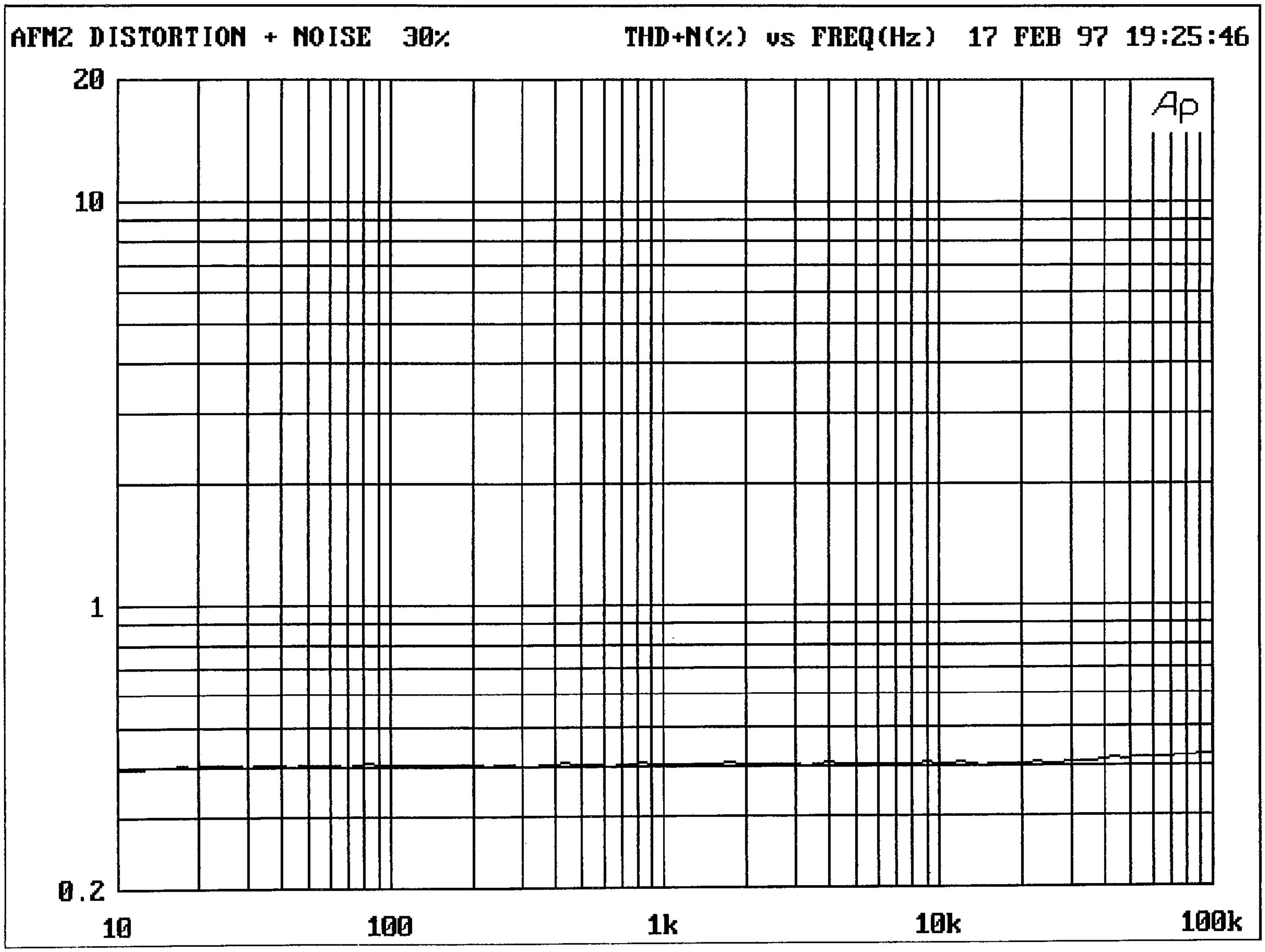


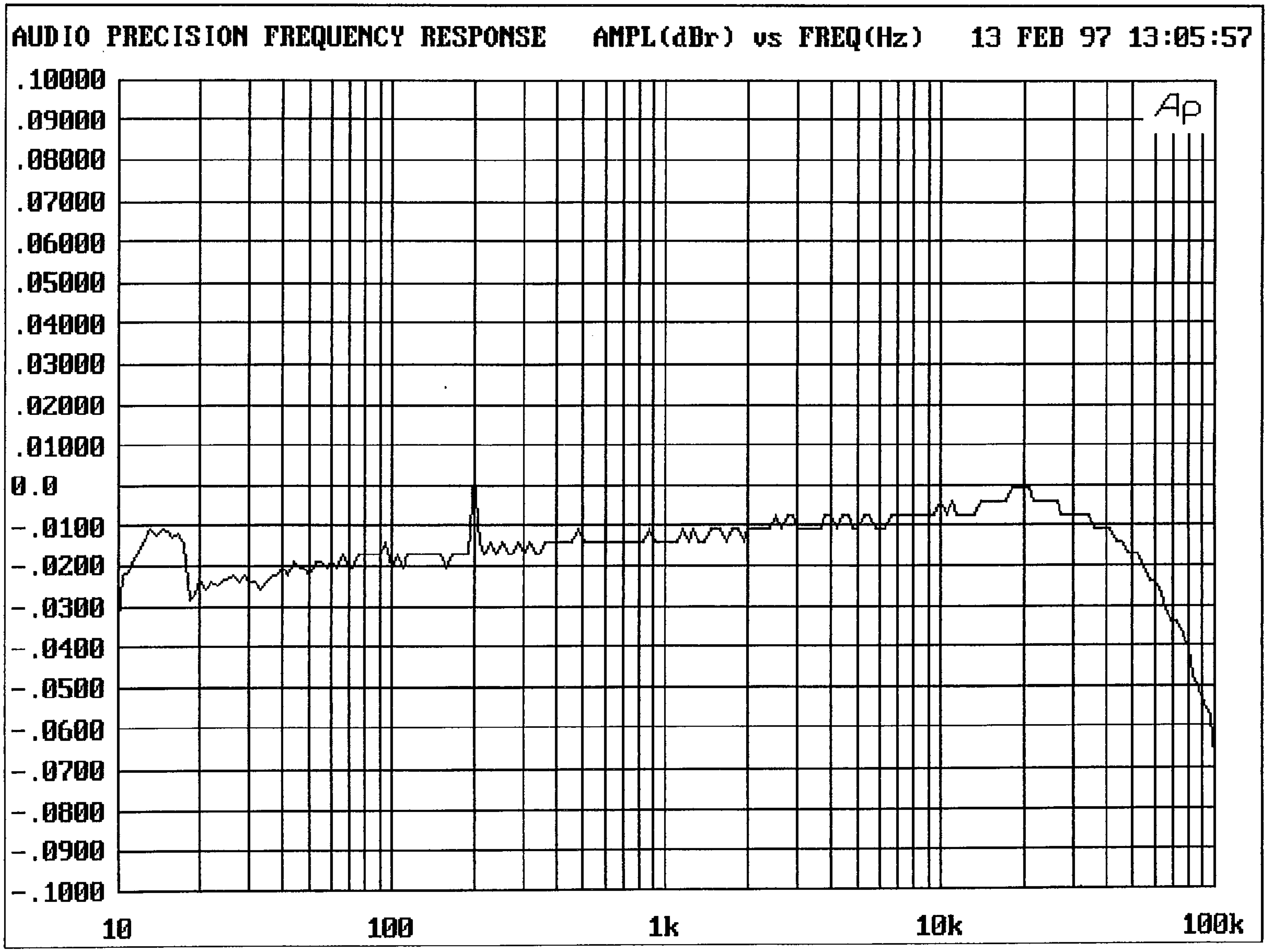

RE AFM2 FREQUENCY RESPONSE
AMPL(dBr) vs FREQ(Hz)
13 FEB 97 13:28:09
.10000
.09000
.08000
.07000
.06000
.05000
.04000
.03000
.02000
.01000
0.0
-.0100
-.0200
-.0300
-.0400
-.0500
-.0600
-.0700
-.0800
-.0900
-.1000
10
100
1k
10k
100k
Ap

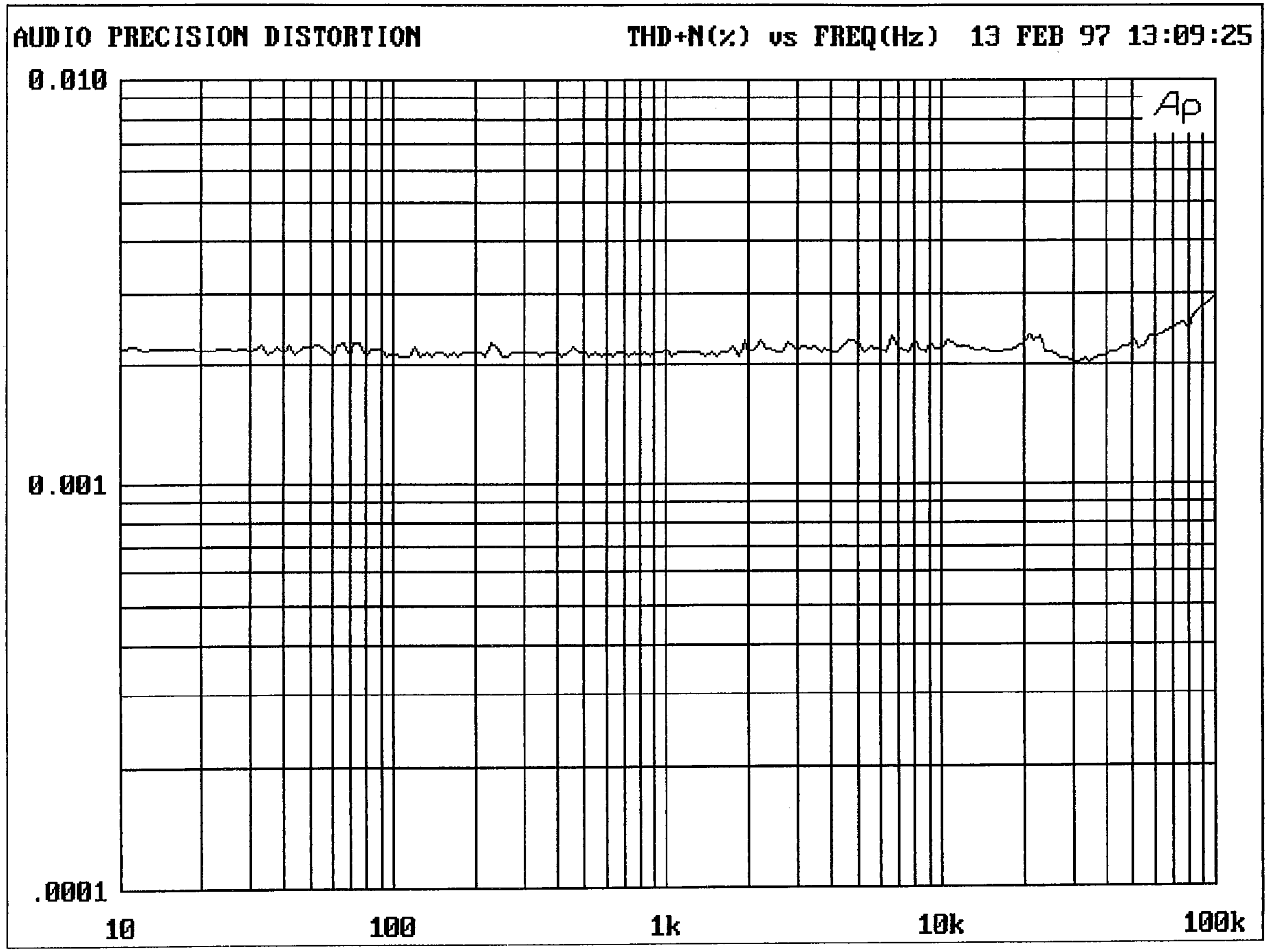
100%

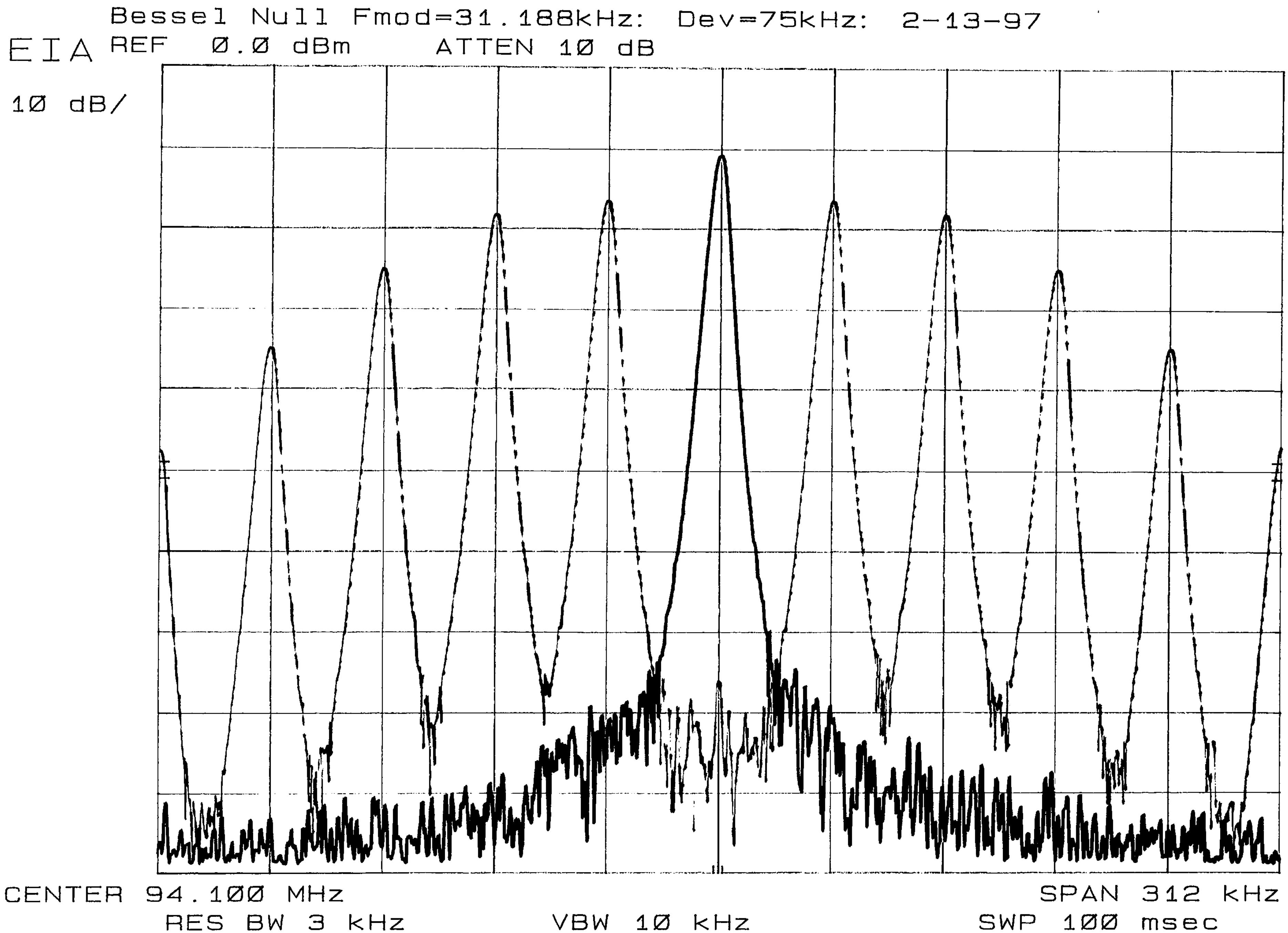


RE AFM2 DISTORTION + NOISE
THD+N(%) vs FREQ(Hz)
13 FEB 97 14:15:01
2
1
0.1
0.020
10
100
1k
10k
100k


AFM2 DISTORTION + NOISE 30%
THD+N(%) vs FREQ(Hz) 17 FEB 97 19:25:46
20
10
1
0.2
10
100
1k
10k
100k
Ap


AUDIO PRECISION FREQUENCY RESPONSE AMPL(dBr) vs FREQ(Hz) 13 FEB 97 13:05:57
.10000
.09000
.08000
.07000
.06000
.05000
.04000
.03000
.02000
.01000
0.0
-.0100
-.0200
-.0300
-.0400
-.0500
-.0600
-.0700
-.0800
-.0900
-.1000
10
100
1k
10k
100k
Ap


AUDIO PRECISION DISTORTION
THD+N(%) vs FREQ(Hz) 13 FEB 97 13:09:25
0.010
0.001
.0001
10
100
1k
10k
100k
Ap

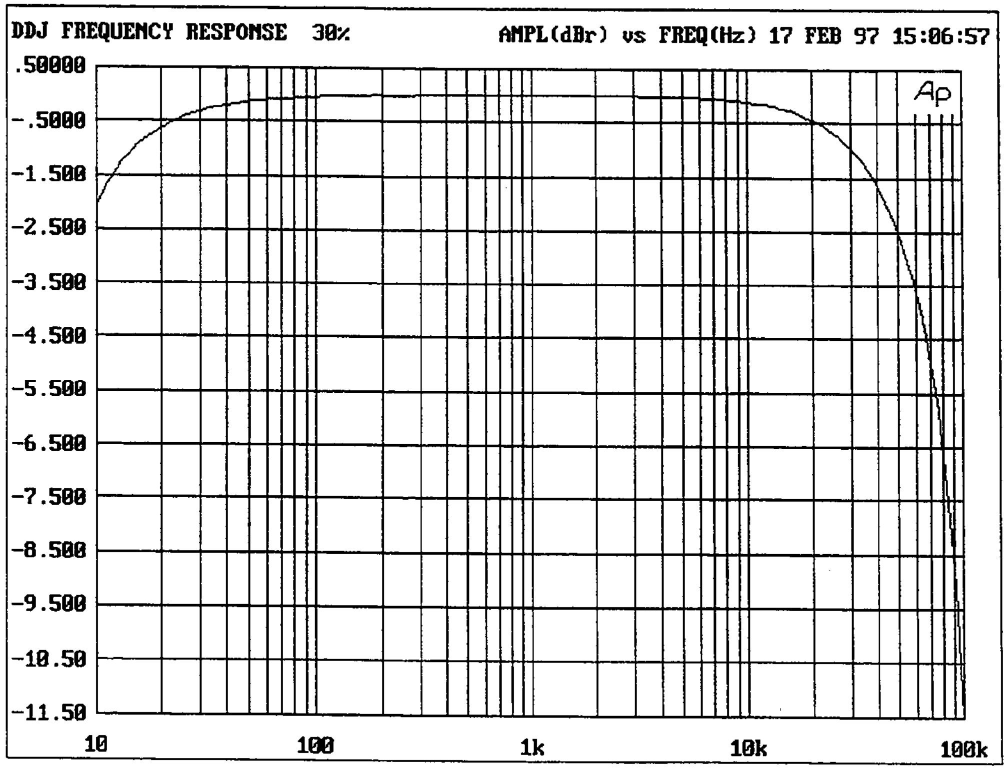


Bessel Null Fmod=31.188kHz: Dev=75kHz: 2-13-97
EIA
REF Ø.Ø dBm ATTEN 1Ø dB
1Ø dB/
CENTER 94.1ØØ MHz
SPAN 312 kHz
RES BW 3 kHz
VBW 1Ø kHz
SWP 1ØØ msec

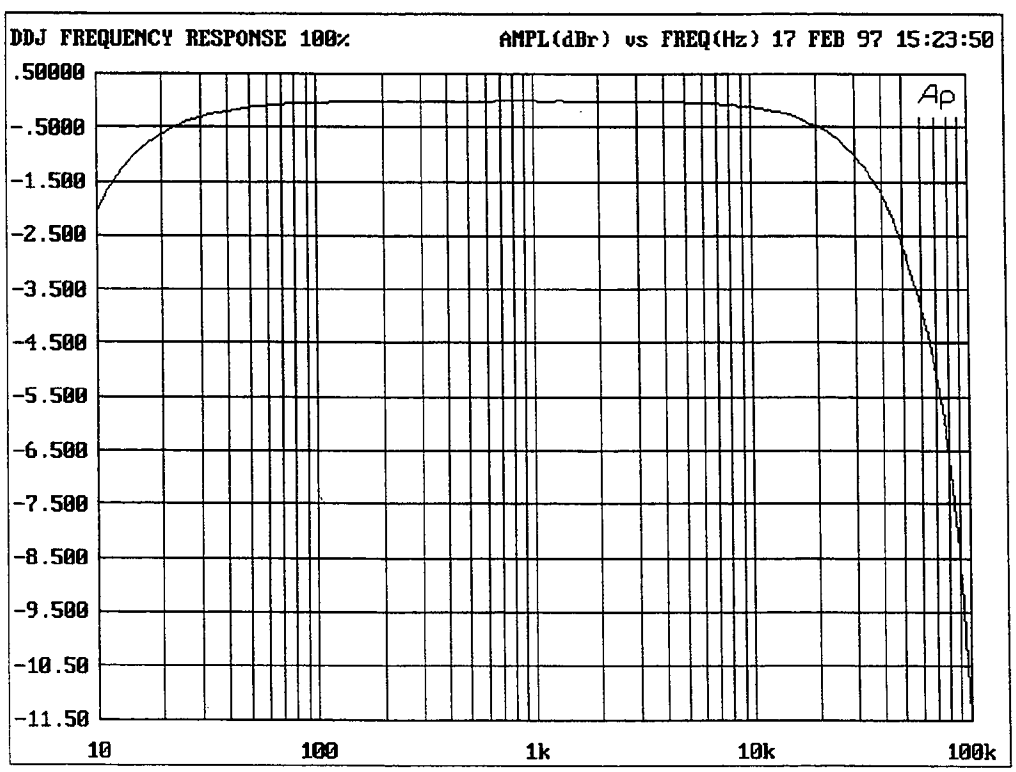
(Handed out at tutorial)

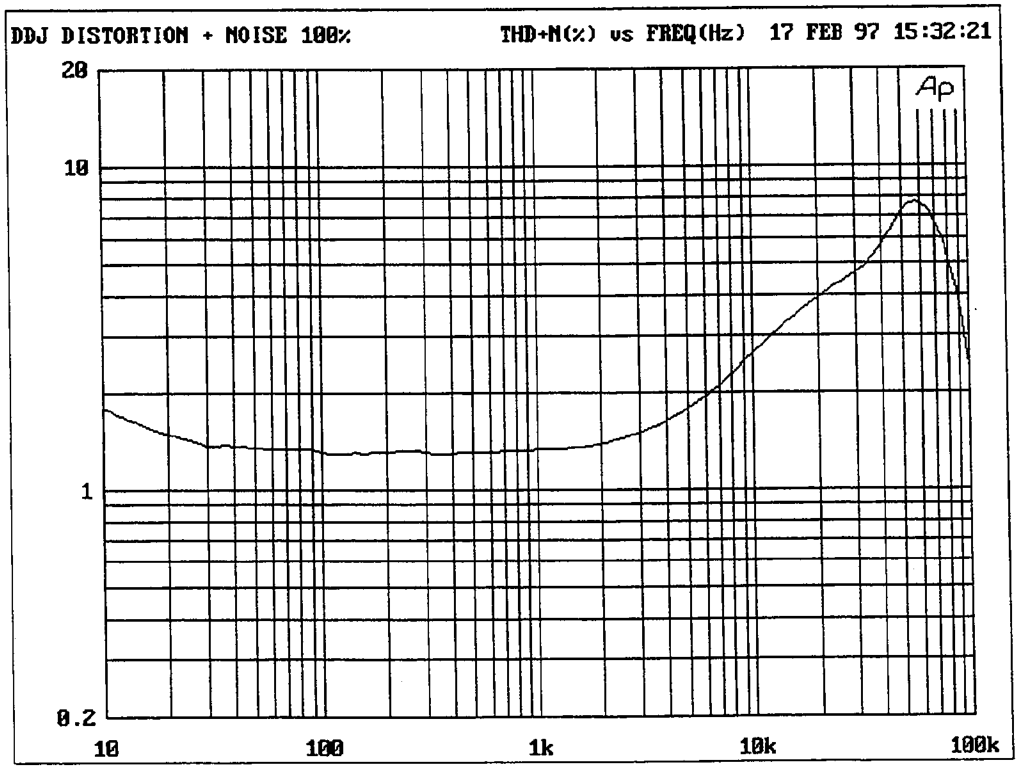
②

0dB = 120mVrms

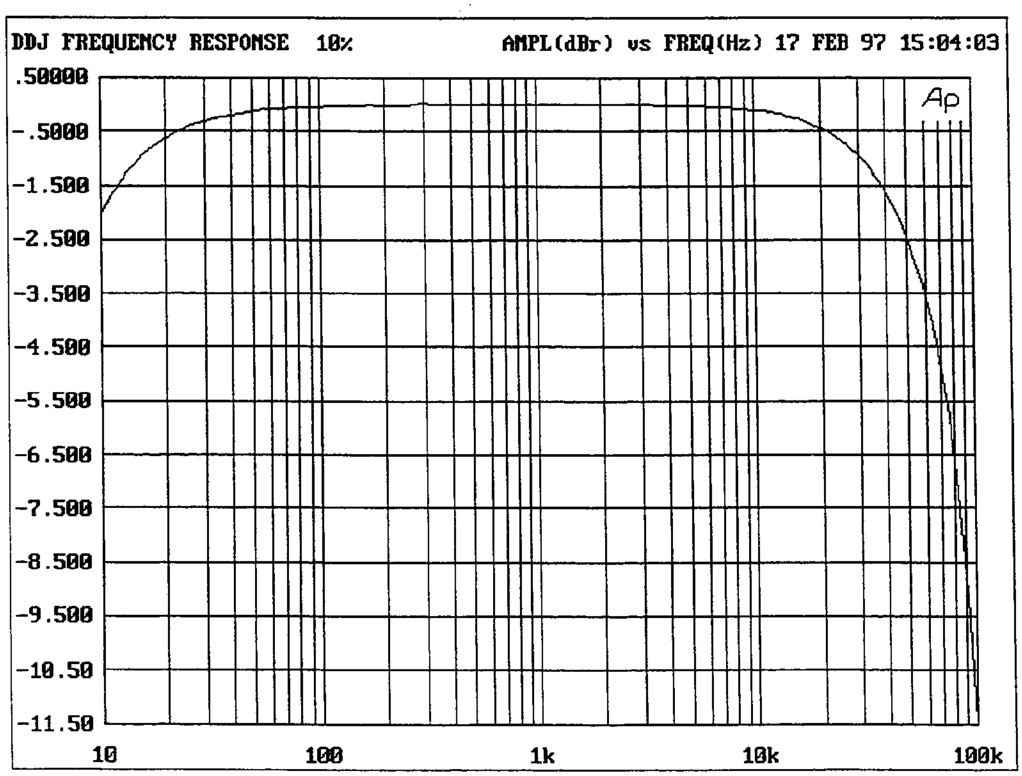


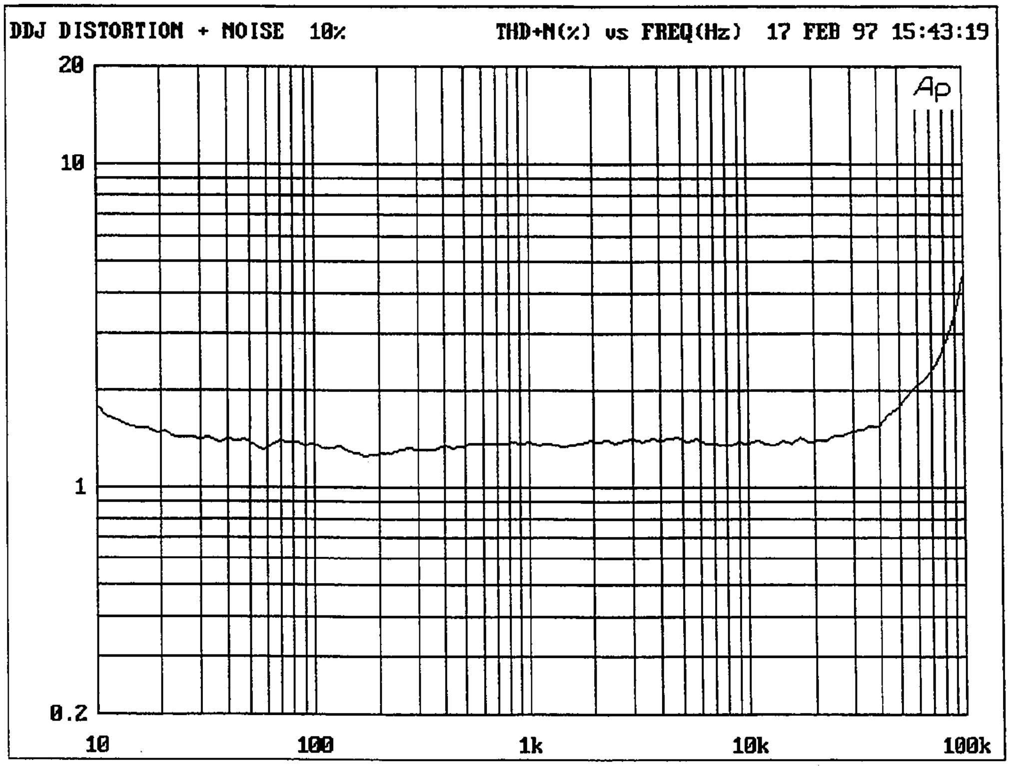
0dB = 403mVrms

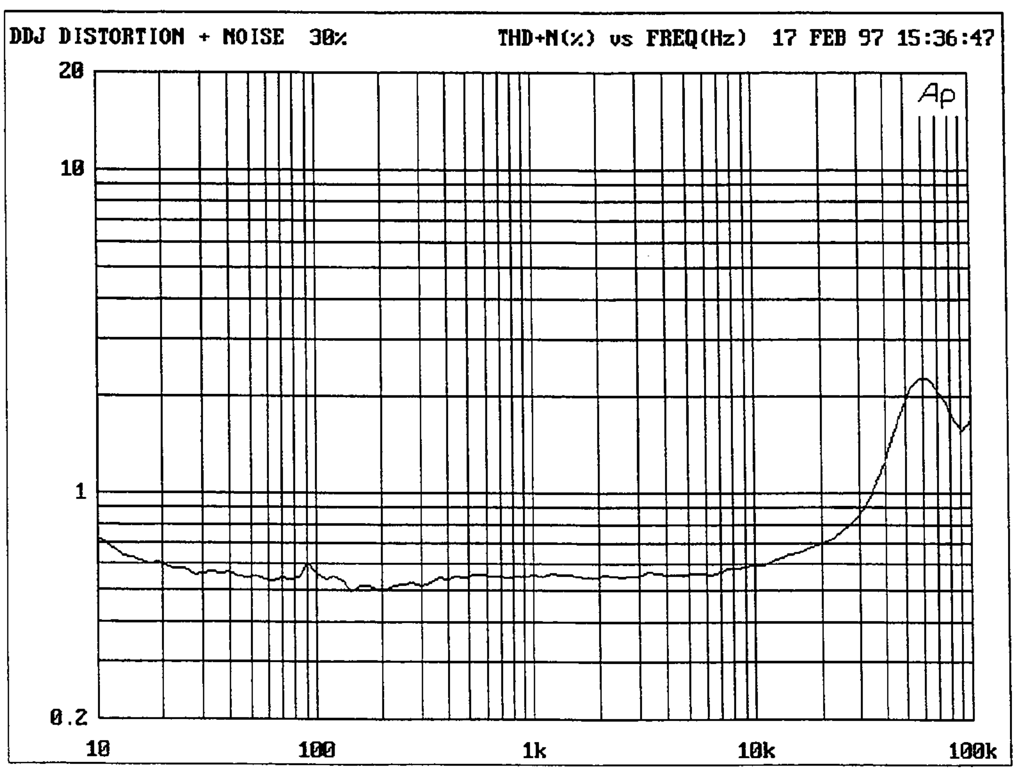




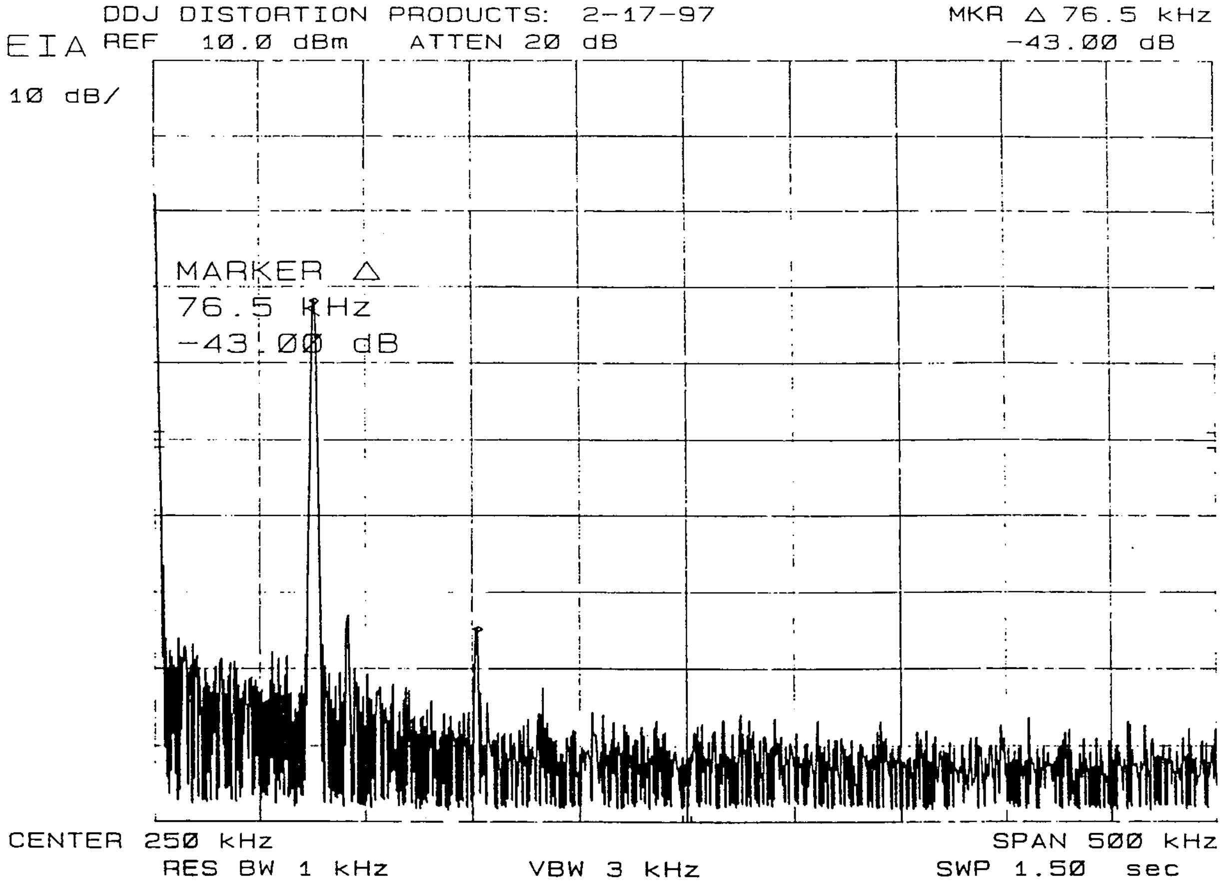
0dB = 39.9mVrms

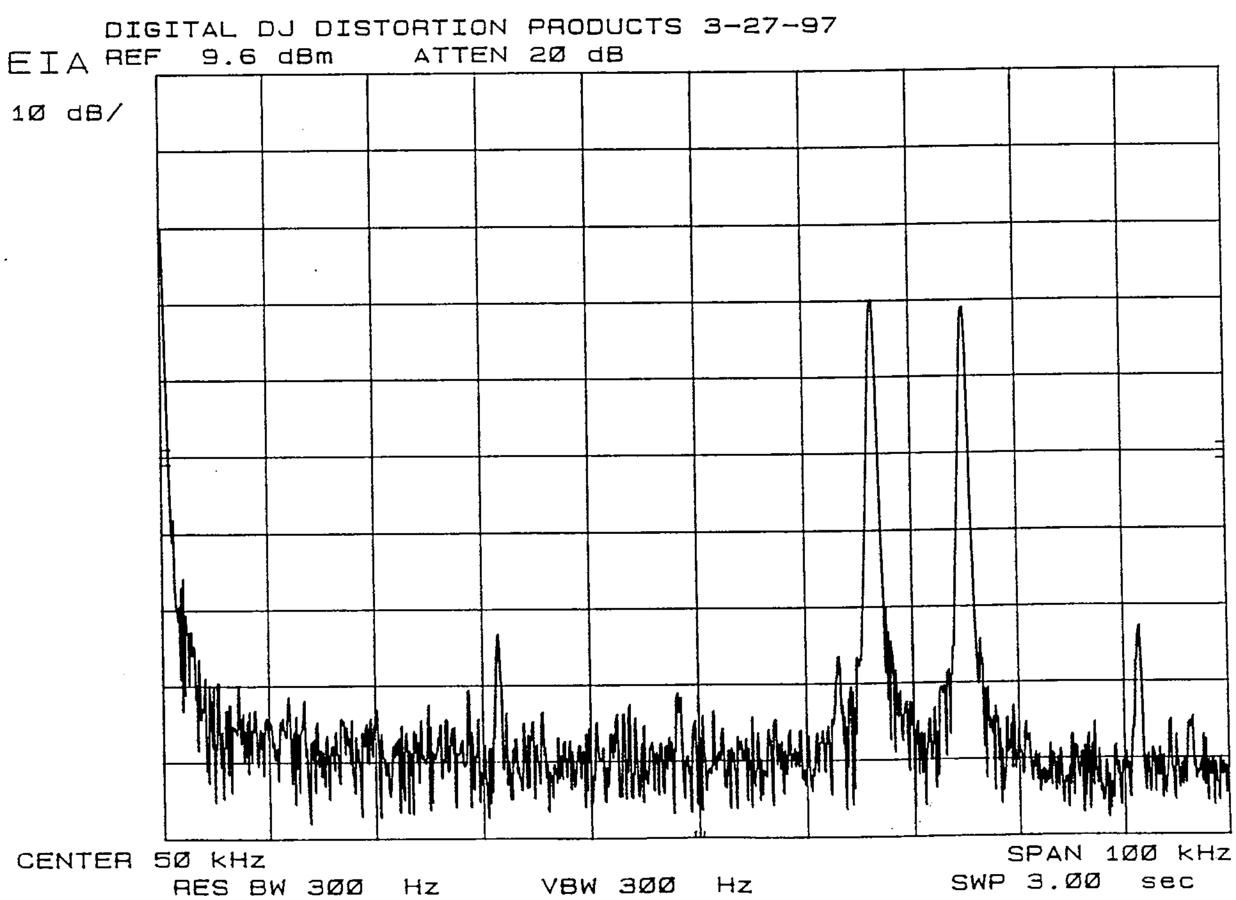



DDJ DISTORTION + NOISE 10%
THD+N(%) vs FREQ(Hz) 17 FEB 97 15:43:19
Ap
20
10
1
0.2
10
100
1k
10k
100k


DDJ DISTORTION + NOISE 30%
THD+N(%) vs FREQ(Hz) 17 FEB 97 15:36:47
Ap
20
10
1
0.2
10
100
1k
10k
100k

(Attachment 6)





Digital Radio Test Laboratory

HSSC Proponent Receiver Characterization

Date: 2/17/97
By: DML

Desired Signal: 94.10 MHz **Modulation:** 1 kHz
Injection: 100 %
0dB: 406 mV

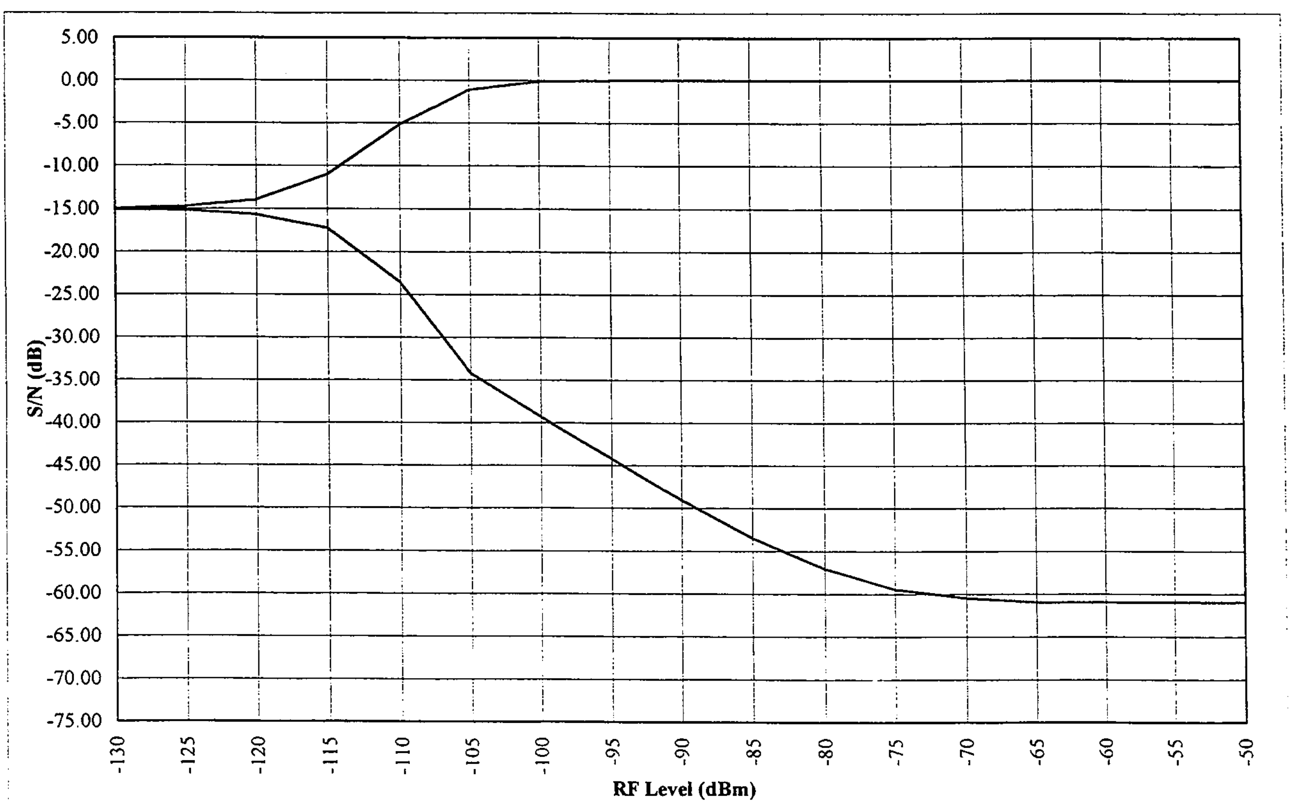
Measurement: Level; RMS, with 15kHz Low Pass Filter

Results: S/N vs RF Level

Radio Type: Logic Control Diversity System

	RF (dBm)	Signal (dB)	Noise (dB)
	-50	0.00	-61.00
	-55	0.00	-61.00
	-60	0.00	-61.00
	-65	0.00	-61.00
	-70	0.00	-60.50
	-75	0.00	-59.50
	-80	0.00	-57.10
	-85	0.00	-53.50
	-90	0.00	-49.00
	-95	0.00	-44.20
Limiting	-100	-0.16	-39.30
Threshold	-105	-1.10	-34.20
	-110	-5.20	-23.60
	-115	-11.00	-17.30
	-120	-14.00	-15.70
	-125	-14.80	-15.20
	-130	-15.00	-15.10

Digital Radio Test Laboratory

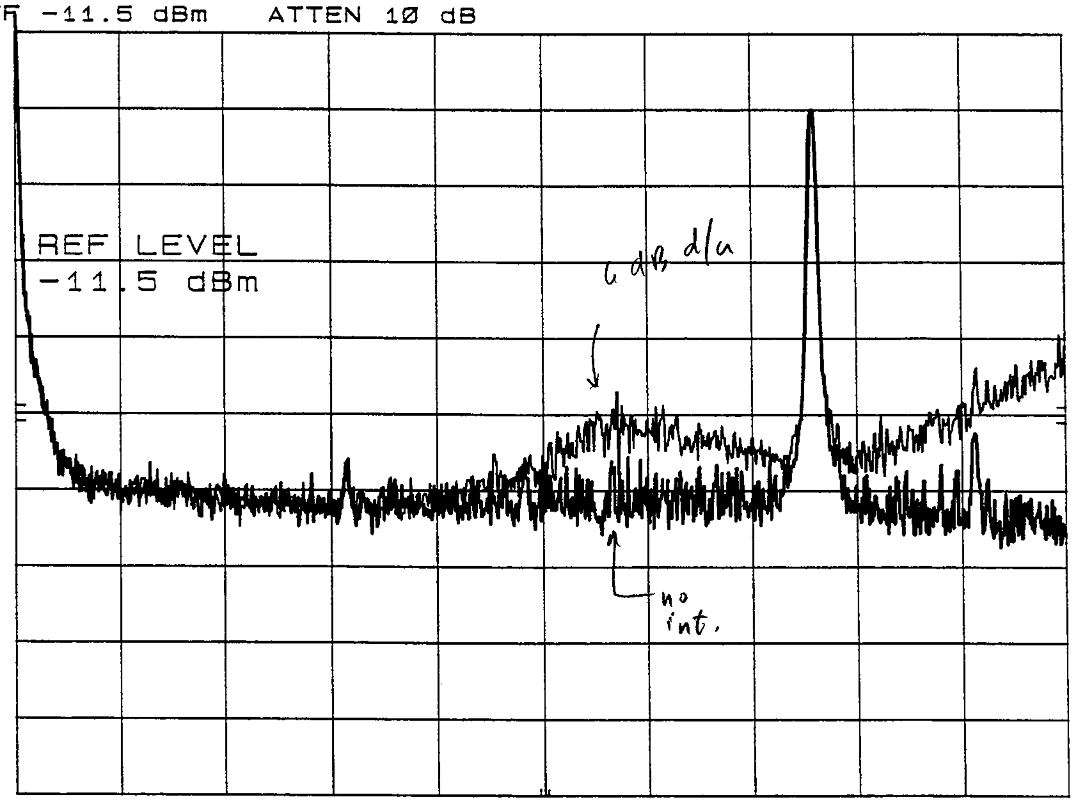


6 dB d/u

DDJ UPPER 1ST ADJACENT: 2-17-97

EIA REF -11.5 dBm ATTEN 10 dB

10 dB/



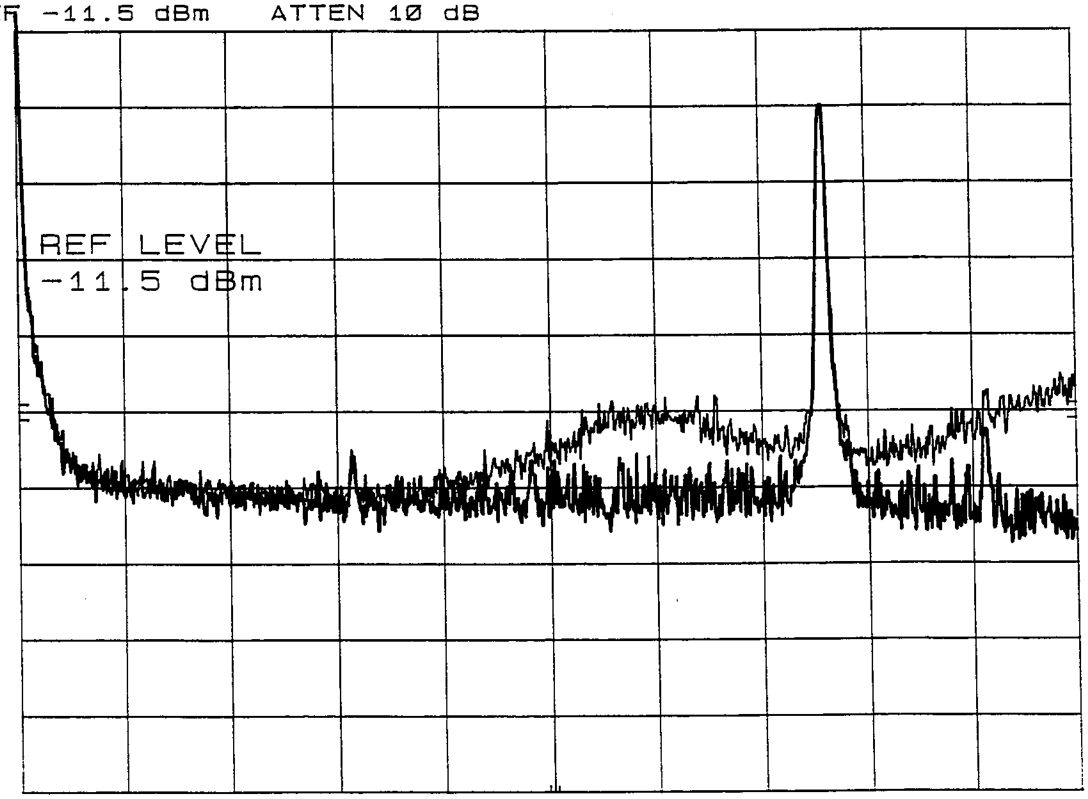
CENTER 50 kHz SPAN 100 kHz

RES BW 300 Hz VBW 1 kHz SWP 3.00 sec

DDJ LOWER 1ST ADJACENT: 2-17-97

EIA REF -11.5 dBm ATTEN 10 dB

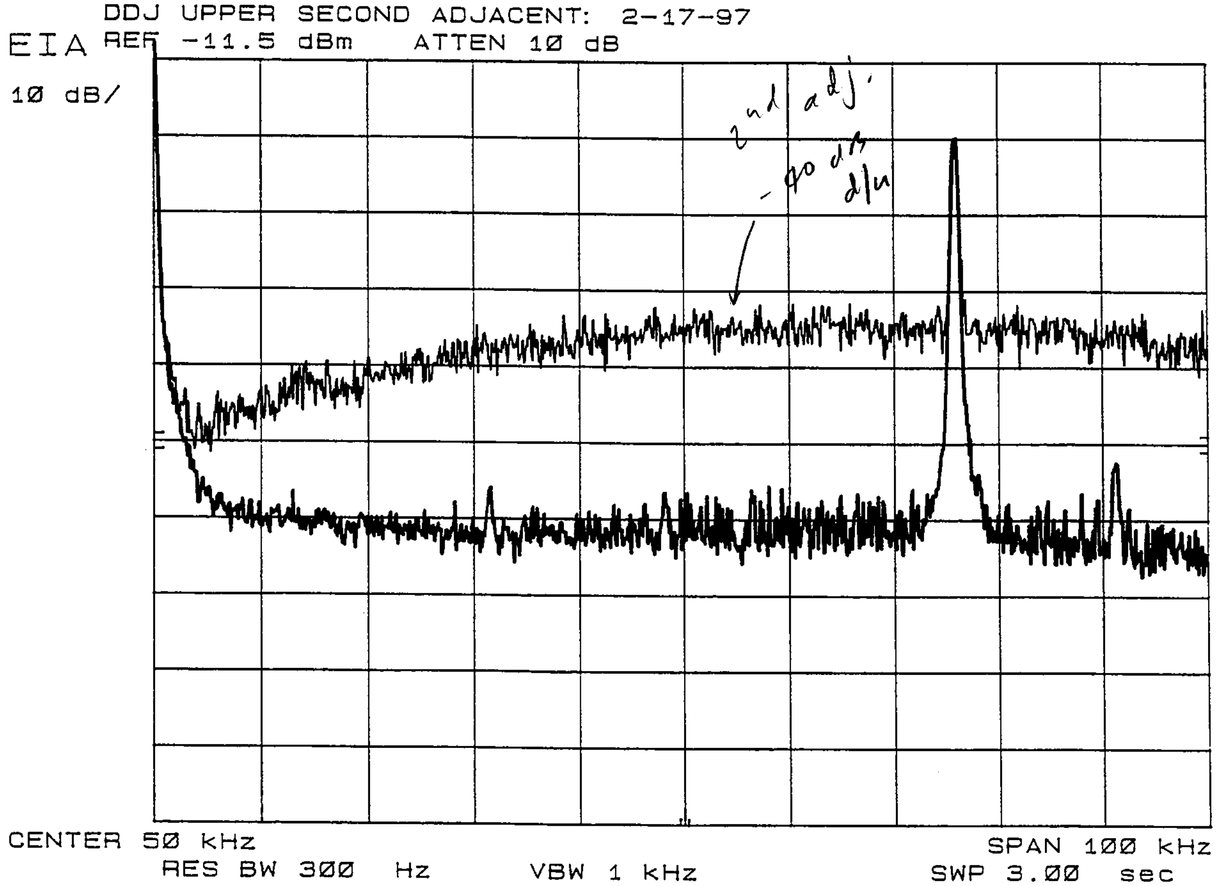
10 dB/



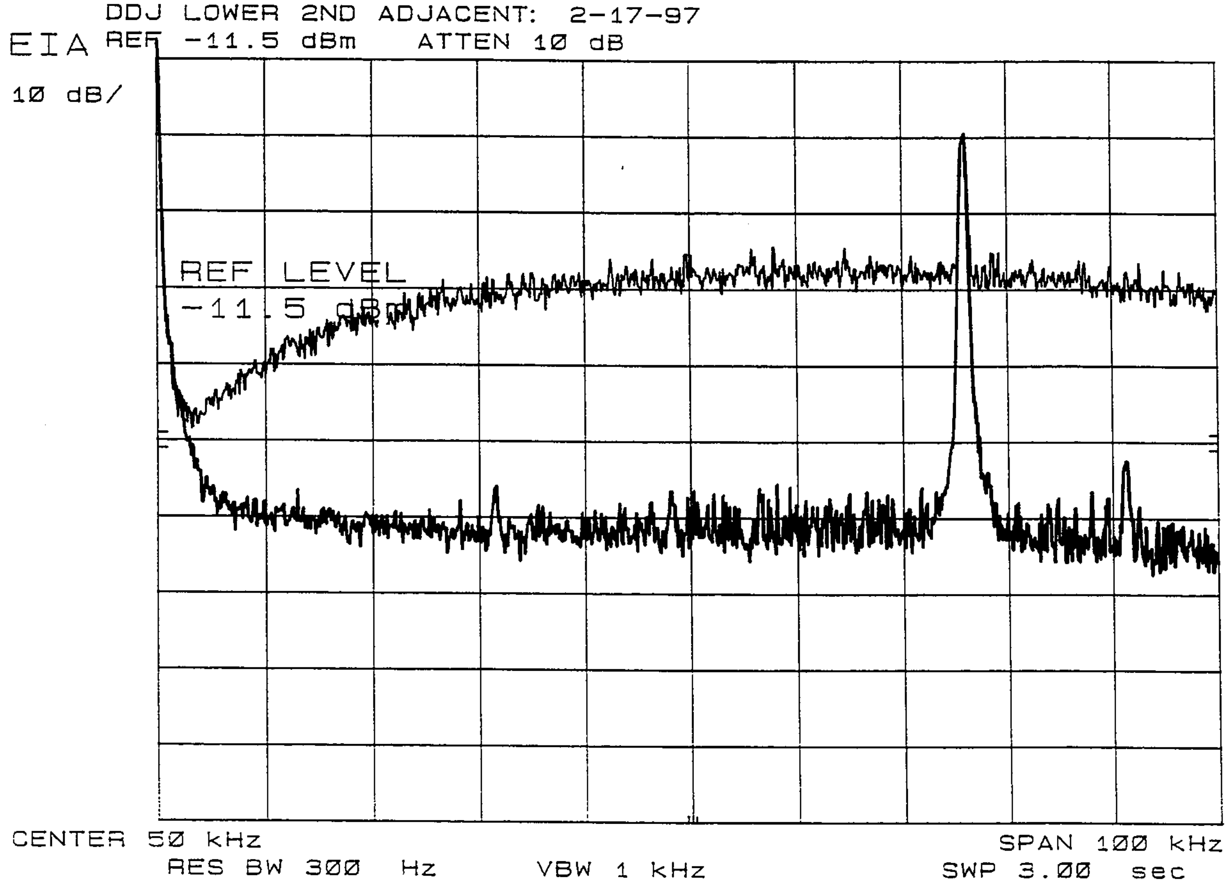
CENTER 50 kHz SPAN 100 kHz

RES BW 300 Hz VBW 1 kHz SWP 3.00 sec

DDJ UPPER SECOND ADJACENT: 2-17-97



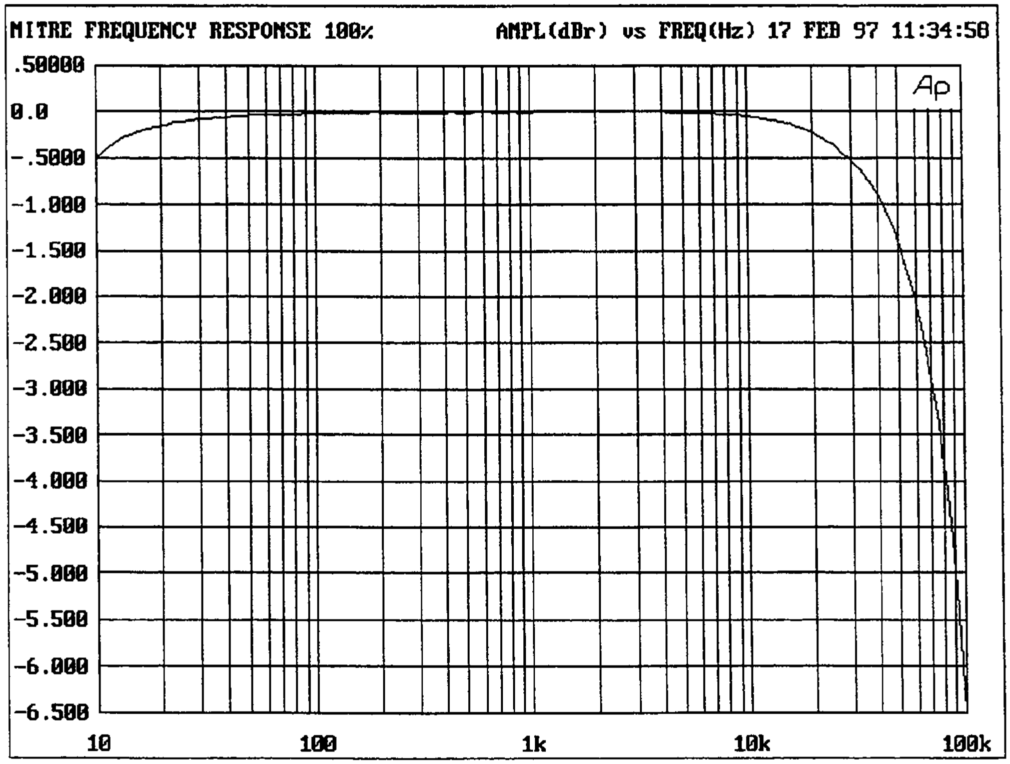
DDJ LOWER 2ND ADJACENT: 2-17-97



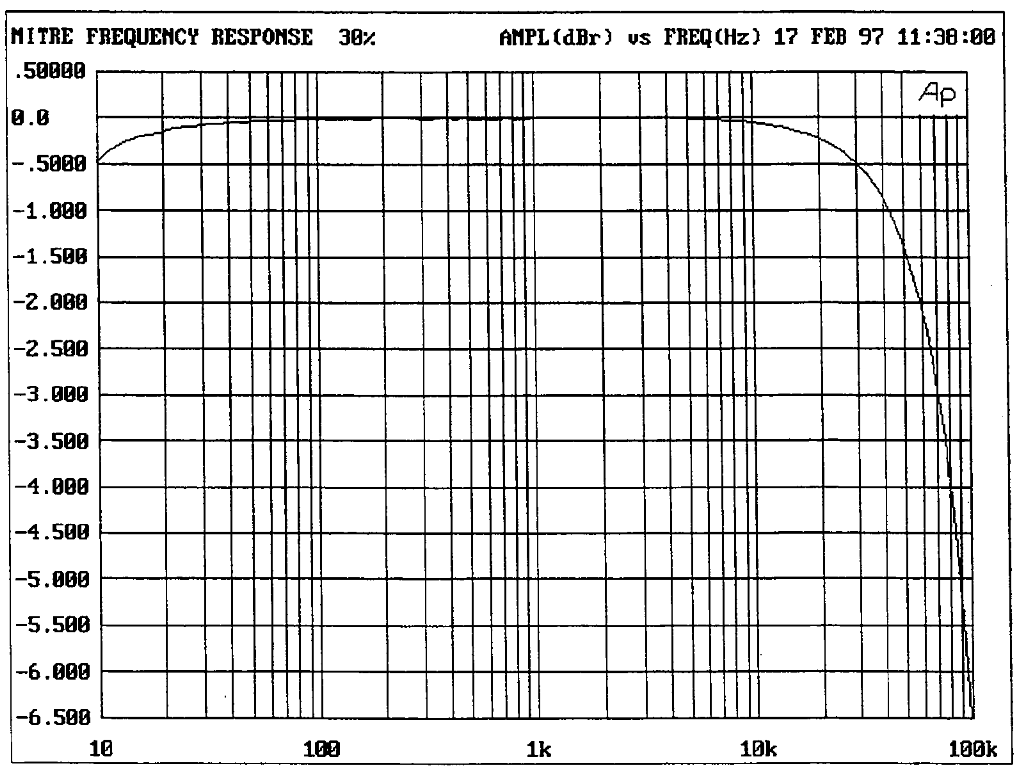
(3)

(Handed out at tutorial)

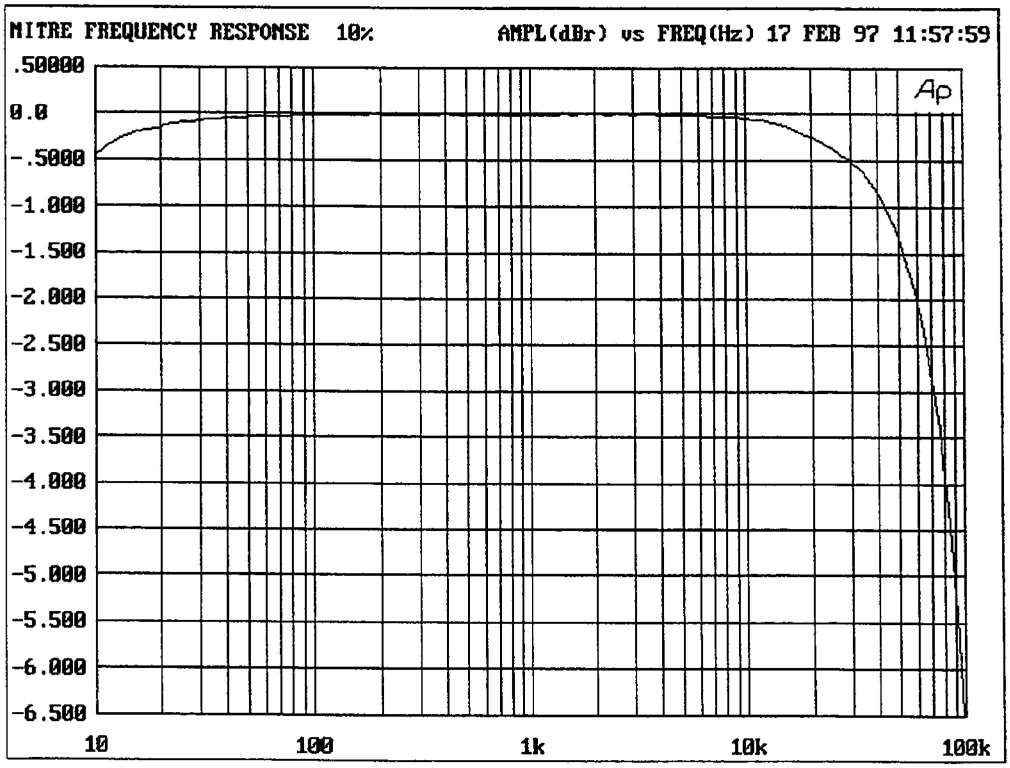
0dB = 403 mVrms

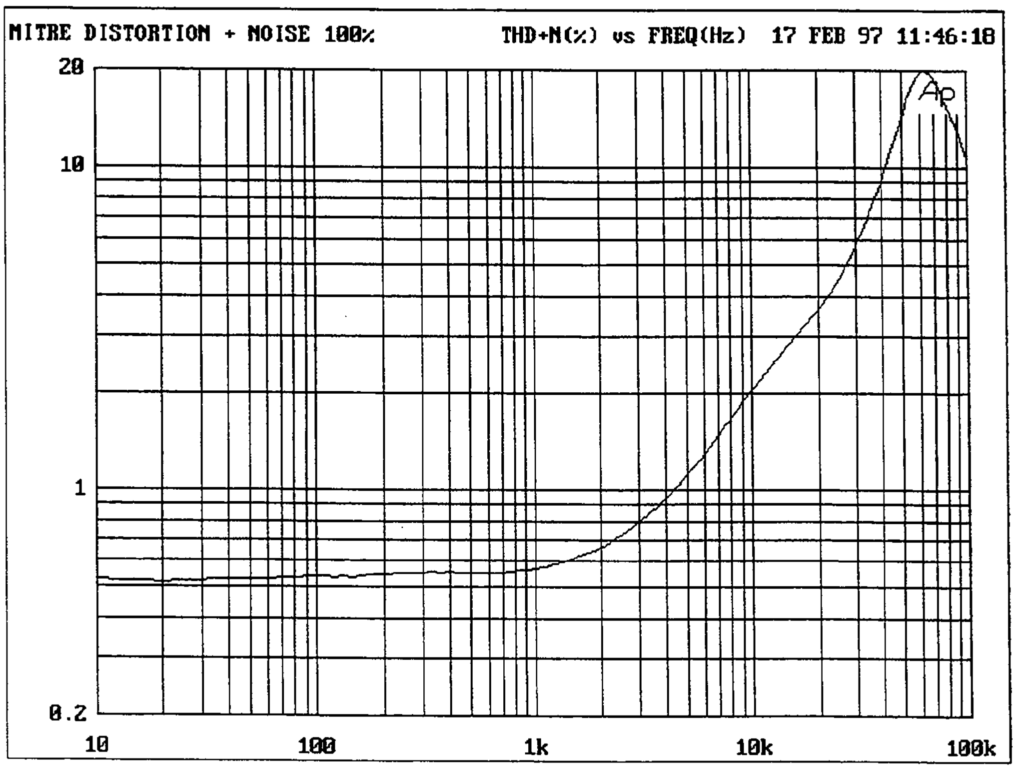


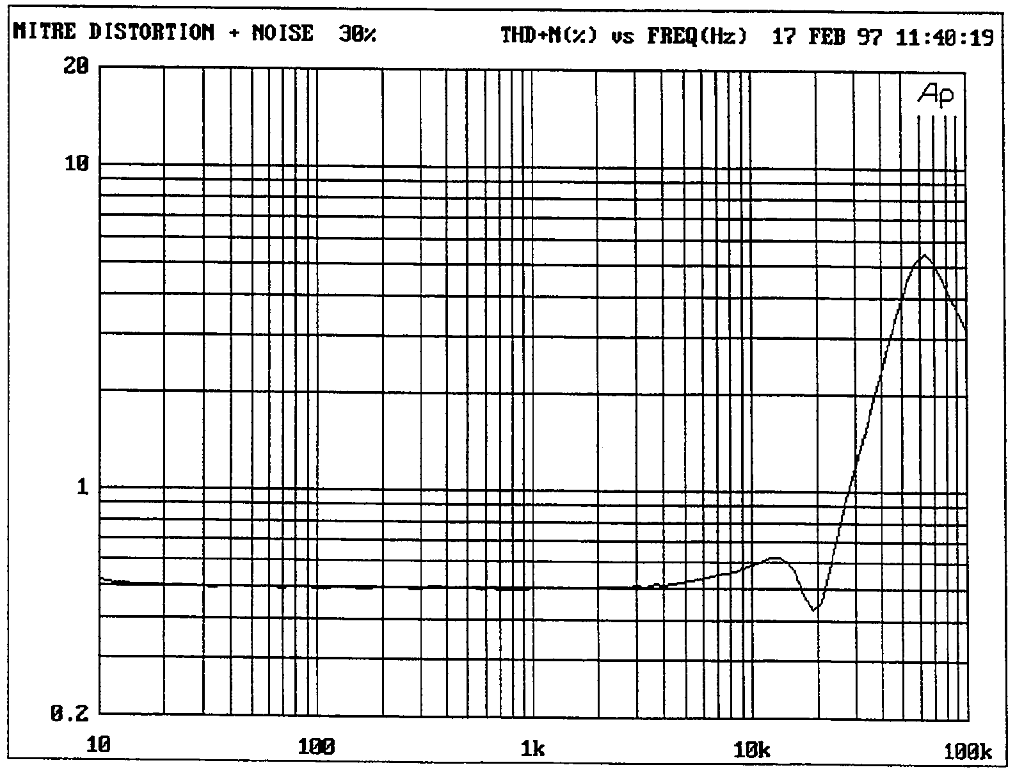
0dB = 119 mVrms

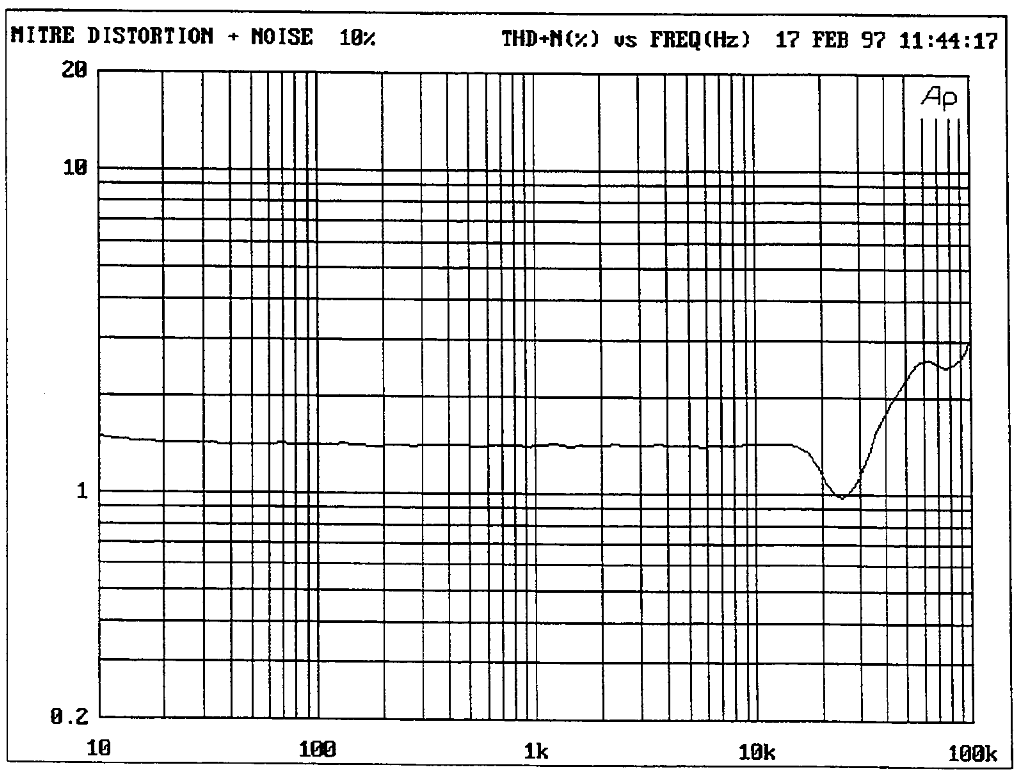


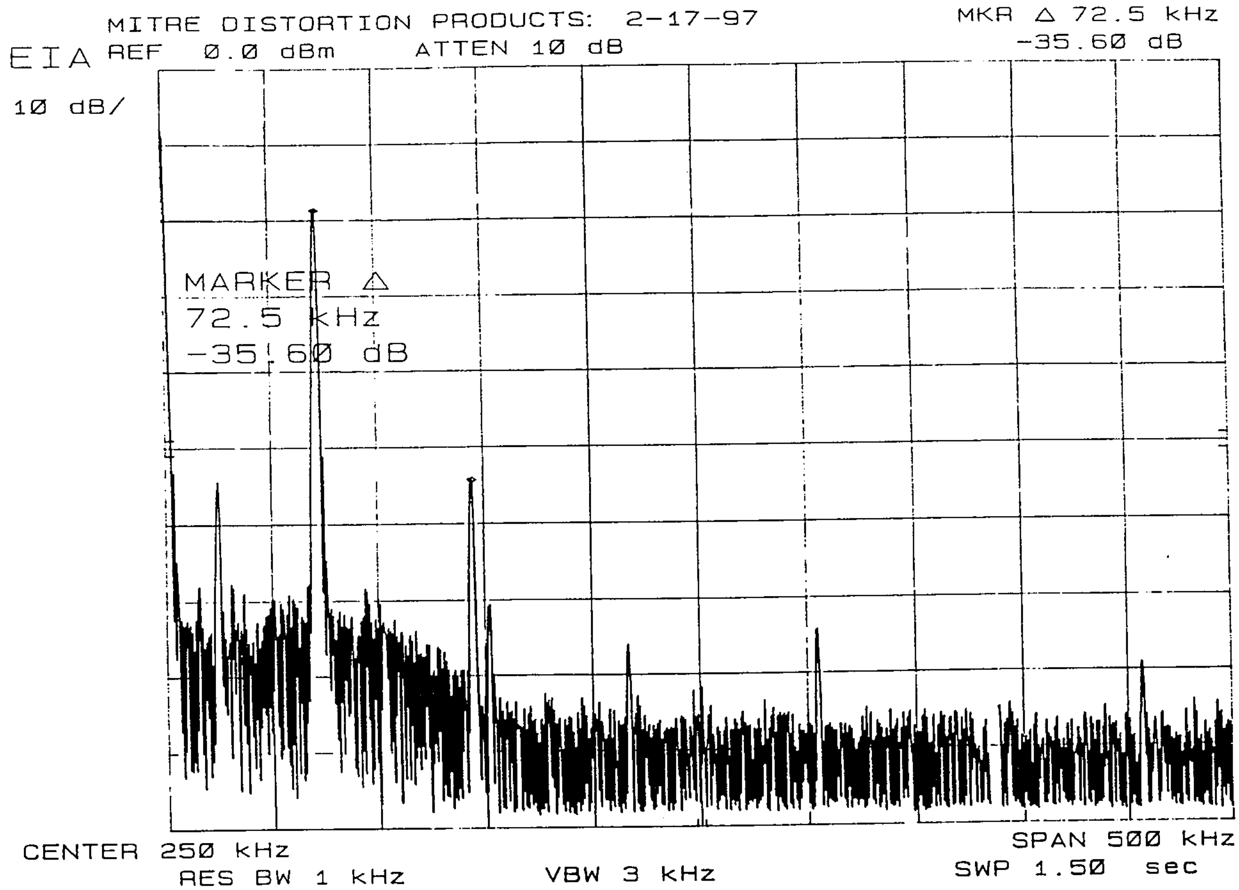
0dB = 39.7 mVrms

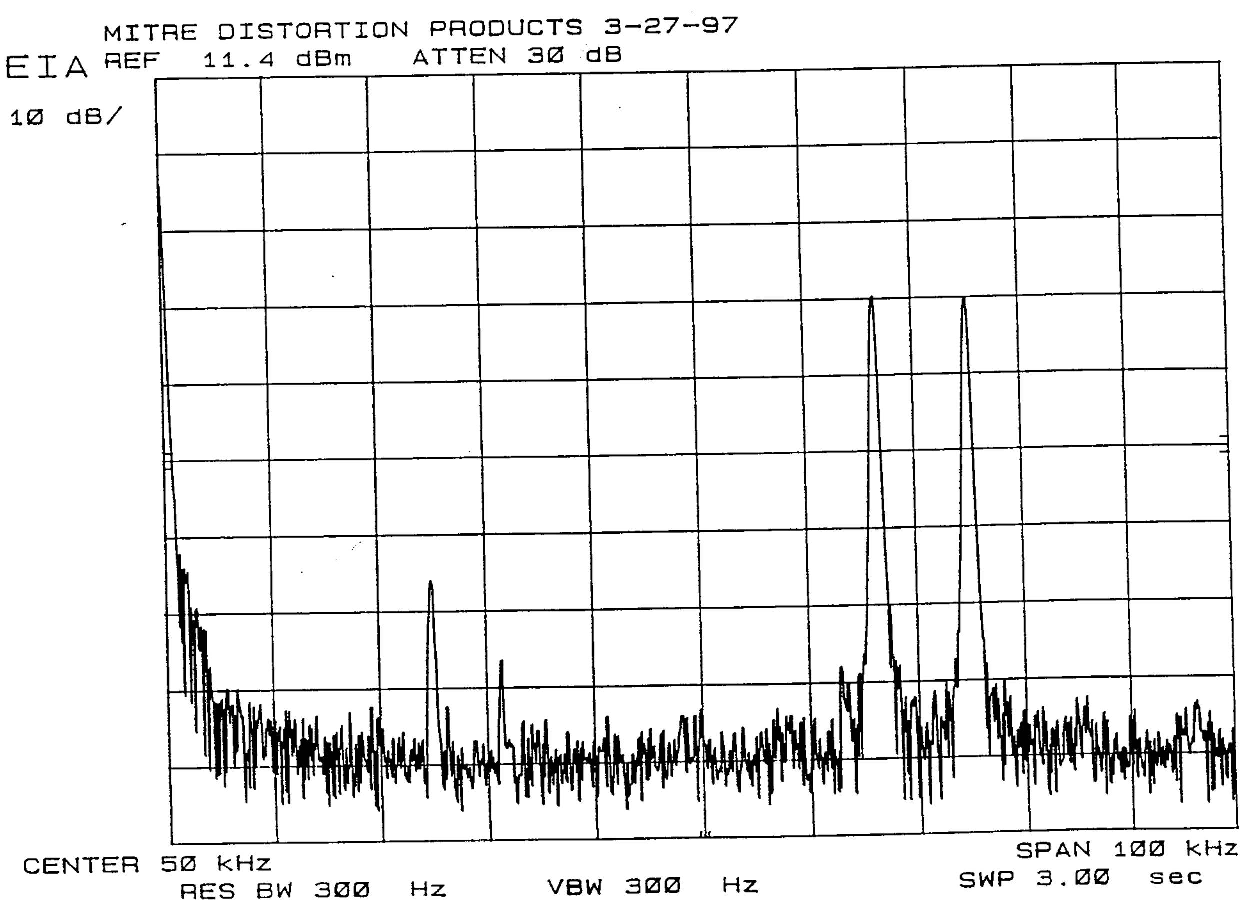





MITRE DISTORTION + NOISE 30%
THD+N(%) vs FREQ(Hz) 17 FEB 97 11:40:19
20
10
1
0.2
10
100
1k
10k
100k
Ap


MITRE DISTORTION + NOISE 10%
THD+N(%) vs FREQ(Hz) 17 FEB 97 11:44:17
20
10
1
0.2
10
100
1k
10k
100k
Ap


MITRE DISTORTION PRODUCTS: 2-17-97
MKR △ 72.5 kHz
-35.60 dB
EIA REF 0.0 dBm ATTEN 10 dB
10 dB/
MARKER △
72.5 kHz
-35.60 dB
CENTER 250 kHz
SPAN 500 kHz
RES BW 1 kHz
VBW 3 kHz
SWP 1.50 sec


MITRE DISTORTION PRODUCTS 3-27-97
EIA REF 11.4 dBm ATTEN 30 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 300 Hz
SWP 3.00 sec

Digital Radio Test Laboratory

HSSC Proponent Receiver Characterization

Date: 2/17/97
By: DML

Desired Signal: 94.10 MHz

Modulation: 1 kHz
Injection: 100 %
0dB: 403 mV

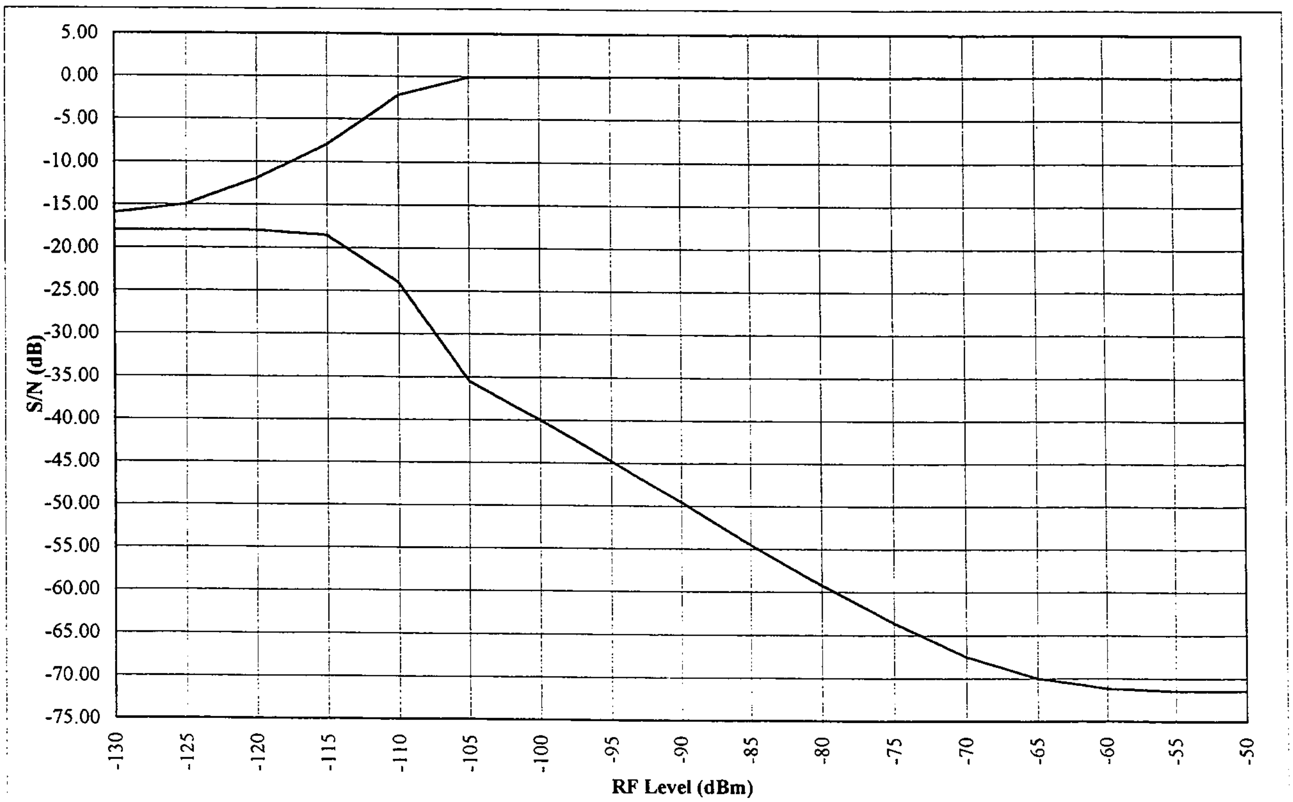
Measurement: Level; RMS, with 15kHz Low Pass Filter

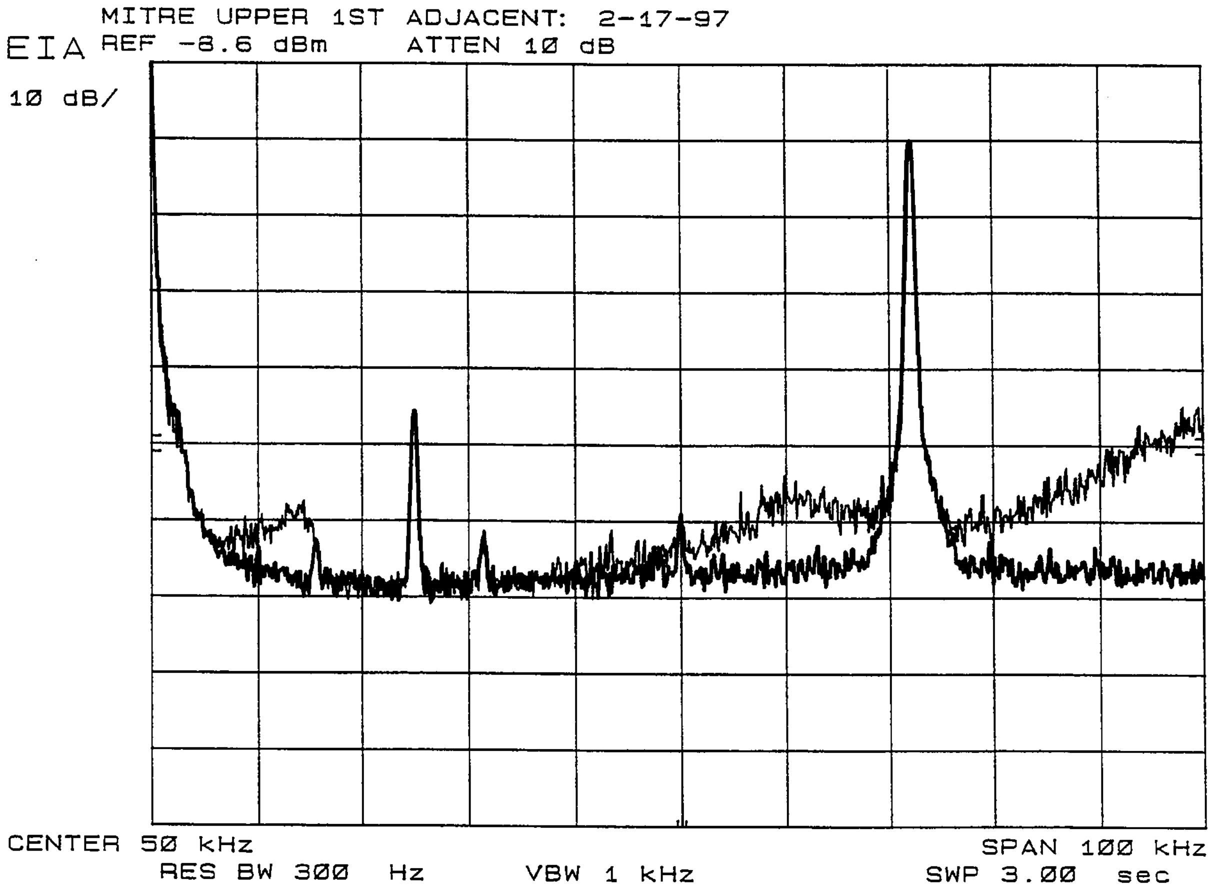
Results: S/N vs RF Level

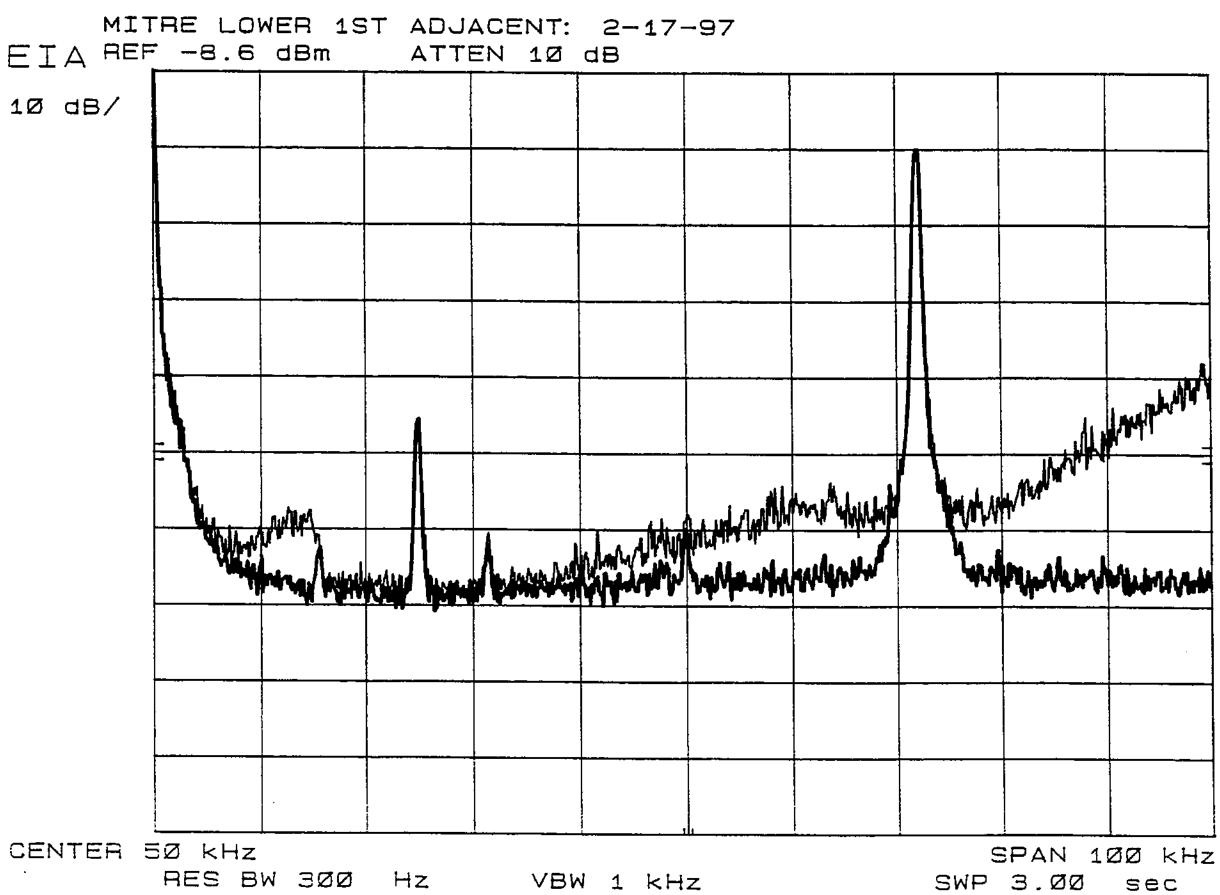
Radio Type: Alpine 7502

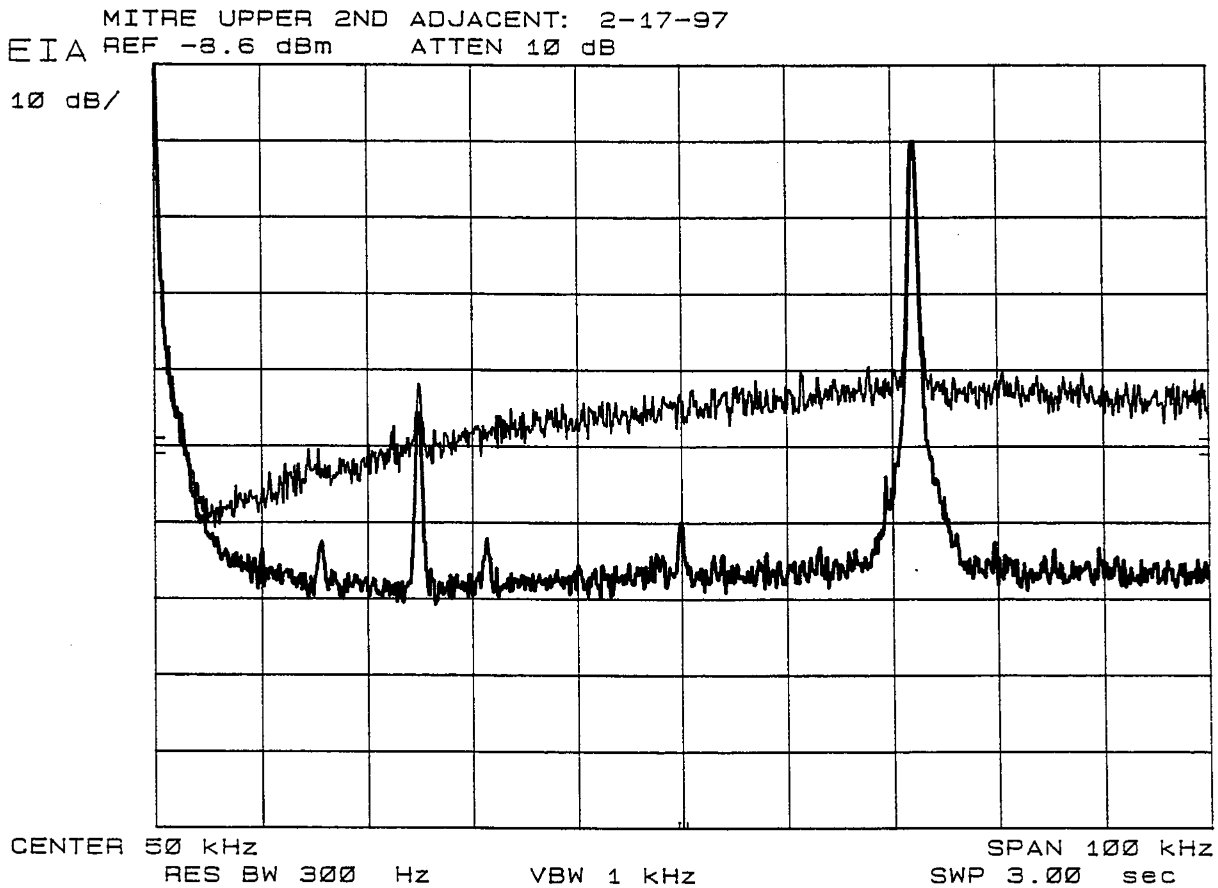
	RF (dBm)	Signal (dB)	Noise (dB)
	-50	0.00	-71.50
	-55	0.00	-71.50
	-60	0.00	-71.20
	-65	0.00	-70.00
	-70	0.00	-67.50
	-75	0.00	-63.60
	-80	0.00	-59.20
	-85	0.00	-54.50
	-90	0.00	-49.50
	-95	0.00	-44.80
	-100	-0.03	-40.00
Limiting	-105	-0.13	-35.50
Threshold	-110	-2.20	-24.00
	-115	-8.00	-18.60
	-120	-12.00	-18.00
	-125	-15.00	-18.00
	-130	-16.00	-18.00

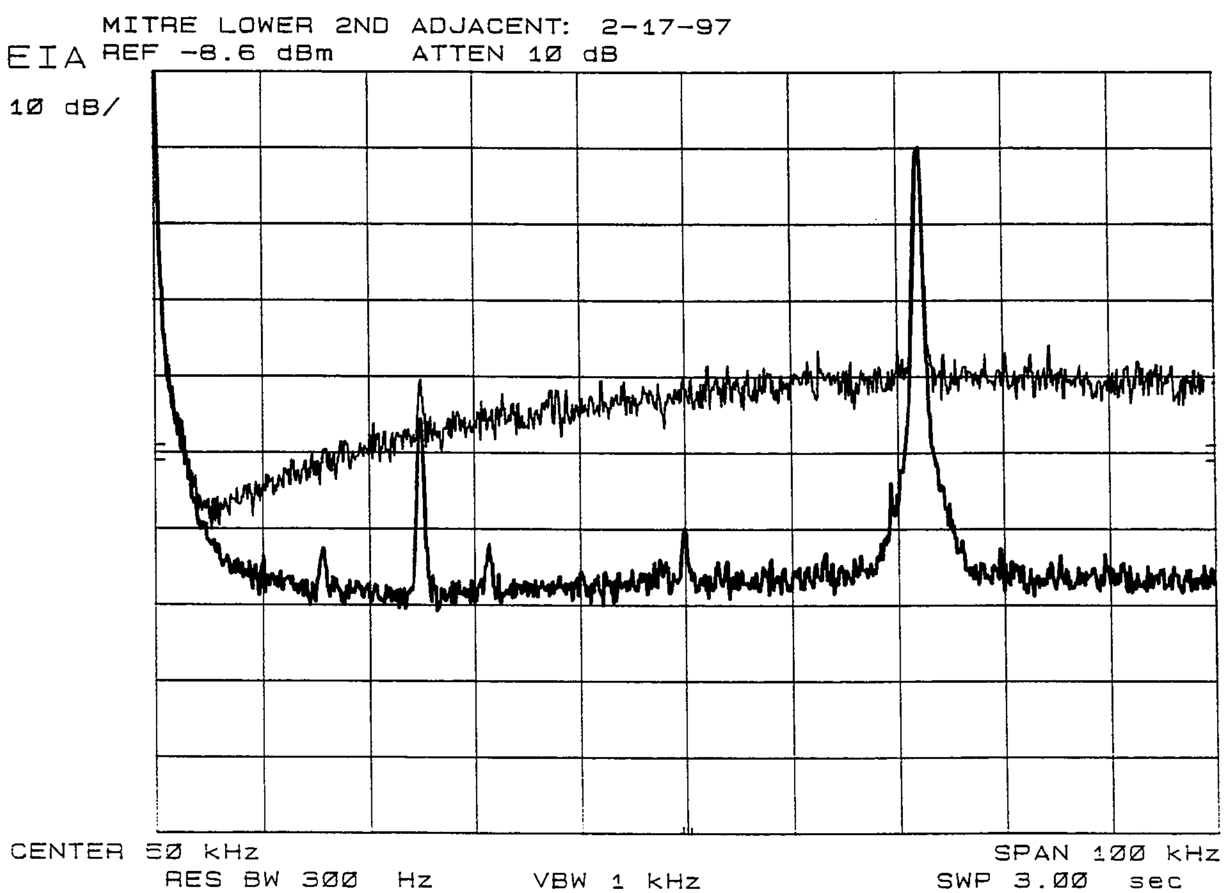
Digital Radio Test Laboratory




MITRE UPPER 1ST ADJACENT: 2-17-97
EIA
REF -8.6 dBm
ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec

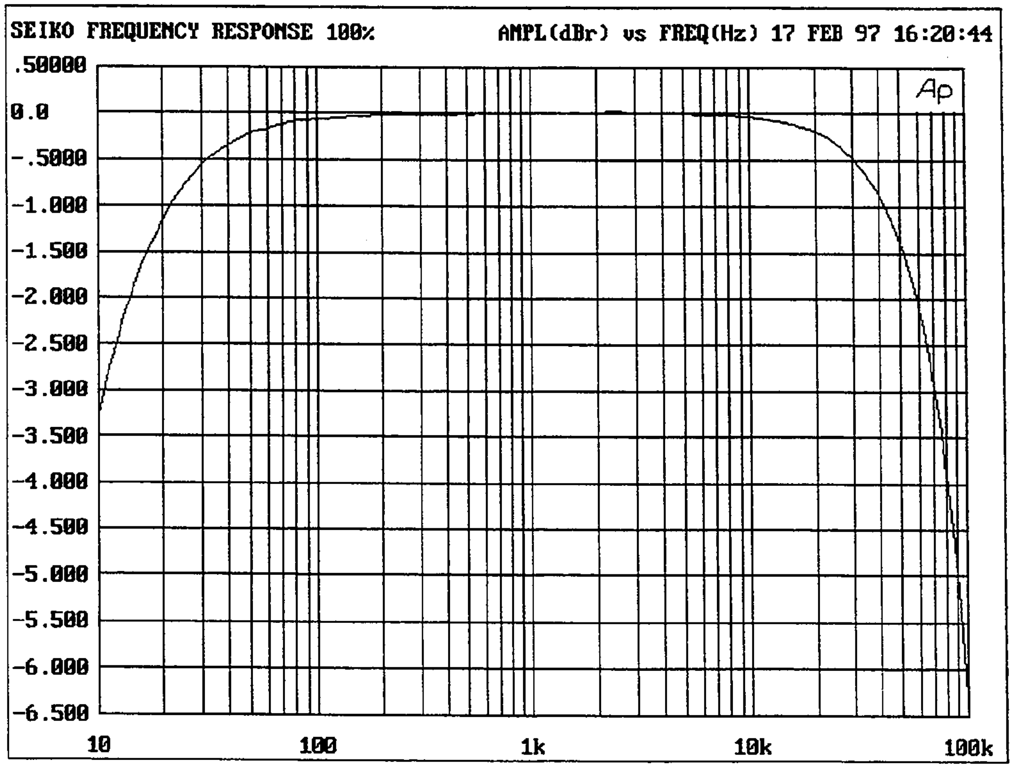

MITRE LOWER 1ST ADJACENT: 2-17-97
EIA
REF -8.6 dBm
ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec


MITRE UPPER 2ND ADJACENT: 2-17-97
EIA
REF -8.6 dBm
ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec

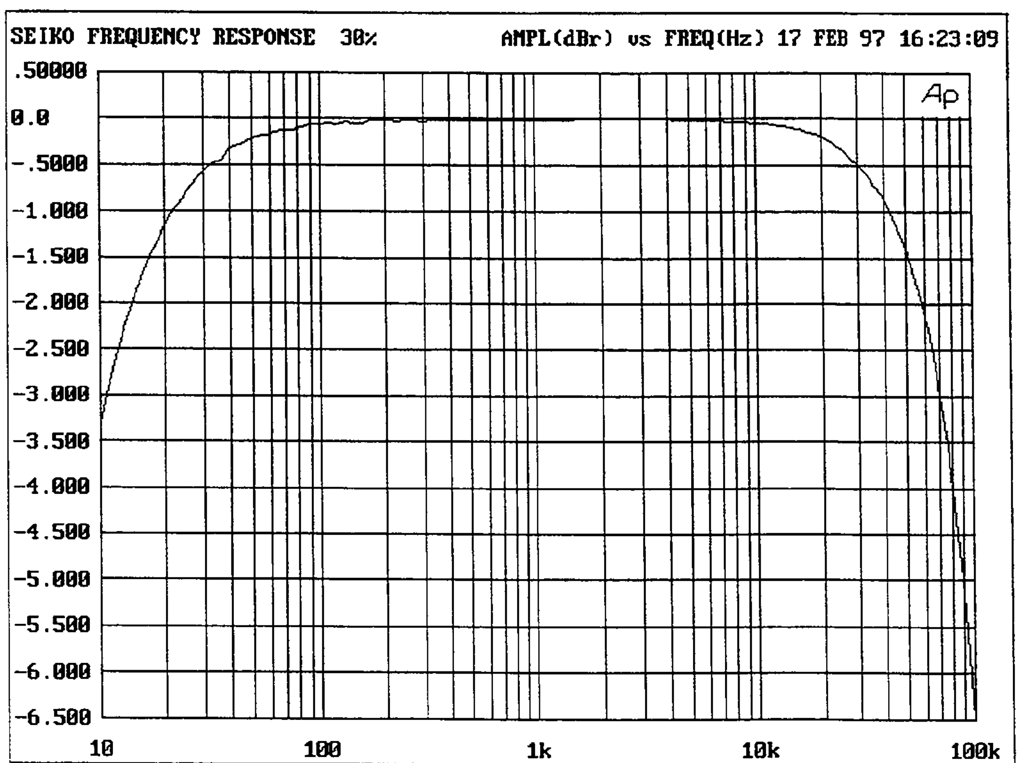

MITRE LOWER 2ND ADJACENT: 2-17-97
EIA
REF -8.6 dBm
ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec

④ (Handed out at tutorial)

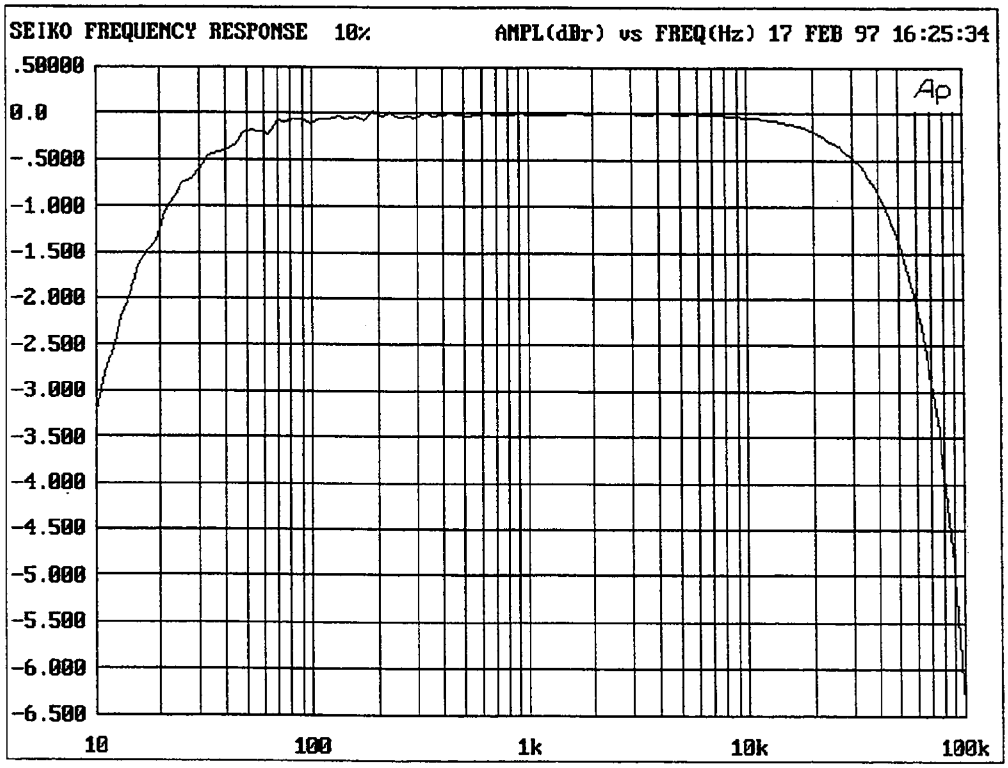
0dB = 765mVrms

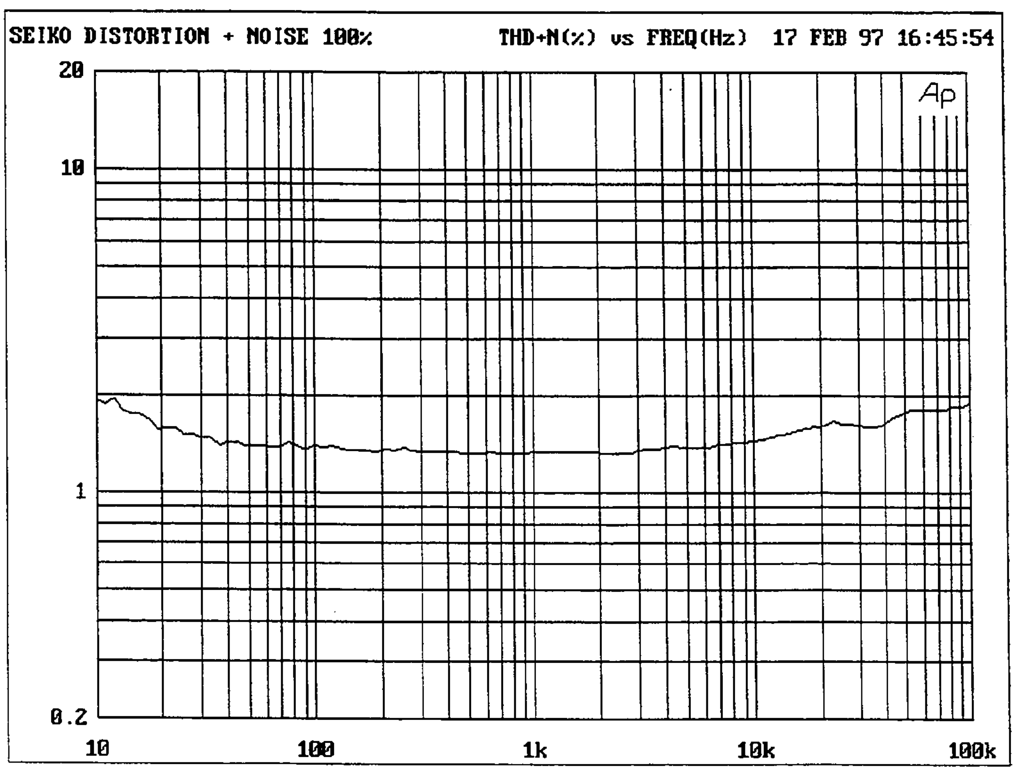


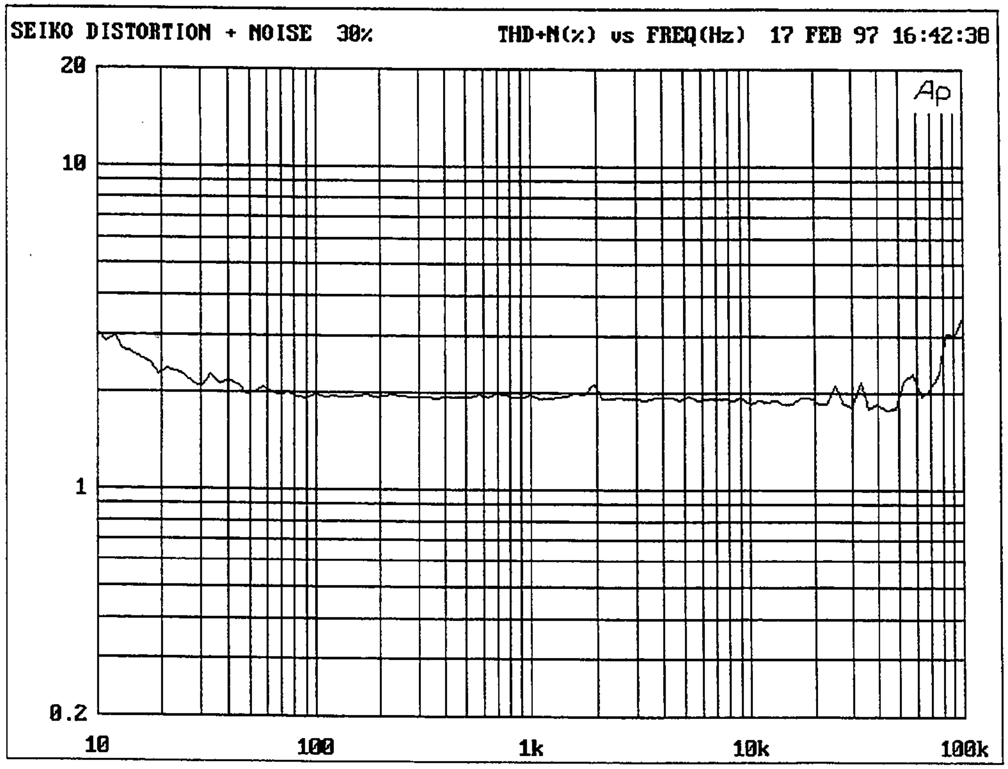
0dB = 231mVrms

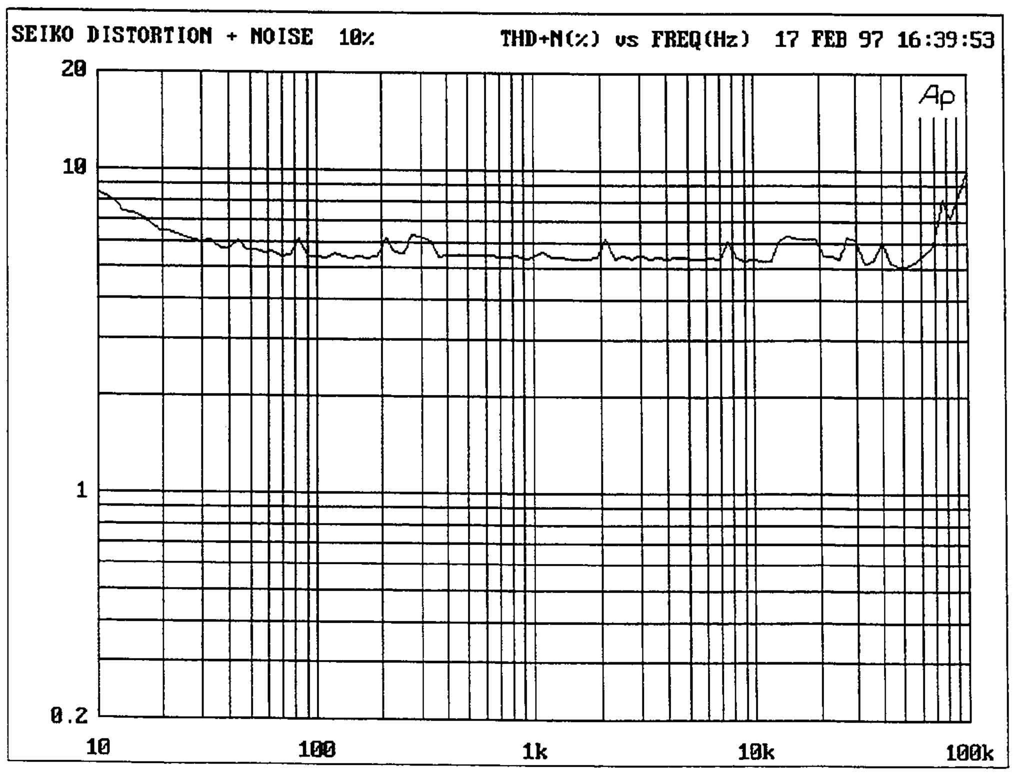


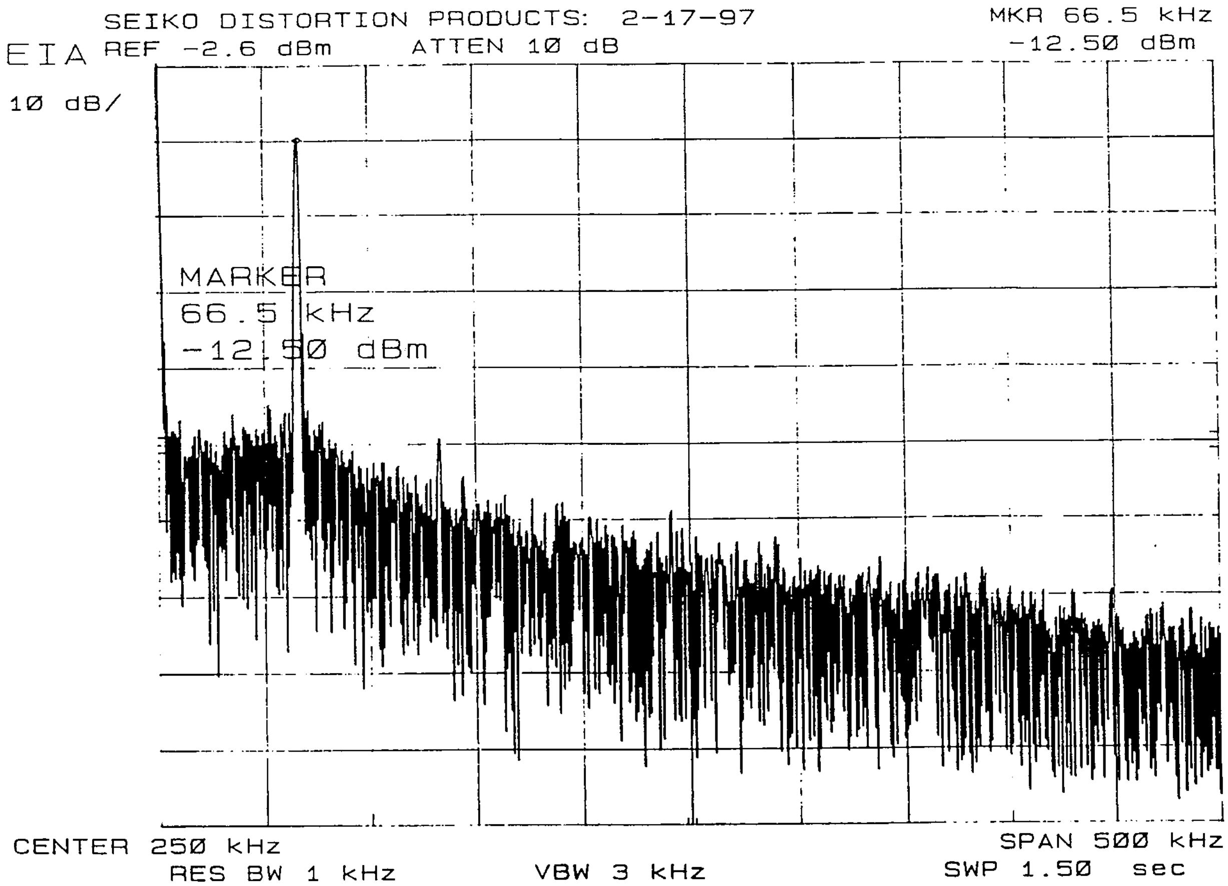
0dB = 75.5mVrms

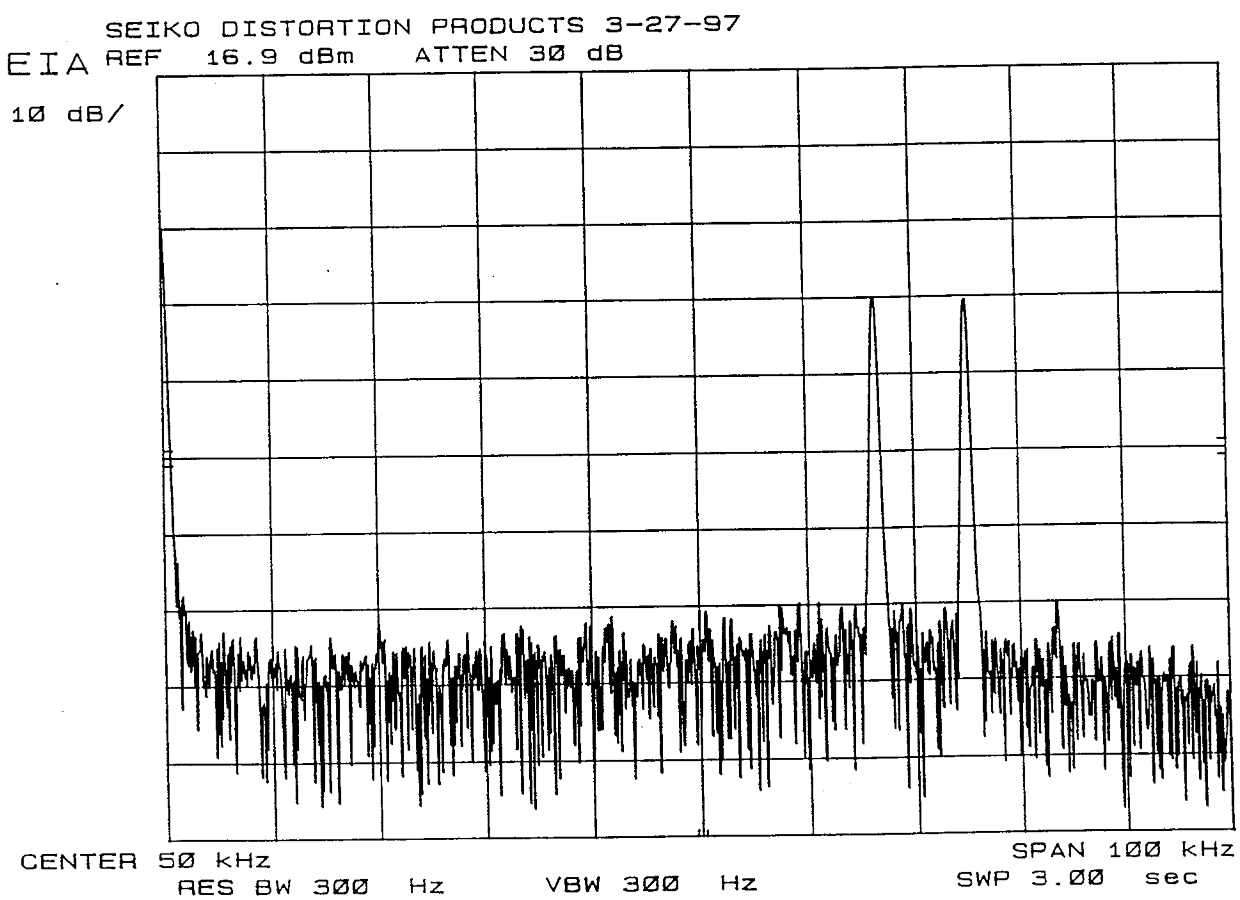





SEIKO DISTORTION + NOISE 30%
THD+N(%) vs FREQ(Hz) 17 FEB 97 16:42:38
20
10
1
0.2
10
100
1k
10k
100k
Ap


SEIKO DISTORTION + NOISE 10%
THD+N(%) vs FREQ(Hz) 17 FEB 97 16:39:53
20
10
1
0.2
10
100
1k
10k
100k
Ap


SEIKO DISTORTION PRODUCTS: 2-17-97
MKR 66.5 kHz
-12.50 dBm
EIA
REF -2.6 dBm
ATTEN 10 dB
10 dB/
MARKER
66.5 kHz
-12.50 dBm
CENTER 250 kHz
SPAN 500 kHz
RES BW 1 kHz
VBW 3 kHz
SWP 1.50 sec


SEIKO DISTORTION PRODUCTS 3-27-97
EIA
REF 16.9 dBm
ATTEN 30 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 300 Hz
SWP 3.00 sec

Digital Radio Test Laboratory

HSSC Proponent Receiver Characterization

Date: 2/17/97
By: DML

Desired Signal: 94.10 MHz **Modulation:** 1 kHz
Injection: 100 %
0dB: 764 mV

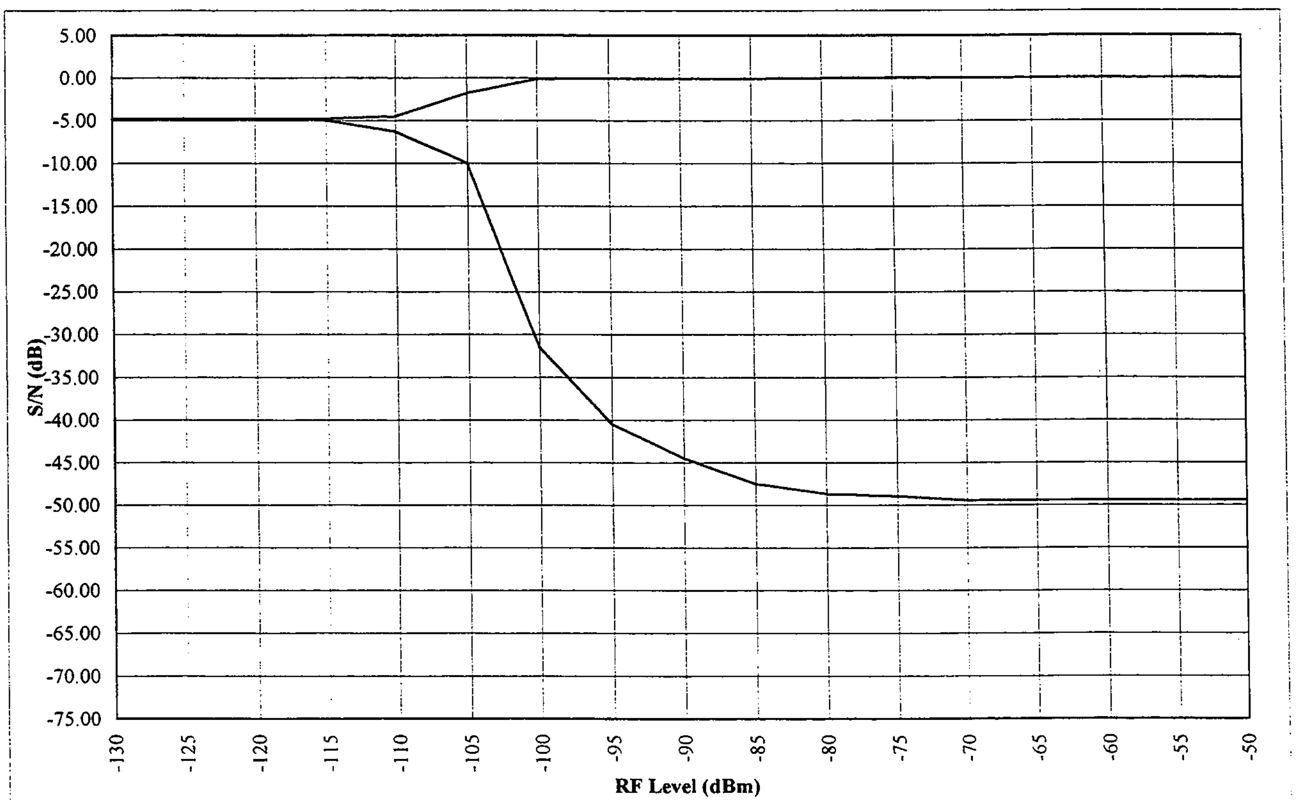
Measurement: Level; RMS, with 15kHz Low Pass Filter

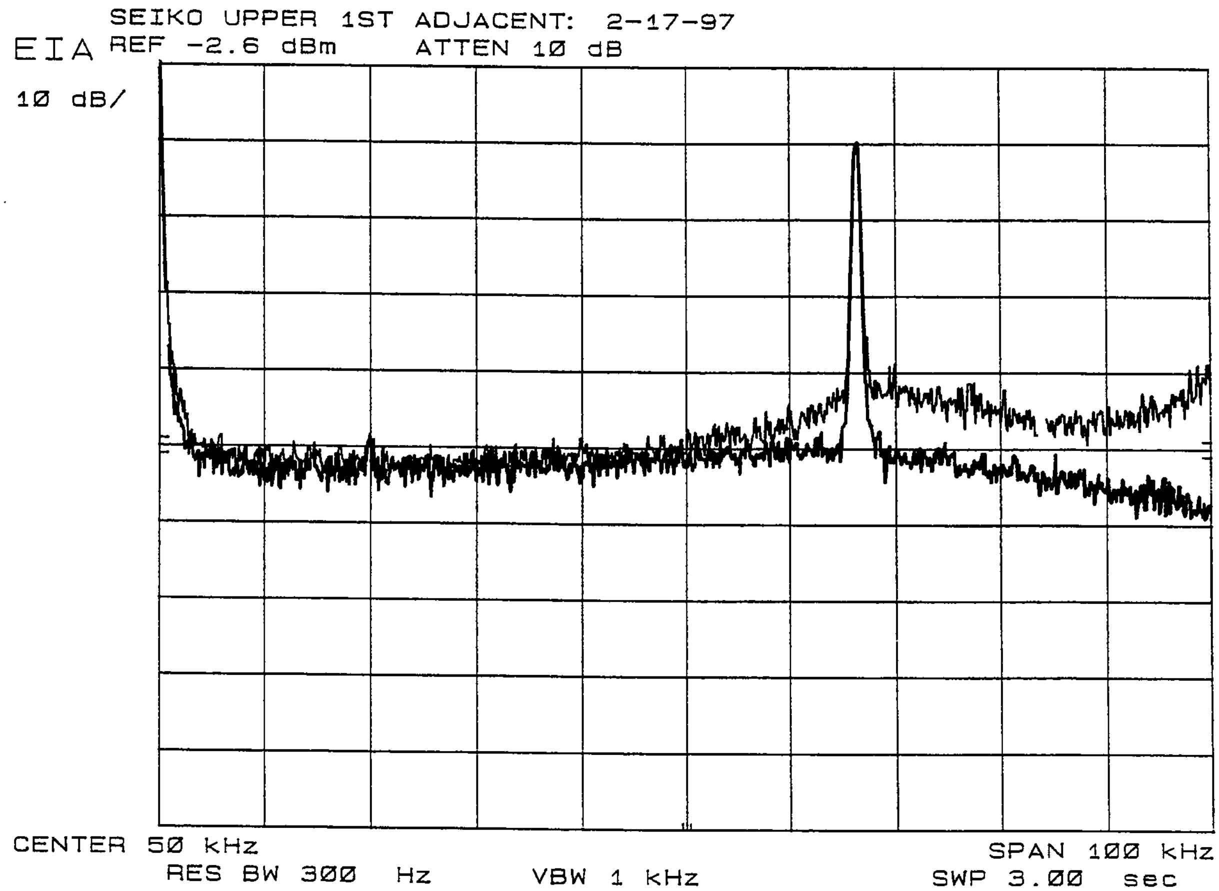
Results: S/N vs RF Level

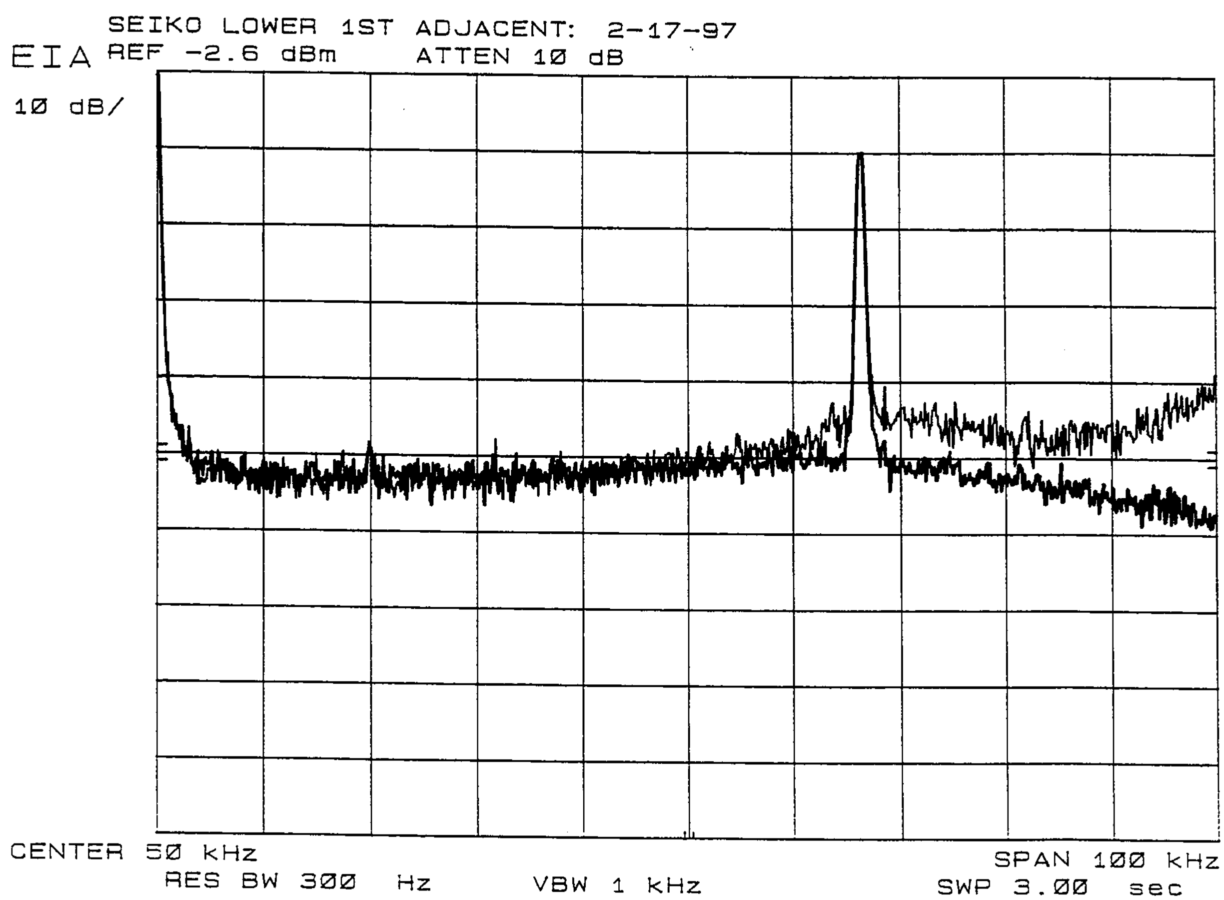
Radio Type: PC Expansion Card

	RF (dBm)	Signal (dB)	Noise (dB)
	-50	0.00	-49.50
	-55	0.00	-49.50
	-60	0.00	-49.50
	-65	0.00	-49.50
	-70	0.00	-49.50
	-75	0.00	-49.00
	-80	0.00	-48.70
	-85	-0.10	-47.50
	-90	-0.10	-44.50
	-95	-0.04	-40.50
Limiting	**-100**	**-0.15**	**-31.50**
Threshold	**-105**	**-1.80**	**-10.00**
	-110	-4.50	-6.30
	-115	-4.80	-5.00
	-120	-4.80	-4.80
	-125	-4.80	-4.80
	-130	-4.80	-4.80

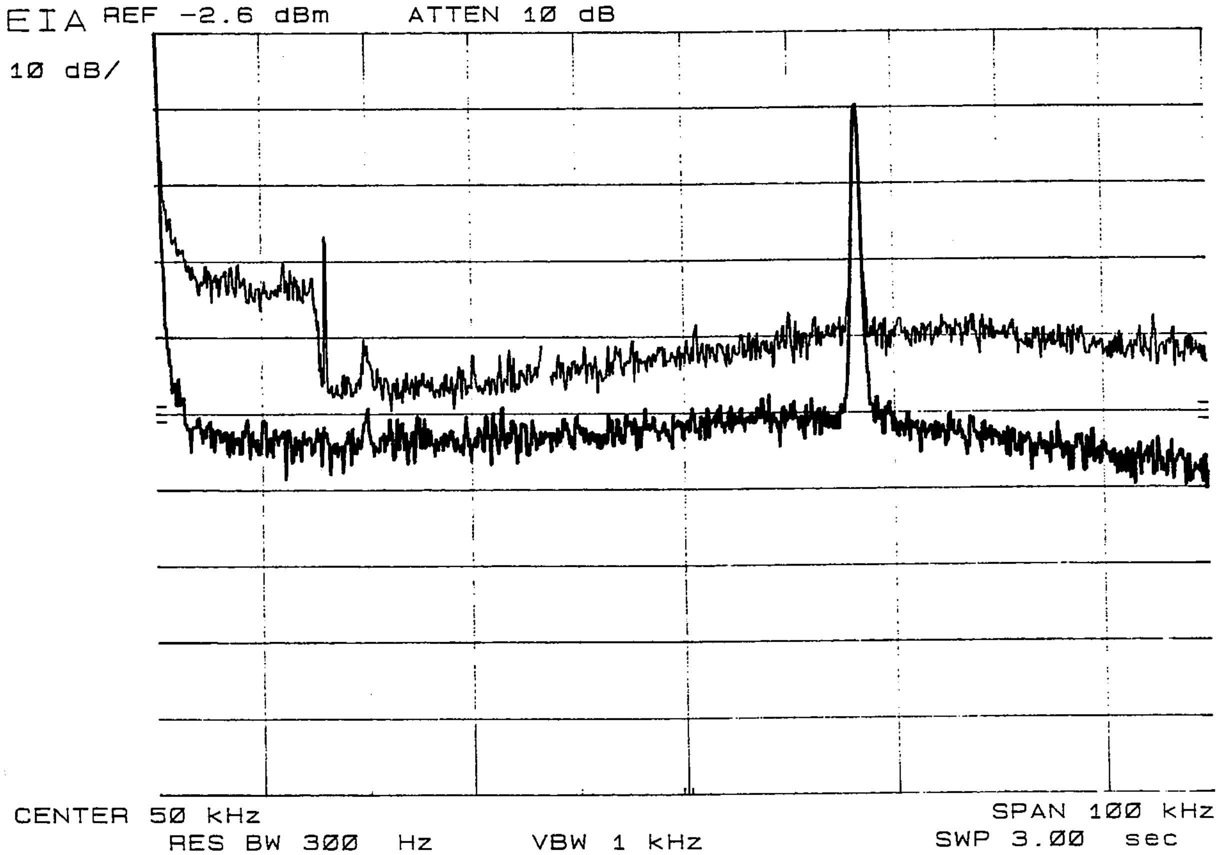
Digital Radio Test Laboratory



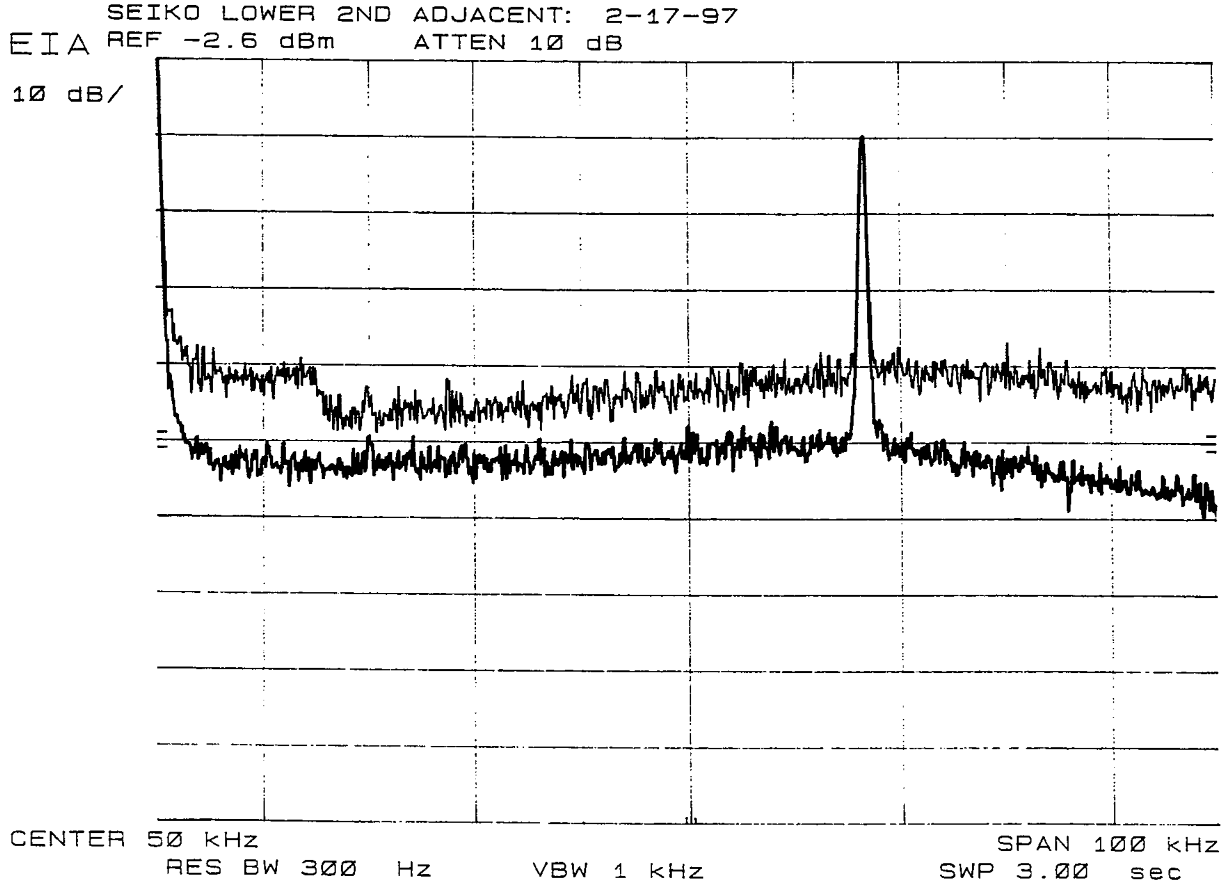

SEIKO UPPER 1ST ADJACENT: 2-17-97
EIA REF -2.6 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec


SEIKO LOWER 1ST ADJACENT: 2-17-97
EIA REF -2.6 dBm ATTEN 10 dB
10 dB/
CENTER 50 kHz
SPAN 100 kHz
RES BW 300 Hz
VBW 1 kHz
SWP 3.00 sec

SEIKO UPPER 2ND ADJACENT: 2-17-97



SEIKO LOWER 2ND ADJACENT: 2-17-97



(Attachment 1)

Appendix P

Co/No Adjustments

Methods for Expressing Signal to Noise Ratios in HSSC Tests

Co/No Adjustments

Introduction

Performance of digital communications systems is often characterized in terms of message error rate (MER) and the required Co/No for these error rates. Co/No is a measure of the signal to noise ratio required for a given performance (see discussion of methods for expressing signal to noise ratio below). In general, for a given MER, the lower the required Co/No the better, since this implies that the system will continue working (i.e. performing with a usable MER) even at lower received signal powers.

A full characterization of a system's MER performance (in fading conditions or otherwise) can be thought of in terms of a "waterfall curve" which is a plot of MER *vs*. Co/No. However, for the tests performed as part of the NRSC's evaluation of HSSC systems, only one point on this curve was typically measured, for each of several fading conditions, for each system of interest, and for each of several message lengths. This was done in the interest of reducing the time needed to complete testing, which was necessary because of the many test combinations required.

Consequently, the results in the Lab Test Report consist of a pair of numbers for each test, i.e. the MER and the required Co/No. In general, a system's performance is better if it has a lower MER and/or a lower required Co/No value. A lower MER means more reliable data, and a lower Co/No means less signal is required for the system to work, implying better station coverage and operation to receivers farther from the transmitter.

The Need for Adjustments

As recorded in the Laboratory Data Report, the Co/No values reflect a "raw" value which needs to be adjusted before it may be used as a parameter for comparing system performance. There are two adjustments that must be made:

1) As recorded in the Report, the Co/No values do not take receiver noise power spectral density (PSD) into account. Adjustments must be made to account for the fact that, in some cases, the proponent receiver front end noise was greater than the noise added as part of the test; and

2) In the case of data obtained when using the multipath simulator, a correction factor needs to be applied to account for the average received power (with multiple taps in Rayleigh mode) relative to the constant power of a single tap (in Doppler mode) in the multipath simulator.

The first of these adjustments is discussed in detail below. Details of the second adjustment mentioned above are provided in Appendix L to the Laboratory Data Report. However, a table of values for the second adjustment is included here, as well, for convenience.

> *Important note (included as a result of action taken at the 6/25/97 HSSC Subcommittee meeting): the adjustments discussed in this appendix are still being studied and any changes or additions will be reported to the Subcommittee and distributed to holders (on record) of the data report.*

A point of clarification is in order regarding exactly what "Co/No" refers to, as it occurs in the Lab Data Report. The values presented in the Report are most accurately described as "Subcarrier Co/No" since they reflect the power in the subcarrier (which is only a fraction of the total RF carrier power). The relationship between RF carrier and subcarrier PSD is explained in Attachment 1 to this appendix.

Determination of Receiver Noise Power Spectral Density

Figure 1 depicts the basic approach used in the HSSC tests to alter signal to noise ratio (and hence Co/No). When tests requiring a changing signal to noise ratio were done, noise was added to the signal (see also, for example, page 5 of the Lab Test Report), as opposed to the alternative approach which is to simply reduce the signal level to the receiver. Assumed in the added-noise approach is the fact that noise energy due to the front end of the receiver does not significantly affect system performance, and furthermore that variations in noise figure of the proponent receivers are not a factor in evaluation.

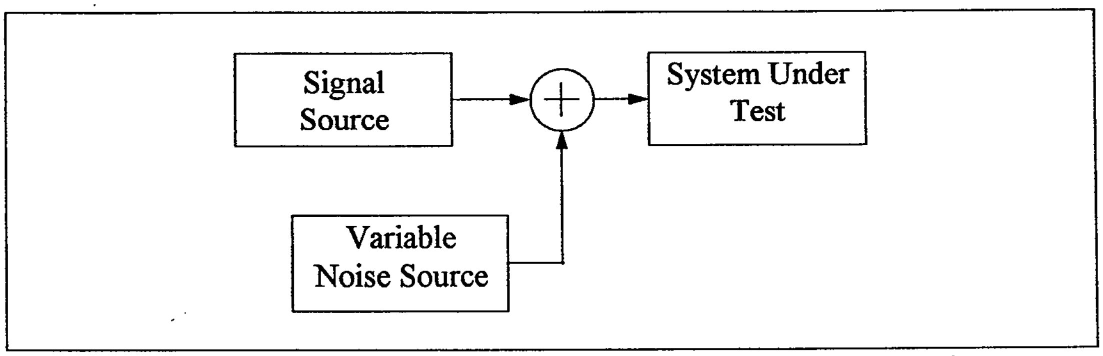


Figure 1. Approach used in HSSC Tests to Vary Signal-to-Noise Ratio

In the HSSC system evaluations, with the additive noise reduced to zero, in some instances message errors still occurred. In these cases, the noise added by the proponent receiver must be characterized to determine the Co/No under which this "no-noise" MER is occurring. The purpose of the following analysis is to determine the noise level added by the proponent receivers, and then to estimate the actual Co/No values for this data.

The first step in this analysis is to determine the noise PSD associated with each proponent receiver. This can be determined by comparing the unfaded system performance measured under two different test conditions. In particular, the results from Test B-1 and Test B-6 can be compared as shown in Table 1.

In the first row of Table 1, the recorded value of subcarrier Co/No at onset of message errors (OME) for test B-1 (system performance with noise) is given. This subcarrier Co/No value is converted to an RF carrier C/No value in row 2, which is more convenient for subsequent calculations (see discussion of methods for expressing signal to noise ratio below). The RF carrier C/No value corresponds to the required RF carrier power to noise PSD ratio at OME. This can be compared to the RF carrier power at OME measured in test B-6 test (weak signal performance). Knowing both the RF carrier C/No (row 2), and the carrier power (row 3) *at the same operating point* (OME), the noise spectral density of the proponent receiver can be estimated as follows:

$$\text{No (dBm / Hz)} = \text{C (dBm)} - \text{C/No (dB Hz)} \qquad (1)$$

The noise PSD of the proponent receivers, calculated using equation (1), is provided in row 4 of Table 1. Noise figure can also be determined as follows:

$$F\ (dB) = No\ (dBm/Hz) - 174\ (dBm/Hz) \quad (2)$$

where F is the noise figure in dB, and –174 dBm/Hz is the reference noise spectral density of thermal noise alone (at 290 Kelvin). Noise figure results are provided in row 5 of the table.

Table 1. Estimated Receiver Noise Power Spectral Densities and Noise Figures
(refer to text for detailed explanation)

No.	Parameter	Units	**DDJ**	**MITRE**	**SEIKO**
1	Subcarrier Co/No at OME (recorded; Test B-1)	(dB)	5.85	5.82	9.35
2	Corresponding RF carrier C/No at OME	(dB-Hz)	73.61	73.58	77.11
3	RF carrier power at OME (Test B-6)	(dBm)	-91.50	-92.50	-82.50
4	Estimated receiver noise power spectral density (PSD)	(dBm/Hz)	-165.11	-166.08	-159.61
5	Estimated receiver noise figure	(dB)	8.89	7.92	14.39

<u>Determining the Subcarrier Co/No of the Recorded Data With Receiver Noise Taken Into Account</u>

With the noise PSD of each receiver now estimated, it is possible to determine adjusted subcarrier Co/No values of the data at OME which will more accurately reflect the actual operating point of the systems. The parameter values for doing this are given in Table 2. In the first row, the recorded subcarrier Co/No values for each system are provided. These values are transformed into corresponding RF carrier C/No values which are given in row 2.

All fading tests were done with an RF carrier power of –65 dBm, as shown in row 3. Using equation (1) and the results given in rows 2 and 3, the PSD of the noise added to the signal can be determined. These results are given in row 4.

Next, the total noise PSD is determined by adding the contributions from "added" noise and receiver noise (in rows 4 and 5). Note that the values in the table are in decibel units, while the addition must be done using linear units (mW/Hz). After doing the necessary conversions, adding, and converting back to dBm/Hz, the results in row 6 are obtained. Notice how the receiver noise dominates in the first three columns of results, while in the fourth column, the added noise dominates.

The final step in the process is to convert the total noise to an equivalent subcarrier Co/No value. This is done in rows 7 and 8. Row 7 shows the net RF carrier C/No, which can be determined assuming a –65 dBm carrier level and using a rearranged version of equation (1) along with the values in row 6. Finally, the RF carrier C/No values can be converted to a estimate of the actual subcarrier Co/No values, as shown in row 8.

Table 2. Estimated Values of Subcarrier Co/No Taking Receiver Noise Into Account
(refer to text for detailed explanation)

No.	Parameter	Units	**No Added Noise** **DDJ** (all B3 and E2 tests)	**MITRE** (B3 and E2 tests, obstructed)	**SEIKO** (all B3 and E2 tests)	**With Added Noise** **MITRE** (maximum of B3 and E2 tests)
1	Subcarrier Co/No at OME (recorded; Tests B-3, E-2)	(dB)	63.30	63.30	63.30	17.00
2	Corresponding RF carrier C/No at OME	(dB-Hz)	131.06	131.06	131.06	84.76
3	RF carrier power (Tests B-3, E-2)	(dBm)	-65.00	-65.00	-65.00	-65.00
4	Added noise PSD	(dBm/Hz)	-196.06	-196.06	-196.06	-149.76
5	Receiver noise power spectral density (PSD)	(dBm/Hz)	-165.11	-166.08	-159.61	-166.08
6	Total noise PSD (linear sum of 4 and 5)	(dBm/Hz)	-165.11	-166.08	-159.61	-149.66
7	Estimated RF carrier C/No (taking receiver noise into account)	(dB-Hz)	100.11	101.08	94.61	84.66
8	Estimated subcarrier Co/No (taking receiver noise into account)	(dB)	32.35	33.32	26.85	16.90

Multipath Simulator Power Correction Factor

In addition to adjusting the subcarrier Co/No values recorded in the lab data report to take into account the receiver noise, an adjustment also is needed to address differences in the average received power, relative to the power from one tap of the fading channel simulator. These values have been determined elsewhere (Appendix L), but are provided here for convenience in Table 3.

Table 3. multipath Simulator Power Correction Factors

Scenario	Correction
Urban	2.45 dB
Rural	5.5 dB
Obstructed	4.0 dB

Using the corrections provided above, summaries of the test results showing performance of the systems in multipath fading are provided in Tables 4 through 6.

Table 4. Digital DJ System – Corrected Co/No Values

Subcarrier group A used for all tests

Fading scenario	Test	Report page #	Main channel audio	Recorded Co/No (dB)	Corrected Co/No (dB)	Message Error Rate (%)	
						20-byte	220-byte
Urban Slow	B-3	14	CPN	63.3	29.90	0.60	2.14
	E-2	25	CPN	63.3	29.90	2.65	4.57
	E-2	25	pilot	63.3	29.90	0.00	0.00
Urban Fast	B-3	14	CPN	63.3	29.90	6.60	33.57
	E-2	25	CPN	63.3	29.90	6.35	34.29
	E-2	25	pilot	63.3	29.90	0.27	1.86
Rural Fast	B-3	14	CPN	63.3	26.85	2.82	17.00
	E-2	25	CPN	63.3	26.85	2.69	16.43
	E-2	25	pilot	63.3	26.85	0.31	2.43
Obstructed	B-3	14	CPN	63.3	28.35	100.00	100.00
	E-2	25	CPN	63.3	28.35	65.50	98.00
	E-2	25	pilot	63.3	28.35	15.56	63.86

Table 5. Mitre System – Corrected Co/No Values

Subcarrier group A used for all tests

Fading scenario	Test	Report page #	Main channel audio	Recorded Co/No (dB)	Corrected Co/No (dB)	Message Error Rate (%)	
						20-byte	220-byte
Urban Slow	B-3	37	CPN	15.5	12.98	0.10	0.30
	E-2	48	CPN	14.5	12.00	0.03	0.15
	E-2	48	pilot	12.5	10.00	0.18	0.52
Urban Fast	B-3	37	CPN	13.5	11.00	1.13	3.26
	E-2	48	CPN	13.0	10.51	0.65	1.64
	E-2	48	pilot	11.0	8.52	1.19	3.41
Rural Fast	B-3	37	CPN	17.0	11.40	0.80	2.74
	E-2	49	CPN	17.0	11.40	0.10	0.30
	E-2	49	pilot	15.5	9.93	0.04	0.15
Obstructed	B-3	37	CPN	63.3	29.32	100.00	100.00
	E-2	49	CPN	63.3	29.32	100.00	100.00
	E-2	49	pilot	17.0	12.90	0.05	0.74

Table 6. Seiko System – Corrected Co/No Values

Subcarrier group A used for all tests

Fading scenario	Test	Report page no.	Main channel audio	Recorded Co/No (dB)	Corrected Co/No (dB)	Message Error Rate (%) 20-byte	Message Error Rate (%) 220-byte
Urban Slow	B-3	59A†	CPN	63.3	24.40	1.30	10.30
	E-2	70	CPN	63.3	24.40	n/a	10.30
	E-2	70	pilot	63.3	24.40	n/a	0.00
Urban Fast	B-3	59A†	CPN	63.3	24.40	23.20	93.70
	E-2	70	CPN	63.3	24.40	n/a	93.70
	E-2	70	pilot	63.3	24.40	n/a	77.70
Rural Fast	B-3	59A†	CPN	63.3	21.35	14.60	54.90
	E-2	70	CPN	63.3	21.35	n/a	62.30
	E-2	70	pilot	63.3	21.35	n/a	58.30
Obstructed	B-3	59A†	CPN	63.3	22.85	100.00	100.00
	E-2	70	CPN	63.3	22.80	n/a	100.00
	E-2	70	pilot	63.3	22.80	n/a	100.00

† *supplemental data taken 3/10/97*

Methods for Expressing Signal to Noise Ratios in HSSC Tests

In evaluating the various results contained in the Lab Test Report, comparisons may be made among the proponent systems. Tests in these groups fall into two categories. First, there are weak signal tests which evaluate various performance measures as the carrier power is reduced (e.g. Tests A-4 and B-6). Results of tests in this category depend on the noise figure performance of the proponent's tuner, as well as the performance of the proponent waveform. Consequently, tests in this category do not provide a good basis for comparison of the proponent waveforms.

A second category of test involves adding noise with the carrier power fixed at a moderate level (e.g. Tests B-3, C-1, and C-2). Tests in this category provide a good basis for comparison of the proponent waveforms, since noise from the tuner is obscured. Consequently, tests results in this category will be determined almost entirely by the performance of the proponent waveform.

In evaluating the results of tests using added noise, an impartial method of expressing the relative signal and noise levels must be selected. One method for expressing these levels is in terms of "C/No." This is the ratio of total carrier power to noise PSD and has units of dB-Hz. This quantity can be used to compare proponent systems in a fair and impartial way since the quantities used in calculating "C/No" will be the same for all proponent systems. Any other means of expressing the relative signal and noise levels which differs from "C/No" by a constant value which is the same for all proponents would also be fair to use.

In this report, results are reported in terms of a nominal "Co/No" which is actually a "subcarrier Co/No" since the carrier PSD utilized reflects only that fraction of the carrier power associated with the subcarrier. Conversions between these two quantities (i.e. RF carrier C/No and subcarrier Co/No), expressed in dB, can be made as follows:

$$\begin{aligned}\text{Nominal Co/No} &= \text{C/No} - 26\text{ dB} - 10\cdot\text{Log}(15\text{ kHz}) \\ &= \text{C/No} - 67.76\text{ dB}\end{aligned} \qquad (3)$$

Here, -26 dB is the nominal level of the subcarrier sidebands relative to the carrier at 10 % injection (7.5 kHz deviation), assuming a 75 kHz subcarrier (refer to Attachment 1 for a derivation of this figure), and 15 kHz is the nominal bandwidth of the proponent modulation. Note that an actual subcarrier Co/No value would vary among proponent systems due to differences in subcarrier center frequency and modulation bandwidth. However, we are more interested in maintaining a constant delta between subcarrier Co/No and RF carrier C/No, among all proponents, than we are in precise subcarrier Co/No descriptions.

Expressing performance in terms of RF carrier C/No has the disadvantage that the quantity provides little insight into performance of a real deployed system since it does not relate directly to other more familiar quantities. One way to remedy this is to express relative signal and noise levels in terms of more familiar quantities that would occur for a reference receiver. For example, a particular reference receiver could be considered which has a 200 kHz noise equivalent bandwidth (NEBW) in the intermediate frequency (IF) stages prior to FM demodulation. Relative signal and noise levels could be expressed in terms of an IF signal to noise ratio (SNR) in this receiver. Conversion between this quantity and C/No, in dB, is as follows:

$$\begin{aligned}\text{IF SNR} &= \text{C/No} - 10\cdot\text{Log}(200\text{ kHz}) \\ &= \text{C/No} - 53.01\text{ dB}\end{aligned} \qquad (4)$$

Also, substituting (4) into (3), the conversion between IF SNR and nominal Co/No, in dB, can be obtained as follows:

$$\text{IF SNR} = \text{Co/No} + 14.75 \text{ dB} \qquad (5)$$

Another familiar quantity is the field strength required for a particular receiver. This quantity can be related to C/No as follows:

$$\text{C/No} = \frac{E^2 \ \lambda^2 \ Gr}{Zo \ 4\pi \ k \ T} \qquad (6)$$

where:

E = the field strength (V/m)
λ = the wavelength (m)
Gr = the receiver antenna gain (power ratio relative to isotropic)
Zo = 377 Ω (the characteristic impedance of free space)
k = 1.38e-23 W/Hz/Kelvin (Boltzmann's constant)
T = equivalent noise temperature (Kelvin)

Expressing quantities in dB, and assuming a wavelength of 3 meters, Equation (6) can be modified to become:

$$\text{C/No} = E - F + Gr + 56.76 \text{ dB} \qquad (7)$$

where:

E = the field strength (dB μV/m)
F = the noise figure (dB)
Gr = the receiver antenna gain (dBi)

For example, consider a fictitious proponent system which requires a nominal Co/No of 20.0 dB for a particular test. This can be converted to the following:

Co/No	= 20.0 dB	
C/No	= 87.76 dB Hz	
IF SNR	= 34.75 dB	(in a reference receiver with 200 kHz IF bandwidth)
E	= 46.0 dB μV/m	(in a reference receiver with 15 dB noise figure, and 0 dBi antenna gain)

Proponent system performance could be fairly compared using any of these four quantities, as long as the assumptions are the same for each proponent.

(Attachment 1)

Digital Radio Test Laboratory

February 18, 1997

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Dear Ralph,

C_0/N_0 is defined as $\frac{\text{Signal Power Spectral Density}}{\text{Noise Power Spectral Density}}$

where,

C_0= Average Carrier Power-26 dB -10log(BW) where BW is the nominal bandwidth of the subcarrier signal which for comparison purposes is set to 15 kHz for all proponent systems and

N_0= Average Noise Power -10log(NFBW) where NFBW is the equivalent noise bandwidth of the noise filter which is 6.449 MHz.

The 26 dB factor in the above C_0 expression comes from the modulation index β, modulating frequency F_m and the Bessel Function relationship between carrier and sideband levels.

Since 10 percent injection relates to 7.5 kHz of deviation and the systems tested range in frequency from 66.5 kHz to 76 kHz the minimum β which corresponds to the minimum sideband level can be calculated as

$$\beta = \frac{7.5\text{ kHz}}{76\text{ kHz}} = .0968421$$

Then substituting into the Bessel Equation for the first sideband level yields:

$$J_1(\beta) = \sum_{n=0}^{\infty} \frac{(-1)^n \beta^{2n+1}}{n!(n+1)!2^{2n+1}} = \frac{(-1)^0 \beta^1}{1(1)2^1} + \frac{(-1)^1 \beta^3}{1(2)2^3} + \frac{(-1)^2 \beta^5}{2(6)2^5} + \frac{(-1)^3 \beta^7}{6(24)2^7} + \ldots = \frac{\beta}{2} - \frac{\beta^3}{2^4} + \frac{\beta^5}{(3)2^7} - \frac{\beta^7}{3^2 2^{11}} + \ldots$$

and where β<1 this quantity converges to $\frac{\beta}{2}$.

Then converting to decibels yields

$$\text{Sideband \#1 Level} = 20\log(\frac{\beta}{2})\text{dBc} = 20\log(\frac{.0968421}{2})\text{dBc} = -26.3\text{ dBc}$$

and with rounding the factor is thus -26 dBc.

Jim Marshall put together a document which details the conversions from C_0/N_0 to other expressions which can be used to evaluate system perfomance.

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:

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