Report No. FAA-CT-81-32

SPECTRUMS OF SIMULTANEOUS SPEECH, DATA, AND TONE CONTROL FUNCTIONS ON FEDERAL AVIATION ADMINISTRATION TELEPHONE LINES

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DATA REPORT

JUNE 1981

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-CT-81-32		

4. Title and Subtitle	5. Report Date
SPECTRUMS OF SIMULTANEOUS SPEECH, DATA, AND TONE CONTROL FUNCTIONS ON FEDERAL AVIATION ADMINISTRATION TELEPHONE LINES	June 1981
	6. Performing Orgonizotion Code
7. Author(s)	8. Performing Organization Report No.
Albert J. Rehmann	FAA-CT-81-32
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405	11. Contract or Grant No. 219-151-200
	13. Type of Report and Period Covered Data September 1979-June 1980
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In support of the Airway Facilities Service's program to provide Remote Monitoring Systems (RMS) at Remote Communications Air-Ground (RCAG) sites, the Technical Center was tasked to determine the necessary characteristics of external filters, modems, etc., which would enable RMS digital data transmission over existing site-to-center telephone lines in accordance with the Federal Aviation Administration (FAA) Specification FAA-E-2699a. Part of the task was an analysis of the spectrums of simultaneous speech and data transmission under several system conditions. The graphs obtained in the spectrum analysis are contained in this report.

17. Key Words	18. Distribution Statement
Remote Monitoring Systems Remote Communications Air-Ground	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	146	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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INTRODUCTION

PURPOSE.

The purpose of this task was to examine and display the spectrums of the simultaneous transmission of speech, control tones, and digital data over simulated existing Federal Aviation Administration (FAA) telephone lines.

The data contained in this report provide supporting documentation for the discussion and analysis in report No. FAA-CT-80-38, "Crosstalk Levels of Speech Plus Data in Remote Communications Air-Ground (RCAG)" (reference 1).

BACKGROUND.

Under amendment 2 of Task 4B of 9550-0-AAF-501-78-002, the FAA Technical Center was tasked (see reference 1) to determine the feasibility of adding a Remote Monitoring System (RMS) data channel to existing FAA telephone circuits. Although the transmission of speech plus data over telephone lines is well established as state-of-the-art, the addition of an RMS data channel to existing FAA voice grade telephone circuits posed several potential problems. The telephone circuits connecting RCAG sites and air route traffic control centers (ARTCC's) are limited bandwidth voice grade circuits which contain a voice channel and a tone channel to provide remote control of site communications equipment. Thus, the potential problems of adding an RMS data channel to the telephone circuits are: possible audible interference to pilot-to-controller communications, loss of site equipment control, as well as unreliable RMS data transmission.

Part of this task employed spectrum analysis to identify and examine any transient energy and steady state energy resulting from the interaction of existing FAA usage and proposed RMS data transmission. The energy versus frequency display of the spectrum analyzer, as opposed to the integrated energy display of ordinary voltmeters, was selected to enable the observation of interfering energy in the presence of legitimate control tones and/or voice. Data from these tests are contained in this document and are intended to serve as a reference guide when installing RMS at RCAG sites and to augment the information found in reference 1.

DISCUSSION

Voice transmission and remote control of RCAG communications equipment over present-day telephone circuits are performed by Voice Frequency Signaling Systems (VFSS's). For the ARTCC-to-site path, site equipment control functions are encoded into a combination of steady tones and pulsed tones by the VFSS (reference 2). The spectrum of the VFSS outputs and proposed RMS data channel is shown in figure 1. The audio mode (AM) sender outputs shown in figure 1 are the pulsed tones mentioned above. Combinations of these tones occur in a series of pulses, or single bursts, each of 60 milliseconds (ms) duration, whenever RCAG site equipment control functions are activated. The number of tone pulses in the series ranges from one to nine. The frequency shift (FS) sender output is the steady tone mentioned above. This tone resides at 2847.5 hertz (Hz) when the frequency shift keyer is upshifted (FSKU), such as in the absence of control functions, and downshifts to 2762.5 Hz when the frequency shift keyer is downshifted (FSKD) in order to signal control activity. For all control functions, except push to talk (PTT), the FS sender downshifts for the duration of the series of AM pulses, then upshifts. Upon the occurrence of PTT, the FS sender downshifts (to allow the proper AM tone bursts to key the desired transmitter) and remains downshifted for the duration of PTT.

The proposed RMS data rate for the ARTCC to site path was 110 baud, occupying a slot approximately 170-Hz wide centered about 2639 Hz. "Off-the-shelf" modems which conform to Bell specifications for channel structure and location were used in the tests where the data rate was 110 baud.

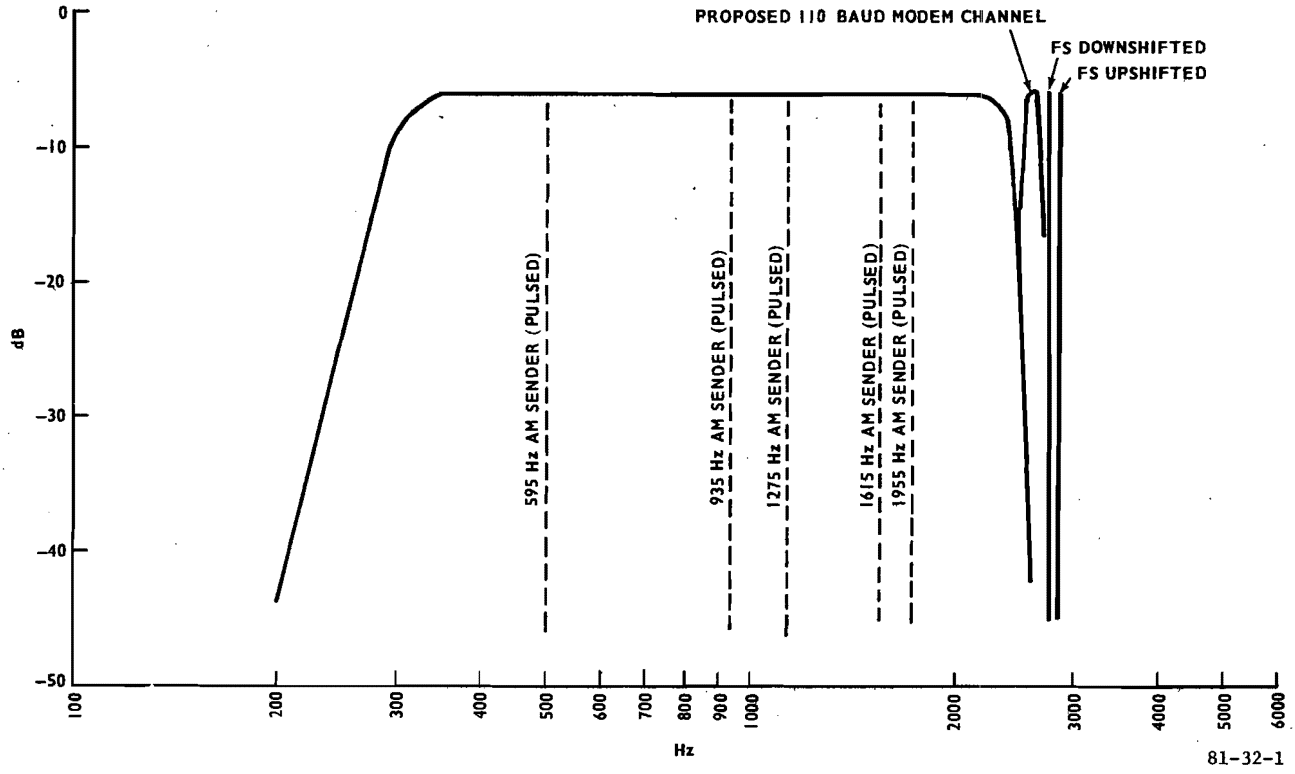

FIGURE 1. SPECTRUM OF VFSS OUTPUTS AND PROPOSED RMS DATA CHANNEL (ARTCC-TO-RCAG SITE PATH)

The site-to-ARTCC path does not contain VFSS control tones, only voice. The spectrum with proposed RMS data channel is shown in figure 2. The proposed RMS data rate for this path was 150 baud, occupying a channel approximately 240-Hz wide centered about 2640 Hz. Off the shelf modems which conform to Comite Consultif International Telephone Telegraph (CCITT) specifications for channel structure and location were used in the tests where the data rate was 150 baud.

The 110-baud modems were manufactured by Commart (model 1105); the 150-baud modems were manufactured by Teledynamics (model 7260B). Table 1 lists manufacturer's specifications and characteristics of both modems.

A total of five sample VFSS's were delivered to the Technical Center and tested; data from each VFSS may be found in the appendices to this document. The appendices are organized by equipment type:

Appendix	Manufacturer	Type
A	GRM	IM-1307
B	Telemodem	FA-8735
C	RFL	CA-1621
D	GRM	IM-2076
E	Orbitronics	FA-5390

TEST CONDUCT.

In order to simulate RMS data, four types of frequency shift keying (FSK) data were used: mark, space, 1:1, and

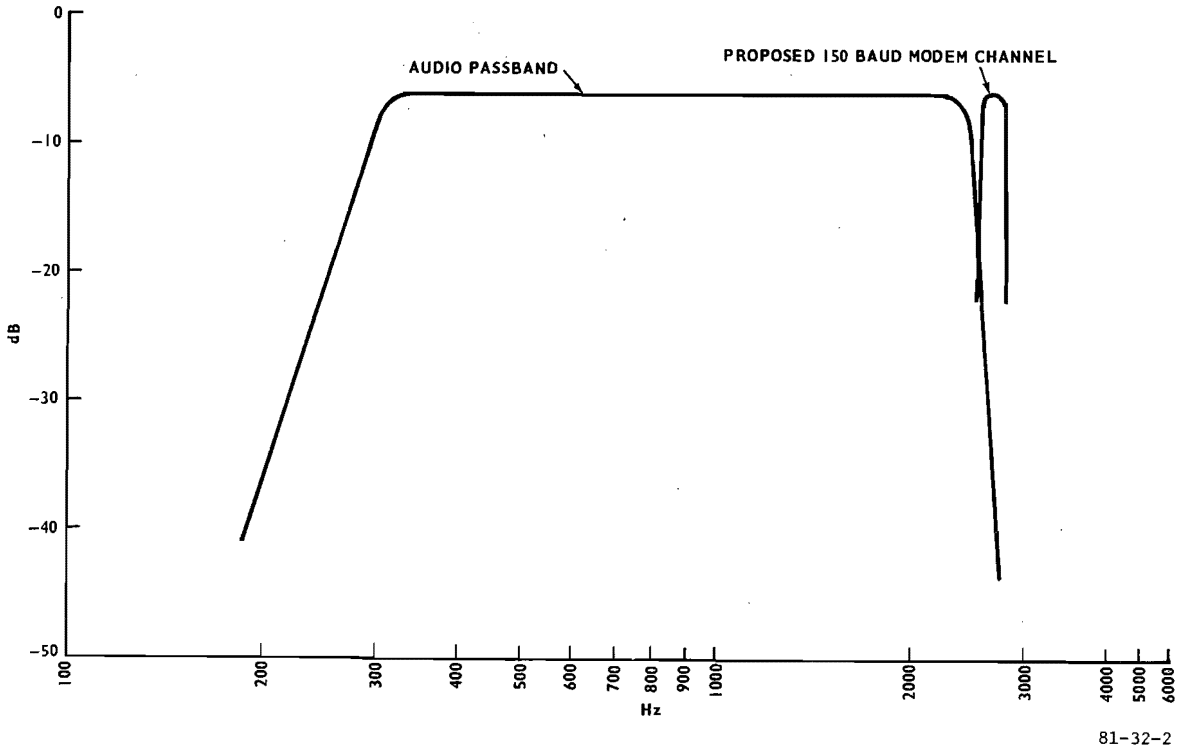

FIGURE 2. SPECTRUM OF VFSS OUTPUTS AND PROPOSED RMS DATA CHANNEL (RCAG-TO-ARTCC SITE PATH)

random. Mark and space cause steady tones that the modem outputs at the upper or lower pilot tone frequencies, respectively. An alternate mark/space pattern is called 1:1; a pseudo random mark/space pattern which repeats every 511 bits is called random. The RMS data were transmitted at both 150 and 110 baud.

The RMS data were combined (figure 3) with the outputs of the sample VFSS's and transmitted over simulated telephone lines. The response characteristics of the simulated lines were adjusted to be in accordance with FAA specification FAA-S-1142a for the simulated ARTCC-to-site path, and Bell specification 2002 for the site-to-ARTCC path (figure 4). A third configuration was also employed in these tests in which the simulator input and output terminals were jumped together. This configuration is called "back-to-back" and is not intended to represent an actual telephone line condition, but rather to show more clearly the RMS data crosstalk in the audio portion of the VFSS.

The 3-way and 4-way matching networks used in the test configuration are resistive impedance matching devices shown schematically in the insert in figure 3. The impedance looking into any port is 600 ohms and the loss from one port to any other is 6 decibels (dB) (3-way network) or 9.5 dB (4-way network), provided that all ports are terminated in 600 ohms.

The test configuration shown in figure 3 was used in other portions of this task aside from those described herein. For this reason, the random noise generator is shown in figure 3. No random noise was required in these tests so the noise generator output was adjusted for a minimum, but the generator was left in the circuit to maintain system impedence.

TABLE 1. MANUFACTURER'S SPECIFICATIONS AND CHARACTERISTICS OF THE 150 BAUD AND 110 BAUD MODEMS

Characteristics Or Feature	Specification Or Description
Operating modes	Full duplex on four-wire line with carrier controlled by request-to-send (CA). Data loopback and audio loopback.
Data format	Asynchronous serial.
Maximum channel	Channels are baud-rate transparent up to the maximum speed specified for the channel width.
	Speed / Width / Shift
CCITT compatible	75 / 120 Hz / +30 Hz 150 / 240 Hz / +60 Hz 300 / 480 Hz / +120 Hz 600 / 960 Hz / +240 Hz
Bell compatible	110 / 170 Hz / +42.5 Hz
Modulation technique	Frequency shift keying (FSK)
Telephone line interface	Private line with 3002 characteristics.
Line impedance matching	600 ohms, balanced.
Transmit output level	+2 to -50 dBm (adjustable).
Receiver sensitivity	-20 to -50 dBm (adjustable).
Data terminal interface	Compatible with EIA-Std RS-232-C and 20-ma TTY.
Interface lines	Protective ground (AA), signal ground (AB), transmitted data (BA), received data (BB), request-to-send (CA), clear to send (CB), data set ready (CC), data terminal ready (CD), received line signal data (CF).
Mark/Space distortion	5% maximum with channel operated at rated speed or less.
Data clamp (strap selectable)	Received data (BB) output is held in mark or space-hold condition when received line signal detector (CF) is off.
Controls and indication	Data audio and RTS switches; data RX, RX, RX CAR, data TX, and TX CAR indicators.
1105 Single Channel Subset	
Physical characteristics	Height: 2 inches Depth: 13.0 inches Width: 10.25 inches Weight: 5 lbs.
Input power	115-volts AC +10%, 60 Hz, 3 watts.
6105 Six Channel Assembly	
PC board complement	Up to six transceiver boards and one power supply PC board.
Physical characteristics	Height: 3.5 inches Depth: 13.0 inches Width: 17.5 inches (desk top) 19.0 inches (rack mount) Weight: 16.0 lbs.
Input power	115-volts AC +10% 60 Hz, 10 watts.

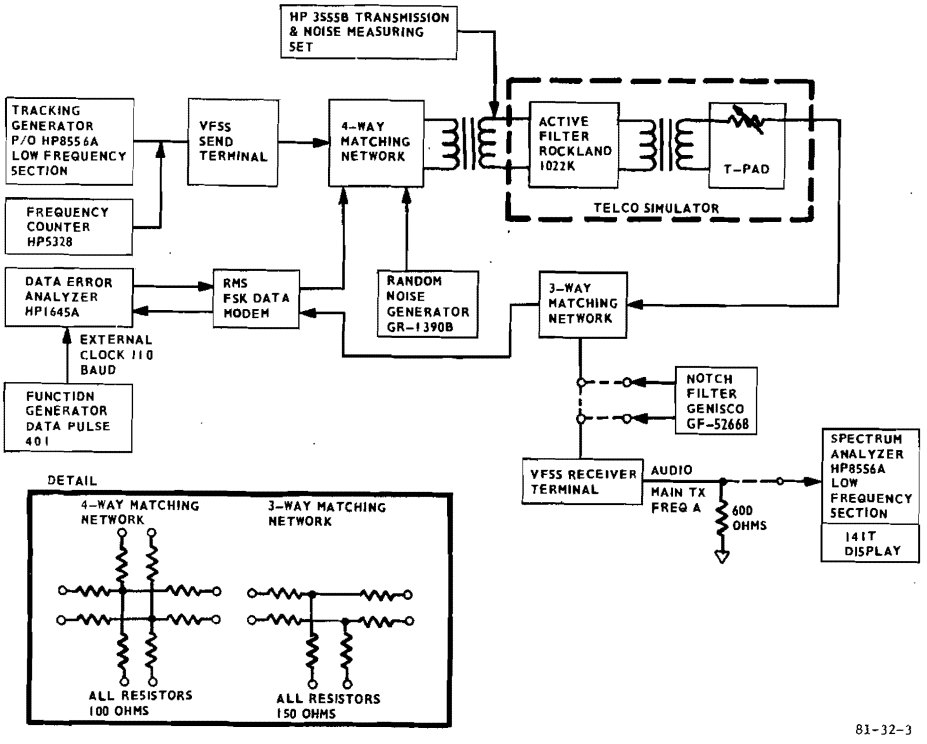

FIGURE 3. TEST SETUP

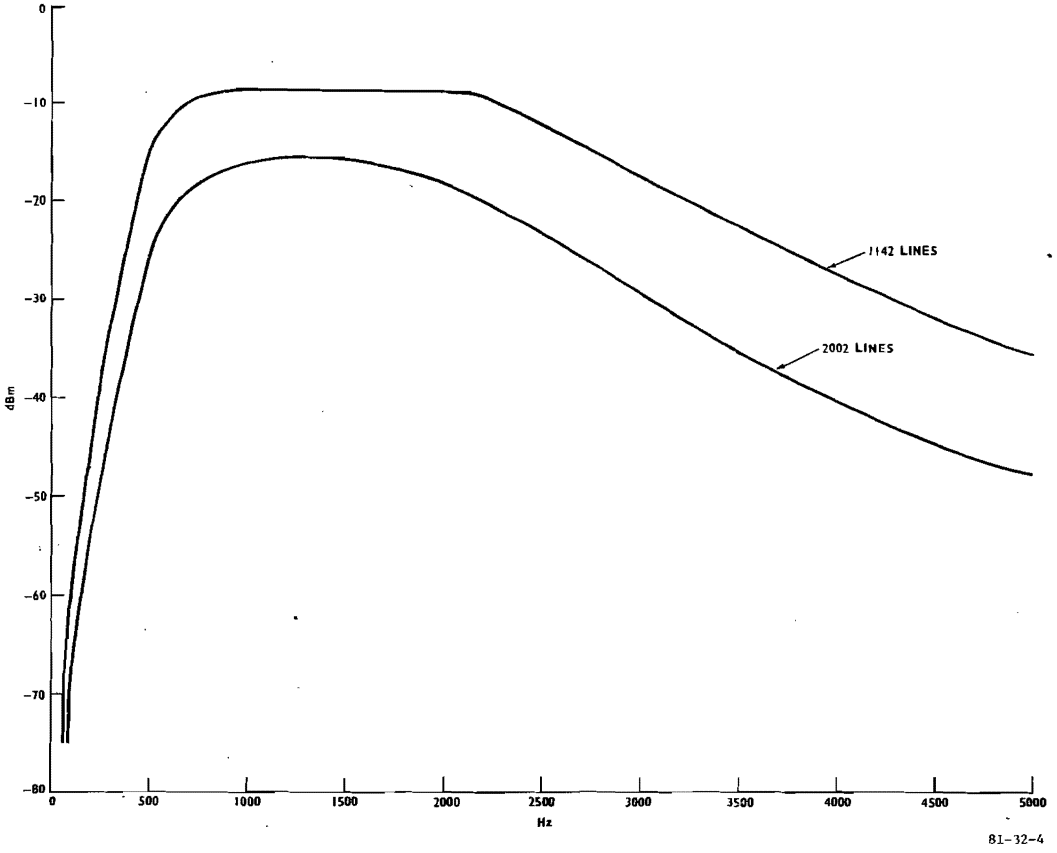

FIGURE 4. TELEPHONE LINE SIMULATOR ATTENUATION CHARACTERISTICS

Voice audio was simulated by using the tracking generator portion of the spectrum analyzer and transmitted through the VFSS. The frequency range and output amplitude of the tracking generator for each spectrum are indicated on the graph of the spectrum.

Reference signal levels used in these tests were as follows:

-16 dBm* = RMS data modem output level

-16 dBm = FS or AM sender output level

-8 dBm = Tracking generator output level measured at 1000 Hz

*decibels referenced to 1 milliwatt

These signal levels were measured at the telephone line simulator input rather than at the device outputs in order to compensate for the 9.5 dB loss across the four-way matching network. The output level of the RMS modem was measured and adjusted with 1:1 simulated RMS data. Output levels of the AM senders were measured and adjusted by activating the test switches corresponding to the desired AM senders, thereby causing the AM sender to output a continuous tone. The FS sender output was turned off during AM sender measurements. The FS sender continuously outputs a tone at either 2847.5 or 2762.5 Hz; its output was measured with the RMS data modem and tracking generator turned off.

All VFSS control functions were activated to ensure observation of the entire system behavior. The specific control functions pertinent to each spectrum which were activated are noted on the graph of the spectrum.

DATA PRESENTATION.

A discussion of each graph follows.

VFSS filter frequency response plots, as shown in the first five pages of each appendix, were made using the test setup in figure 5. These plots show the response characteristics of the internal filters in each of the VFSS equipments. They may be used to examine the interaction of the RMS data and VFSS equipments. The information provided in appendices A to E, pages 1 through 5, respectively, are listed below:

Page 1. Frequency response — audio low-pass sender filter, local terminal.

Page 2. Frequency response — audio low-pass receiver filter, local terminal.

Page 3. Frequency response — audio low-pass sender filter, remote terminal.

Page 4. Frequency response — audio low-pass receiver filter, remote terminal.

Page 5. Frequency response — AM and FS band pass receiver filters. (All six response plots are shown on this graph.)

Spectral density plots, showing interference signals generated by steady state or switched VFSS control tones and RMS data, are listed by appendices' pages 6 and 7. These spectrums are used to evaluate the amount of energy present in the RMS data channel resulting from VFSS equipment operation. The widths and locations of the data channels, shown in figures 1 and 2, extend from 2520 to 2760 Hz centered at 2640 Hz (150 baud), or from 2554 to 2724 Hz centered at 2639 Hz (110 baud).

Page 6. Expanded spectrum of switched and steady state PTT without RMS data showing FS sender output. PTT was switched at 5 Hz (to simulate control functions other than PTT).

Page 7. Spectrum of switched PTT (without RMS data) showing the outputs of the AM and FS senders. PTT was switched at 5 Hz (to simulate control functions other than PTT).

Pages 8, 9, and 10 are graphs used to examine the intermodulation products

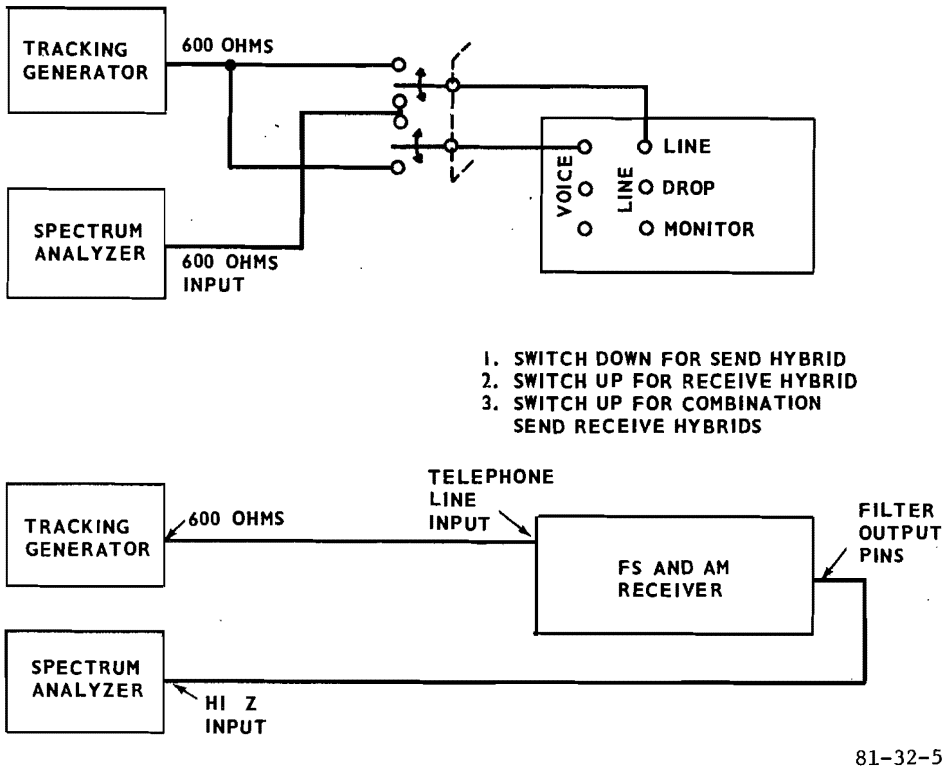

FIGURE 5. VFSS FILTER FREQUENCY RESPONSE MEASUREMENT

generated by VFSS control tones and RMS data that would lie in the audio portion of the communication channel, possibly causing audible crosstalk or false triggering of the AM receivers. The spectrums were recorded at the input of the telephone line simulator.

Page 8. Spectrum of steady state RMS data and steady state PTT. This spectrum was swept four times:

1. Mark and FSKD
2. Mark and FSKU
3. Space and FSKD
4. Space and FSKU

Page 9. Spectrum of steady state PTT and transitional RMS data. This spectrum was swept four times:

1. 1:1 data and FSKD
2. 1:1 data and FSKU
3. Random data and FSKD
4. Random data and FSKU

Page 10. Spectrum of switched PTT and transitional RMS data. This spectrum was swept twice:

1. 1:1 data and switched PTT
2. Random data and switched PTT

Pages 11 through 23 contain spectrums that were recorded at test point C (see figure 3) showing the crosstalk in the audio portion of the communication channel resulting from the RMS data. These graphs are organized via telephone line simulation in three subdivisions:

(1) pages 11 through 15 show spectrums of crosstalk in systems using simulated 1142a telephone lines, forming the ARTCC-to-site path; (2) pages 16 through 19 using simulated 2002 telephone lines, forming the site-to-ARTCC path; and (3) pages 20 through 23, using the back-to-back configuration. The list of graphs, appendices' pages 11 through 23, are as follows:

Page 11. End-to-end frequency response of the VFSS. These graphs show the characteristics of the VFSS presently in use in the field. Use these graphs for comparison to graphs on pages 12 through 23 to examine the effects of the crosstalk and external filters.

Page 12. Spectrum of crosstalk from 110-baud RMS data. No external filters are in the system and the audio tone is on for level comparison.

Page 13. Spectrum of crosstalk from 110-baud RMS data. The audio tone is removed to display the crosstalk. No external filters are installed.

Page 14. Spectrum showing the reduction of crosstalk after the addition of the external notch filter in series with the VFSS remote terminal (see figure 3).

Page 15. Spectrum of crosstalk from 110-baud RMS data after the addition of the external notch filter. The audio tone is turned on to show the attenuation of the audio passband by the external notch filter.

The conditions for graphs on pages 16 through 19 are the same as graphs on pages 12 through 15 except that the telephone line simulation is 2002 and the RMS data rate is 150 baud.

The conditions from graphs on pages 20 through 23 are the same as graphs on pages 12 through 15 except that the line simulation is back-to-back and the data rate is 110 baud.

ANALYSIS OF DATA.

Appendices pages 1 through 4 show the frequency response of the audio low-pass filters in each VFSS. The filters in each VFSS, except CA-1621 (appendix C) and FA-5390 (appendix E), have similar shape factors and cutoff points. A very notable difference in the CA-1621 and FA-5390 filter performance is the audio attenuation in the proposed RMS data channel. The other VFSS filters cut off (-3 dB) at approximately 2500 Hz, while the CA-1621 and FA-5390 filters cut off at approximately 2650 Hz. The center frequency of the proposed modem channel is 2640 Hz.

The following comments apply to all appendices except D which will be discussed separately.

Page 5 in each appendix shows the frequency response of the AM and FS receiver bandpass filters in each VFSS. The loss of each filter is indicated on the graph in the legend because the loss is not apparent from the vertical scale. The differences in filter input impedances (600 ohms) and output impedances (20 kohms AM and 100 kohms FS) affect the calibration of the vertical scale.

Page 6 of each appendix shows the expanded spectrum of switched PTT and steady state PTT. These graphs show that the transients caused by switching the FS sender are bounded by the steady state upshifted and downshifted FS sender frequencies. Therefore, interference to RMS modem equipment may be measured with the steady state upshifted and/or downshifted FS sender (reference 1).

Page 7 of each appendix shows the spectrum of switched PTT. These graphs show that transient energy from the AM senders is concentrated in bands around the sender frequencies and that intermodulation products in the modem channel are below -55 dBm.

Intermodulation products of RMS data and VFSS tones are shown on appendices' pages 8 through 10. The unmarked products, which show up darker, are actually leakage from the AM senders and are not products. Occasionally, however, a product will occur coincident with the leakage of one of the AM senders. The occurrence of this is marked on the graph. The level of products required to cause false triggering of AM receivers is at least -26 dBm measured at the telephone line simulator input (reference 2).

By comparing passbands of the audio low-pass filters (graphs 1 through 4) with graphs 8 through 10 of a particular VFSS, it may be observed that the level of products occurring in the voice band is below -75 dBm. (Note: in order for these products to be totally inaudible, the VFSS amplifiers must have been aligned with a 1-kilohertz (kHz) test tone (simulating voice audio) of amplitude no less than -10 dBm measured at the telephone line input (reference 1). In actual VFSS's, the amplifiers are aligned with a -8 dBm, 1-kHz test tone.)

The following comments apply to pages 5 through 10 in appendix D only. The IM-2706 is a VFSS which does not use AM and FS sender operation to provide remote control. Instead, desired control frunctions are encoded into digital data and transmitted at 150 baud to the site by a FSK modem identical in operation to the RMS modems, except that the IM-2076 modem center frequency is at 2880 Hz. Another difference in the IM-2076 is that the return path (site-to-ARTCC) also contains control data which are used to provide indications of remote control function actuation.

Page D-6 shows the "Expanded Spectrum of IM-2076 FSK modem." The IM-2076 integrated modem energy in the proposed RMS data channel is below -40 dBm. Energy levels higher than -27 dBm in the channel will cause errors in data transmission (reference 1).

Pages D-8 and D-9 show the intermodulation products of the RMS and IM-2076 modems. There are no significant products generated. The only spurious energy is the leakage from the IM-2076 modem, observed on page D-6, and residual noise at -85 dBm.

The following comments apply to all VFSS's.

Page 11 of each appendix shows the "End-to-End Frequency Response" of the VFSS. This graph shows the frequency response of the audio channel of the composite VFSS. Also, any leakage from the FS sender may be observed. Use these graphs for comparison to those showing the audio channel response after the addition of external filters to illustrate the attenuation by the filters.

Pages 12 through 15 display audio crosstalk from the 110 baud RMS modem in the audio channel before and after the addition of external filters. Page 12 shows the RMS data crosstalk and the test tone (used to simulate voice audio) in order to display the relative amplitudes of the tone and data. Page 13 shows the crosstalk only to display the absolute crosstalk amplitude. Page 14 shows the RMS data crosstalk in the audio portion of the channel after the addition of the external notch filter. Page 15 shows the amount of attenuation of the audio channel by the external notch filter. By comparing graphs 11 and 15, it is evident that the external notch filter does not attenuate audio signals more than 2 dB over the range 200 to 2400 Hz, as required in FAA-E-2699a (reference 3).

Pages 16 through 19 contain the same information as pages 12 through 15 except that the line simulation is 2002 and the data rate is 150 baud.

Page 20 through 23 contain the same information as pages 12 through 15 except that the line simulation is back-to-back and the data rate is 110 baud.

REFERENCES

1. Crosstalk Levels of Speech Plus Data in Remote Communications Air-Ground (RCAG), FAA Report, FAA-CT-80-38, June 1981.

2. Maintenance of Voice Frequency Signaling System VFSS Equipment, FAA Order 6650.4A, September 27, 1978.

3. RCAG Remote Monitoring Subsystem, FAA Specification, FAA-E-2699a, July 12, 1979.

APPENDIX A

IM-1307

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A-23	Spectrum of 110 Baud (RMS Data) Crosstalk After the Addition of the External Notch Filter	A-23

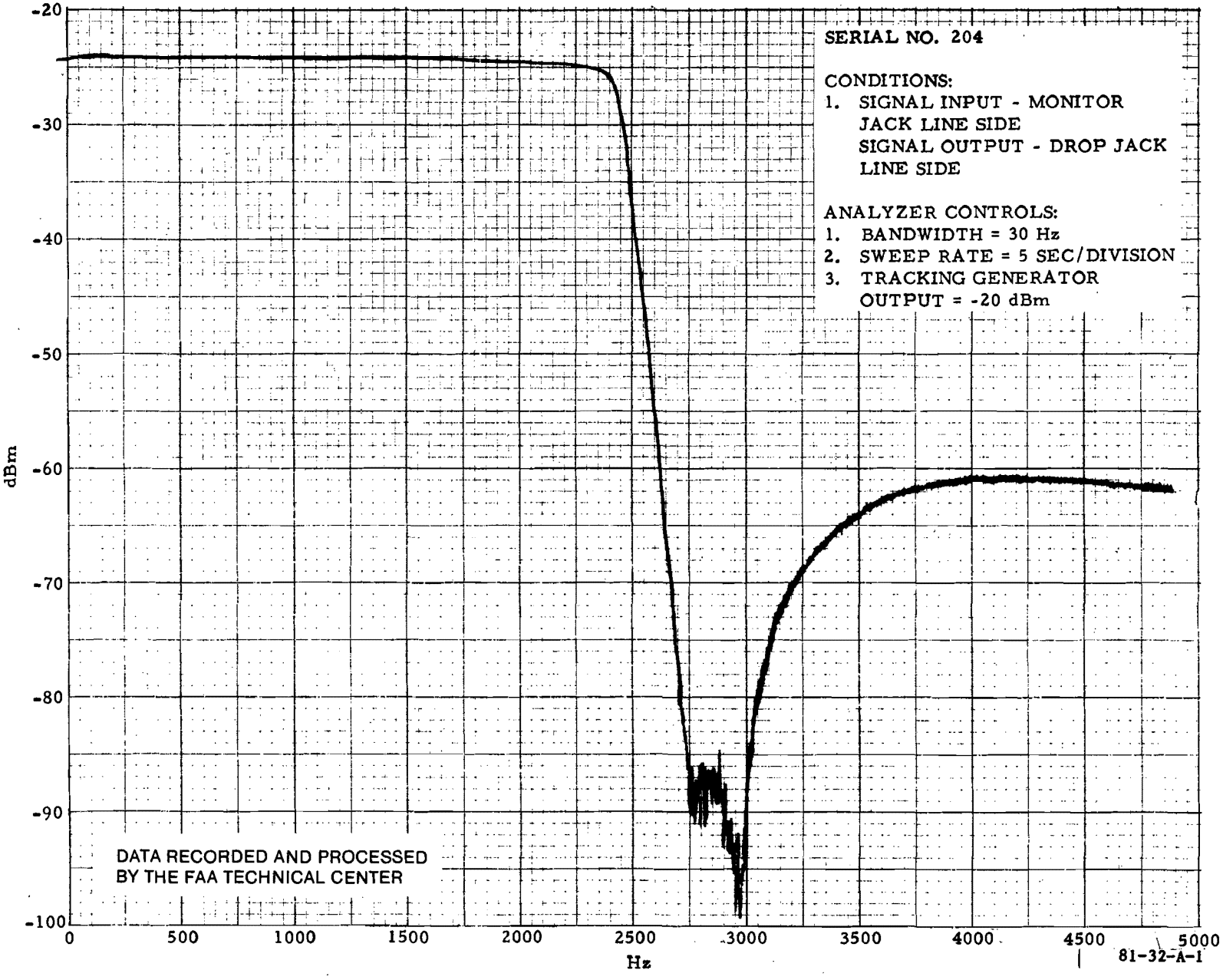


FIGURE A-1. FREQUENCY RESPONSE, SEND FILTER HYBRID-LOCAL TERMINAL

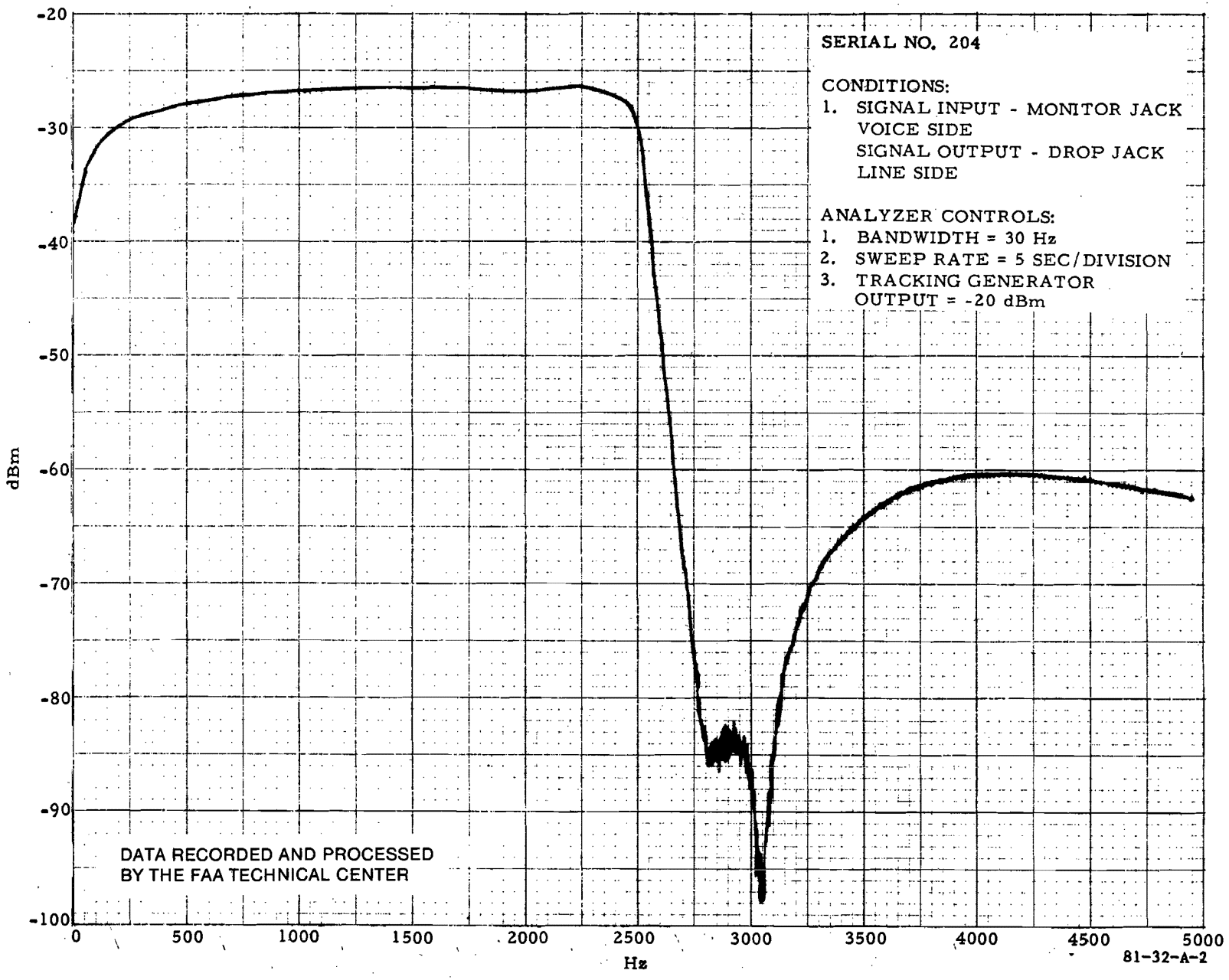


FIGURE A-2. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-LOCAL TERMINAL

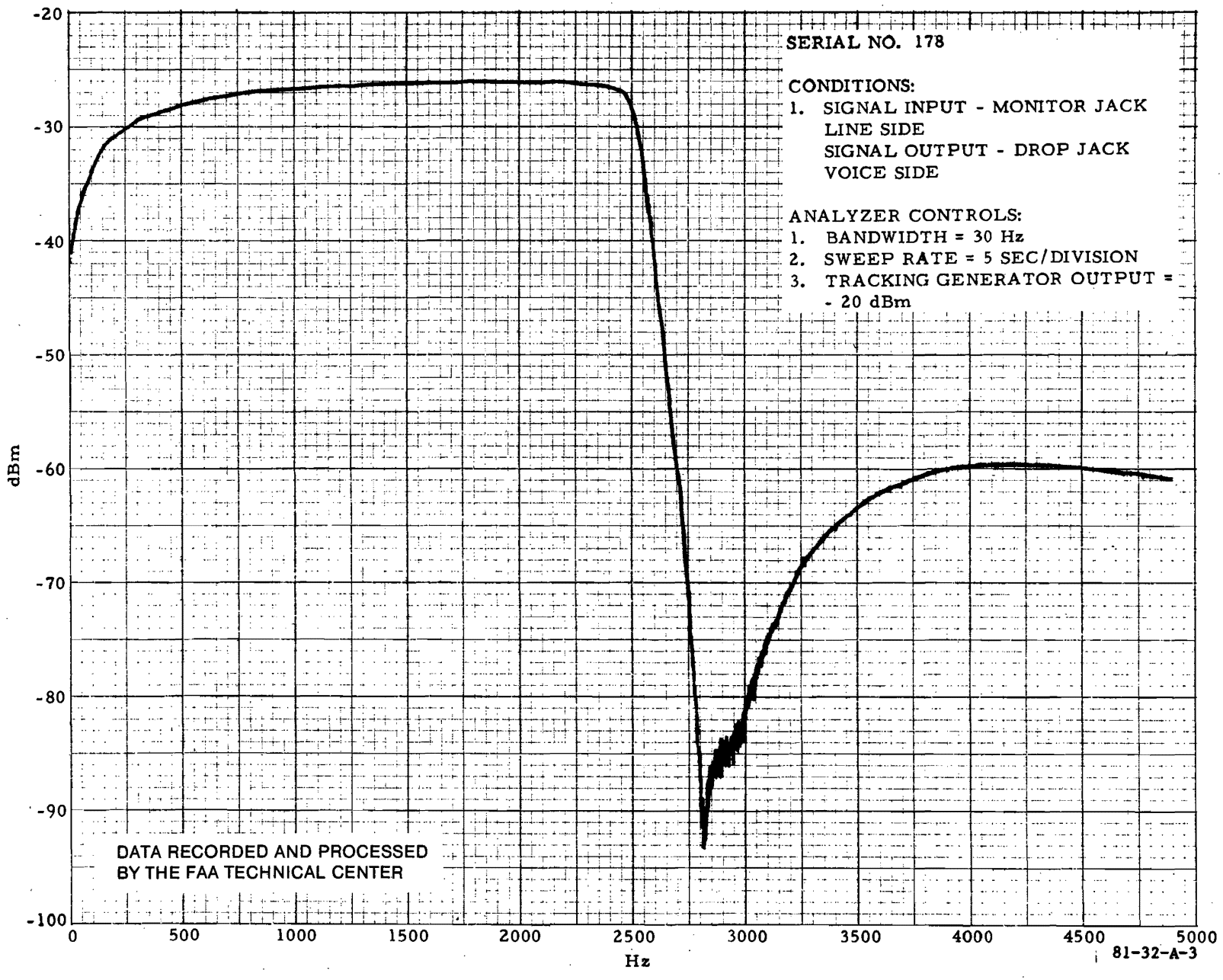


FIGURE A-3. FREQUENCY RESPONSE, SEND FILTER HYBRID-REMOTE TERMINAL

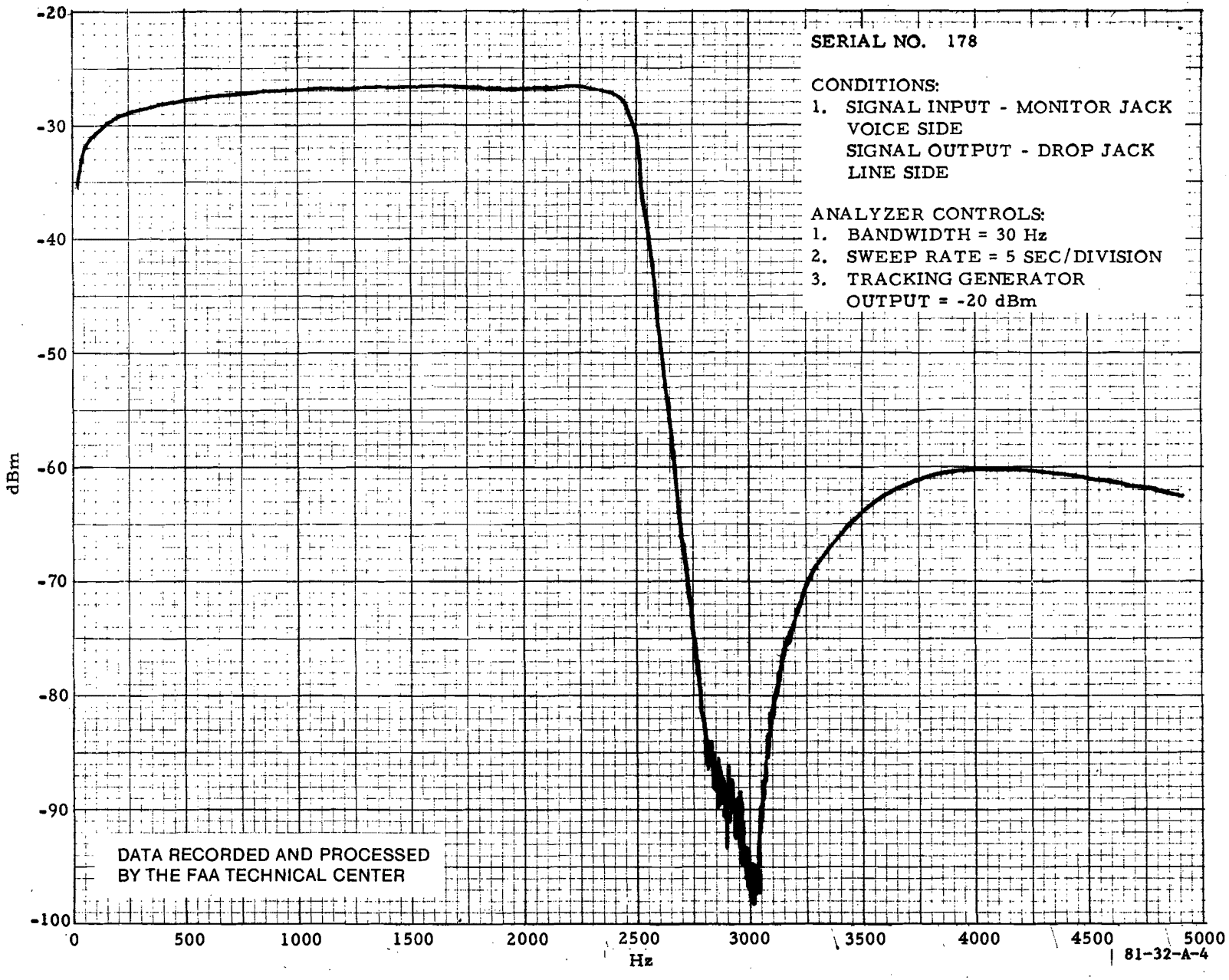


FIGURE A-4. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-REMOTE TERMINAL

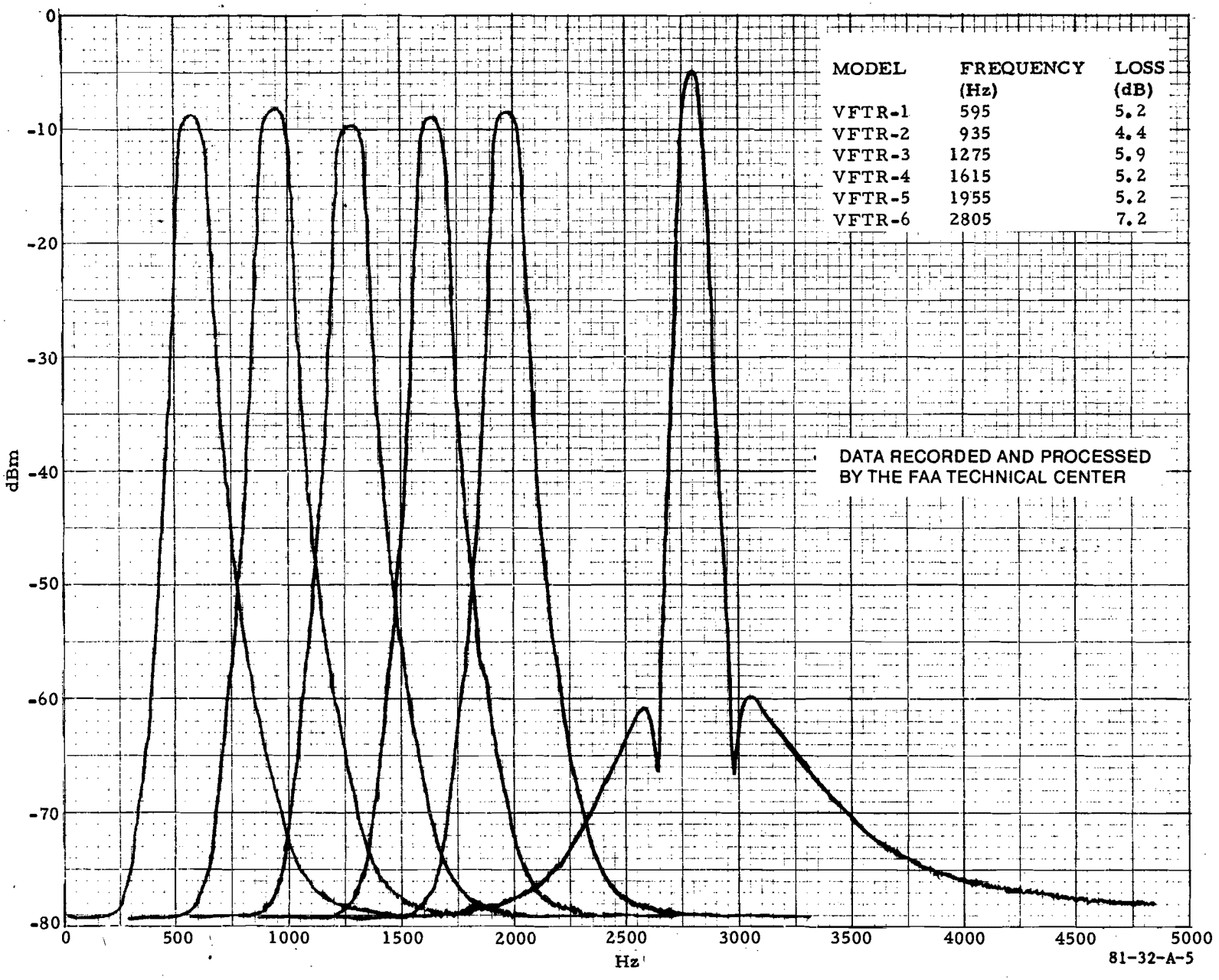


FIGURE A-5. FREQUENCY RESPONSE, AM RECEIVER BANDPASS FILTERS

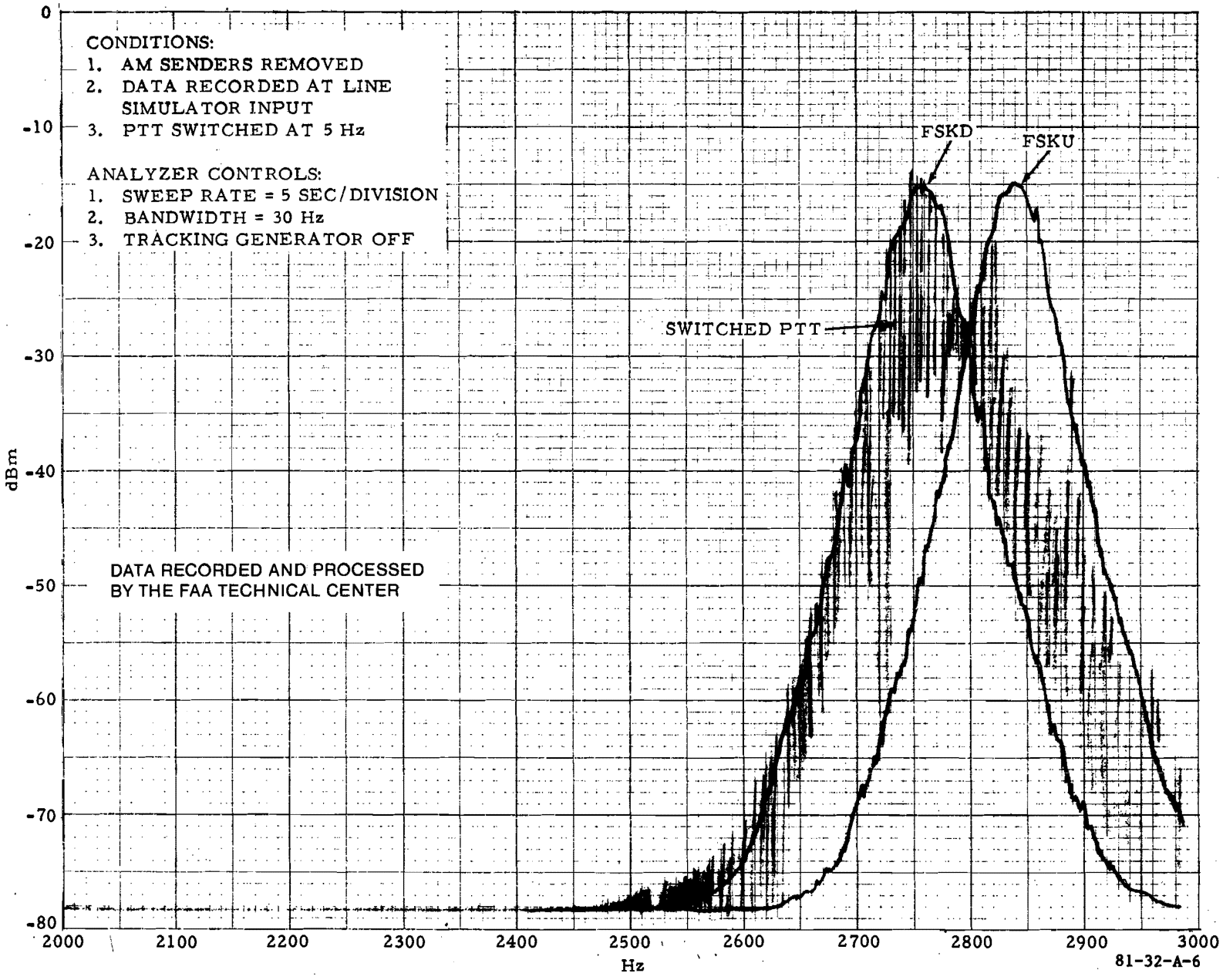


FIGURE A-6. EXPANDED SPECTRUM OF SWITCHED PTT, AND STEADY STATE PTT

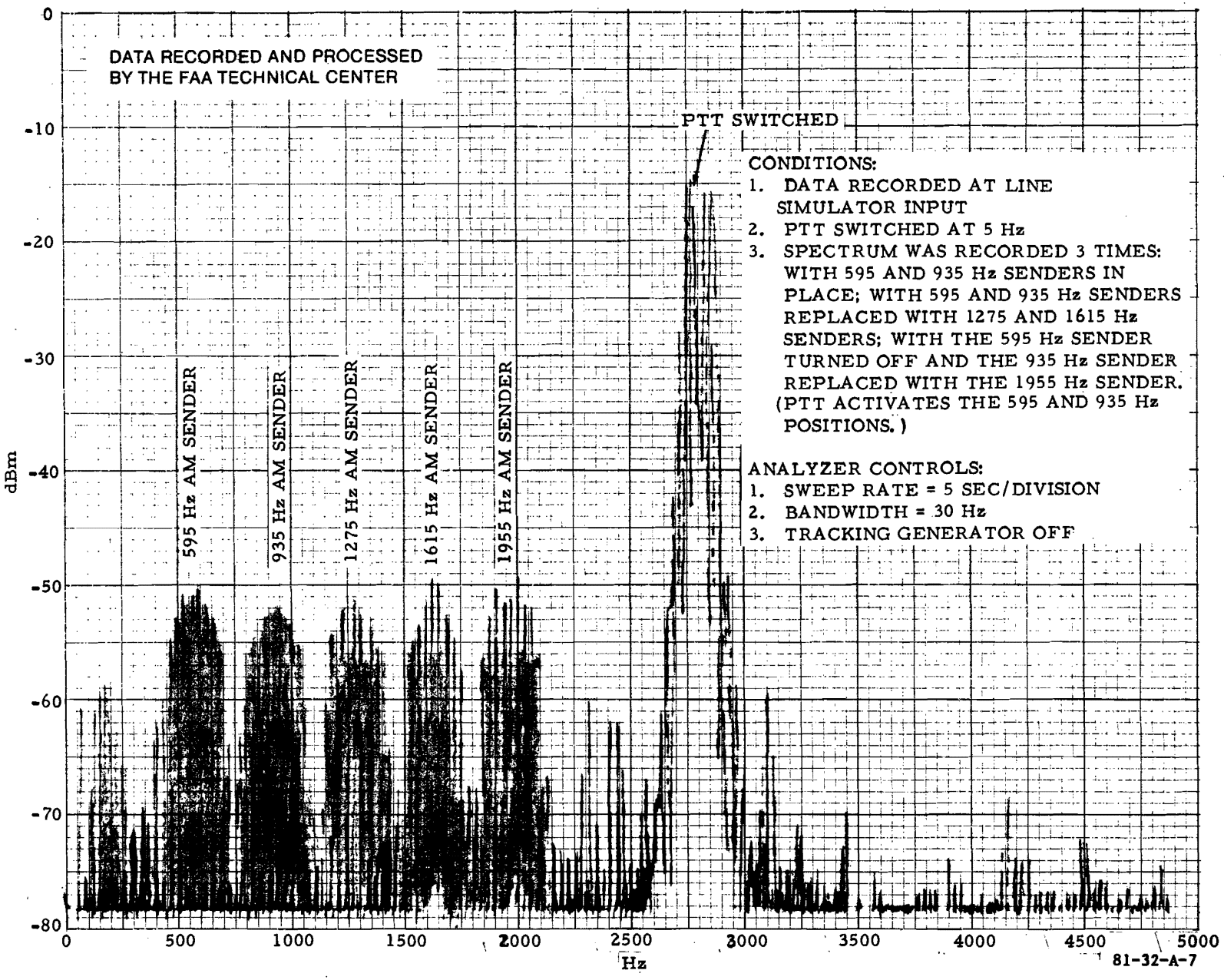


FIGURE A-7. SPECTRUM OF SWITCHED PTT

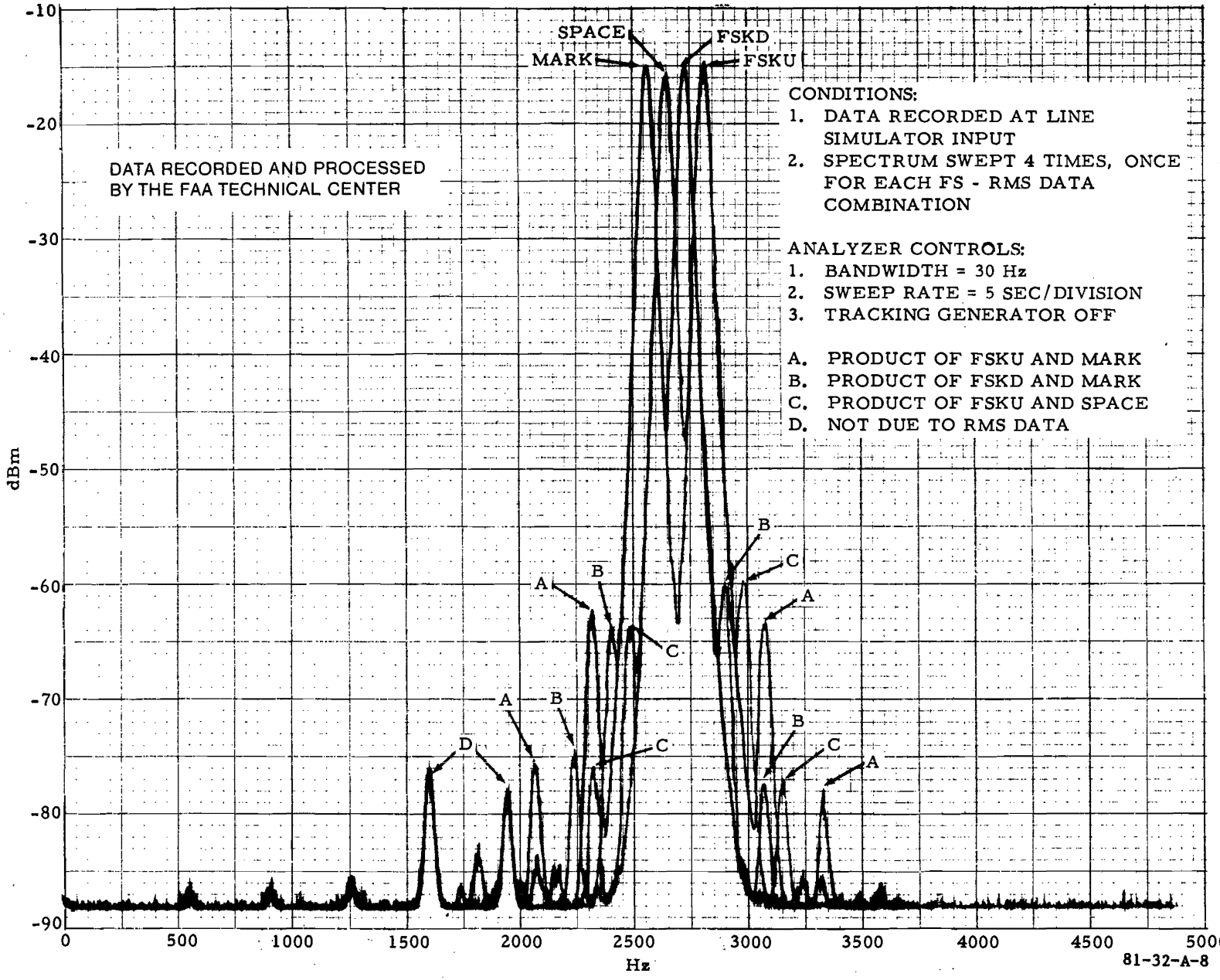
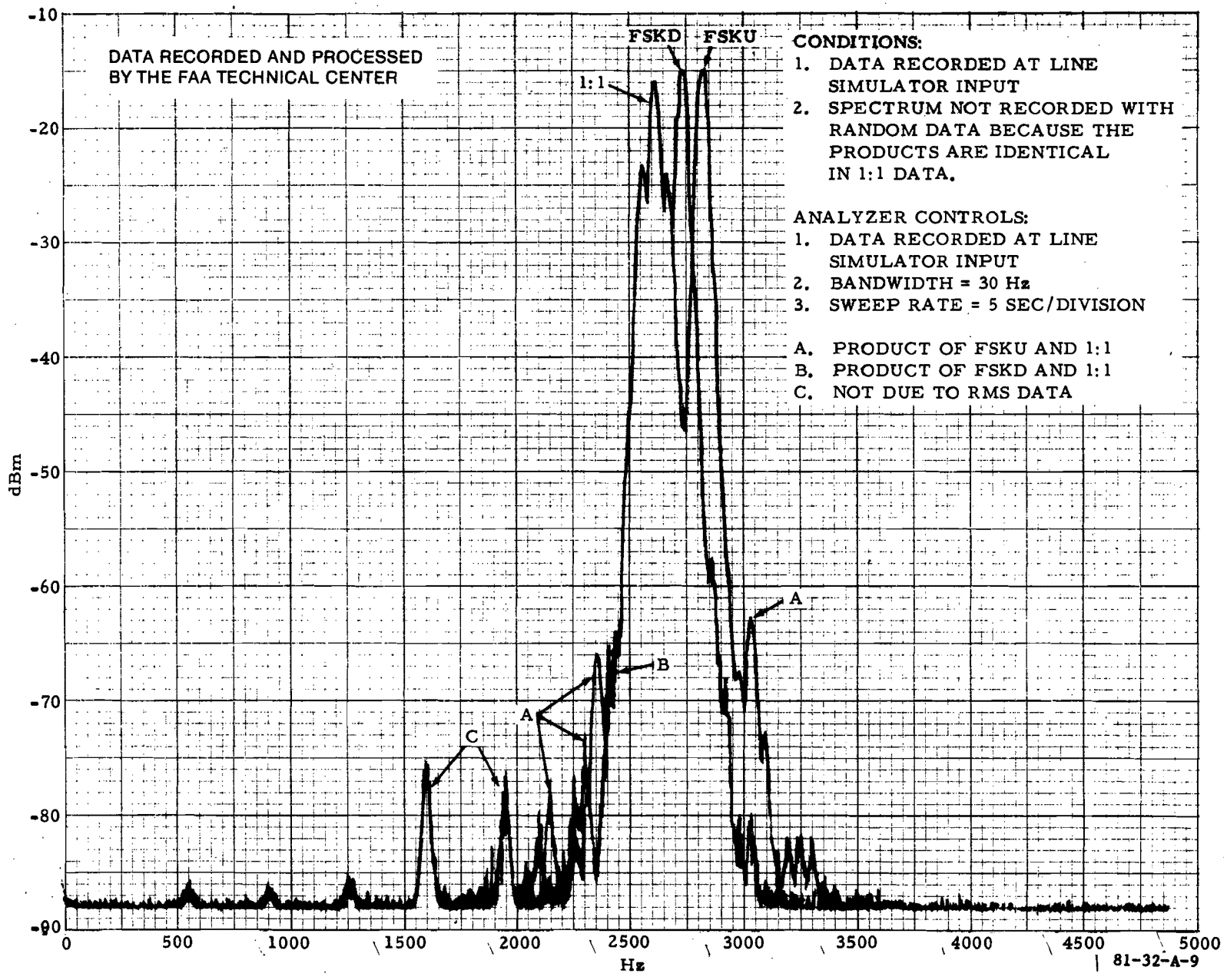


FIGURE A-8. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND STEADY STATE RMS DATA (MARK AND SPACE)



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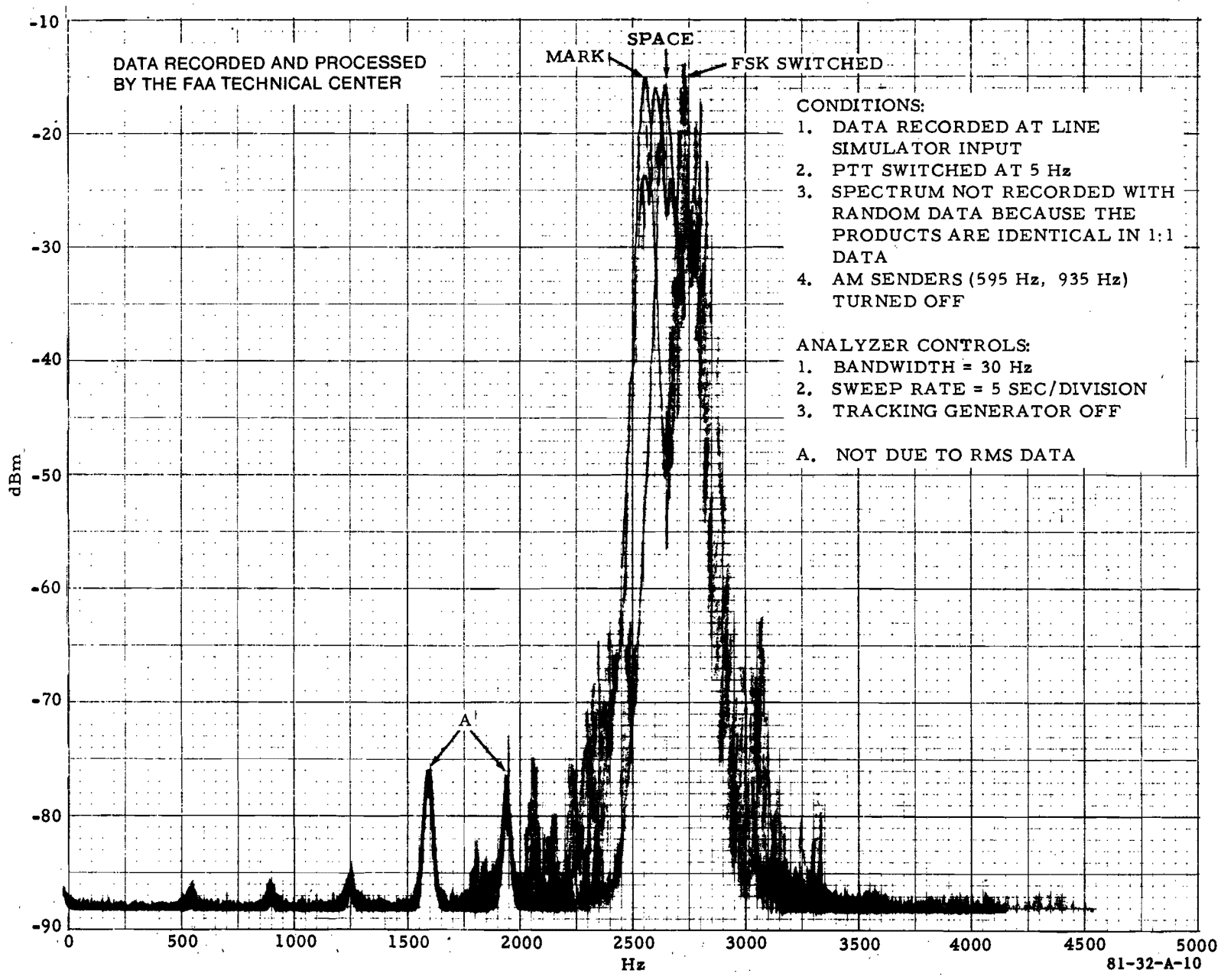

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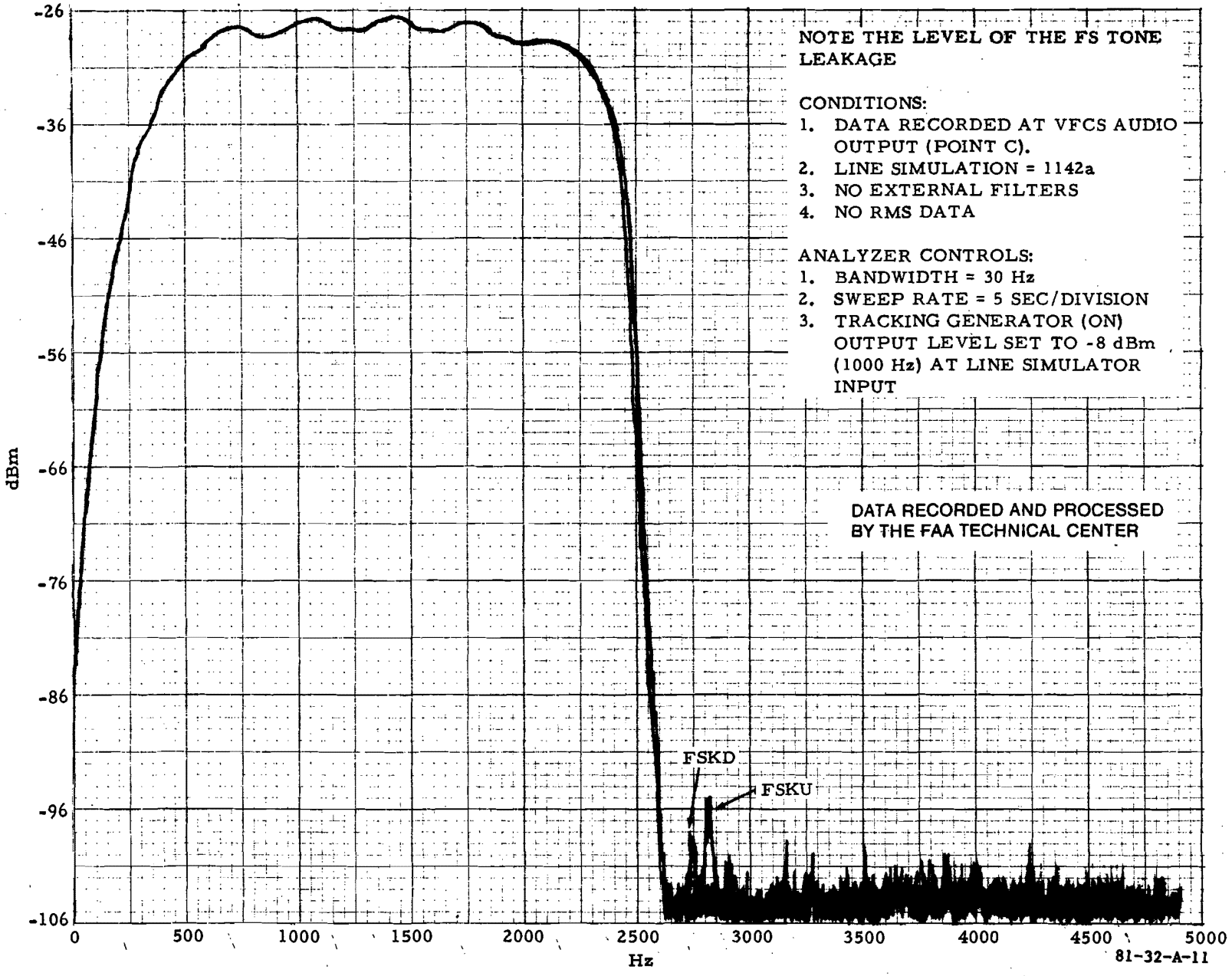

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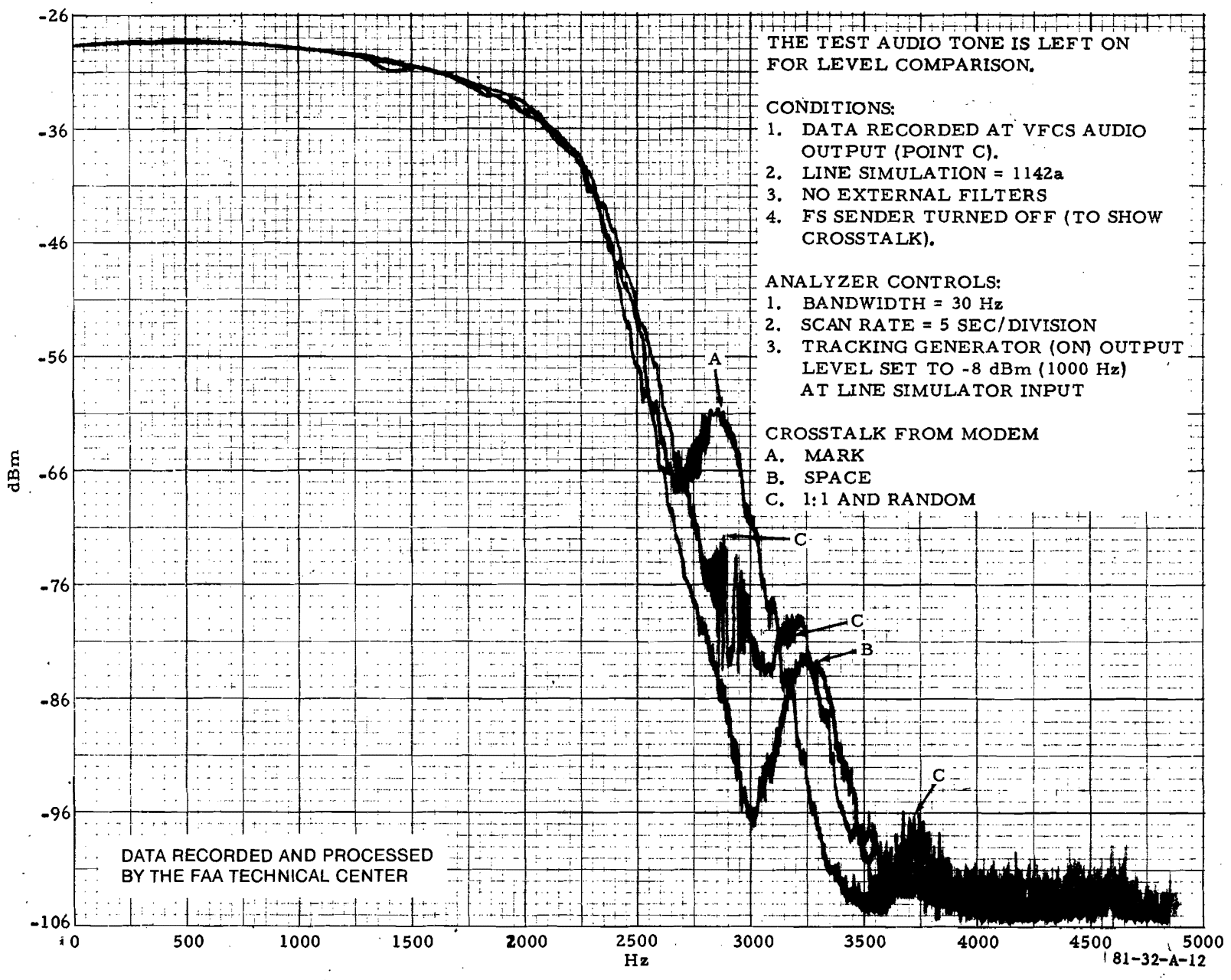


FIGURE A-12. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

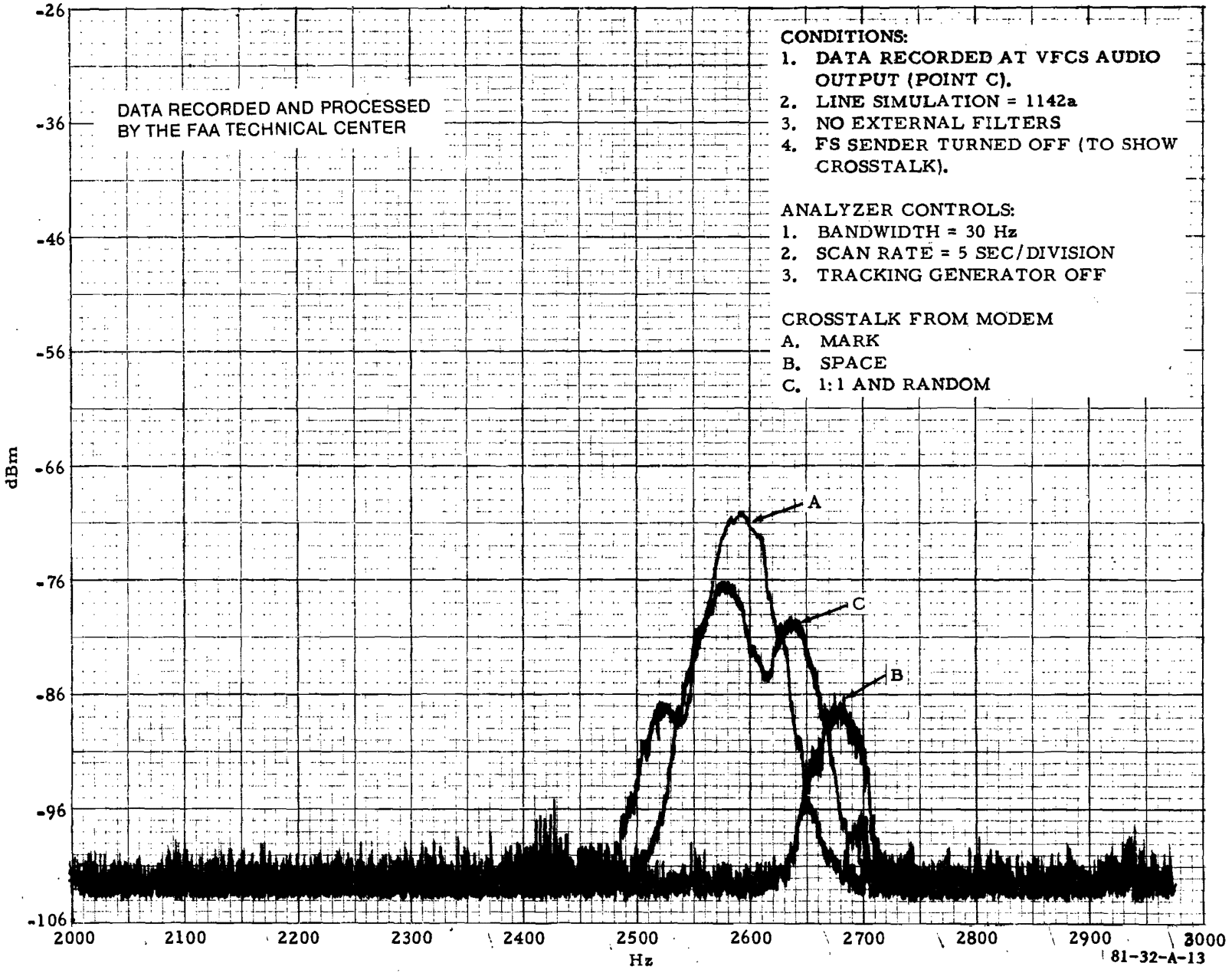
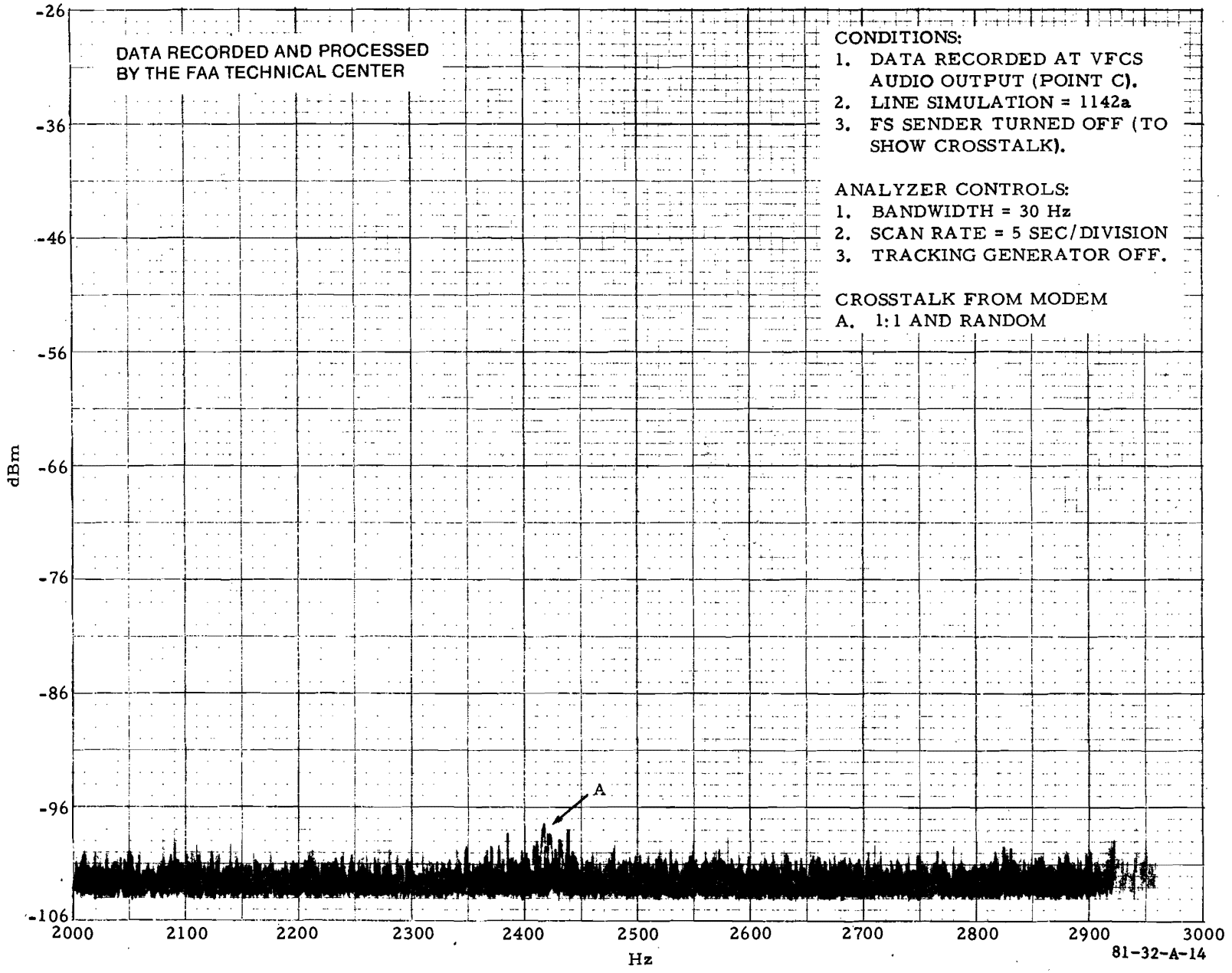


FIGURE A-13. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED



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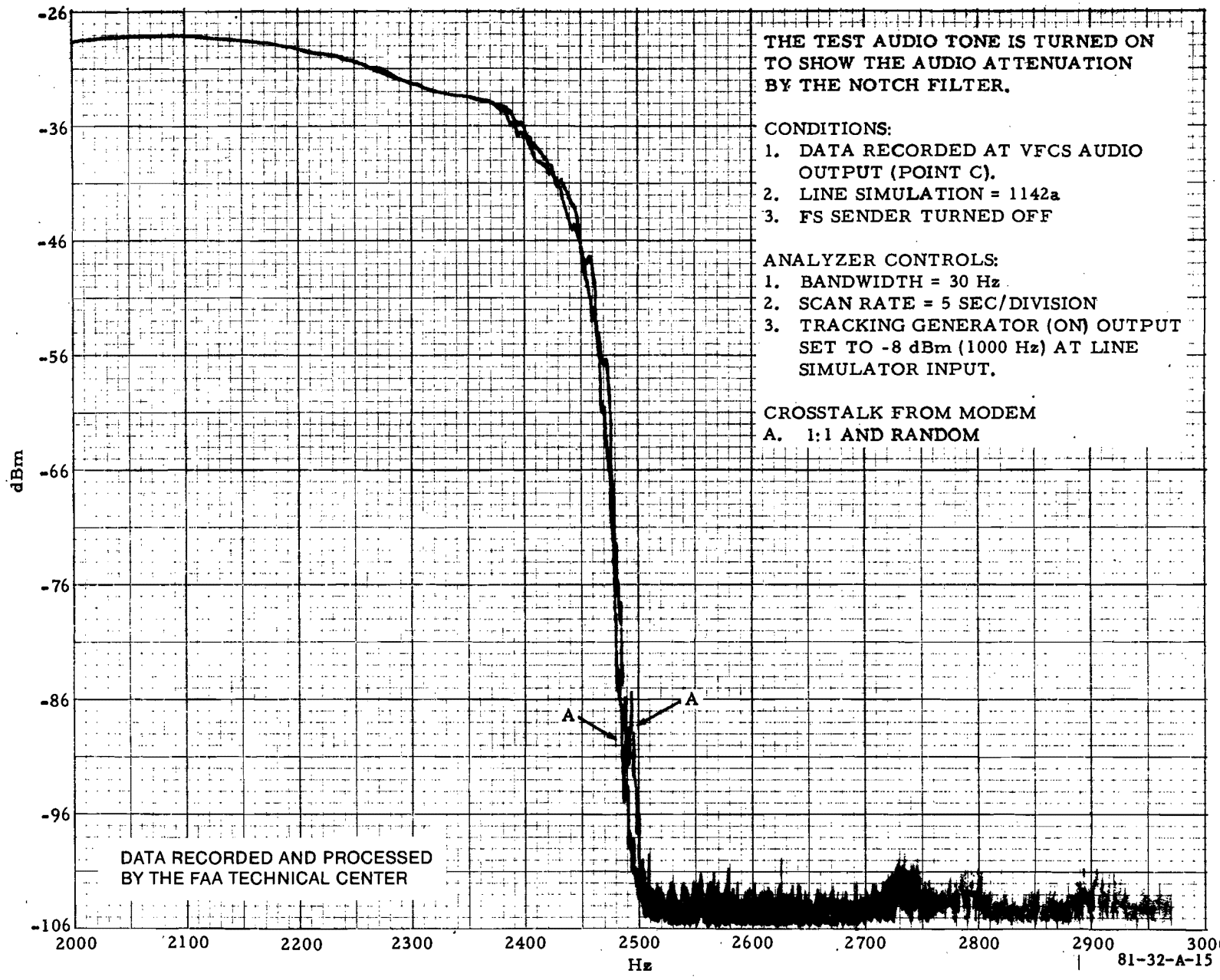

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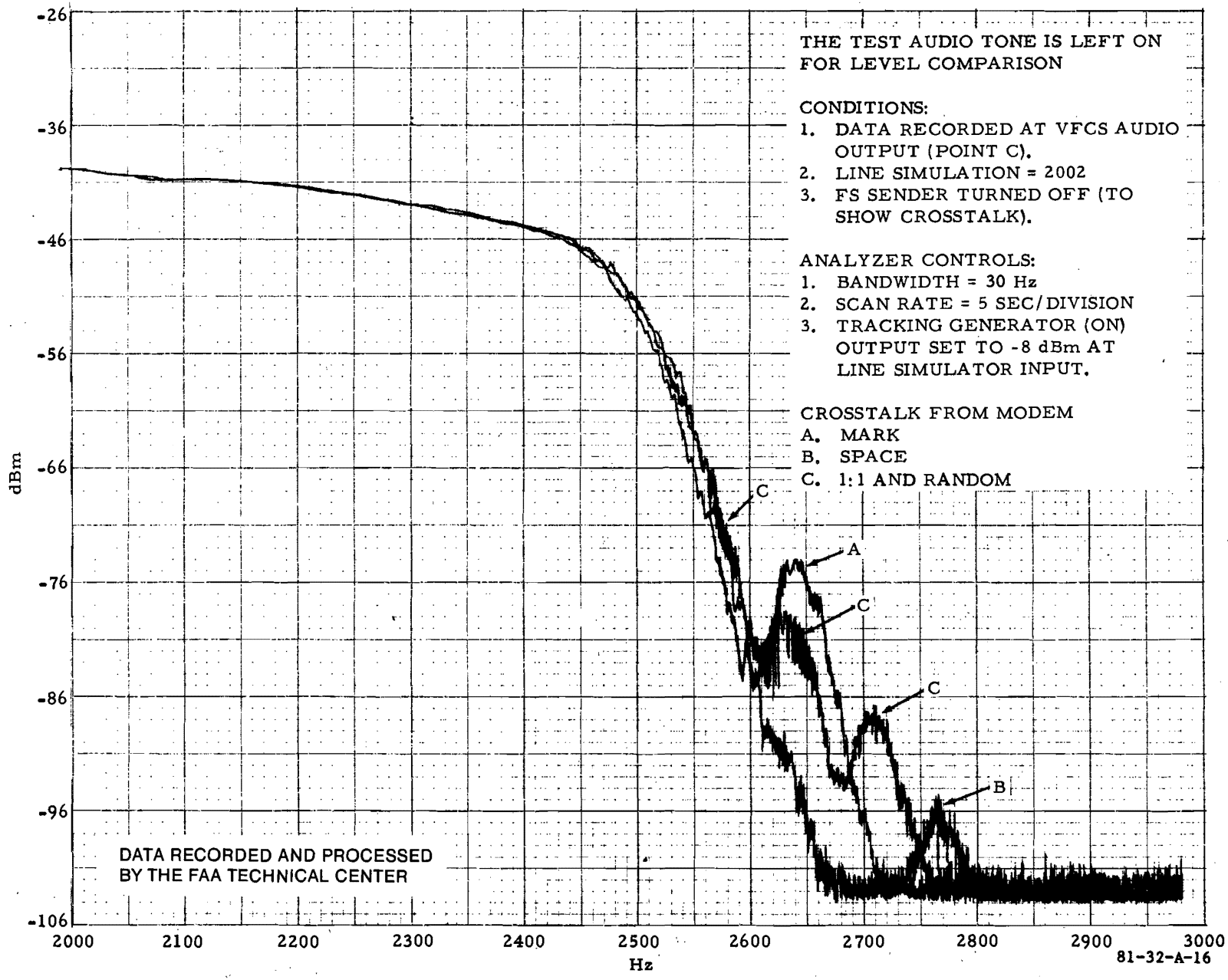

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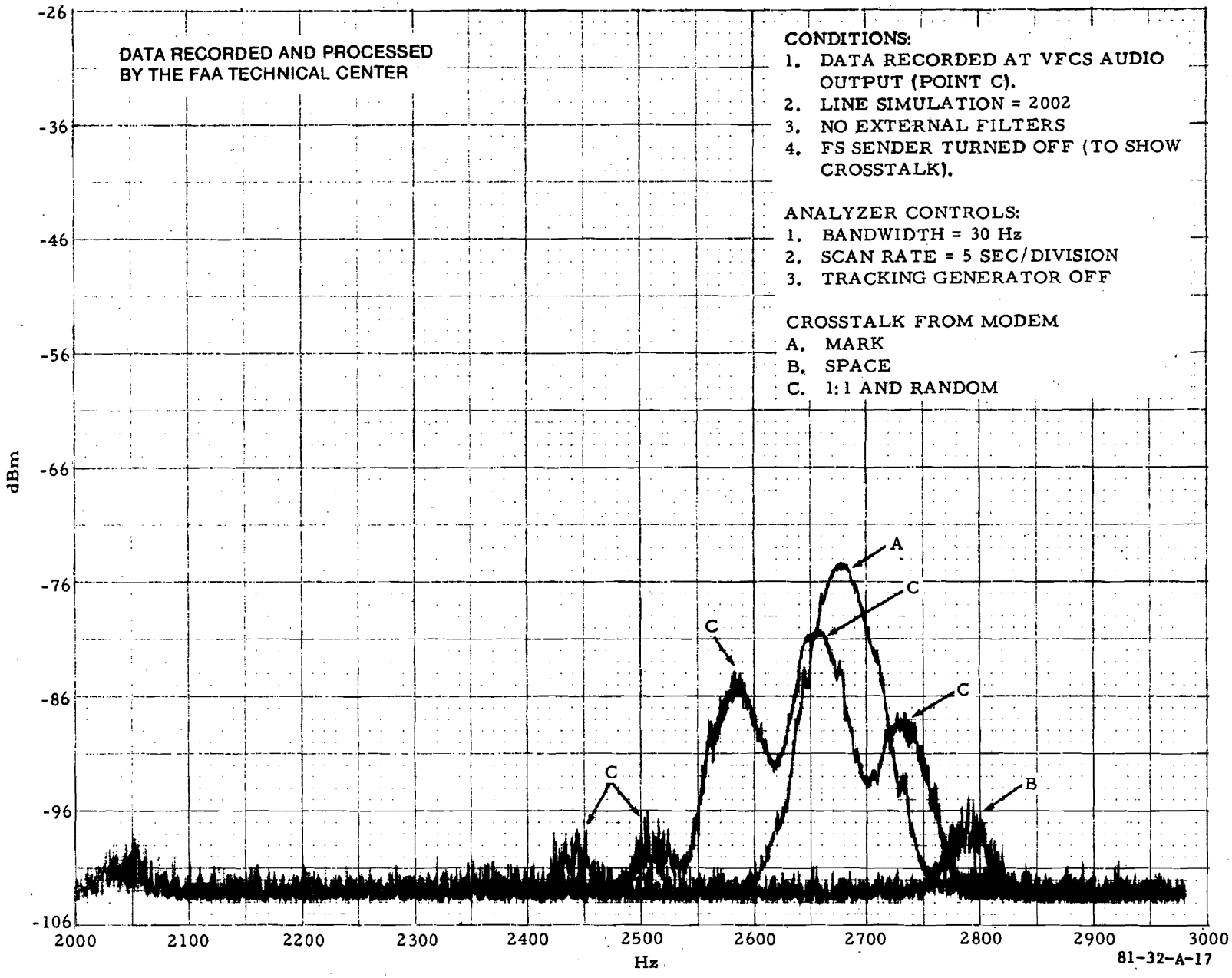

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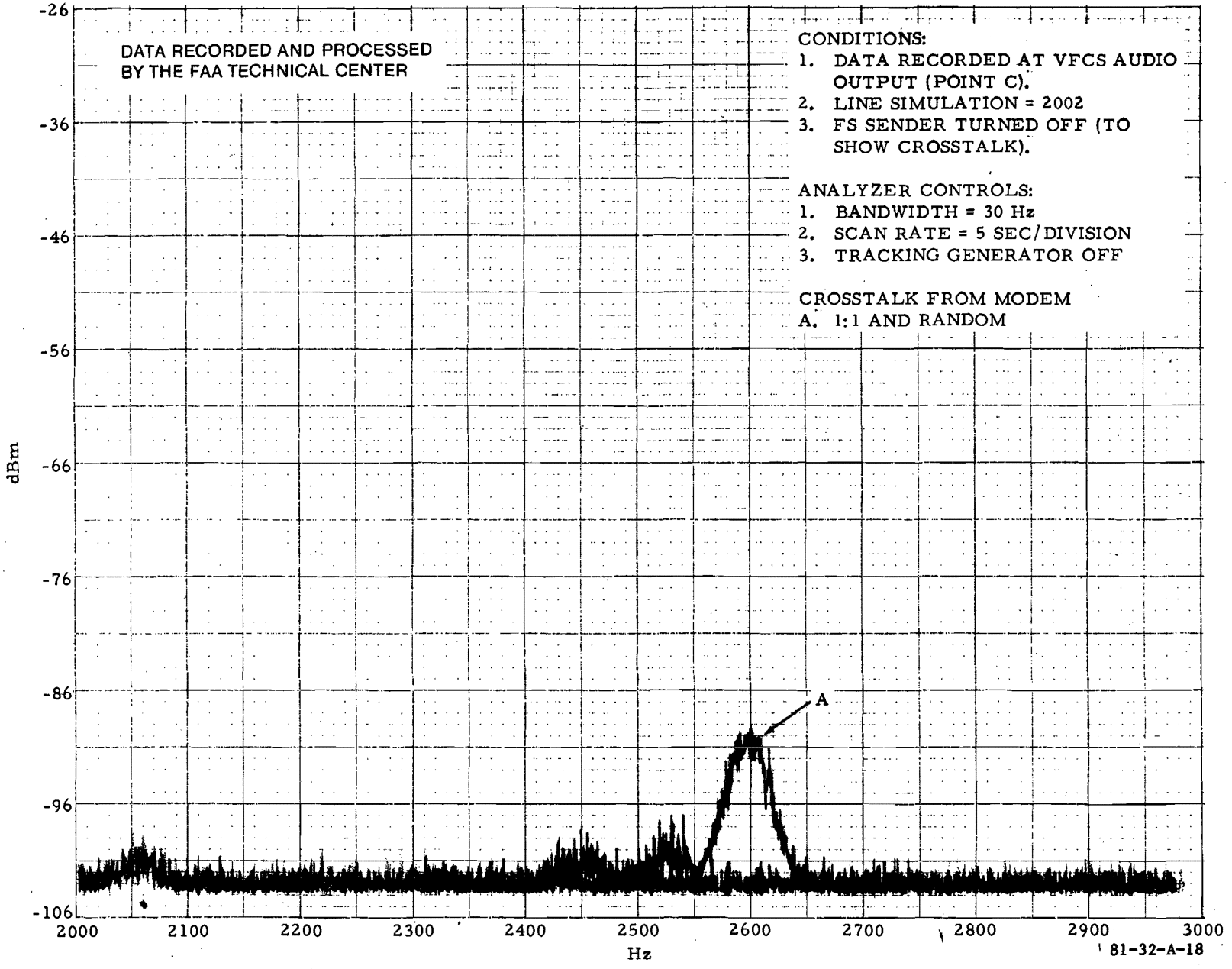

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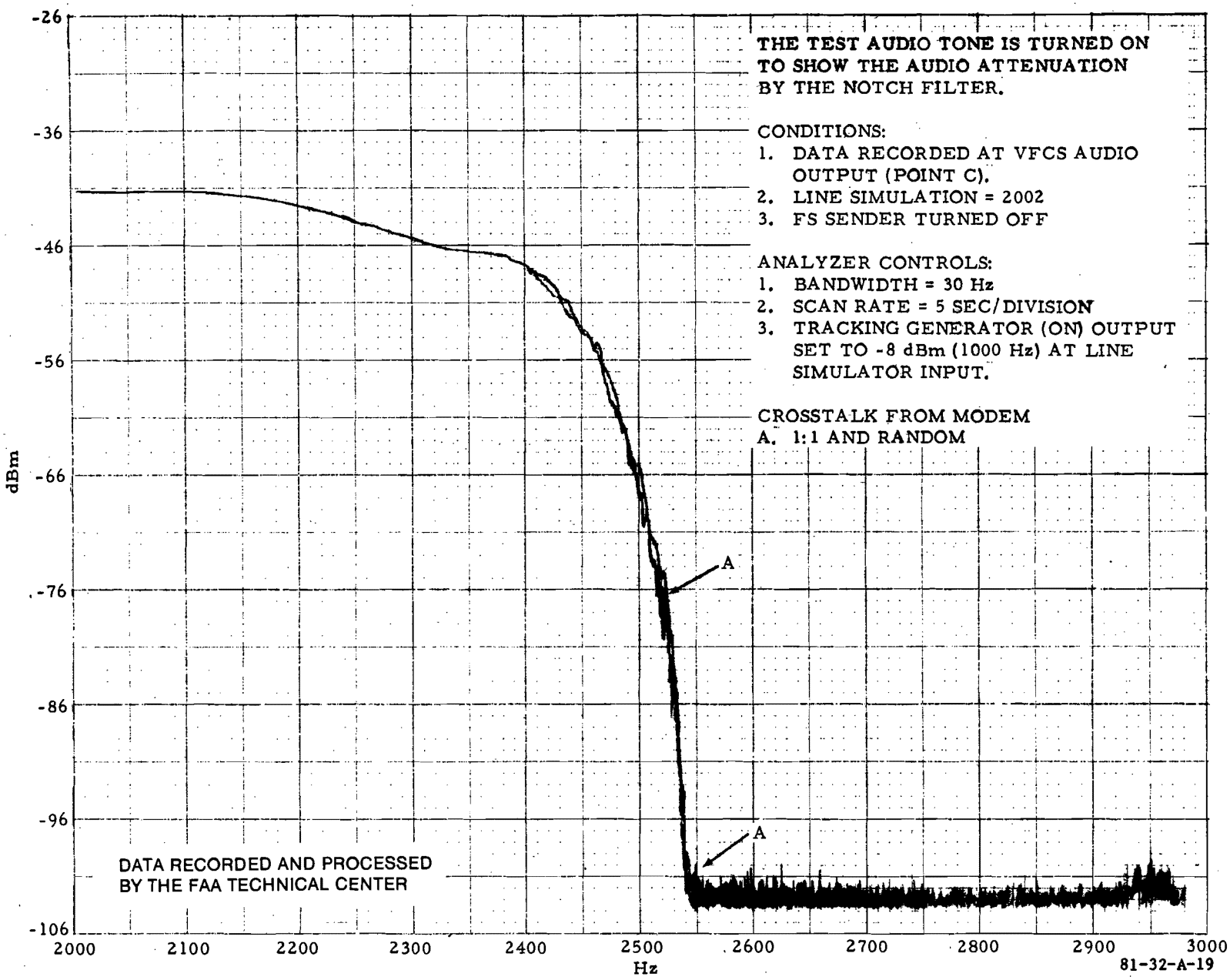


FIGURE A-19. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

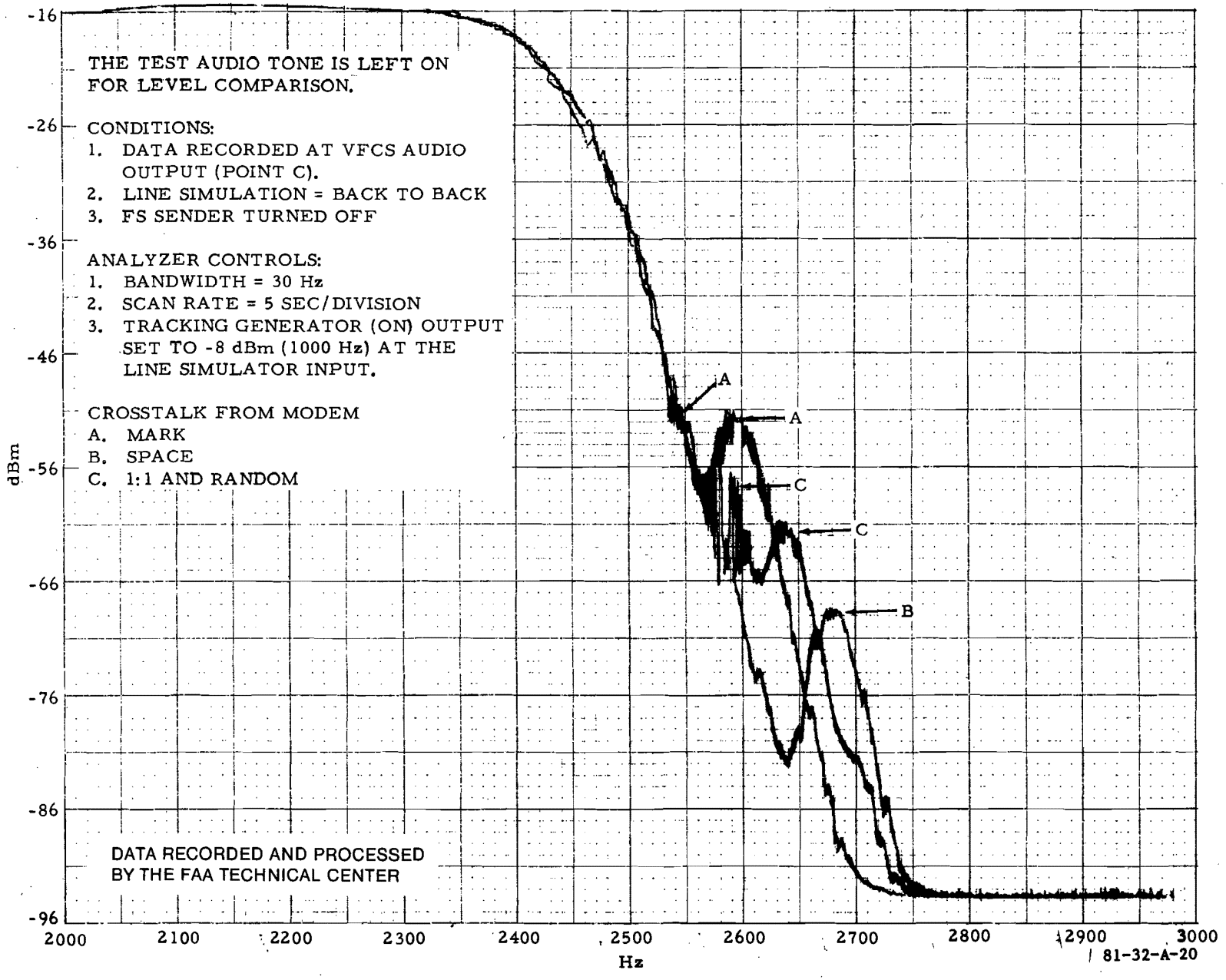


FIGURE A-20. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

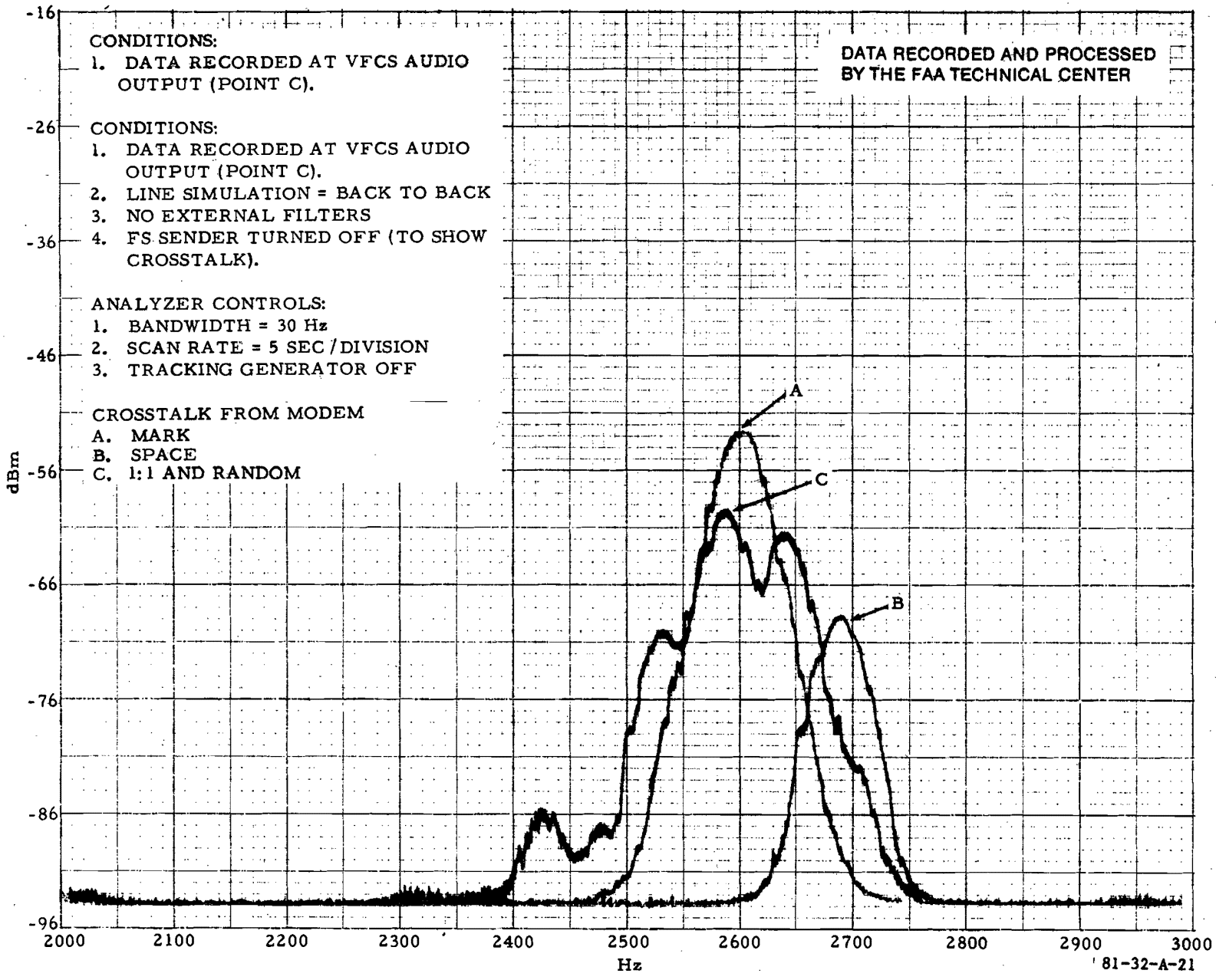


FIGURE A-21. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

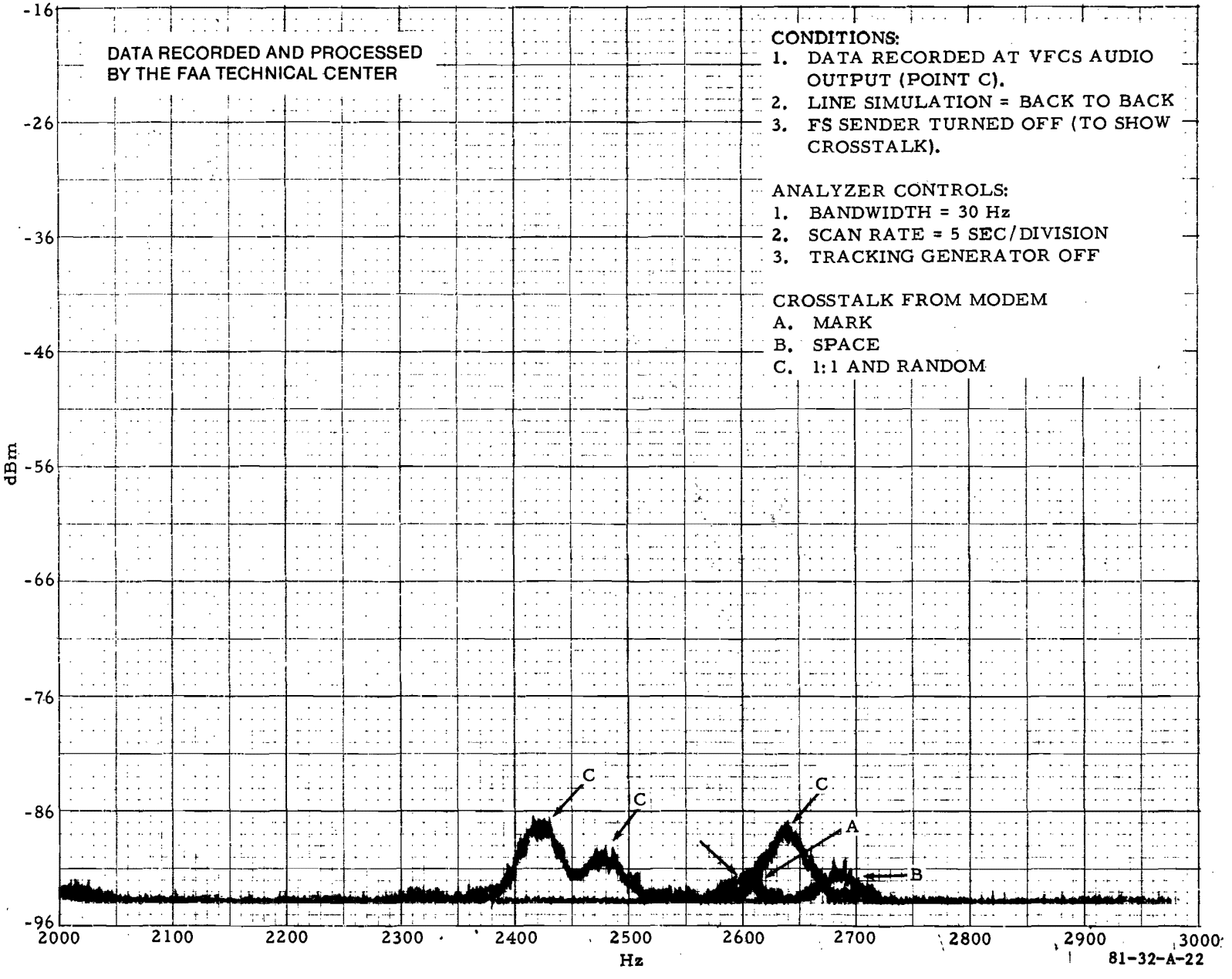
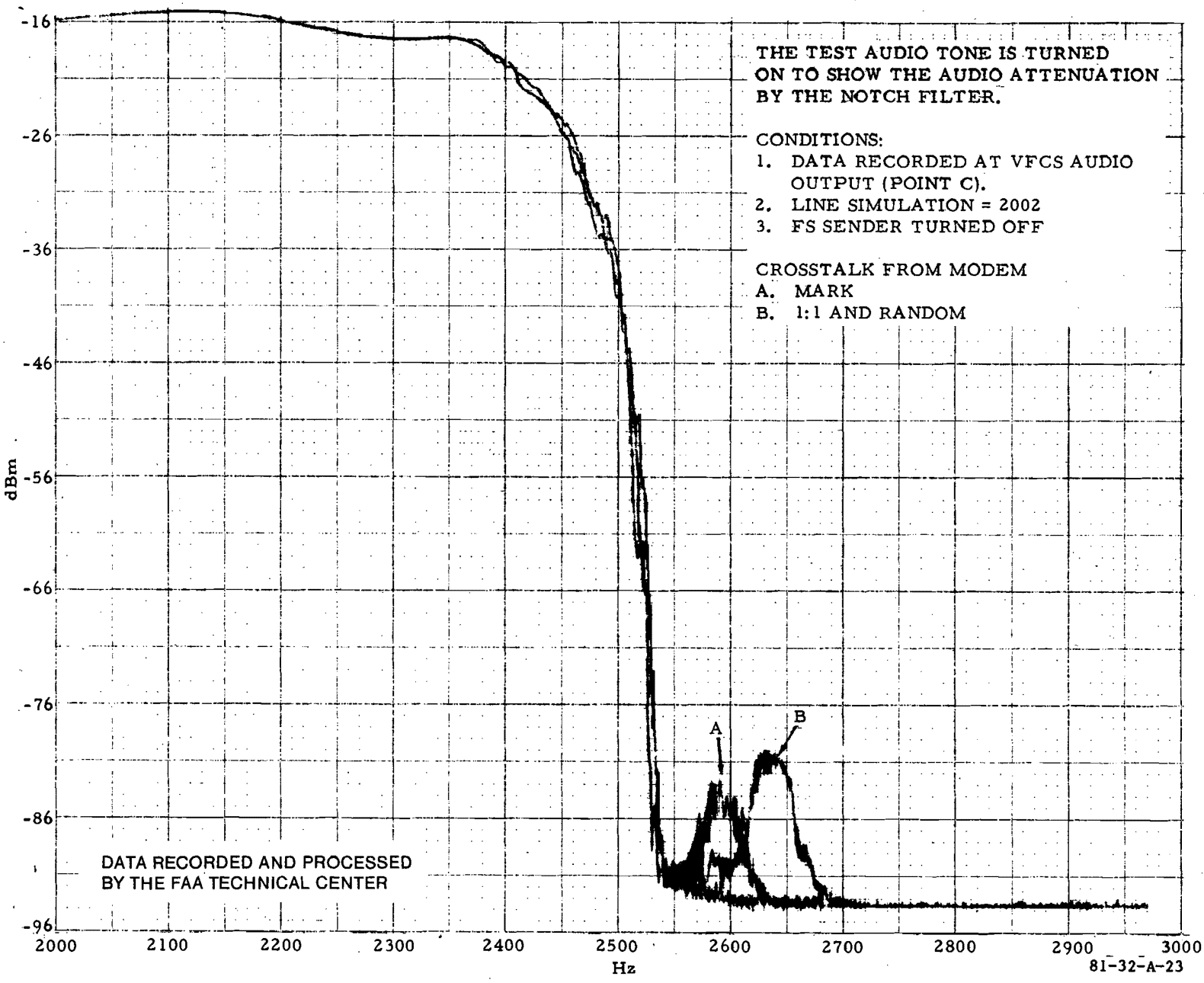


FIGURE A-22. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL



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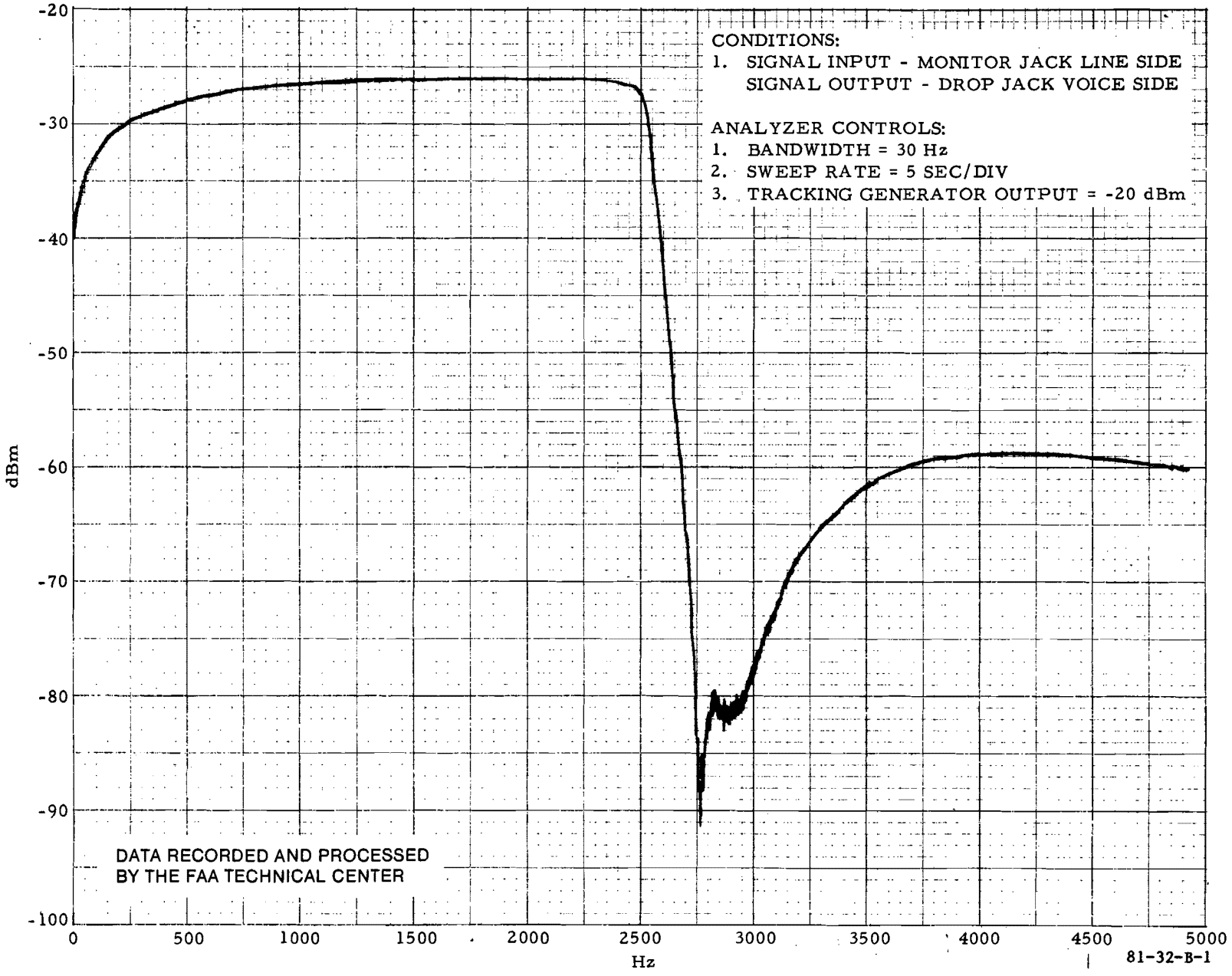
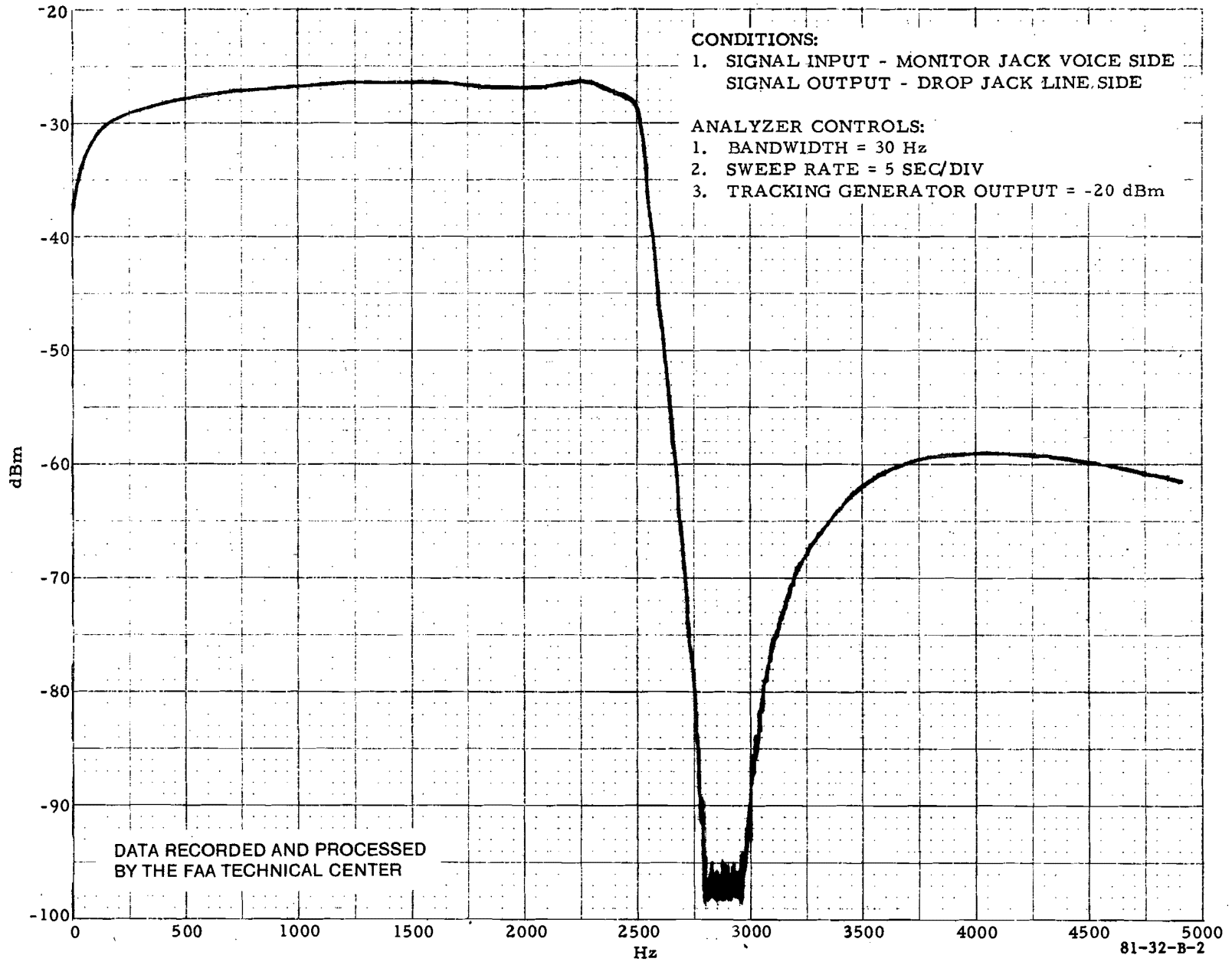


FIGURE B-1. FREQUENCY RESPONSE, SEND FILTER HYBRID-LOCAL TERMINAL



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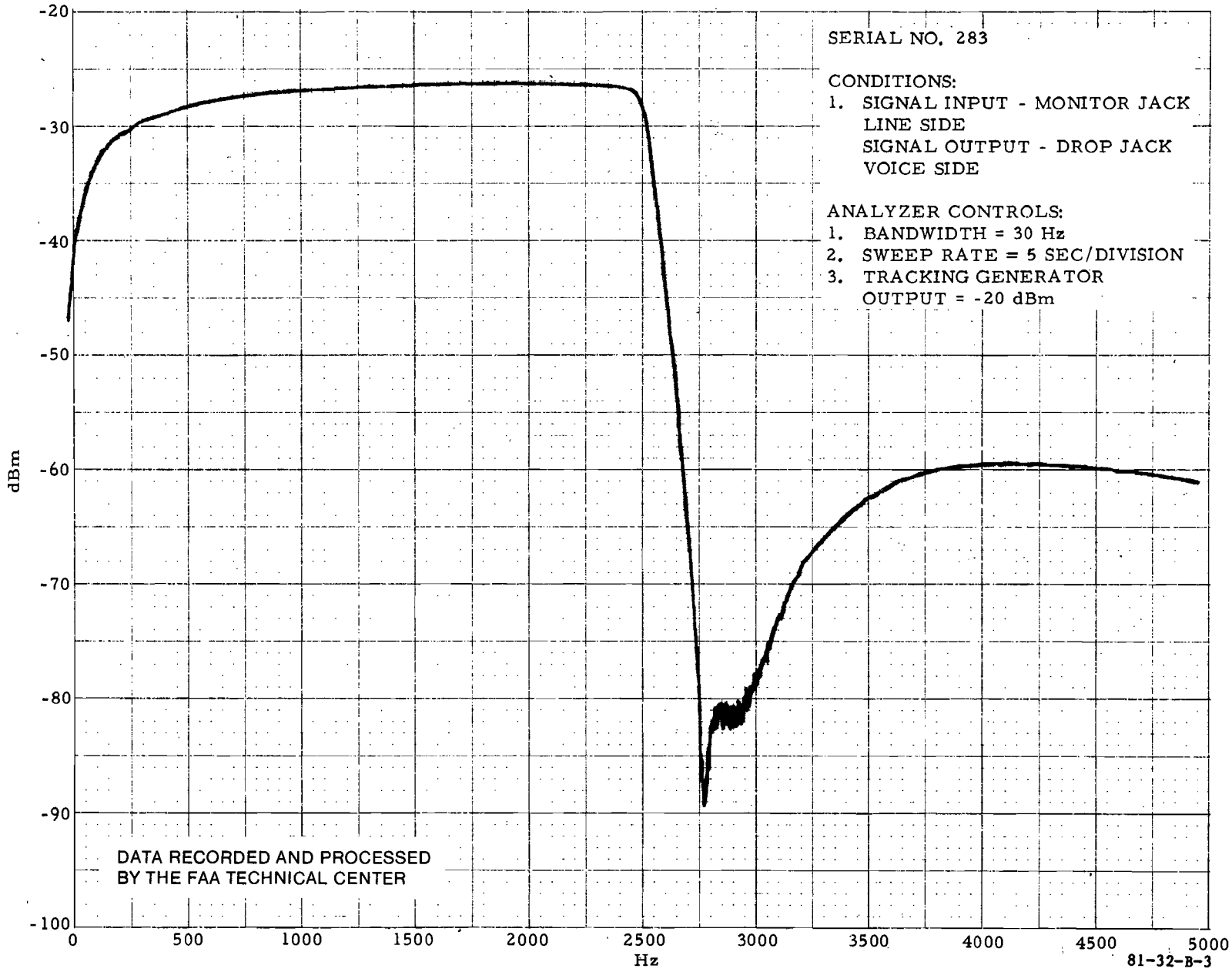

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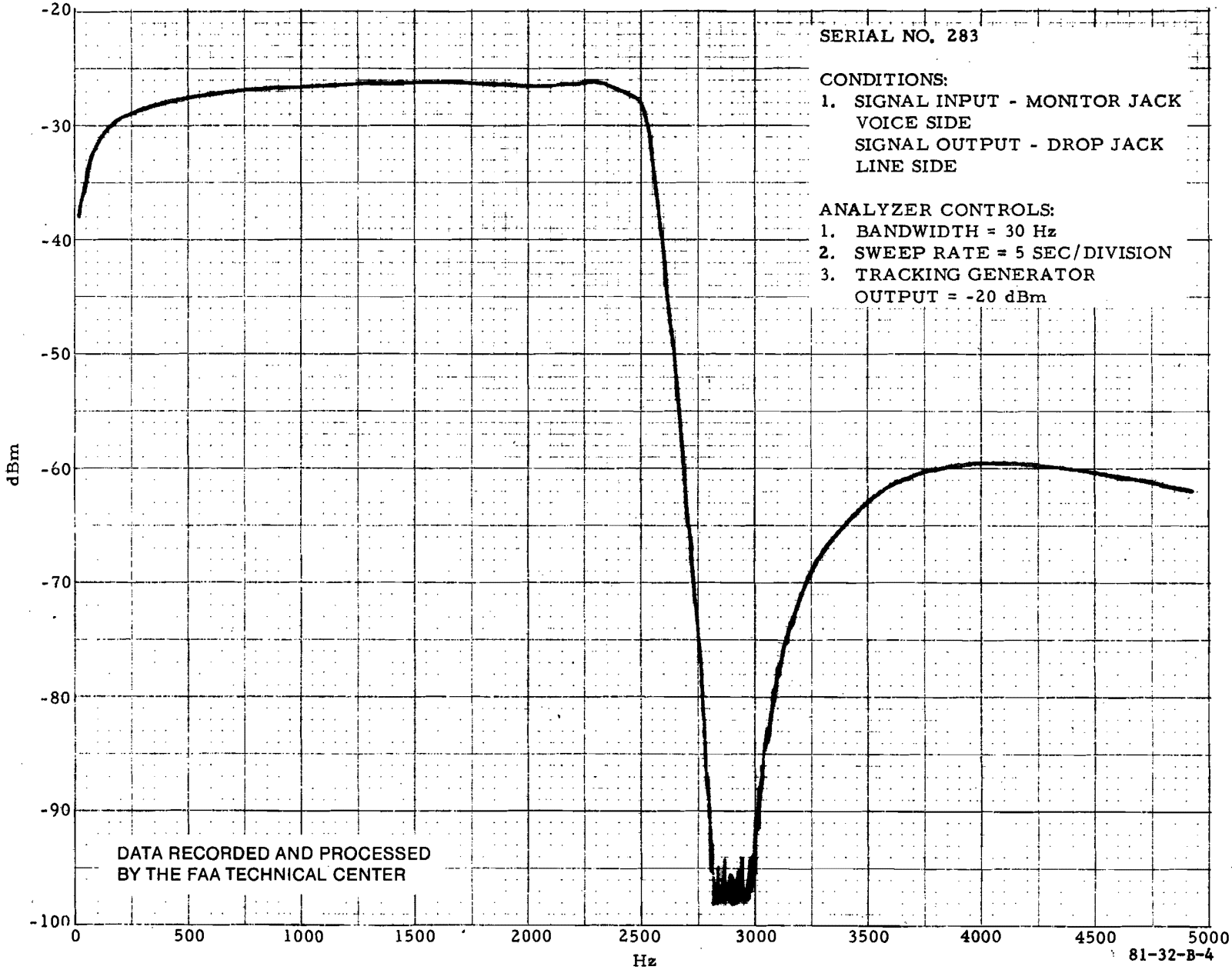

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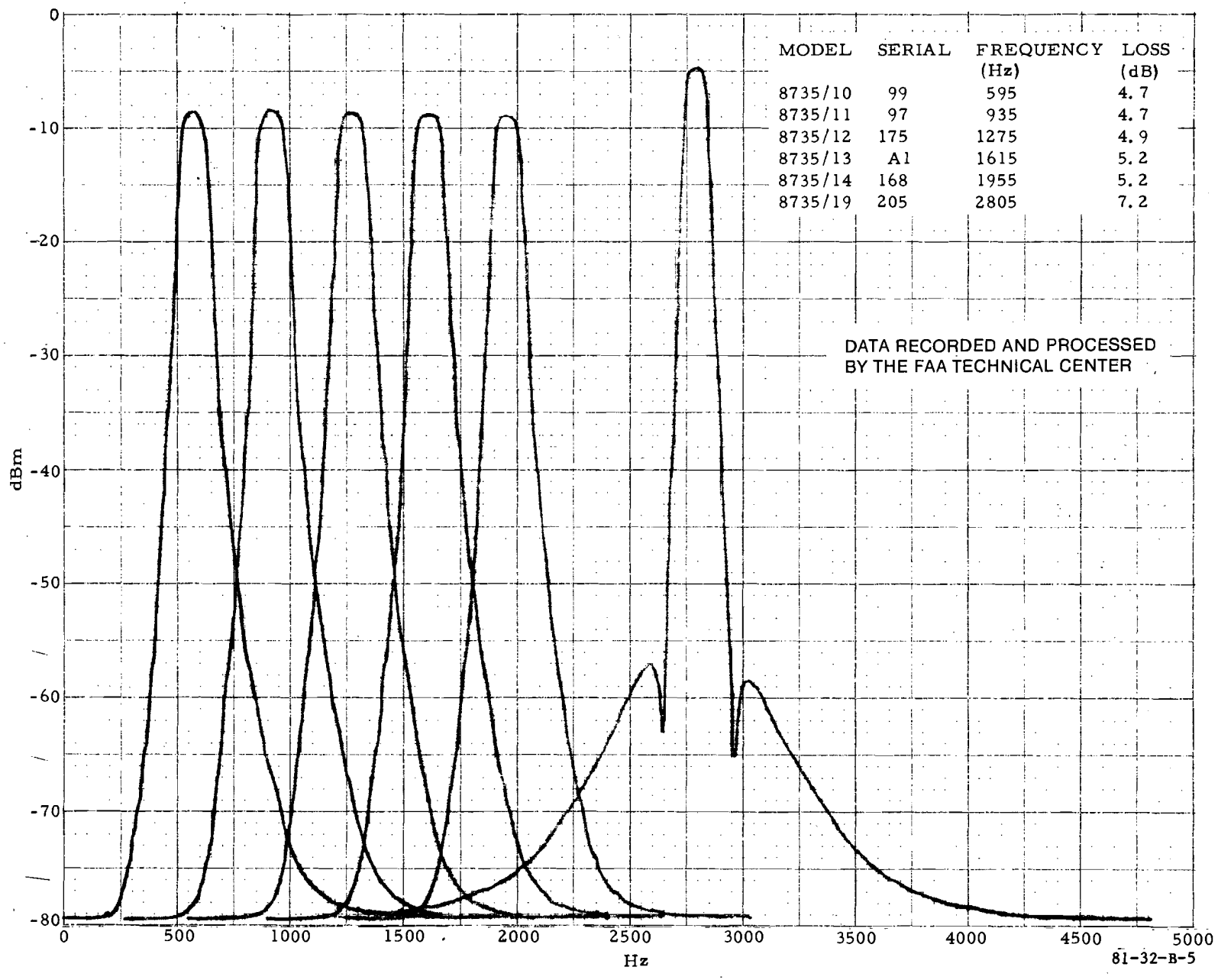

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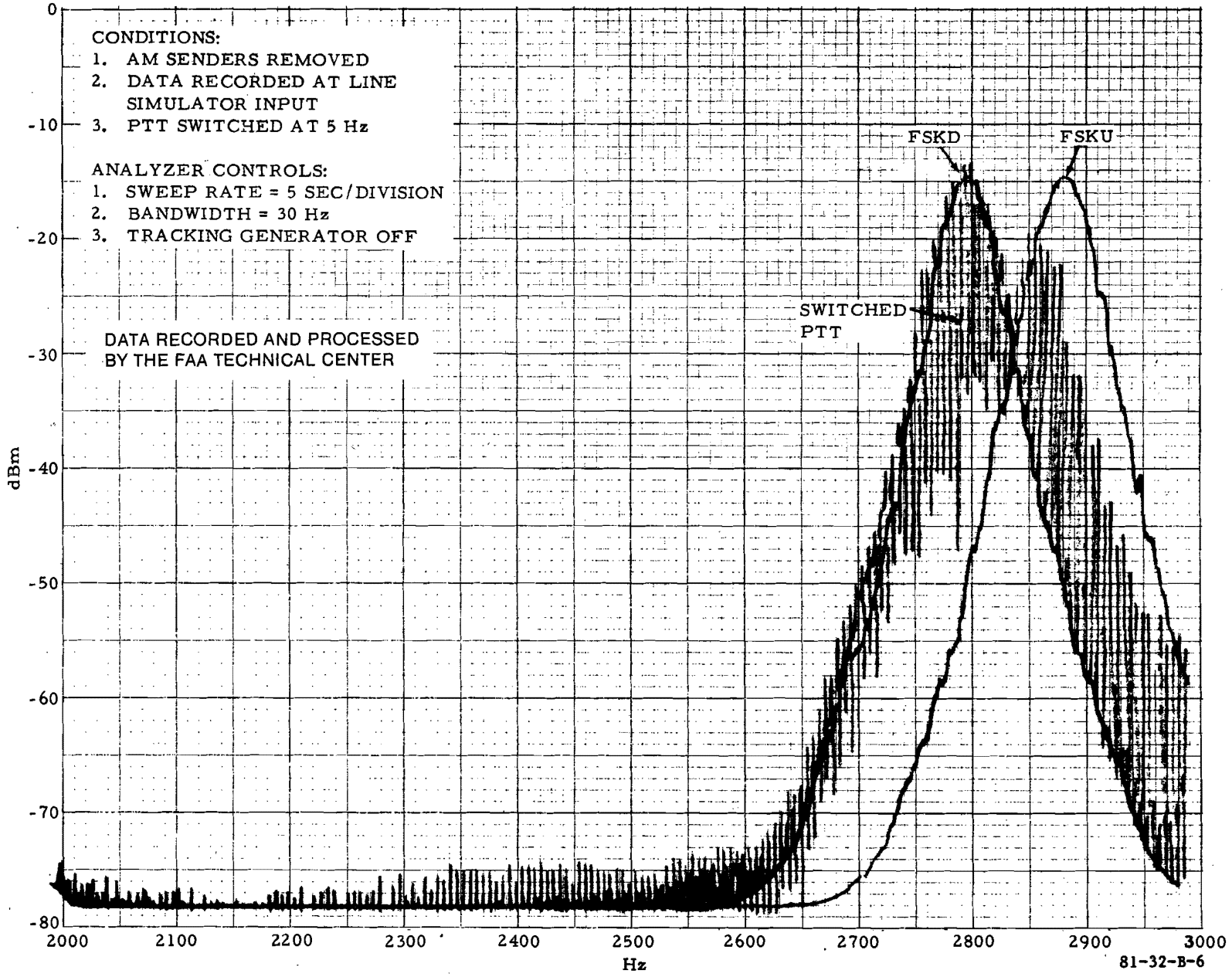

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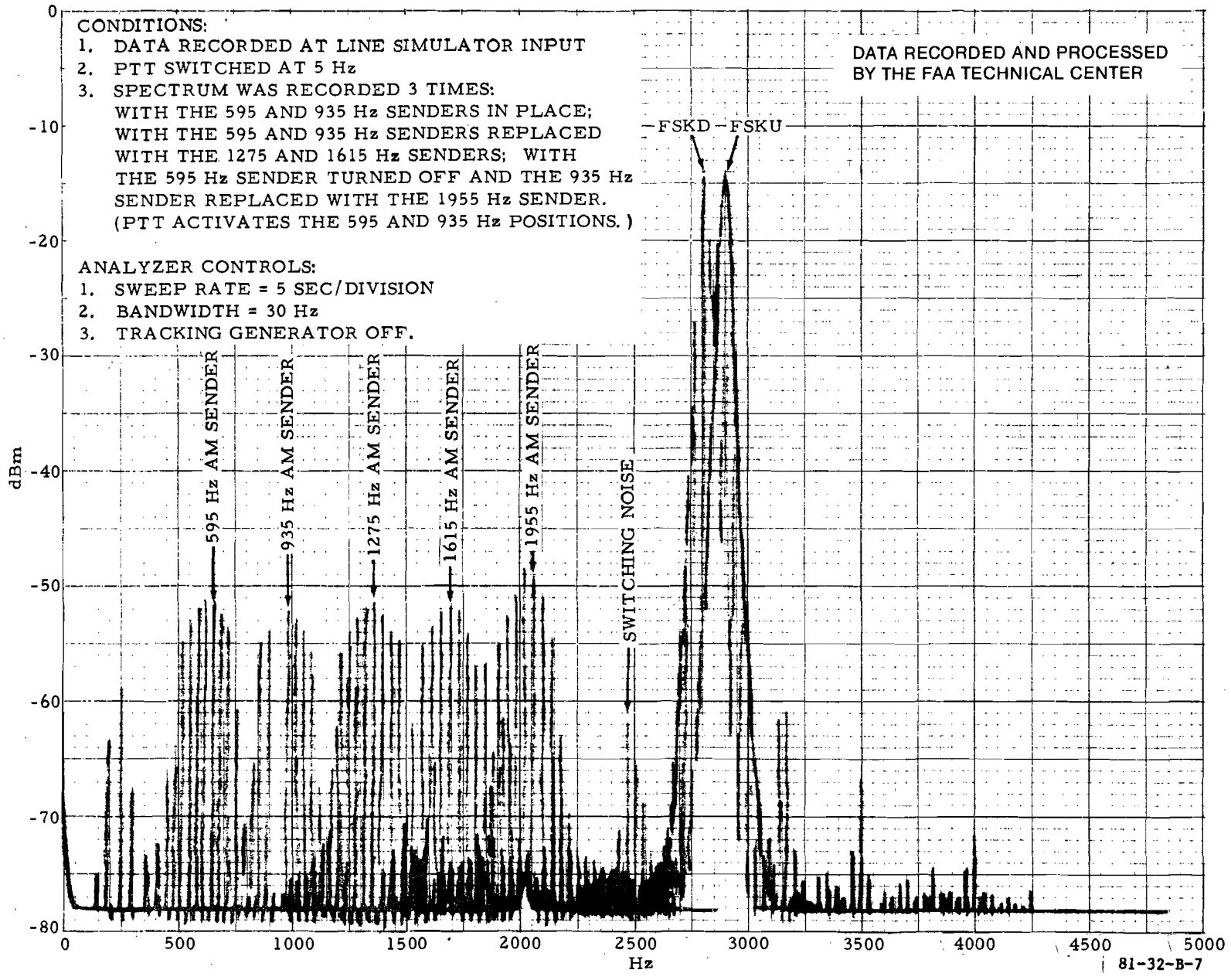
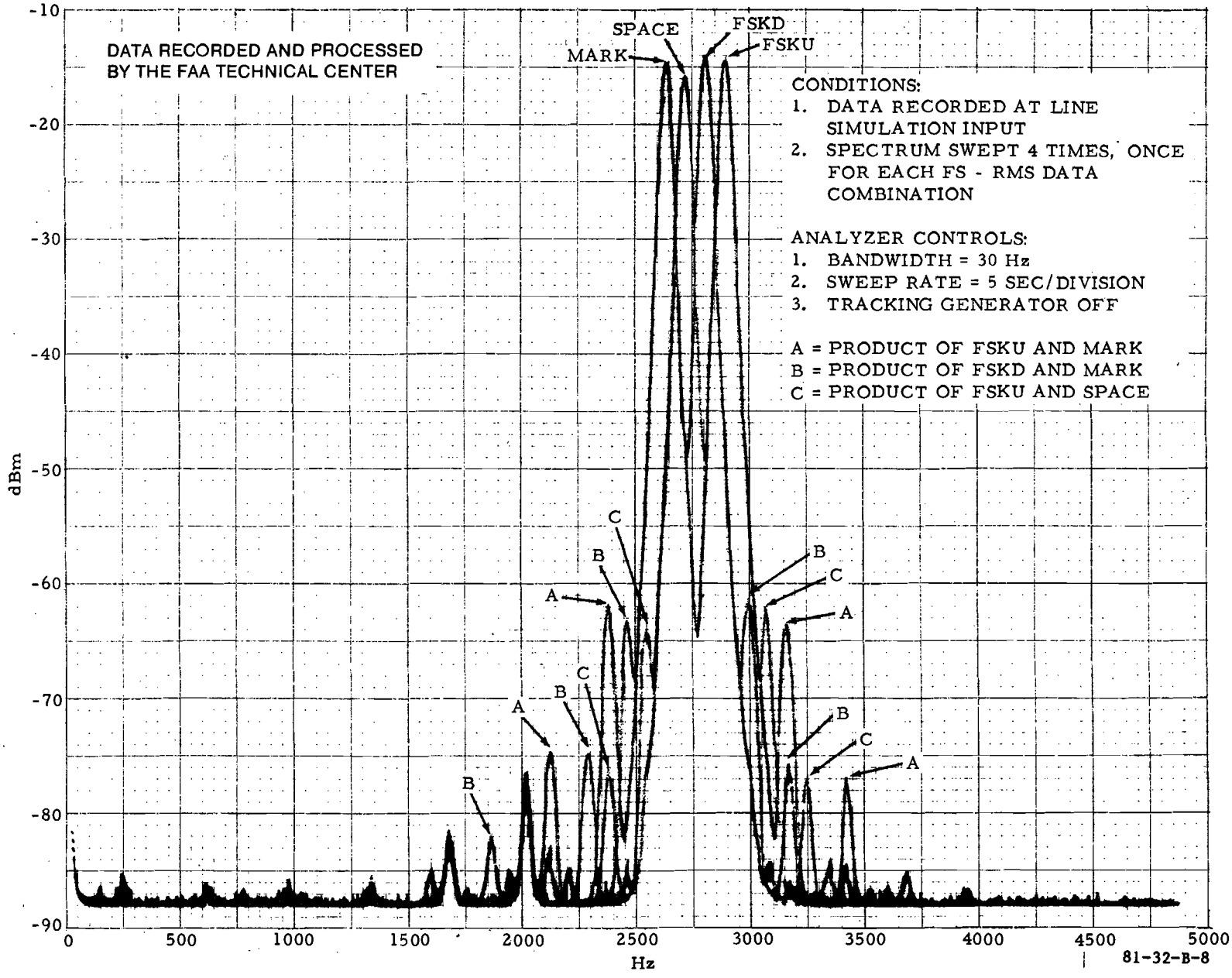


FIGURE B-7. SPECTRUM OF SWITCHED PTT



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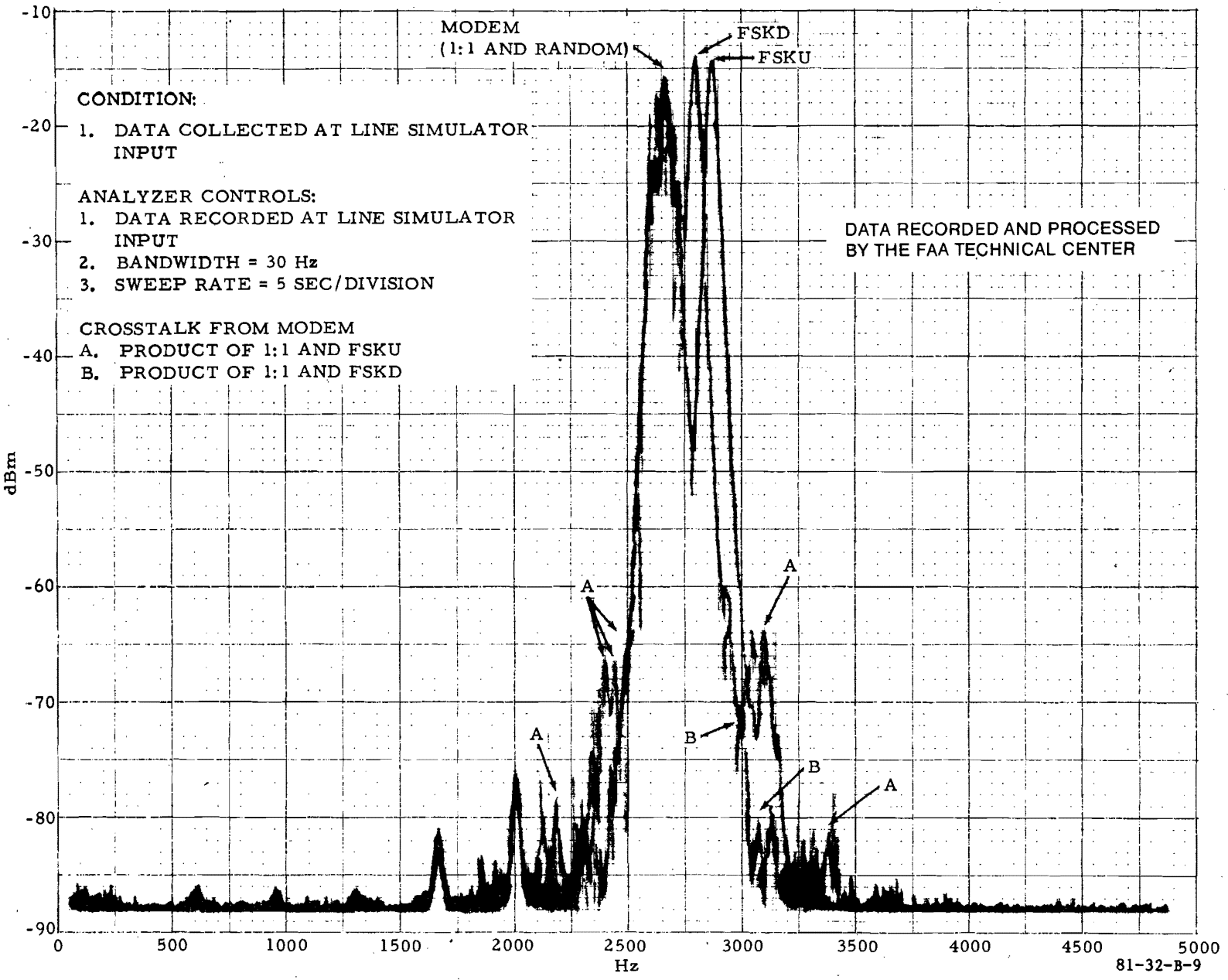
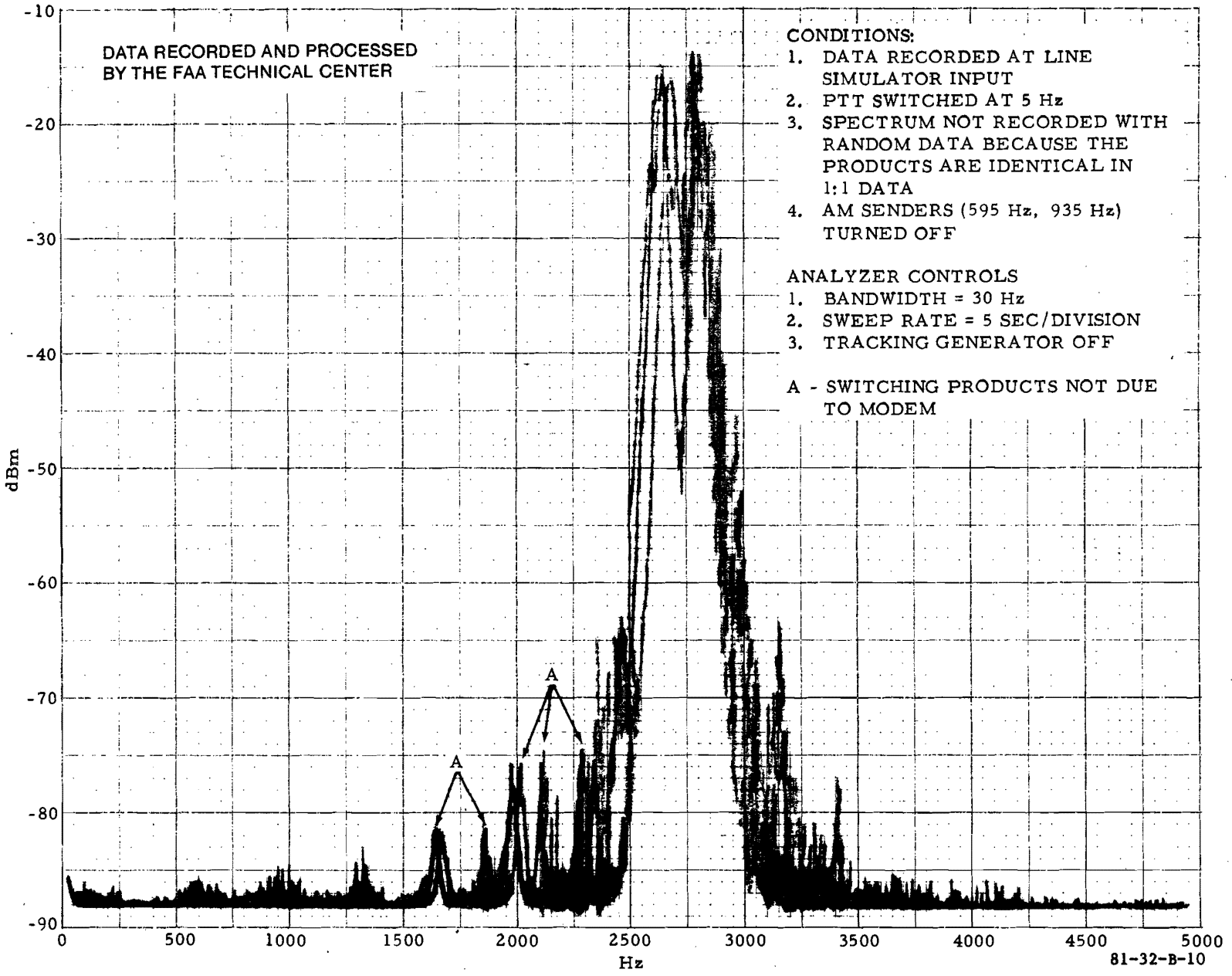


FIGURE B-9. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND TRANSITIONAL RMS DATA (1:1 AND RANDOM)



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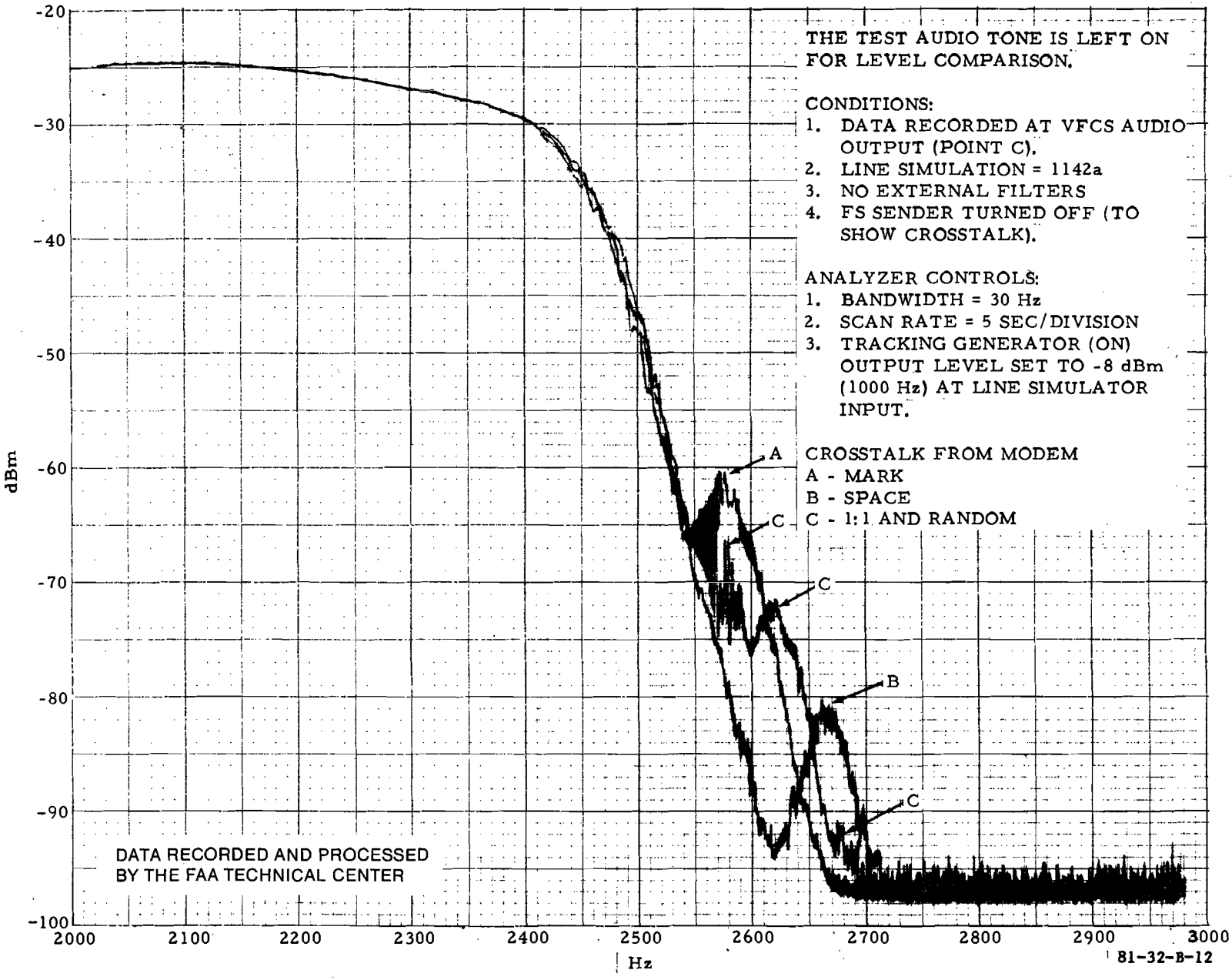

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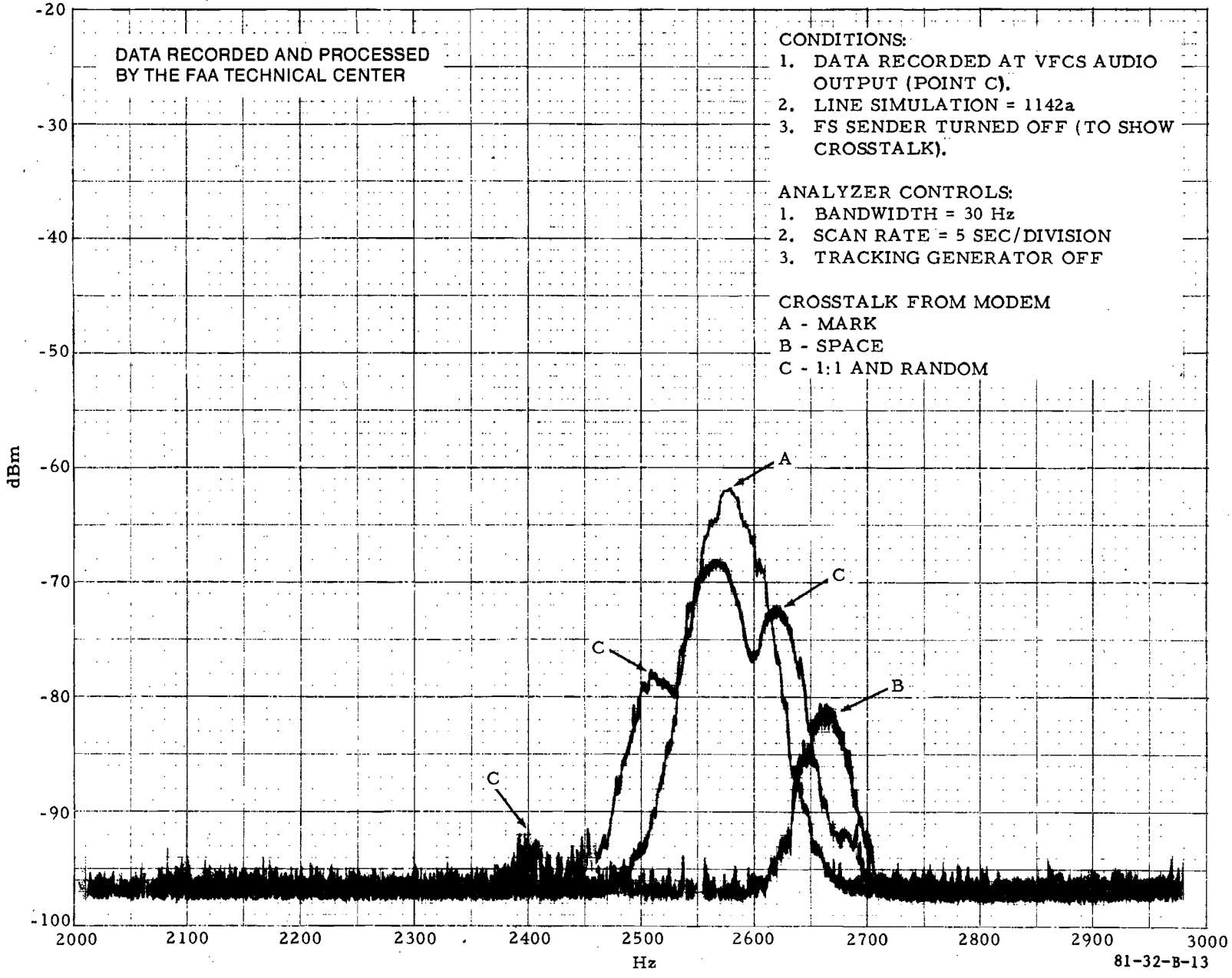


FIGURE B-13. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

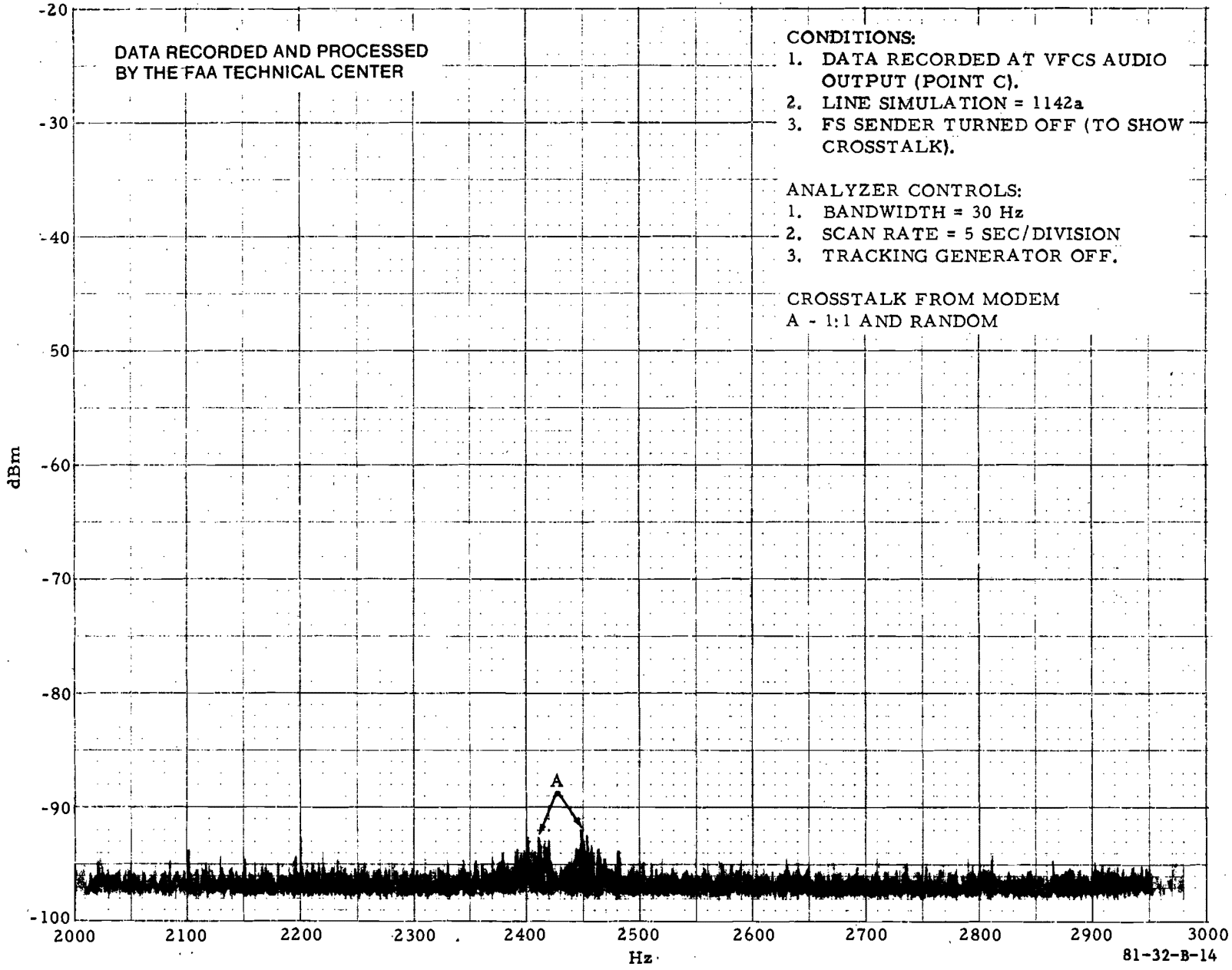
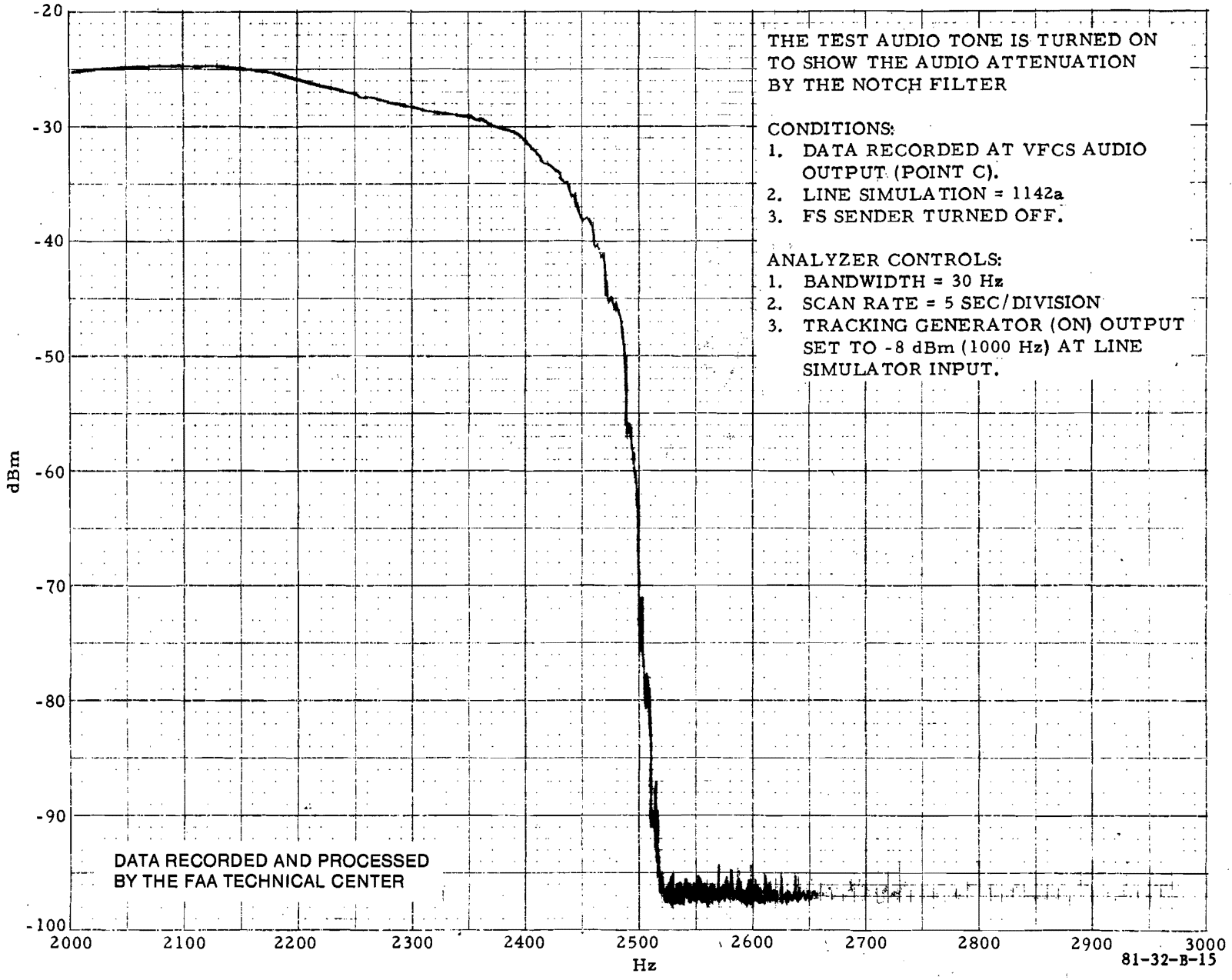


FIGURE B-14. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVER TERMINAL



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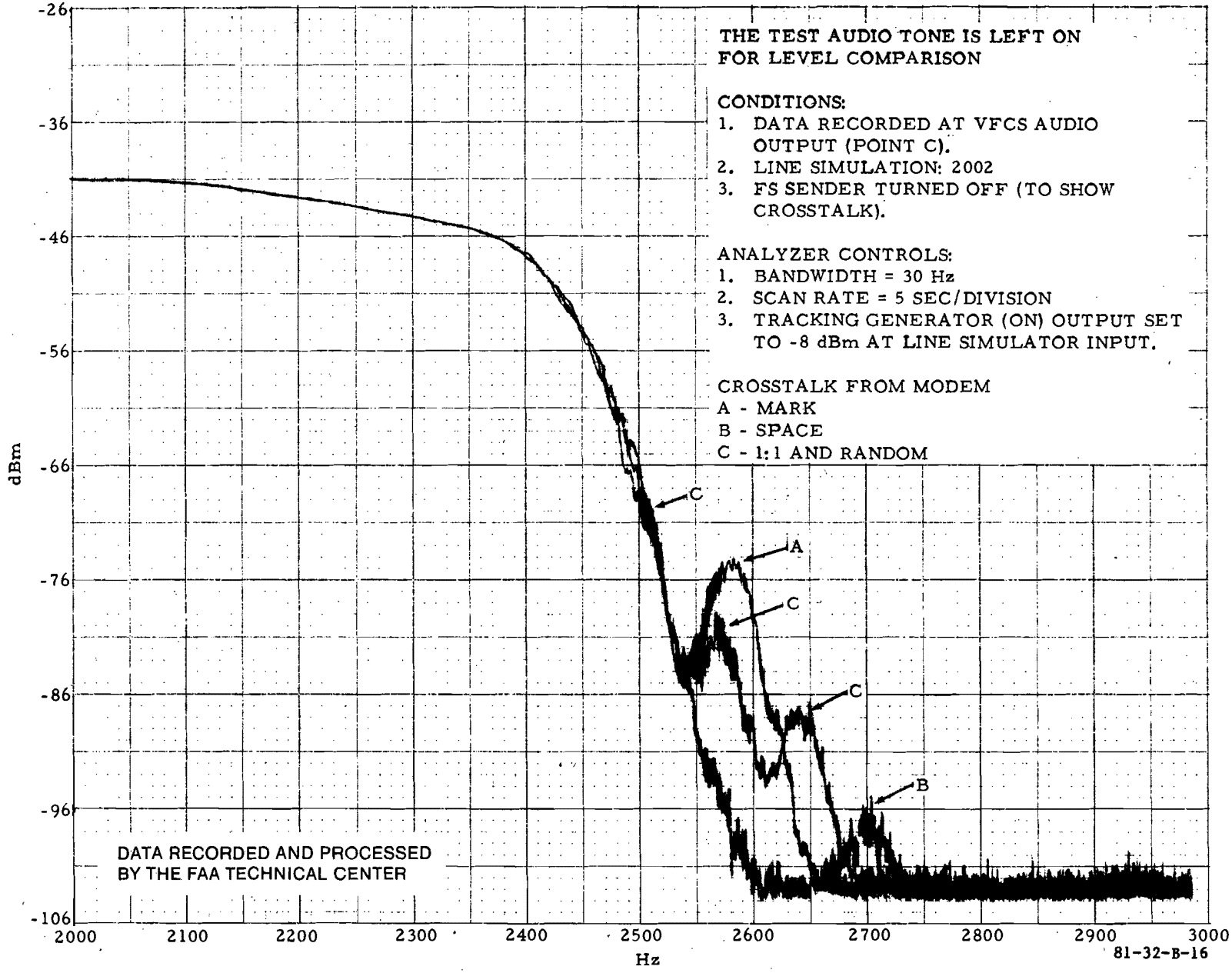

FIGURE B-16. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA

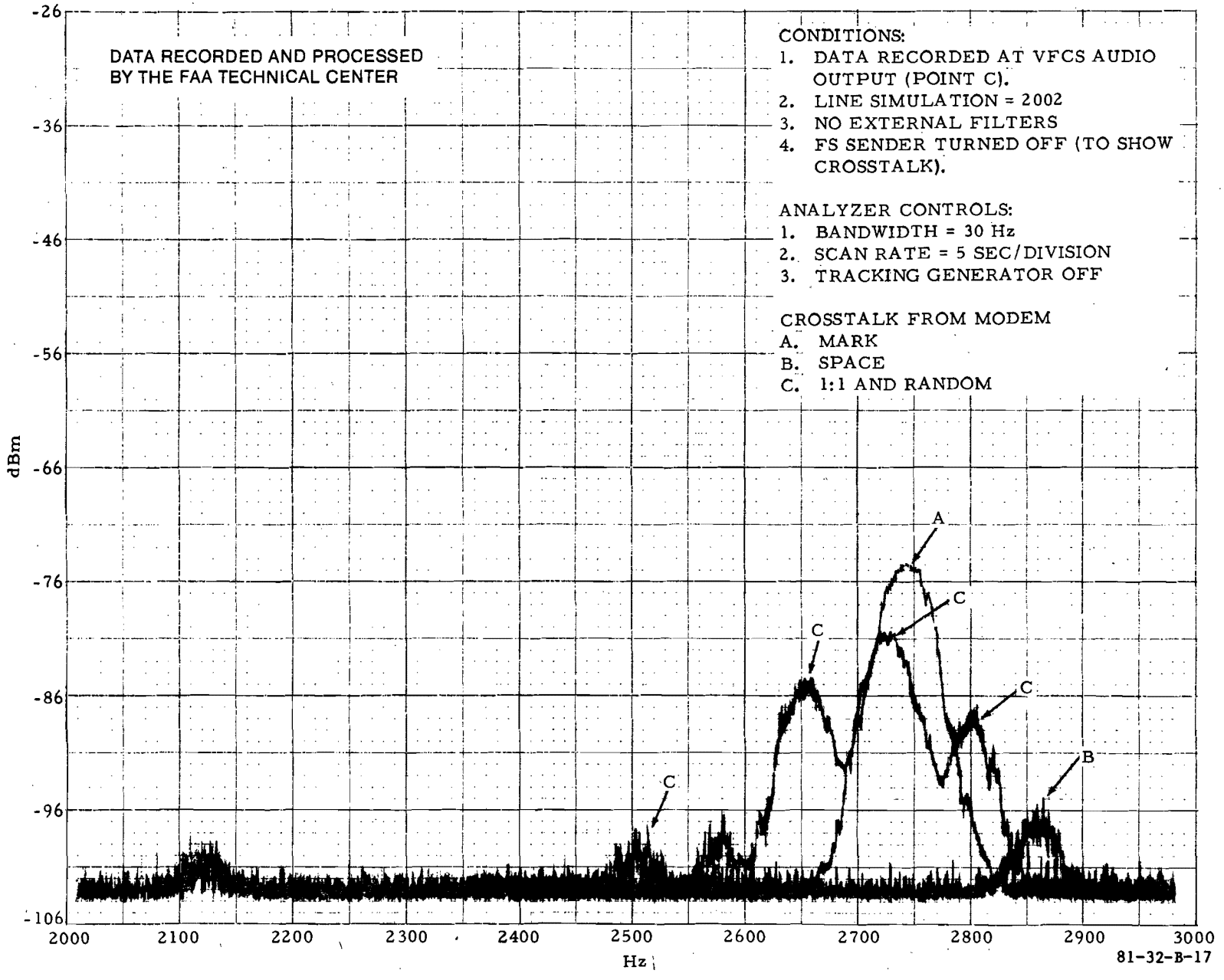

FIGURE B-17. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA; AUTIO REMOVED

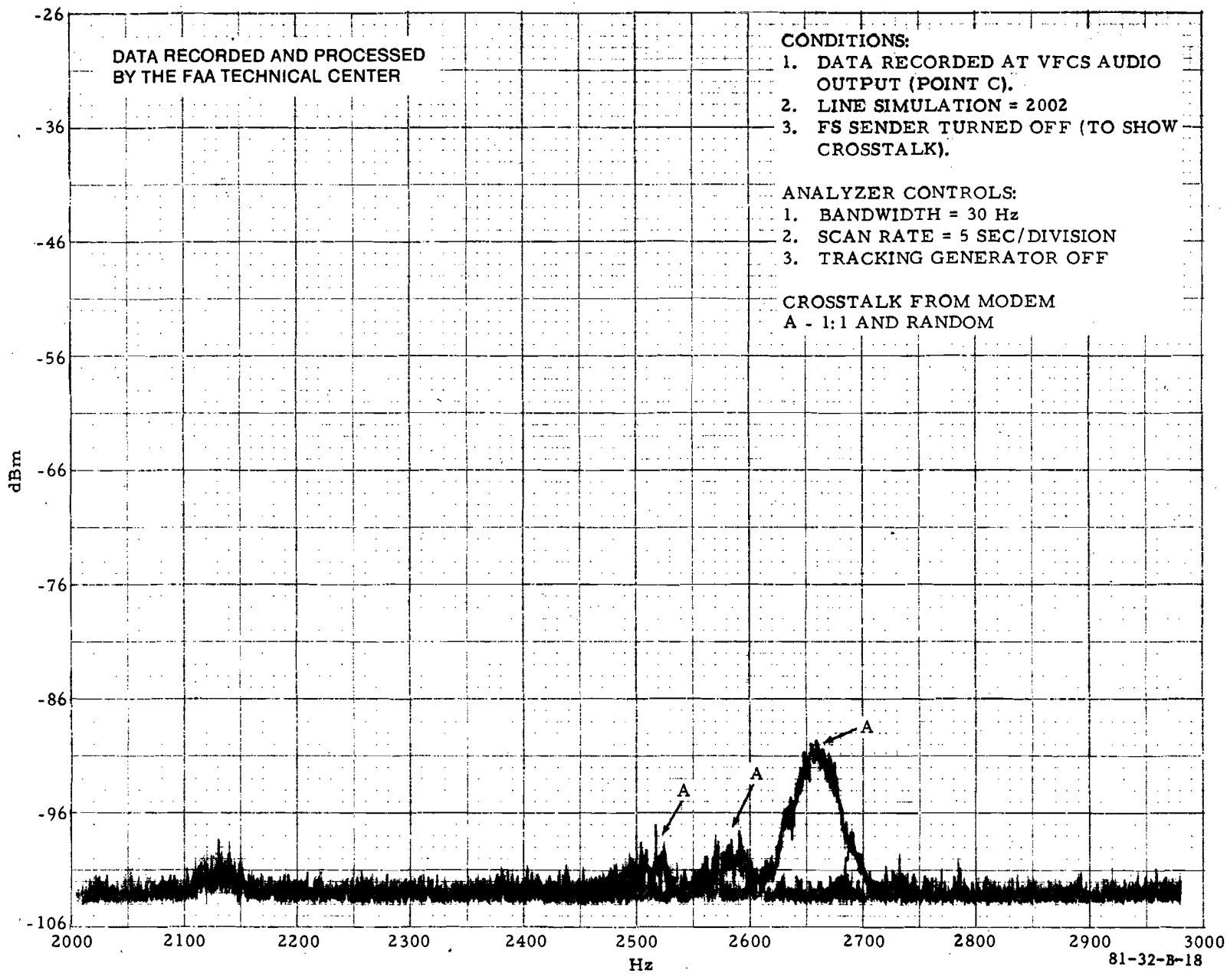

FIGURE B-18. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

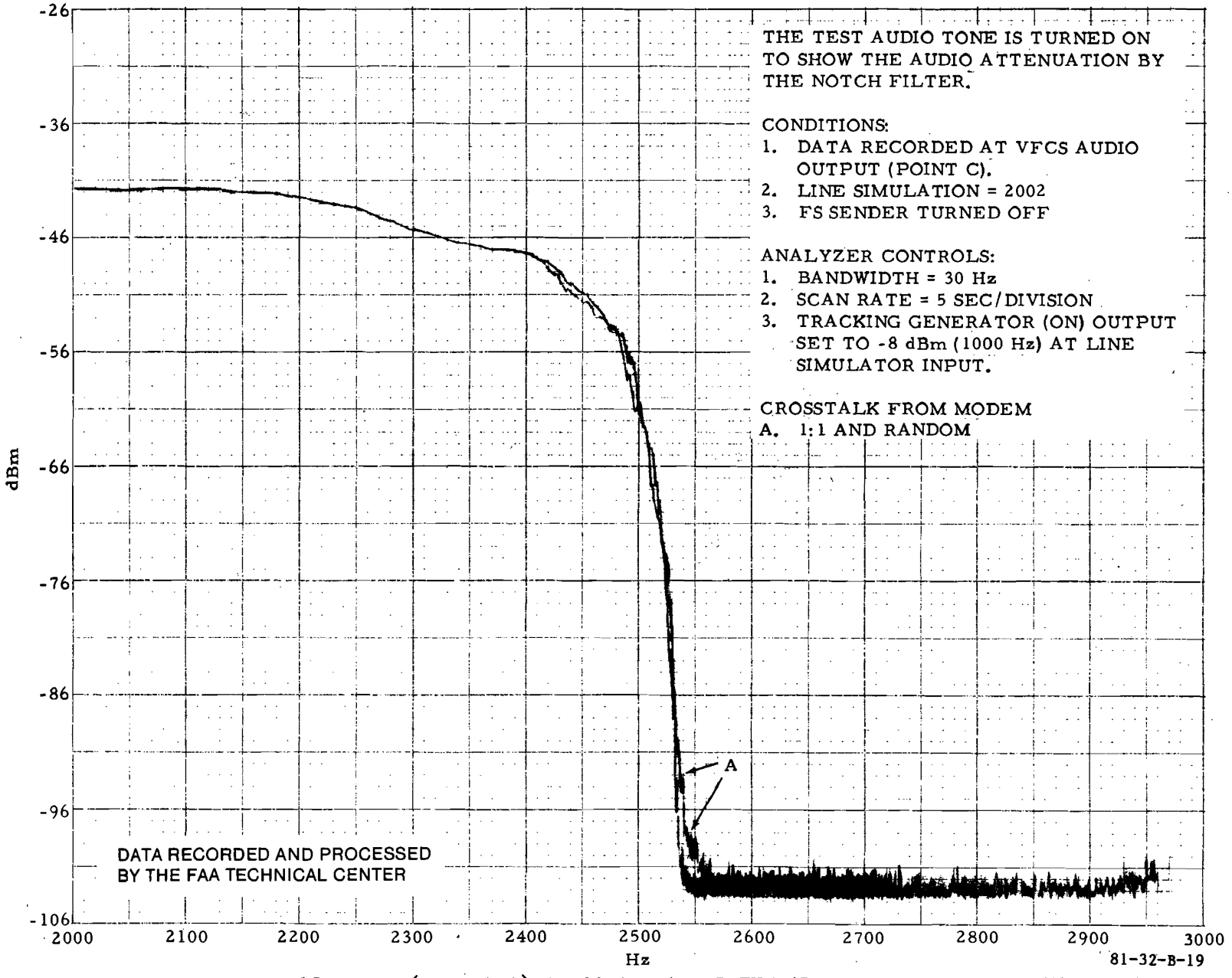

FIGURE B-19. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

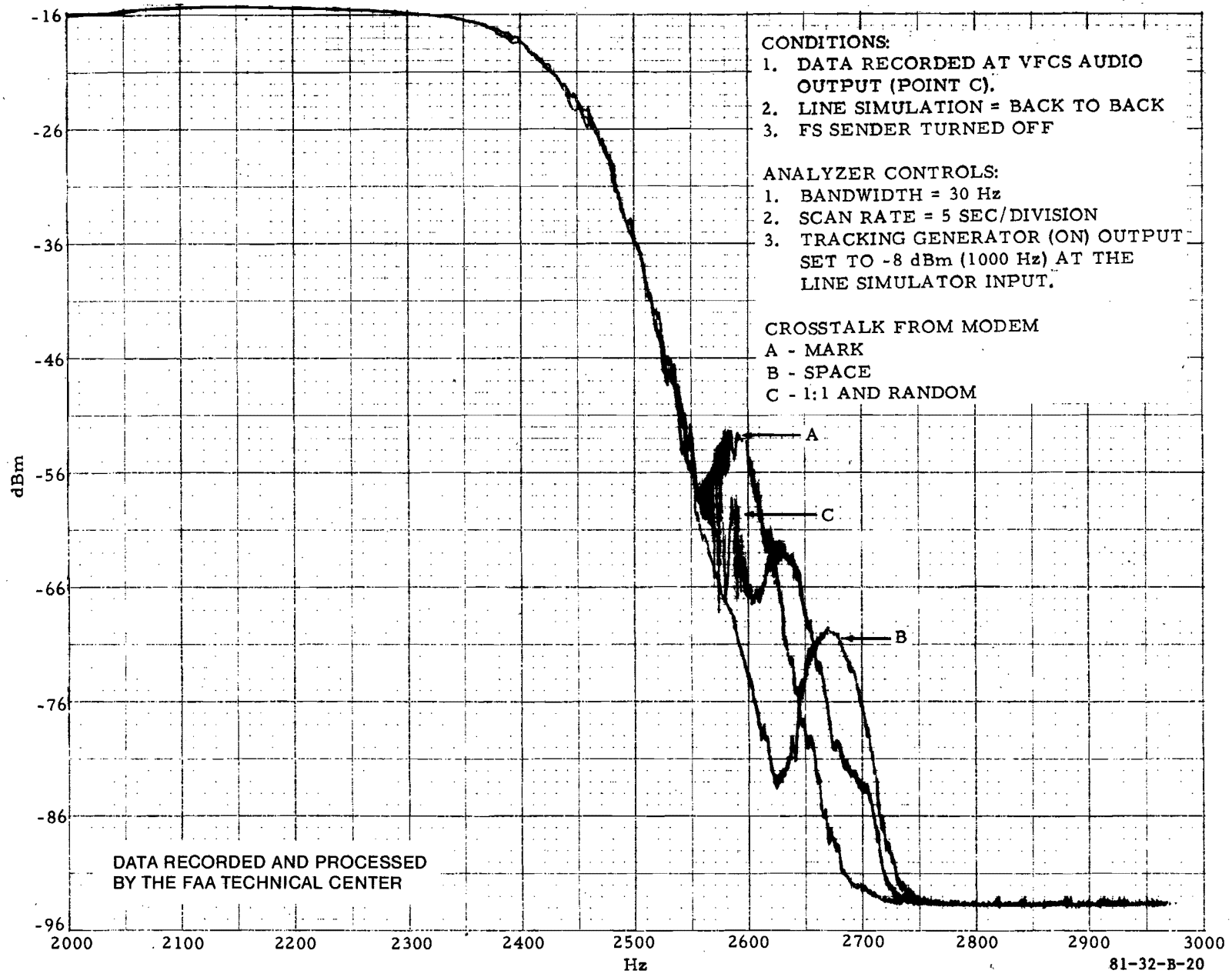

FIGURE B-20. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

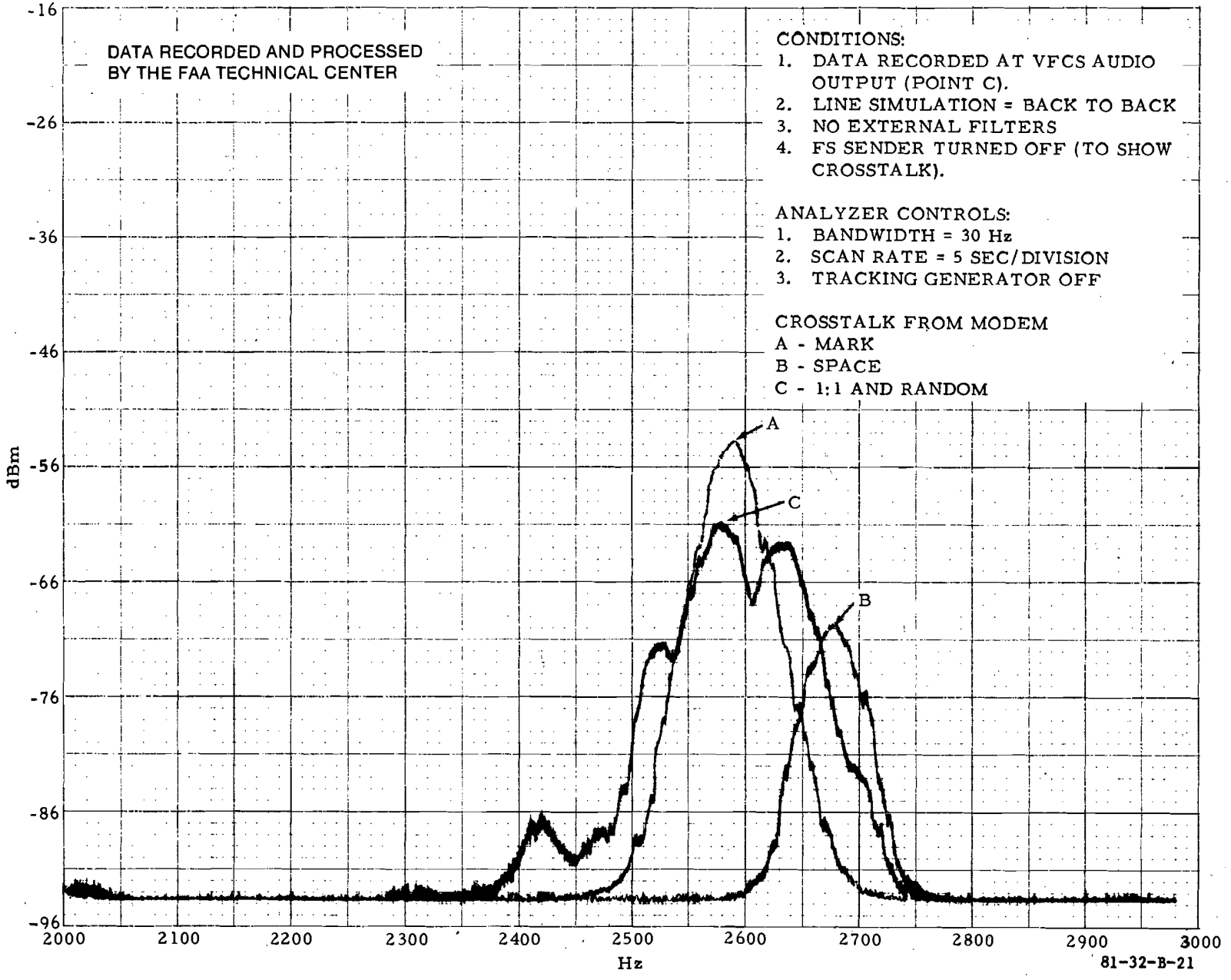

FIGURE B-21. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

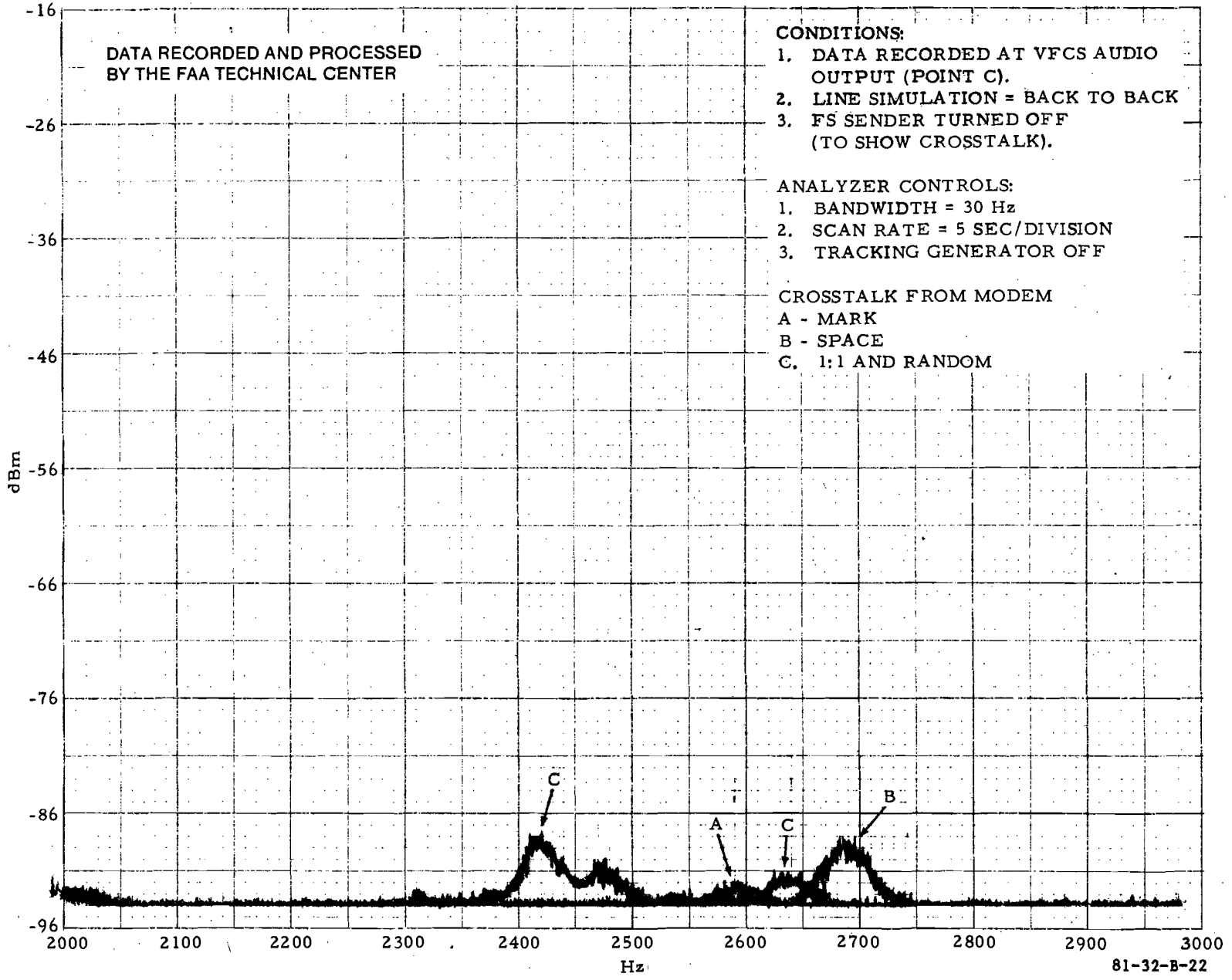

FIGURE B-22. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

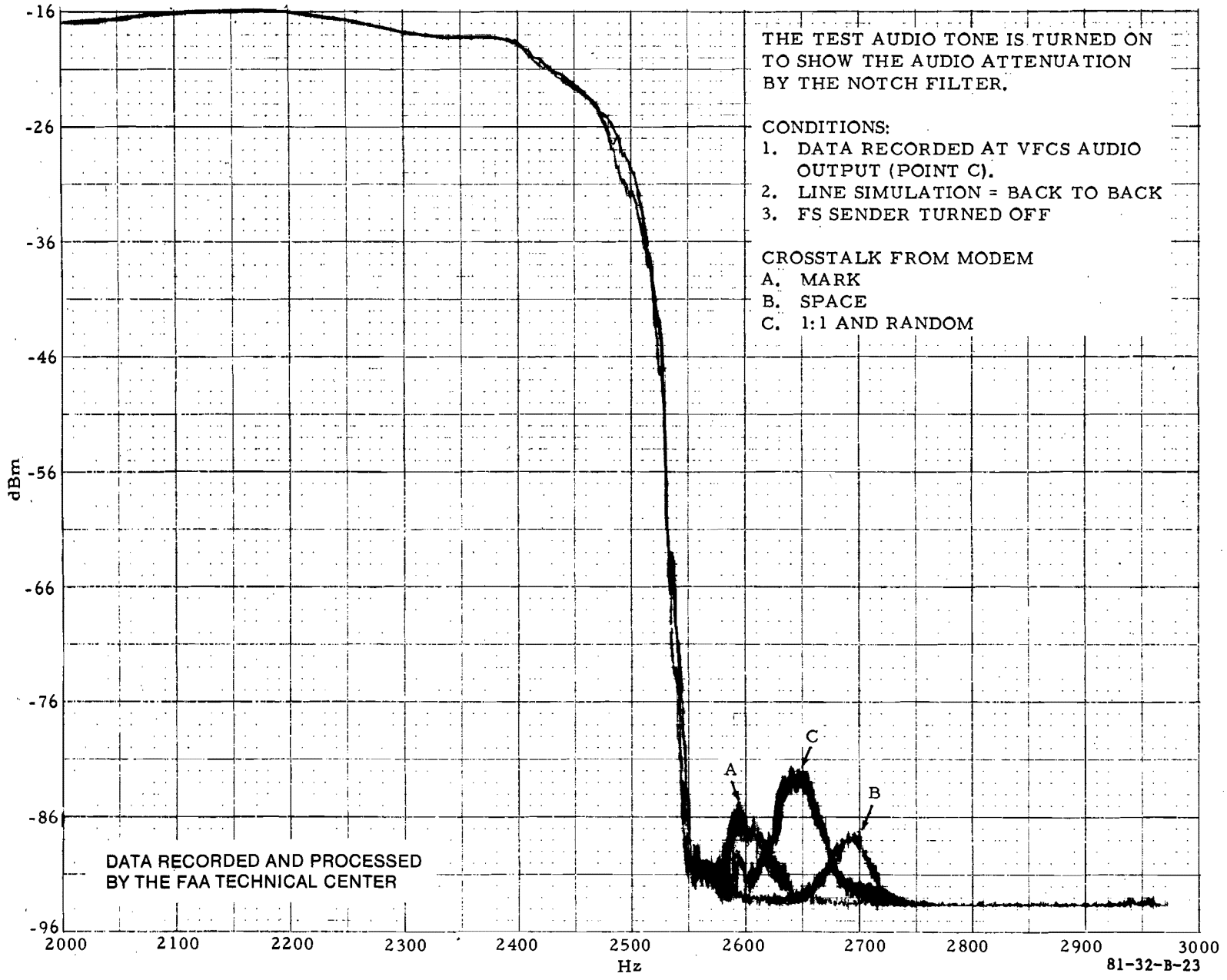

FIGURE B-23. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

APPENDIX C

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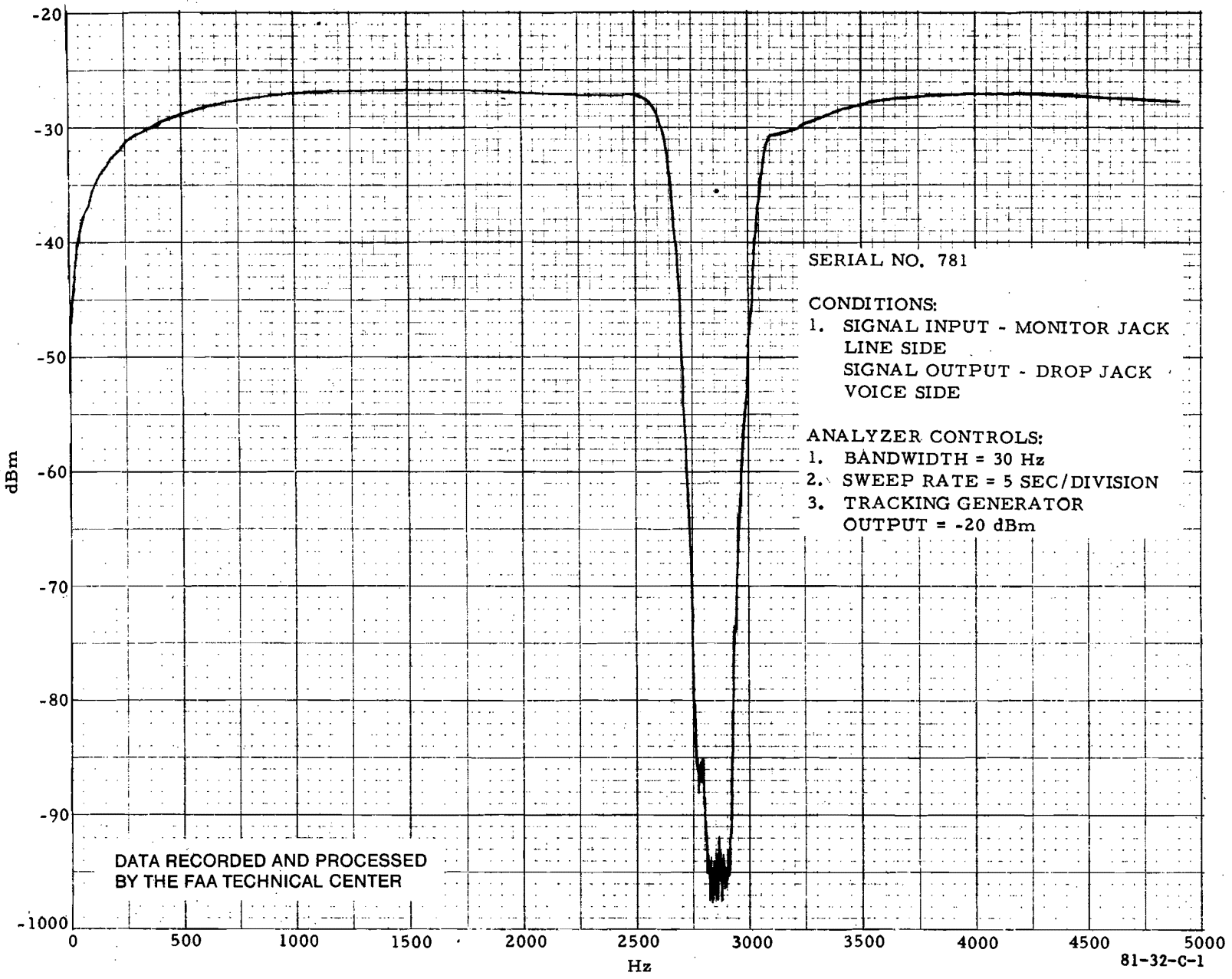
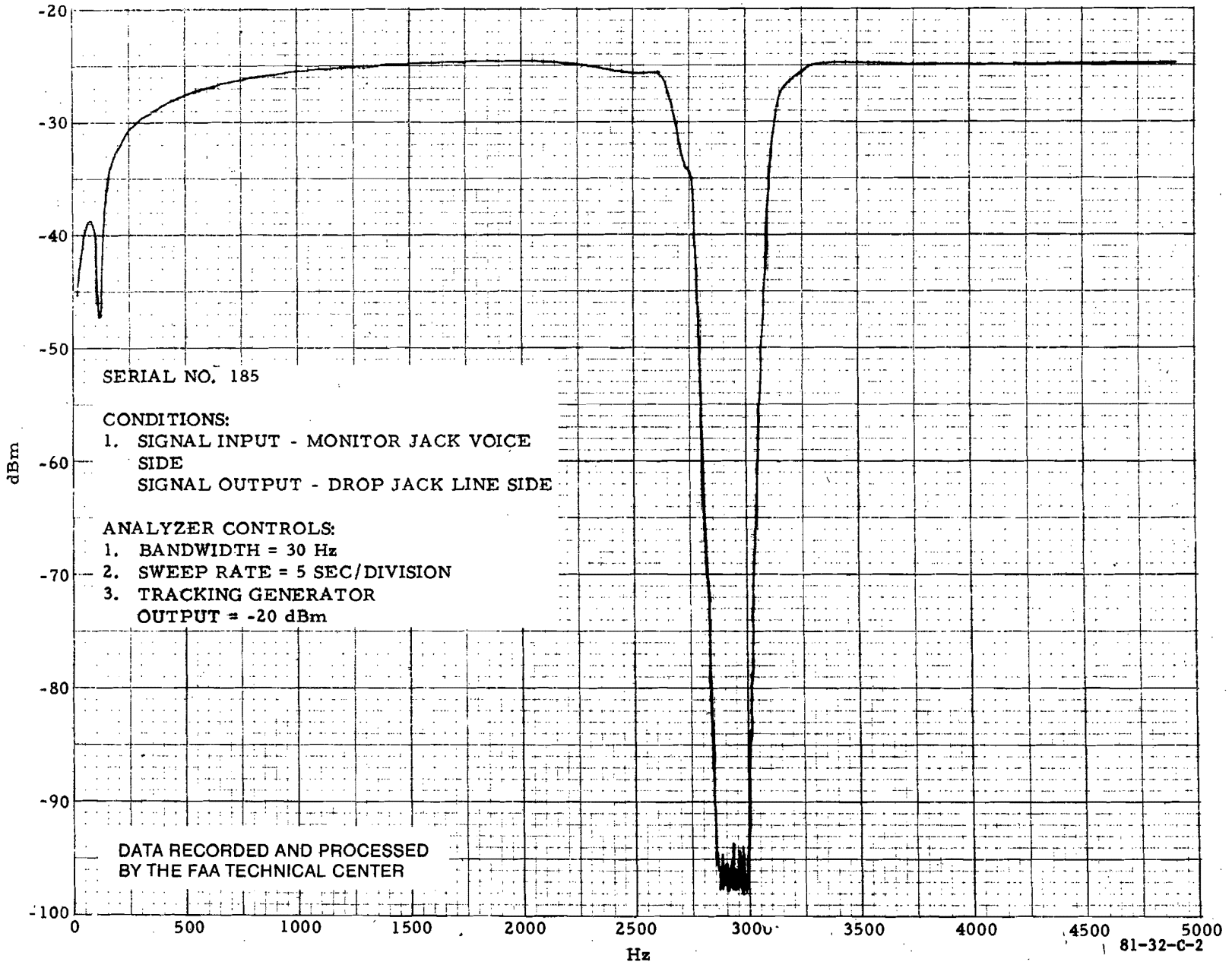


FIGURE C-1. FREQUENCY RESPONSE, SEND FILTER HYBRID-LOCAL TERMINAL



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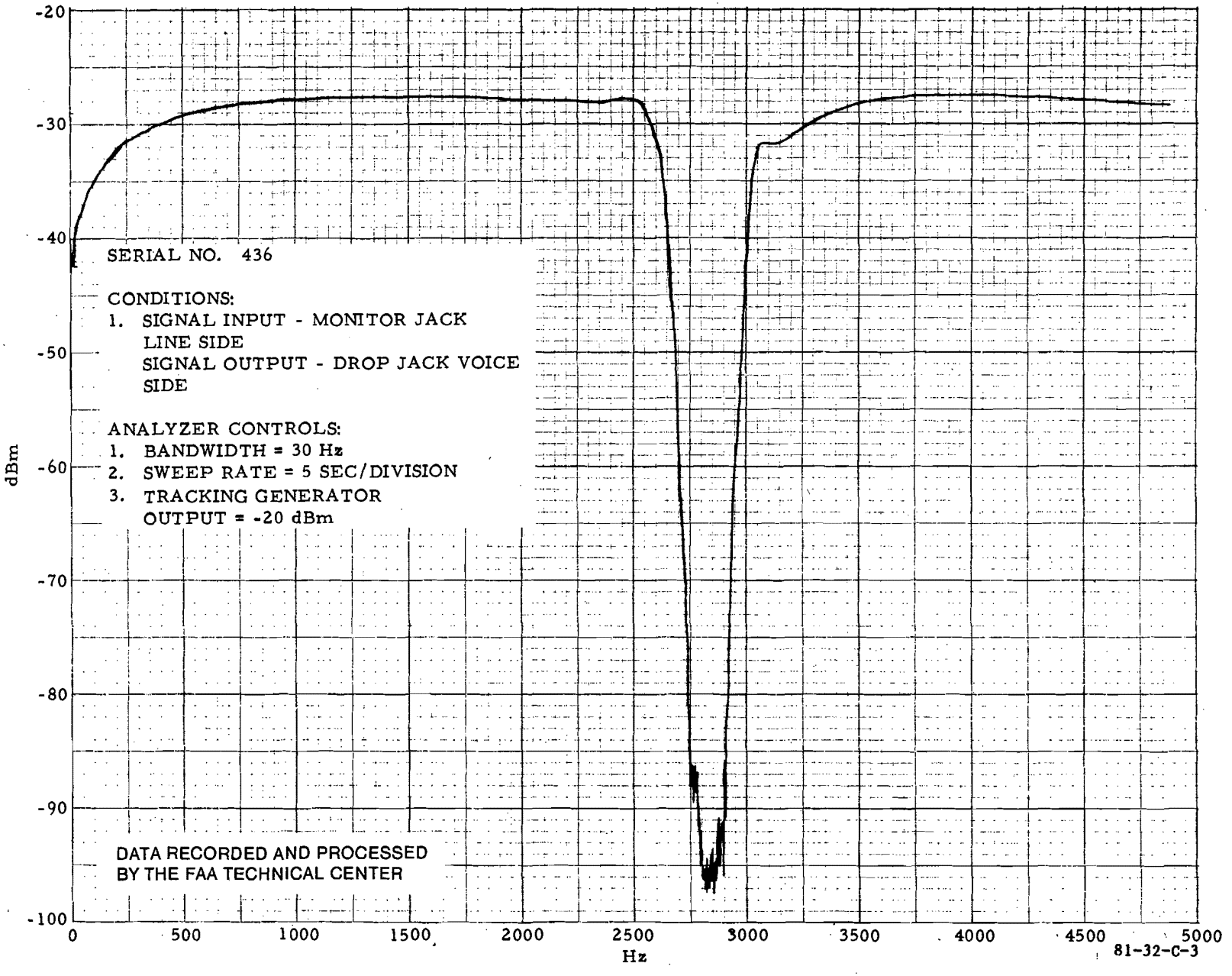

FIGURE C-3. FREQUENCY RESPONSE, SEND FILTER HYBRID-REMOTE TERMINAL

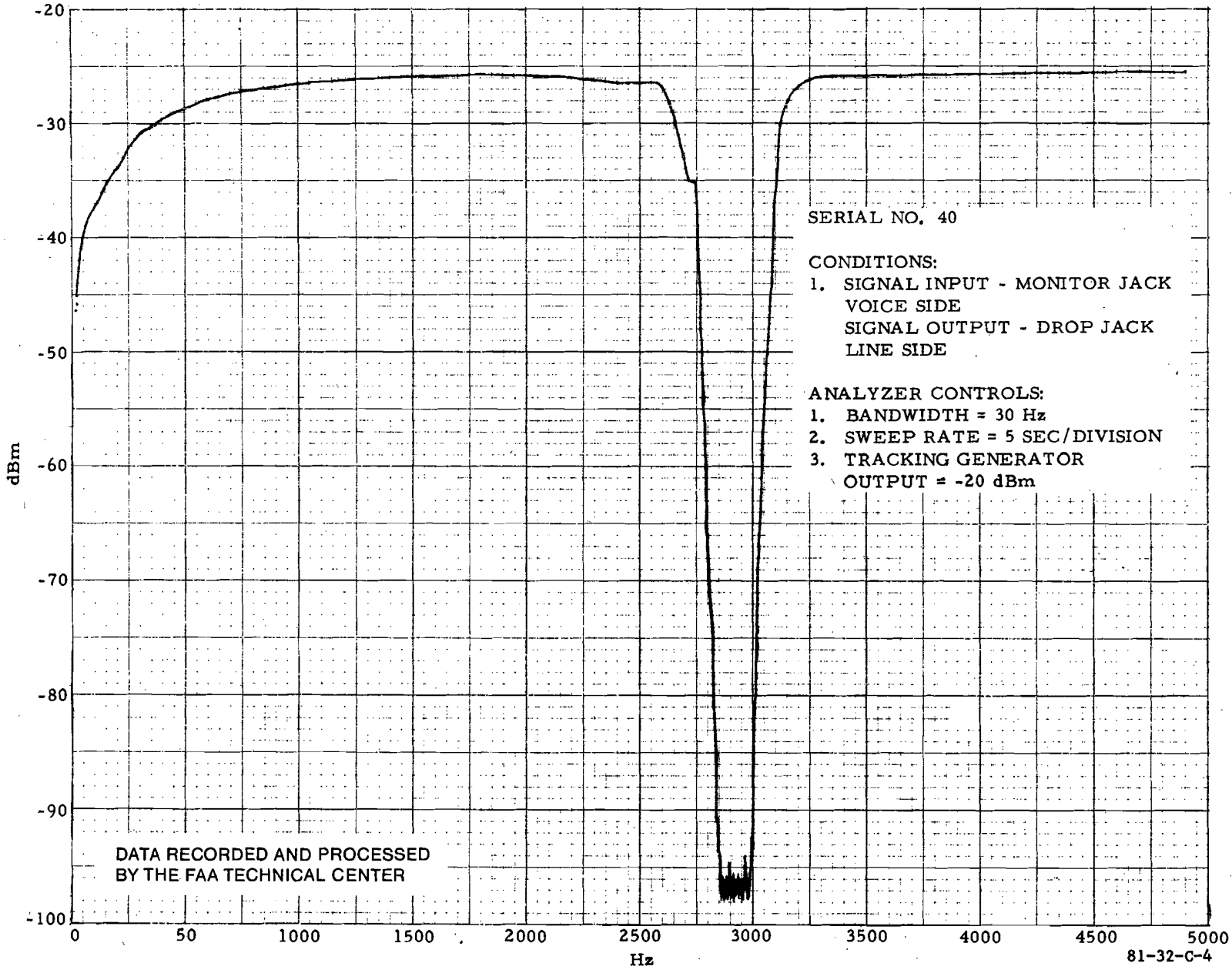

FIGURE C-4. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-REMOTE TERMINAL

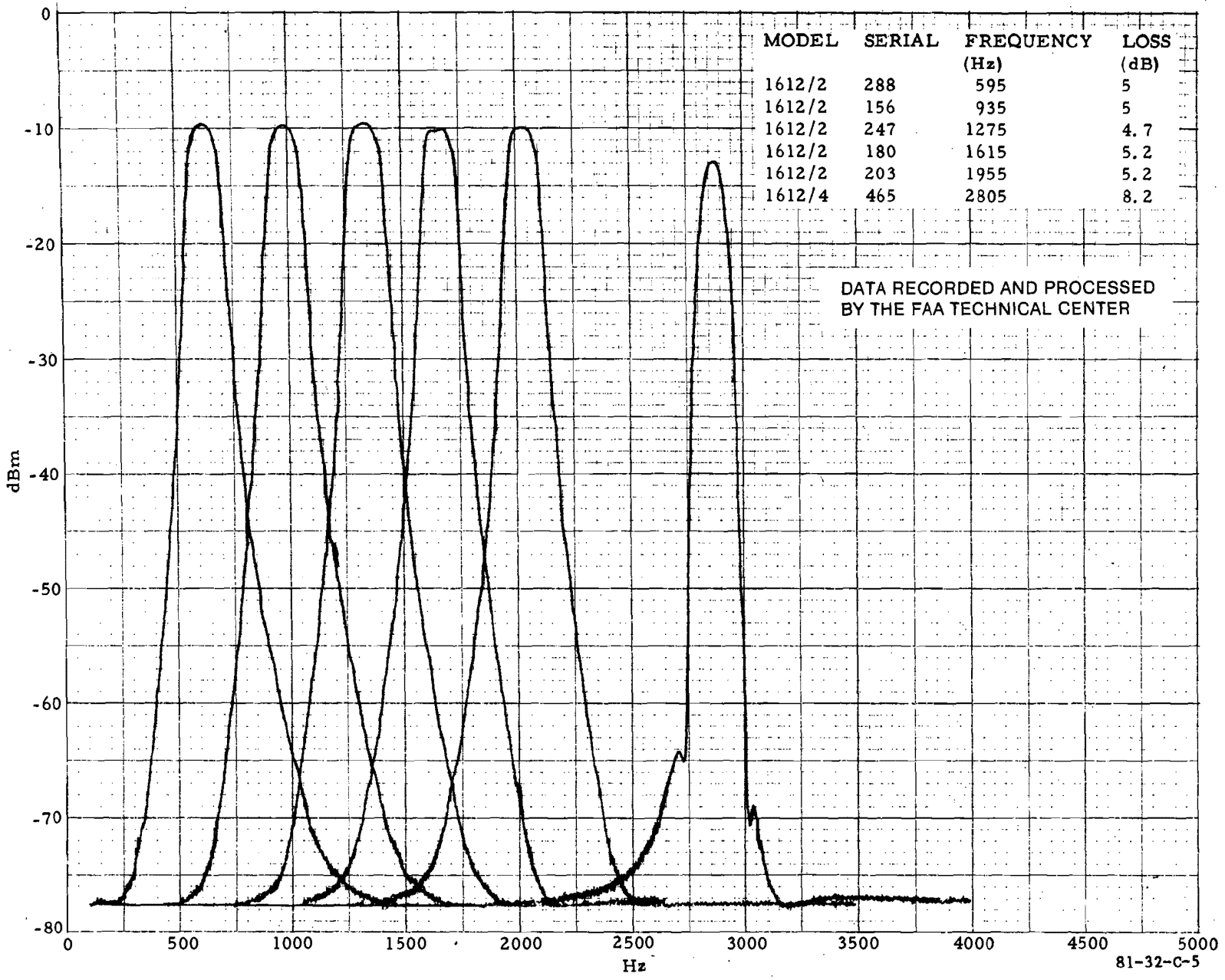

FIGURE C-5. FREQUENCY RESPONSE, AM RECEIVER BANDPASS FILTERS

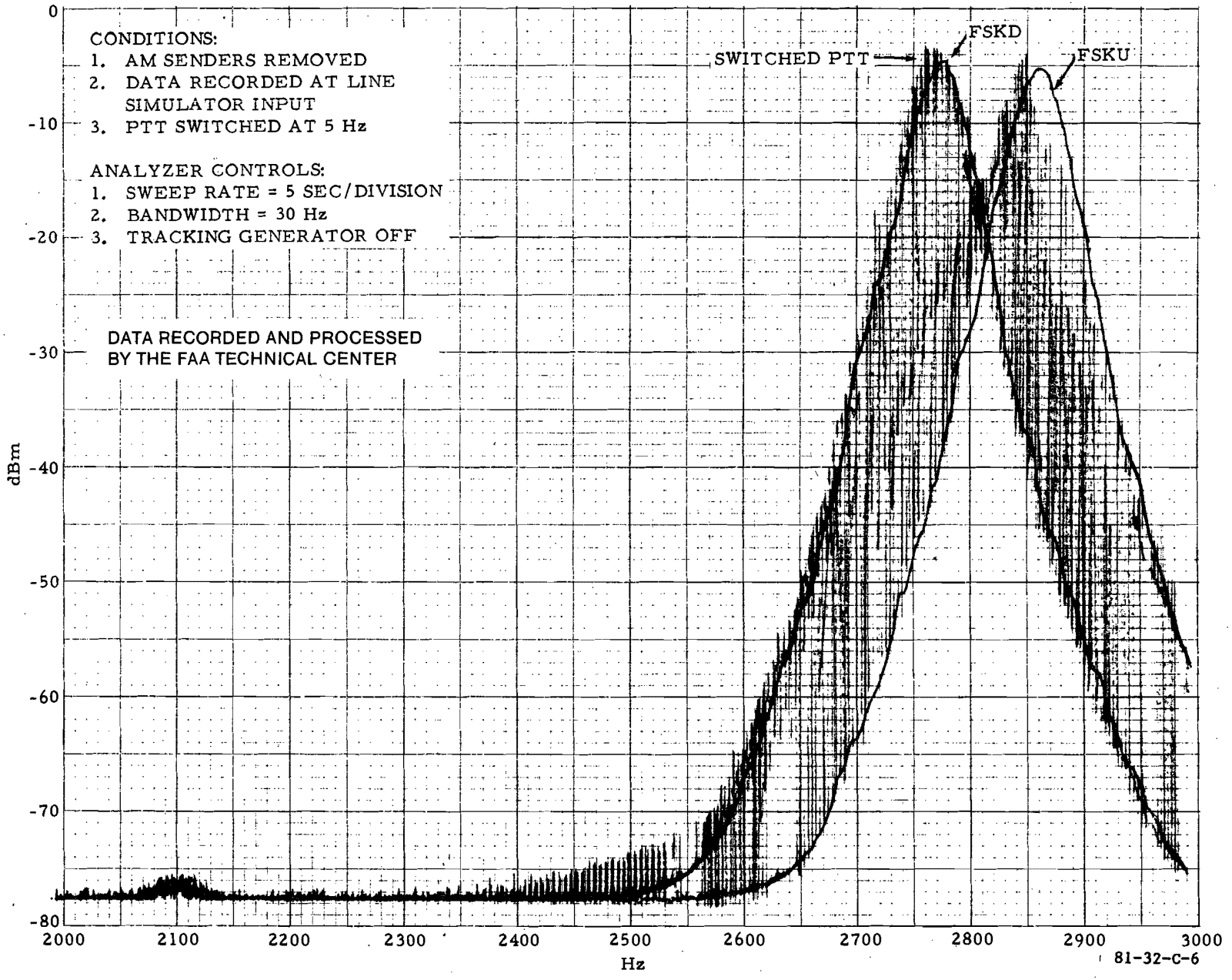

FIGURE C-6. EXPANDED SPECTRUM OF SWITCHED PTT, AND STEADY STATE PTT

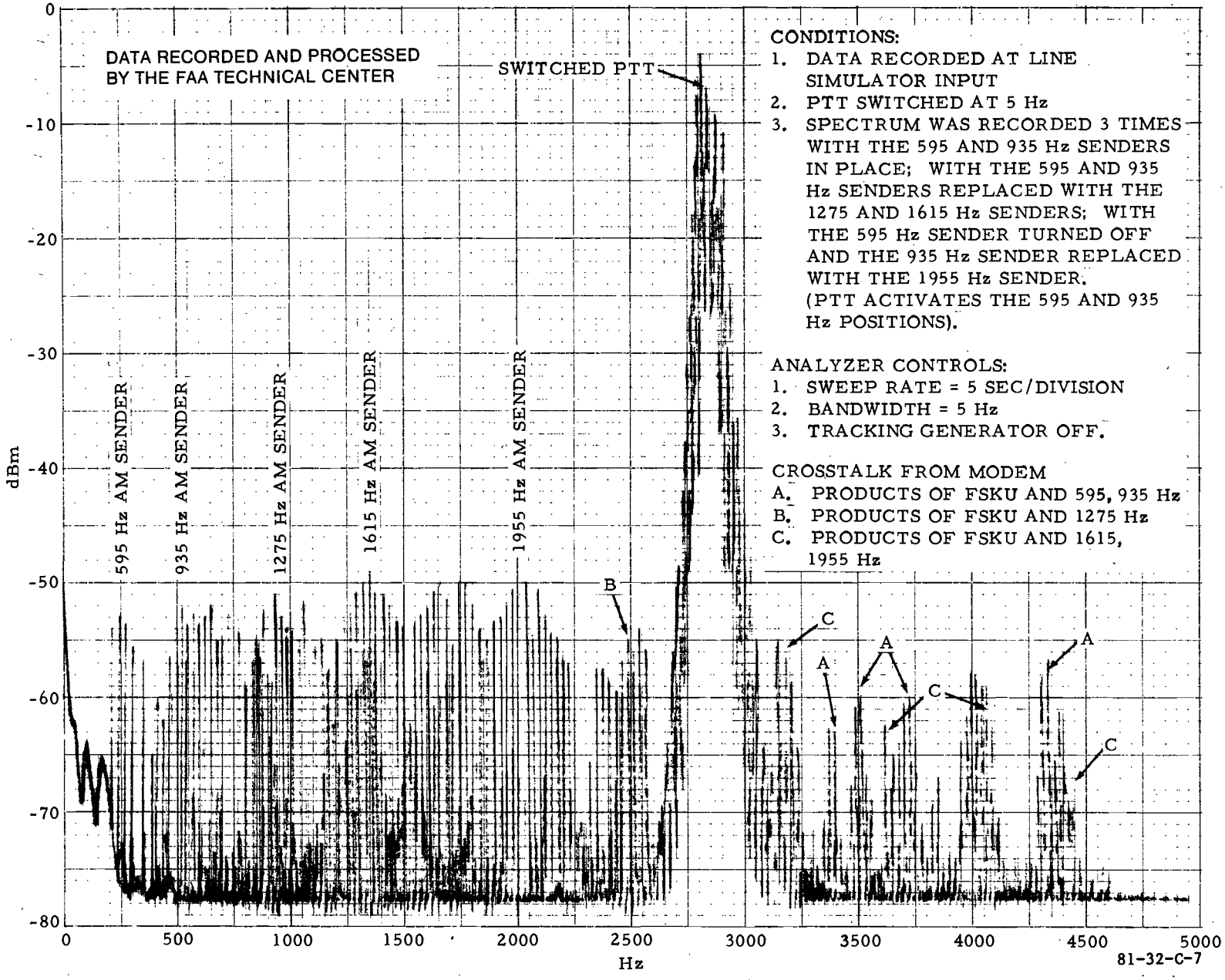

FIGURE C-7. SPECTRUM OF SWITCHED PTT

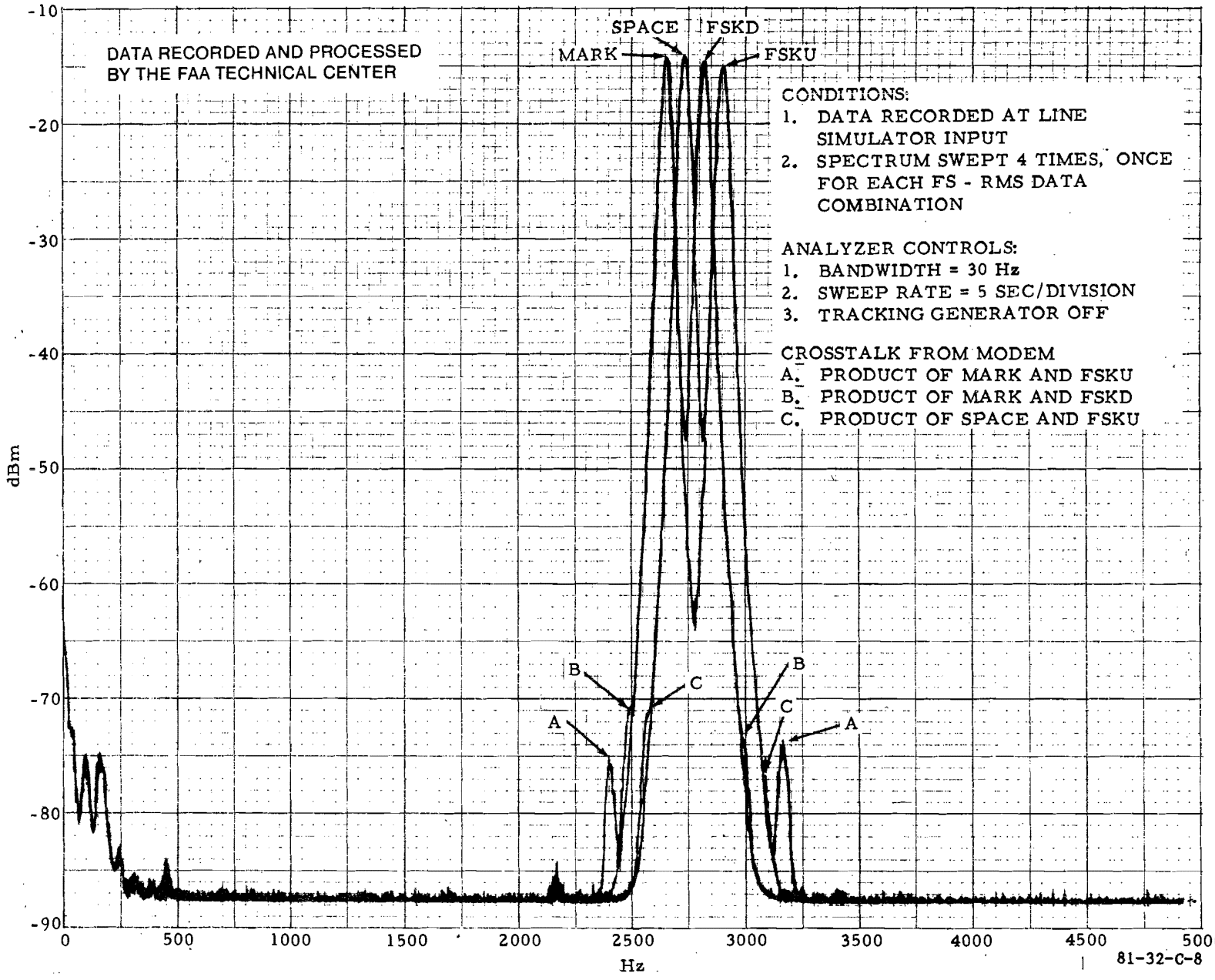

FIGURE C-8. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND STEADY STATE RMS DATA (MARK AND SPACE)

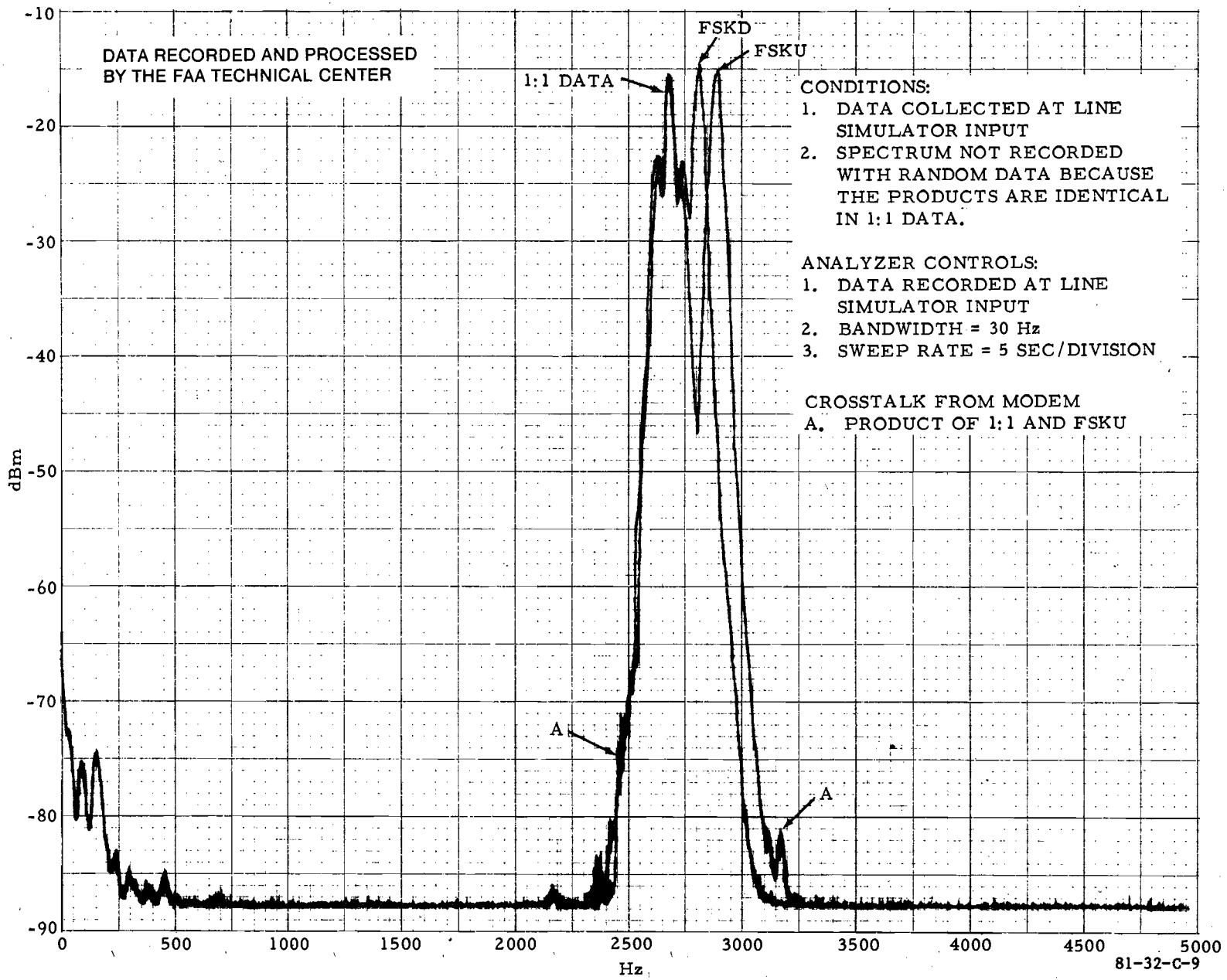

FIGURE C-9. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND TRANSITIONAL RMS DATA (1:1 AND RANDOM)

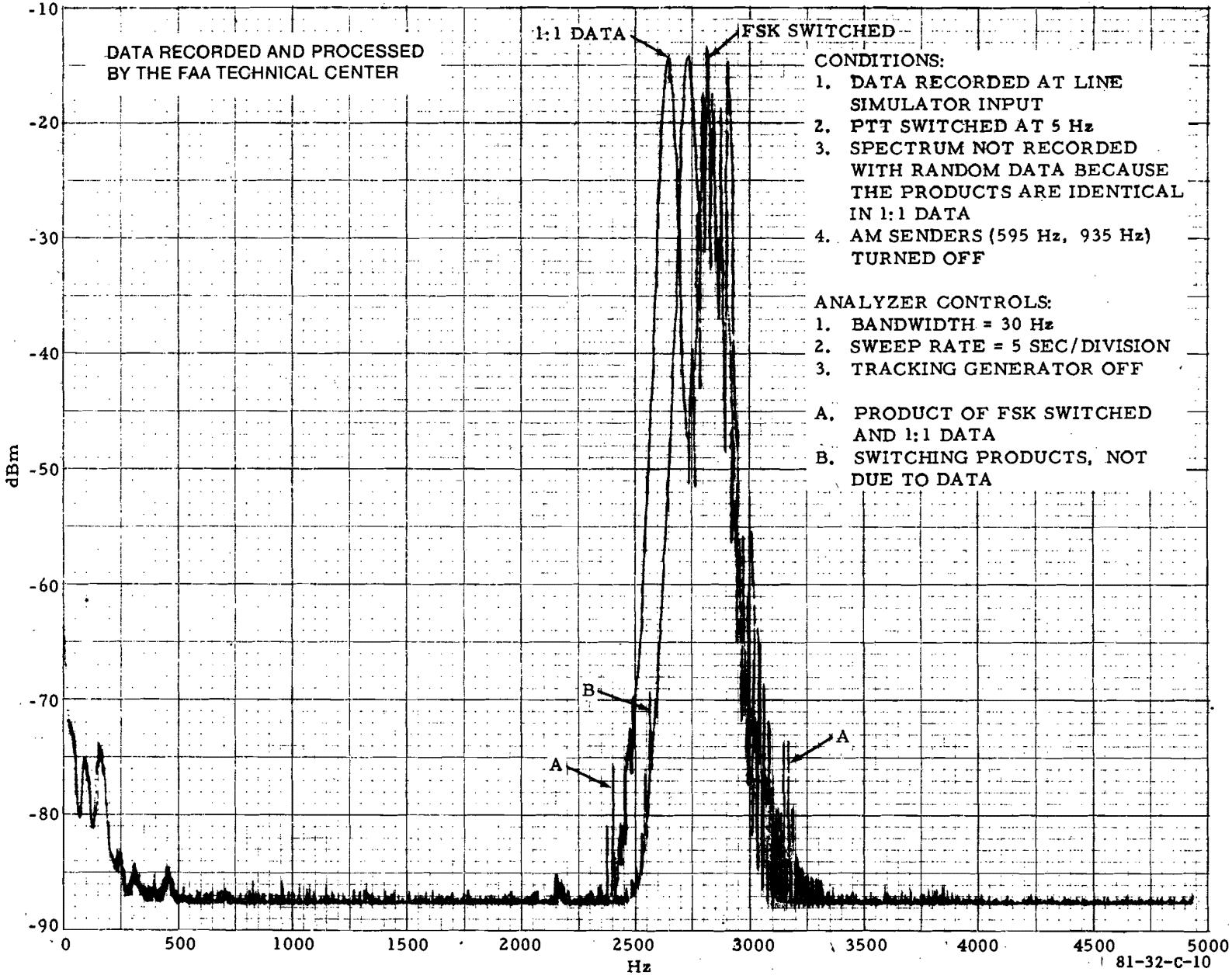

FIGURE C-10. SPECTRUM OF PRODUCTS OF SWITCHED PTT AND TRANSITIONAL RMS DATA

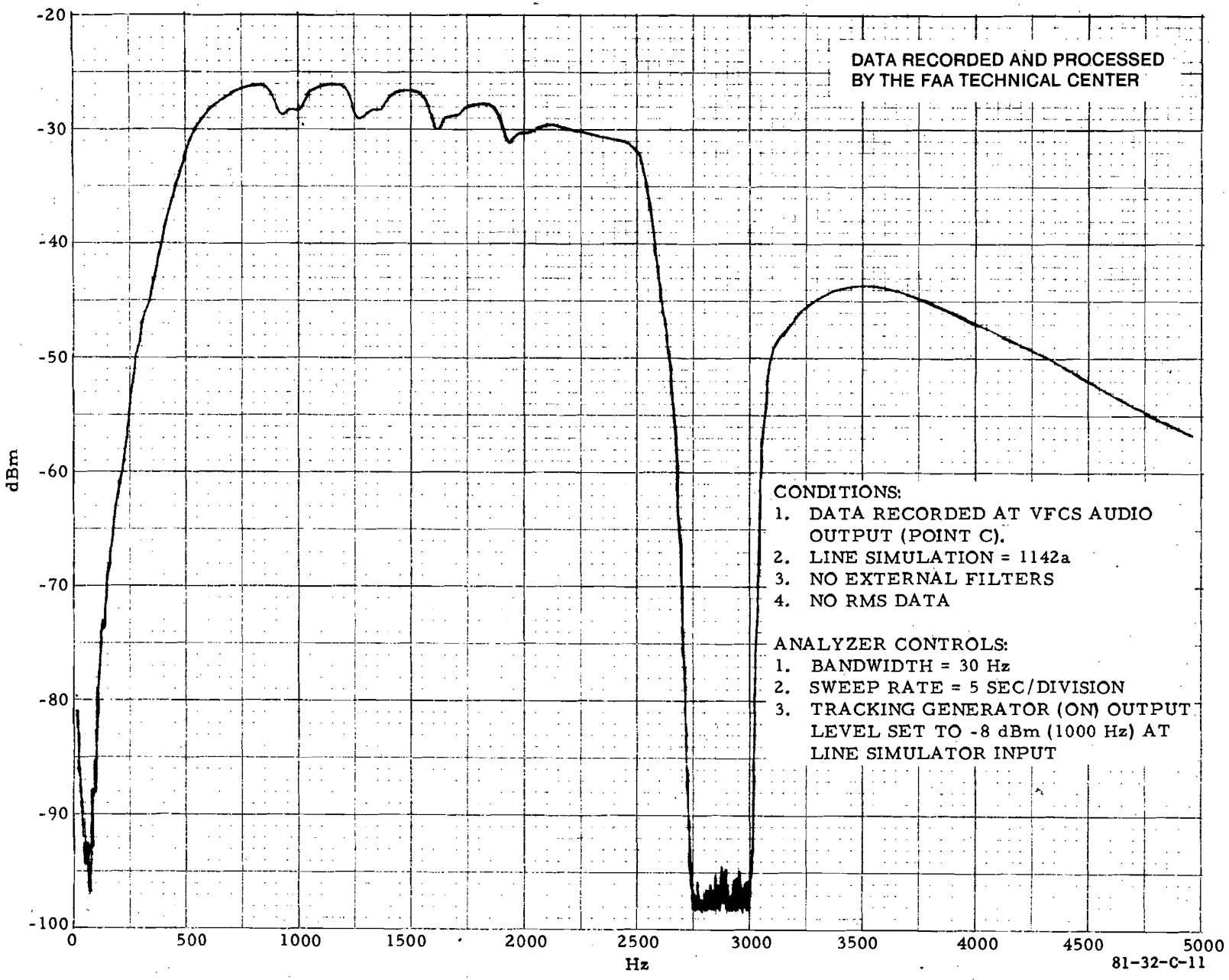

FIGURE C-11. END TO END FREQUENCY RESPONSE OF VFSS

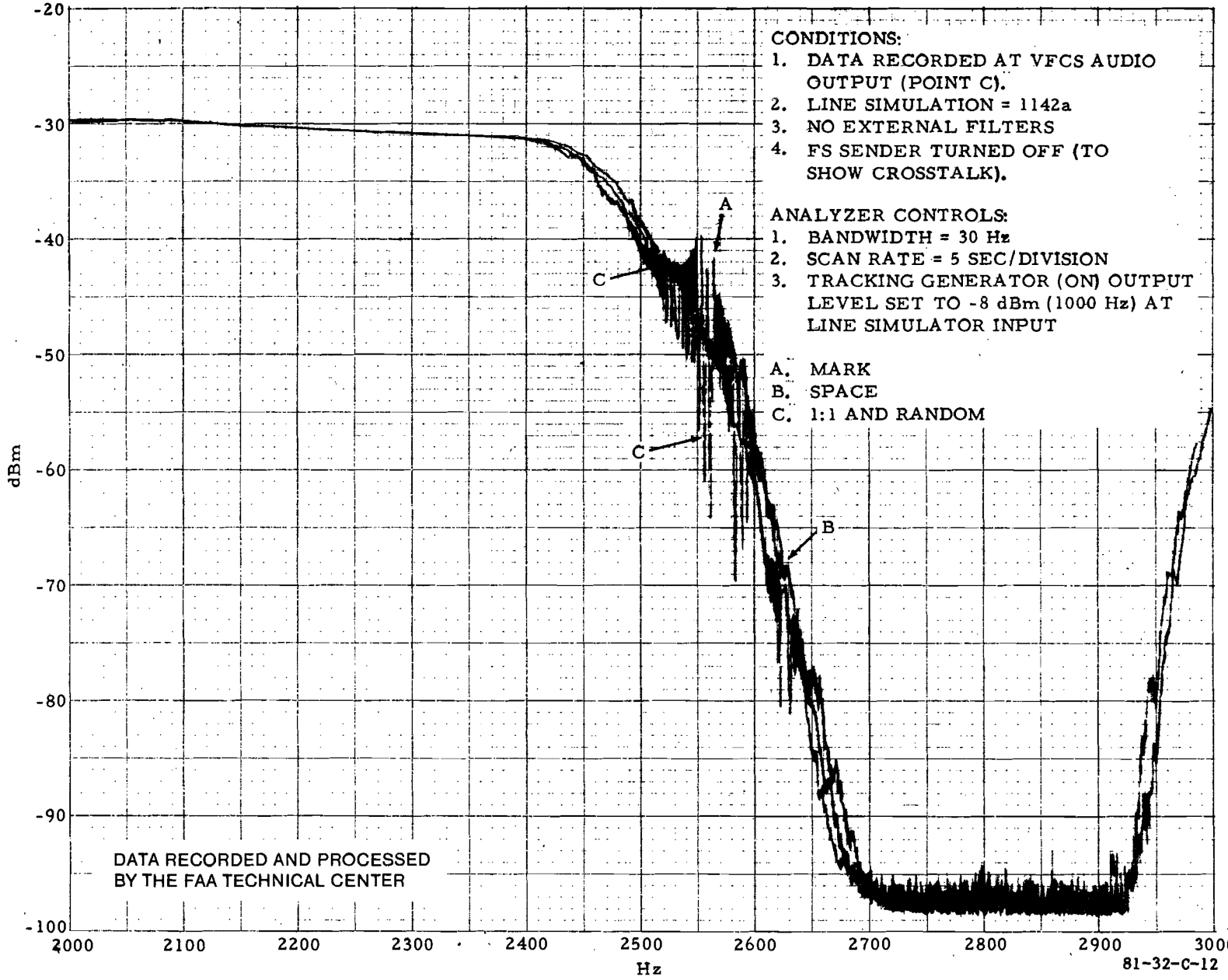

FIGURE C-12. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

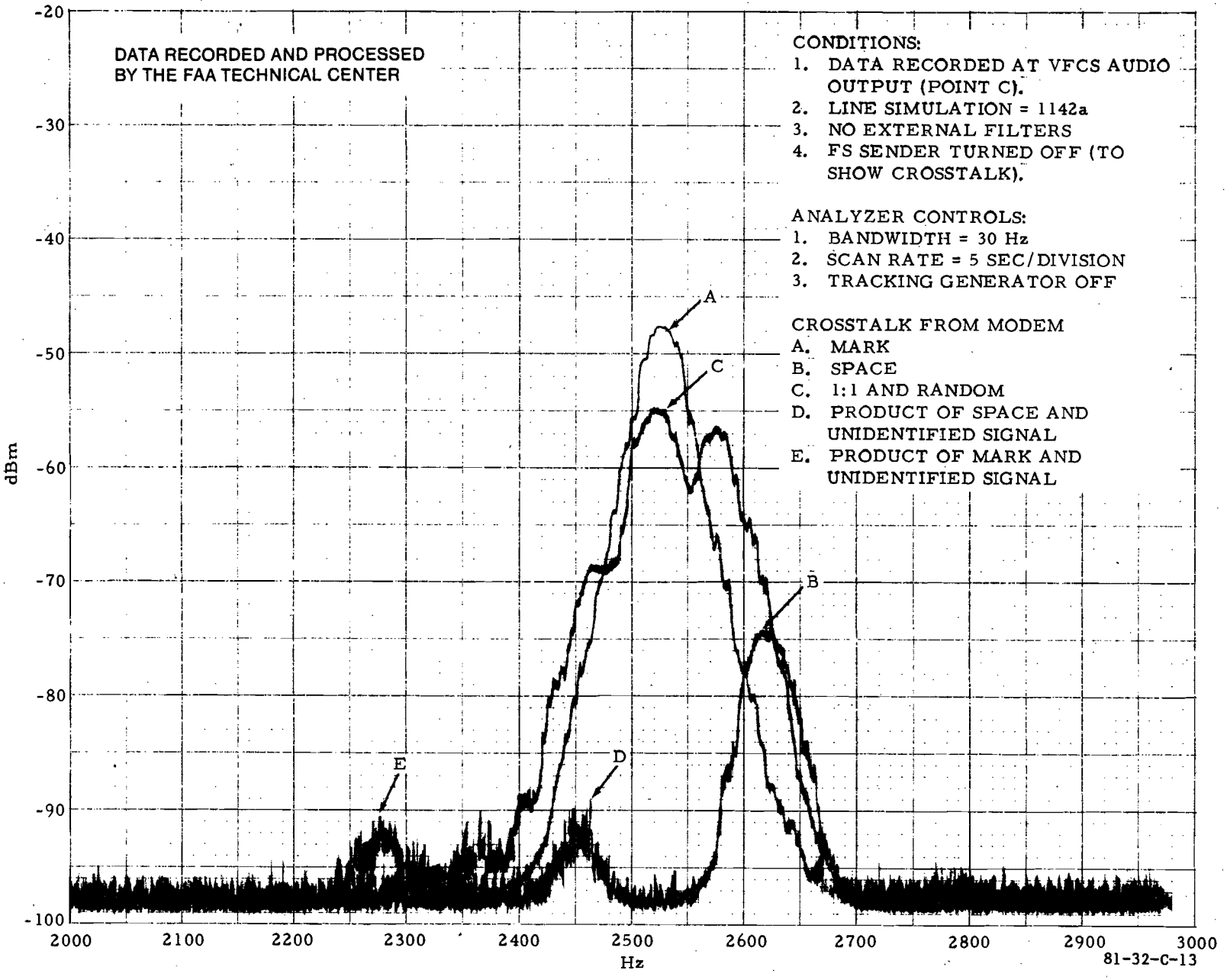

FIGURE C-13. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

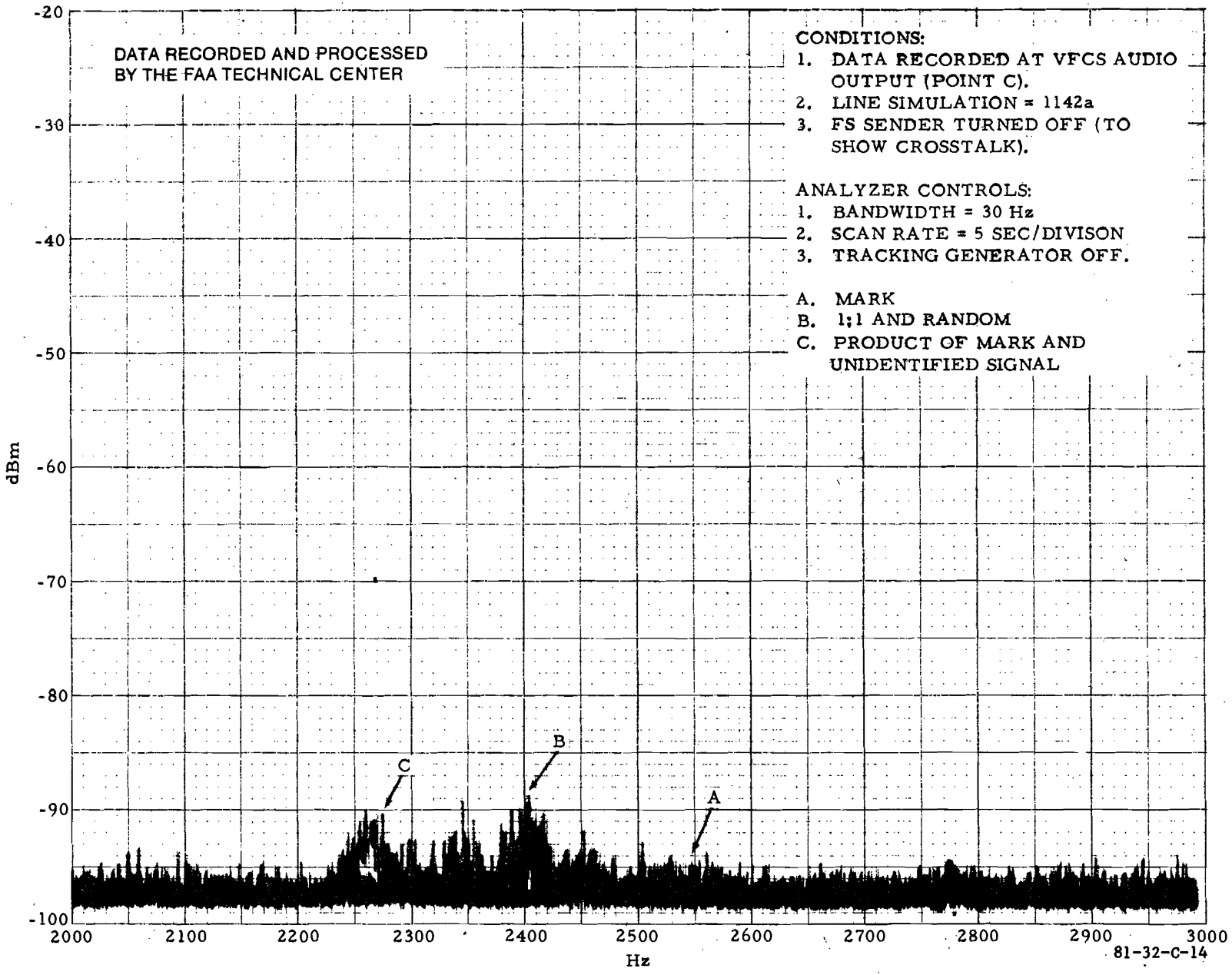

FIGURE C-14. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVER TERMINAL

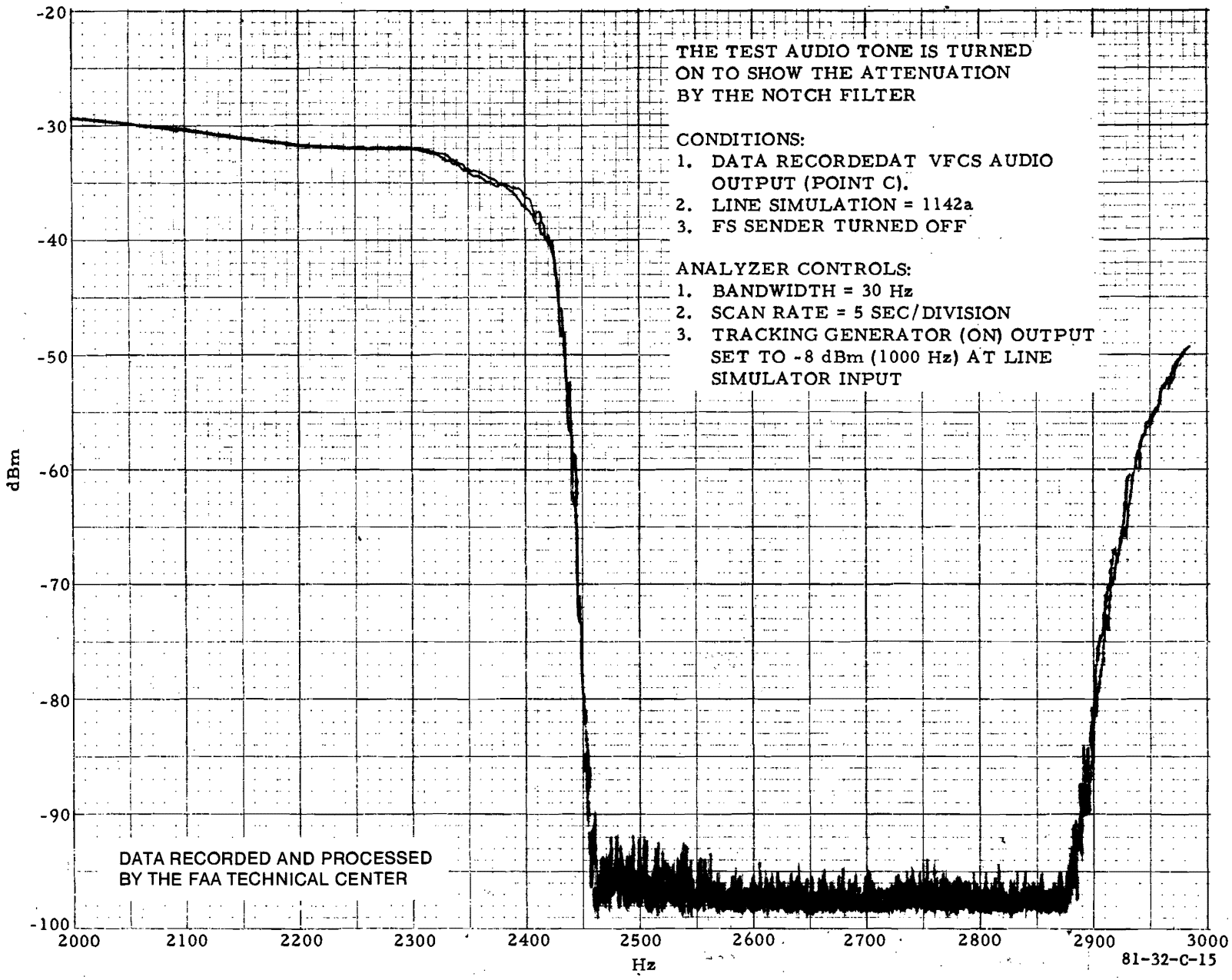

FIGURE C-15. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

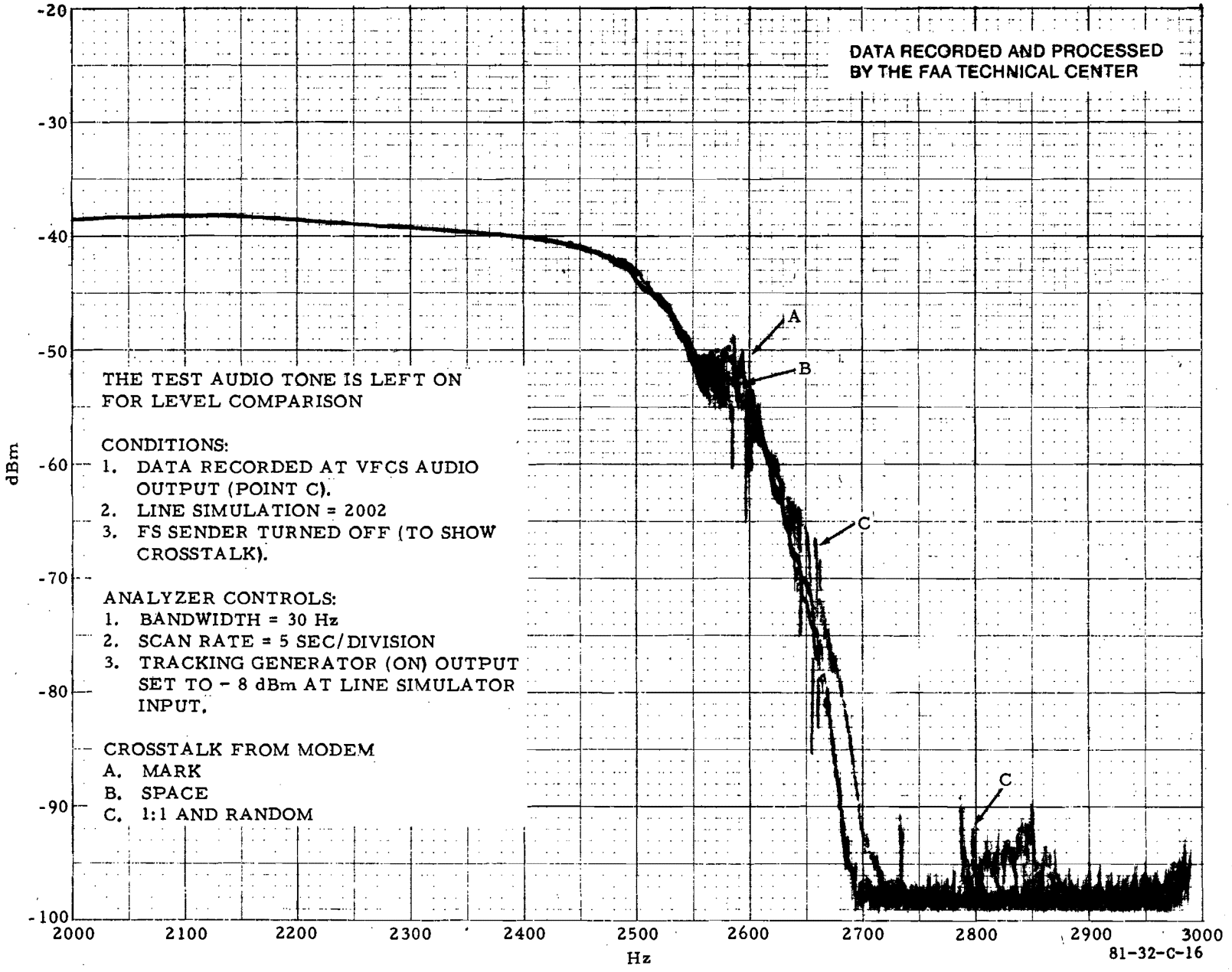

FIGURE C-16. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA

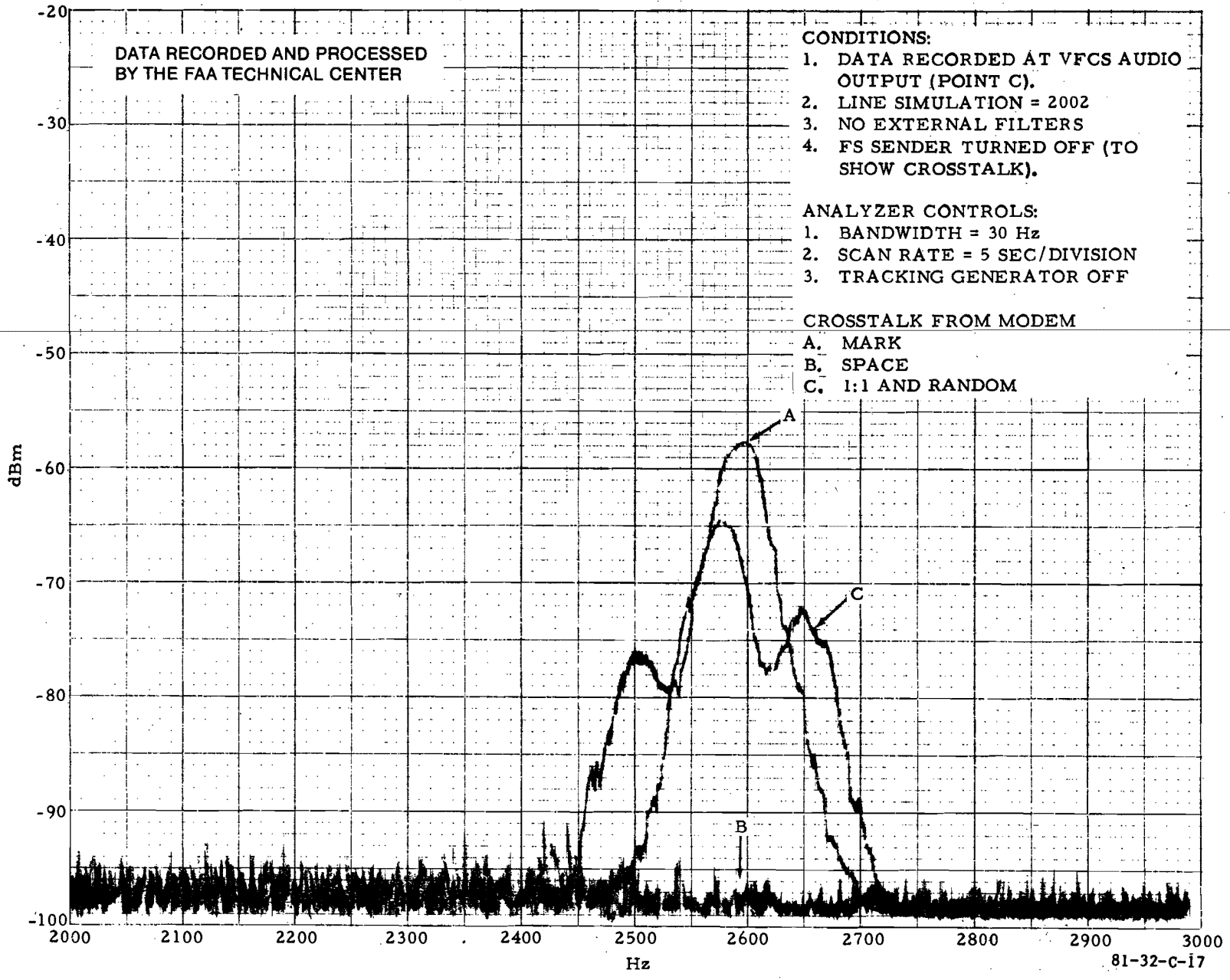

FIGURE C-17. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA; AUTIO REMOVED

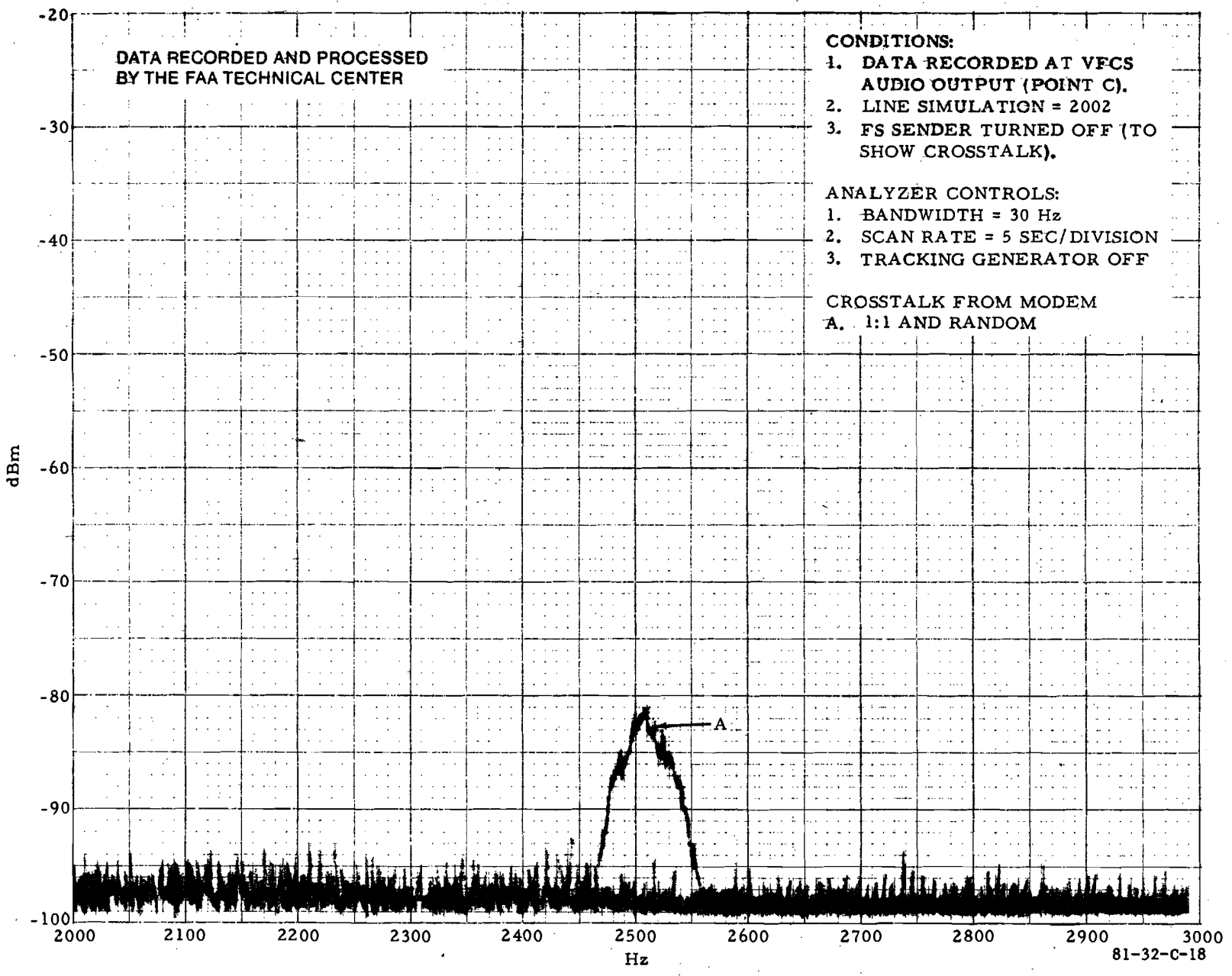

FIGURE C-18. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

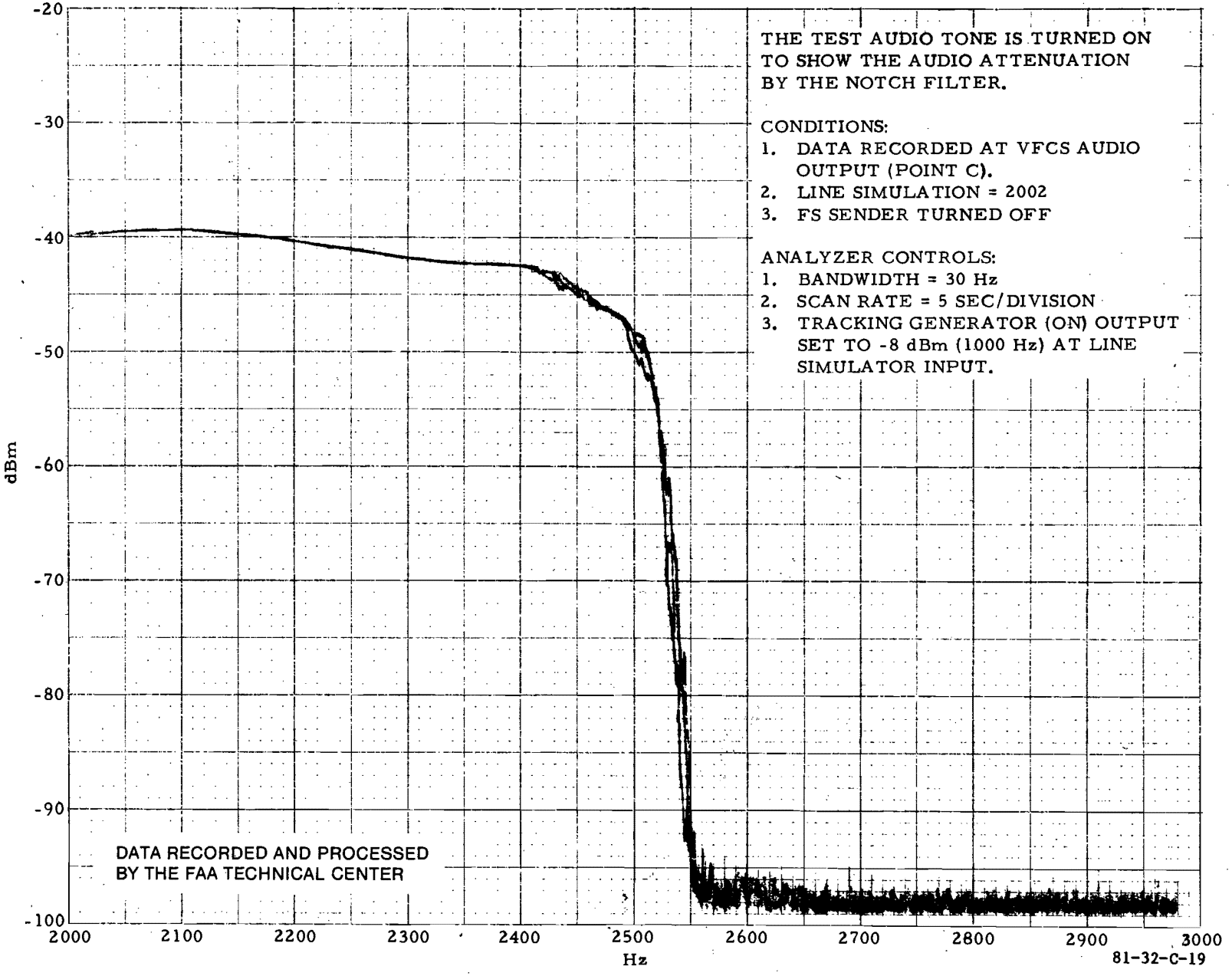

FIGURE C-19. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

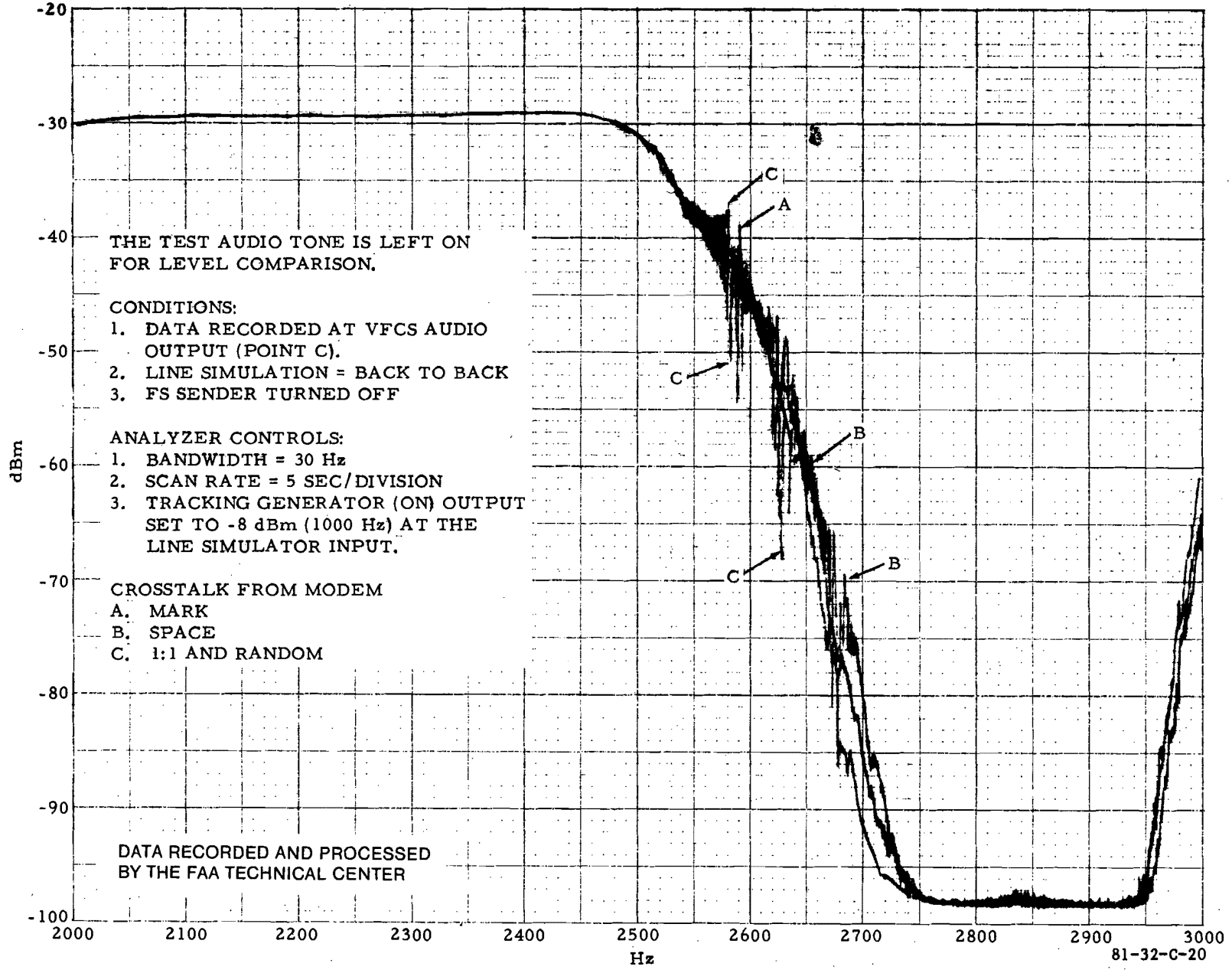

FIGURE C-20. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

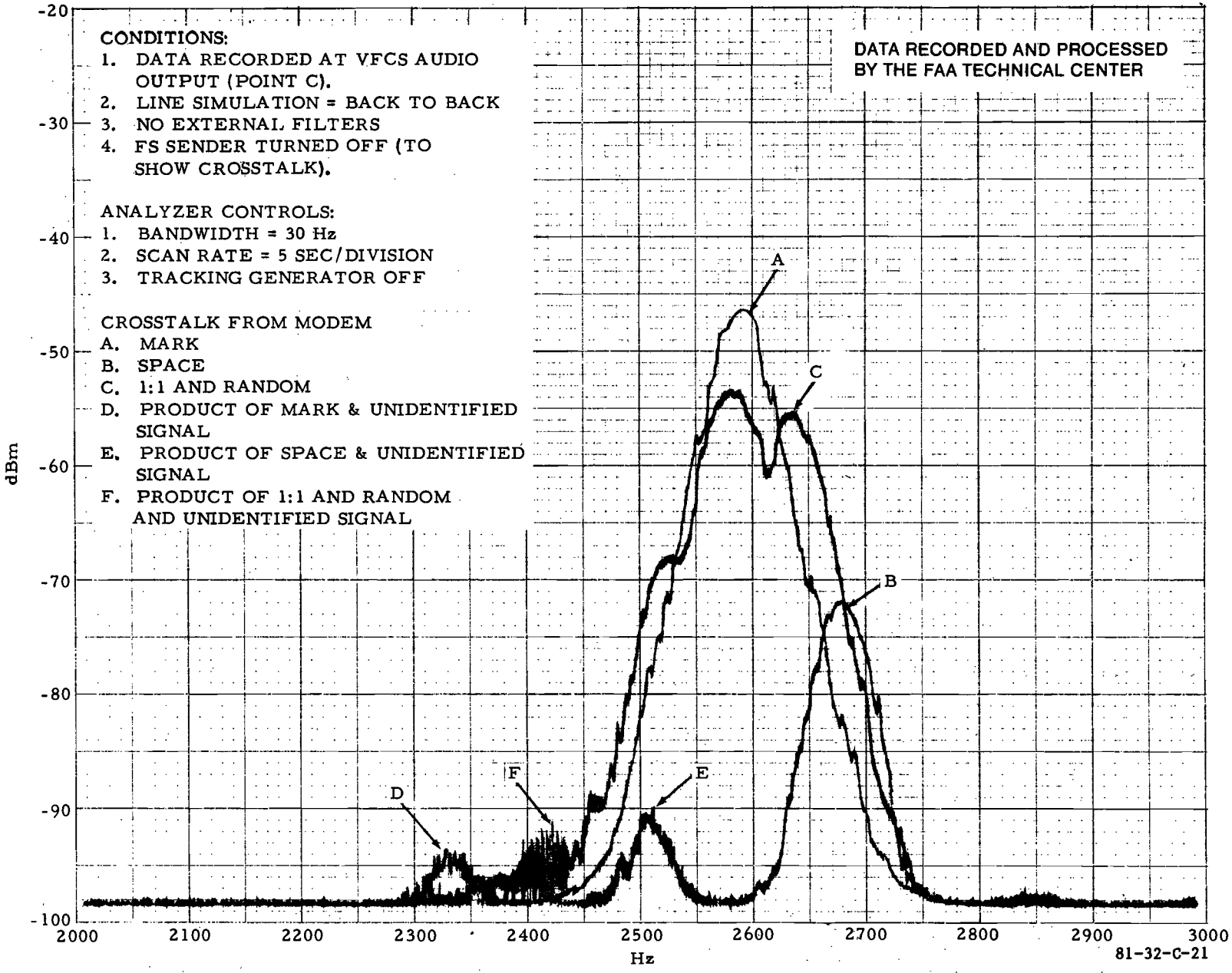

FIGURE C-21. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

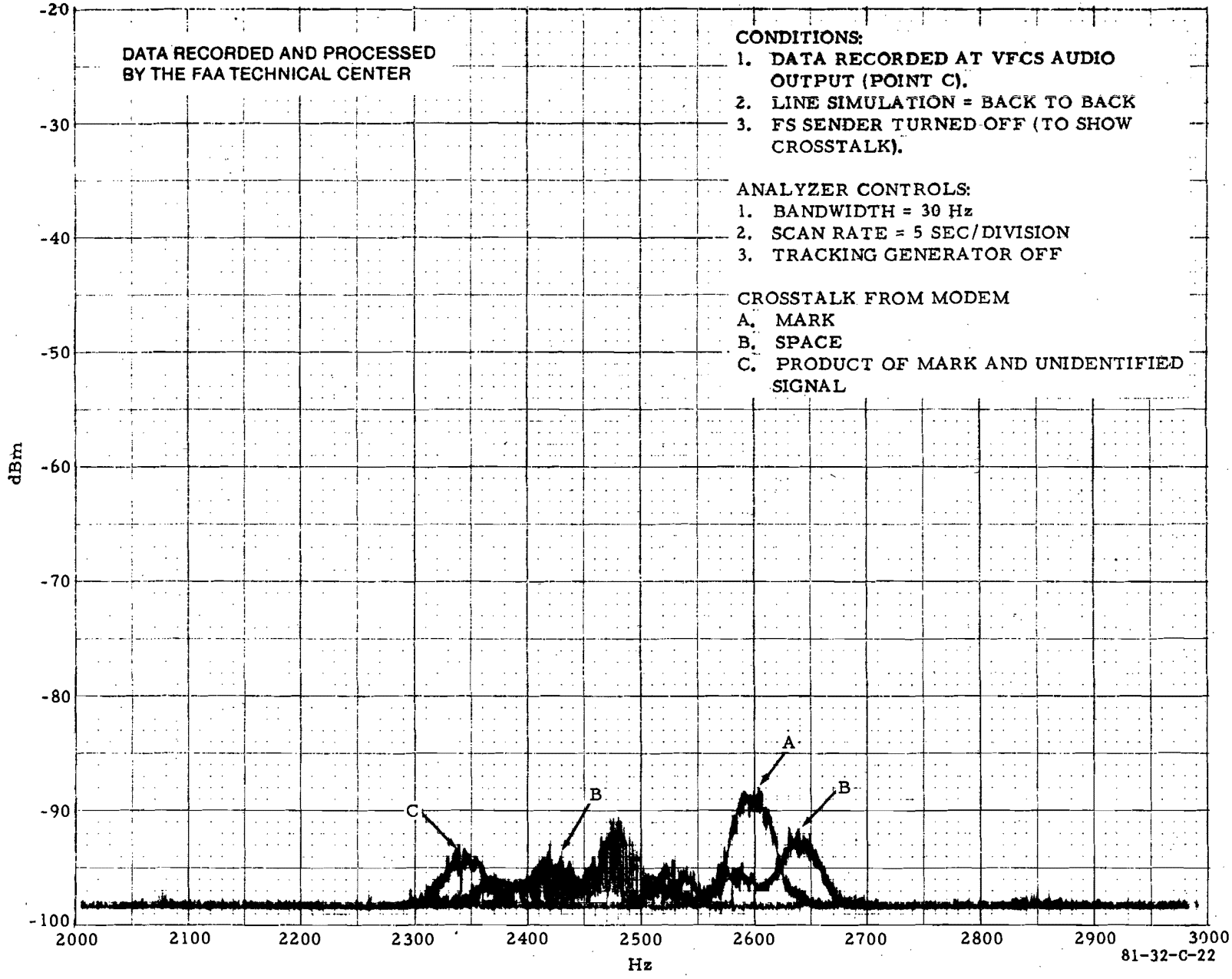

FIGURE C-22. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

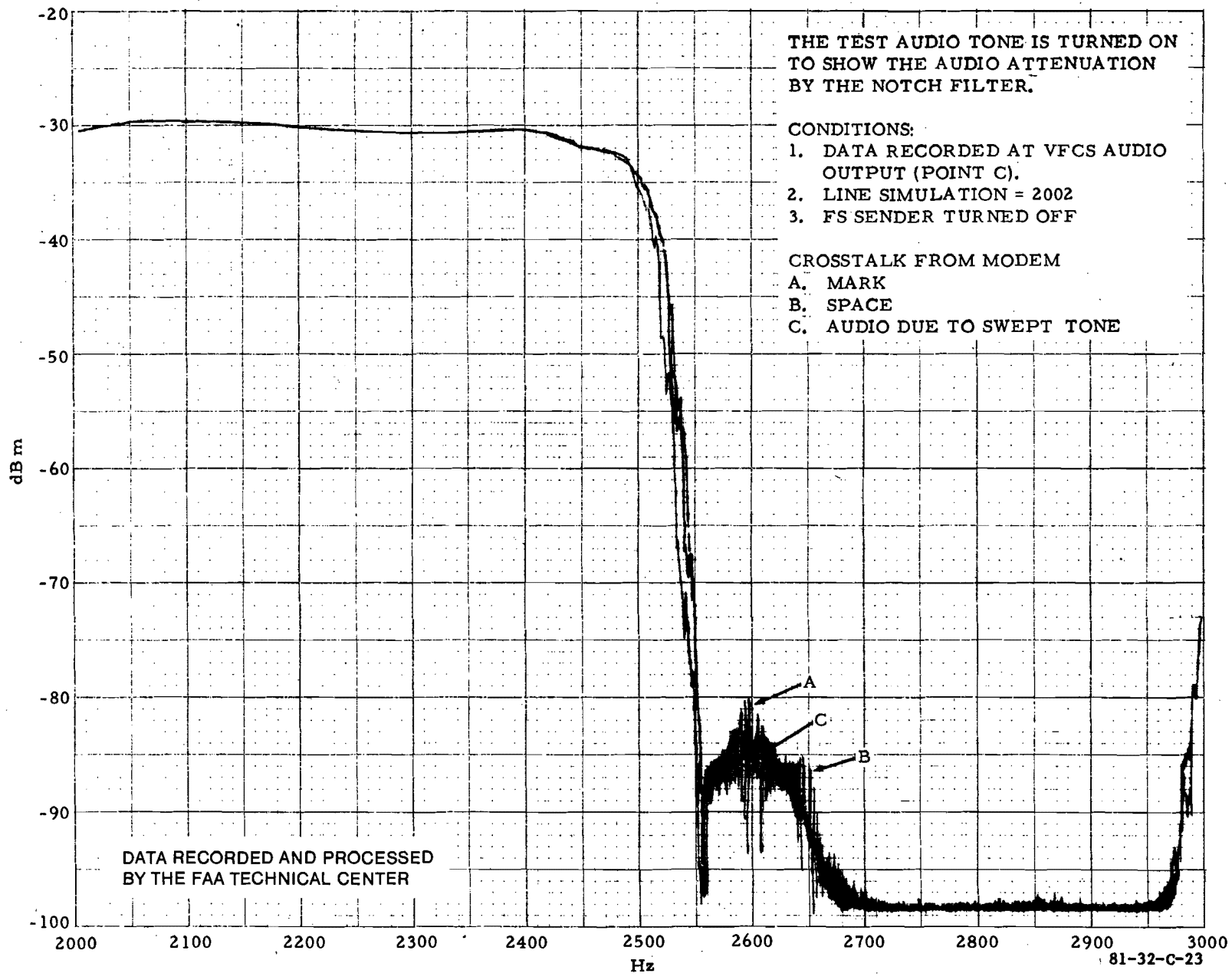

FIGURE C-23. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

APPENDIX D

IM-2076

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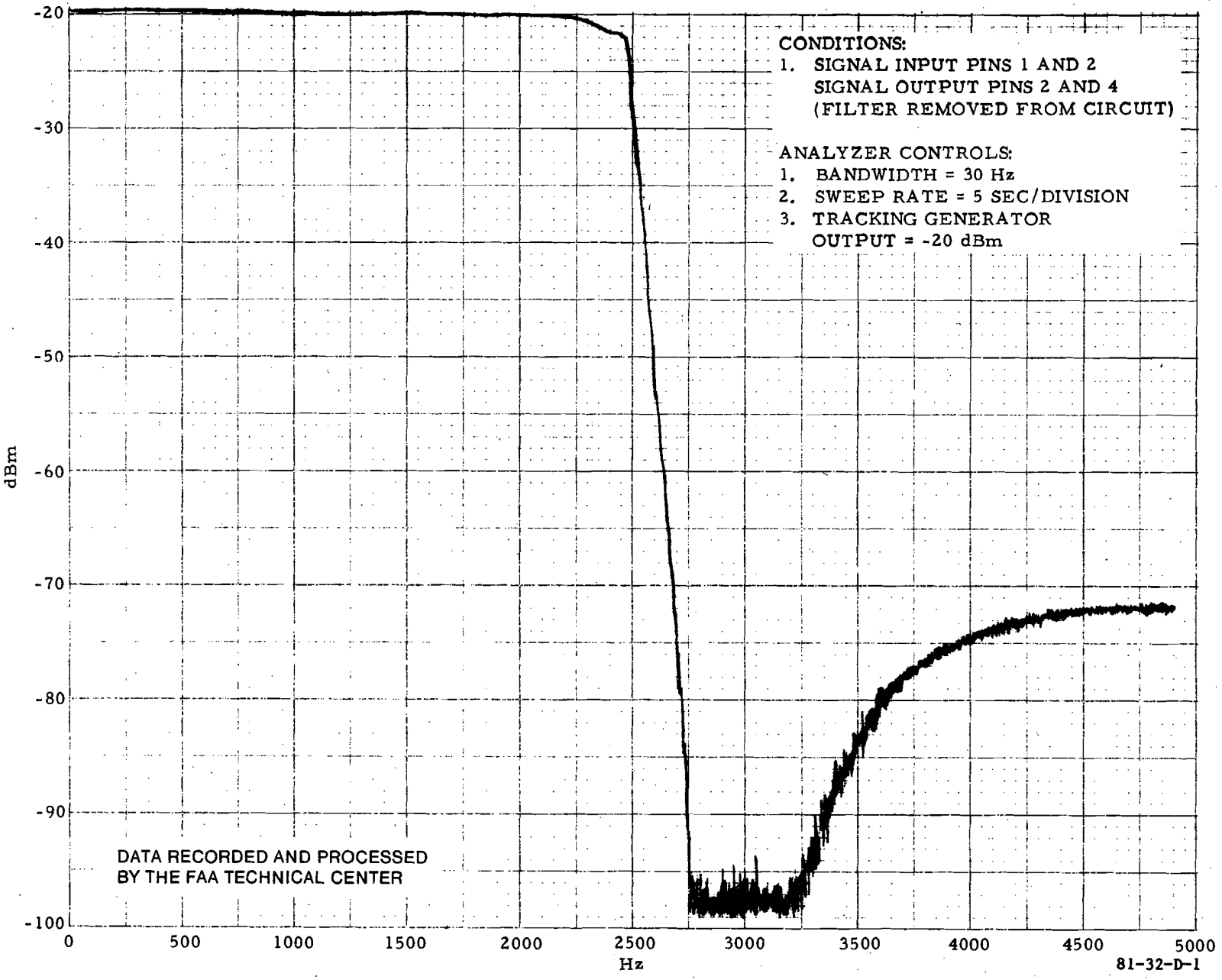

FIGURE D-1. FREQUENCY RESPONSE, SEND FILTER HYBRID-LOCAL TERMINAL

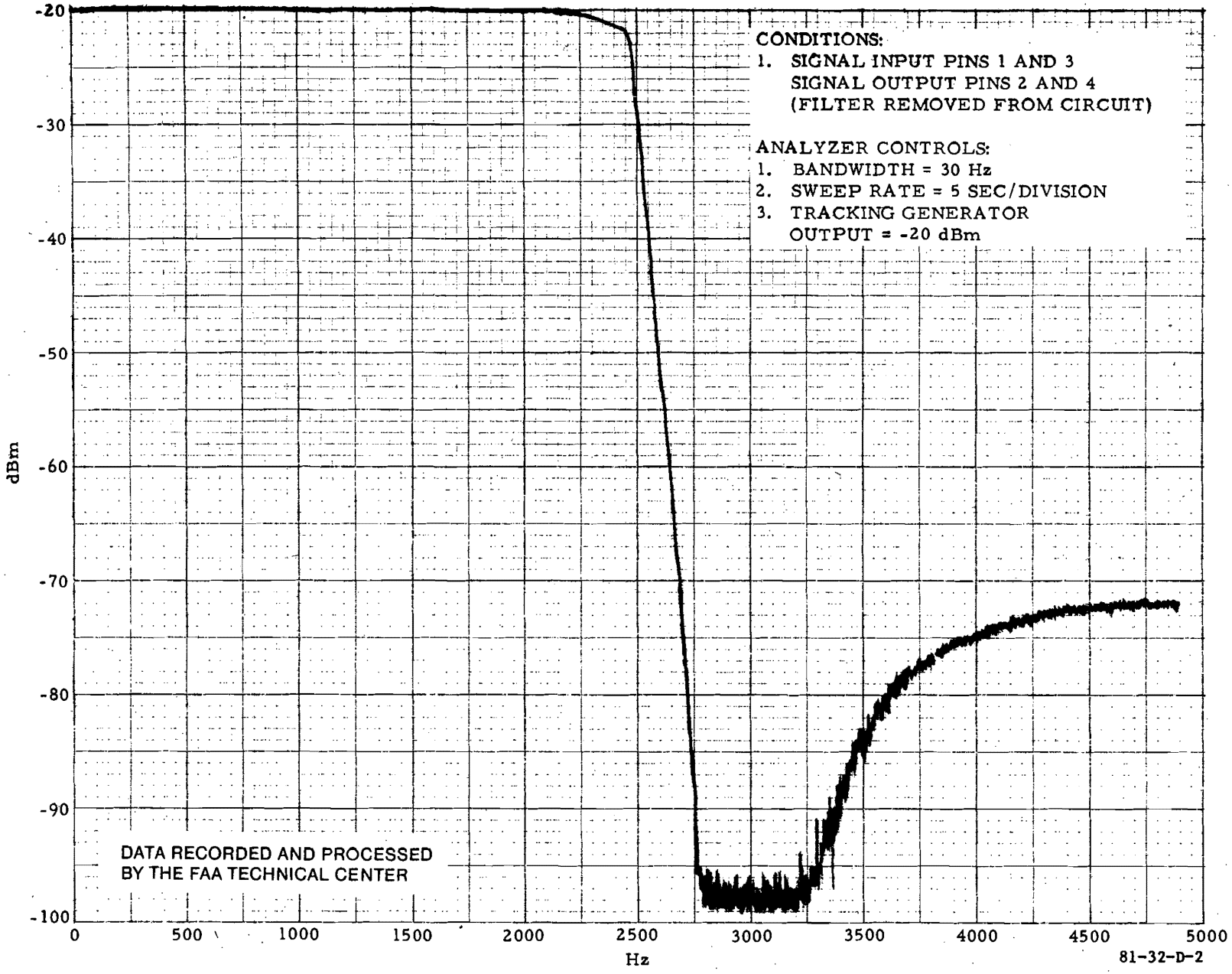

FIGURE D-2. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-LOCAL TERMINAL

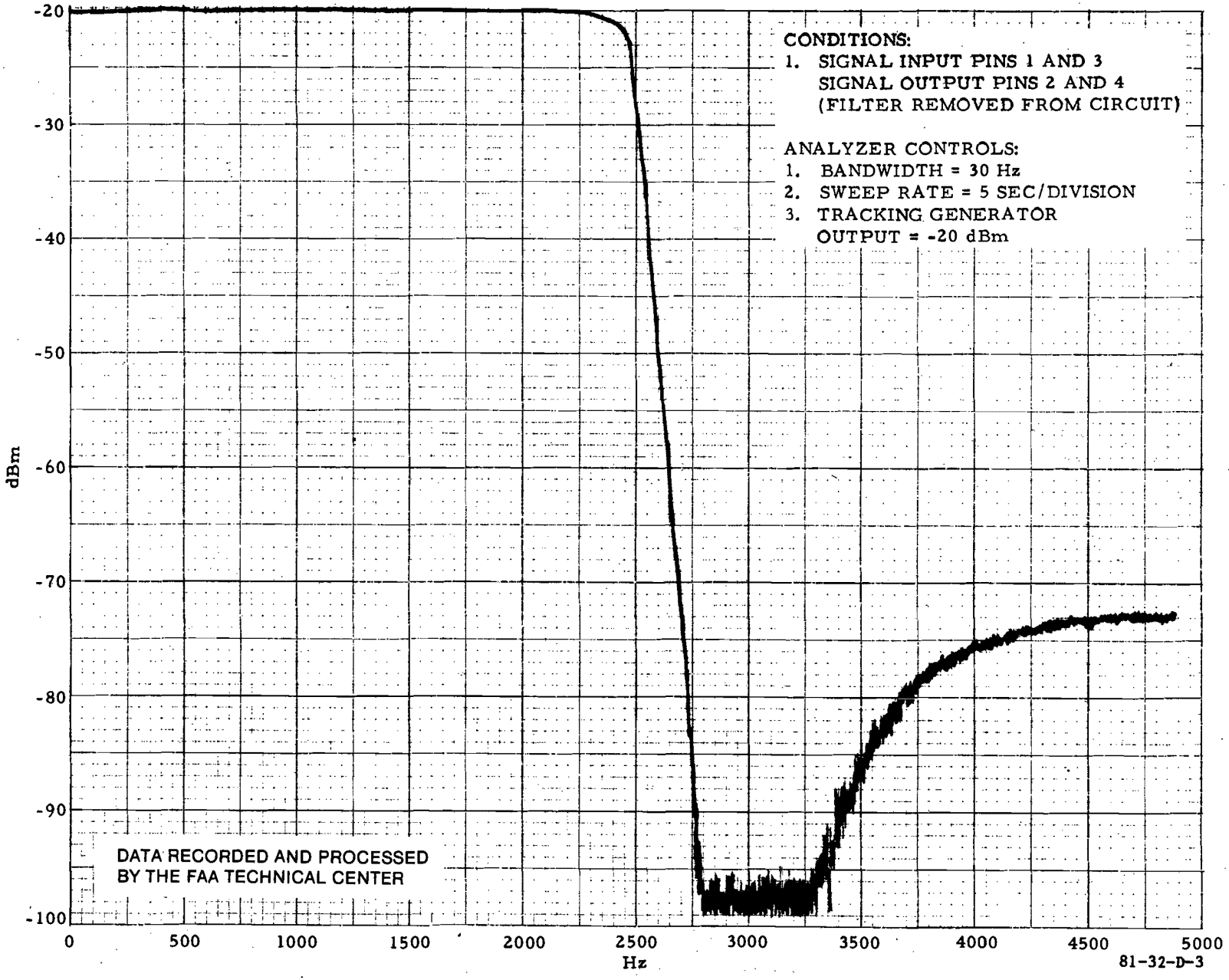

FIGURE D-3. FREQUENCY RESPONSE, SEND FILTER HYBRID-REMOTE TERMINAL

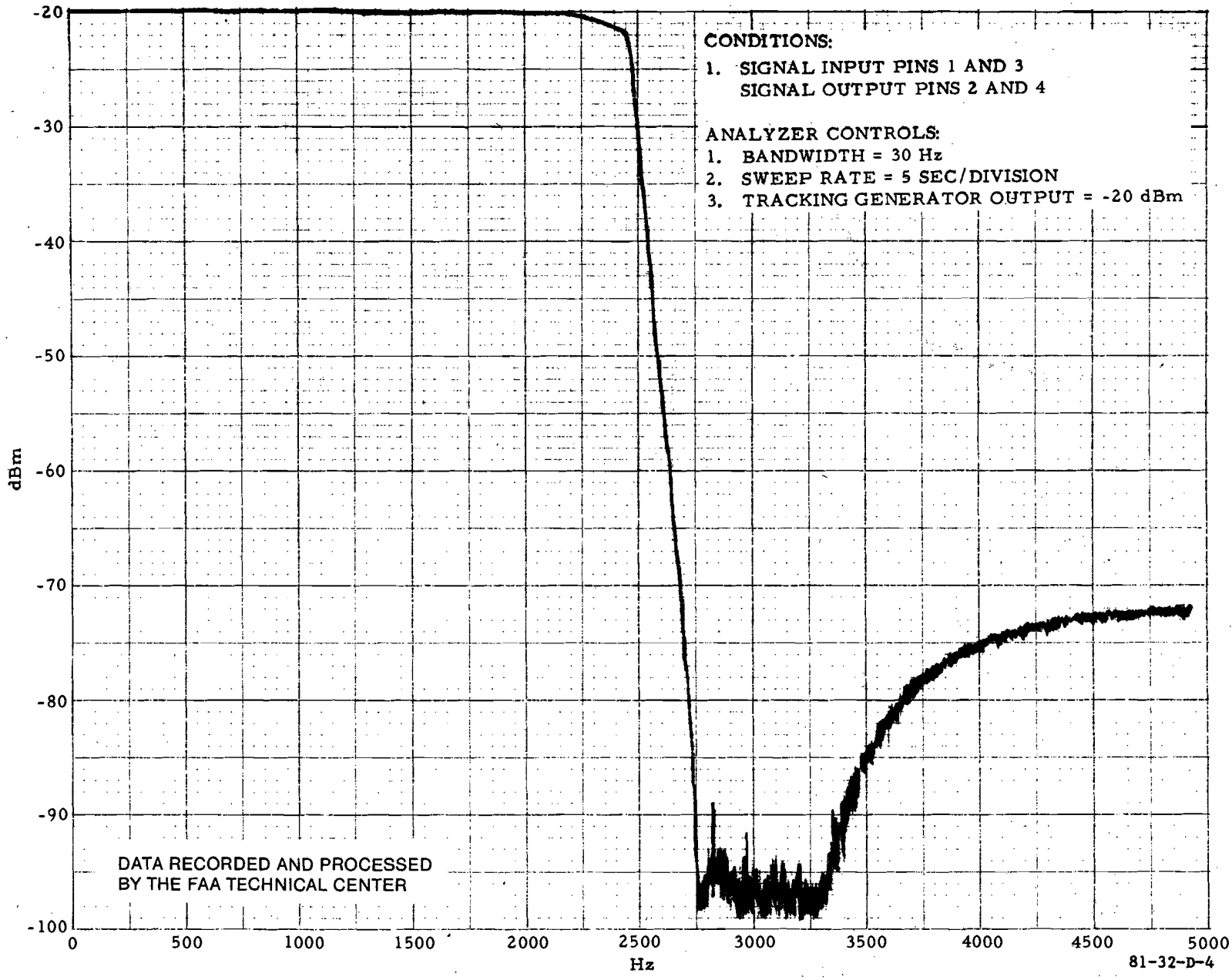

FIGURE D-4. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-REMOTE TERMINAL

The GRM IM-2076 does not have AM receivers. The AM receiver contains the bandpass filter. Therefore, the graph showing the AM and FS bandpass filter's response plots is unavailable.

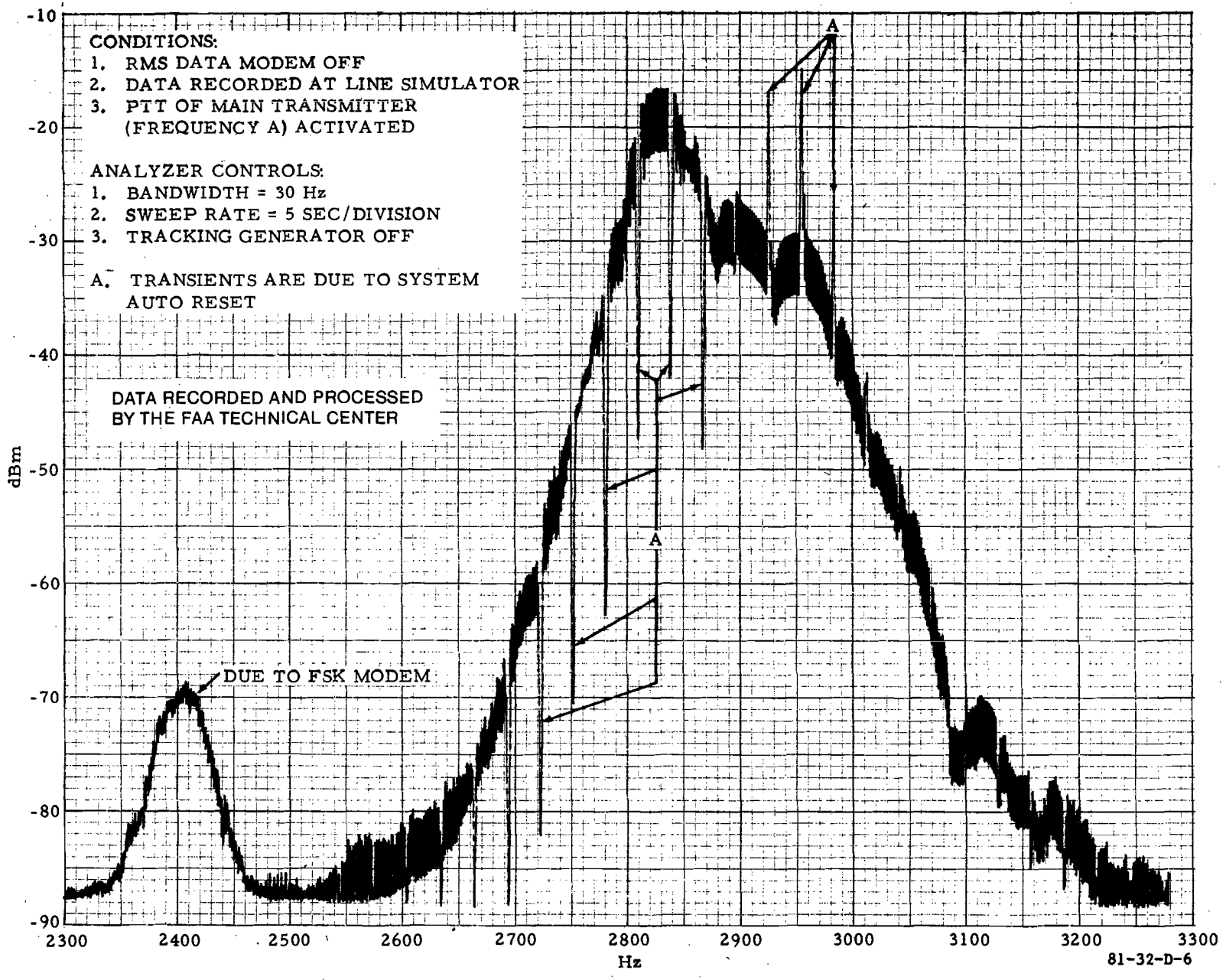

FIGURE D-6. EXPANDED SPECTRUM OF IM-2076 FSK MODEM

The GRM IM-2076 does not have AM receivers. Therefore, the graph showing the spectrum of switched PTT with the expanded horizontal scale to show the outputs of the AM and FS senders is unavailable.

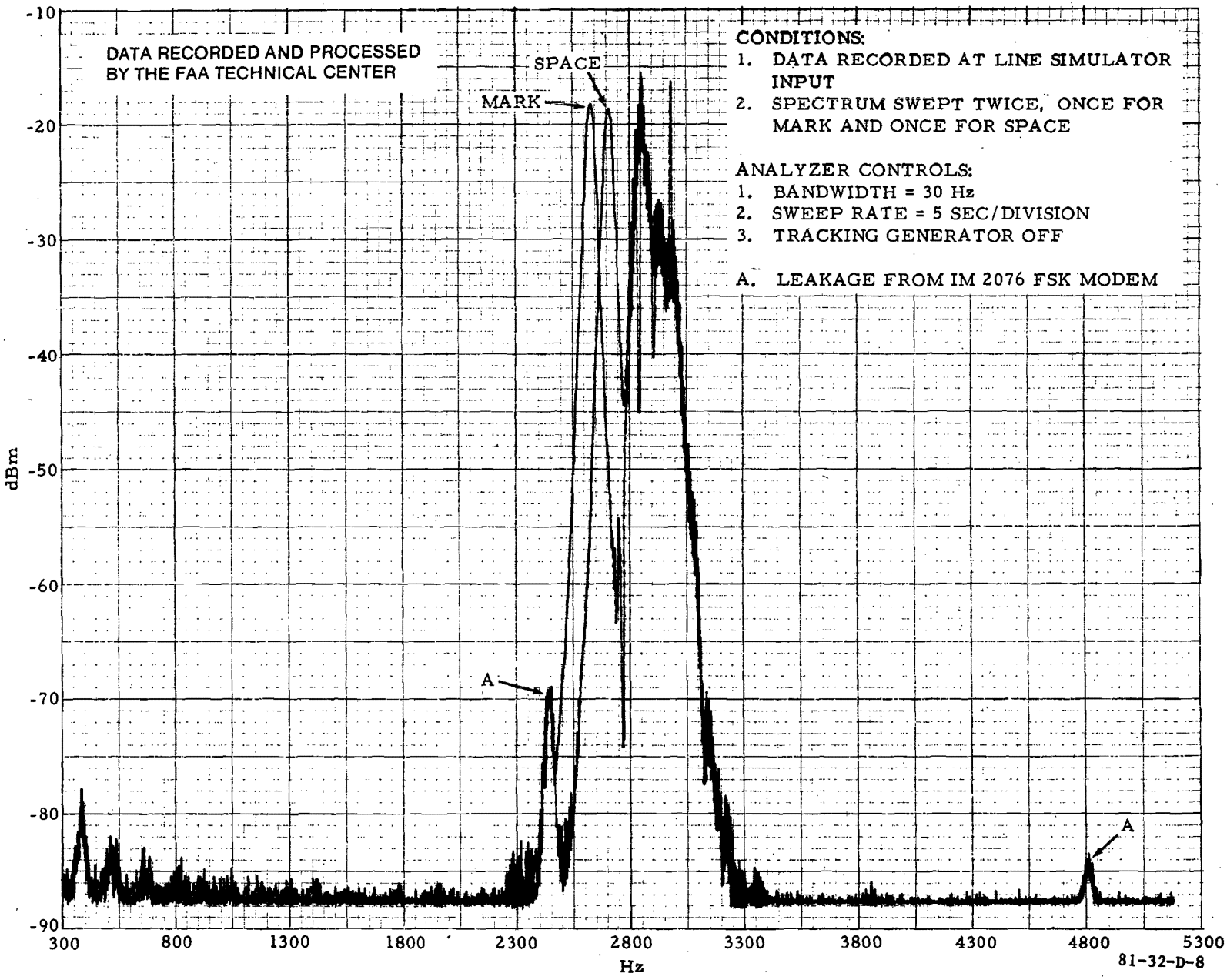

FIGURE D-8. SPECTRUM OF STEADY STATE RMS DATA (MARK AND SPACE) AND IM-2076 FSK MODEM

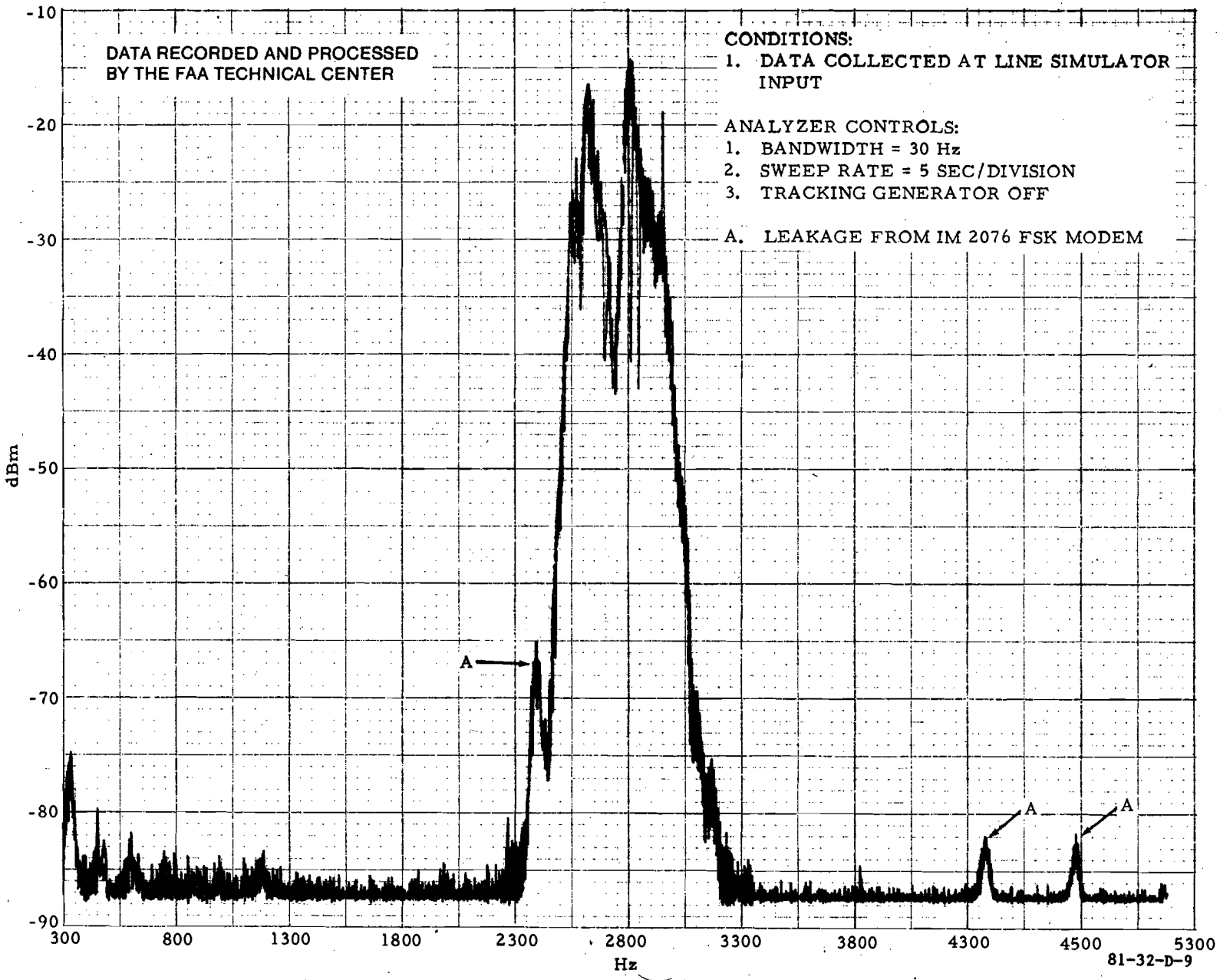

FIGURE D-9. SPECTRUM OF PRODUCTS OF TRANSITIONAL RMS DATA (1:1 AND RANDOM) AND IM-2076 FSK MODEM

The GRM IM-2076 does not have a steady state FS sender, it is replaced by the FSK data modem. Therefore, the graph showing the spectrum of steady state PTT and transitional RMS data is unavailable.

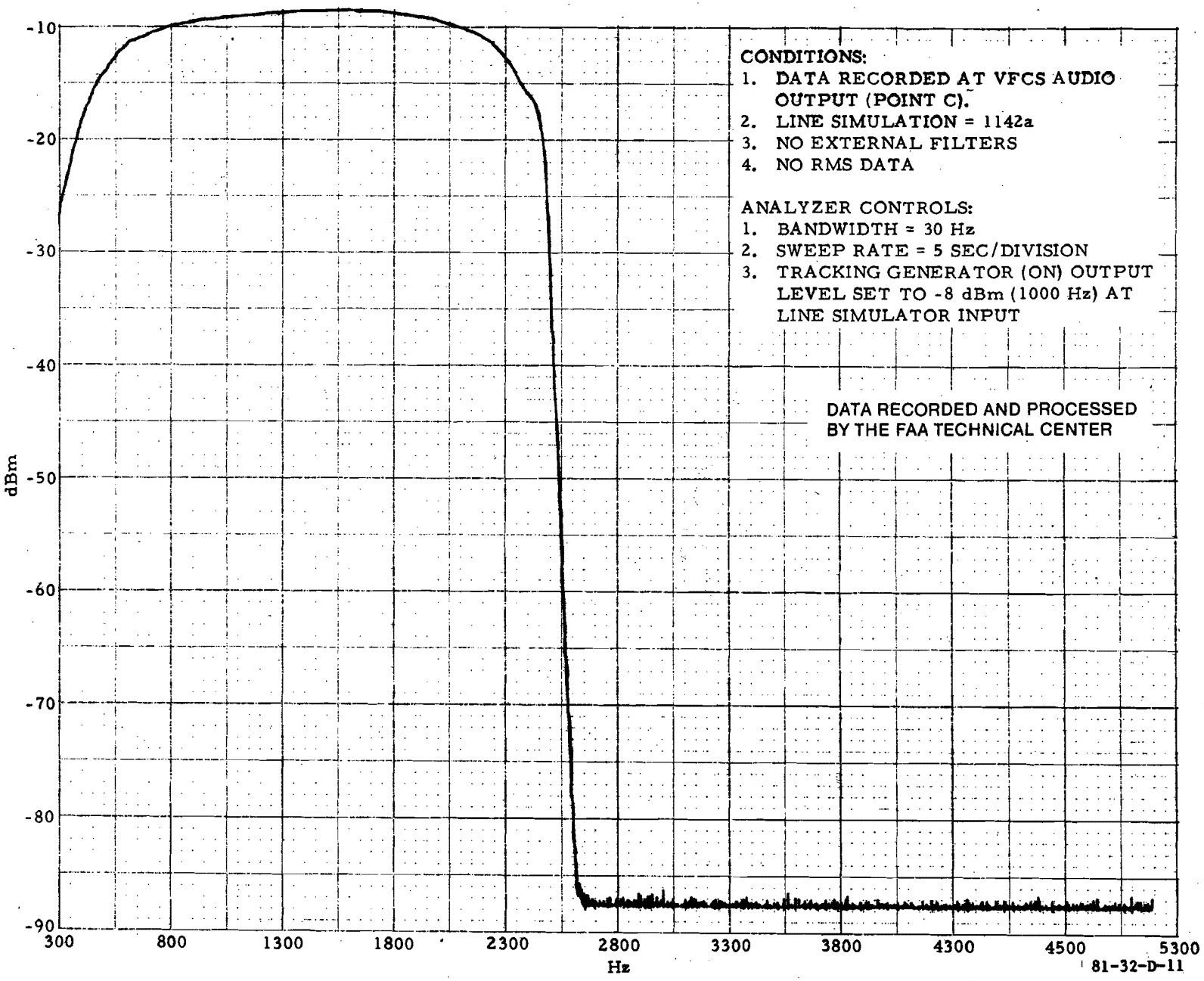

FIGURE D-11. END TO END FREQUENCY RESPONSE OF VFSS

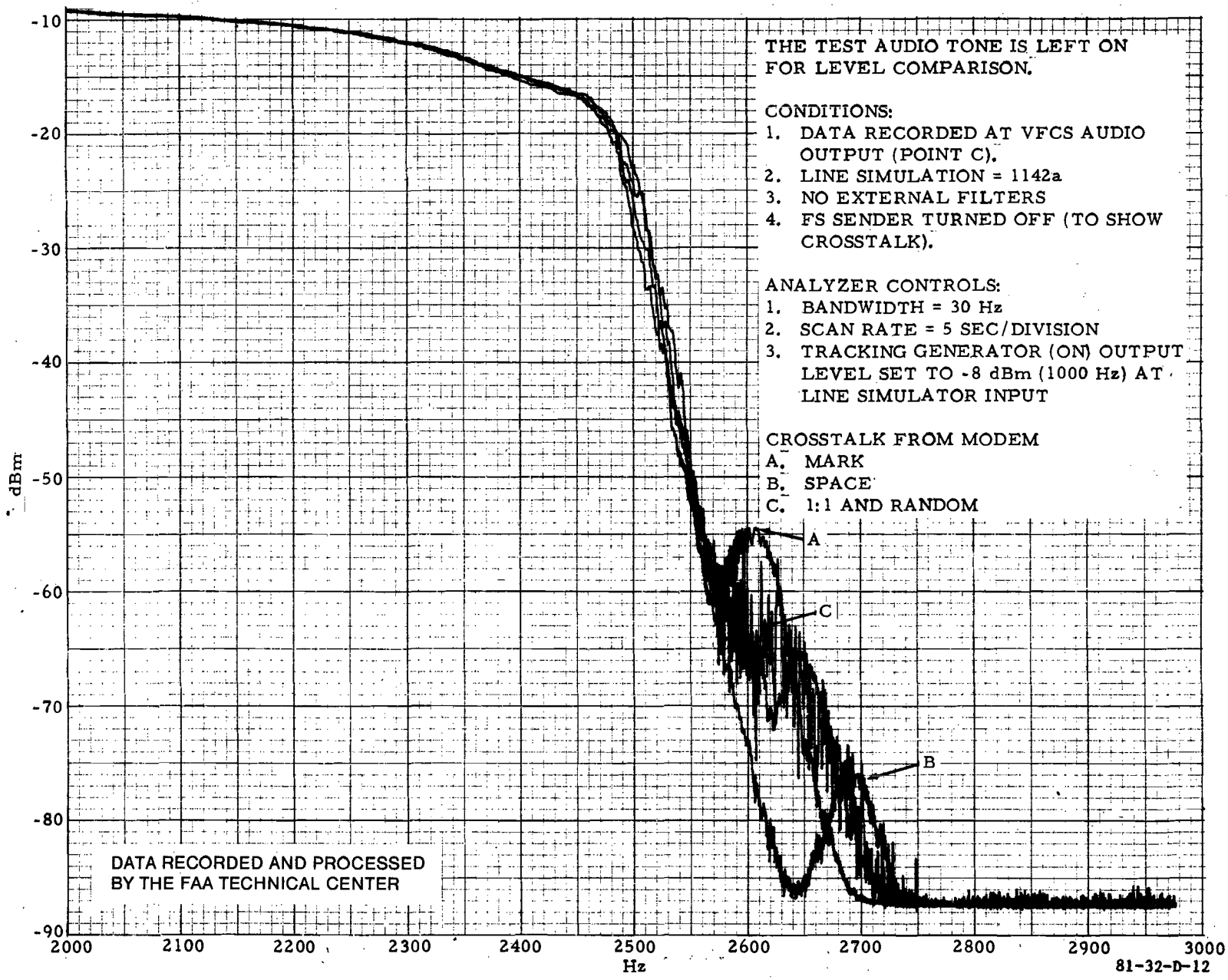

FIGURE D-12. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

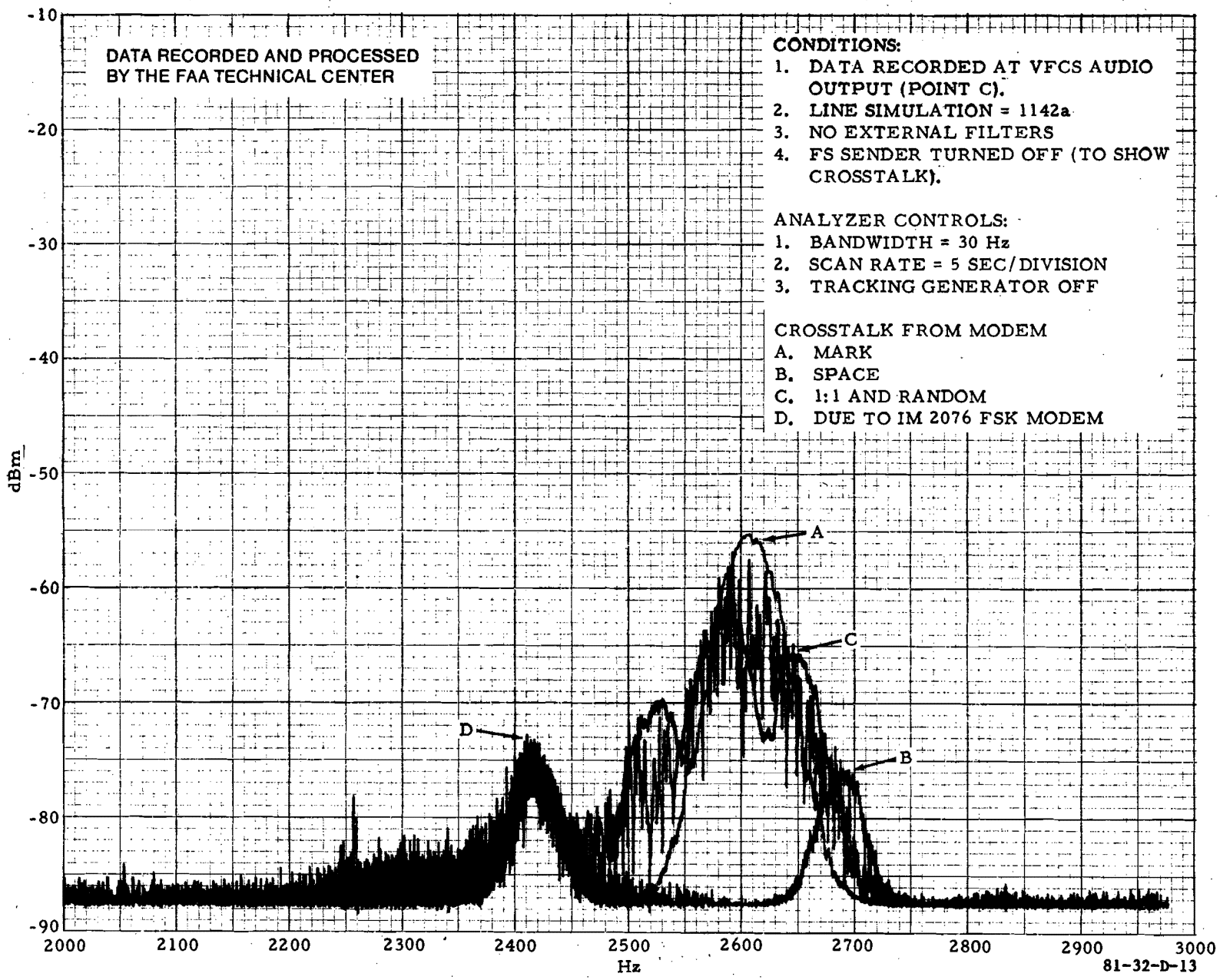

FIGURE D-13. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

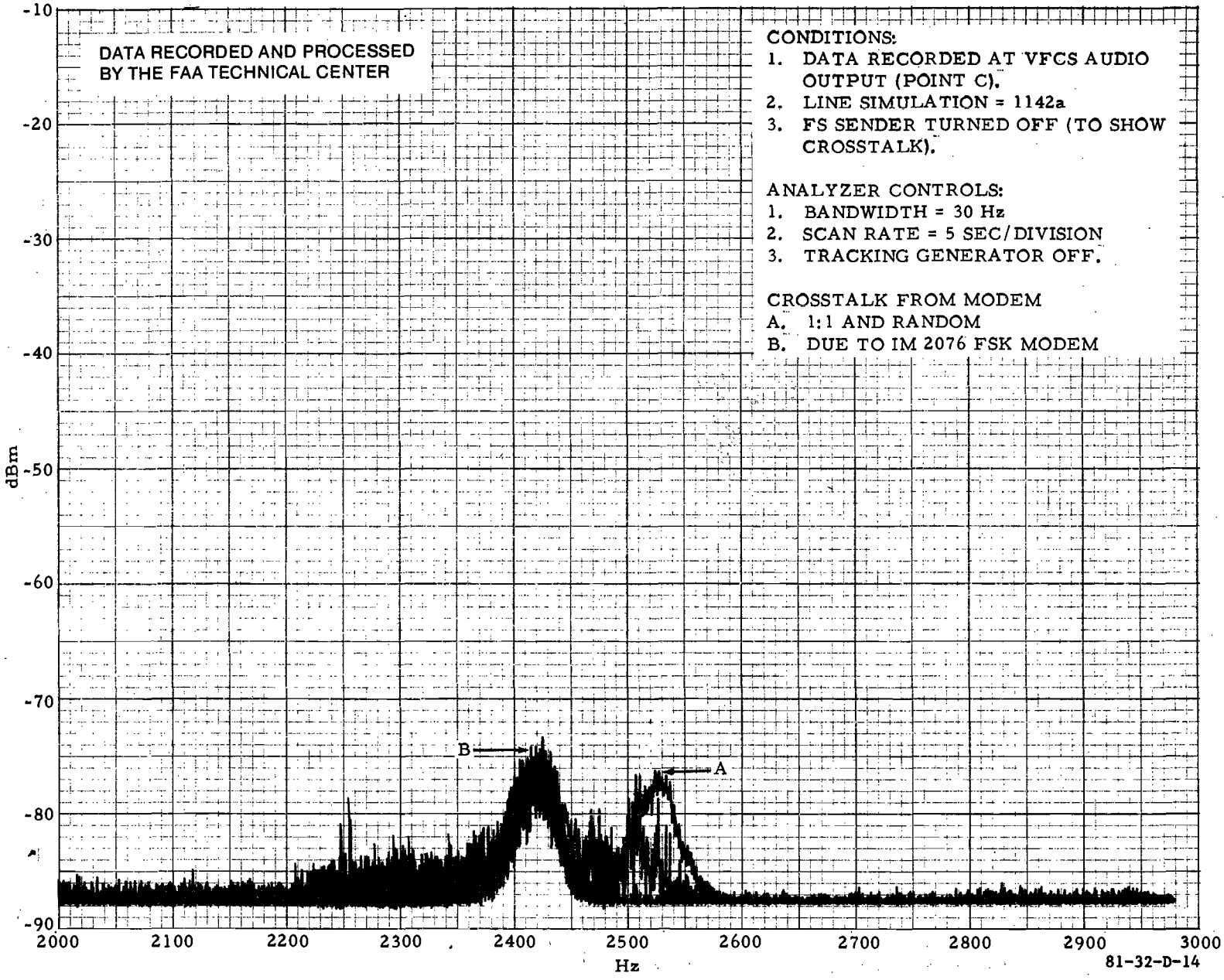

FIGURE D-14. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVER TERMINAL

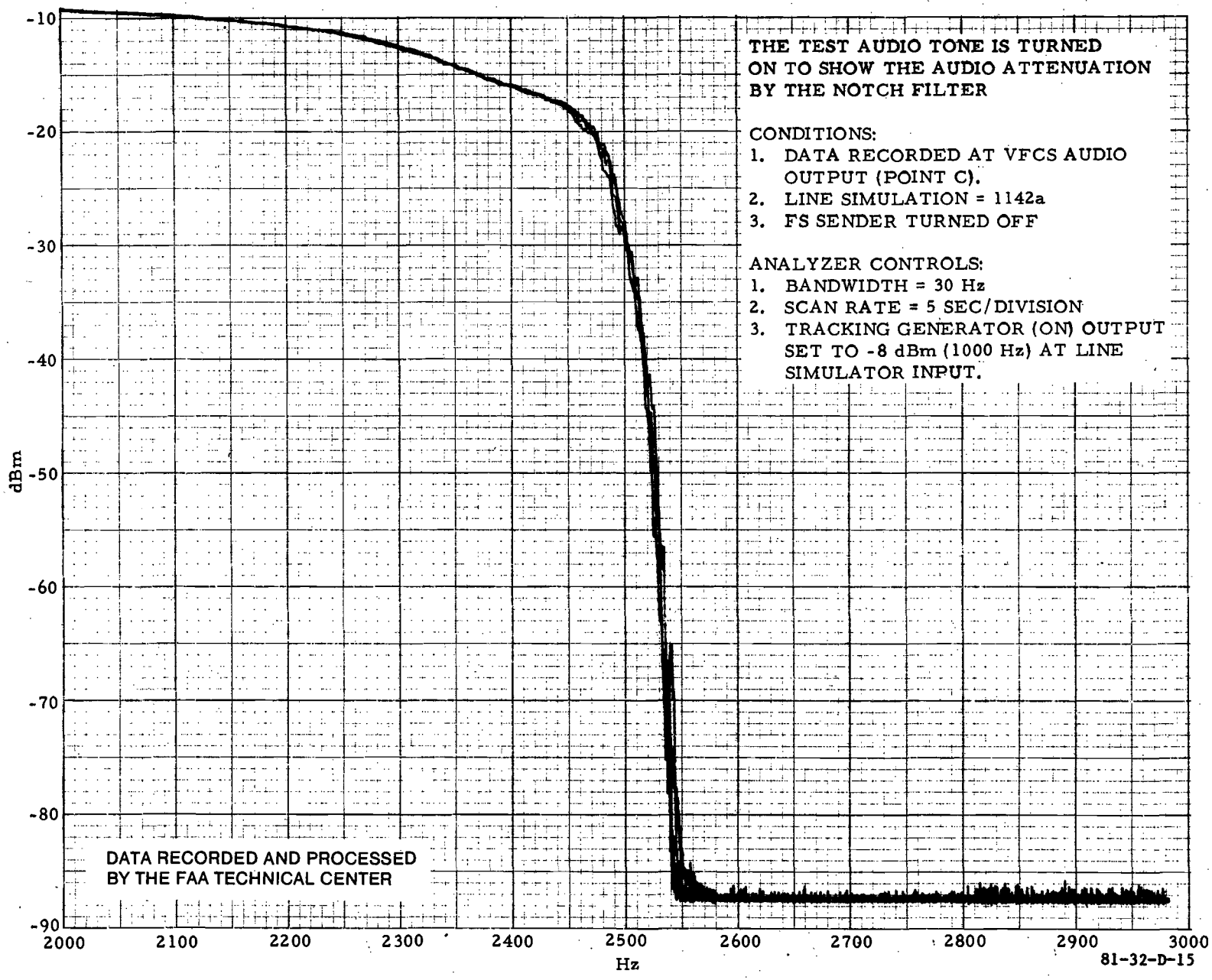

FIGURE D-15. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

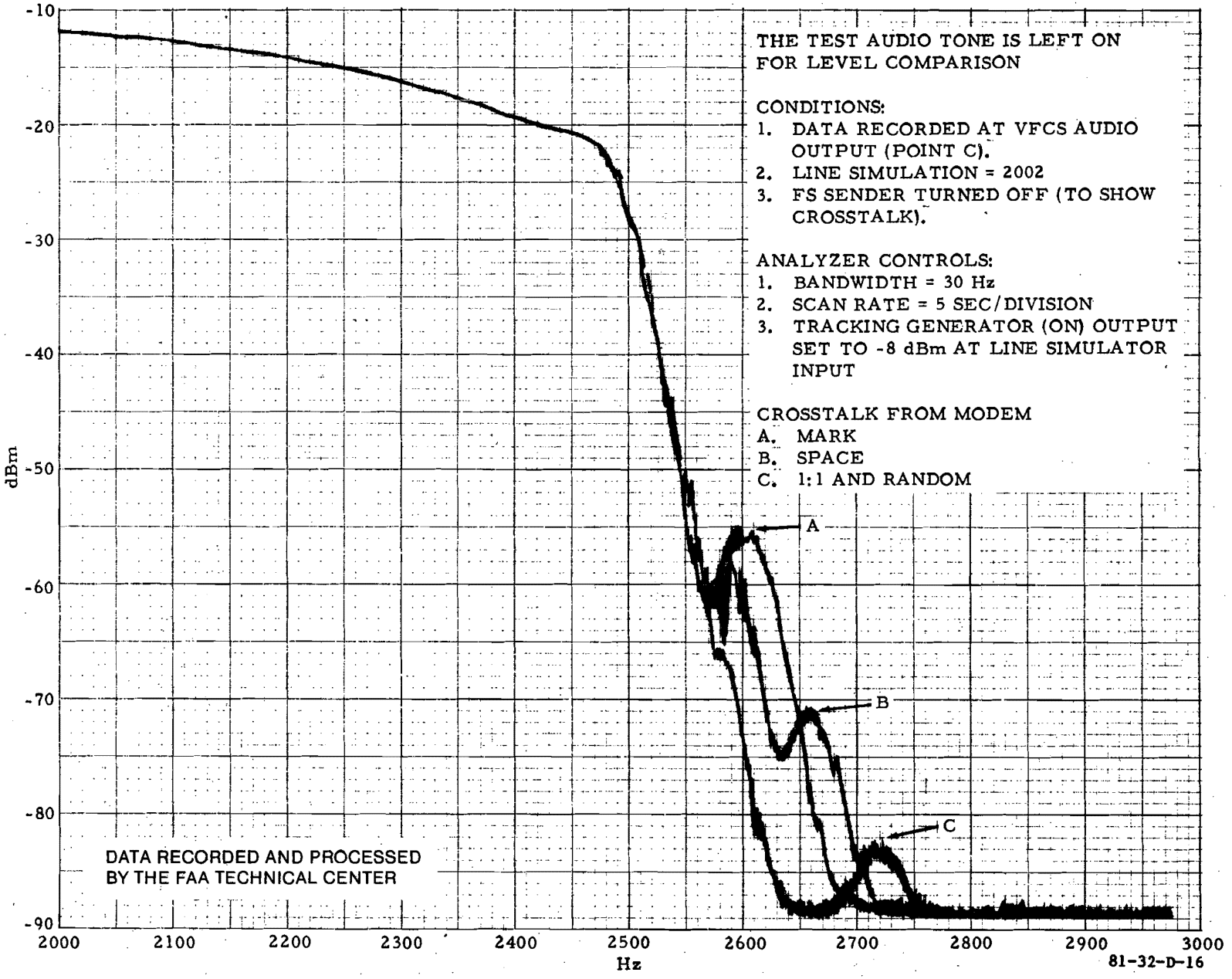

FIGURE D-16. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA

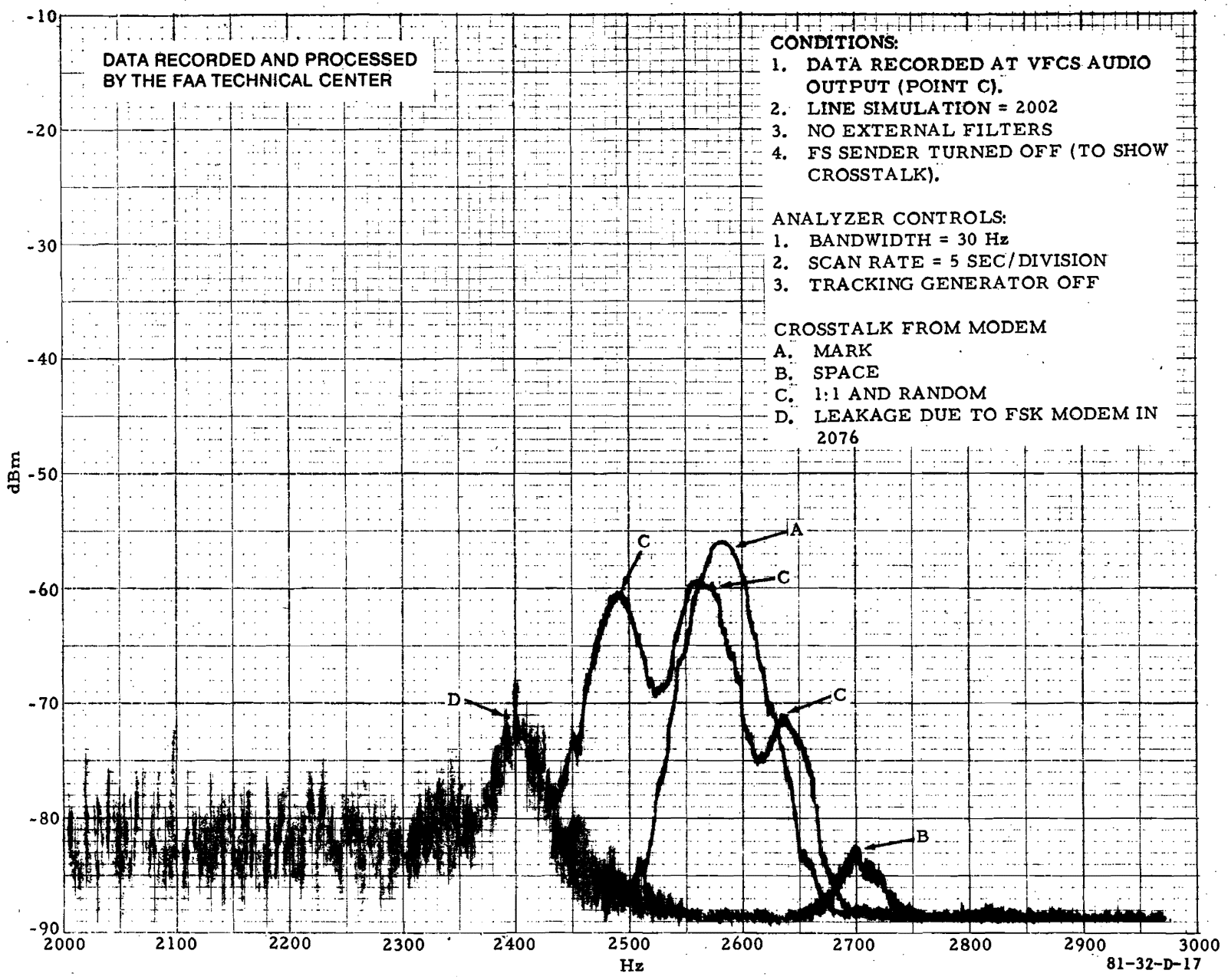

FIGURE D-17. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA; AUDIO REMOVED

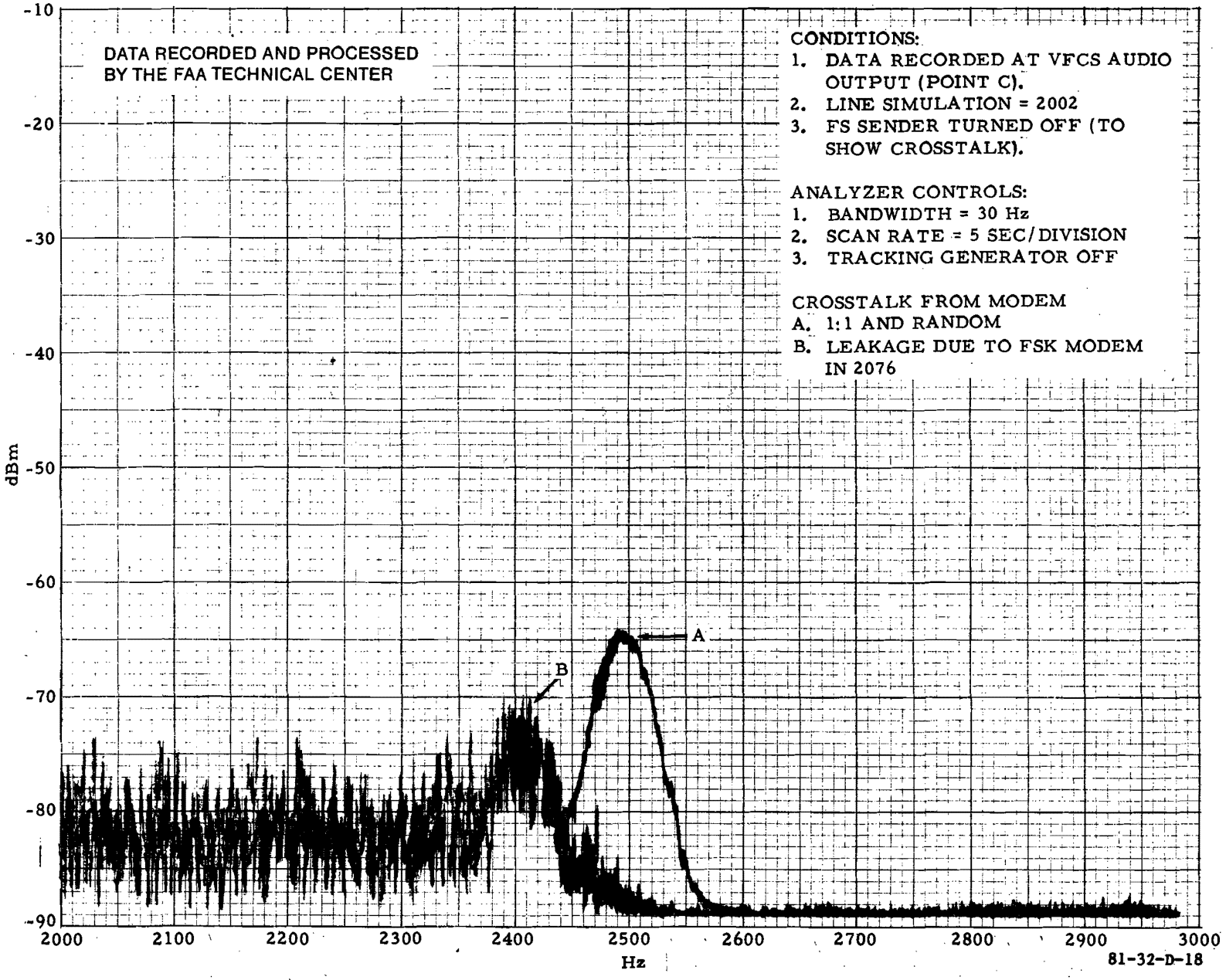

FIGURE D-18. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

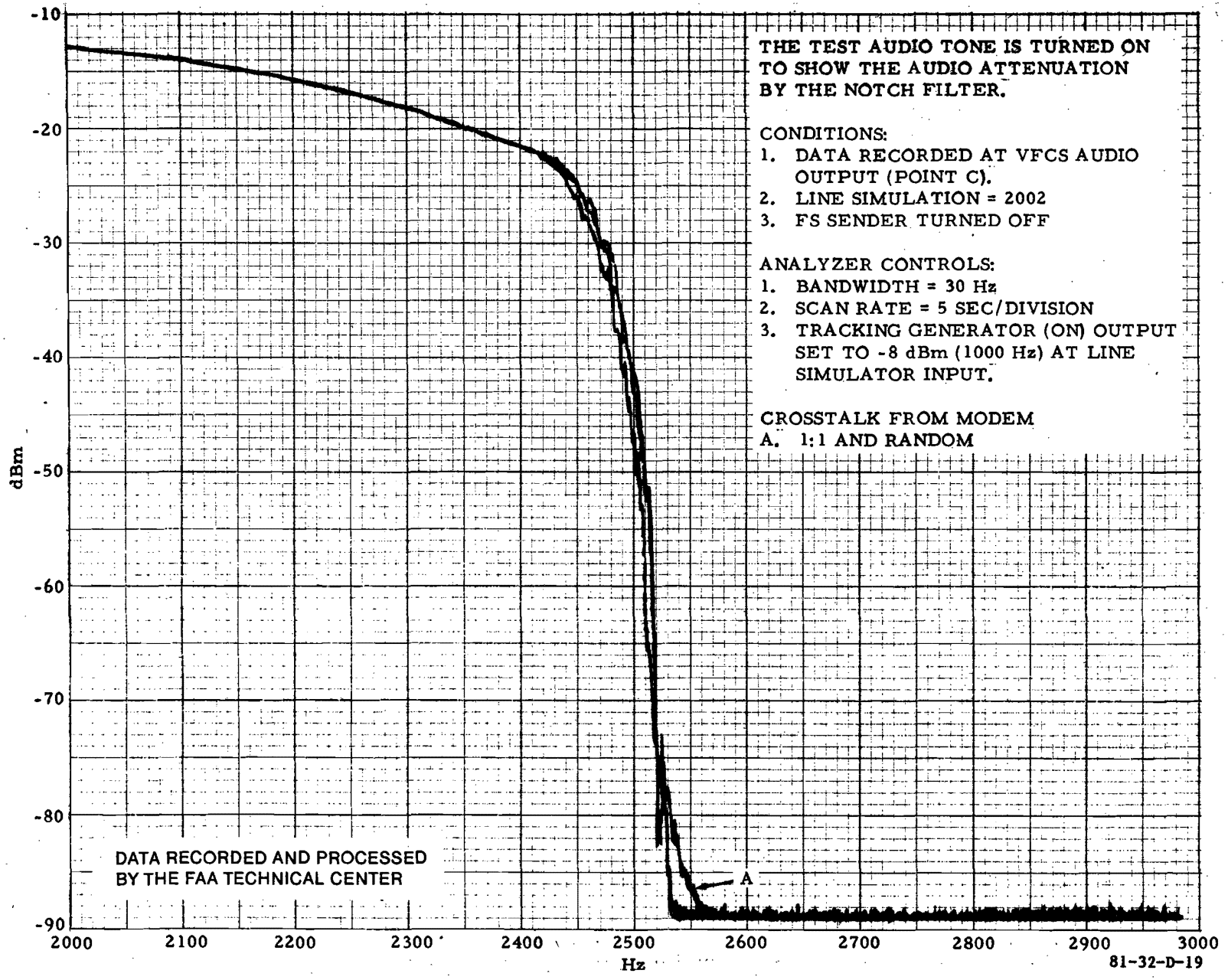

FIGURE D-19. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

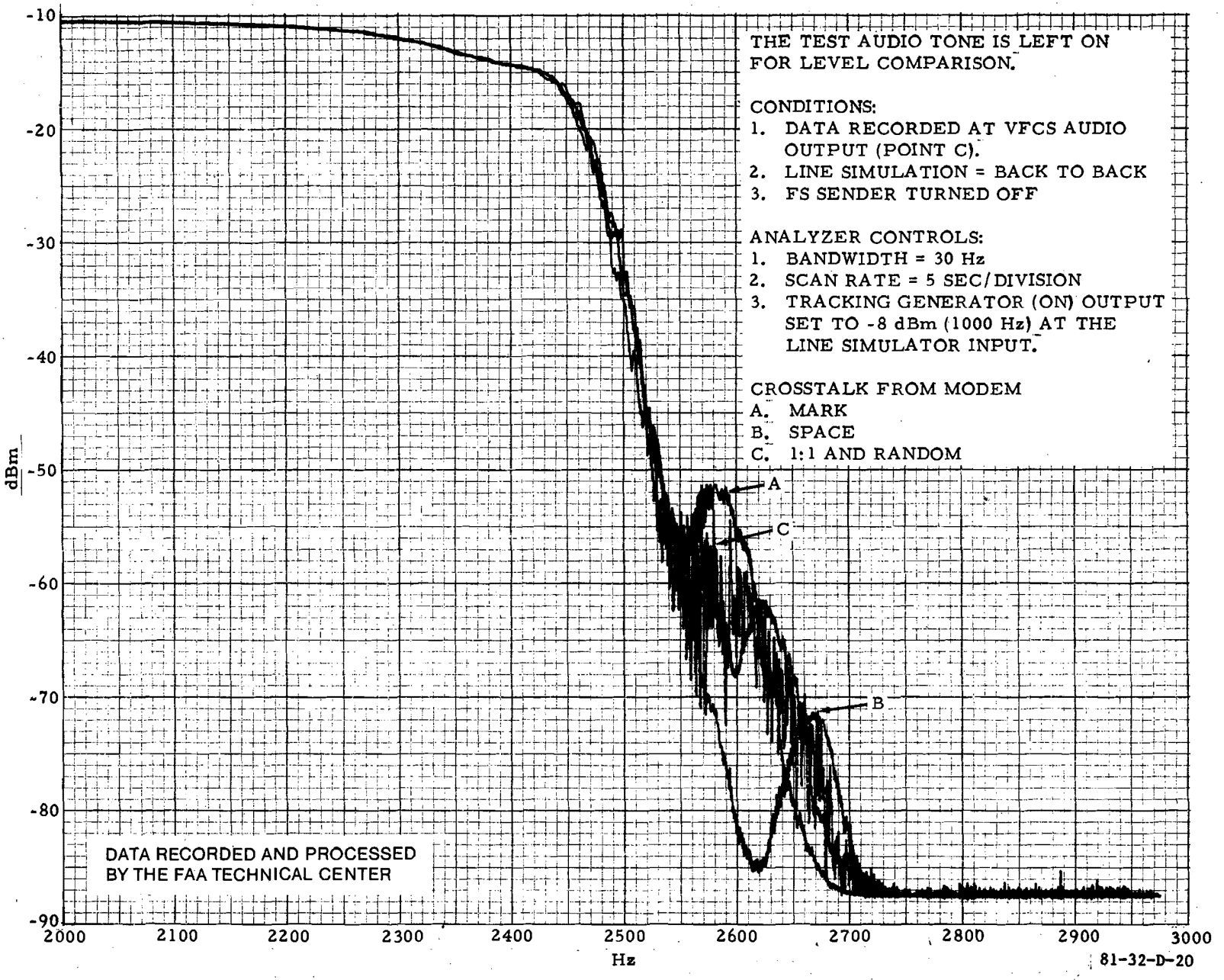

FIGURE D-20. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

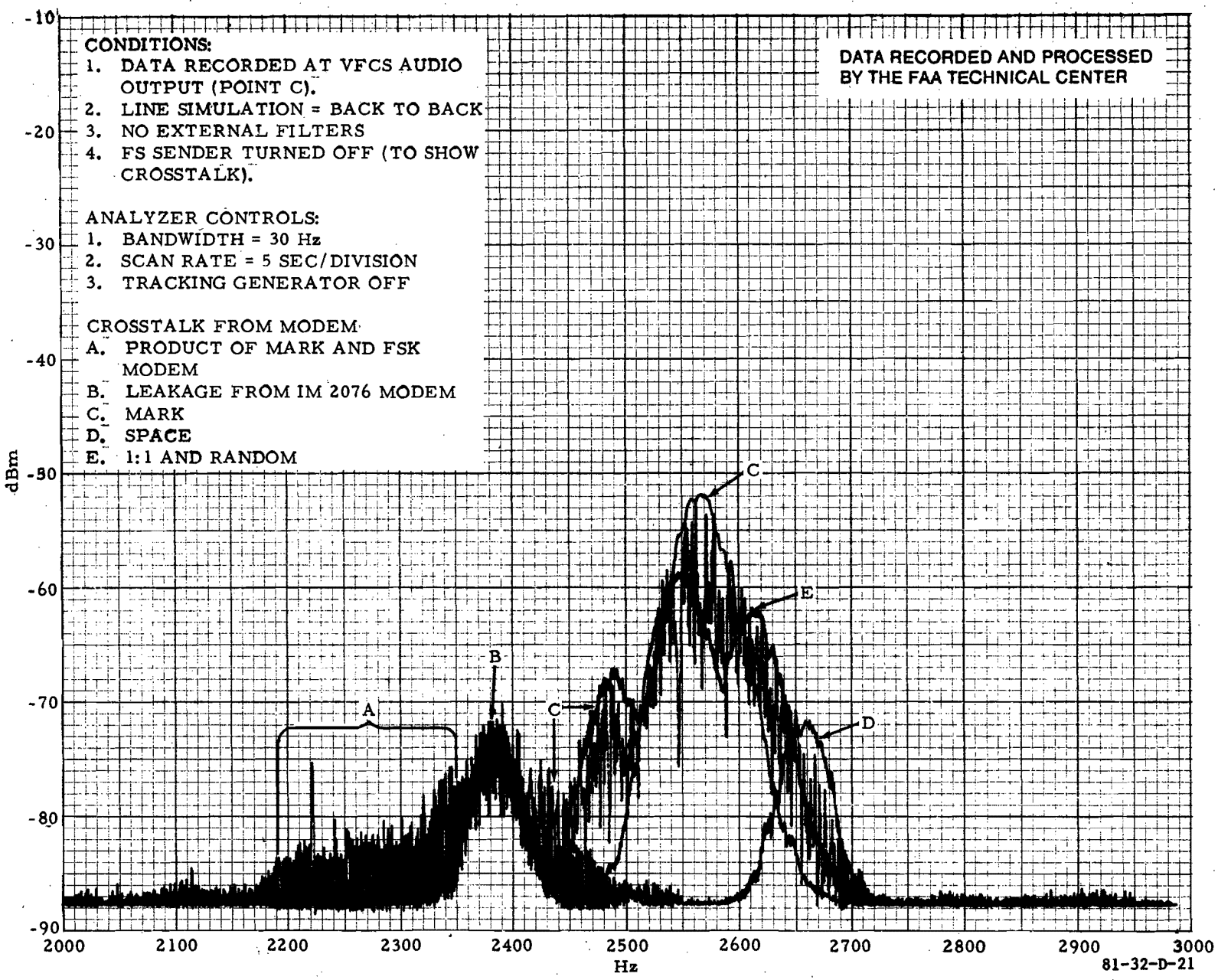

FIGURE D-21. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

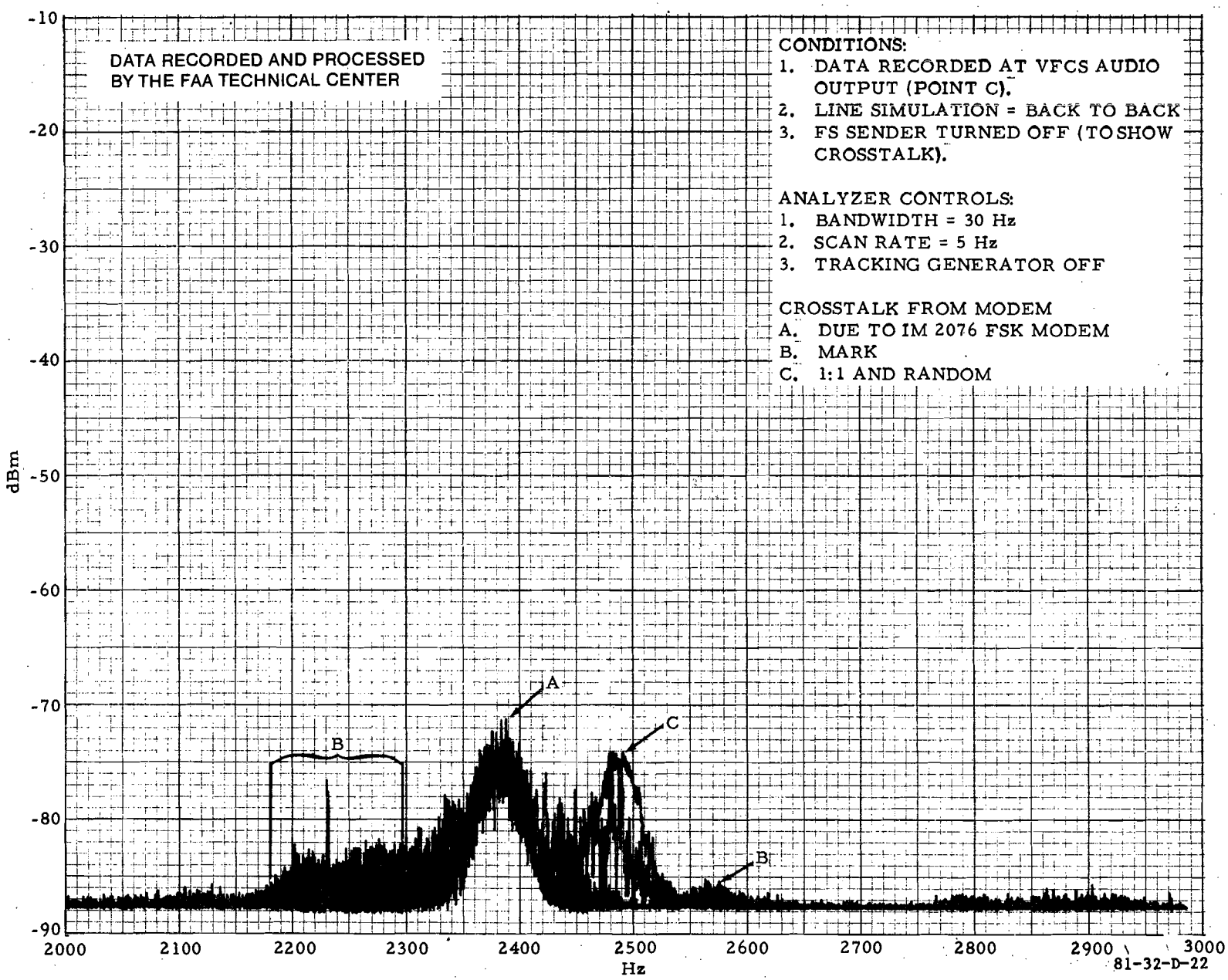

FIGURE D-22. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

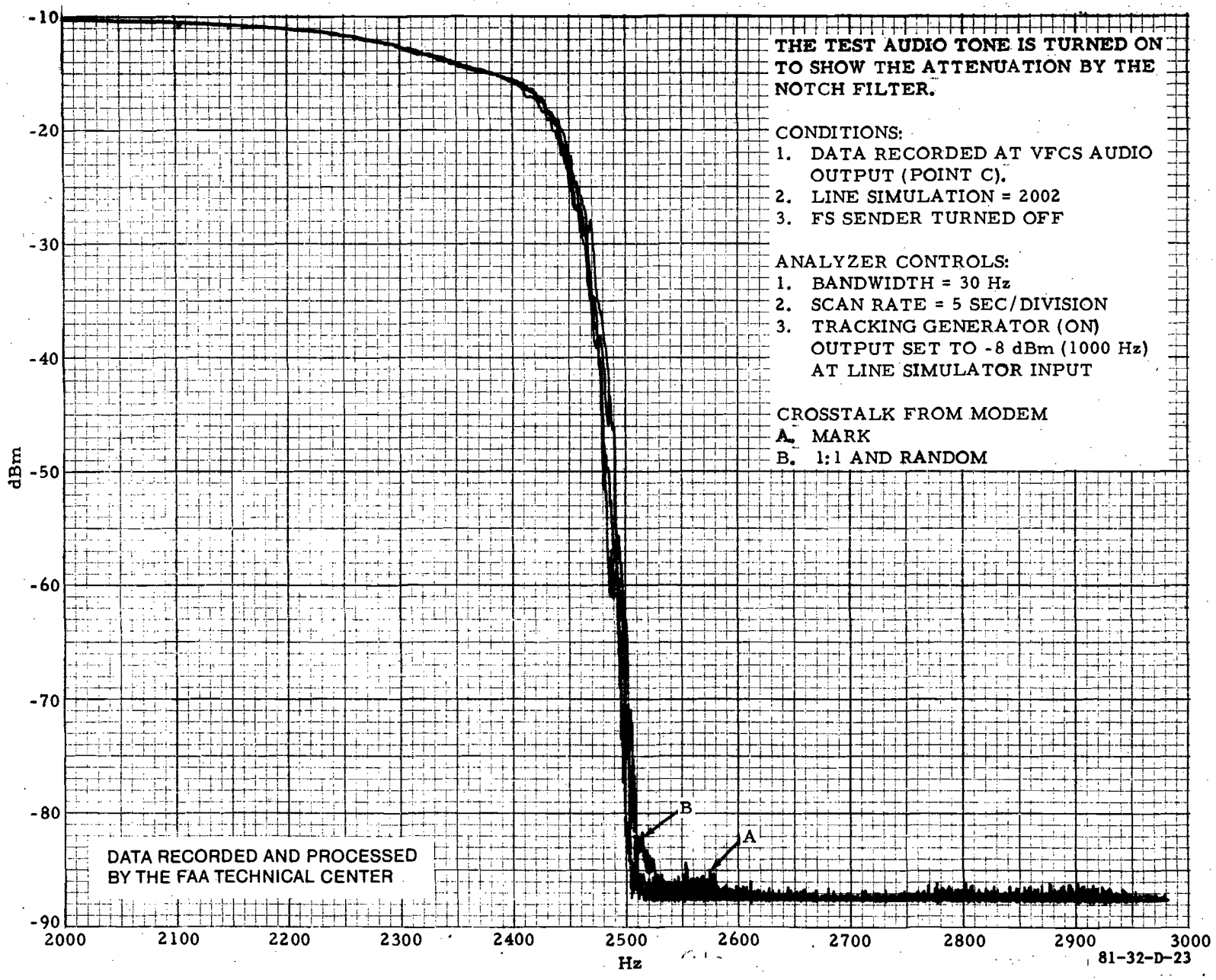

FIGURE D-23. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

APPENDIX E

FA-5390

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E-22	Spectrum of 110 Baud (RMS Data) Crosstalk After the Addition of the External Notch Filter in Series With the VFSS Receive Terminal	E-22
E-23	Spectrum of 110 Baud (RMS Data) Crosstalk After the Addition of the External Notch Filter	E-23

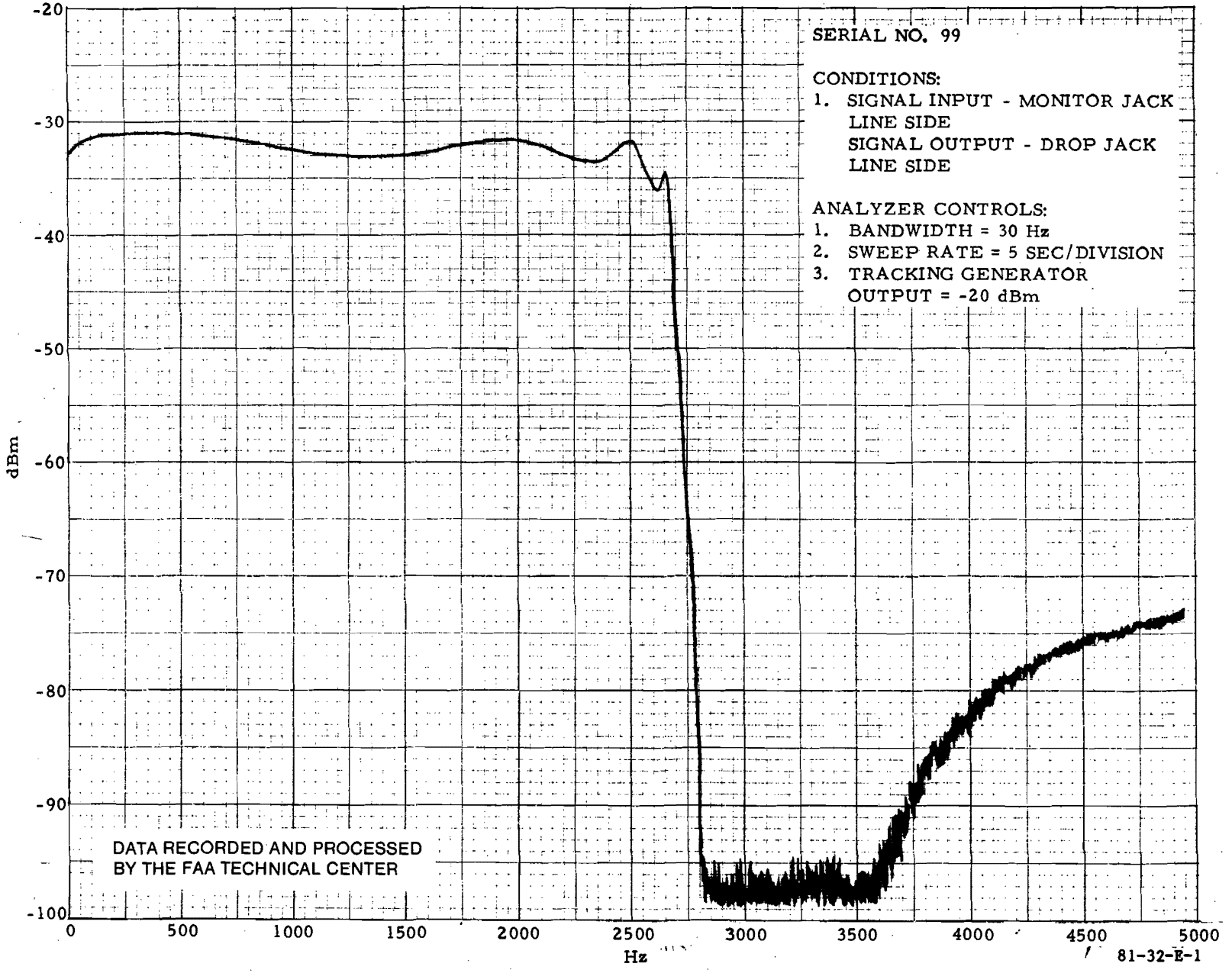

FIGURE E-1. FREQUENCY RESPONSE, SEND FILTER HYBRID-LOCAL TERMINAL

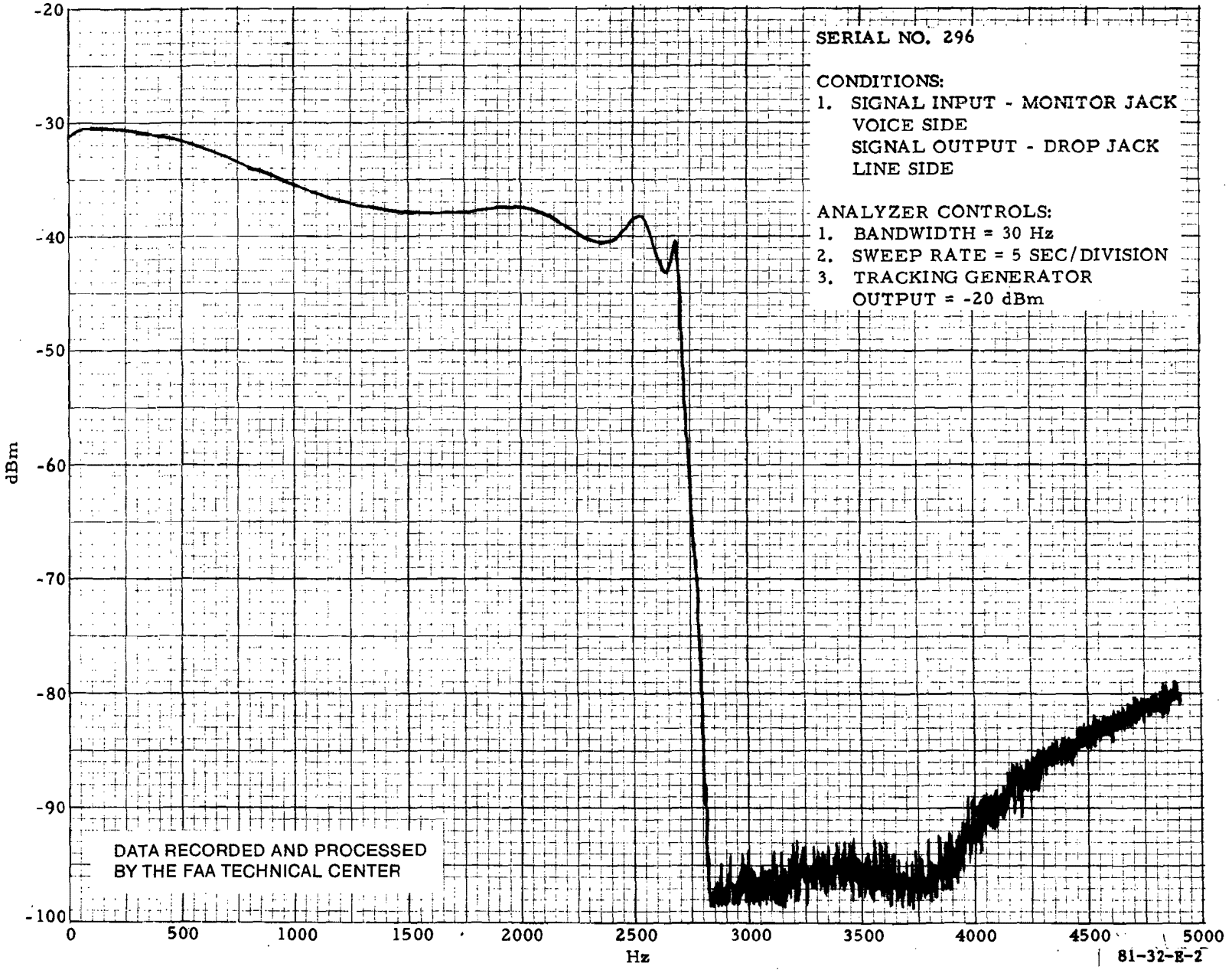

FIGURE E-2. FREQUENCY RESPONSE, RECEIVE FILTER HYBRID-LOCAL TERMINAL

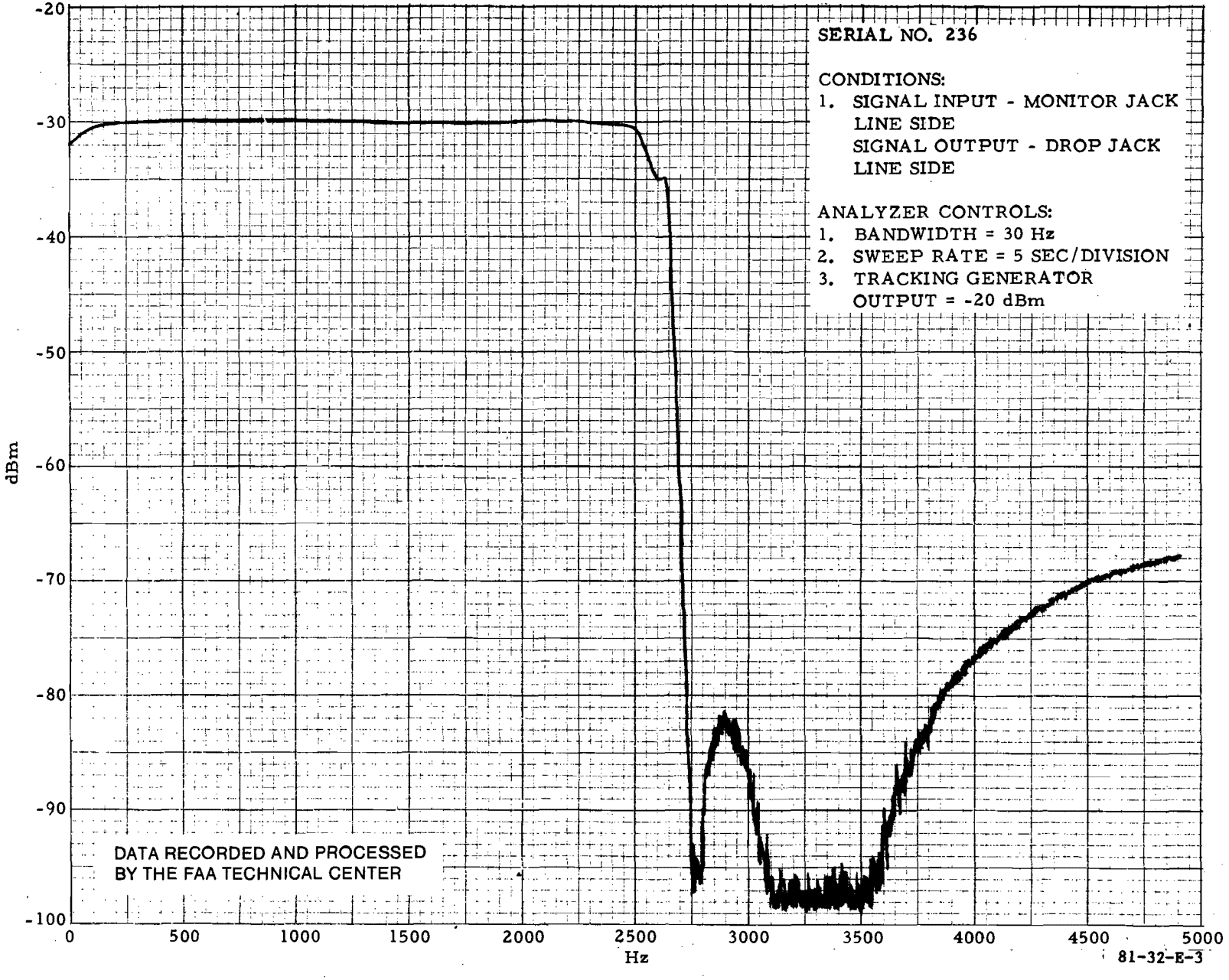

FIGURE E-3. FREQUENCY RESPONSE, SEND FILTER HYBRID-REMOTE TERMINAL

The receive filter hybrid (remote terminal) was not supplied with the system. Therefore, the frequency response low-pass send filter, receive filter graph is unavailable.

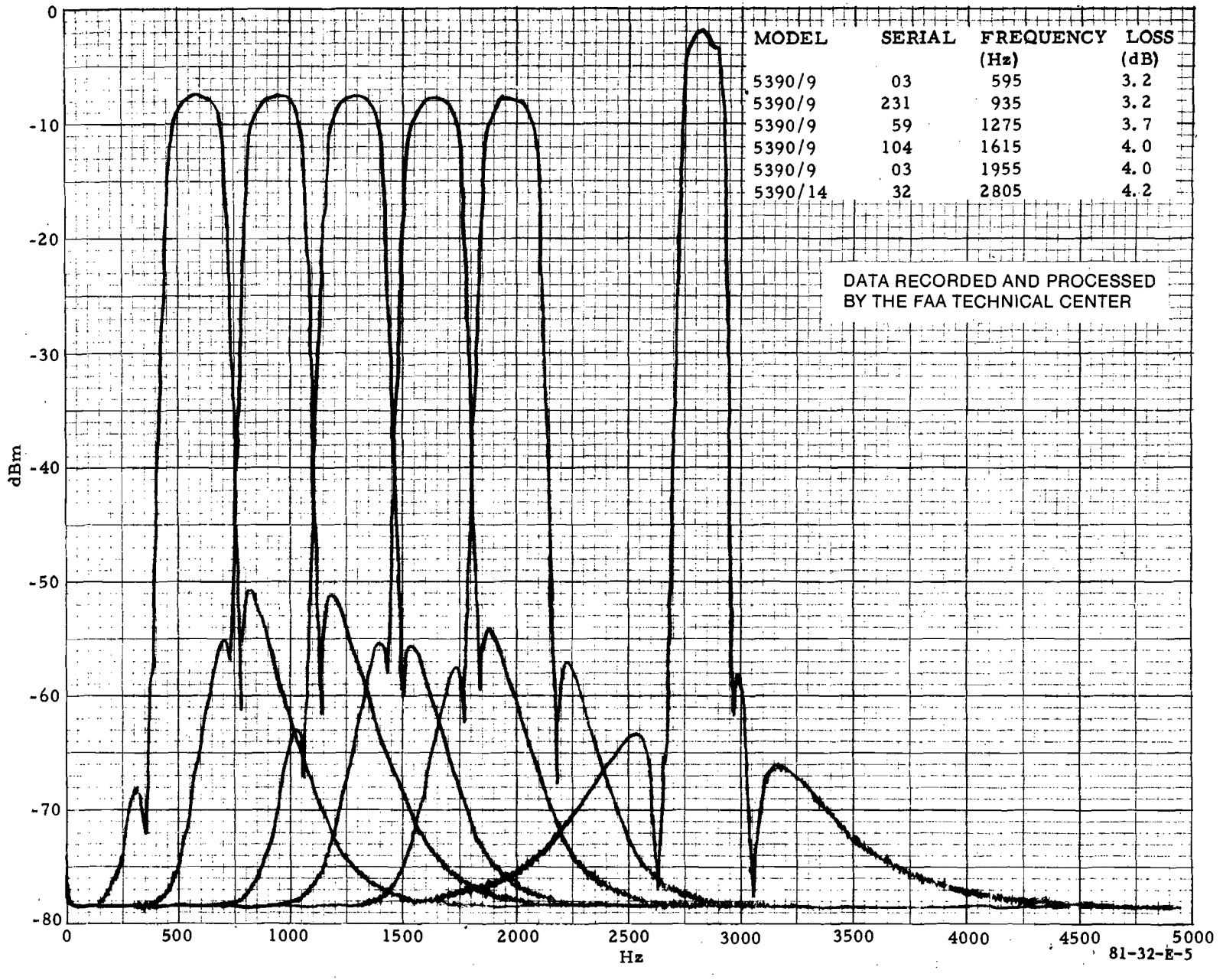

FIGURE E-5. FREQUENCY RESPONSE, AM RECEIVER BANDPASS FILTERS

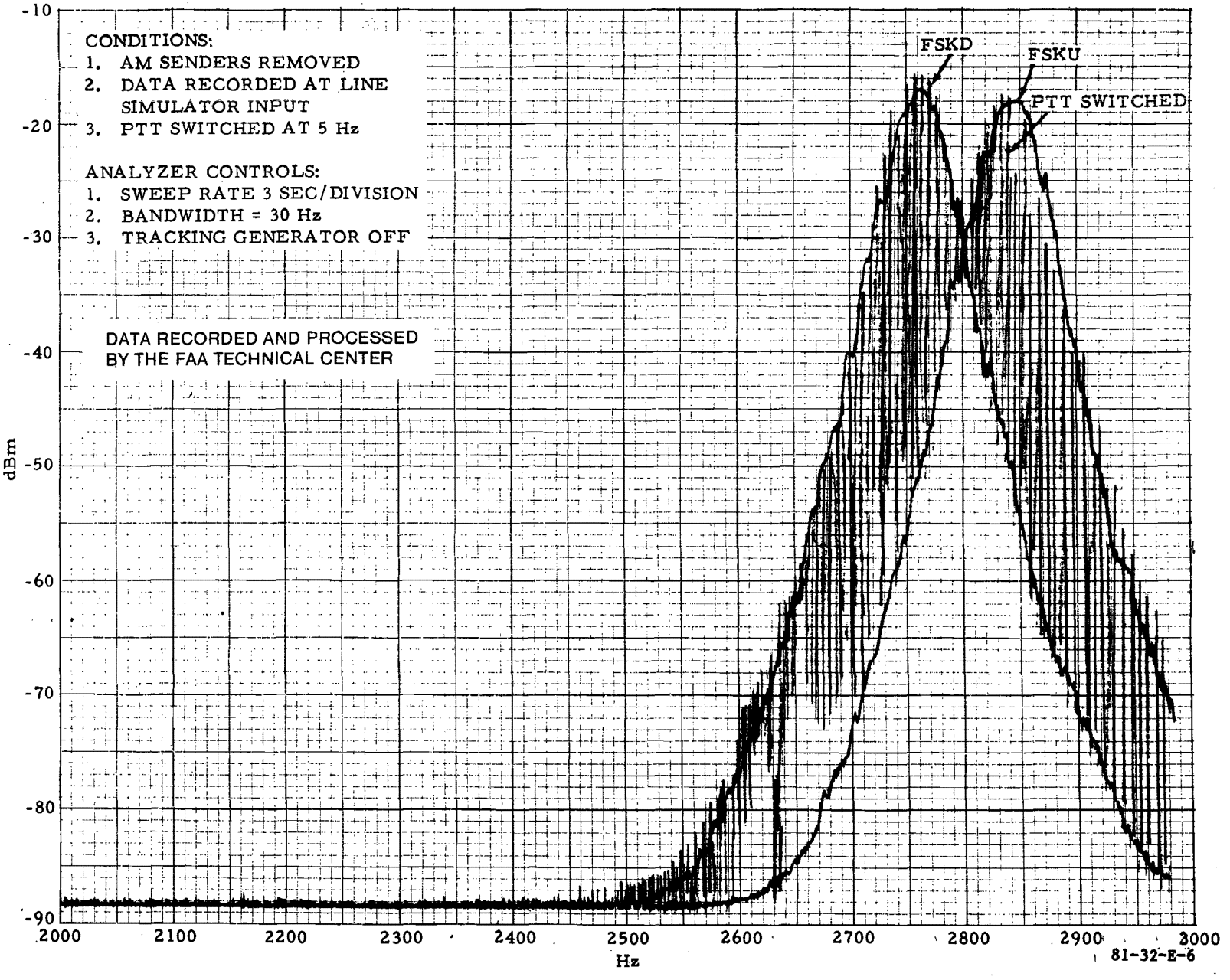

FIGURE E-6. EXPANDED SPECTRUM OF SWITCHED PTT, AND STEADY STATE PTT

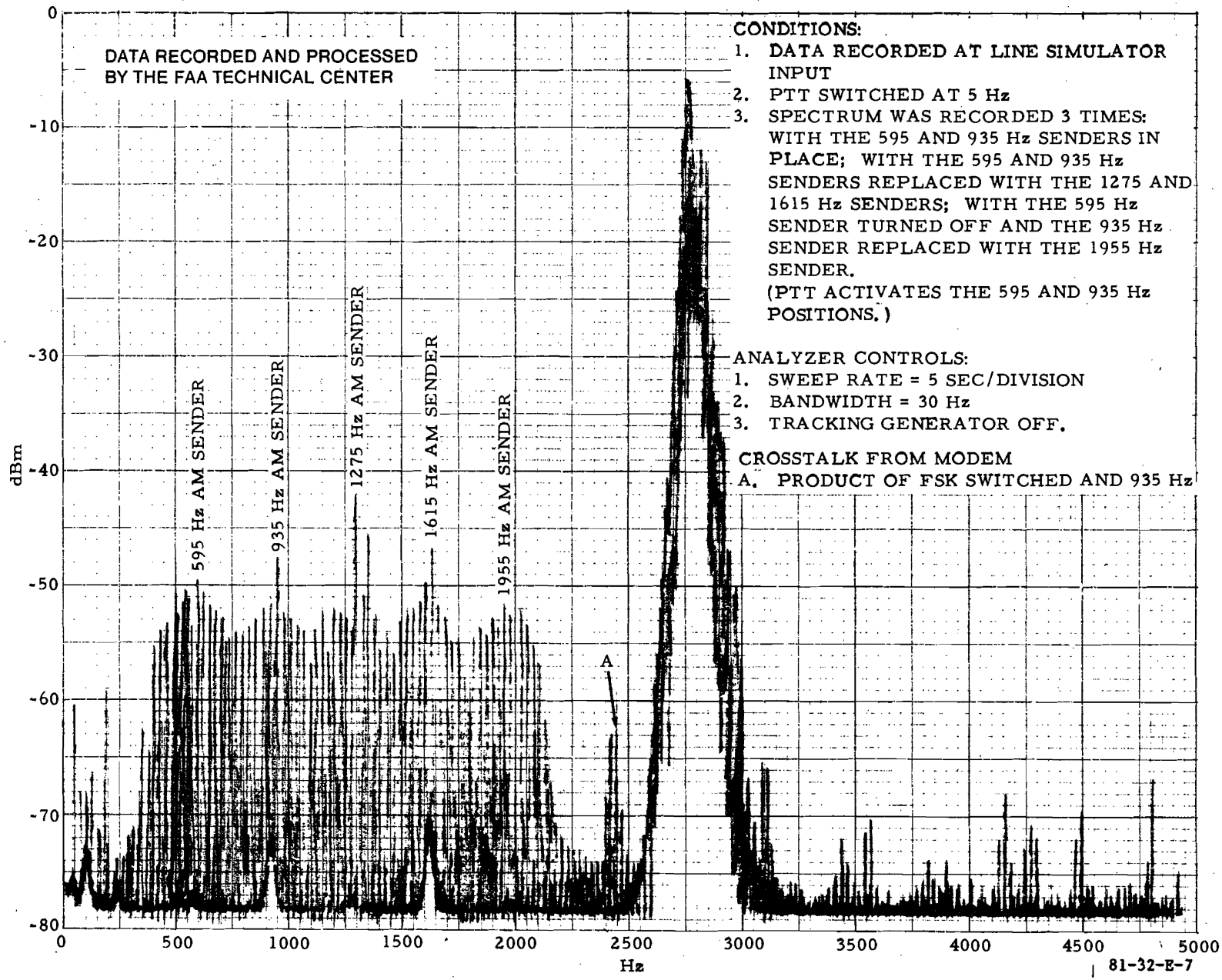

FIGURE E-7. SPECTRUM OF SWITCHED PTT

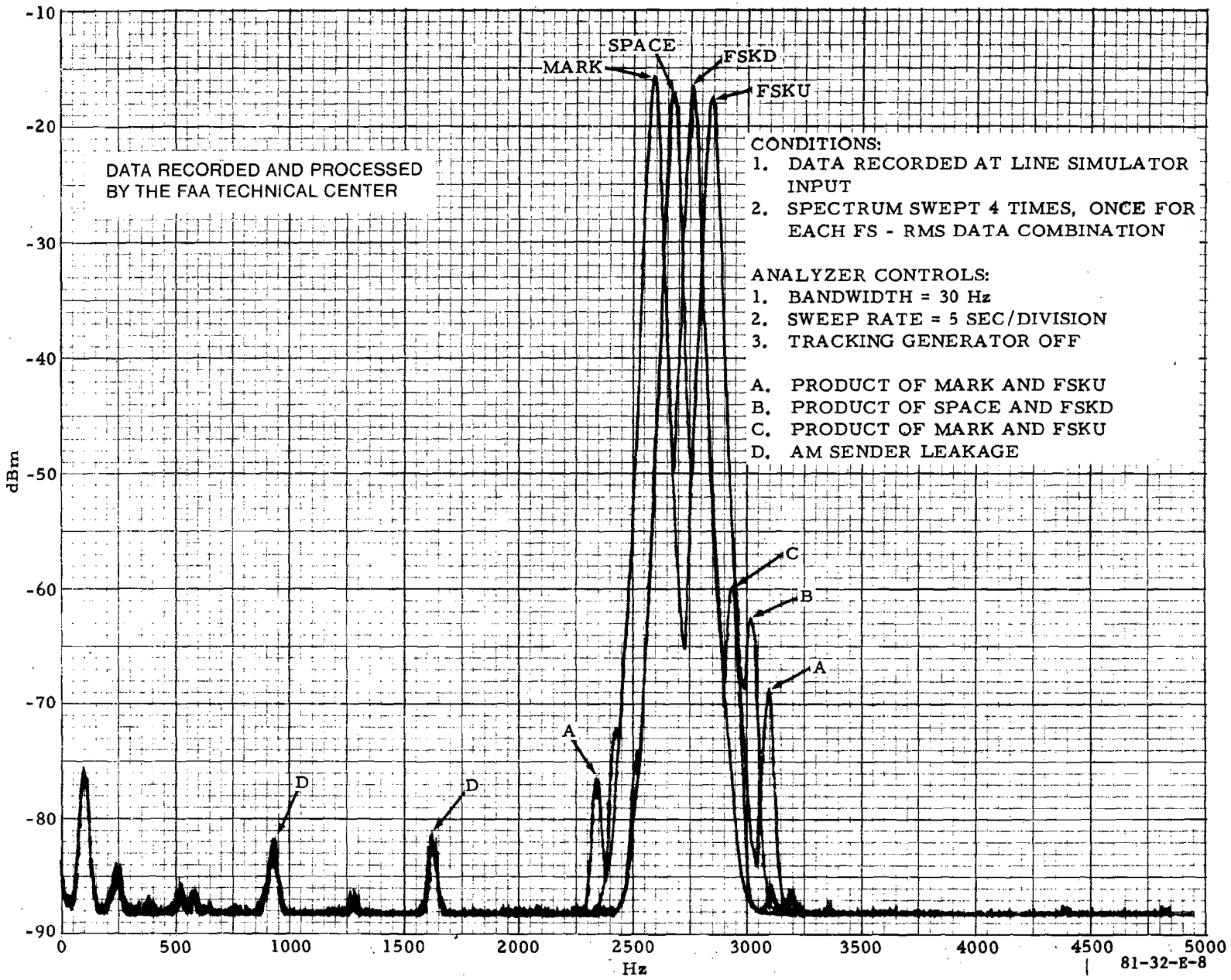

FIGURE E-8. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND STEADY STATE RMS DATA (MARK AND SPACE)

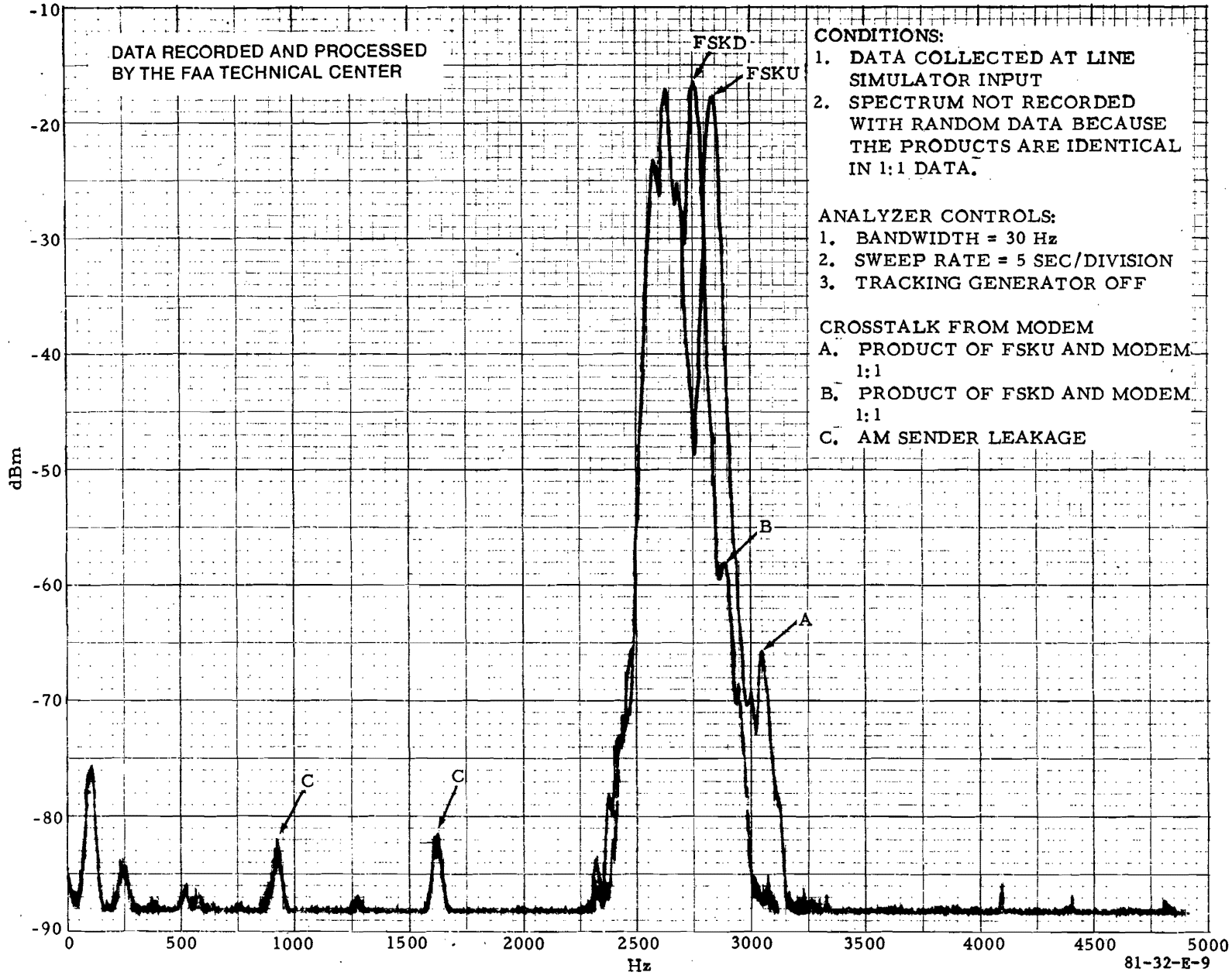

FIGURE E-9. SPECTRUM OF PRODUCTS OF STEADY STATE FS SENDER AND TRANSITIONAL RMS DATA (1:1 AND RANDOM)

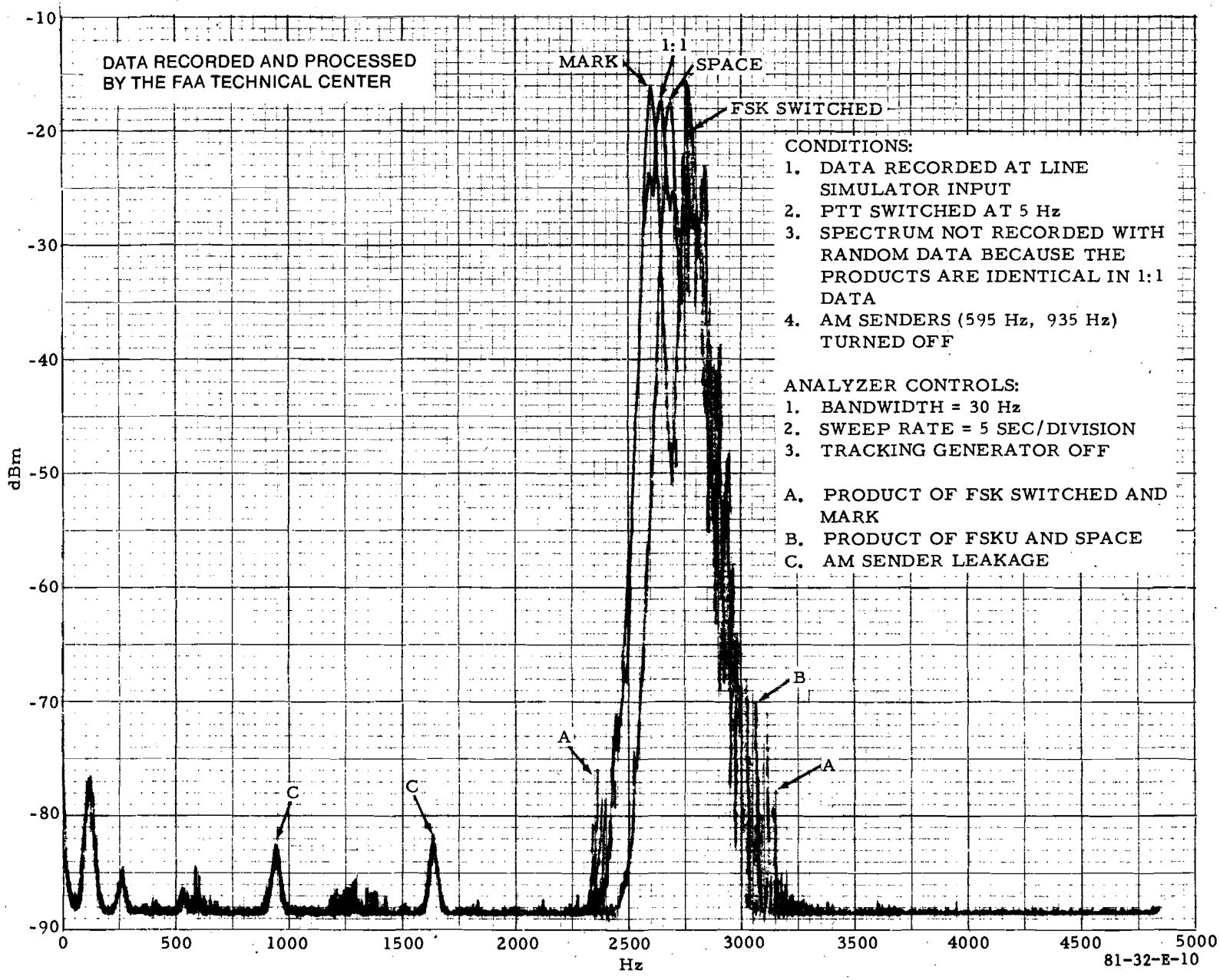

FIGURE E-10. SPECTRUM OF PRODUCTS OF SWITCHED PTT AND TRANSITIONAL RMS DATA

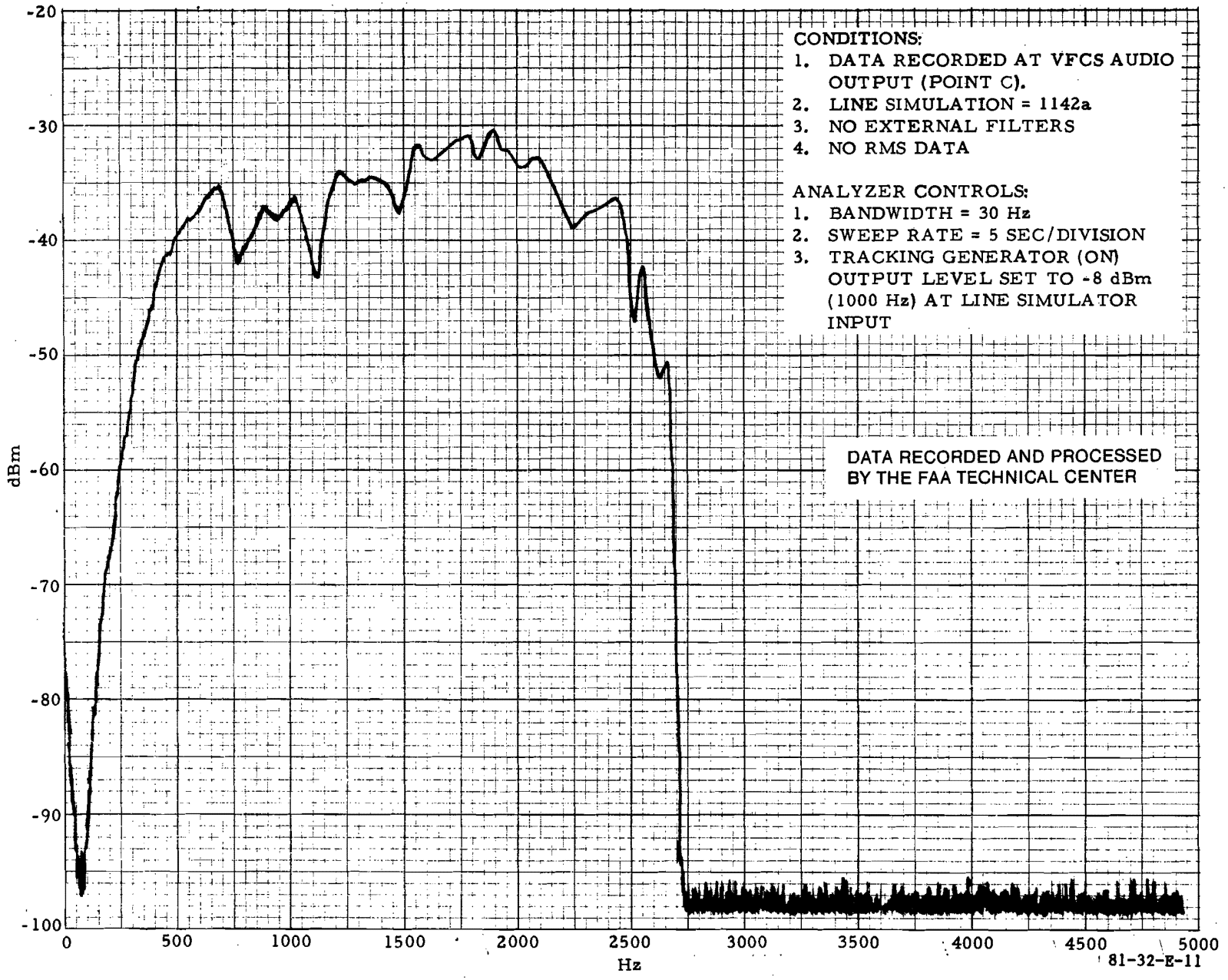

FIGURE E-11. END TO END FREQUENCY RESPONSE OF VFSS

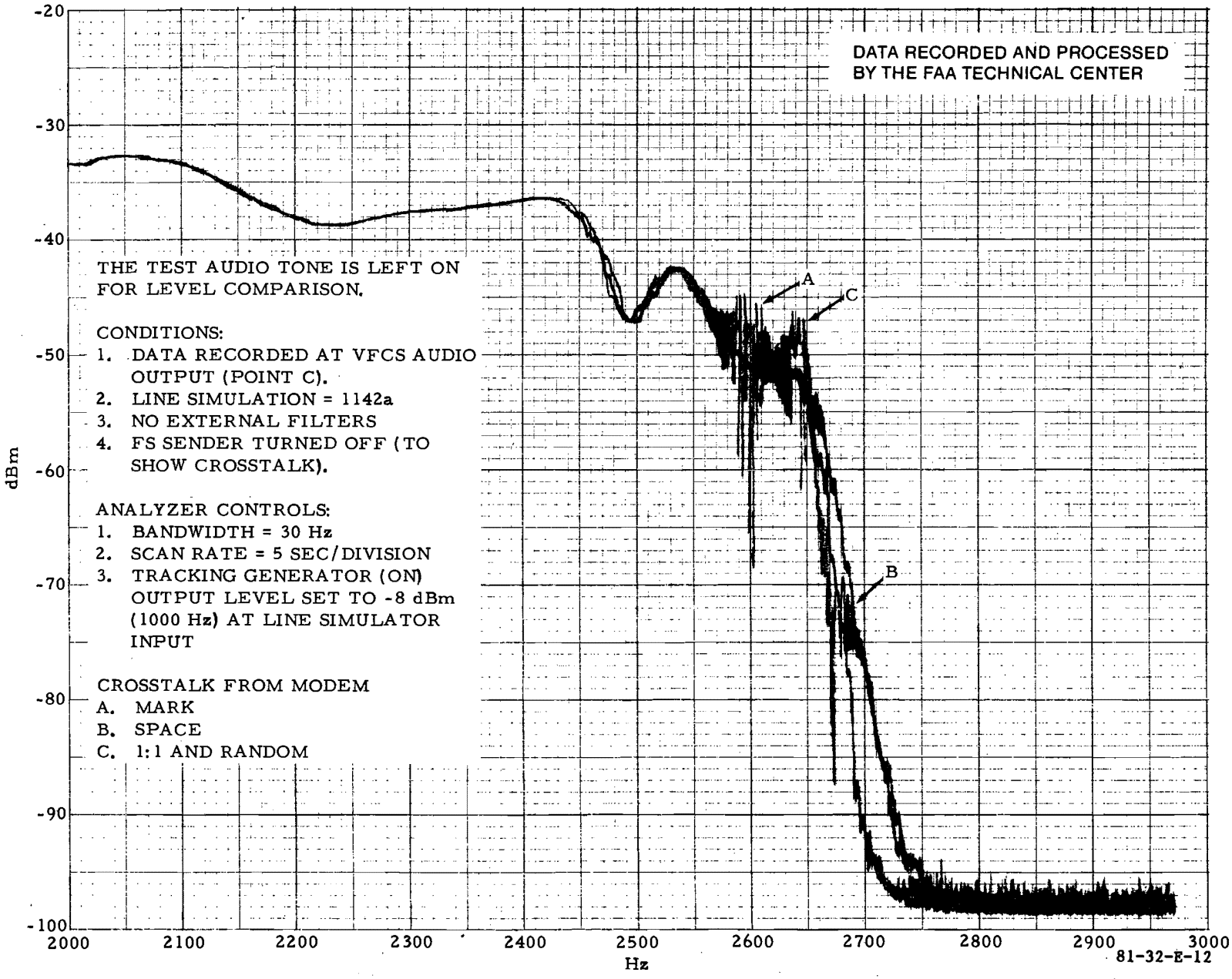

FIGURE E-12. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

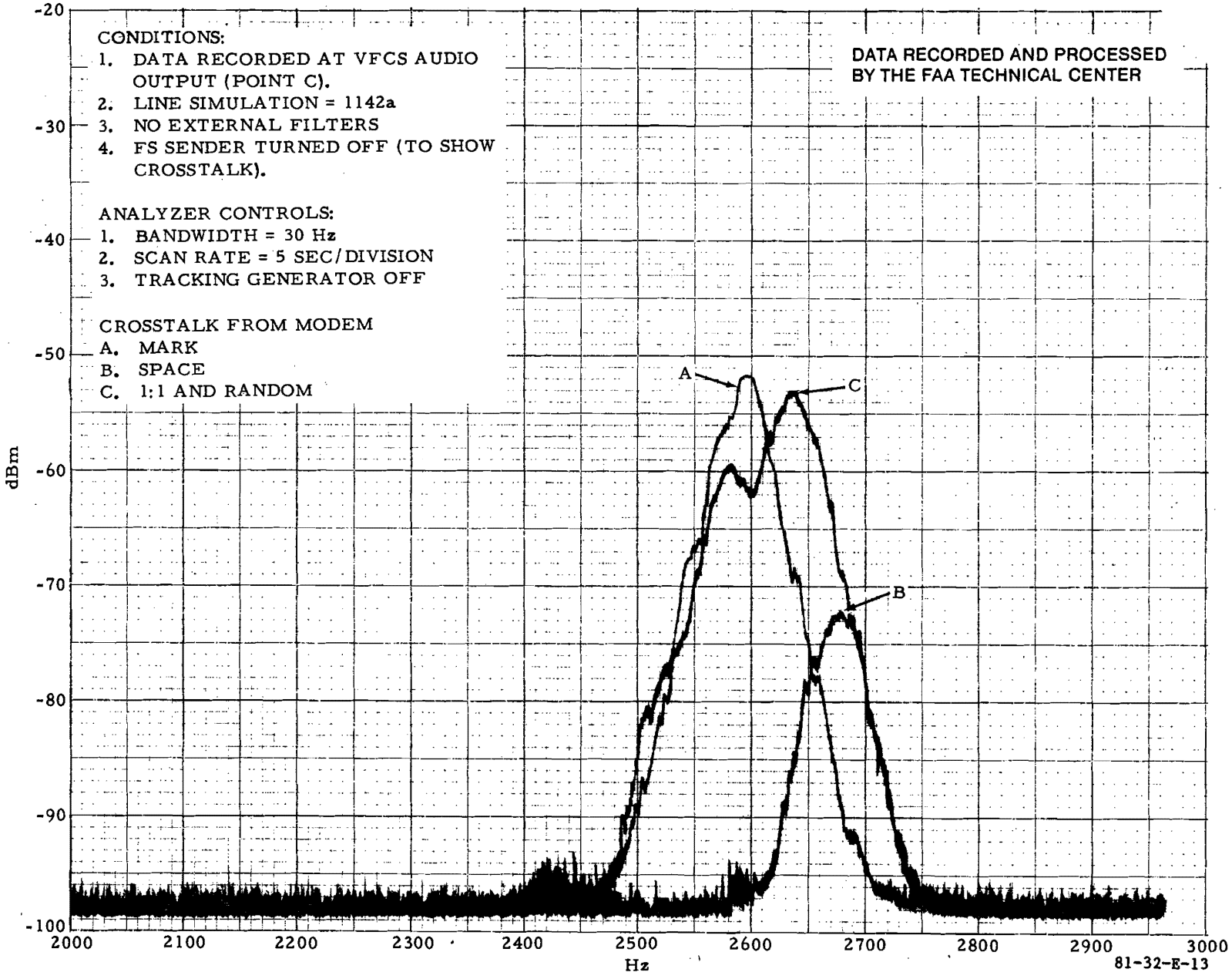

FIGURE E-13. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

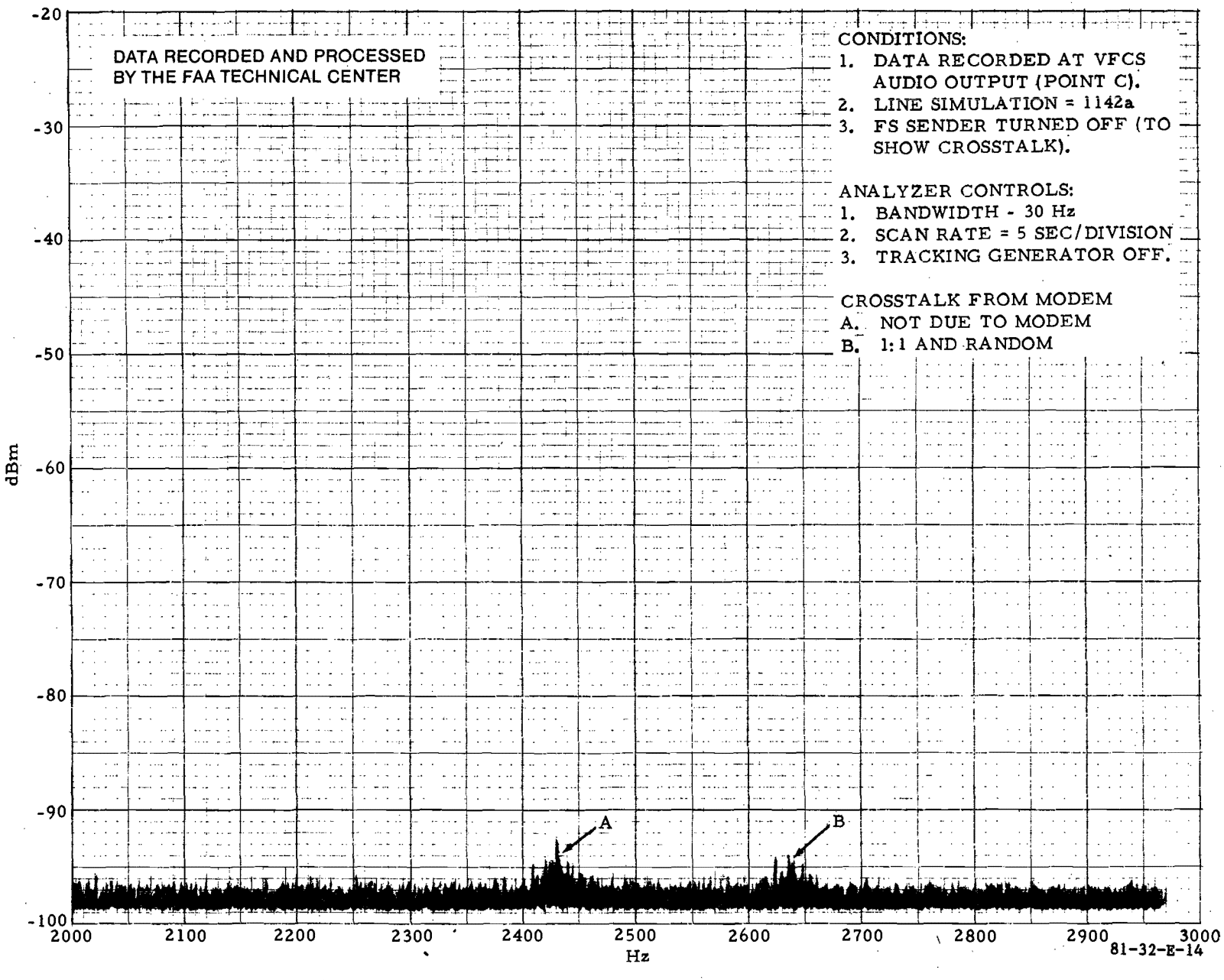

FIGURE E-14. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVER TERMINAL

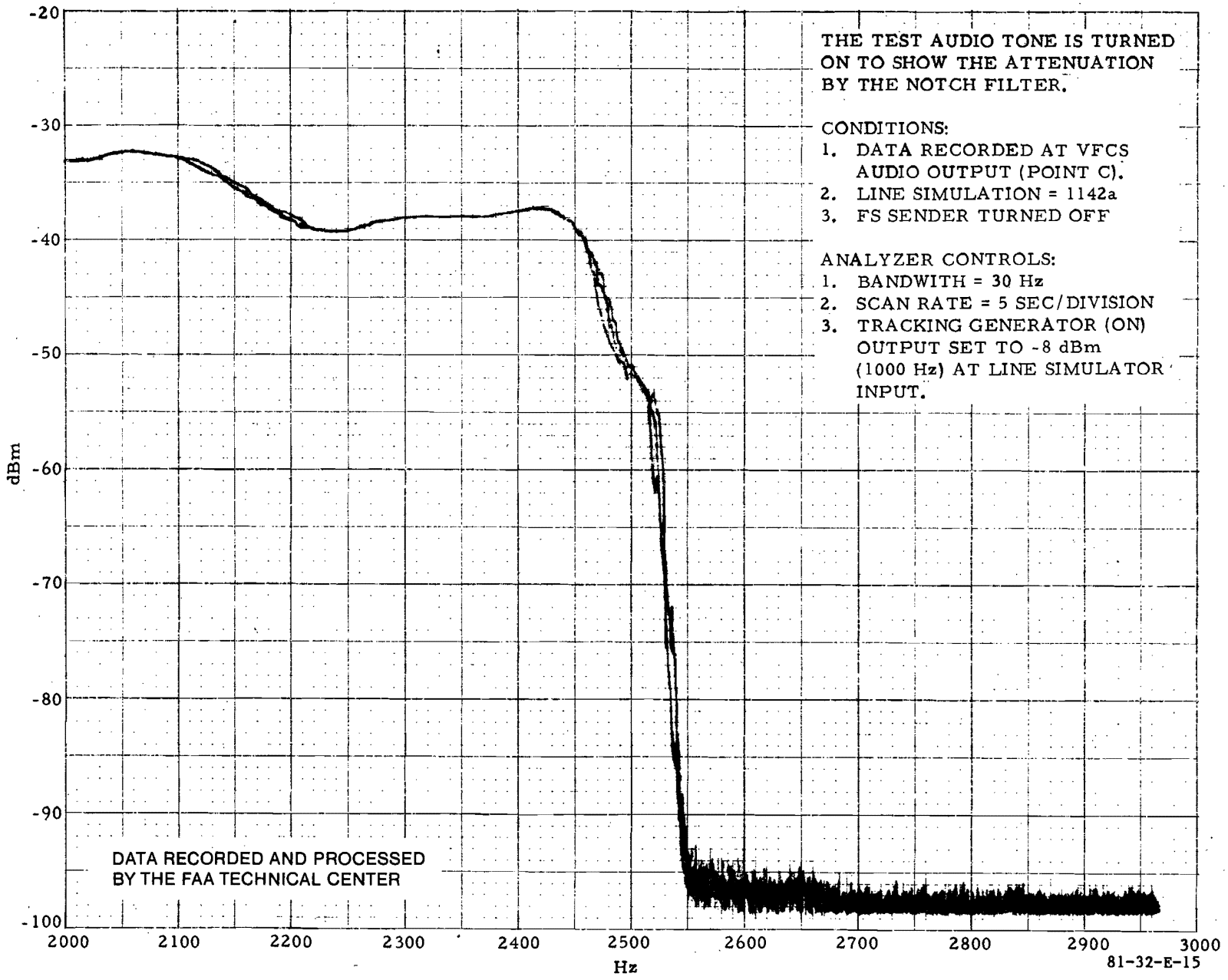

FIGURE E-15. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

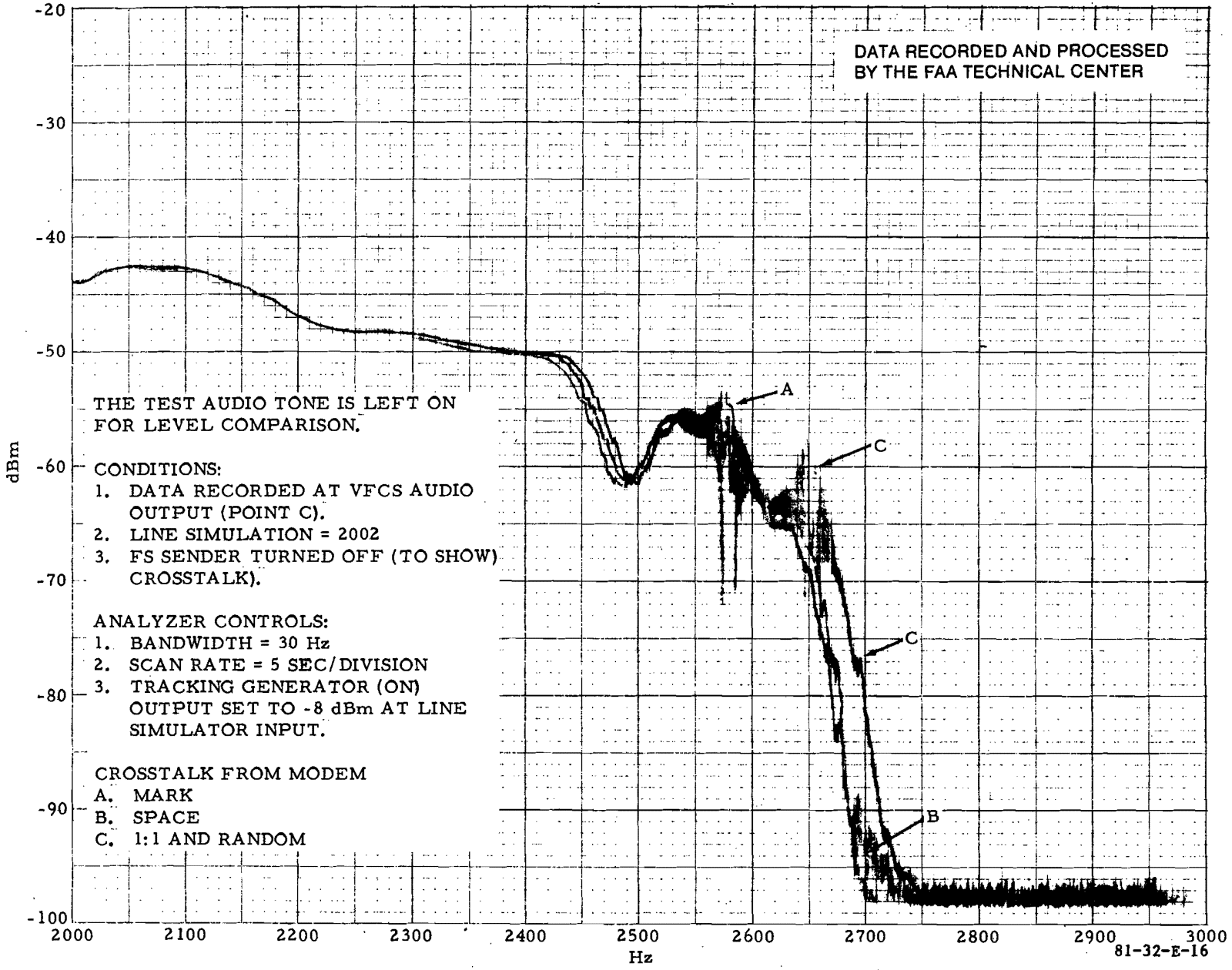

FIGURE E-16. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA

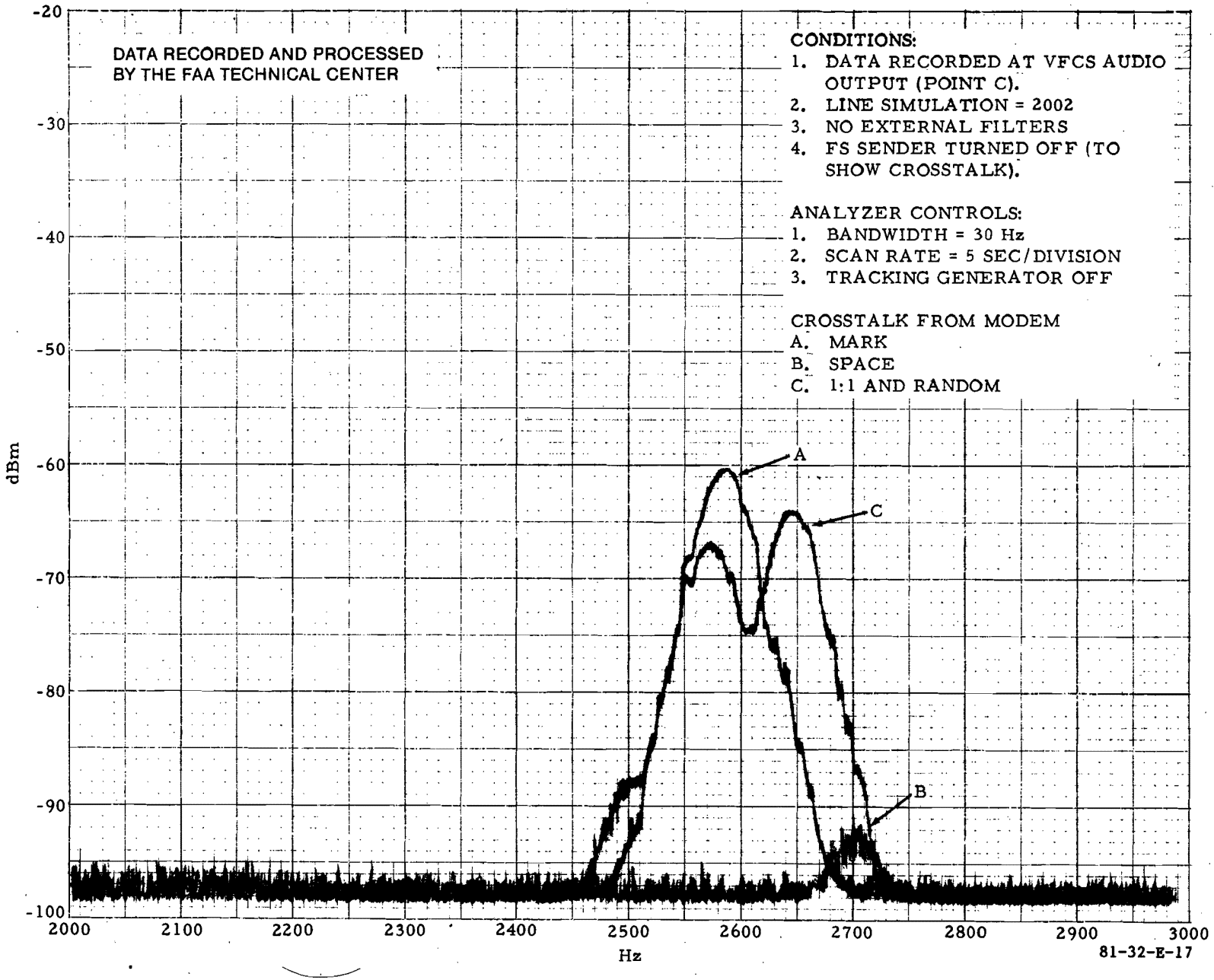

FIGURE E-17. SPECTRUM OF CROSSTALK RESULTING FROM 150 BAUD RMS DATA; AUDIO REMOVED

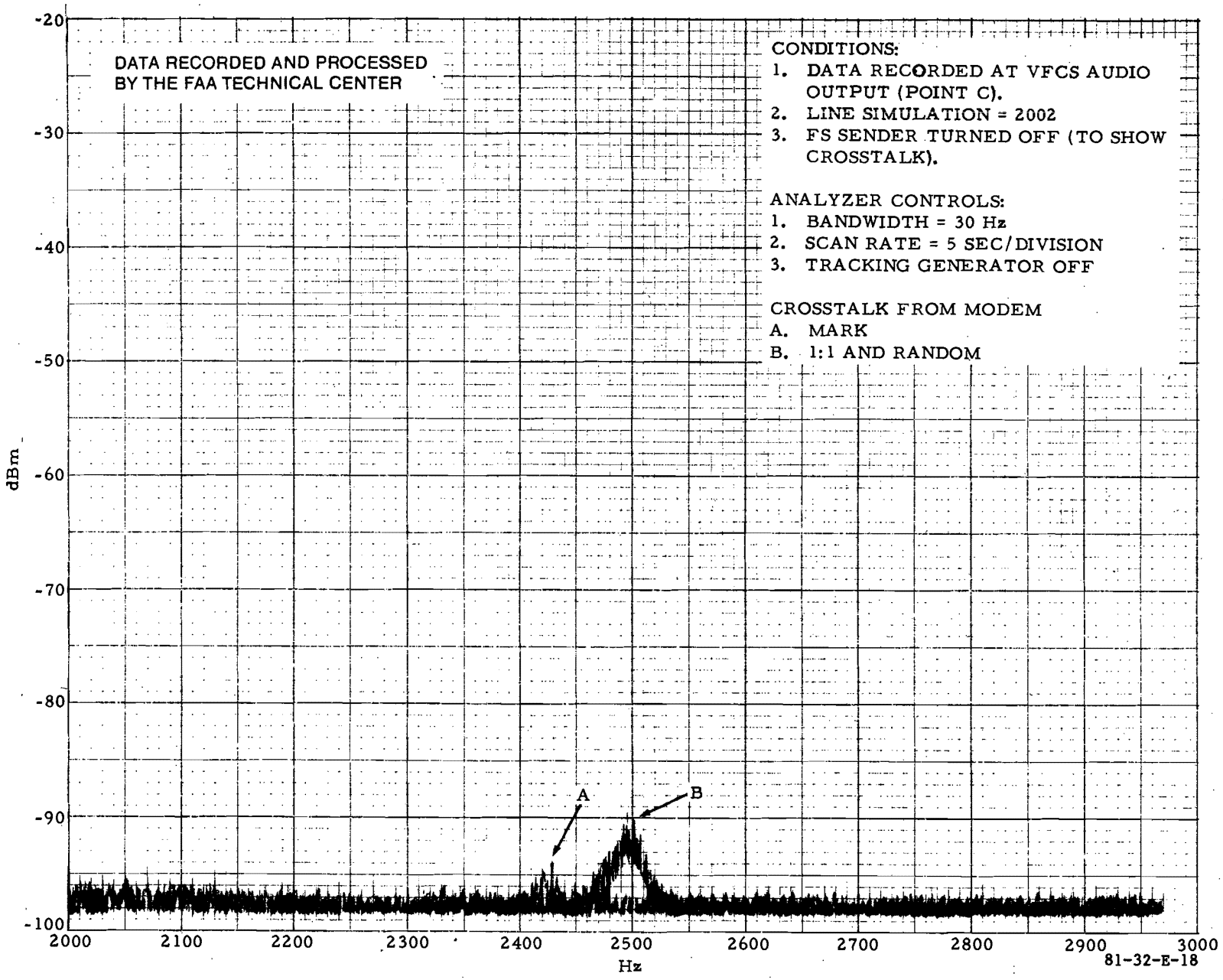

FIGURE E-18. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

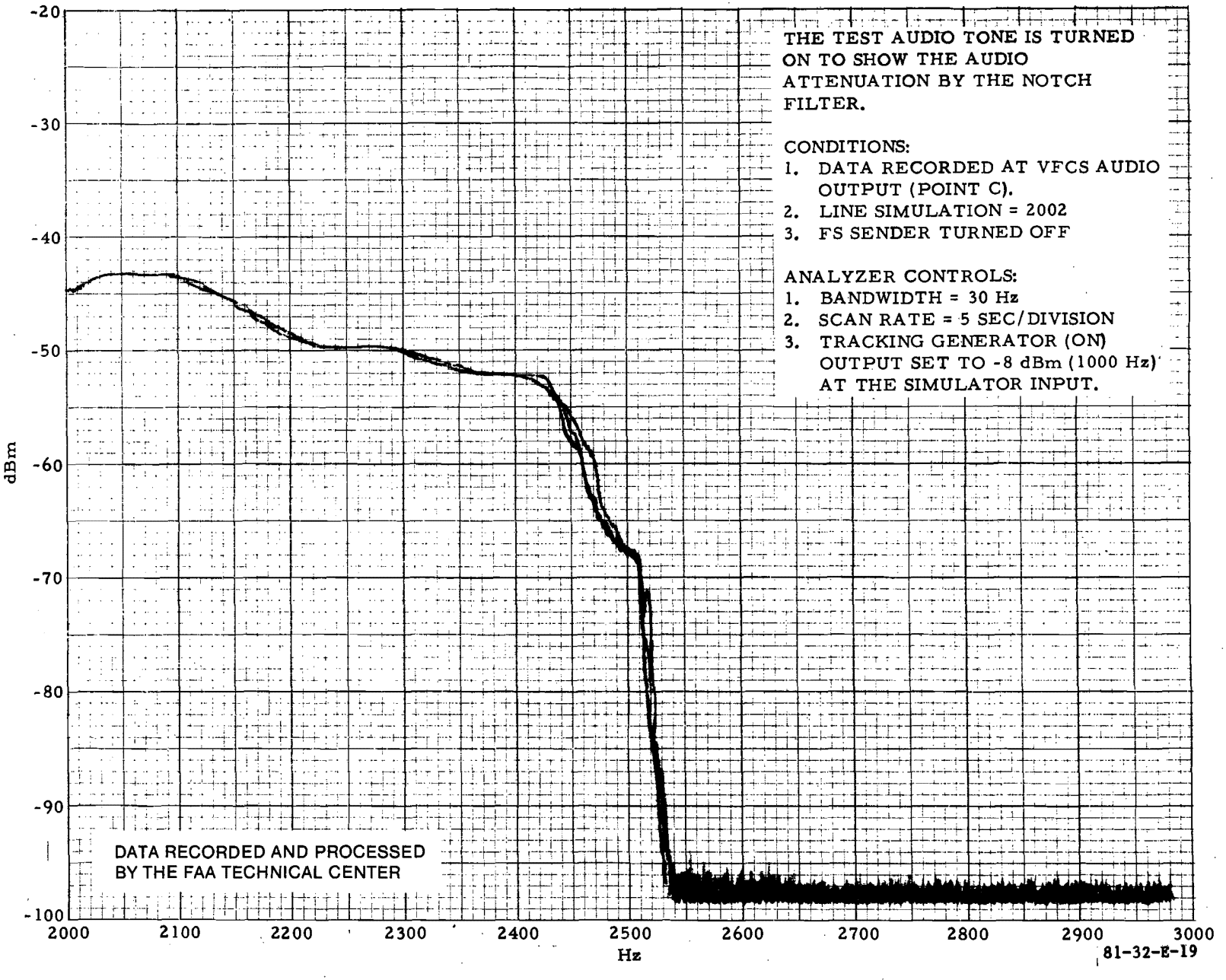

FIGURE E-19. SPECTRUM OF 150 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER

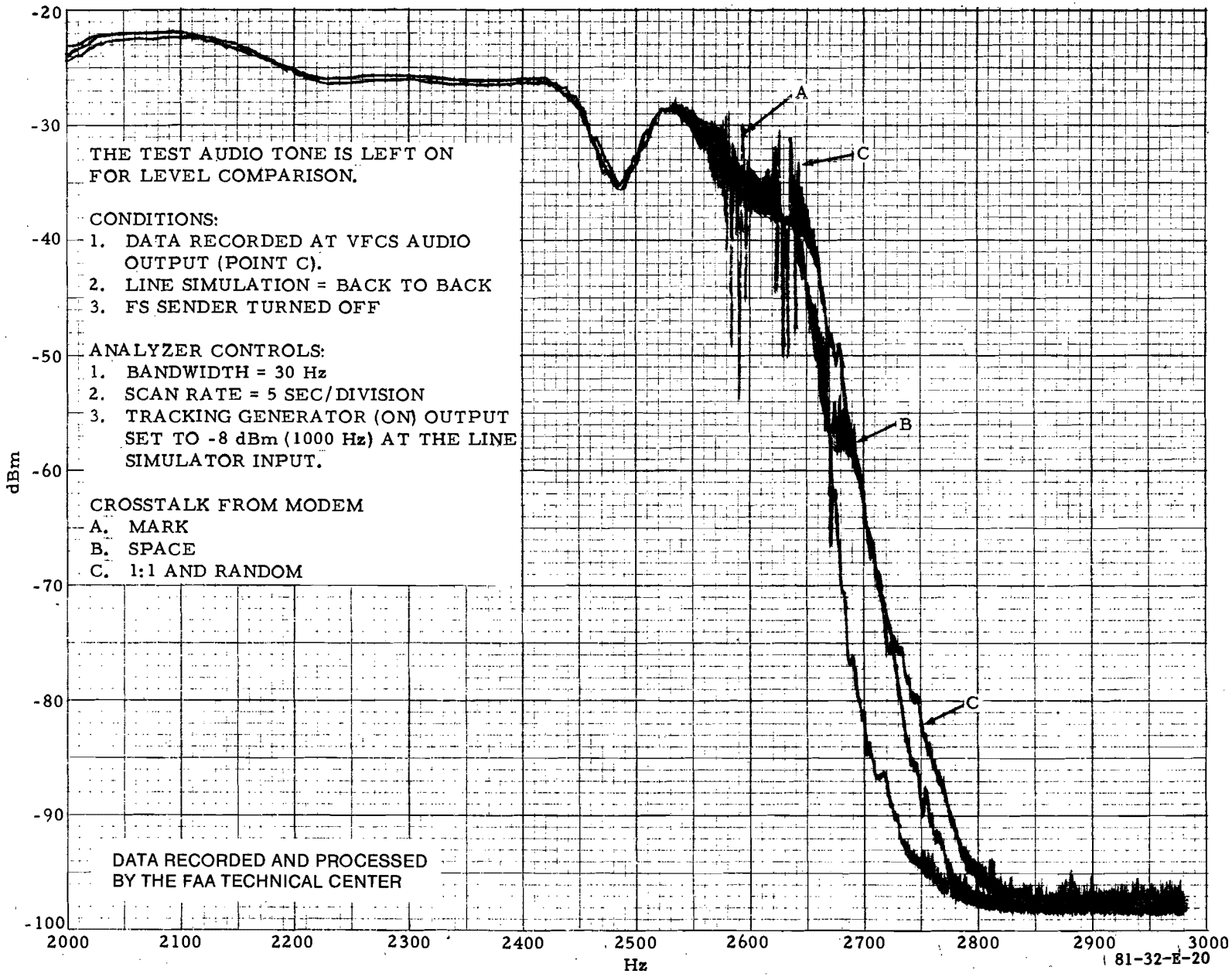

FIGURE E-20. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA

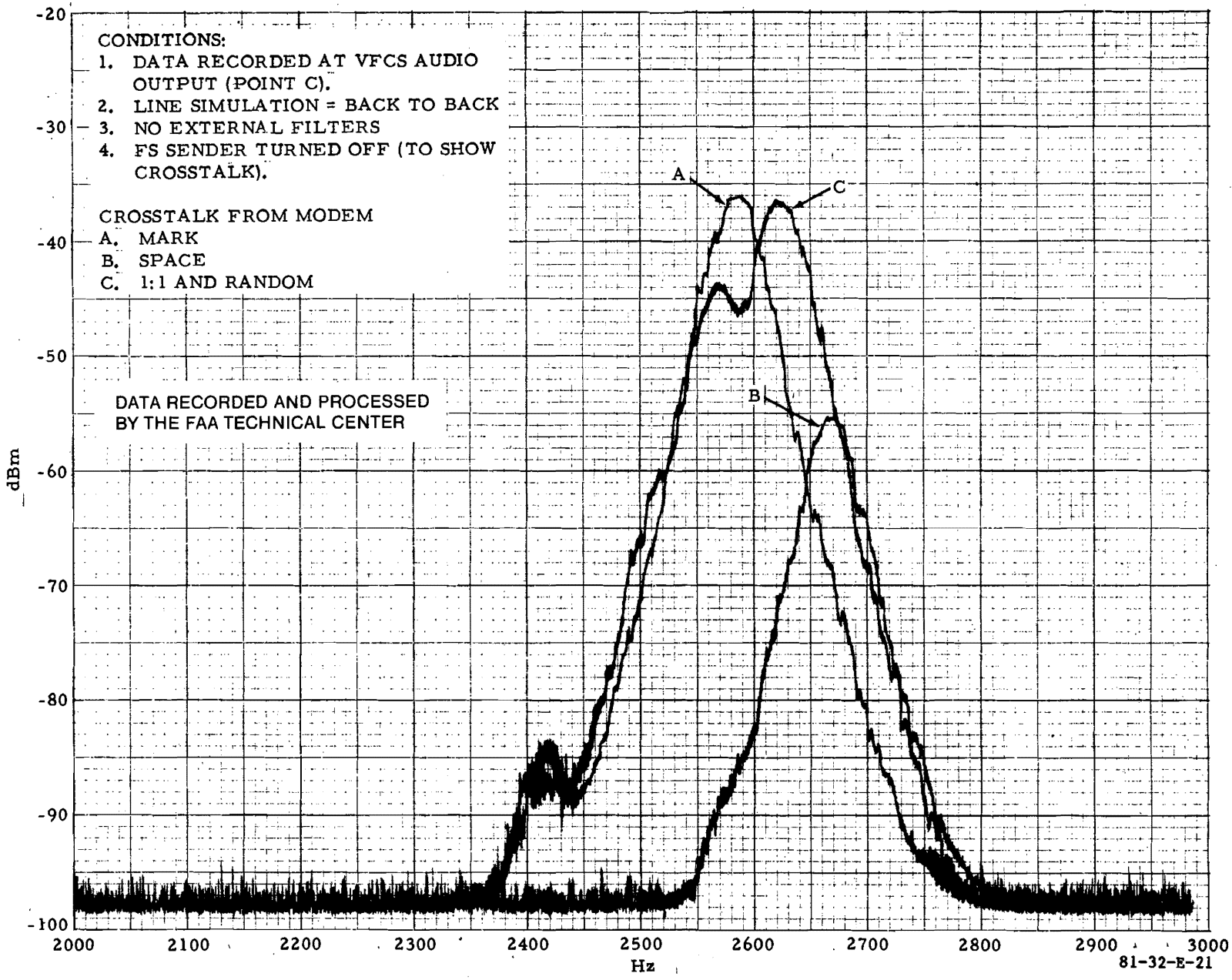

FIGURE E-21. SPECTRUM OF CROSSTALK RESULTING FROM 110 BAUD RMS DATA; AUDIO REMOVED

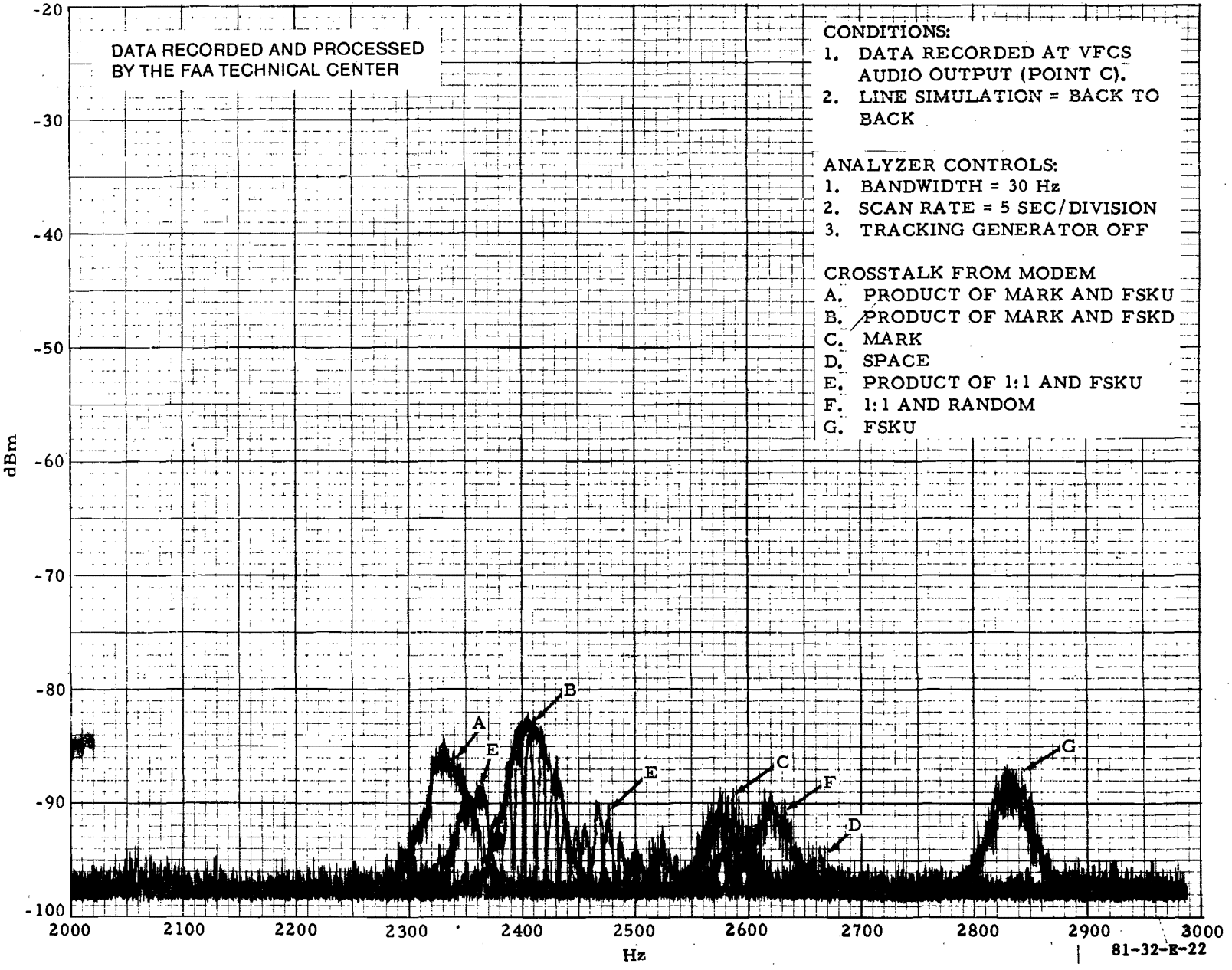

FIGURE E-22. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER IN SERIES WITH THE VFSS RECEIVE TERMINAL

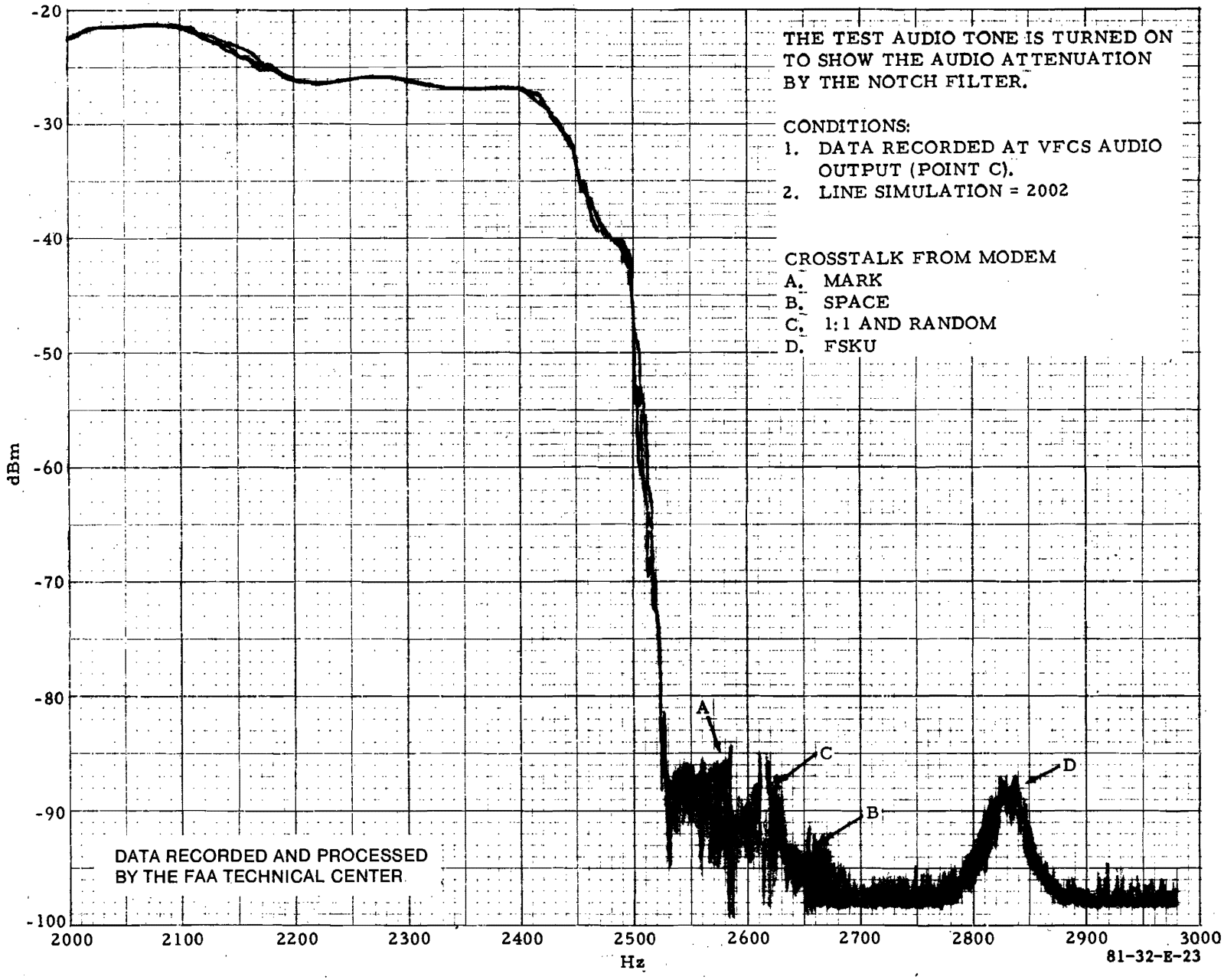

FIGURE E-23. SPECTRUM OF 110 BAUD (RMS DATA) CROSSTALK AFTER THE ADDITION OF THE EXTERNAL NOTCH FILTER