1984

Effect of boundary conditions on the damping characteristics of a randomly excited cast nickel-aluminum bronze specimen at low stress levels.

Knouse, Stephen T.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

EFFECT OF BOUNDARY CONDITIONS ON THE DAMPING CHARACTERISTICS OF A RANDOMLY EXCITED CAST NICKEL-ALUMINUM BRONZE SPECIMEN AT LOW STRESS LEVELS

by

Stephen T. Knouse

March 1984

Thesis Advisor: Y. S. Shin

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Effect of Boundary Conditions on the Damping Characteristics of a Randomly Excited Cast Nickel-Aluminum Bronze Specimen at Low Stress Levels	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1984
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Stephen T. Knouse	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	12. REPORT DATE March 1984
	13. NUMBER OF PAGES 158
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Material Damping
Modal Analysis
Boundary Conditions
Low Stress Level High Frequency Measurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research examines how various specimen support arrangements affect a material's damping characteristics. The 74 lb. sample studied is cast nickel-aluminum bronze and measures 19.8 x 13.65 x 1 inches. Using previously documented Naval Postgraduate School research, desired random vibration analysis has been verified by impulse hammer techniques. Input excitation is provided by a combination piezoelectric-electromagnetic vibration generator system and response is recorded through the use of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

piezoelectric accelerometers. The frequency range studied varies from 100 Hertz to 12,500 Hertz. The vibration generator is threaded into the specimen and the accelerometers are attached to the machined surface of the sample with a cyanoacrylate adhesive. Boundary support conditions include various: foam, bolted and shock-chord configurations.

Approved for public release; distribution unlimited.

Effect of Boundary Conditions on the Damping Characteristics of a Randomly Excited Cast Nickel-Aluminum Bronze Specimen at Low Stress Levels

by

Stephen T. Knouse
Lieutenant, United States Navy
B.S.M.E., University of Nebraska, 1976

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1984

ABSTRACT

This research examines how various specimen support arrangements affect a material's damping characteristics. The 74 lb. sample studied is cast nickel-aluminum bronze and measures 19.8 x 13.65 x 1 inches. Using previously documented Naval Postgraduate School research, desired random vibration analysis has been verified by impulse hammer techniques. Input excitation is provided by a combination piezoelectric-electromagnetic vibration generator system and response is recorded through the use of piezoelectric accelerometers. The frequency range studied varies from 100 Hertz to 12,500 Hertz. The vibration generator is threaded into the specimen and the accelerometers are attached to the machined surface of the sample with a cyanoacrylate adhesive. Boundary support conditions include various: foam, bolted and shock-chord configurations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENT

The following individuals have provided me with the technical expertise necessary to complete this research. Their moral support and comradeship were the contributing factors in making this undertaking an enjoyable and worthwhile learning experience.

To them, I extend a heartfelt "Thank you!".

Y.S. Shin, Associate Professor, Naval Postgraduate School

Ferman Milster, Lieutenant, United States Navy

Ricky Heidgerken, Lieutenant, United States Navy

I. INTRODUCTION

A. NOTE TO THE READER

Please note that all tables and figures are chronologically grouped together in appendixes A and B respectively. The intent of this format is to facilitate location of the vital information contained therein for those readers using this document as reference material in the future. The casual and one-time reader may find it beneficial to review the contents of appendixes A and B prior to reading the remainder of this report.

B. REVIEW OF PREVIOUS PERTINENT NAVAL POSTGRADUATE SCHOOL RESEARCH

This study follows the work initiated and performed by Lt. Ricky A. Heidgerken [Ref. 1]. There, a procedure for measuring the damping characteristics of relatively large metal plates at low stress levels has been designed and introduced. The testing environment is projected to be lab air or non-distilled water with medium (air/water) temperature control in the range of 30 to 90 degrees Fahrenheit. Samples are to be bolted into a support structure which can be immersed into a test chamber, specifically designed to allow for temperature control. His research has utilized the capabilities of a Hewlet-Packard 5451C Digital Fourier

Analysis system, combined with impulse hammer excitation, to determine desired damping characteristics in a frequency range between 100 Hertz and 12,500 Hertz. Maximum frequency is restricted to the frequency range of the available response accelerometers.

Lt. Heidgerken's work evolved to a point where he was able to take preliminary measurements on the test chamber itself, a cast nickel-aluminum bronze specimen bolted into a removable test chamber support structure and on the same specimen supported solely by a 3/4" thick foam pad. Conditions for these measurements are as follows: uncontrolled temperature (lab air), wax mounting for accelerometers, three or fewer measurement locations per test situation, impulse excitation and no specimen surface preparation other than mechanical cleaning. Future research, to include: random excitation, completion of the test chamber temperature control system and improvements to the established testing procedure, has been left for follow-on investigation.

C. NATURE OF CURRENT RESEARCH

In a continuation of the broad scope of the research formalized in Ref. 1, this study centers on the effect of various boundary conditions on the damping characteristics of a 74 pound cast nickel-aluminum bronze specimen. The boundary support conditions include various foam, bolted and shock chord configurations. Random excitation is also

introduced (and validated) as the input energy source, replacing the impact hammer techniques utilized in the previous work with this specimen.

Various experimental considerations are explored to ascertain the optimal testing procedure to accomplish the goals set forth by the preceding research [Ref. 1]. Areas to investigate include: alternative accelerometer mounting techniques, specimen surface preparation, random excitation hardware mounting and the number of response pick-up locations desired.

II. BACKGROUND

A. DAMPING

The capacity to remove from a structural vibration some of the energy associated with that vibration is termed structural damping [Ref. 2]. It increases the rate at which the free vibrations of a structure decay. Additionally, damping can lead to decreased sound transmission through a structure. Determination of material damping characteristics in the acoustic frequency range (100 Hertz to 20,000 Hertz), as they relate to structure silencing applications, is the overall objective of this ongoing research project.

Some commonly employed measures of damping are defined on the basis of viscous damping (i.e., damping that results from a retarding force that is proportional to the velocity). The ratio of the magnitude of that force to the velocity is called the viscous damping coefficient, "C." The smallest viscous damping coefficient for which nonoscillatory behavior is obtained is called the critical (viscous) damping coefficient, "C_c." Damping factor is defined as the percent of critical damping, i.e., C/C_c. Loss factor equals twice the damping factor and is defined as the fraction of the system's energy that is dissipated per radian of the vibratory motion.

Theoretical discussion of pertinent vibration topics is covered in the preceding NPS thesis work [Ref. 1] and will not

be repeated here. For ease of location, the page numbers [Ref. 1] of important concepts are provided below.

B. AVAILABLE VIBRATION EXCITATION TYPES

Two types of input excitation are available to conduct damping measurements for this project. Impact testing was previously used [Ref. 1]. This form of input excitation testing does have some advantages. Namely, it is fast and requires no electro-mechanical shakers or noise sources. There are, however, some drawbacks. Variation between successive measurements can result from input force power spectrum fluctuations. Note: the input force is more easily controlled when using mechanical shakers (random excitation).

Poor signal-to-noise ratios in impact measurements can result from a low excitation energy density. This is the result of the total energy, supplied by an impulse, being distributed over a broad frequency range. Inadequate frequency resolution can also be a problem. In order to obtain good frequency resolution for quantifying very lightly damped resonances, a large number of digital data points must be used to represent the signal. As the response signal decays to zero, its signal-to-noise ratio becomes smaller and smaller. If it has decayed to a small value before a data record is completely filled, the Fourier transform will be operating mostly on noise, causing uncertainties in the transfer function measurement. This can be reduced by using a force window on the input power spectrum. The problem becomes acute as higher frequency resolutions are needed and as more heavily damped structures are tested. Even with the above limitations, impact testing is a valuable tool for vibration analysis [Ref. 3].

Three types of random excitation can be used for making frequency response measurements. They are: (1) pure random, (2) pseudo random and (3) periodic random [Ref. 4]. Pure random is not periodic. Pseudo random is exactly periodic every "t" seconds. Periodic random is a combination of both; i.e., a pseudo random signal that is changed for every measurement. Both pseudo and periodic random signals are generated by the analyzer's (HP-5451C) processor and output

to the structure via a digital-to-analog (DAC) converter, whereas pure random must be generated by an external signal generator.

Pure random excitation is used for this research. The external signal generator output is passed through a by-pass filter in order to concentrate energy in the band of interest. Except for the filter roll-off, the signal spectrum will be flat and the overall level easily controlled. An Hewlett-Packard 3582A Spectrum Analyzer is used to provide band-limited white noise for the damping measurements contained herein. White noise is defined to have a constant spectral density, S_o, at all frequencies (i.e., random data with energy distributed uniformly over all frequencies [Ref. 5]). With a pure random signal, each sampled record of data "t" seconds long is different from preceding and following records. As such, successive records of frequency domain data can be averaged together to remove nonlinear effects, noise and distortion from the measurement. As more and more averages are taken, all of the components of noise will average toward an expected value of zero in the frequency domain data. Thus, a much better measure of the response of the structure can be obtained. This is the single most important advantage of using a pure random signal for transfer function measurements.

A drawback of pure random excitation is that the measured input and response signals are not periodic in the measurement time window of the analyzer. A key assumption of digital

Fourier analysis is that the time waveforms be exactly periodic in the observation window. If this condition is not met, the corresponding frequency spectrum will contain so-called leakage due to the nature of the discrete Fourier transform; that is, energy from the non-periodic parts of the signal will leak into the periodic parts of the spectrum, thus giving a less accurate result.

To combat the effects of leakage, Band Selectable Fourier Analysis (BSFA), the so-called zoom transform, is used to collect data. Here, the Fourier transform is performed over a frequency band whose lower and upper limits are independently selectable. BSFA provides increased frequency resolution without increasing the number of spectral lines in the computer (the same number of data points are used, but now in a small frequency bandwidth). Zoom transforms also increase the dynamic range of the measurement to 90 dB or more in many cases. By using BSFA, leakage is no longer an important source of error. Coherence measurements taken during this research were unity in most cases, indicating the absence of any error due to leakage, and confirming the quality of the BSFA measurements taken.

Neither pseudo or periodic random excitation were used to take the 960 zoom transfer function measurements required by this research. However, 32 baseband measurements were taken using pseudo random excitation to assist in choosing

center frequencies for the boundary condition BSFA measurements.

C. ACCELEROMETER MOUNTING CONSIDERATIONS

Three types of accelerometer mounting techniques are available for use in testing (wax, glue or screwed). Using BSFA, coherence measurements were conducted to ascertain the optimum accelerometer mounting technique to be used throughout the remainder of the research. The two accelerometers tested were a PCB #302A (fmax - 5,000 Hertz) and a PCB #303A (fmax = 10,000 Hertz). Center frequencies were chosen at 3,650 Hertz and 8,500 Hertz respectively. Bandwidths for each measurement were 1,000 Hertz. Figure 1 through 5 provide the results of these preliminary experiments. The specimen tested is the cast nickel-aluminum bronze plate previously studied [Ref. 1]. It is supported fully by a 3" foam pad. Figures 1, 2 and 3 are the coherence measurements for wax, screwed and glue mounting respectively. Notice that the coherence becomes progressively better, with the glue being optimum. Similar results were obtained with the PCB #303A accelerometer. The wax mounting (Figure 4) is degraded as compared to the glue mounting (Figure 5). From these measurements, glue accelerometer mounting is chosen to conduct the boundary condition measurements. Note: the glue utilized is a commercial "Super Glue" type cyanoacrylate adhesive.

III. EXPERIMENTAL PROCEDURE

A. EQUIPMENT DESCRIPTION

As noted in chapter II, zoom measurement techniques using random excitation provide excellent frequency resolution for data collection. Obtaining these BSFA measurements accurately is the essence of this study of boundary condition effects. To clearly understand how these measurements are taken, a sequential description of the equipment utilized for a typical zoom measurement is provided below. Using a line diagram (Figure 6) as a guide, the order of equipment presented will be from the random noise source to the data reduction hardware. Other equipment used in: baseband determinations, the alternative accelerometer mounting investigation and impulse hammer vs. random comparisons will then be highlighted.

(1) HEWLETT-PACKARD #3582 SPECTRUM ANALYZER: Supplies white noise to drive the vibration generator. Also allows monitoring of the Fourier analyzer's A & B input channels, thus serving as an independent check for transfer function measurements.

(2) HEWLETT-PACKARD #467A POWER AMPLIFIER: Boosts random signal to the minimum required by the vibration generator system power amplifier.

(3) HEWLETT-PACKARD #3400 RMS VOLTMETER: Allows monitoring of the H.P. amplifier output.

(4) WILCOXIN RESEARCH #PA7C POWER AMPLIFIER: Provides 100 watts of power per channel to vibration generator system.

(5) WILCOXIN RESEARCH #N7C MATCHING NETWORK: Provides impedance matching for the reactive load of the F7 shaker and overload protection for the F4 shaker.

(6) WILCOXIN RESEARCH #F7/F4 VIBRATION GENERATOR: Provides actual input excitation to test specimen. The shaker base contains a force sensing element to monitor the actual force applied to the sample (i.e., channel "A" input to the Fourier analyzer).

(7a) PCB #302A QUARTZ ACCELEROMETER: Measures acceleration of vibration motion fmax = 5,000 Hertz.

(7b) ENDEVCO #2250A PIEZOELECTRIC ACCELEROMETER: Measures acceleration of vibration motion, fmax = 15,000 Hertz.

(8a) PCB #480D06 SIGNAL CONDITIONER: Supplies constant-current power to the accelerometer's transducer.

(8b) ENDEVCO #4416A SIGNAL CONDITIONER: Supplies constant-current power to the accelerometer's transducer.

(9) HEWLETT-PACKARD #54440A PROGRAMMABLE LOW PASS FILTERS: Automatically protects measurements from errors due to aliasing of out-of-band frequencies.

(10) HEWLETT-PACKARD #54470A PRE-PROCESSOR: Allows fast and convenient Band Selectable Fourier Analysis.

(11) HEWLETT-PACKARD #5451C FOURIER ANALYZER: Provides digital frequency domain analysis of complex time

signals. Its modal analysis application package operates on measured transfer function data to determine modal properties (i.e., natural frequencies, damping factors and mode shapes).

The remaining equipment used includes: (1) A PCB #086B03 impulse hammer, used as an excitation source in impact vs. random comparisons, (2) A PCB #303A accelerometer, used in preliminary testing of accelerometer mounting techniques, and (3) A Hewlett-Packard #54420A digital-to-analog converter, used to generate a pseudo random source signal for baseband measurements. Note: Figure 7 is a line drawing of the experimental baseband measurement set-up. The Naval Postgraduate School Modal Analysis Laboratory equipment room is shown in Figure 8.

Examples of the HP-5451C Fourier analyzer's graphical displays (either by CRT, terminal screen or printer) available to the user are shown in Figure 9 thru 16. They are representations of: coherence, log mag/polar/rectangular/complex (Nyquist) transfer functions, and input/output/cross power spectrum measurements respectively.

B. SAMPLE PREPARATION

Various preliminary steps need to be taken to prepare the specimen for testing. To ensure reliable data acquisition, accelerometer mounting surfaces (i.e., entire plate) should be squared and machined flat. A 3/8" diameter mounting hole must be drilled and tapped into the specimen in order to accept the

vibration generator's threaded stud. A 1" by 1" square grid system, laid out on the specimen with a permanent marker, is recommended to enable documentation of response locations. Four samples (a cast magnesium bronze, an aluminum alloy (5086-H116), a steel plate (HY-130) and a cast nickel-aluminum bronze) in various stages of preparation are shown in Figure 17. A close-up of the cast nickel-aluminum bronze sample ready for testing is shown in Figure 18.

C. MEASUREMENT TECHNIQUE

The basic procedural steps required to conduct data collection and reduction are as follows:

(1) Conduct baseband measurements to determine location (frequency) of the vibration modes to be studied.

(2) Take BSFA measurements centered on the frequencies chosen in step one above.

(3) Manually store, via the 5451C's mass store commands, zoom transfer function measurements (in rectangular form) onto the removeable modal disk.

(4) Perform modal analysis, using the Fourier analyzer's application package, on the stored zoom transfer function data to determine desired damping characteristics.

Four different boundary conditions are analyzed for their effect on the specimen's damping factor throughout a frequency range up to 12,500 Hertz. They are described in chapter IV and are designated boundary condition #1, #2, #3 and #4. For

each boundary condition, grid locations 3, 6, 14 and 20 are used to record specimen response (via an attached accelerometer) to random excitation for baseband measurements, 0 Hertz to some fmax. For a given boundary condition, two separate baseband measurements (0 to 5,000 Hertz and 0 to 12,500 Hertz) are taken at each of the four designated baseband grid locations. This provides higher resolution in the frequencies below 5,000 Hertz, as compared against a single 0 to 12,500 Hertz baseband. Considering two basebands per grid location and four designated baseband grid locations per boundary condition, eight baseband measurements are required for each of the boundary conditions (32 total to completely document specimen baseband response for the four support configurations studied). These 32 baseband measurements are displayed in Figure 19 thru 50. They are arranged sequentially according to boundary condition number and accordingly by response grid location within the grouping for a particular boundary condition. The four lower frequency basebands are first, followed by the four higher frequency basebands. Note: Only a portion (5,000 Hertz to 12,500 Hertz) of the higher frequency baseband is plotted since a higher resolution baseband below 5,000 Hertz has already been produced. The PCB #302A accelerometer is used in boundary condition #1 to take the lower frequency baseband data. The Endevco #2250A accelerometer is used to take the higher frequency baseband data for all boundary conditions, as well

as for the remaining lower frequency basebands for the second, third and fourth boundary conditions. Because of the frequency limitations (fmax = 5,000 Hertz) of the PCB accelerometer, the switch to the Endevco transducer for all measurements substantially reduces the actual elapsed time of the data acquisition process. This is due to the additional time expended in breaking free and cleaning the PCB accelerometer, then mounting the Endevco accelerometer to complete the data acquisition (for frequencies beyond the PCB's range) at a given measurement location.

Individually, compare the eight baseband plots for each of the four boundary conditions. Choose twelve peaks per boundary condition (from the plotted polar representations of baseband transfer functions) that span the entire frequency range studied, 100 Hertz to 12,500 Hertz. These peaks become the center frequencies for follow-on BSFA measurements. Note: The number twelve is arbitrary and is a function of the time available to conduct the research more than anything else. Twice as many peaks could easily be identified and analyzed. It is felt that 12 is the minimum number of BSFA measurements needed to analyze the effect of a particular boundary condition, allowing an average separation between center frequencies of 1,000 Hertz. Vary the center frequencies chosen, from one boundary condition to the next, to obtain a more complete representation of the specimen's damping characteristics across the desired frequency spectrum.

Once center frequencies are identified for a particular boundary condition, take zoom transfer function measurements as desired and store them (in rectangular form) on the removeable modal disk via the analyzer's mass store commands. Check coherence measurements at each measurement to ensure correctness of the stored data. Beginning with boundary condition #2, temperatures of the sample for each measurement are recorded. This is accomplished using a thermocouple taped onto the bottom of the specimen during testing. All experimental data and disk storage locations are documented in Tables I thru IV. The following conditions are recorded for each of the 960 transfer function measurements taken:

*** Disk label (i.e., "Steve's Modal One")

*** Disk storage record number (e.g., 1 to 500)

*** Grid location of response accelerometer (e.g., 1 to 20)

*** Number of averages taken by the Analyzer per measurement (i.e., 10)

*** Center frequency of the zoom measurement (Hertz)

*** Bandwidth selected (i.e., 50 Hertz)

*** Type of input excitation (e.g., Impact or Random)

*** Temperature (measured in degrees Celsius)

*** Computer set-up data number (e.g., 1 to 5)

*** Boundary condition description (i.e., "FOAM (pad)")

Note: The computer set-up data number contains the following line items: number of measurements, disk storage location

(record number) of the first measurement, block size, polar transfer function display type (linear or log), input and response transducer scale factors and input and response amplifier gain values.

After all of the BSFA measurements are recorded for a certain boundary condition, the Fourier analyzer's modal analysis application package can be utilized to retrieve stored transfer function data from the removeable disk. Damping factors and natural frequencies for individual modes of vibration can now be determined through a number of interactive steps between user and computer [Ref. 6].

D. USER DEVELOPED KEYBOARD PROGRAMS

To facilitate the above procedure, and to automate certain capabilities of the HP-5451C Fourier analyzer, five locally developed interactive keyboard programs have been written. Their actual program listings are provided in Figure 51 thru 55. They are invoked from the graphics mode of the modal analysis measurement step (No. 2) with the command "JUMP 0 (space) nn." Where "nn" represents the keyboard program numerical label. A brief description of what these five programs do is provided below:

LABEL "1"--Interactive impact testing procedure, utilizing Hewlett-Packard pre-processor.

LABEL "5"--Partial plot of CRT display.

LABEL "10"--Interactive random testing procedure, utilizing Hewlett-Packard pre-processor.

LABEL "15"--Data transfer between removeable disks.

LABEL "16"--Plotting routine for stored animated mode shapes (to be used in follow-on research).

E. IMPACT TESTING vs. RANDOM TESTING

To obtain correlation between impact and random testing, five zoom measurements were compared using similar test conditions for each method of excitation. The PCB #302A accelerometer was used for the impact response measurements, and the Endevco #2250A accelerometer utilized for random response data. Three different pick-up locations were used per center frequency tested. The almost identical results between the two methods are shown in Table V and displayed graphically in Figure 56. This close correlation was expected, but needed to be confirmed to lend credibility to the 960 BSFA transfer function measurements taken during this project to determine boundary condition effects.

IV. BOUNDARY CONDITION TESTING

A. DESCRIPTION OF BOUNDARY CONDITIONS TESTED

As previously indicated, four different support configurations for testing the cast nickel-aluminum bronze sample are investigated as to their possible effect on the material's damping factor. A brief description of each of the conditions analyzed follows:

(#1) FOAM (pad): The specimen is laid on a large 3" thick foam pad. Testing is done on a 4 by 6 foot marble table to isolate possible extraneous excitations from the environment. Figure 57 shows the configuration.

(#2) BOLTED (tank): The specimen is bolted at one end into the removeable test chamber support structure. Eight 3/4" diameter bolts (four on each side of the plate) are used to secure the sample in place. Two 1/8" thick metal strips are placed between the bolts and the specimen to distribute the bolt force along the edge of the sample. Figure 58 shows the configuration.

(#3) CHORD (tank): The specimen is cradled in four 1/2" diameter shock chords. Hose clamps are used to secure the chords to the removeable test chamber

support structure. Figure 59 and 60 show different aspects of this configuration.

(#4) FOAM (ends): The specimen is supported at each end by a 2 inch square foam strip. When in place, the sample rests 3/8" above the marble testing table surface. Figure 61 shows the configuration.

B. REFINED EXPERIMENTAL PROCEDURE

The following is a review of experimental techniques employed in the preceding vibration testing [Ref. 1] of this specimen:

*** The sample was tested in the as received condition, with the exception of minor mechanical cleaning.

*** Wax was used to mount accelerometers.

*** Input excitation was provided by an impulse hammer.

*** Three measurement points (hammer impact locations in the case of impulse testing) per center frequency were tested.

*** BSFA measurements were limited to four or fewer averages and wider bandwidths (less zoom power) due to lengthy computer measurement times encountered without pre-processing hardware. Using 4 averages at a zoom power of 128, a twenty minute measurement time was common for one BSFA measurement.

Current research, with the addition of the necessary equipment, has allowed refinement and improvement of these procedural steps as follows:

(1) The specimen is squared and machined flat prior to testing. A grid system is drawn onto the sample to accurately document response measurement locations.

(2) Glue is used for accelerometer mounting.

(3) White noise is used for input excitation.

(4) Twenty measurement locations (accelerometer pickup locations in the case of random testing) are utilized.

(5) Pre-processing equipment is incorporated to greatly reduce actual measurement times (thus allowing for more averages and smaller bandwidths). Note: The time required to complete one measurement has been reduced by as much as 95% in some cases and done with greater accuracy (resulting from the increased number of averages and a higher input spectral densities).

C. RESULTS AND OBSERVATIONS

Modal analysis was performed on the stored data for each boundary condition using the application package available with the HP-5451C Fourier analyzer. The results (damping factors and natural frequencies) are shown in tabular form in Table VI. Graphical results (damping & loss factors vs. frequency) for boundary conditions 1, 2, 3 and 4 are represe- sented in Figure 62 to 65 respectively. Note: Loss Factor = 2 times Damping Factor. A summary plot of all data collected for the four support arrangements is shown in Figure 66.

The curves through the data points of Figure 62 to 65 were produced using a rational spline interpolation technique. A spline smoothing routine was used to generate the Experimental Summary curve (Figure 66).

All of the individual boundary condition curves show rapid decreases in the damping factor from zero to 1,000 Hertz. The summary plot indicates a leveling off of the damping factor to an average value between 0.05% and 0.15% throughout the remainder of the frequency spectrum studied. Relatively high damping factors are seen between 8,000 Hertz and 10,000 Hertz in all individual boundary condition plots except number 2. The damping factors for the FOAM (pad) boundary condition are notably higher than those for the FOAM (ends) condition at a given frequency.

One final note of interest regarding the bolted boundary condition was observed. In conducting the measurements, it is seen that many more modes are appearing during BSFA for the bolted case then show up for the other support arrangements under similar testing conditions. Figure 67 shows a Nyquist plot taken for the CHORD (tank) boundary condition at a center frequency of 8,221 Hertz over a bandwidth of 50 Hertz. A similar measurement (CF = 8,152, BW = 50) taken for the bolted boundary condition shows a significant increase in the number of modes excited (Figure 68).

V. CONCLUSIONS

Although there is some scatter in the experimental results, boundary conditions do not appear to be a significant contributor to the material's damping characteristics. The order of magnitude of the resulting damping factors do not vary from one boundary condition to the next. Temperature fluctuations of as much as 8 degrees Celsius were encountered during some BSFA measurements (during the time required to complete the 20 measurements at a particular center frequency). This may be a significant factor in the observed scattering of resulting damping characteristics. Considering the extremely small values calculated for the damping factor, i.e., averaging 0.05% to 0.15% for frequencies above 1,000 Hz., this material can be expected to readily transmit energy in the acoustic frequency range.

Since increases in damping between 8,000 and 10,000 Hertz are noted in all of the boundary conditions (less notable for the bolted case), it is felt that this is more likely to be a material property of the metal rather than the result of a particular support configuration.

A possible cause for the relatively high damping observed in boundary condition #1, FOAM (pad), is coupling of the foam support to the metal plate. This interaction takes place on the entire bottom surface of the sample. The weight of the

specimen, 75 lbs., causes it to sink 1" into the 3" thick foam pad. The contact area between the foam and the metal plate equals 270 square inches. In contrast, the contact area between the sample and supporting foam in boundary condition #4, FOAM (ends), is only 20 square inches. Note: The damping factor for this end support configuration is lower throughout the frequency range studied as compared against the full pad support case.

The bolted boundary condition revealed increases in the number of modes excited to an extent that isolation of single modes of interest in BSFA was difficult. The contributing factor is attributed to transmission of the removeable test chamber support structure's own modes through the pressure bolts into the test specimen. This being the case, a switch to shock chord specimen support for the follow-on research is recommended.

VI. RECOMMENDATIONS FOR FUTURE WORK

Having refined the testing procedure to accommodate random excitation, the most significant remaining original tasking is to take measurements at a constant temperature, initially in air. This is to be followed by varying temperature experiments in a water environment. The capability to test at a designated temperature will allow analysis as to the effect of the temperature on the damping characteristics of the specimen in question, i.e., in the same regard that this report studied boundary condition effects. Testing other available samples (aluminum, steel and magnesium bronze) will allow comparisons against a standard, the cast nickel-aluminum bronze specimen, under similar testing environments. Finally, a comparison of the HP-5451C's animated mode shapes against NASTRAN generated data may help to validate experimental procedures.

APPENDIX A

TABLES

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
101	1	10	12206	150	Random	--	4	POAM (pad)
102	2	10	12206	150	Random	--	4	POAM (pad)
103	3	10	12206	50	Random	--	4	POAM (pad)
104	4	10	12206	50	Random	--	4	POAM (pad)
105	5	10	12206	50	Random	--	4	POAM (pad)
106	6	10	12206	50	Random	--	4	POAM (pad)
107	7	10	12206	50	Random	--	4	POAM (pad)
108	8	10	12206	50	Random	--	4	POAM (pad)
109	9	10	12206	50	Random	--	4	POAM (pad)
110	10	10	12206	50	Random	--	4	POAM (pad)
111	11	10	12206	50	Random	--	4	POAM (pad)
112	12	10	12206	50	Random	--	4	POAM (pad)
113	13	10	12206	50	Random	--	4	POAM (pad)
114	14	10	12206	50	Random	--	4	POAM (pad)
115	15	10	12206	50	Random	--	4	POAM (pad)
116	16	10	12206	50	Random	--	4	POAM (pad)
117	17	10	12206	50	Random	--	4	POAM (pad)
118	18	10	12206	50	Random	--	4	POAM (pad)
119	19	10	12206	50	Random	--	4	POAM (pad)
120	20	10	12206	50	Random	--	4	POAM (pad)

Table I. Experimental data - POAM (pad)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
121	1	15	11152	50	Random	--	4	FOAM (pad)
122	2	15	11152	50	Random	--	4	FOAM (pad)
123	3	15	11152	50	Random	--	4	FOAM (pad)
124	4	15	11152	50	Random	--	4	FOAM (pad)
125	5	10	11152	50	Random	--	4	FOAM (pad)
126	6	10	11152	50	Random	--	4	FOAM (pad)
127	7	10	11152	50	Random	--	4	FOAM (pad)
128	8	10	11152	50	Random	--	4	FOAM (pad)
129	9	10	11152	50	Random	--	4	FOAM (pad)
130	10	10	11152	50	Random	--	4	FOAM (pad)
131	11	10	11152	50	Random	--	4	FOAM (pad)
132	12	10	11152	50	Random	--	4	FOAM (pad)
133	13	10	11152	50	Random	--	4	FOAM (pad)
134	14	10	11152	50	Random	--	4	FOAM (pad)
135	15	10	11152	50	Random	--	4	FOAM (pad)
136	16	10	11152	50	Random	--	4	FOAM (pad)
137	17	10	11152	50	Random	--	4	FOAM (pad)
138	18	10	11152	50	Random	--	4	FOAM (pad)
139	19	10	11152	50	Random	--	4	FOAM (pad)
140	20	10	11152	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"

Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
141	1	10	10665	50	Random	--	4	FOAM (pad)
142	2	10	10665	50	Random	--	4	FOAM (pad)
143	3	10	10665	50	Random	--	4	FOAM (pad)
144	4	10	10665	50	Random	--	4	FOAM (pad)
145	5	10	10665	50	Random	--	4	FOAM (pad)
146	6	10	10665	50	Random	--	4	FOAM (pad)
147	7	10	10665	50	Random	--	4	FOAM (pad)
148	8	10	10665	50	Random	--	4	FOAM (pad)
149	9	10	10665	50	Random	--	4	FOAM (pad)
150	10	10	10665	50	Random	--	4	FOAM (pad)
151	11	10	10665	50	Random	--	4	FOAM (pad)
152	12	10	10665	50	Random	--	4	FOAM (pad)
153	13	10	10665	50	Random	--	4	FOAM (pad)
154	14	10	10665	50	Random	--	4	FOAM (pad)
155	15	10	10665	50	Random	--	4	FOAM (pad)
156	16	10	10665	50	Random	--	4	FOAM (pad)
157	17	10	10665	50	Random	--	4	FOAM (pad)
158	18	10	10665	50	Random	--	4	FOAM (pad)
159	19	10	10665	50	Random	--	4	FOAM (pad)
160	20	10	10665	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
161	1	15	9664	50	Random	--	4	FOAM (pad)
162	2	15	9664	50	Random	--	4	FOAM (pad)
163	3	15	9664	50	Random	--	4	FOAM (pad)
164	4	15	9664	50	Random	--	4	FOAM (pad)
165	5	10	9664	50	Random	--	4	FOAM (pad)
166	6	10	9664	50	Random	--	4	FOAM (pad)
167	7	10	9664	50	Random	--	4	FOAM (pad)
168	8	10	9664	50	Random	--	4	FOAM (pad)
169	9	10	9664	50	Random	--	4	FOAM (pad)
170	10	10	9664	50	Random	--	4	FOAM (pad)
171	11	10	9664	50	Random	--	4	FOAM (pad)
172	12	10	9664	50	Random	--	4	FOAM (pad)
173	13	10	9664	50	Random	--	4	FOAM (pad)
174	14	10	9664	50	Random	--	4	FOAM (pad)
175	15	10	9664	50	Random	--	4	FOAM (pad)
176	16	10	9664	50	Random	--	4	FOAM (pad)
177	17	10	9664	50	Random	--	4	FOAM (pad)
178	18	10	9664	50	Random	--	4	FOAM (pad)
179	19	10	9664	50	Random	--	4	FOAM (pad)
180	20	10	9664	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
181	1	15	8529	50	Random	--	4	FOAM (pad)
182	2	15	8529	50	Random	--	4	FOAM (pad)
183	3	15	8529	50	Random	--	4	FOAM (pad)
184	4	15	8529	50	Random	--	4	FOAM (pad)
185	5	10	8529	50	Random	--	4	FOAM (pad)
186	6	10	8529	50	Random	--	4	FOAM (pad)
187	7	10	8529	50	Random	--	4	FOAM (pad)
188	8	10	8529	50	Random	--	4	FOAM (pad)
189	9	10	8529	50	Random	--	4	FOAM (pad)
190	10	10	8529	50	Random	--	4	FOAM (pad)
191	11	10	8529	50	Random	--	4	FOAM (pad)
192	12	10	8529	50	Random	--	4	FOAM (pad)
193	13	10	8529	50	Random	--	4	FOAM (pad)
194	14	10	8529	50	Random	--	4	FOAM (pad)
195	15	10	8529	50	Random	--	4	FOAM (pad)
196	16	10	8529	50	Random	--	4	FOAM (pad)
197	17	10	8529	50	Random	--	4	FOAM (pad)
198	18	10	8529	50	Random	--	4	FOAM (pad)
199	19	10	8529	50	Random	--	4	FOAM (pad)
200	20	10	8529	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
201	1	15	7169	50	Random	--	4	FOAM (pad)
202	2	15	7169	50	Random	--	4	FOAM (pad)
203	3	15	7169	50	Random	--	4	FOAM (pad)
204	4	15	7169	50	Random	--	4	FOAM (pad)
205	5	10	7169	50	Random	--	4	FOAM (pad)
206	6	10	7169	50	Random	--	4	FOAM (pad)
207	7	10	7169	50	Random	--	4	FOAM (pad)
208	8	10	7169	50	Random	--	4	FOAM (pad)
209	9	10	7169	50	Random	--	4	FOAM (pad)
210	10	10	7169	50	Random	--	4	FOAM (pad)
211	11	10	7169	50	Random	--	4	FOAM (pad)
212	12	10	7169	50	Random	--	4	FOAM (pad)
213	13	10	7169	50	Random	--	4	FOAM (pad)
214	14	10	7169	50	Random	--	4	FOAM (pad)
215	15	10	7169	50	Random	--	4	FOAM (pad)
216	16	10	7169	50	Random	--	4	FOAM (pad)
217	17	10	7169	50	Random	--	4	FOAM (pad)
218	18	10	7169	50	Random	--	4	FOAM (pad)
219	19	10	7169	50	Random	--	4	FOAM (pad)
220	20	10	7169	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
221	1	20	6095	50	Random	--	4	FOAM (pad)
222	2	20	6095	50	Random	--	4	FOAM (pad)
223	3	20	6095	50	Random	--	4	FOAM (pad)
224	4	20	6095	50	Random	--	4	FOAM (pad)
225	5	10	6095	50	Random	--	4	FOAM (pad)
226	6	10	6095	50	Random	--	4	FOAM (pad)
227	7	10	6095	50	Random	--	4	FOAM (pad)
228	8	10	6095	50	Random	--	4	FOAM (pad)
229	9	10	6095	50	Random	--	4	FOAM (pad)
230	10	10	6095	50	Random	--	4	FOAM (pad)
231	11	10	6095	50	Random	--	4	FOAM (pad)
232	12	10	6095	50	Random	--	4	FOAM (pad)
233	13	10	6095	50	Random	--	4	FOAM (pad)
234	14	10	6095	50	Random	--	4	FOAM (pad)
235	15	10	6095	50	Random	--	4	FOAM (pad)
236	16	10	6095	50	Random	--	4	FOAM (pad)
237	17	10	6095	50	Random	--	4	FOAM (pad)
238	18	10	6095	50	Random	--	4	FOAM (pad)
239	19	10	6095	50	Random	--	4	FOAM (pad)
240	20	10	6095	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
241	1	15	4728	50	Random	--	4	FOAM (pad)
242	2	15	4728	50	Random	--	4	FOAM (pad)
243	3	15	4728	50	Random	--	4	FOAM (pad)
244	4	15	4728	50	Random	--	4	FOAM (pad)
245	5	10	4728	50	Random	--	4	FOAM (pad)
246	6	10	4728	50	Random	--	4	FOAM (pad)
247	7	10	4728	50	Random	--	4	FOAM (pad)
248	8	10	4728	50	Random	--	4	FOAM (pad)
249	9	10	4728	50	Random	--	4	FOAM (pad)
250	10	10	4728	50	Random	--	4	FOAM (pad)
251	11	30	4728	50	Random	--	4	FOAM (pad)
252	12	10	4728	50	Random	--	4	FOAM (pad)
253	13	10	4728	50	Random	--	4	FOAM (pad)
254	14	10	4728	50	Random	--	4	FOAM (pad)
255	15	10	4728	50	Random	--	4	FOAM (pad)
256	16	10	4728	50	Random	--	4	FOAM (pad)
257	17	10	4728	50	Random	--	4	FOAM (pad)
258	18	10	4728	50	Random	--	4	FOAM (pad)
259	19	10	4728	50	Random	--	4	FOAM (pad)
260	20	10	4728	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
261	1	10	3672	50	Random	--	4	FOAM (pad)
262	2	10	3672	50	Random	--	4	FOAM (pad)
263	3	10	3672	50	Random	--	4	FOAM (pad)
264	4	10	3672	50	Random	--	4	FOAM (pad)
265	5	10	3672	50	Random	--	4	FOAM (pad)
266	6	10	3672	50	Random	--	4	FOAM (pad)
267	7	10	3672	50	Random	--	4	FOAM (pad)
268	8	10	3672	50	Random	--	4	FOAM (pad)
269	9	10	3672	50	Random	--	4	FOAM (pad)
270	10	10	3672	50	Random	--	4	FOAM (pad)
271	11	10	3672	50	Random	--	4	FOAM (pad)
272	12	10	3672	50	Random	--	4	FOAM (pad)
273	13	10	3672	50	Random	--	4	FOAM (pad)
274	14	10	3672	50	Random	--	4	FOAM (pad)
275	15	10	3672	50	Random	--	4	FOAM (pad)
276	16	10	3672	50	Random	--	4	FOAM (pad)
277	17	10	3672	50	Random	--	4	FOAM (pad)
278	18	10	3672	50	Random	--	4	FOAM (pad)
279	19	10	3672	50	Random	--	4	FOAM (pad)
280	20	10	3672	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
281	1	10	2611	50	Random	--	4	FOAM (pad)
282	2	10	2611	50	Random	--	4	FOAM (pad)
283	3	10	2611	50	Random	--	4	FOAM (pad)
284	4	10	2611	50	Random	--	4	FOAM (pad)
285	5	10	2611	50	Random	--	4	FOAM (pad)
286	6	10	2611	50	Random	--	4	FOAM (pad)
287	7	10	2611	50	Random	--	4	FOAM (pad)
288	8	10	2611	50	Random	--	4	FOAM (pad)
289	9	10	2611	50	Random	--	4	FOAM (pad)
290	10	10	2611	50	Random	--	4	FOAM (pad)
291	11	10	2611	50	Random	--	4	FOAM (pad)
292	12	10	2611	50	Random	--	4	FOAM (pad)
293	13	10	2611	50	Random	--	4	FOAM (pad)
294	14	10	2611	50	Random	--	4	FOAM (pad)
295	15	10	2611	50	Random	--	4	FOAM (pad)
296	16	10	2611	50	Random	--	4	FOAM (pad)
297	17	10	2611	50	Random	--	4	FOAM (pad)
298	18	10	2611	50	Random	--	4	FOAM (pad)
299	19	10	2611	50	Random	--	4	FOAM (pad)
300	20	10	2611	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
301	1	10	1261	40	Random	--	4	FOAM (pad)
302	2	10	1261	50	Random	--	4	FOAM (pad)
303	3	10	1261	50	Random	--	4	FOAM (pad)
304	4	10	1261	50	Random	--	4	FOAM (pad)
305	5	10	1261	50	Random	--	4	FOAM (pad)
306	6	10	1261	50	Random	--	4	FOAM (pad)
307	7	10	1261	50	Random	--	4	FOAM (pad)
308	8	10	1261	50	Random	--	4	FOAM (pad)
309	9	10	1261	50	Random	--	4	FOAM (pad)
310	10	10	1261	50	Random	--	4	FOAM (pad)
311	11	10	1261	50	Random	--	4	FOAM (pad)
312	12	10	1261	50	Random	--	4	FOAM (pad)
313	13	10	1261	50	Random	--	4	FOAM (pad)
314	14	10	1261	50	Random	--	4	FOAM (pad)
315	15	10	1261	50	Random	--	4	FOAM (pad)
316	16	10	1261	50	Random	--	4	FOAM (pad)
317	17	10	1261	50	Random	--	4	FOAM (pad)
318	18	10	1261	50	Random	--	4	FOAM (pad)
319	19	10	1261	50	Random	--	4	FOAM (pad)
320	20	10	1261	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (one)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
321	1	10	421	50	Random	--	4	FOAM (pad)
322	2	10	421	50	Random	--	4	FOAM (pad)
323	3	10	421	50	Random	--	4	FOAM (pad)
324	4	10	421	50	Random	--	4	FOAM (pad)
325	5	10	421	50	Random	--	4	FOAM (pad)
326	6	10	421	50	Random	--	4	FOAM (pad)
327	7	10	421	50	Random	--	4	FOAM (pad)
328	8	10	421	50	Random	--	4	FOAM (pad)
329	9	10	421	50	Random	--	4	FOAM (pad)
330	10	10	421	50	Random	--	4	FOAM (pad)
331	11	10	421	50	Random	--	4	FOAM (pad)
332	12	10	421	50	Random	--	4	FOAM (pad)
333	13	10	421	50	Random	--	4	FOAM (pad)
334	14	10	421	50	Random	--	4	FOAM (pad)
335	15	10	421	50	Random	--	4	FOAM (pad)
336	16	10	421	50	Random	--	4	FOAM (pad)
337	17	10	421	50	Random	--	4	FOAM (pad)
338	18	10	421	50	Random	--	4	FOAM (pad)
339	19	10	421	50	Random	--	4	FOAM (pad)
340	20	10	421	50	Random	--	4	FOAM (pad)

Table I. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
1	1	10	278	50	Random	12	4	BOLTED (tank)
2	2	10	278	50	Random	12	4	BOLTED (tank)
3	3	10	278	50	Random	12	4	BOLTED (tank)
4	4	10	278	50	Random	12	4	BOLTED (tank)
5	5	10	278	50	Random	10	4	BOLTED (tank)
6	6	10	278	50	Random	9	4	BOLTED (tank)
7	7	10	278	50	Random	8	4	BOLTED (tank)
8	8	10	278	50	Random	7	4	BOLTED (tank)
9	9	10	278	50	Random	10	4	BOLTED (tank)
10	10	10	278	50	Random	10	4	BOLTED (tank)
11	11	10	278	50	Random	10	4	BOLTED (tank)
12	12	10	278	50	Random	13	4	BOLTED (tank)
13	13	10	278	50	Random	14	4	BOLTED (tank)
14	14	10	278	50	Random	14	4	BOLTED (tank)
15	15	10	278	50	Random	14	4	BOLTED (tank)
16	16	10	278	50	Random	14	4	BOLTED (tank)
17	17	10	278	50	Random	14	4	BOLTED (tank)
18	18	10	278	50	Random	13	4	BOLTED (tank)
19	19	10	278	50	Random	12	4	BOLTED (tank)
20	20	10	278	50	Random	11	4	BOLTED (tank)

Table II. Experimental data - BOLTED (tank)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
21	1	10	618	50	Random	12	4	BOLTED (tank)
22	2	10	618	50	Random	12	4	BOLTED (tank)
23	3	10	618	50	Random	12	4	BOLTED (tank)
24	4	10	618	50	Random	12	4	BOLTED (tank)
25	5	10	618	50	Random	10	4	BOLTED (tank)
26	6	10	618	50	Random	9	4	BOLTED (tank)
27	7	10	618	50	Random	8	4	BOLTED (tank)
28	8	10	618	50	Random	7	4	BOLTED (tank)
29	9	10	618	50	Random	10	4	BOLTED (tank)
30	10	10	618	50	Random	10	4	BOLTED (tank)
31	11	10	618	50	Random	10	4	BOLTED (tank)
32	12	10	618	50	Random	13	4	BOLTED (tank)
33	13	10	618	50	Random	14	4	BOLTED (tank)
34	14	10	618	50	Random	14	4	BOLTED (tank)
35	15	10	618	50	Random	14	4	BOLTED (tank)
36	16	10	618	50	Random	14	4	BOLTED (tank)
37	17	10	618	50	Random	14	4	BOLTED (tank)
38	18	10	618	50	Random	13	4	BOLTED (tank)
39	19	10	618	50	Random	12	4	BOLTED (tank)
40	20	10	618	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"

Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
41	1	10	1914	50	Random	12	4	BOLTED (tank)
42	2	10	1914	50	Random	12	4	BOLTED (tank)
43	3	10	1914	50	Random	12	4	BOLTED (tank)
44	4	10	1914	50	Random	12	4	BOLTED (tank)
45	5	10	1914	50	Random	10	4	BOLTED (tank)
46	6	10	1914	50	Random	9	4	BOLTED (tank)
47	7	10	1914	50	Random	8	4	BOLTED (tank)
48	8	10	1914	50	Random	7	4	BOLTED (tank)
49	9	10	1914	50	Random	10	4	BOLTED (tank)
50	10	10	1914	50	Random	10	4	BOLTED (tank)
51	11	10	1914	50	Random	10	4	BOLTED (tank)
52	12	10	1914	50	Random	13	4	BOLTED (tank)
53	13	10	1914	50	Random	14	4	BOLTED (tank)
54	14	10	1914	50	Random	14	4	BOLTED (tank)
55	15	10	1914	50	Random	14	4	BOLTED (tank)
56	16	10	1914	50	Random	14	4	BOLTED (tank)
57	17	10	1914	50	Random	14	4	BOLTED (tank)
58	18	10	1914	50	Random	13	4	BOLTED (tank)
59	19	10	1914	50	Random	12	4	BOLTED (tank)
60	20	10	1914	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
61	1	10	3196	50	Random	12	4	BOLTED (tank)
62	2	10	3196	50	Random	12	4	BOLTED (tank)
63	3	10	3196	50	Random	12	4	BOLTED (tank)
64	4	10	3196	50	Random	12	4	BOLTED (tank)
65	5	10	3196	50	Random	10	4	BOLTED (tank)
66	6	10	3196	50	Random	9	4	BOLTED (tank)
67	7	10	3196	50	Random	8	4	BOLTED (tank)
68	8	10	3196	50	Random	7	4	BOLTED (tank)
69	9	10	3196	50	Random	10	4	BOLTED (tank)
70	10	10	3196	50	Random	10	4	BOLTED (tank)
71	11	10	3196	50	Random	10	4	BOLTED (tank)
72	12	10	3196	50	Random	13	4	BOLTED (tank)
73	13	10	3196	50	Random	14	4	BOLTED (tank)
74	14	10	3196	50	Random	14	4	BOLTED (tank)
75	15	10	3196	50	Random	14	4	BOLTED (tank)
76	16	10	3196	50	Random	14	4	BOLTED (tank)
77	17	10	3196	50	Random	14	4	BOLTED (tank)
78	18	10	3196	50	Random	13	4	BOLTED (tank)
79	19	10	3196	50	Random	12	4	BOLTED (tank)
80	20	10	3196	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
81	1	10	4256	50	Random	12	4	BOLTED (tank)
82	2	10	4256	50	Random	12	4	BOLTED (tank)
83	3	10	4256	50	Random	12	4	BOLTED (tank)
84	4	10	4256	50	Random	12	4	BOLTED (tank)
85	5	10	4256	50	Random	10	4	BOLTED (tank)
86	6	10	4256	50	Random	9	4	BOLTED (tank)
87	7	10	4256	50	Random	8	4	BOLTED (tank)
88	8	10	4256	50	Random	7	4	BOLTED (tank)
89	9	10	4256	50	Random	10	4	BOLTED (tank)
90	10	10	4256	50	Random	10	4	BOLTED (tank)
91	11	10	4256	50	Random	10	4	BOLTED (tank)
92	12	10	4256	50	Random	13	4	BOLTED (tank)
93	13	10	4256	50	Random	14	4	BOLTED (tank)
94	14	10	4256	50	Random	14	4	BOLTED (tank)
95	15	10	4256	50	Random	14	4	BOLTED (tank)
96	16	10	4256	50	Random	14	4	BOLTED (tank)
97	17	10	4256	50	Random	14	4	BOLTED (tank)
98	18	10	4256	50	Random	13	4	BOLTED (tank)
99	19	10	4256	50	Random	12	4	BOLTED (tank)
100	20	10	4256	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)".								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
101	1	10	5616	50	Random	12	4	BOLTED (tank)
102	2	10	5616	50	Random	12	4	BOLTED (tank)
103	3	10	5616	50	Random	12	4	BOLTED (tank)
104	4	10	5616	50	Random	12	4	BOLTED (tank)
105	5	10	5616	50	Random	10	4	BOLTED (tank)
106	6	10	5616	50	Random	9	4	BOLTED (tank)
107	7	10	5616	50	Random	8	4	BOLTED (tank)
108	8	10	5616	50	Random	7	4	BOLTED (tank)
109	9	10	5616	50	Random	10	4	BOLTED (tank)
100	10	10	5616	50	Random	10	4	BOLTED (tank)
111	11	10	5616	50	Random	10	4	BOLTED (tank)
112	12	10	5616	50	Random	13	4	BOLTED (tank)
113	13	10	5616	50	Random	14	4	BOLTED (tank)
114	14	10	5616	50	Random	14	4	BOLTED (tank)
115	15	10	5616	50	Random	14	4	BOLTED (tank)
116	16	10	5616	50	Random	14	4	BOLTED (tank)
117	17	10	5616	50	Random	14	4	BOLTED (tank)
118	18	10	5616	50	Random	13	4	BOLTED (tank)
119	19	10	5616	50	Random	12	4	BOLTED (tank)
120	20	10	5616	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
121	1	10	6880	50	Random	12	4	BOLTED (tank)
122	2	10	6880	50	Random	12	4	BOLTED (tank)
123	3	10	6880	50	Random	12	4	BOLTED (tank)
124	4	10	6880	50	Random	12	4	BOLTED (tank)
125	5	10	6880	50	Random	10	4	BOLTED (tank)
126	6	10	6880	50	Random	9	4	BOLTED (tank)
127	7	10	6880	50	Random	8	4	BOLTED (tank)
128	8	10	6880	50	Random	7	4	BOLTED (tank)
129	9	10	6880	50	Random	10	4	BOLTED (tank)
130	10	10	6880	50	Random	10	4	BOLTED (tank)
131	11	10	6880	50	Random	10	4	BOLTED (tank)
132	12	10	6880	50	Random	13	4	BOLTED (tank)
133	13	10	6880	50	Random	14	4	BOLTED (tank)
134	14	10	6880	50	Random	14	4	BOLTED (tank)
135	15	10	6880	50	Random	14	4	BOLTED (tank)
136	16	10	6880	50	Random	14	4	BOLTED (tank)
137	17	10	6880	50	Random	14	4	BOLTED (tank)
138	18	10	6880	50	Random	13	4	BOLTED (tank)
139	19	10	6880	50	Random	12	4	BOLTED (tank)
140	20	10	6880	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
141	1	10	8152	50	Random	12	4	BOLTED (tank)
142	2	10	8152	50	Random	12	4	BOLTED (tank)
143	3	10	8152	50	Random	12	4	BOLTED (tank)
144	4	10	8152	50	Random	12	4	BOLTED (tank)
145	5	10	8152	50	Random	10	4	BOLTED (tank)
146	6	10	8152	50	Random	9	4	BOLTED (tank)
147	7	10	8152	50	Random	8	4	BOLTED (tank)
148	8	10	8152	50	Random	7	4	BOLTED (tank)
149	9	10	8152	50	Random	10	4	BOLTED (tank)
150	10	10	8152	50	Random	10	4	BOLTED (tank)
151	11	10	8152	50	Random	10	4	BOLTED (tank)
152	12	10	8152	50	Random	13	4	BOLTED (tank)
153	13	10	8152	50	Random	14	4	BOLTED (tank)
154	14	10	8152	50	Random	14	4	BOLTED (tank)
155	15	10	8152	50	Random	14	4	BOLTED (tank)
156	16	10	8152	50	Random	14	4	BOLTED (tank)
157	17	10	8152	50	Random	14	4	BOLTED (tank)
158	18	10	8152	50	Random	13	4	BOLTED (tank)
159	19	10	8152	50	Random	12	4	BOLTED (tank)
160	20	10	8152	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
161	1	10	8640	50	Random	12	4	BOLTED (tank)
162	2	10	8640	50	Random	12	4	BOLTED (tank)
163	3	10	8640	50	Random	12	4	BOLTED (tank)
164	4	10	8640	50	Random	12	4	BOLTED (tank)
165	5	10	8640	50	Random	10	4	BOLTED (tank)
166	6	10	8640	50	Random	9	4	BOLTED (tank)
167	7	10	8640	50	Random	8	4	BOLTED (tank)
168	8	10	8640	50	Random	7	4	BOLTED (tank)
169	9	10	8640	50	Random	10	4	BOLTED (tank)
170	10	10	8640	50	Random	10	4	BOLTED (tank)
171	11	10	8640	50	Random	10	4	BOLTED (tank)
172	12	10	8640	50	Random	13	4	BOLTED (tank)
173	13	10	8640	50	Random	14	4	BOLTED (tank)
174	14	10	8640	50	Random	14	4	BOLTED (tank)
175	15	10	8640	50	Random	14	4	BOLTED (tank)
176	16	10	8640	50	Random	14	4	BOLTED (tank)
177	17	10	8640	50	Random	14	4	BOLTED (tank)
178	18	10	8640	50	Random	13	4	BOLTED (tank)
179	19	10	8640	50	Random	12	4	BOLTED (tank)
180	20	10	8640	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
181	1	10	9116	50	Random	12	4	BOLTED (tank)
182	2	10	9116	50	Random	12	4	BOLTED (tank)
183	3	10	9116	50	Random	12	4	BOLTED (tank)
184	4	10	9116	50	Random	12	4	BOLTED (tank)
185	5	10	9116	50	Random	10	4	BOLTED (tank)
186	6	10	9116	50	Random	9	4	BOLTED (tank)
187	7	10	9116	50	Random	8	4	BOLTED (tank)
188	8	10	9116	50	Random	7	4	BOLTED (tank)
189	9	10	9116	50	Random	10	4	BOLTED (tank)
190	10	10	9116	50	Random	10	4	BOLTED (tank)
191	11	10	9116	50	Random	10	4	BOLTED (tank)
192	12	10	9116	50	Random	13	4	BOLTED (tank)
193	13	10	9116	50	Random	14	4	BOLTED (tank)
194	14	10	9116	50	Random	14	4	BOLTED (tank)
195	15	10	9116	50	Random	14	4	BOLTED (tank)
196	16	10	9116	50	Random	14	4	BOLTED (tank)
197	17	10	9116	50	Random	14	4	BOLTED (tank)
198	18	10	9116	50	Random	13	4	BOLTED (tank)
199	19	10	9116	50	Random	12	4	BOLTED (tank)
200	20	10	9116	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
201	1	10	11136	50	Random	12	4	BOLTED (tank)
202	2	10	11136	50	Random	12	4	BOLTED (tank)
203	3	10	11136	50	Random	12	4	BOLTED (tank)
204	4	10	11136	50	Random	12	4	BOLTED (tank)
205	5	10	11136	50	Random	10	4	BOLTED (tank)
206	6	10	11136	50	Random	9	4	BOLTED (tank)
207	7	10	11136	50	Random	8	4	BOLTED (tank)
2C8	8	10	11136	50	Random	7	4	BOLTED (tank)
209	9	10	11136	50	Random	10	4	BOLTED (tank)
210	10	10	11136	50	Random	10	4	BOLTED (tank)
211	11	10	11136	50	Random	10	4	BOLTED (tank)
212	12	10	11136	50	Random	13	4	BOLTED (tank)
213	13	10	11136	50	Random	14	4	BOLTED (tank)
214	14	10	11136	50	Random	14	4	BOLTED (tank)
215	15	10	11136	50	Random	14	4	BOLTED (tank)
216	16	10	11136	50	Random	14	4	BOLTED (tank)
217	17	10	11136	50	Random	14	4	BOLTED (tank)
218	18	10	11136	50	Random	13	4	BOLTED (tank)
219	19	10	11136	50	Random	12	4	BOLTED (tank)
220	20	10	11136	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
221	1	10	12217	50	Random	12	4	BOLTED (tank)
222	2	10	12217	50	Random	12	4	BOLTED (tank)
223	3	10	12217	50	Random	12	4	BOLTED (tank)
224	4	10	12217	50	Random	12	4	BOLTED (tank)
225	5	10	12217	50	Random	10	4	BOLTED (tank)
226	6	10	12217	50	Random	9	4	BOLTED (tank)
227	7	10	12217	50	Random	8	4	BOLTED (tank)
228	8	10	12217	50	Random	7	4	BOLTED (tank)
229	9	10	12217	50	Random	10	4	BOLTED (tank)
230	10	10	12217	50	Random	10	4	BOLTED (tank)
231	11	10	12217	50	Random	10	4	BOLTED (tank)
232	12	10	12217	50	Random	13	4	BOLTED (tank)
233	13	10	12217	50	Random	14	4	BOLTED (tank)
234	14	10	12217	50	Random	14	4	BOLTED (tank)
235	15	10	12217	50	Random	14	4	BOLTED (tank)
236	16	10	12217	50	Random	14	4	BOLTED (tank)
237	17	10	12217	50	Random	14	4	BOLTED (tank)
238	18	10	12217	50	Random	13	4	BOLTED (tank)
239	19	10	12217	50	Random	12	4	BOLTED (tank)
240	20	10	12217	50	Random	11	4	BOLTED (tank)

Table II. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
251	1	10	421	50	Random	13	4	CHORD (tank)
252	2	10	421	50	Random	14	4	CHORD (tank)
253	3	10	421	50	Random	14	4	CHORD (tank)
254	4	10	421	50	Random	13	4	CHORD (tank)
255	5	10	421	50	Random	11	4	CHORD (tank)
256	6	10	421	50	Random	7	4	CHORD (tank)
257	7	10	421	50	Random	6	4	CHORD (tank)
258	8	10	421	50	Random	5	4	CHORD (tank)
259	9	10	421	50	Random	4	4	CHORD (tank)
260	10	10	421	50	Random	11	4	CHORD (tank)
261	11	10	421	50	Random	11	4	CHORD (tank)
262	12	10	421	50	Random	12	4	CHORD (tank)
263	13	10	421	50	Random	12	4	CHORD (tank)
264	14	10	421	50	Random	12	4	CHORD (tank)
265	15	10	421	50	Random	12	4	CHORD (tank)
266	16	10	421	50	Random	12	4	CHORD (tank)
267	17	10	421	50	Random	10	4	CHORD (tank)
268	18	10	421	50	Random	8	4	CHORD (tank)
269	19	10	421	50	Random	6	4	CHORD (tank)
270	20	10	421	50	Random	11	4	CHORD (tank)

Table III. Experimental data - CHORD (tank)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
271	1	10	850	50	Random	13	4	CHORD (tank)
272	2	10	850	50	Random	14	4	CHORD (tank)
273	3	10	850	50	Random	14	4	CHORD (tank)
274	4	10	850	50	Random	13	4	CHORD (tank)
275	5	10	850	50	Random	11	4	CHORD (tank)
276	6	10	850	50	Random	7	4	CHORD (tank)
277	7	10	850	50	Random	6	4	CHORD (tank)
278	8	10	850	50	Random	5	4	CHORD (tank)
279	9	10	850	50	Random	4	4	CHORD (tank)
280	10	10	850	50	Random	11	4	CHORD (tank)
281	11	10	850	50	Random	11	4	CHORD (tank)
282	12	10	850	50	Random	12	4	CHORD (tank)
283	13	10	850	50	Random	12	4	CHORD (tank)
284	14	10	850	50	Random	12	4	CHORD (tank)
285	15	10	850	50	Random	12	4	CHORD (tank)
286	16	10	850	50	Random	12	4	CHORD (tank)
287	17	10	850	50	Random	10	4	CHORD (tank)
288	18	10	850	50	Random	8	4	CHORD (tank)
289	19	10	850	50	Random	6	4	CHORD (tank)
290	20	10	850	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Locaticn	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
291	1	10	920	50	Random	13	4	CHORD (tank)
292	2	10	920	50	Random	14	4	CHORD (tank)
293	3	10	920	50	Random	14	4	CHORD (tank)
294	4	10	920	50	Random	13	4	CHORD (tank)
295	5	10	920	50	Random	11	4	CHORD (tank)
296	6	10	920	50	Random	7	4	CHORD (tank)
297	7	10	920	50	Random	6	4	CHORD (tank)
298	8	10	920	50	Random	5	4	CHORD (tank)
299	9	10	920	50	Random	4	4	CHORD (tank)
300	10	10	920	50	Random	11	4	CHORD (tank)
301	11	10	920	50	Random	11	4	CHORD (tank)
3C2	12	10	920	50	Random	12	4	CHORD (tank)
303	13	10	920	50	Random	12	4	CHORD (tank)
304	14	10	920	50	Random	12	4	CHORD (tank)
305	15	10	920	50	Random	12	4	CHORD (tank)
306	16	10	920	50	Random	12	4	CHORD (tank)
307	17	10	920	50	Random	10	4	CHORD (tank)
308	18	10	920	50	Random	8	4	CHORD (tank)
309	19	10	920	50	Random	6	4	CHORD (tank)
310	20	10	920	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
311	1	10	1261	50	Random	13	4	CHORD (tank)
312	2	10	1261	50	Random	14	4	CHORD (tank)
313	3	10	1261	50	Random	14	4	CHORD (tank)
314	4	10	1261	50	Random	13	4	CHORD (tank)
315	5	10	1261	50	Random	11	4	CHORD (tank)
316	6	10	1261	50	Random	7	4	CHORD (tank)
317	7	10	1261	50	Random	6	4	CHORD (tank)
318	8	10	1261	50	Random	5	4	CHORD (tank)
319	9	10	1261	50	Random	4	4	CHORD (tank)
320	10	10	1261	50	Random	11	4	CHORD (tank)
321	11	10	1261	50	Random	11	4	CHORD (tank)
322	12	10	1261	50	Random	12	4	CHORD (tank)
323	13	10	1261	50	Random	12	4	CHORD (tank)
324	14	10	1261	50	Random	12	4	CHORD (tank)
325	15	10	1261	50	Random	12	4	CHORD (tank)
326	16	10	1261	50	Random	12	4	CHORD (tank)
327	17	10	1261	50	Random	10	4	CHORD (tank)
328	18	10	1261	50	Random	8	4	CHORD (tank)
329	19	10	1261	50	Random	6	4	CHORD (tank)
330	20	10	1261	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
331	1	10	3258	50	Random	13	4	CHORD (tank)
332	2	10	3258	50	Random	14	4	CHORD (tank)
333	3	10	3258	50	Random	14	4	CHORD (tank)
334	4	10	3258	50	Random	13	4	CHORD (tank)
335	5	10	3258	50	Random	11	4	CHORD (tank)
336	6	10	3258	50	Random	7	4	CHORD (tank)
337	7	10	3258	50	Random	6	4	CHORD (tank)
338	8	10	3258	50	Random	5	4	CHORD (tank)
339	9	10	3258	50	Random	4	4	CHORD (tank)
340	10	10	3258	50	Random	11	4	CHORD (tank)
341	11	10	3258	50	Random	11	4	CHORD (tank)
342	12	10	3258	50	Random	12	4	CHORD (tank)
343	13	10	3258	50	Random	12	4	CHORD (tank)
344	14	10	3258	50	Random	12	4	CHORD (tank)
345	15	10	3258	50	Random	12	4	CHORD (tank)
346	16	10	3258	50	Random	12	4	CHORD (tank)
347	17	10	3258	50	Random	10	4	CHORD (tank)
348	18	10	3258	50	Random	8	4	CHORD (tank)
349	19	10	3258	50	Random	6	4	CHORD (tank)
350	20	10	3258	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"

Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
351	1	10	5030	50	Random	13	4	CHORD (tank)
352	2	10	5030	50	Random	14	4	CHORD (tank)
353	3	10	5030	50	Random	14	4	CHORD (tank)
354	4	10	5030	50	Random	13	4	CHORD (tank)
355	5	10	5030	50	Random	11	4	CHORD (tank)
356	19	10	5030	50	Random	7	4	CHORD (tank)
357	7	10	5030	50	Random	6	4	CHORD (tank)
358	8	10	5030	50	Random	5	4	CHORD (tank)
359	9	10	5030	50	Random	4	4	CHORD (tank)
360	10	10	5030	50	Random	11	4	CHORD (tank)
361	11	10	5030	50	Random	11	4	CHORD (tank)
362	12	10	5030	50	Random	12	4	CHORD (tank)
363	13	10	5030	50	Random	12	4	CHORD (tank)
364	14	10	5030	50	Random	12	4	CHORD (tank)
365	20	10	5030	50	Random	12	4	CHORD (tank)
366	16	10	5030	50	Random	12	4	CHORD (tank)
367	17	10	5030	50	Random	10	4	CHORD (tank)
368	18	10	5030	50	Random	8	4	CHORD (tank)
369	6	10	5030	50	Random	6	4	CHORD (tank)
370	15	10	5030	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
371	1	10	7100	50	Random	13	4	CHORD (tank)
372	2	10	7100	50	Random	14	4	CHORD (tank)
373	3	10	7100	50	Random	14	4	CHORD (tank)
374	4	10	7100	50	Random	13	4	CHORD (tank)
375	5	10	7100	50	Random	11	4	CHORD (tank)
376	6	10	7100	50	Random	7	4	CHORD (tank)
377	7	10	7100	50	Random	6	4	CHORD (tank)
378	8	10	7100	50	Random	5	4	CHORD (tank)
379	9	10	7100	50	Random	4	4	CHORD (tank)
380	10	10	7100	50	Random	11	4	CHORD (tank)
381	11	10	7100	50	Random	11	4	CHORD (tank)
382	12	10	7100	50	Random	12	4	CHORD (tank)
383	13	10	7100	50	Random	12	4	CHORD (tank)
384	14	10	7100	50	Random	12	4	CHORD (tank)
385	15	10	7100	50	Random	12	4	CHORD (tank)
386	16	10	7100	50	Random	12	4	CHORD (tank)
387	17	10	7100	50	Random	10	4	CHORD (tank)
388	18	10	7100	50	Random	8	4	CHORD (tank)
389	19	10	7100	50	Random	6	4	CHORD (tank)
390	20	10	7100	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
391	1	10	8221	50	Random	13	4	CHORD (tank)
392	2	10	8221	50	Random	14	4	CHORD (tank)
393	3	10	8221	50	Random	14	4	CHORD (tank)
394	4	10	8221	50	Random	13	4	CHORD (tank)
395	5	10	8221	50	Random	11	4	CHORD (tank)
396	6	10	8221	50	Random	7	4	CHORD (tank)
397	7	10	8221	50	Random	6	4	CHORD (tank)
398	8	10	8221	50	Random	5	4	CHORD (tank)
399	9	10	8221	50	Random	4	4	CHORD (tank)
400	10	10	8221	50	Random	11	4	CHORD (tank)
401	11	10	8221	50	Random	11	4	CHORD (tank)
402	12	10	8221	50	Random	12	4	CHORD (tank)
403	13	10	8221	50	Random	12	4	CHORD (tank)
404	14	10	8221	50	Random	12	4	CHORD (tank)
405	15	10	8221	50	Random	12	4	CHORD (tank)
406	16	10	8221	50	Random	12	4	CHORD (tank)
407	17	10	8221	50	Random	10	4	CHORD (tank)
408	18	10	8221	50	Random	8	4	CHORD (tank)
409	19	10	8221	50	Random	6	4	CHORD (tank)
410	20	10	8221	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
411	1	10	8447	50	Random	13	4	CHORD (tank)
412	2	10	8447	50	Random	14	4	CHORD (tank)
413	3	10	8447	50	Random	14	4	CHORD (tank)
414	4	10	8447	50	Random	13	4	CHORD (tank)
415	5	10	8447	50	Random	11	4	CHORD (tank)
416	6	10	8447	50	Random	7	4	CHORD (tank)
417	7	10	8447	50	Random	6	4	CHORD (tank)
418	8	10	8447	50	Random	5	4	CHORD (tank)
419	9	10	8447	50	Random	4	4	CHORD (tank)
420	10	10	8447	50	Random	11	4	CHORD (tank)
421	11	10	8447	50	Random	11	4	CHORD (tank)
422	12	10	8447	50	Random	12	4	CHORD (tank)
423	13	10	8447	50	Random	12	4	CHORD (tank)
424	14	10	8447	50	Random	12	4	CHORD (tank)
425	15	10	8447	50	Random	12	4	CHORD (tank)
426	16	10	8447	50	Random	12	4	CHORD (tank)
427	17	10	8447	50	Random	10	4	CHORD (tank)
428	18	10	8447	50	Random	8	4	CHORD (tank)
429	19	10	8447	50	Random	6	4	CHORD (tank)
430	20	10	8447	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
431	1	10	9065	50	Random	13	4	CHORD (tank)
432	2	10	9065	50	Random	14	4	CHORD (tank)
433	3	10	9065	50	Random	14	4	CHORD (tank)
434	4	10	9065	50	Random	13	4	CHORD (tank)
435	5	10	9065	50	Random	11	4	CHORD (tank)
436	6	10	9065	50	Random	7	4	CHORD (tank)
437	7	10	9065	50	Random	6	4	CHORD (tank)
438	8	10	9065	50	Random	5	4	CHORD (tank)
439	9	10	9065	50	Random	4	4	CHORD (tank)
440	10	10	9065	50	Random	11	4	CHORD (tank)
441	11	10	9065	50	Random	11	4	CHORD (tank)
442	12	10	9065	50	Random	12	4	CHORD (tank)
443	13	10	9065	50	Random	12	4	CHORD (tank)
444	14	10	9065	50	Random	12	4	CHORD (tank)
445	15	10	9065	50	Random	12	4	CHORD (tank)
446	16	10	9065	50	Random	12	4	CHORD (tank)
447	17	10	9065	50	Random	10	4	CHORD (tank)
448	18	10	9065	50	Random	8	4	CHORD (tank)
449	19	10	9065	50	Random	6	4	CHORD (tank)
450	20	10	9065	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
451	1	10	9668	50	Random	13	4	CHORD (tank)
452	2	10	9668	50	Random	14	4	CHORD (tank)
453	3	10	9668	50	Random	14	4	CHORD (tank)
454	4	10	9668	50	Random	13	4	CHORD (tank)
455	5	10	9668	50	Random	11	4	CHORD (tank)
456	6	10	9668	50	Random	7	4	CHORD (tank)
457	7	10	9668	50	Random	6	4	CHORD (tank)
458	8	10	9668	50	Random	5	4	CHORD (tank)
459	9	10	9668	50	Random	4	4	CHORD (tank)
460	10	10	9668	50	Random	11	4	CHORD (tank)
461	11	10	9668	50	Random	11	4	CHORD (tank)
462	12	10	9668	50	Random	12	4	CHORD (tank)
463	13	10	9668	50	Random	12	4	CHORD (tank)
464	14	10	9668	50	Random	12	4	CHORD (tank)
465	15	10	9668	50	Random	12	4	CHORD (tank)
466	16	10	9668	50	Random	12	4	CHORD (tank)
467	17	10	9668	50	Random	10	4	CHORD (tank)
468	18	10	9668	50	Random	8	4	CHORD (tank)
469	19	10	9668	50	Random	6	4	CHORD (tank)
470	20	10	9668	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (two)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
471	1	10	11512	50	Random	13	4	CHORD (tank)
472	2	10	11512	50	Random	14	4	CHORD (tank)
473	3	10	11512	50	Random	14	4	CHORD (tank)
474	4	10	11512	50	Random	13	4	CHORD (tank)
475	5	10	11512	50	Random	11	4	CHORD (tank)
476	6	10	11512	50	Random	7	4	CHORD (tank)
477	7	10	11512	50	Random	6	4	CHORD (tank)
478	8	10	11512	50	Random	5	4	CHORD (tank)
479	9	10	11512	50	Random	4	4	CHORD (tank)
480	10	10	11512	50	Random	11	4	CHORD (tank)
481	11	10	11512	50	Random	11	4	CHORD (tank)
482	12	10	11512	50	Random	12	4	CHORD (tank)
483	13	10	11512	50	Random	12	4	CHORD (tank)
484	14	10	11512	50	Random	12	4	CHORD (tank)
485	15	10	11512	50	Random	12	4	CHORD (tank)
486	16	10	11512	50	Random	12	4	CHORD (tank)
487	17	10	11512	50	Random	10	4	CHORD (tank)
488	18	10	11512	50	Random	8	4	CHORD (tank)
489	19	10	11512	50	Random	6	4	CHORD (tank)
490	20	10	11512	50	Random	11	4	CHORD (tank)

Table III. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
1	1	10	420	50	Random	14	4	FOAM (ends)
2	2	10	420	50	Random	14	4	FOAM (ends)
3	3	10	420	50	Random	15	4	FOAM (ends)
4	4	10	420	50	Random	16	4	FOAM (ends)
5	5	10	420	50	Random	16	4	FOAM (ends)
6	6	10	420	50	Random	16	4	FOAM (ends)
7	7	10	420	50	Random	16	4	FOAM (ends)
8	8	10	420	50	Random	15	4	FOAM (ends)
9	9	10	420	50	Random	7	4	FOAM (ends)
10	10	10	420	50	Random	8	4	FOAM (ends)
11	11	10	420	50	Random	9	4	FOAM (ends)
12	12	10	420	50	Random	10	4	FOAM (ends)
13	13	10	420	50	Random	13	4	FOAM (ends)
14	14	10	420	50	Random	14	4	FOAM (ends)
15	15	10	420	50	Random	14	4	FOAM (ends)
16	16	10	420	50	Random	14	4	FOAM (ends)
17	17	10	420	50	Random	14	4	FOAM (ends)
18	18	10	420	50	Random	13	4	FOAM (ends)
19	19	10	420	50	Random	13	4	FOAM (ends)
20	20	10	420	50	Random	12	4	FOAM (ends)

Table IV. Experimental data - FOAM (ends)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
21	1	10	850	50	Random	14	4	FOAM (ends)
22	2	10	850	50	Random	14	4	FOAM (ends)
23	3	10	850	50	Random	15	4	FOAM (ends)
24	4	10	850	50	Random	16	4	FOAM (ends)
25	5	10	850	50	Random	16	4	FOAM (ends)
26	6	10	850	50	Random	16	4	FOAM (ends)
27	7	10	850	50	Random	16	4	FOAM (ends)
28	8	10	850	50	Random	15	4	FOAM (ends)
29	9	10	850	50	Random	7	4	FOAM (ends)
30	10	10	850	50	Random	8	4	FOAM (ends)
31	11	10	850	50	Random	9	4	FOAM (ends)
32	12	10	850	50	Random	10	4	FOAM (ends)
33	13	10	850	50	Random	13	4	FOAM (ends)
34	14	10	850	50	Random	14	4	FOAM (ends)
35	15	10	850	50	Random	14	4	FOAM (ends)
36	16	10	850	50	Random	14	4	FOAM (ends)
37	17	10	850	50	Random	14	4	FOAM (ends)
38	18	10	850	50	Random	13	4	FOAM (ends)
39	19	10	850	50	Random	13	4	FOAM (ends)
40	20	10	850	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
41	1	10	1070	50	Random	14	4	FOAM (ends)
42	2	10	1070	50	Random	14	4	FOAM (ends)
43	3	10	1070	50	Random	15	4	FOAM (ends)
44	4	10	1070	50	Random	16	4	FOAM (ends)
45	5	10	1070	50	Random	16	4	FOAM (ends)
46	6	10	1070	50	Random	16	4	FOAM (ends)
47	7	10	1070	50	Random	16	4	FOAM (ends)
48	8	10	1070	50	Random	15	4	FOAM (ends)
49	9	10	1070	50	Random	7	4	FOAM (ends)
50	10	10	1070	50	Random	8	4	FOAM (ends)
51	11	10	1070	50	Random	9	4	FOAM (ends)
52	12	10	1070	50	Random	10	4	FOAM (ends)
53	13	10	1070	50	Random	13	4	FOAM (ends)
54	14	10	1070	50	Random	14	4	FOAM (ends)
55	15	10	1070	50	Random	14	4	FOAM (ends)
56	16	10	1070	50	Random	14	4	FOAM (ends)
57	17	10	1070	50	Random	14	4	FOAM (ends)
58	18	10	1070	50	Random	13	4	FOAM (ends)
59	19	10	1070	50	Random	13	4	FOAM (ends)
60	20	10	1070	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
61	1	10	3670	50	Random	14	4	FOAM (ends)
62	2	10	3670	50	Random	14	4	FOAM (ends)
63	3	10	3670	50	Random	15	4	FOAM (ends)
64	4	10	3670	50	Random	16	4	FOAM (ends)
65	5	10	3670	50	Random	16	4	FOAM (ends)
66	6	10	3670	50	Random	16	4	FOAM (ends)
67	7	10	3670	50	Random	16	4	FOAM (ends)
68	8	10	3670	50	Random	15	4	FOAM (ends)
69	9	10	3670	50	Random	7	4	FOAM (ends)
70	10	10	3670	50	Random	8	4	FOAM (ends)
71	11	10	3670	50	Random	9	4	FOAM (ends)
72	12	10	3670	50	Random	10	4	FOAM (ends)
73	13	10	3670	50	Random	13	4	FOAM (ends)
74	14	10	3670	50	Random	14	4	FOAM (ends)
75	15	10	3670	50	Random	14	4	FOAM (ends)
76	16	10	3670	50	Random	14	4	FOAM (ends)
77	17	10	3670	50	Random	14	4	FOAM (ends)
78	18	10	3670	50	Random	13	4	FOAM (ends)
79	19	10	3670	50	Random	13	4	FOAM (ends)
80	20	10	3670	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
81	1	10	5365	50	Random	14	4	FOAM (ends)
82	2	10	5365	50	Random	14	4	FOAM (ends)
83	3	10	5365	50	Random	15	4	FOAM (ends)
84	4	10	5365	50	Random	16	4	FOAM (ends)
85	5	10	5365	50	Random	16	4	FOAM (ends)
86	6	10	5365	50	Random	16	4	FOAM (ends)
87	7	10	5365	50	Random	16	4	FOAM (ends)
88	8	10	5365	50	Random	15	4	FOAM (ends)
89	9	10	5365	50	Random	7	4	FOAM (ends)
90	10	10	5365	50	Random	8	4	FOAM (ends)
91	11	10	5365	50	Random	9	4	FOAM (ends)
92	12	10	5365	50	Random	10	4	FOAM (ends)
93	13	10	5365	50	Random	13	4	FOAM (ends)
94	14	10	5365	50	Random	14	4	FOAM (ends)
95	15	10	5365	50	Random	14	4	FOAM (ends)
96	16	10	5365	50	Random	14	4	FOAM (ends)
97	17	10	5365	50	Random	14	4	FOAM (ends)
98	18	10	5365	50	Random	13	4	FOAM (ends)
99	19	10	5365	50	Random	13	4	FOAM (ends)
100	20	10	5365	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
101	1	10	7090	50	Random	14	4	FOAM (ends)
102	2	10	7090	50	Random	14	4	FOAM (ends)
103	3	10	7090	50	Random	15	4	FOAM (ends)
104	4	10	7090	50	Random	16	4	FOAM (ends)
105	5	10	7090	50	Random	16	4	FOAM (ends)
106	6	10	7090	50	Random	16	4	FOAM (ends)
107	7	10	7090	50	Random	16	4	FOAM (ends)
108	8	10	7090	50	Random	15	4	FOAM (ends)
109	9	10	7090	50	Random	7	4	FOAM (ends)
100	10	10	7090	50	Random	8	4	FOAM (ends)
111	11	10	7090	50	Random	9	4	FOAM (ends)
112	12	10	7090	50	Random	10	4	FOAM (ends)
113	13	10	7090	50	Random	13	4	FOAM (ends)
114	14	10	7090	50	Random	14	4	FOAM (ends)
115	15	10	7090	50	Random	14	4	FOAM (ends)
116	16	10	7090	50	Random	14	4	FOAM (ends)
117	17	10	7090	50	Random	14	4	FOAM (ends)
118	18	10	7090	50	Random	13	4	FOAM (ends)
119	19	10	7090	50	Random	13	4	FOAM (ends)
120	20	10	7090	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
121	1	10	8220	50	Random	14	4	FOAM (ends)
122	2	10	8220	50	Random	14	4	FOAM (ends)
123	3	10	8220	50	Random	15	4	FOAM (ends)
124	4	10	8220	50	Random	16	4	FOAM (ends)
125	5	10	8220	50	Random	16	4	FOAM (ends)
126	6	10	8220	50	Random	16	4	FOAM (ends)
127	7	10	8220	50	Random	16	4	FOAM (ends)
128	8	10	8220	50	Random	15	4	FOAM (ends)
129	9	10	8220	50	Random	7	4	FOAM (ends)
130	10	10	8220	50	Random	8	4	FOAM (ends)
131	11	10	8220	50	Random	9	4	FOAM (ends)
132	12	10	8220	50	Random	10	4	FOAM (ends)
133	13	10	8220	50	Random	13	4	FOAM (ends)
134	14	10	8220	50	Random	14	4	FOAM (ends)
135	15	10	8220	50	Random	14	4	FOAM (ends)
136	16	10	8220	50	Random	14	4	FOAM (ends)
137	17	10	8220	50	Random	14	4	FOAM (ends)
138	18	10	8220	50	Random	13	4	FOAM (ends)
139	19	10	8220	50	Random	13	4	FOAM (ends)
140	20	10	8220	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"

Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
141	1	10	8540	50	Random	14	4	FOAM (ends)
142	2	10	8540	50	Random	14	4	FOAM (ends)
143	3	10	8540	50	Random	15	4	FOAM (ends)
144	4	10	8540	50	Random	16	4	FOAM (ends)
145	5	10	8540	50	Random	16	4	FOAM (ends)
146	6	10	8540	50	Random	16	4	FOAM (ends)
147	7	10	8540	50	Random	16	4	FOAM (ends)
148	8	10	8540	50	Random	15	4	FOAM (ends)
149	9	10	8540	50	Random	7	4	FOAM (ends)
150	10	10	8540	50	Random	8	4	FOAM (ends)
151	11	10	8540	50	Random	9	4	FOAM (ends)
152	12	10	8540	50	Random	10	4	FOAM (ends)
153	13	10	8540	50	Random	13	4	FOAM (ends)
154	14	10	8540	50	Random	14	4	FOAM (ends)
155	15	10	8540	50	Random	14	4	FOAM (ends)
156	16	10	8540	50	Random	14	4	FOAM (ends)
157	17	10	8540	50	Random	14	4	FOAM (ends)
158	18	10	8540	50	Random	13	4	FOAM (ends)
159	19	10	8540	50	Random	13	4	FOAM (ends)
160	20	10	8540	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
161	1	10	9065	50	Random	14	4	FOAM (ends)
162	2	10	9065	50	Random	14	4	FOAM (ends)
163	3	10	9065	50	Random	15	4	FOAM (ends)
164	4	10	9065	50	Random	16	4	FOAM (ends)
165	5	10	9065	50	Random	16	4	FOAM (ends)
166	6	10	9065	50	Random	16	4	FOAM (ends)
167	7	10	9065	50	Random	16	4	FOAM (ends)
168	8	10	9065	50	Random	15	4	FOAM (ends)
169	9	10	9065	50	Random	7	4	FOAM (ends)
170	10	10	9065	50	Random	8	4	FOAM (ends)
171	11	10	9065	50	Random	9	4	FOAM (ends)
172	12	10	9065	50	Random	10	4	FOAM (ends)
173	13	10	9065	50	Random	13	4	FOAM (ends)
174	14	10	9065	50	Random	14	4	FOAM (ends)
175	15	10	9065	50	Random	14	4	FOAM (ends)
176	16	10	9065	50	Random	14	4	FOAM (ends)
177	17	10	9065	50	Random	14	4	FOAM (ends)
178	18	10	9065	50	Random	13	4	FOAM (ends)
179	19	10	9065	50	Random	13	4	FOAM (ends)
180	20	10	9065	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
181	1	10	9275	50	Random	14	4	FOAM (ends)
182	2	10	9275	50	Random	14	4	FOAM (ends)
183	3	10	9275	50	Random	15	4	FOAM (ends)
184	4	10	9275	50	Random	16	4	FOAM (ends)
185	5	10	9275	50	Random	16	4	FOAM (ends)
186	6	10	9275	50	Random	16	4	FOAM (ends)
187	7	10	9275	50	Random	16	4	FOAM (ends)
188	8	10	9275	50	Random	15	4	FOAM (ends)
189	9	10	9275	50	Random	7	4	FOAM (ends)
190	10	10	9275	50	Random	8	4	FOAM (ends)
191	11	10	9275	50	Random	9	4	FOAM (ends)
192	12	10	9275	50	Random	10	4	FOAM (ends)
193	13	10	9275	50	Random	13	4	FOAM (ends)
194	14	10	9275	50	Random	14	4	FOAM (ends)
195	15	10	9275	50	Random	14	4	FOAM (ends)
196	16	10	9275	50	Random	14	4	FOAM (ends)
197	17	10	9275	50	Random	14	4	FOAM (ends)
198	18	10	9275	50	Random	13	4	FOAM (ends)
199	19	10	9275	50	Random	13	4	FOAM (ends)
200	20	10	9275	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
201	1	10	10660	50	Random	14	4	FOAM (ends)
202	2	10	10660	50	Random	14	4	FOAM (ends)
203	3	10	10660	50	Random	15	4	FOAM (ends)
204	4	10	10660	50	Random	16	4	FOAM (ends)
205	5	10	10660	50	Random	16	4	FOAM (ends)
206	6	10	10660	50	Random	16	4	FOAM (ends)
207	7	10	10660	50	Random	16	4	FOAM (ends)
208	8	10	10660	50	Random	15	4	FOAM (ends)
209	9	10	10660	50	Random	7	4	FOAM (ends)
210	10	10	10660	50	Random	8	4	FOAM (ends)
211	11	10	10660	50	Random	9	4	FOAM (ends)
212	12	10	10660	50	Random	10	4	FOAM (ends)
213	13	10	10660	50	Random	13	4	FOAM (ends)
214	14	10	10660	50	Random	14	4	FOAM (ends)
215	15	10	10660	50	Random	14	4	FOAM (ends)
216	16	10	10660	50	Random	14	4	FOAM (ends)
217	17	10	10660	50	Random	14	4	FOAM (ends)
218	18	10	10660	50	Random	13	4	FOAM (ends)
219	19	10	10660	50	Random	13	4	FOAM (ends)
220	20	10	10660	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

Disk Label : "Steve's Modal (three)"								
Disk Record	Grid Location	Number Averages	Center Frequency	Band Width	Input Excitation	Temp. (C)	Setup Data No.	Boundary Condition
221	1	10	12200	50	Random	14	4	FOAM (ends)
222	2	10	12200	50	Random	14	4	FOAM (ends)
223	3	10	12200	50	Random	15	4	FOAM (ends)
224	4	10	12200	50	Random	16	4	FOAM (ends)
225	5	10	12200	50	Random	16	4	FOAM (ends)
226	6	10	12200	50	Random	16	4	FOAM (ends)
227	7	10	12200	50	Random	16	4	FOAM (ends)
228	8	10	12200	50	Random	15	4	FOAM (ends)
229	9	10	12200	50	Random	7	4	FOAM (ends)
230	10	10	12200	50	Random	8	4	FOAM (ends)
231	11	10	12200	50	Random	9	4	FOAM (ends)
232	12	10	12200	50	Random	10	4	FOAM (ends)
233	13	10	12200	50	Random	13	4	FOAM (ends)
234	14	10	12200	50	Random	14	4	FOAM (ends)
235	15	10	12200	50	Random	14	4	FOAM (ends)
236	16	10	12200	50	Random	14	4	FOAM (ends)
237	17	10	12200	50	Random	14	4	FOAM (ends)
238	18	10	12200	50	Random	13	4	FOAM (ends)
239	19	10	12200	50	Random	13	4	FOAM (ends)
240	20	10	12200	50	Random	12	4	FOAM (ends)

Table IV. (Continued)

AVERAGE MODAL FREQUENCIES AND DAMPING			
FOAM (pad) - Impact		FOAM (pad) - Random	
Natural Frequency (Hertz)	Damping Factor (%)	Natural Frequency (Hertz)	Damping Factor (%)
2276.8271	0.1068	2277.6323	0.1121
2396.0981	0.1021	2397.2002	0.1091
2629.7700	0.0920	2637.3799	0.0967
3253.0483	0.0954	3248.5352	0.0954
4589.0020	0.0740	4572.2363	0.0833

Table V. Results of Impact vs. Random Comparison

AVERAGE MODAL FREQUENCIES AND DAMPING							
FOAM (pad)		BOLTED (tank)		CHORD (tank)		FOAM (ends)	
Natural Frequency (Hertz)	Damping Factor (%)	Natural Frequency (Hertz)	Damping Factor (%)	Natural Frequency (Hertz)	Damping Factor (%)	Natural Frequency (Hertz)	Damping Factor (%)
420.060	0.3030	277.590	0.5045	422.641	0.3496	422.686	0.1873
1262.487	0.1259	621.142	0.2540	851.768	0.2027	851.784	0.0659
2605.433	0.1284	1903.937	0.1224	918.969	0.1345	1072.964	0.0793
3669.019	0.1230	3188.707	0.0550	1264.705	0.1221	3675.915	0.0703
4702.096	0.1156	4251.911	0.0405	3257.515	0.1886	5366.419	0.0477
6093.651	0.0903	5613.253	0.1115	5029.354	0.0360	7093.827	0.0336
7169.448	0.0819	6879.277	0.0836	7098.269	0.0339	8218.264	0.0542
8553.596	0.2494	8159.321	0.0491	8222.945	0.0377	8538.205	0.1410
9659.422	0.1089	8633.895	0.0603	8446.225	0.1036	9062.781	0.0938
10660.674	0.0774	9099.016	0.0782	9064.914	0.1697	9265.479	0.0232
11150.273	0.0744	11124.402	0.0591	9669.775	0.0920	10655.359	0.0361
12200.746	0.0697	12212.816	0.0630	11510.981	0.0155	12205.299	0.0372

Table VI. Experimental Summary of Damping Characteristics

APPENDIX B

FIGURES

Figure 1. Coherence, ECB #302A, wax mounting.

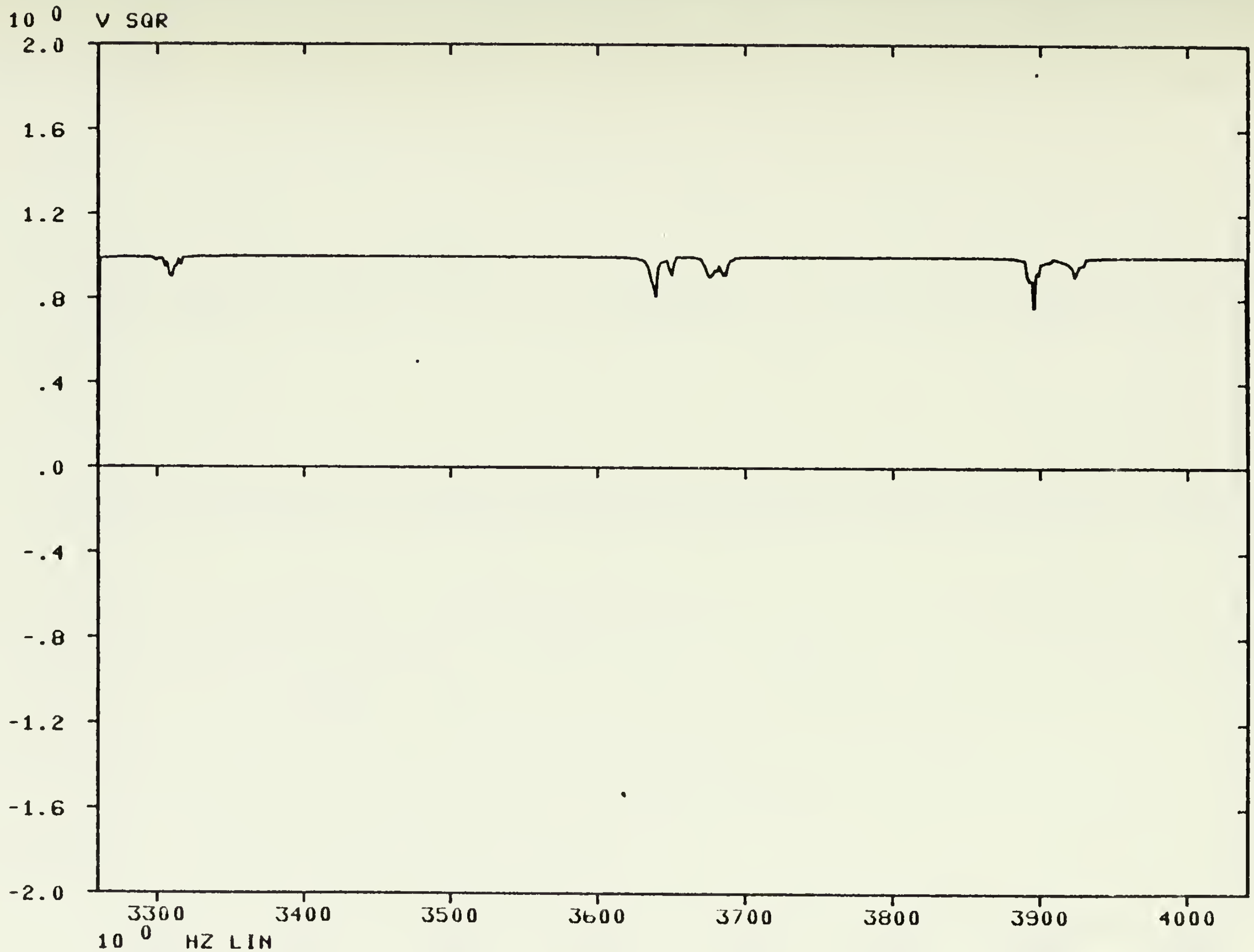

Figure 2. Coherence, PCB #302A, screw mounting.

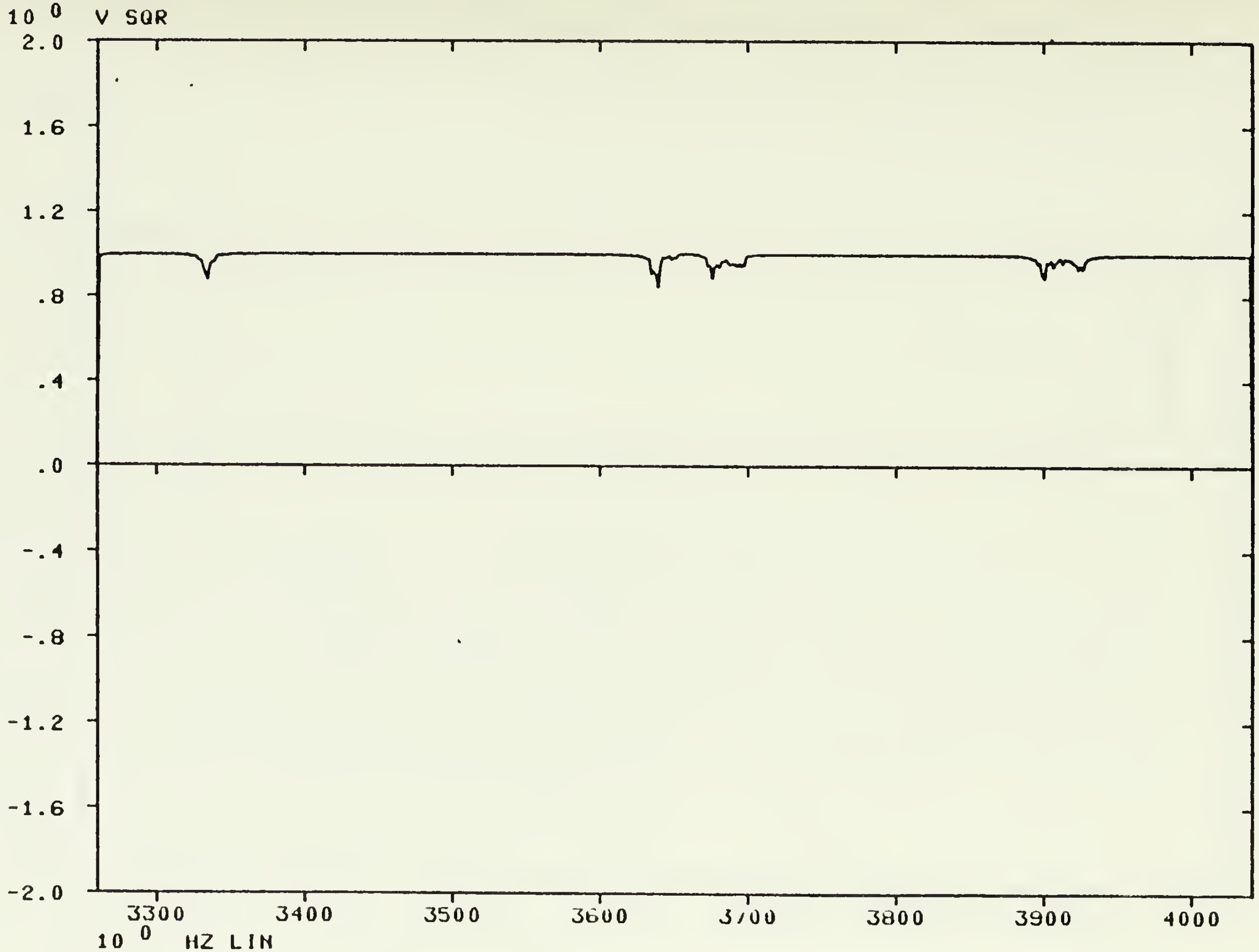

Figure 3. Coherence, PCB #302A, glue mounting.

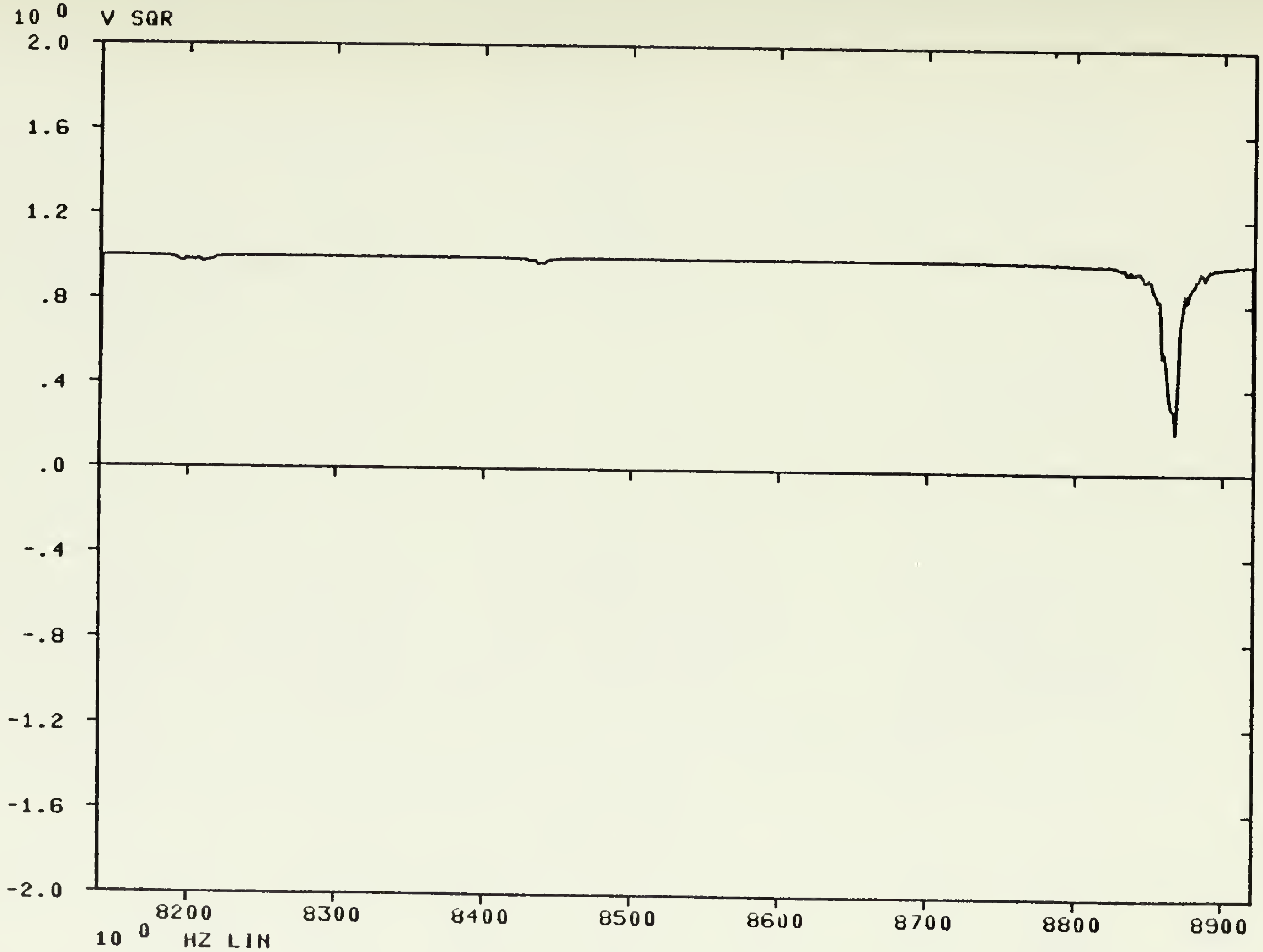

Figure 4. Coherence, PCB #303A, wax mounting.

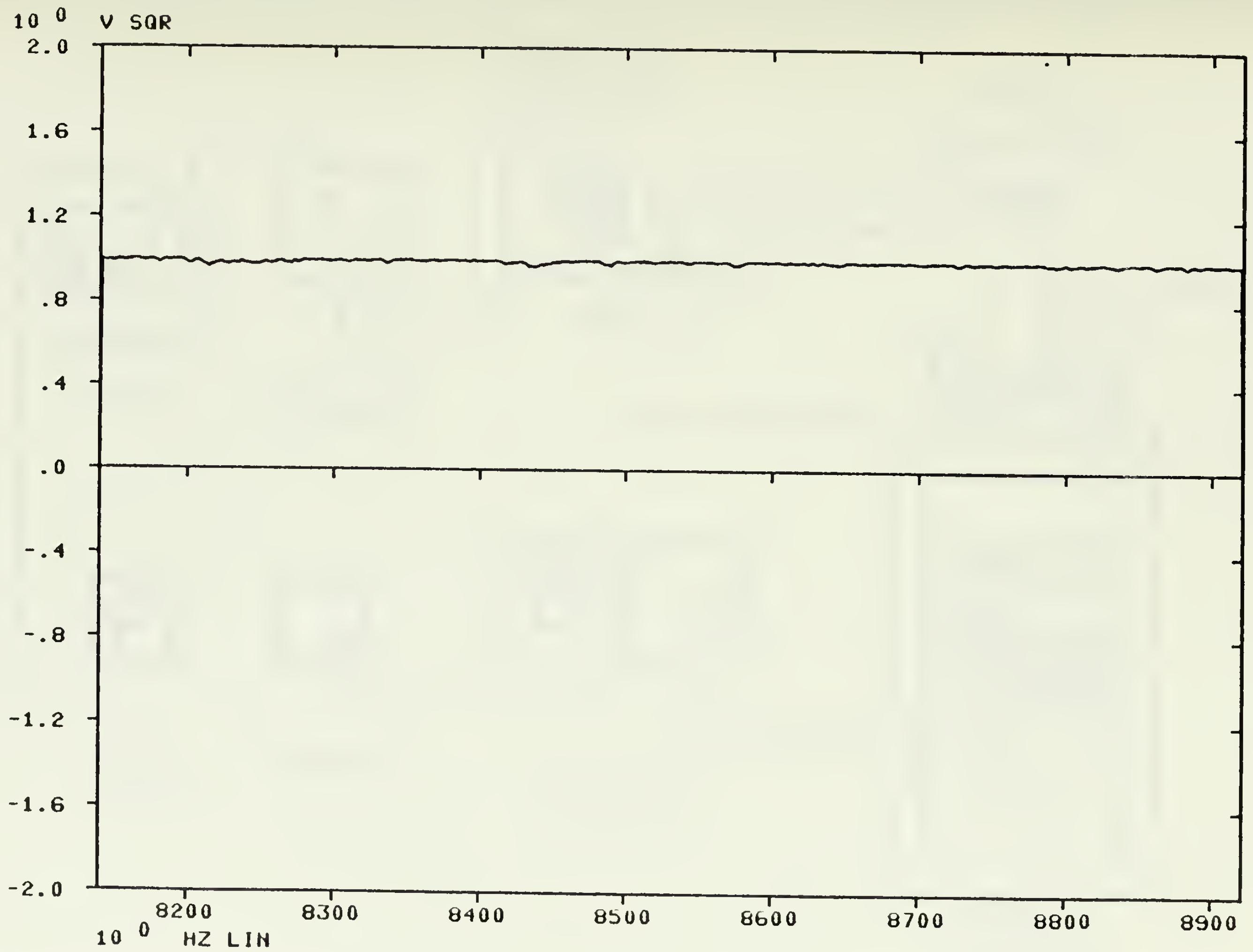

Figure 5. Coherence, ECB #303A, glue mounting.

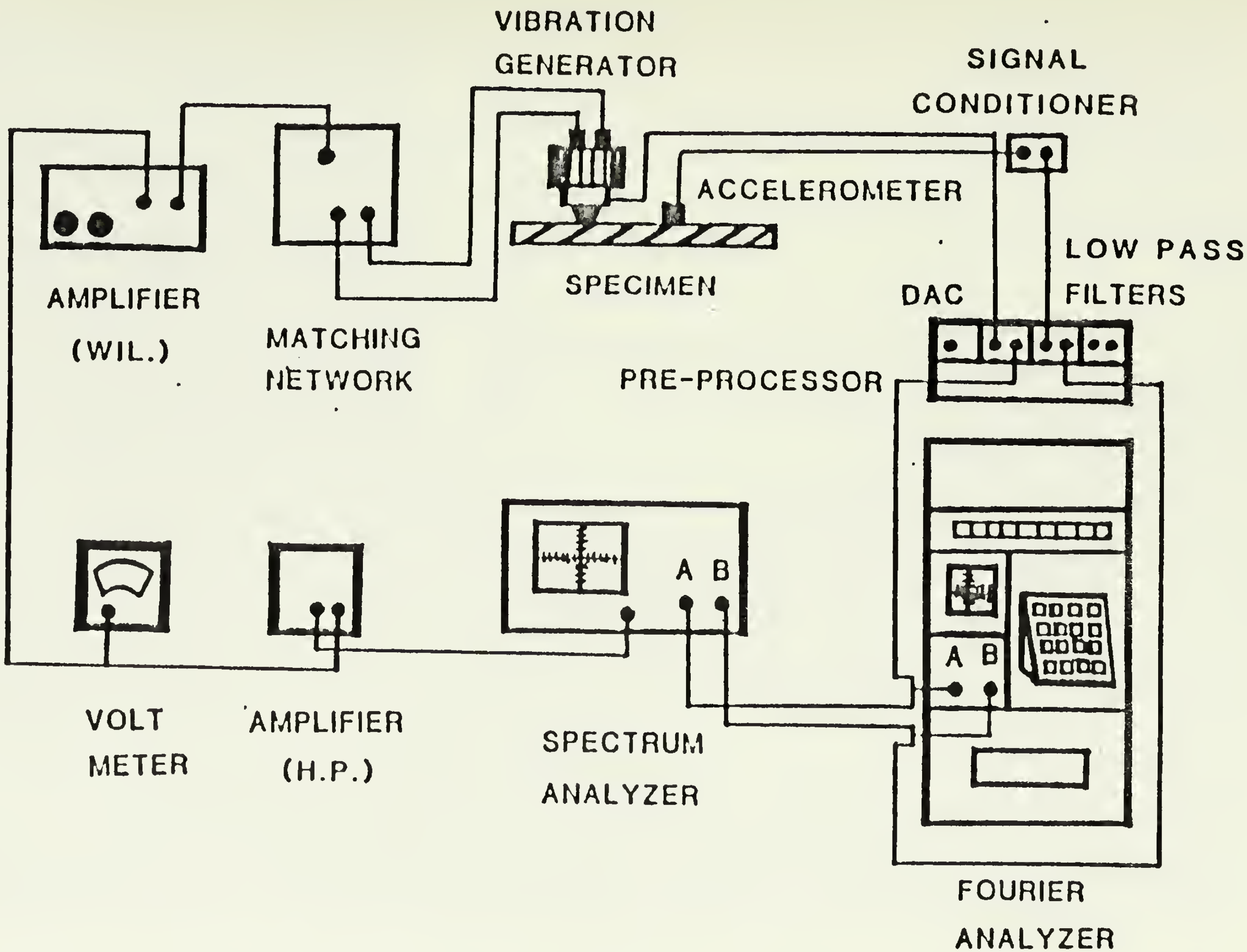

Figure 6. Equipment line diagram, Zcom measurement.

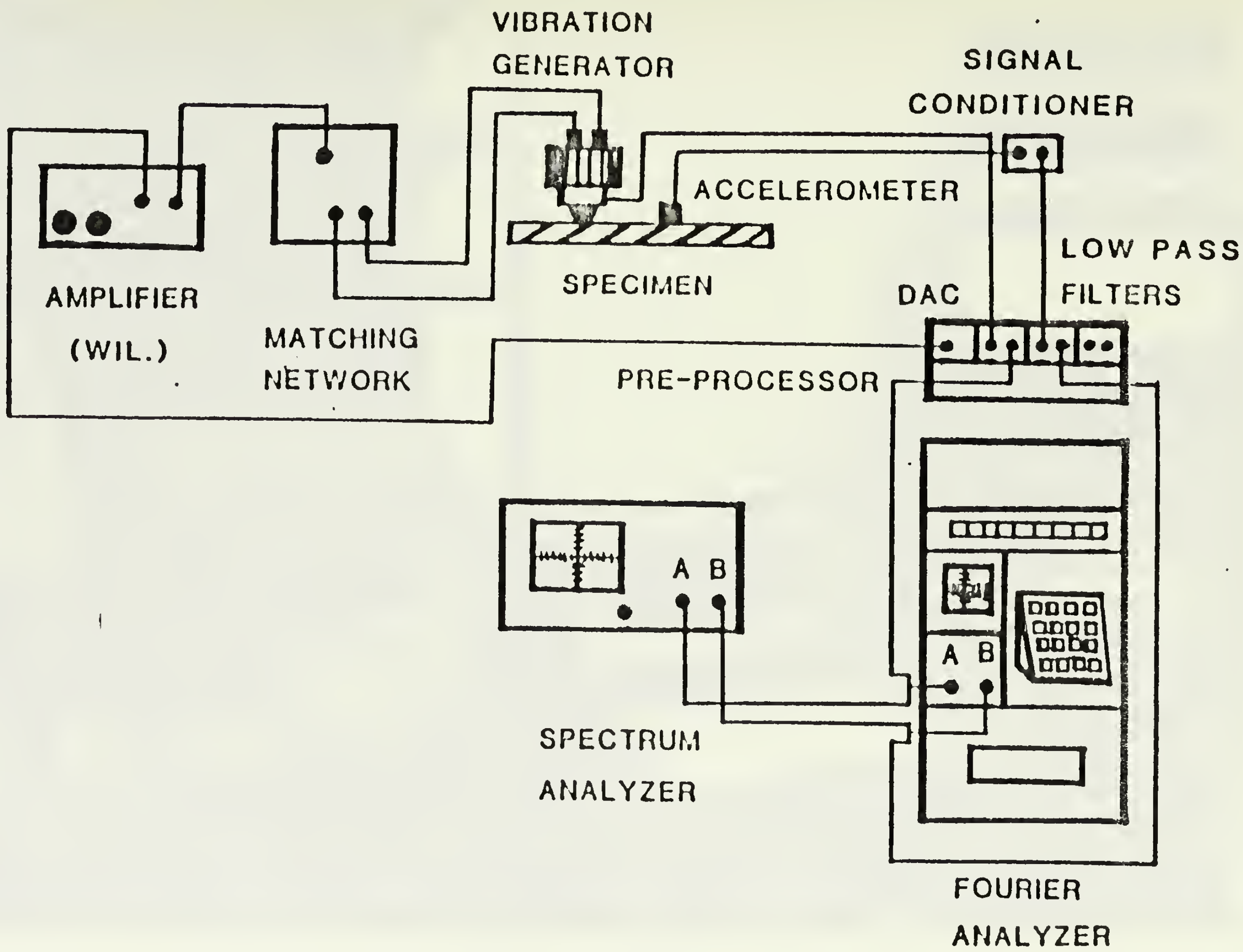

Figure 7. Equipment line diagram, Baseband measurement.

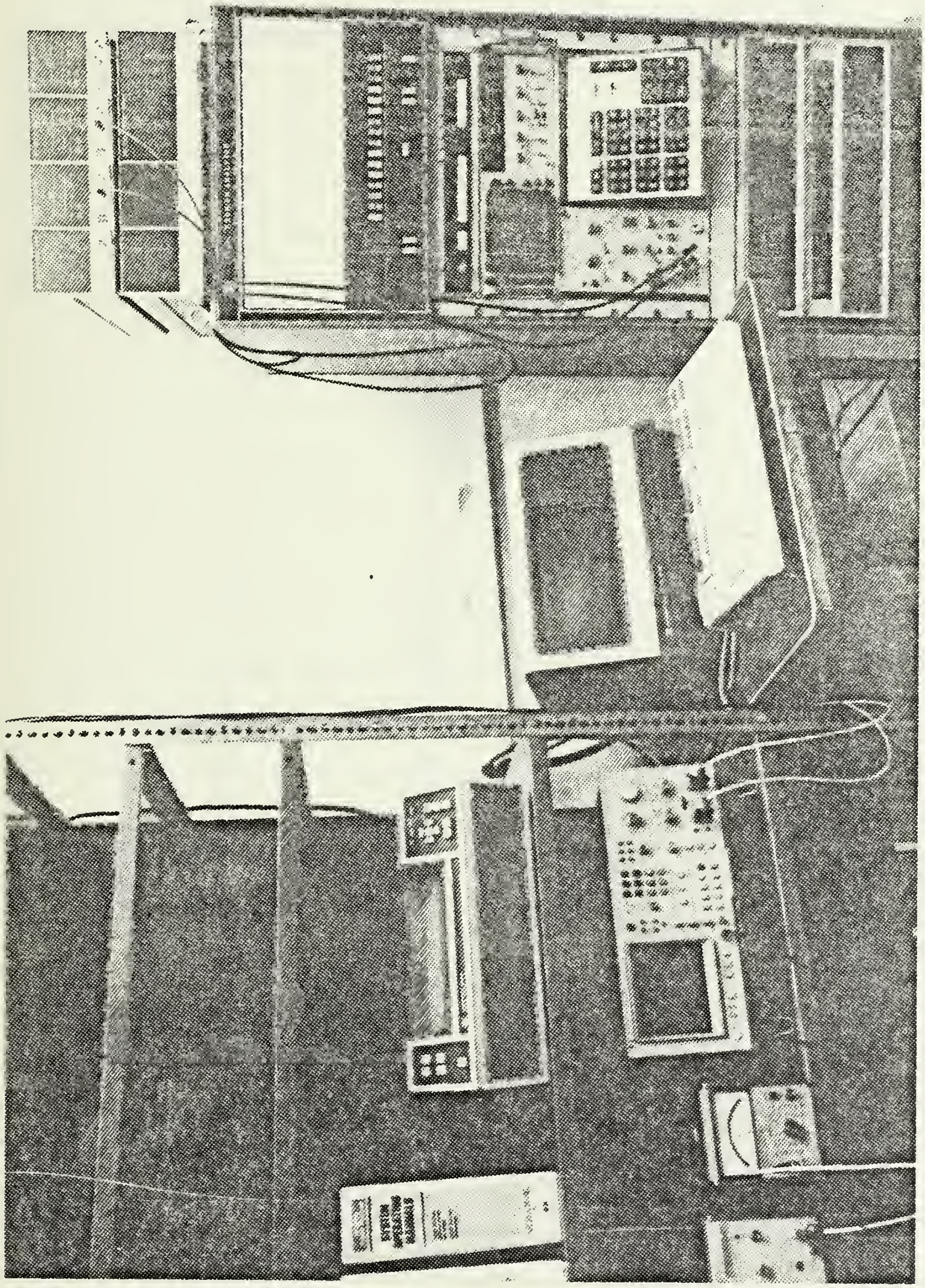

Figure 8. NPS Modal Analysis Laboratory.

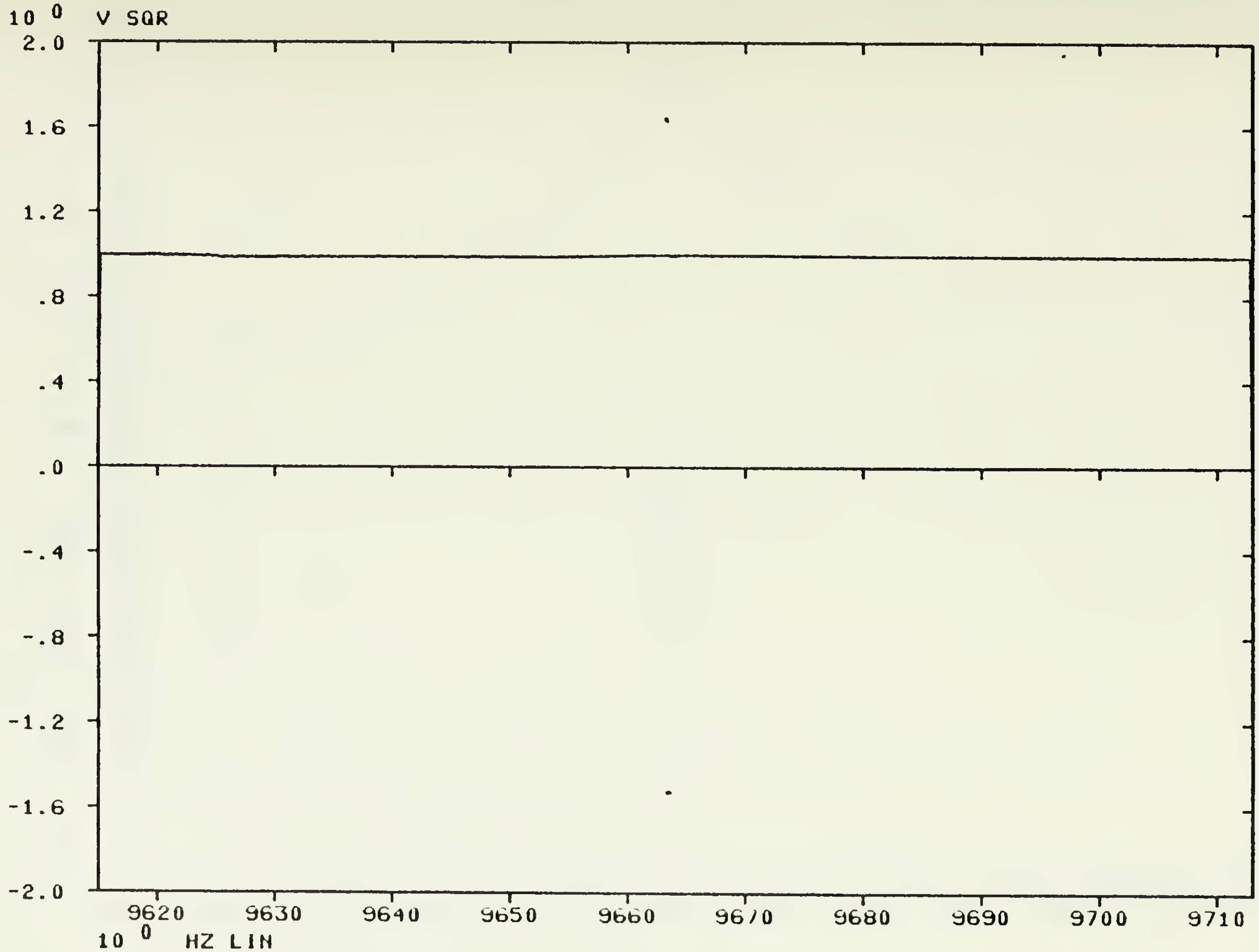

Figure 9. BSFA coherence measurement.

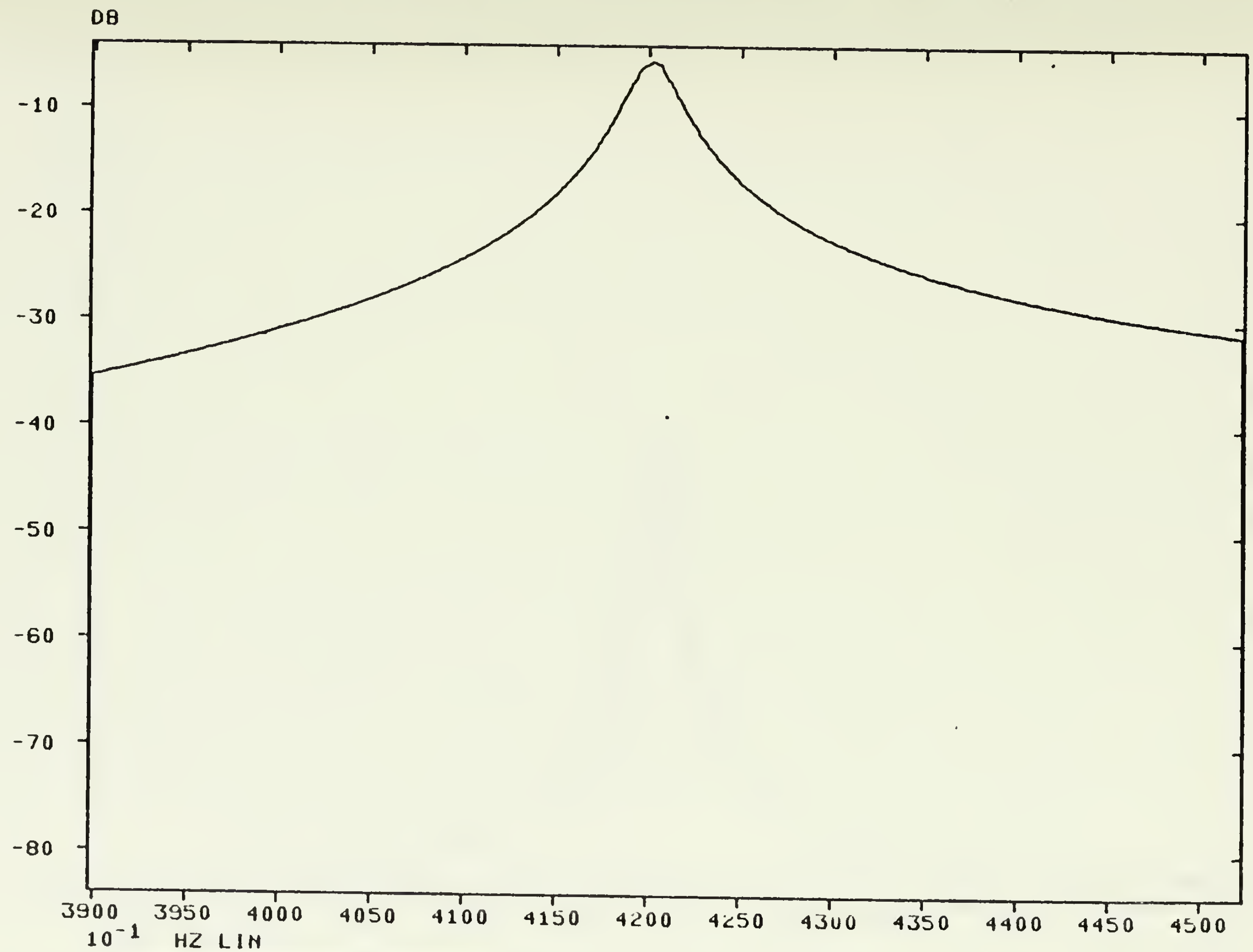

Figure 10. BSFA LOG MAG transfer function measurement.

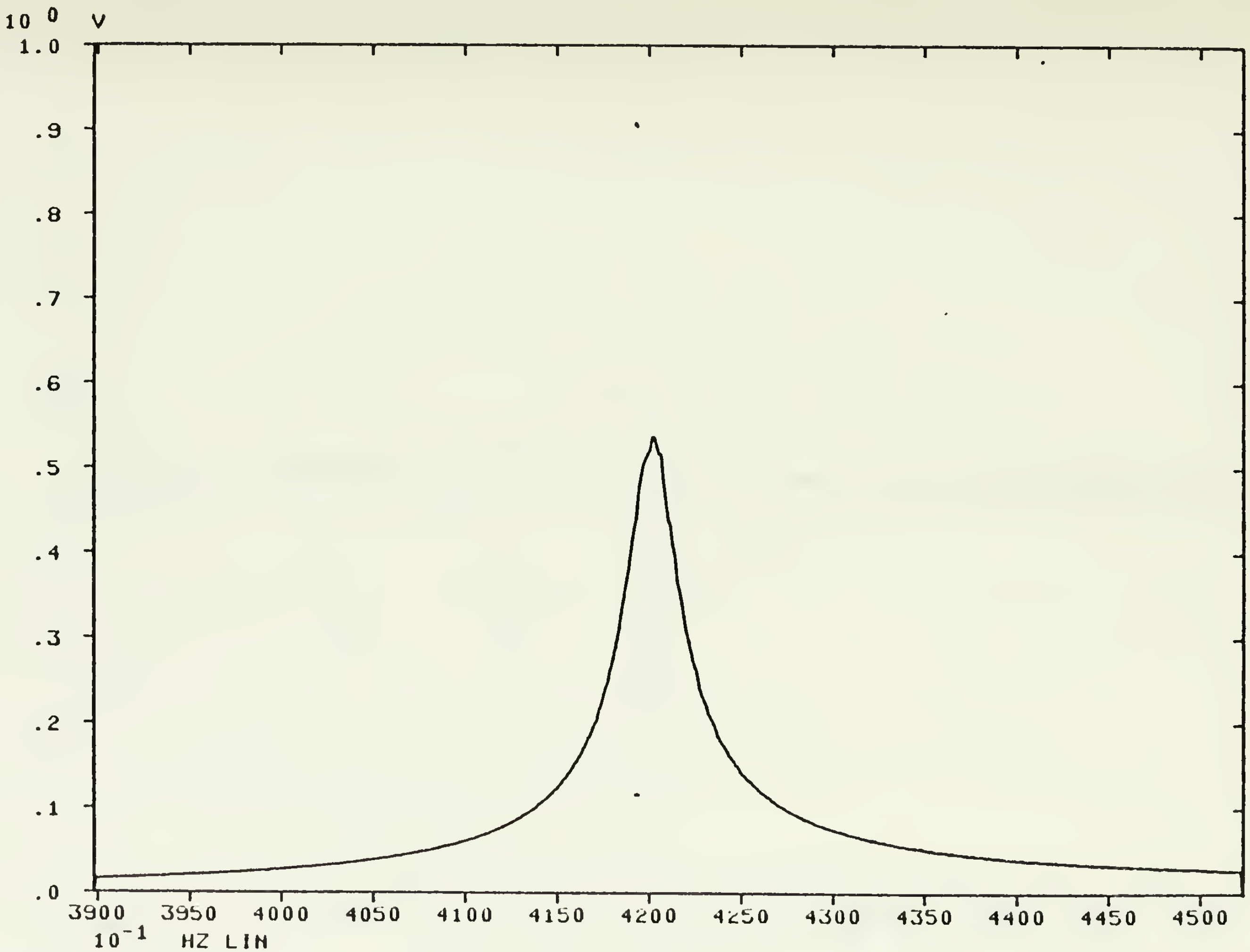

Figure 11. BSFA POLAB transfer function measurement.

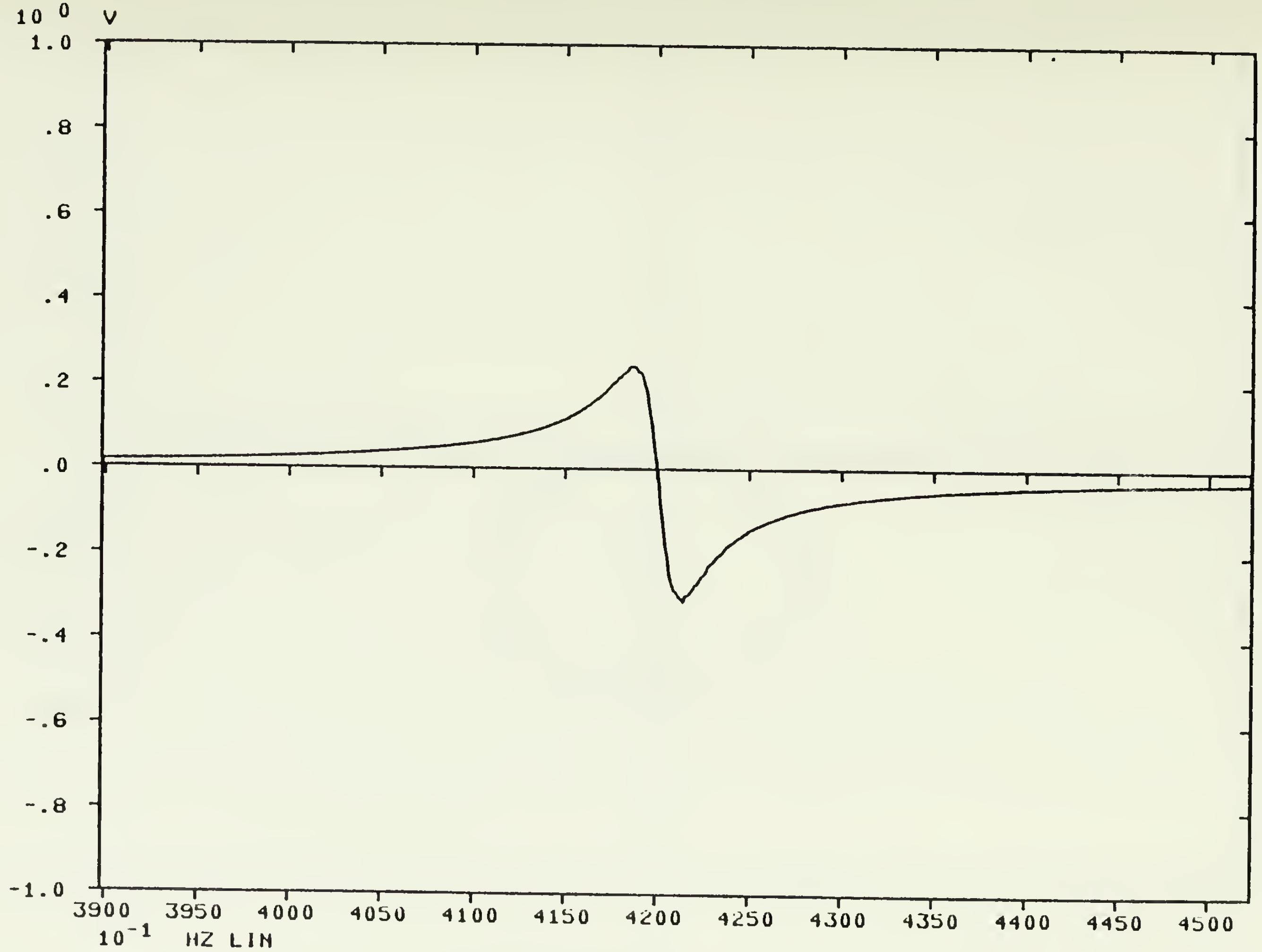

Figure 12. BSFA RECTANGULAR transfer function measurement.

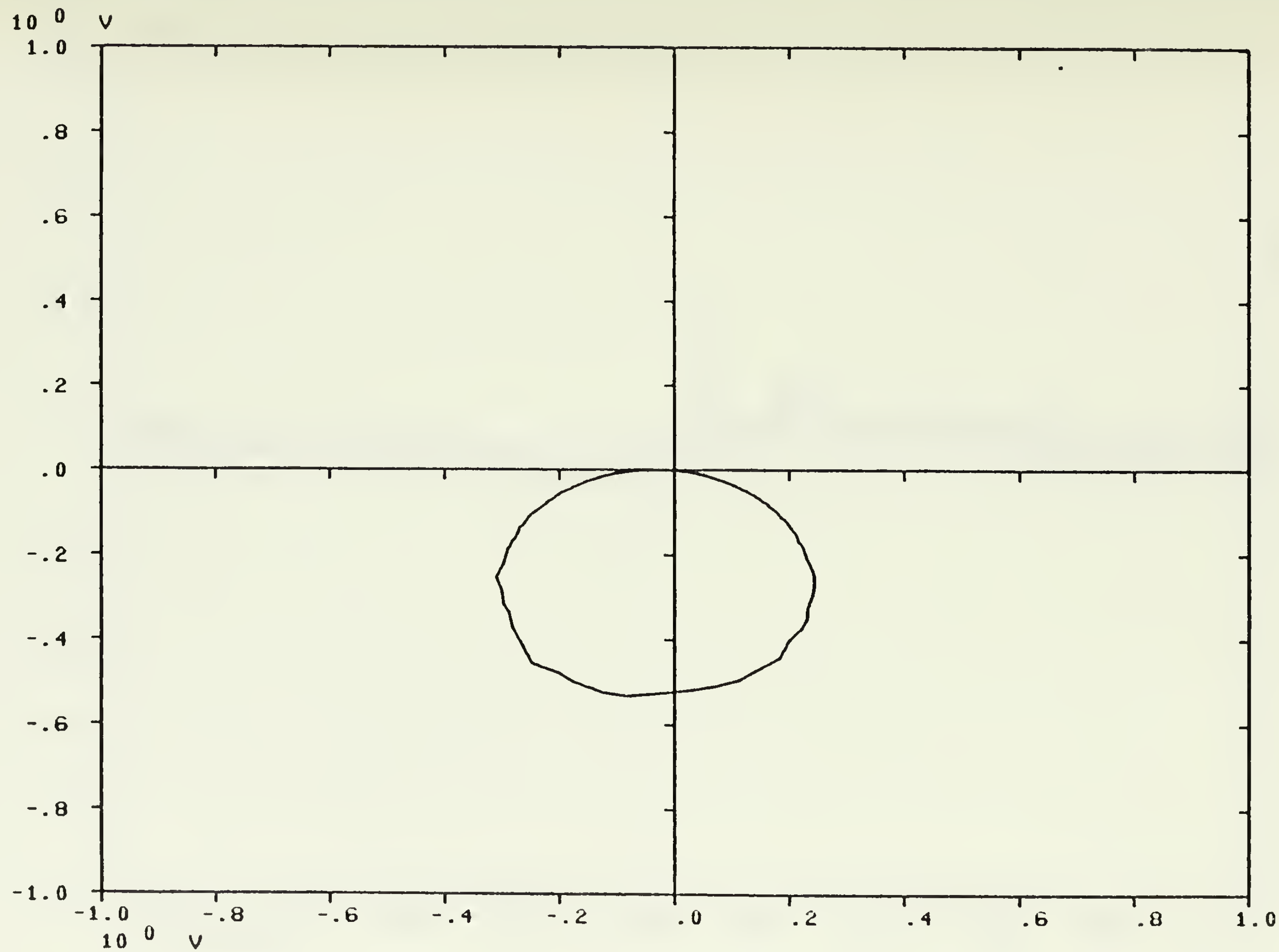

Figure 13. BSFA COMPLEX (NYQUIST) transfer function measurement.

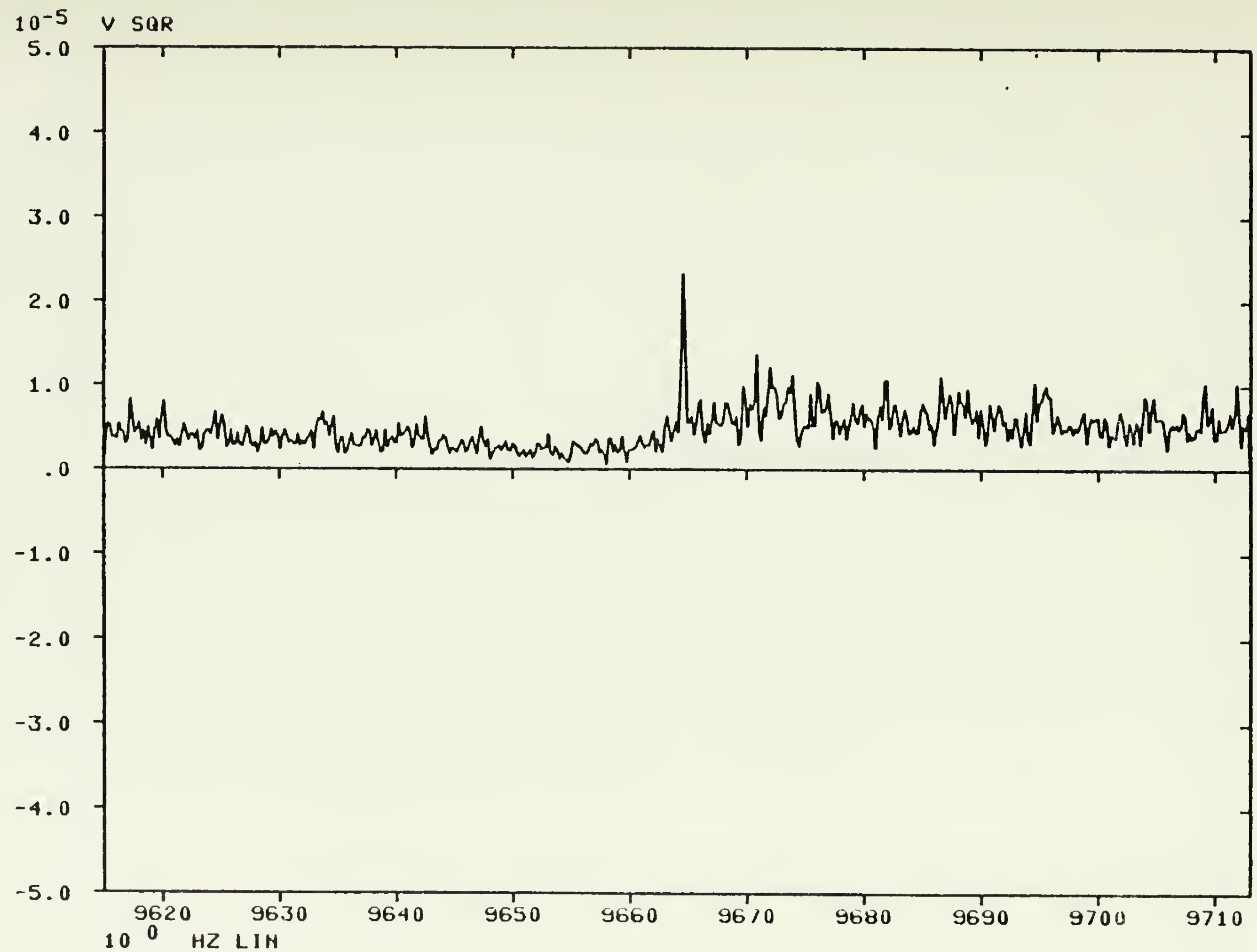

Figure 14. BSFA Input Power Spectrum measurement.

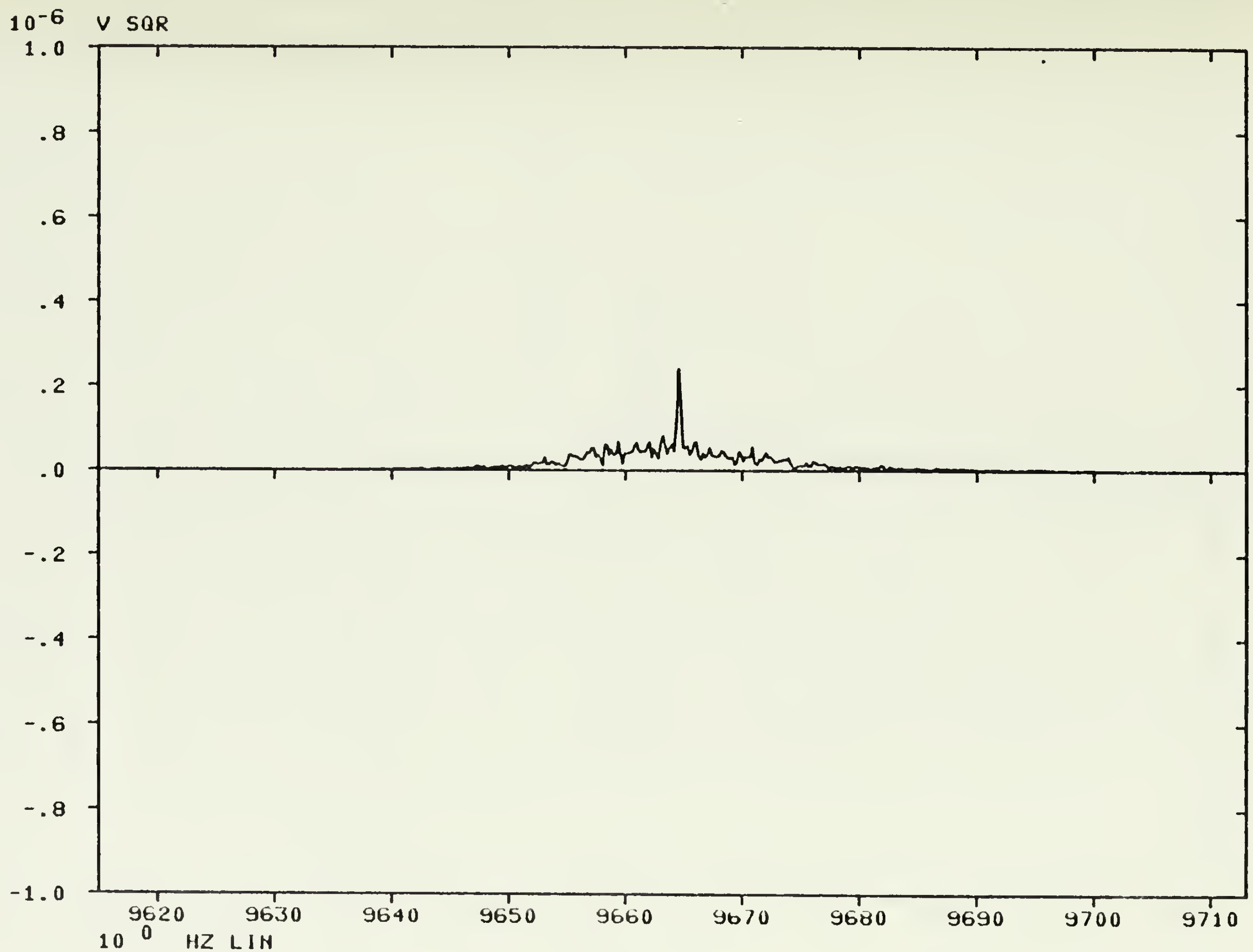

Figure 15. BSFA Output Power Spectrum measurement.

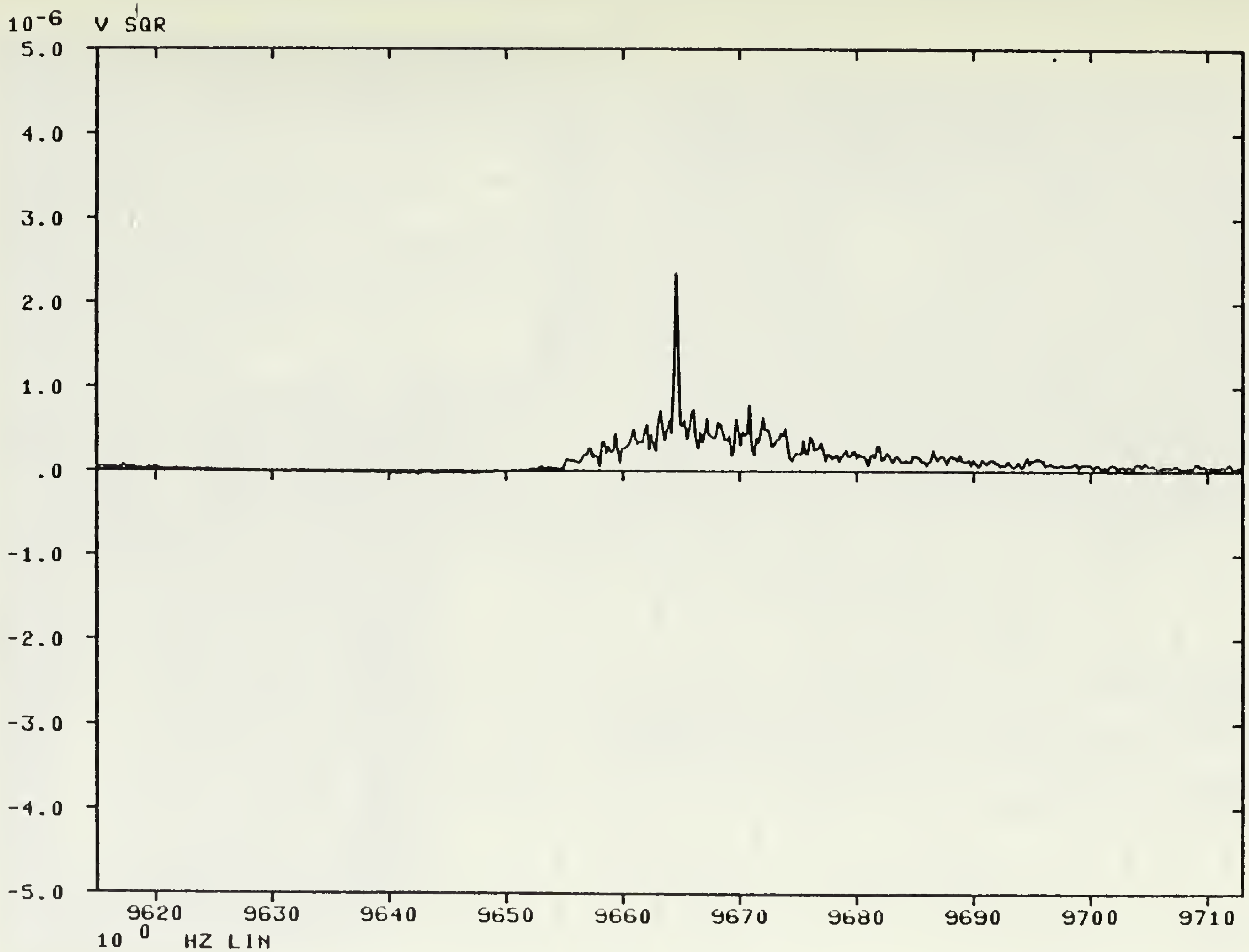

Figure 16. BSPA Cross Power Spectrum measurement.

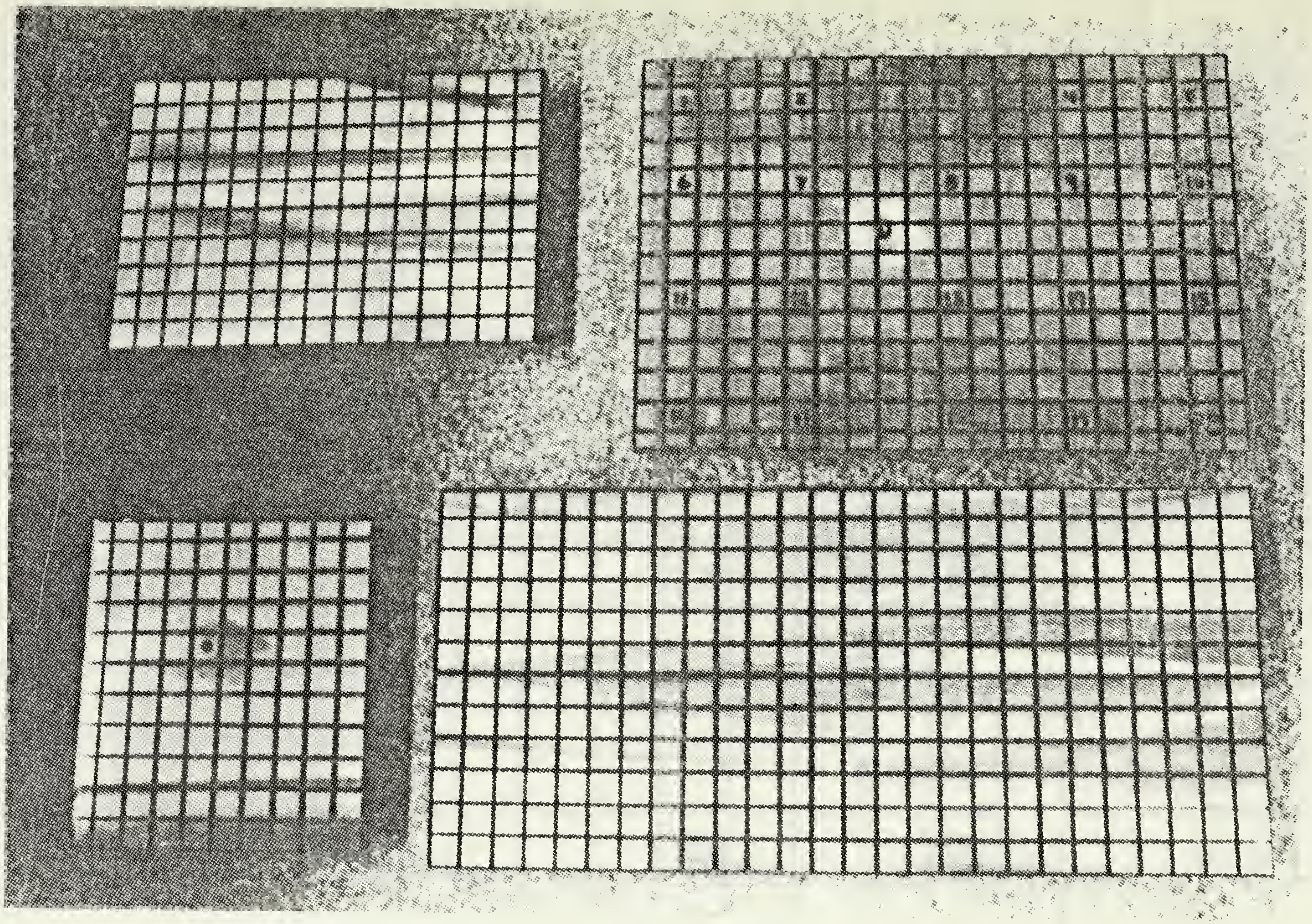

Figure 17. Samples ready for testing.

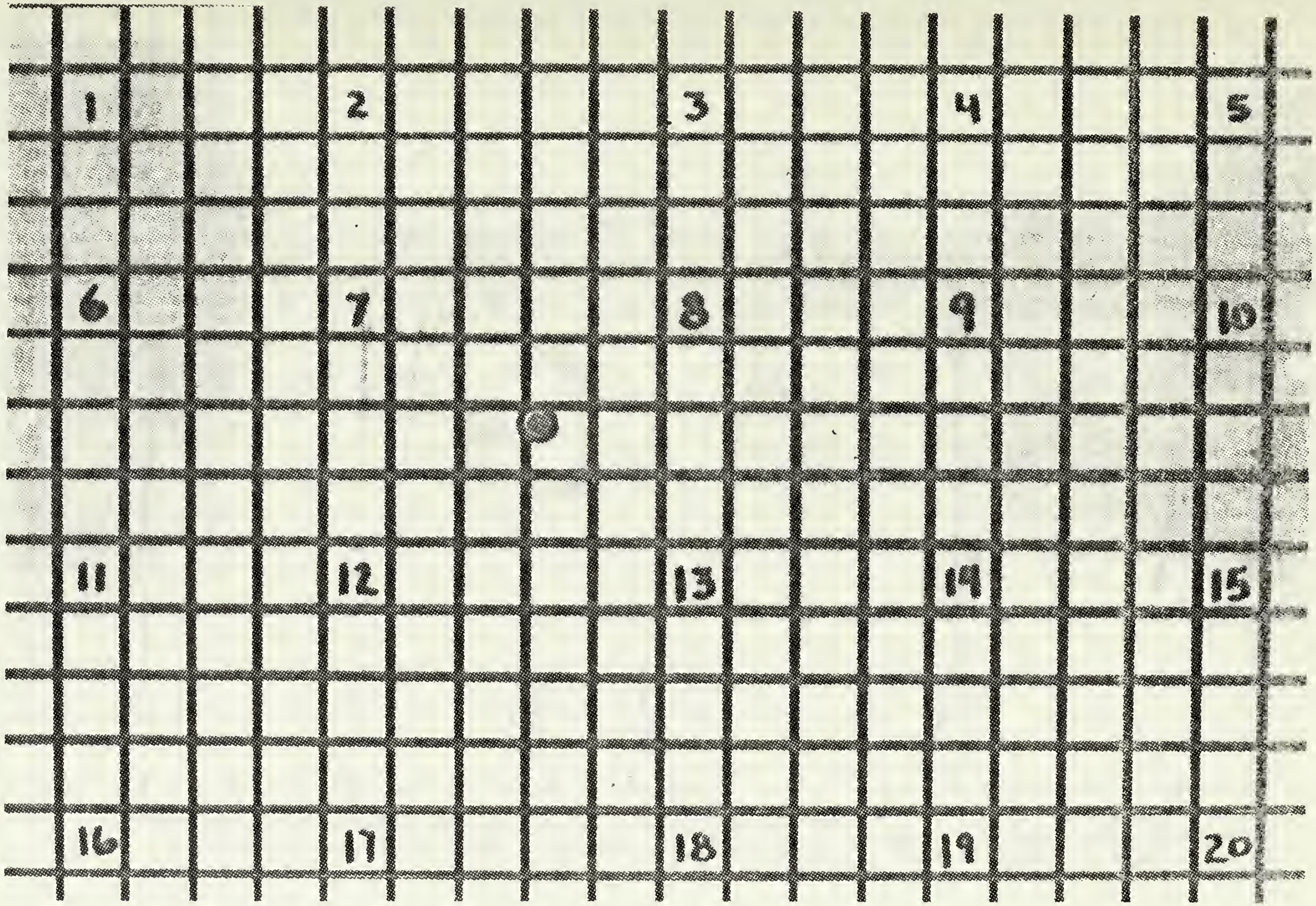

Figure 18. Cast Nickel-Aluminum Bronze specimen.

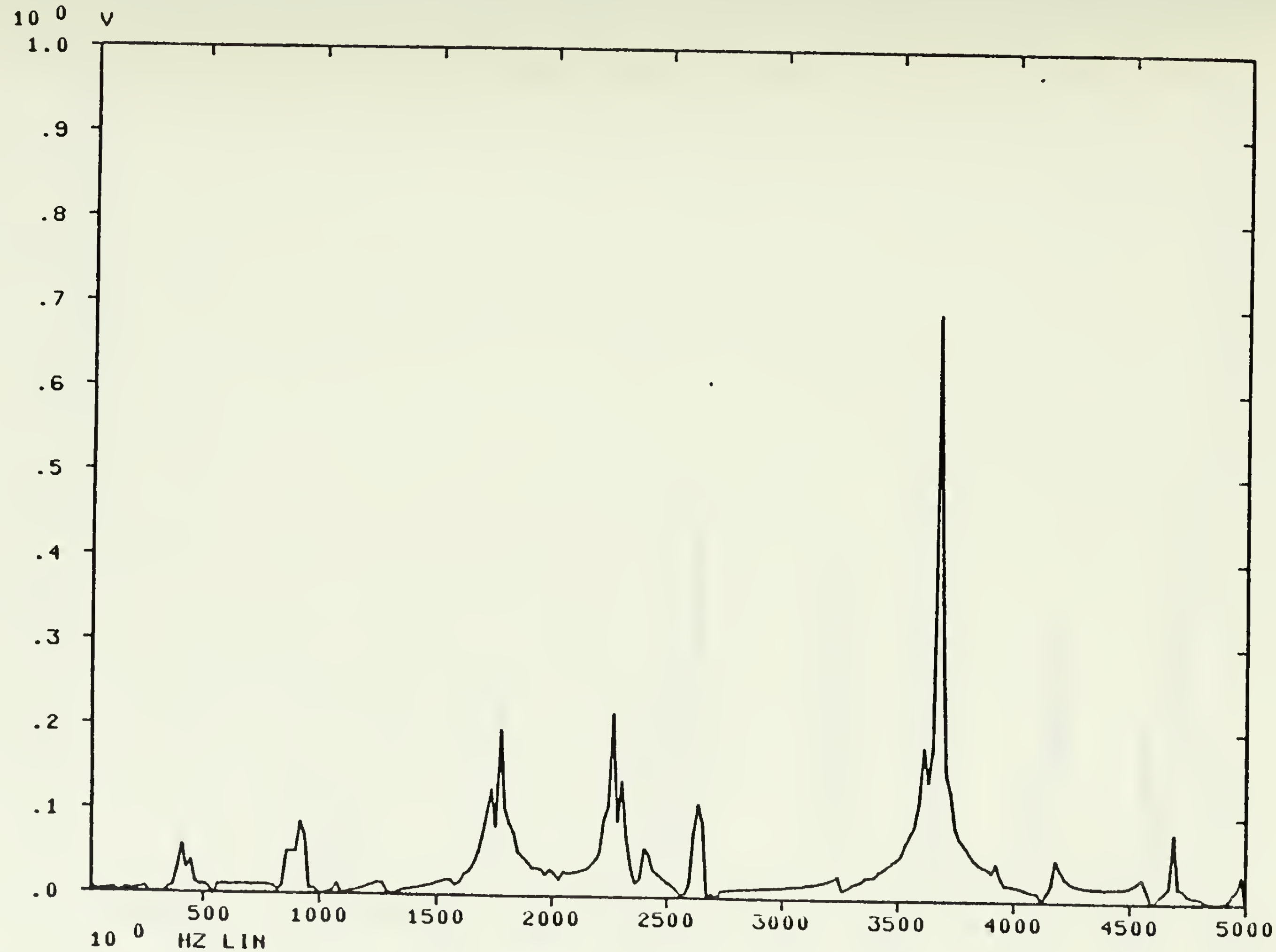

Figure 19. Baseband, 0 to 5 KHz., EC #1, grid location 3.

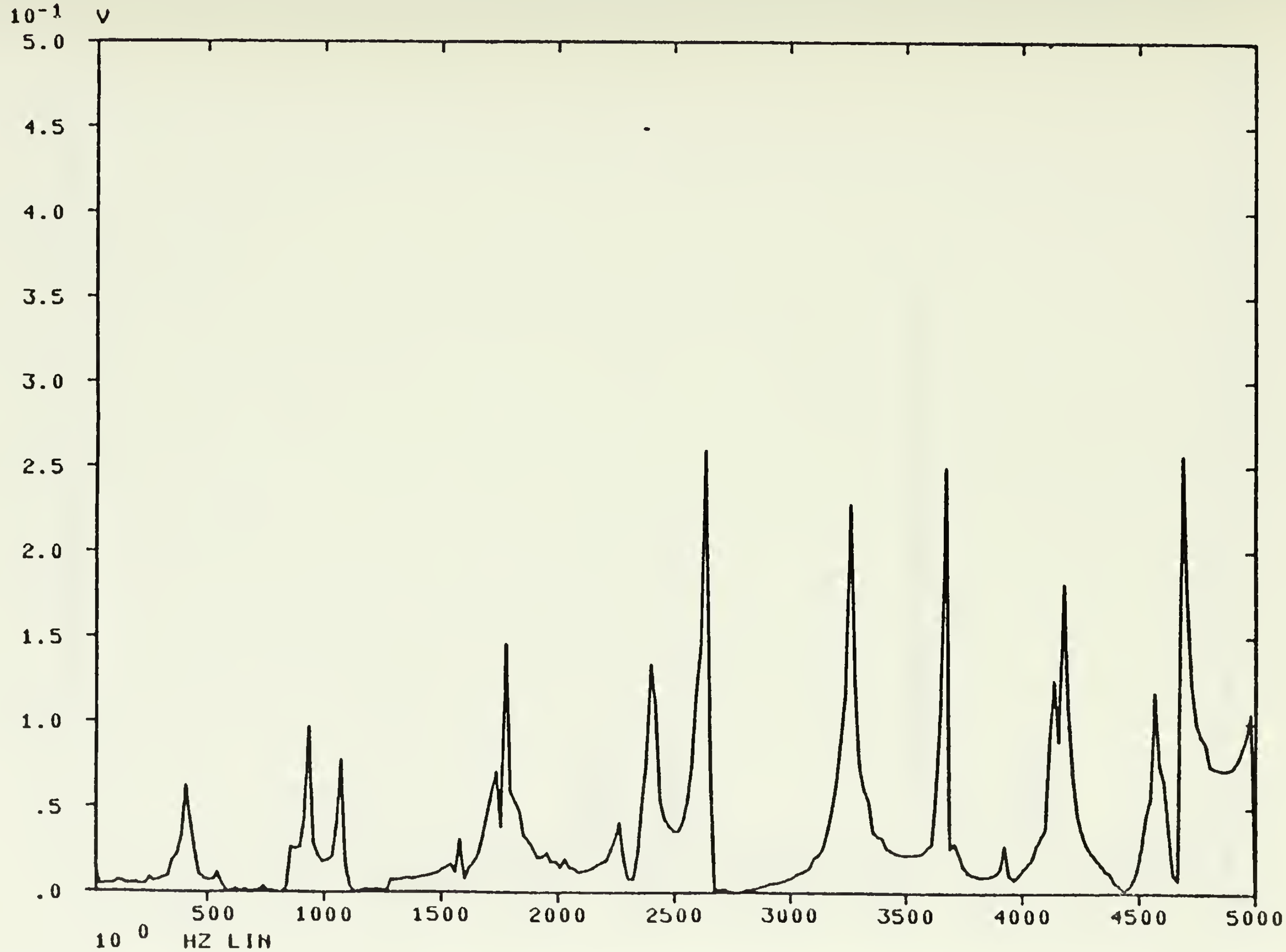

Figure 20. Baseband, 0 to 5 KHz., EC #1, grid location 6.

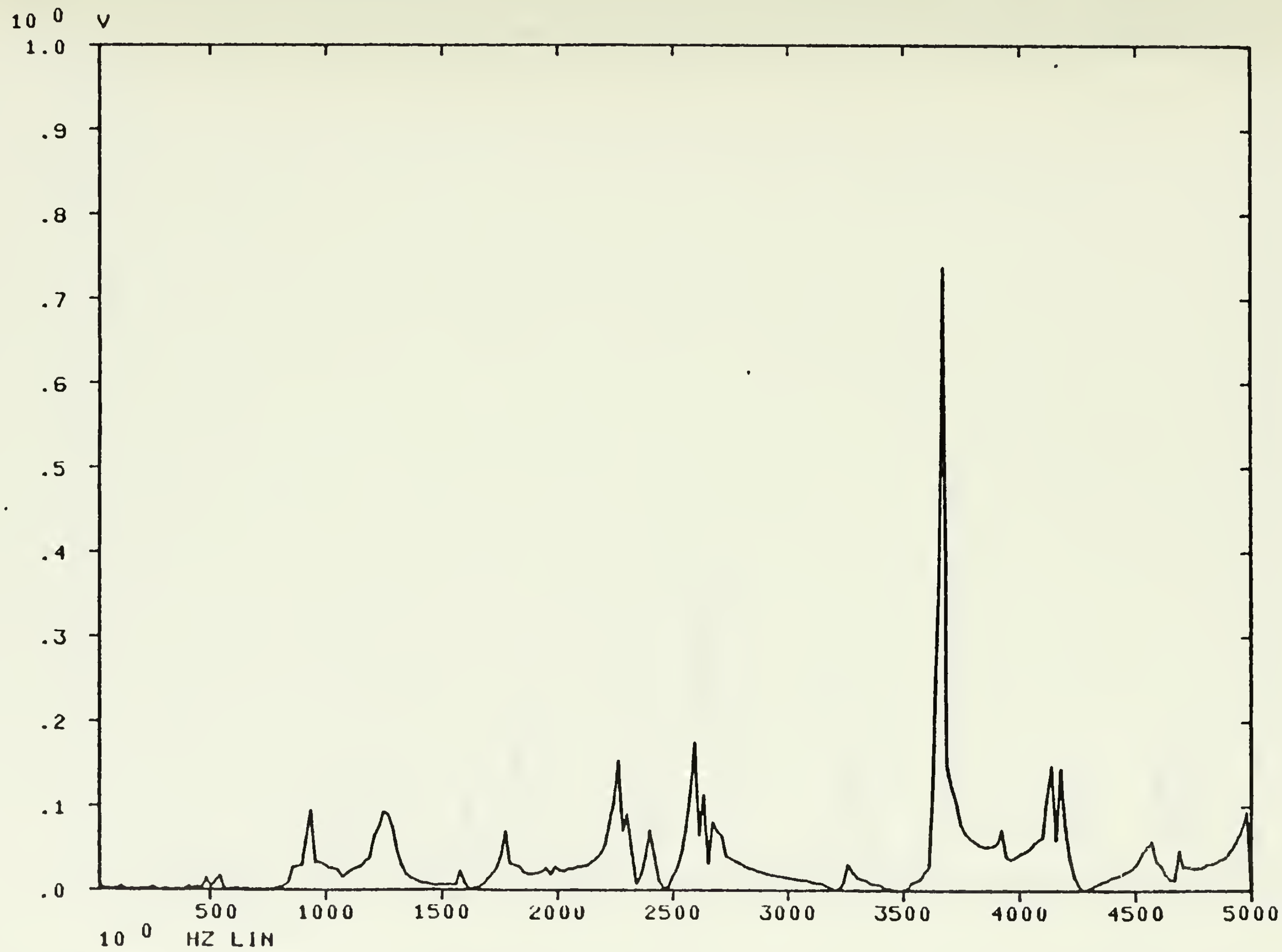

Figure 21. Baseband, 0 to 5 KHz., EC #1, grid location 14.

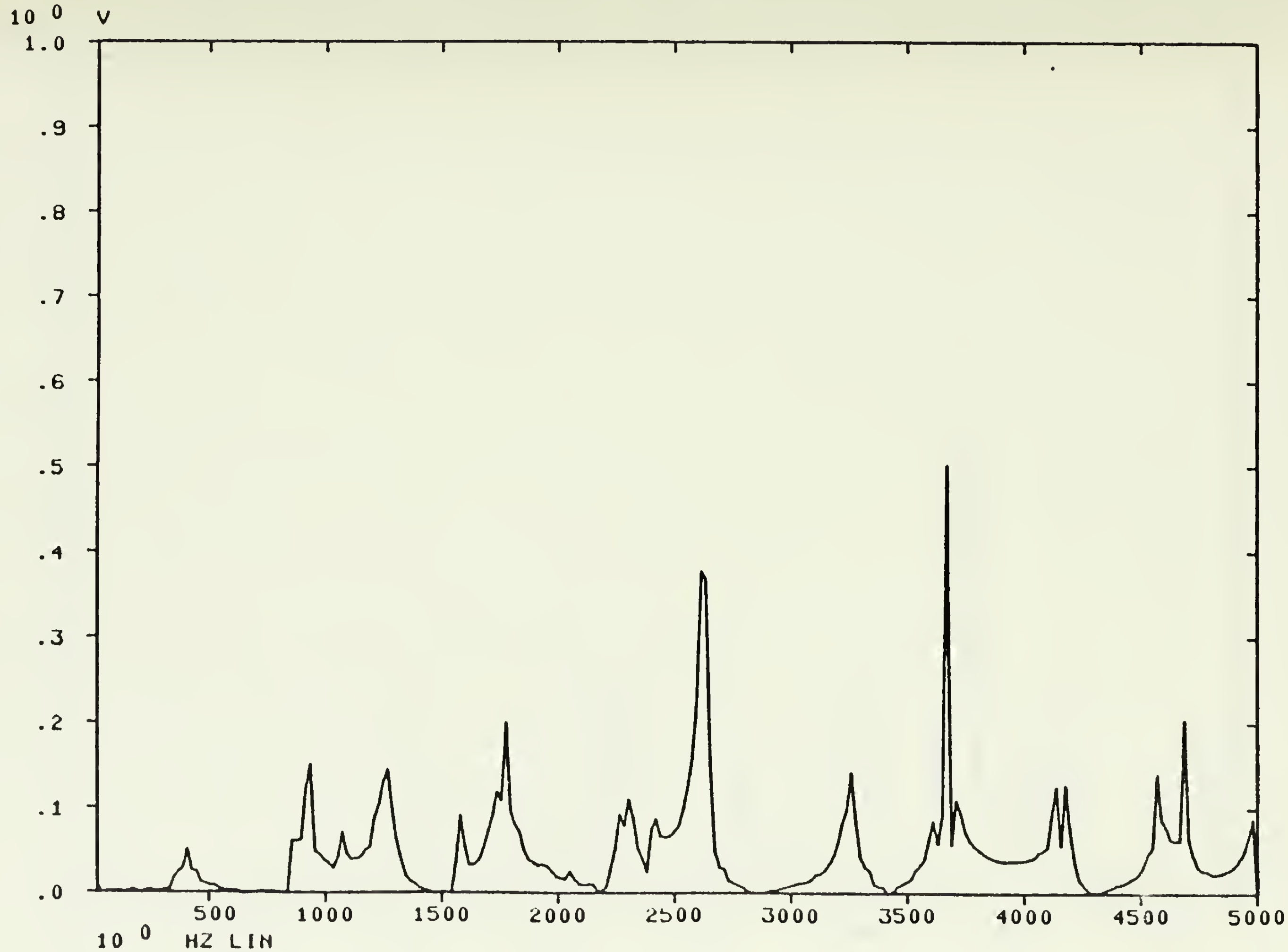

Figure 22. Baseband, 0 to 5 KHz., EC #1, grid location 20.

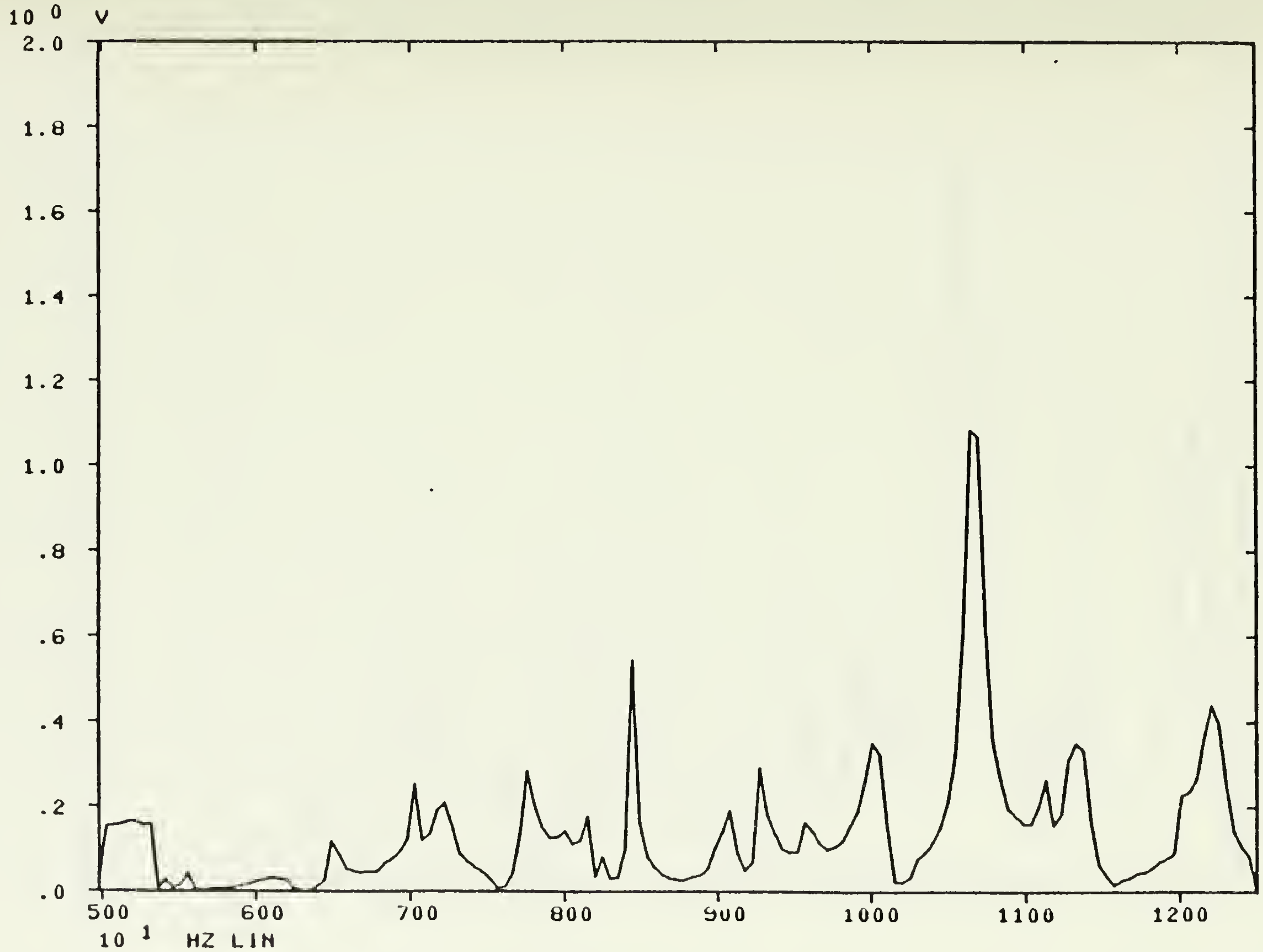

Figure 23. Baseband, 5 to 12.5 KHz., BC #1, grid location 3.

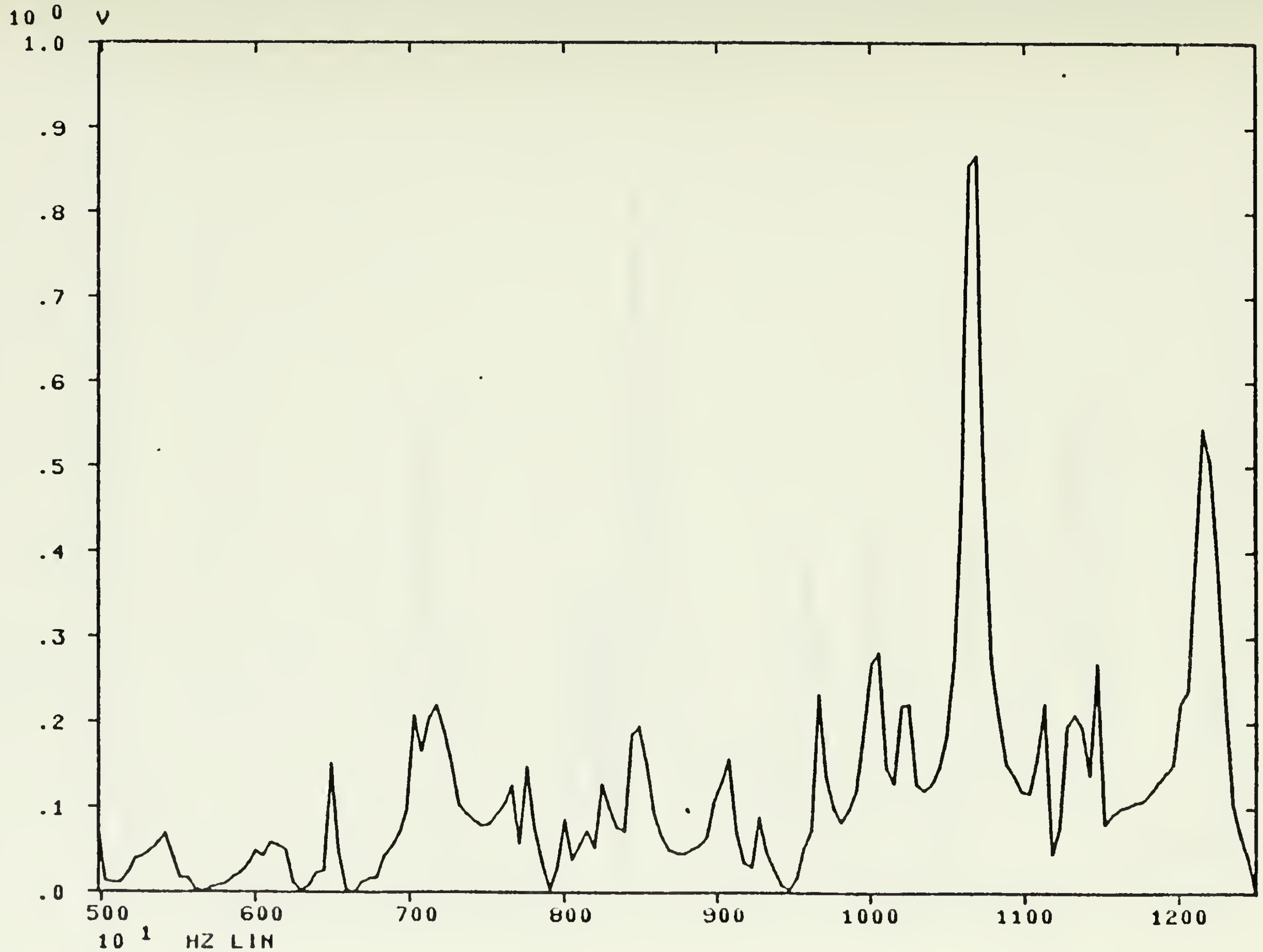

Figure 24. Baseband, 5 tc 12.5 KHz., BC #1, grid location 6.

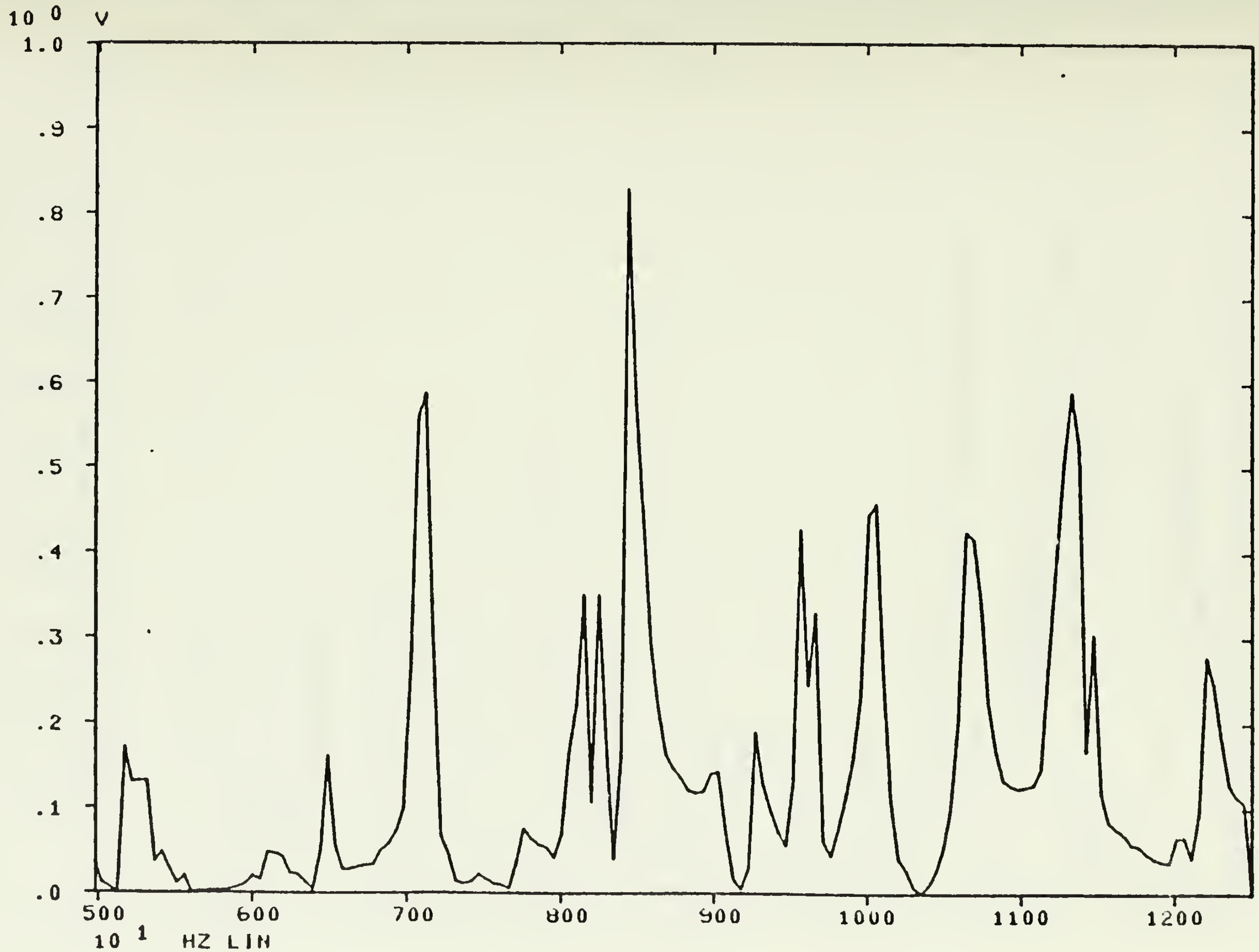

Figure 25. Baseband, 5 to 12.5 KHz., BC #1, grid location 14.

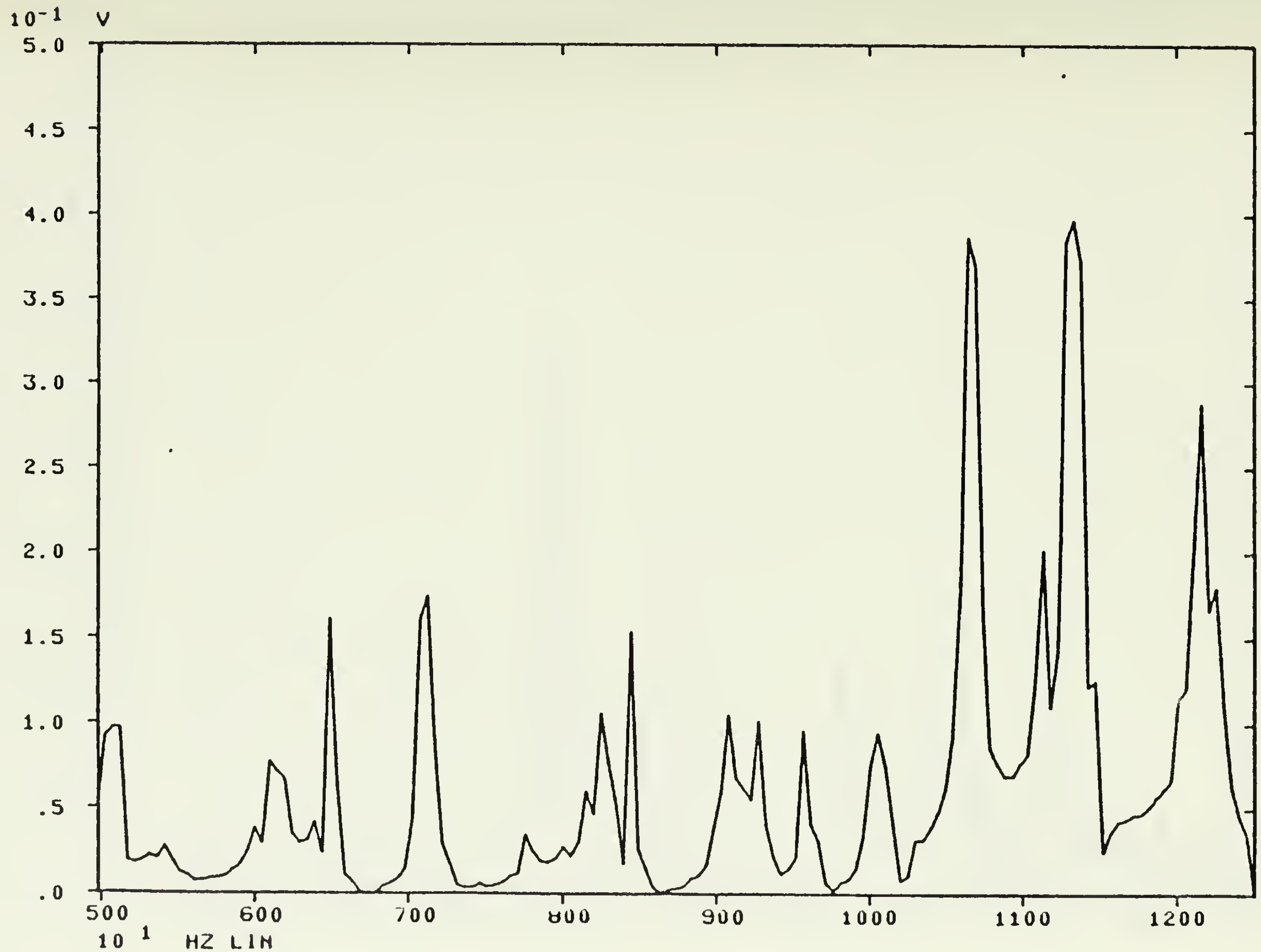

Figure 26. Baseband, 5 to 12.5 KHz., BC #1, grid location 20.

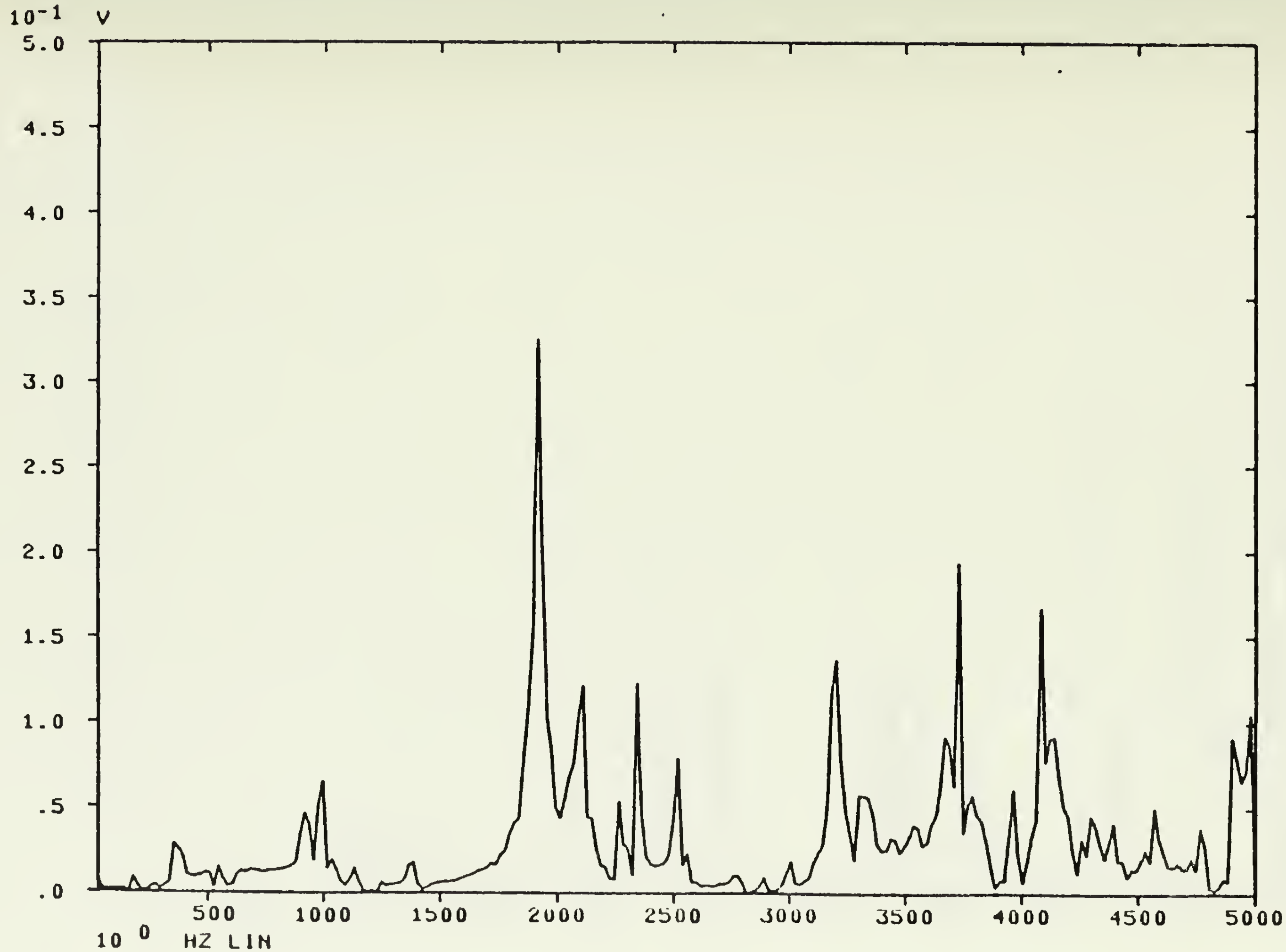

Figure 27. Baseband, 0 to 5 KHz., EC #2, grid location 3.

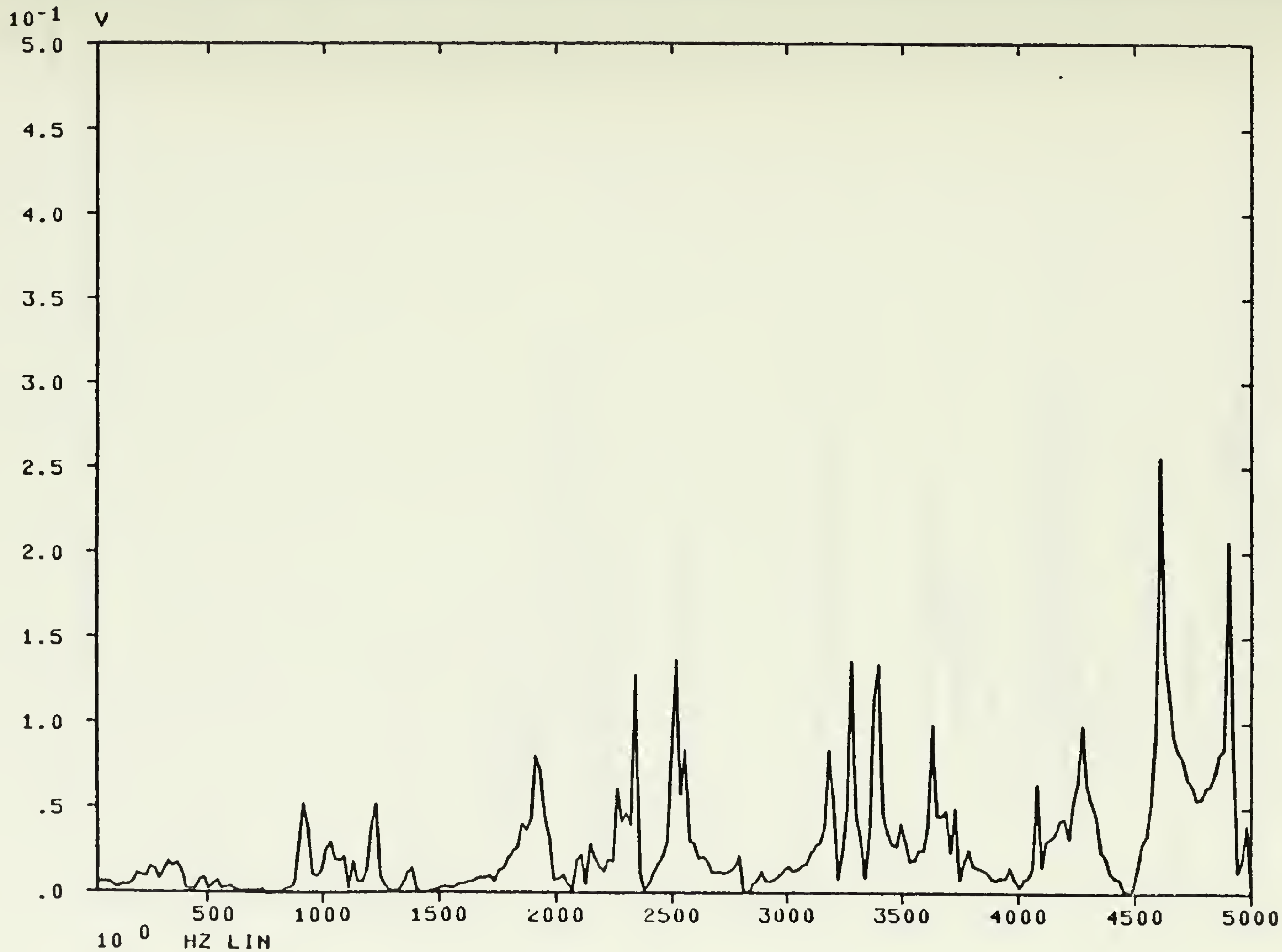

Figure 28. Baseband, 0 to 5 KHz., EC #2, grid location 6.

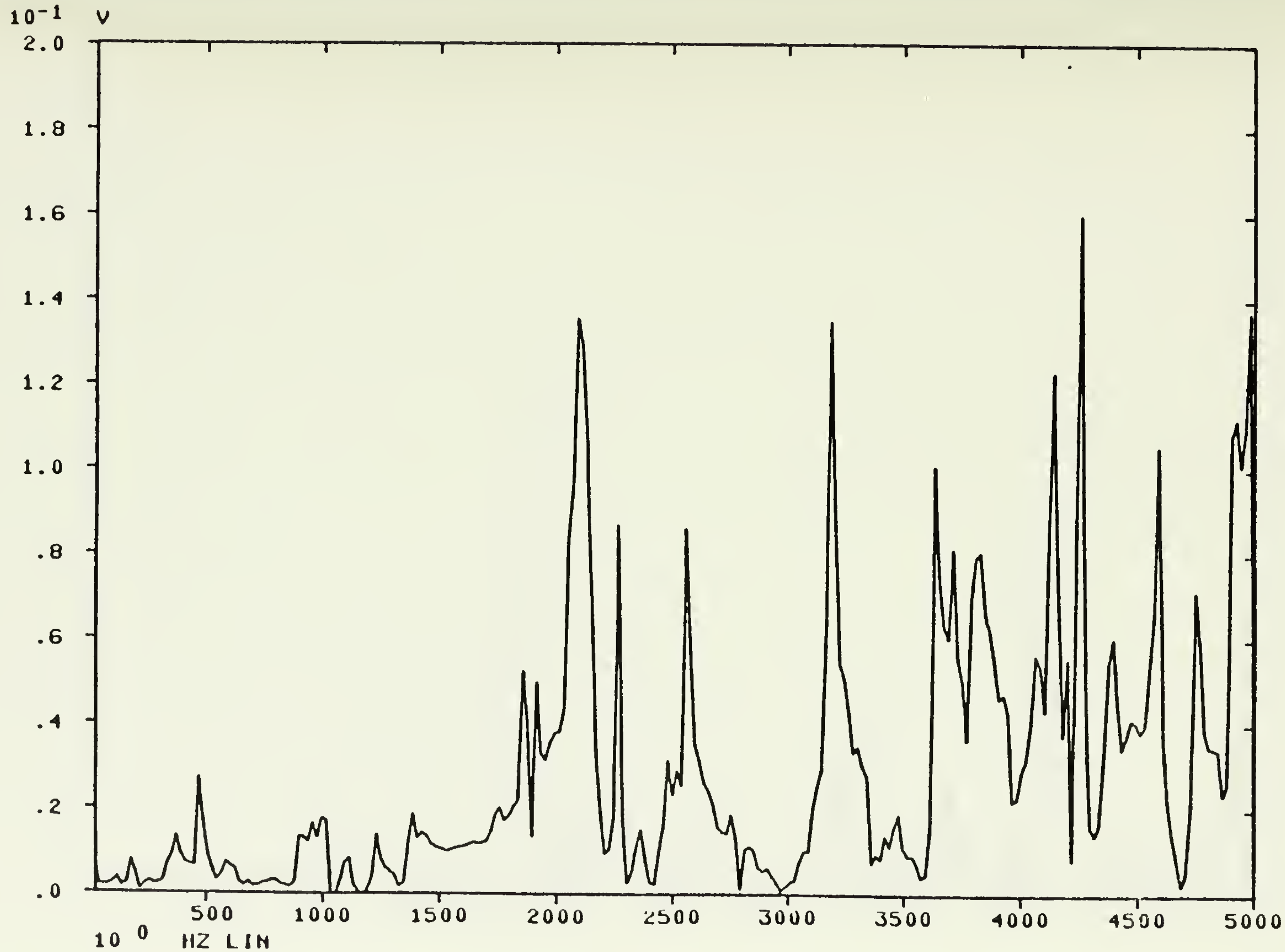

Figure 29. Baseband, 0 to 5 KHz., EC #2, grid location 14.

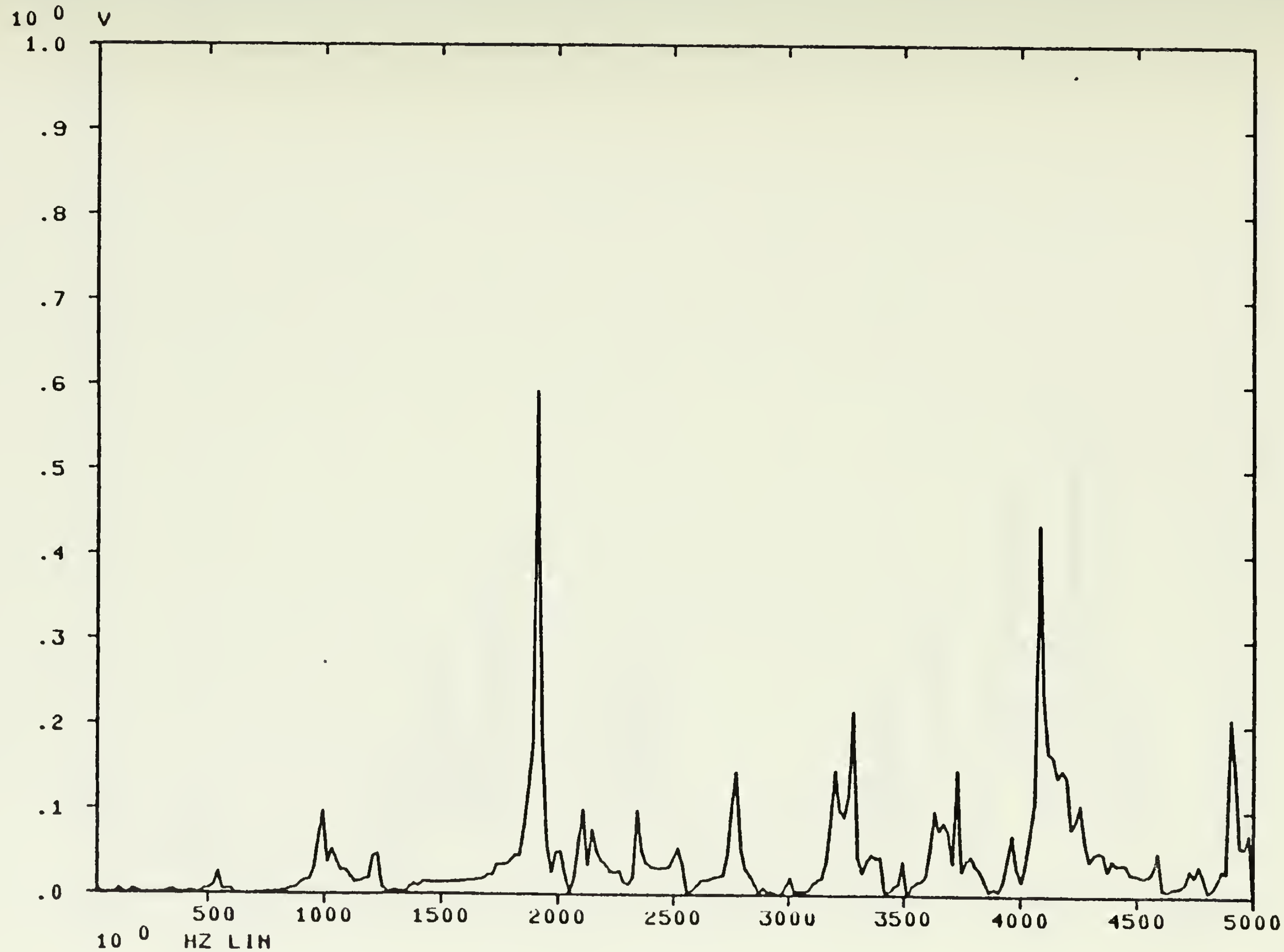

Figure 30. Baseband, 0 to 5 KHz., EC #2, grid location 20.

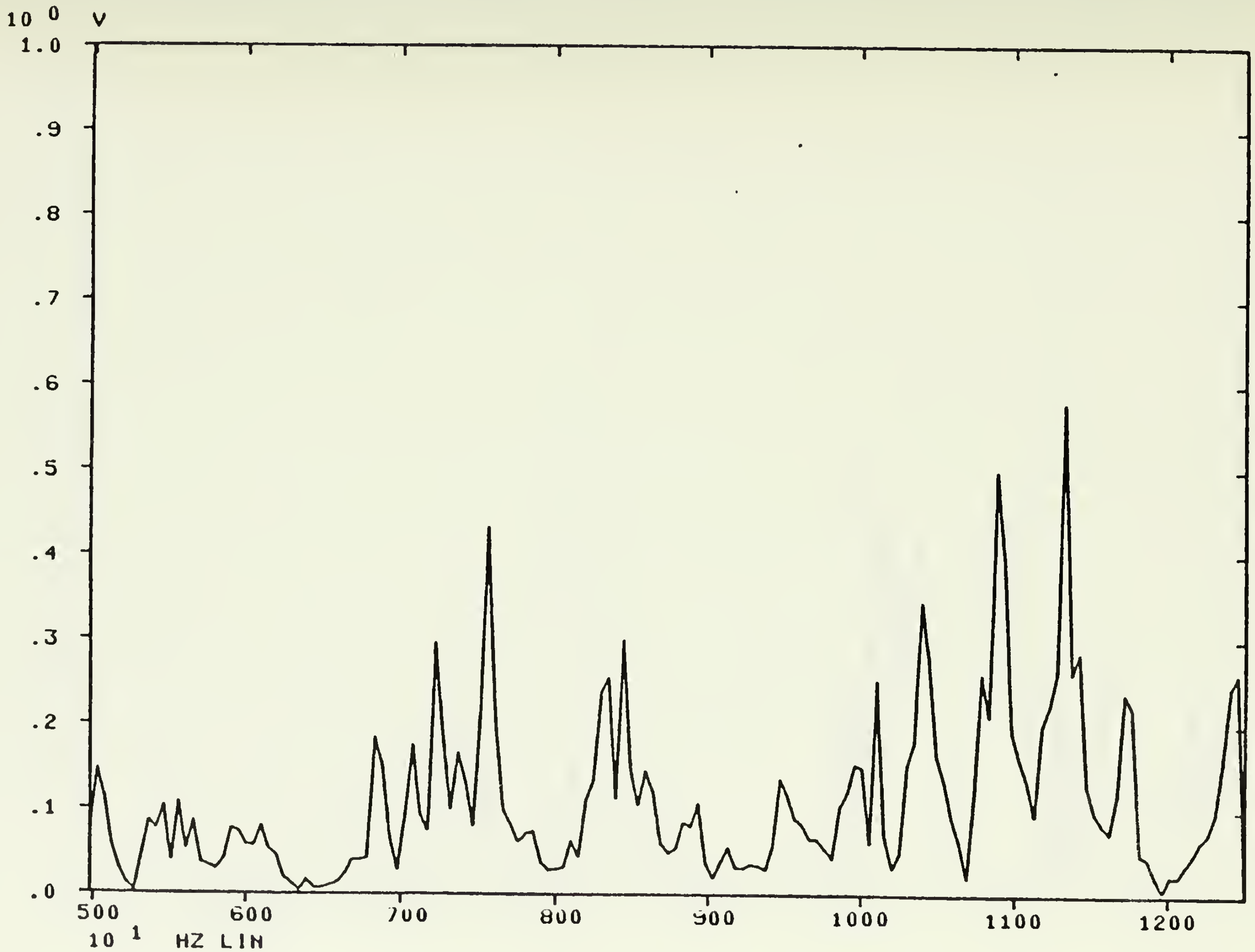

Figure 31. Baseband, 5 tc 12.5 KHz., BC #2, grid location 3.

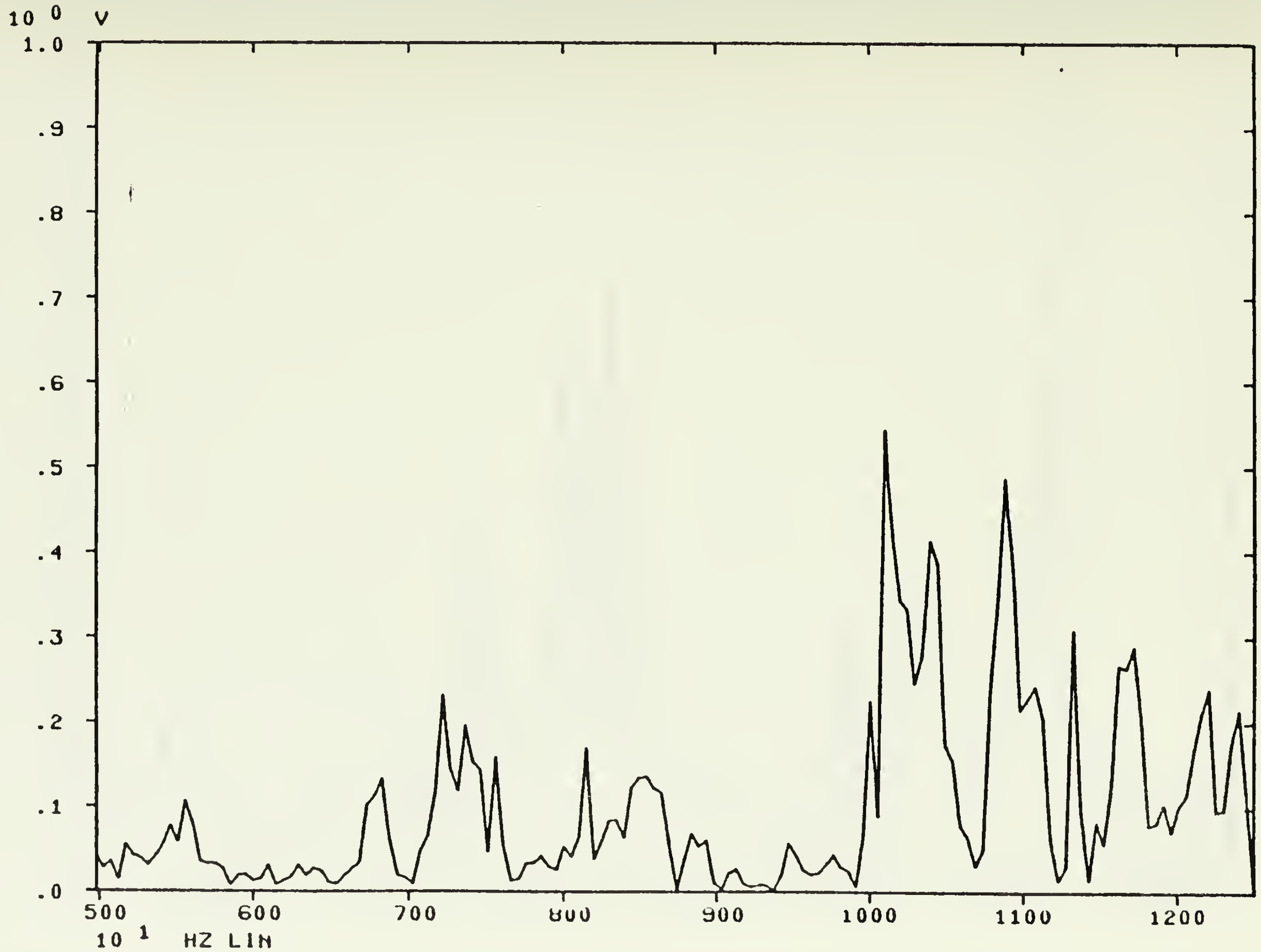

Figure 32. Baseband, 5 tc 12.5 KHz., BC #2, grid location 6.

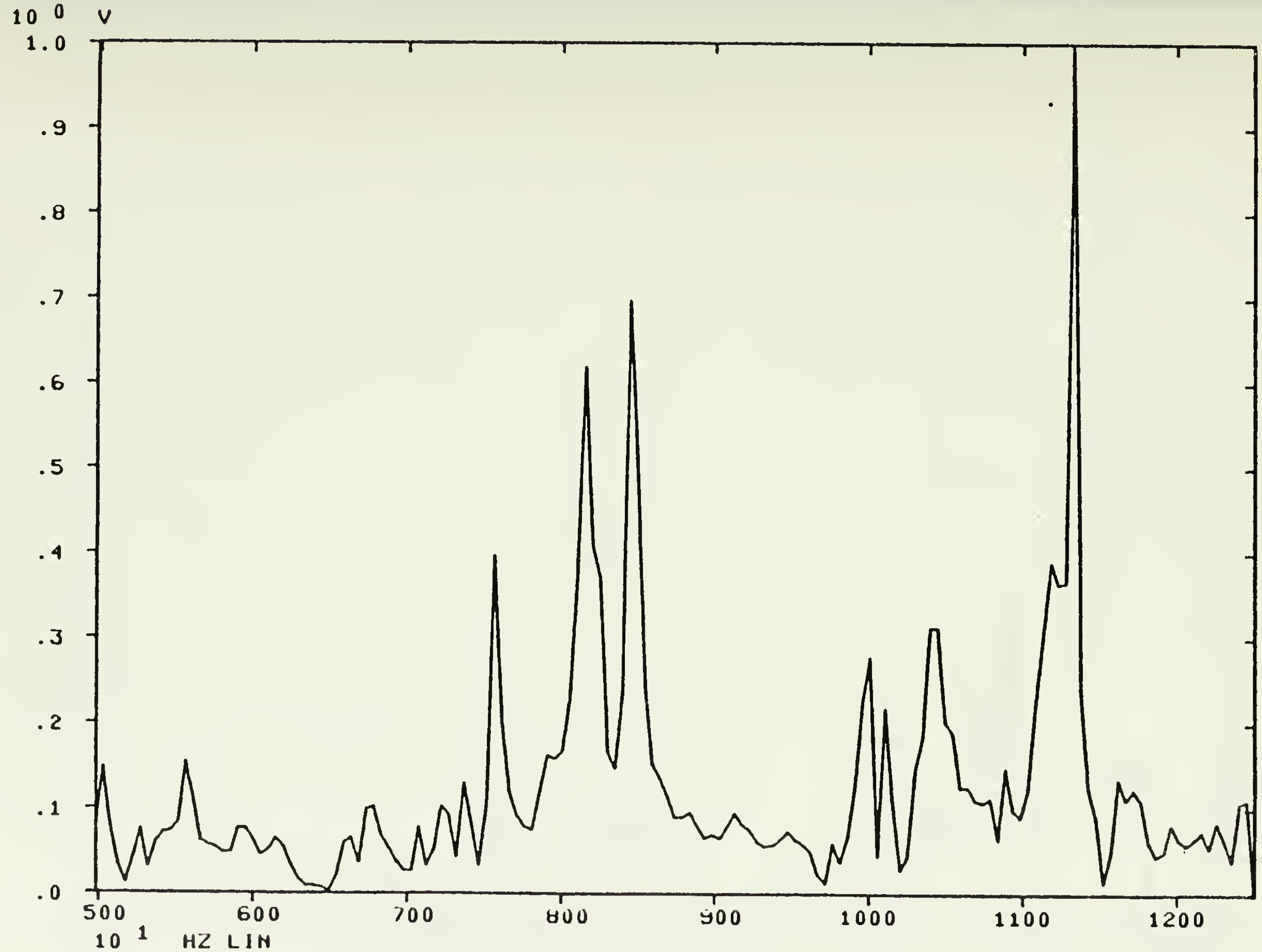

Figure 33. Baseband, 5 to 12.5 KHz., BC #2, grid location 14.

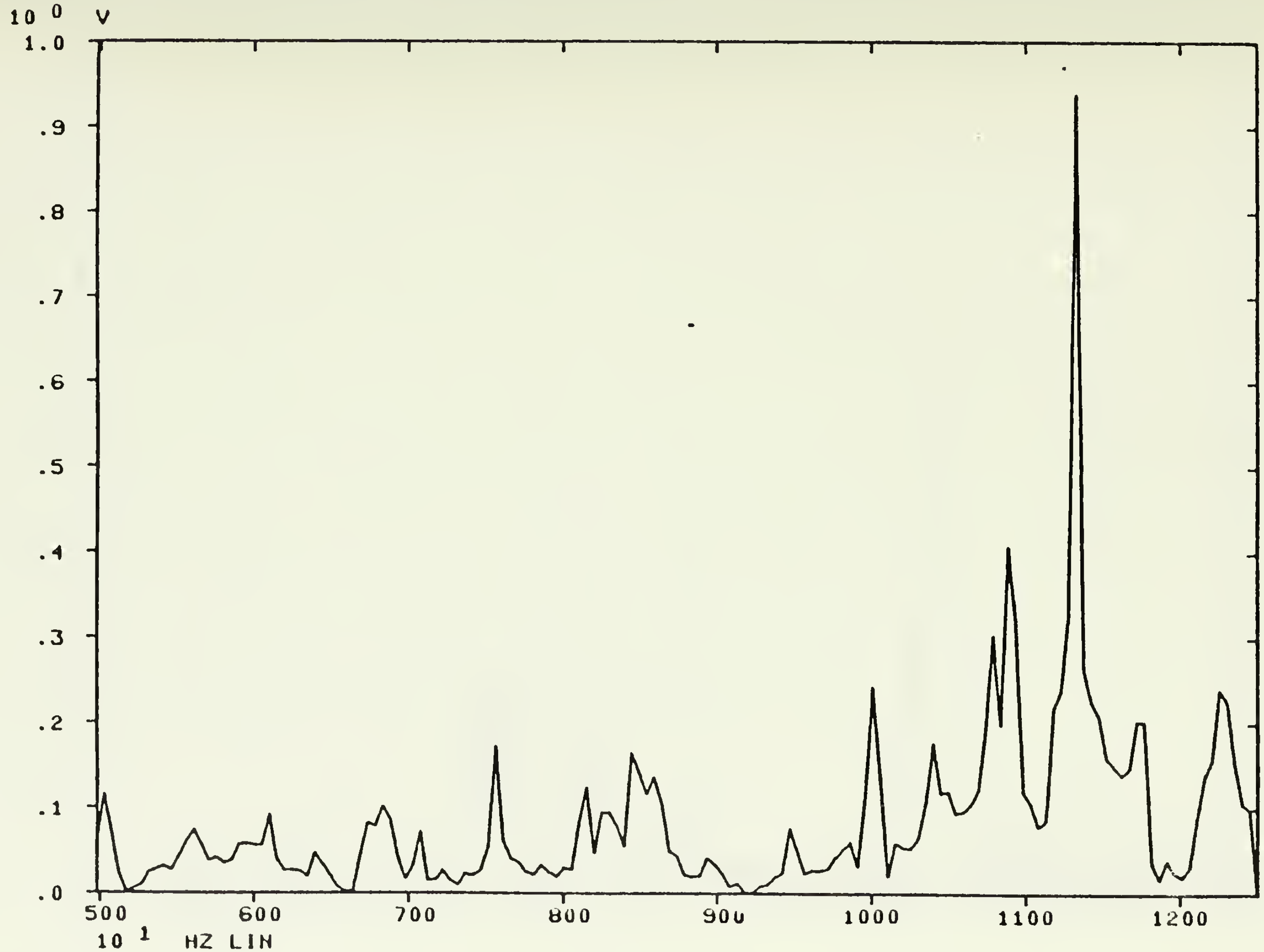

Figure 34. Baseband, 5 to 12.5 KHz., BC #2, grid location 20.

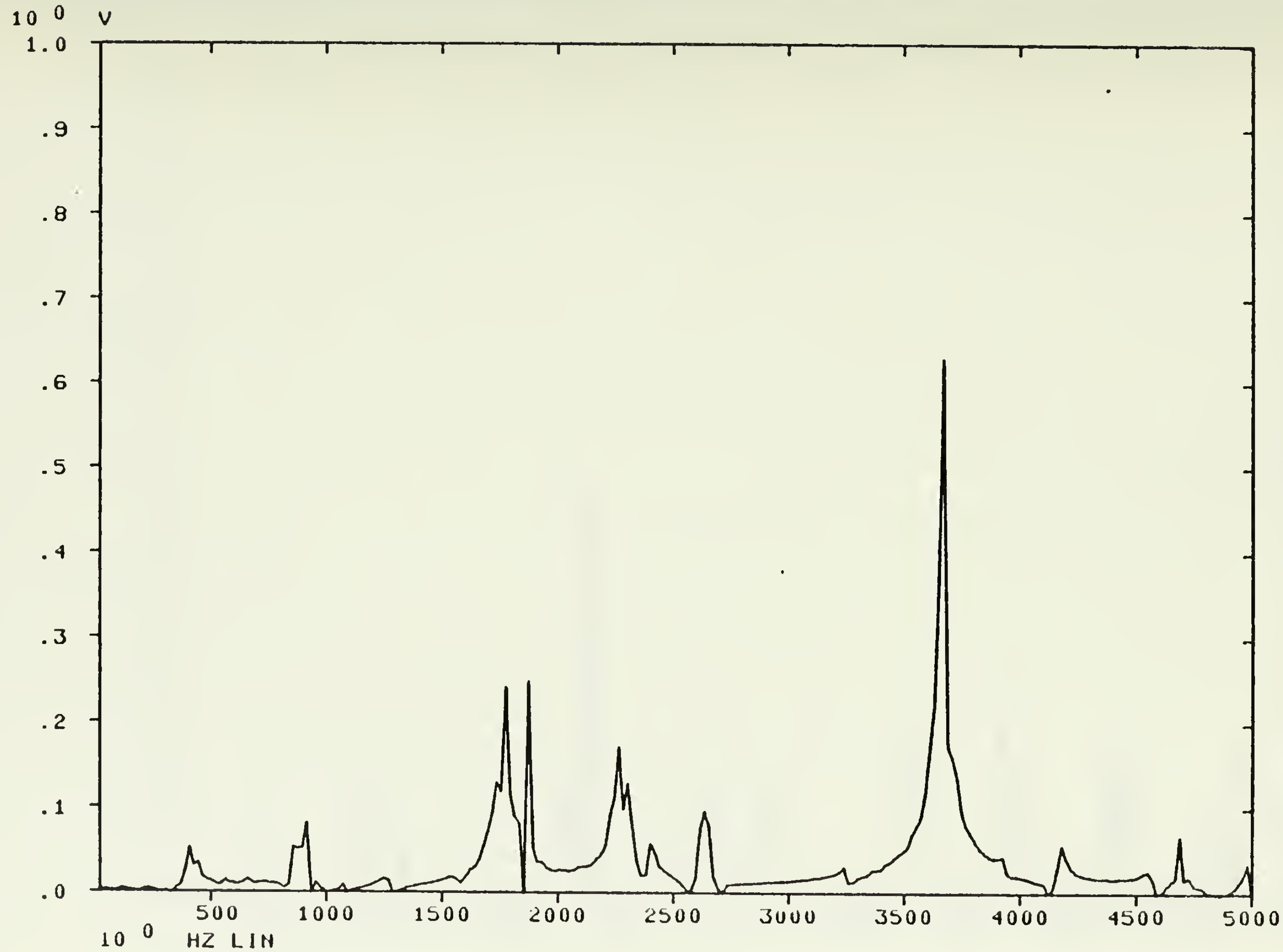

Figure 35. Baseband, 0 to 5 KHz., EC #3, grid location 3.

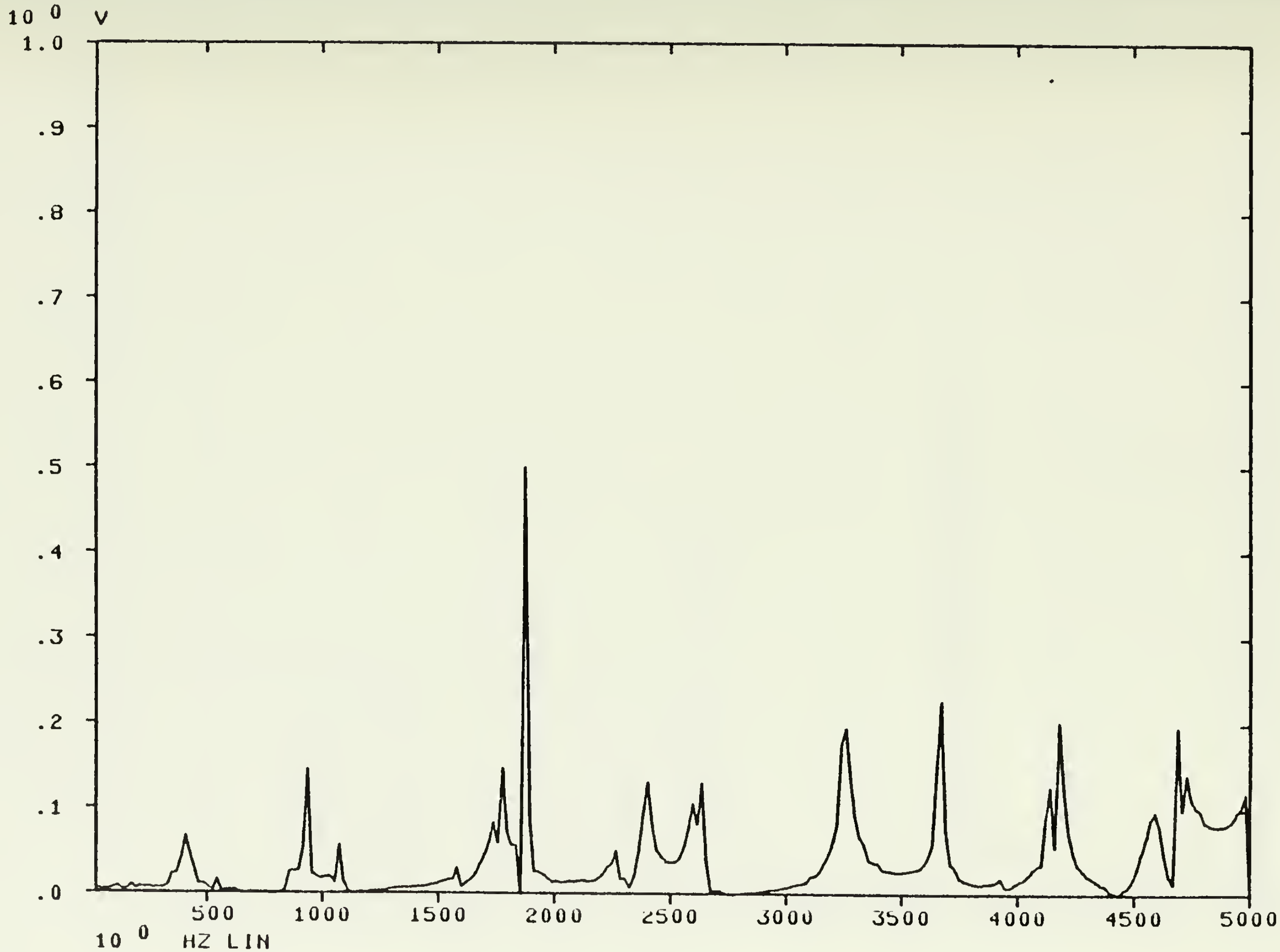

Figure 36. Baseband, 0 to 5 KHz., EC #3, grid location 6.

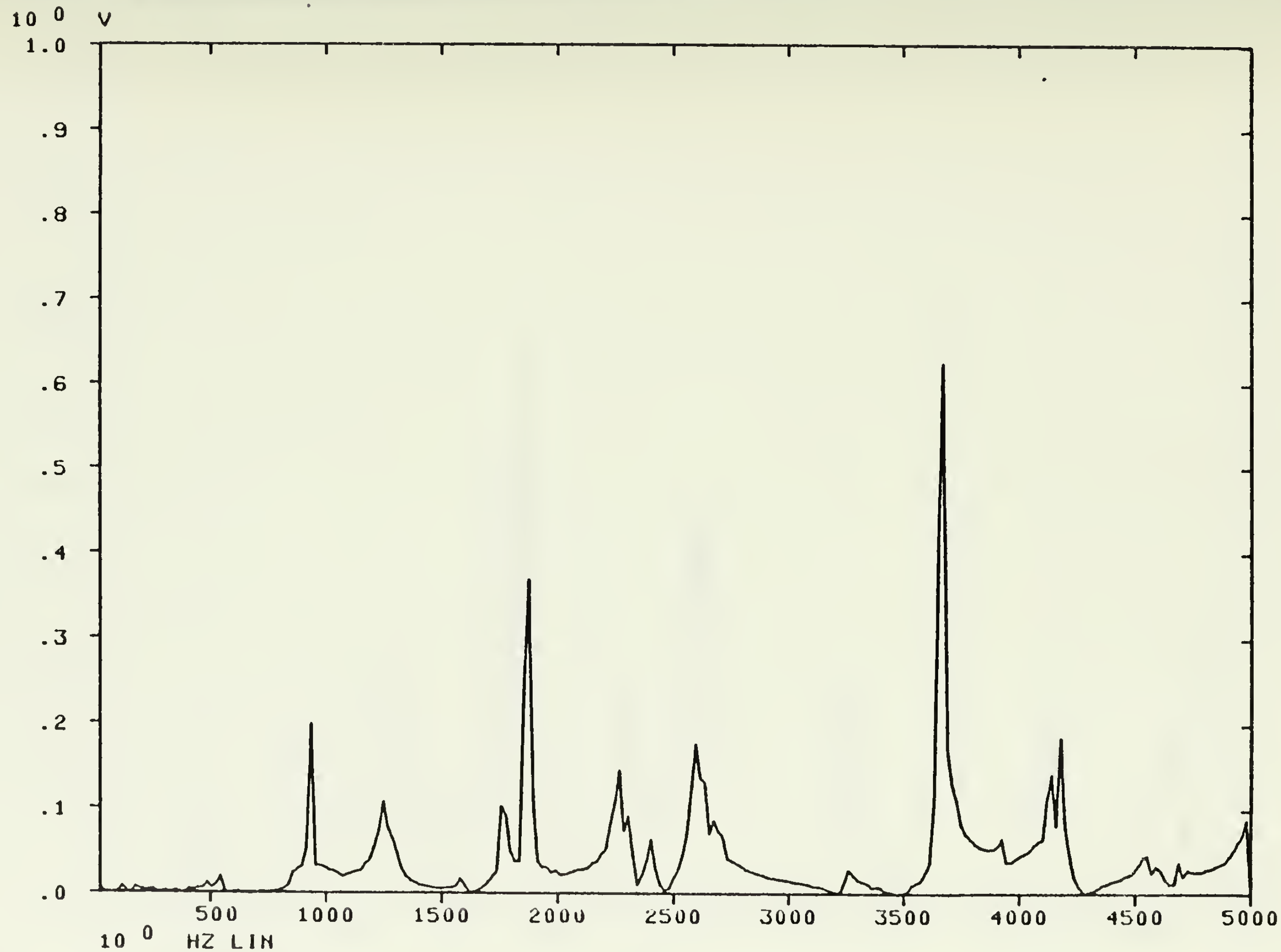

Figure 37. Baseband, 0 to 5 KHz., EC #3, grid location 14.

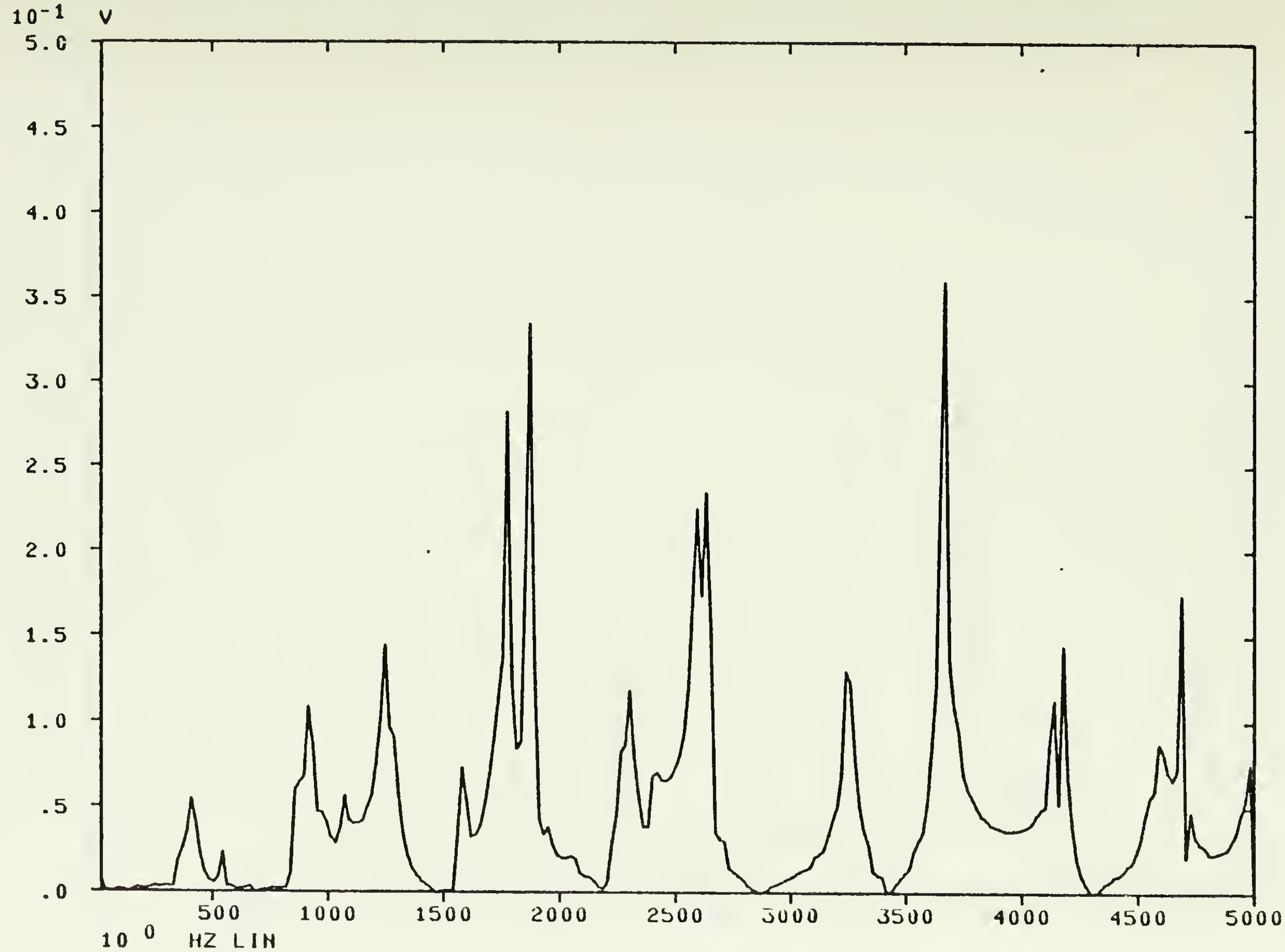

Figure 38. Baseband, 0 tc 5 KHz., EC #3, grid location 20.

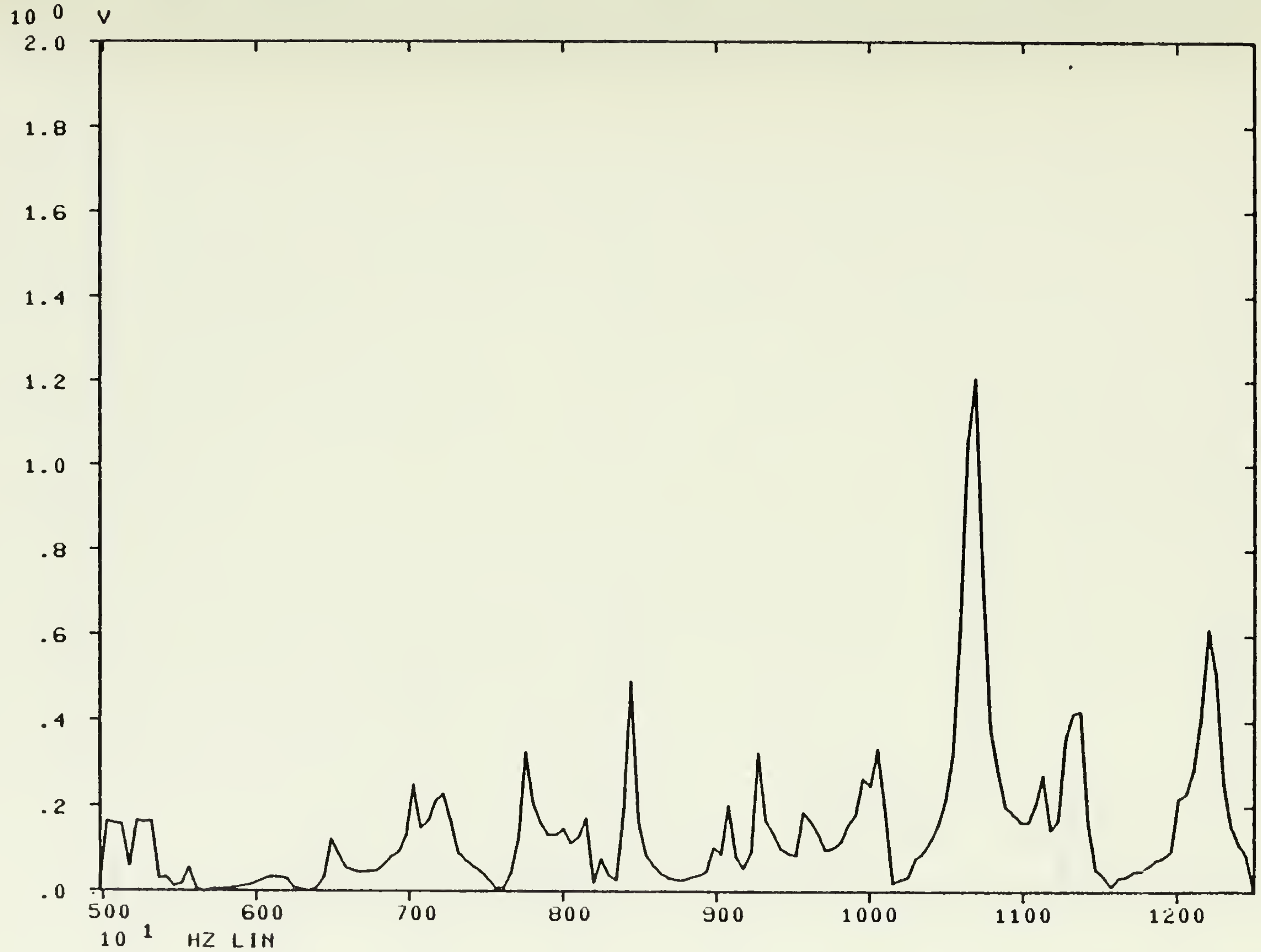

Figure 39. Baseband, 5 to 12.5 KHz., BC #3, grid location 3.

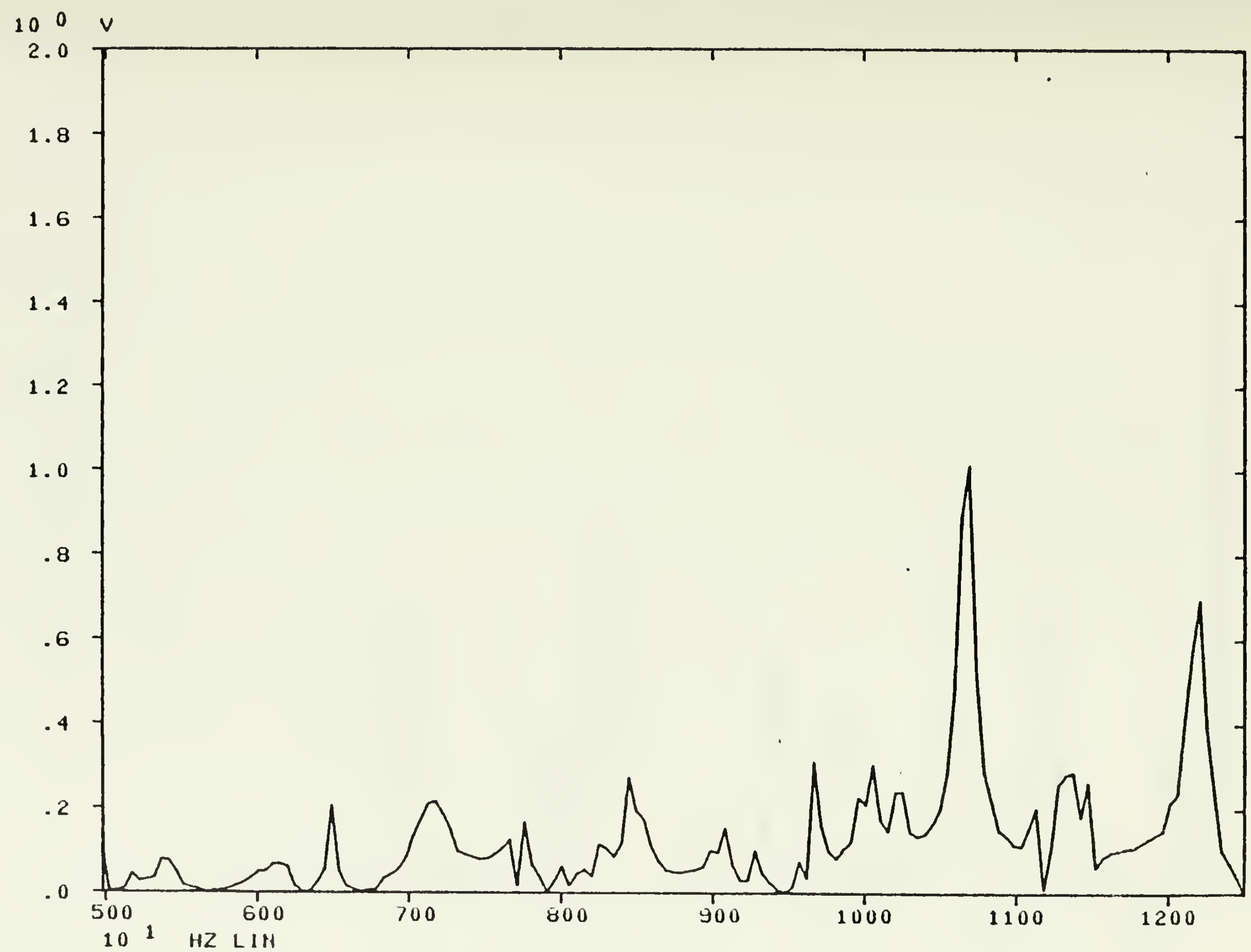

Figure 40. Baseband, 5 to 12.5 KHz., BC #3, grid location 6.

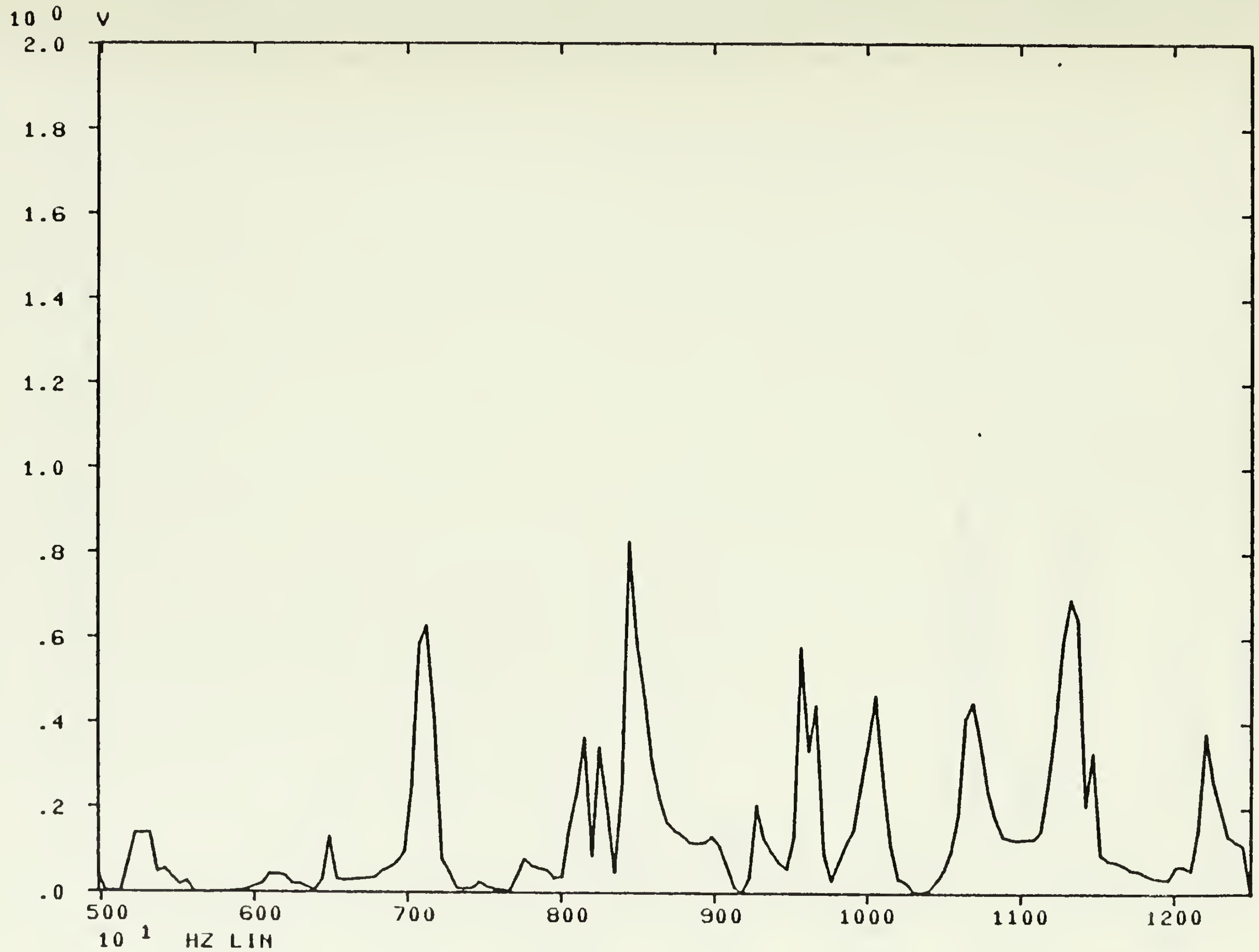

Figure 41. Baseband, 5 to 12.5 KHz., BC #3, grid location 14.

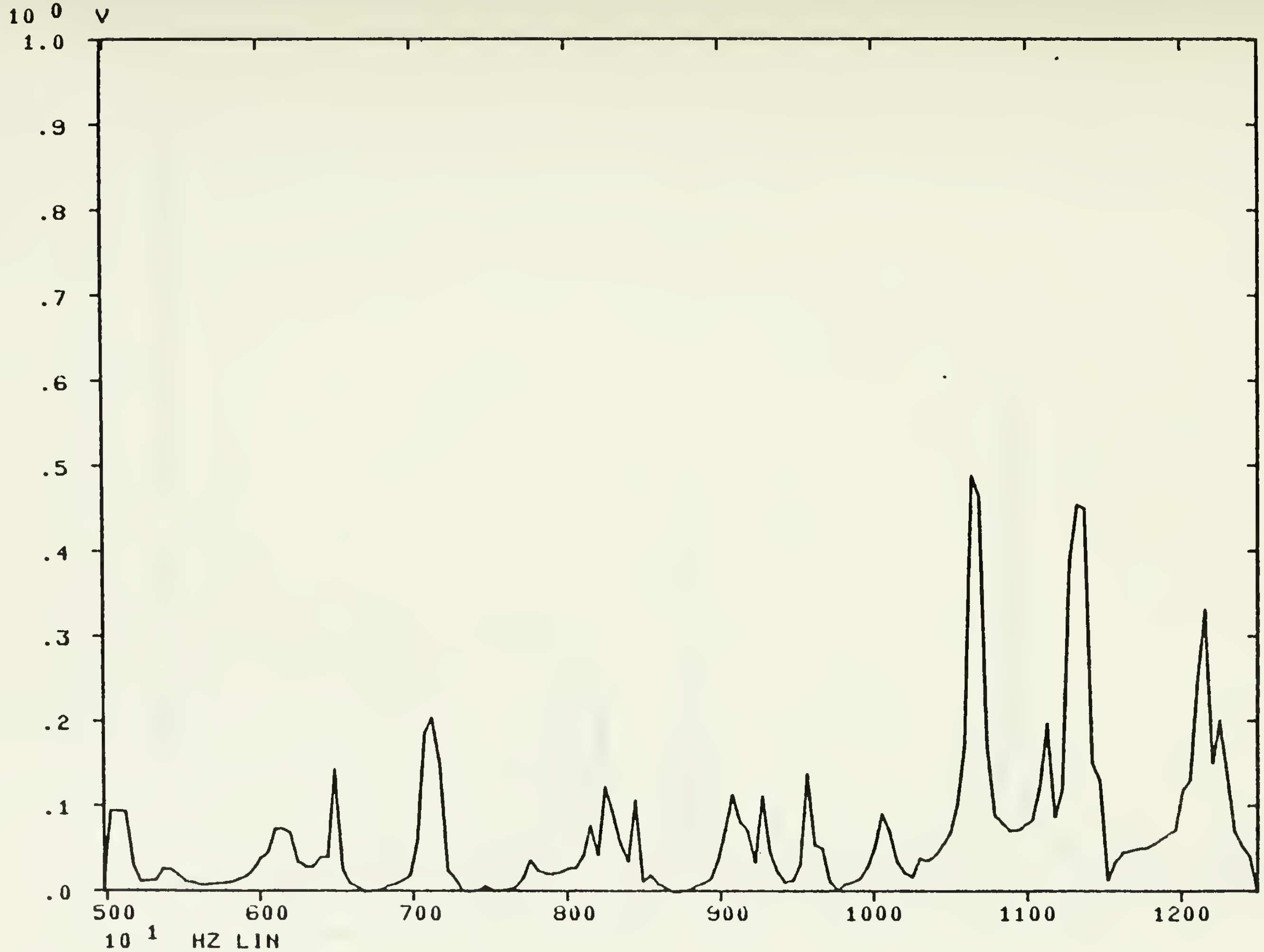

Figure 42. Baseband, 5 to 12.5 KHz., BC #3, grid location 20.

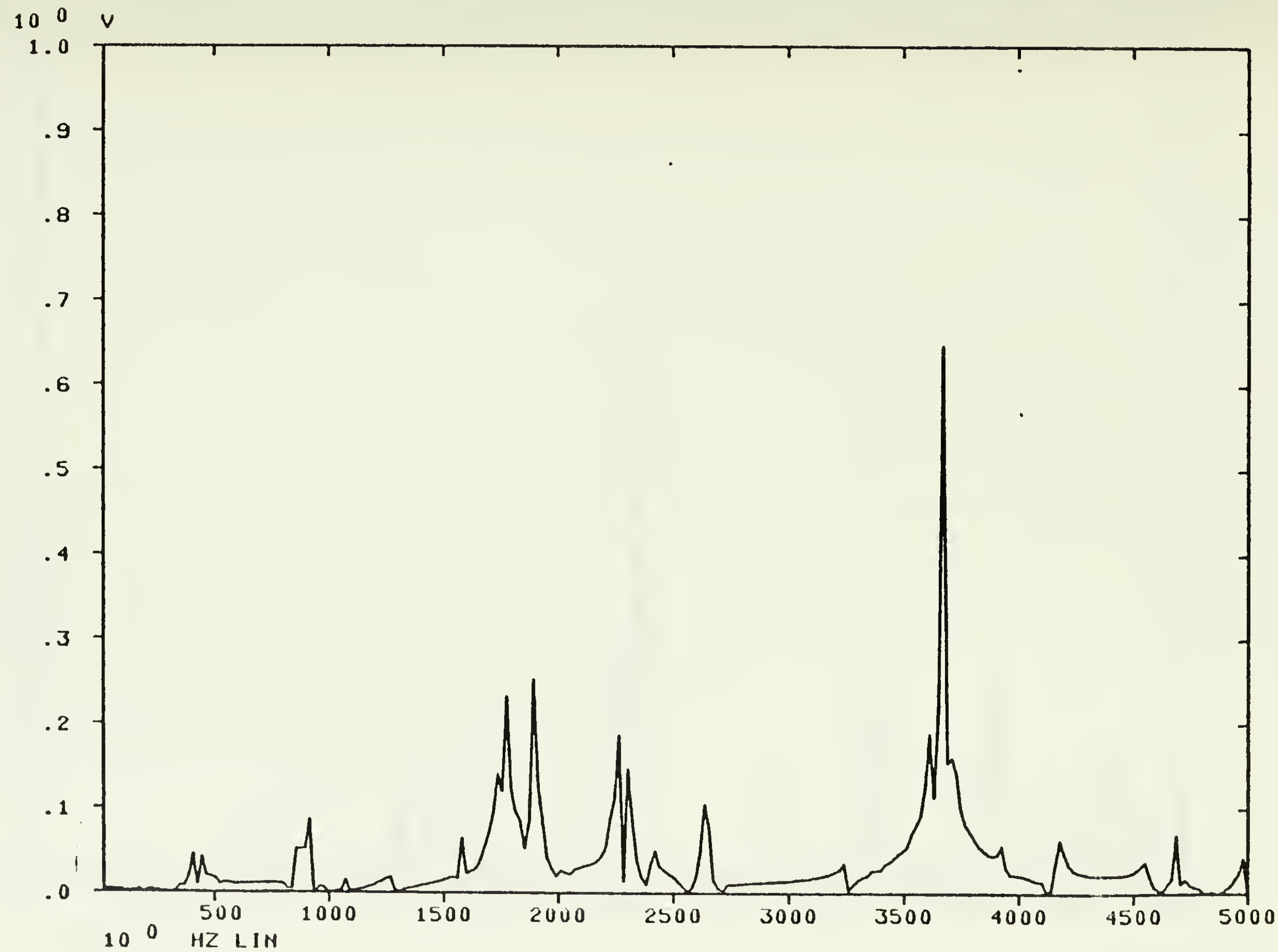

Figure 43. Baseband, 0 to 5 KHz., EC #4, grid location 3.

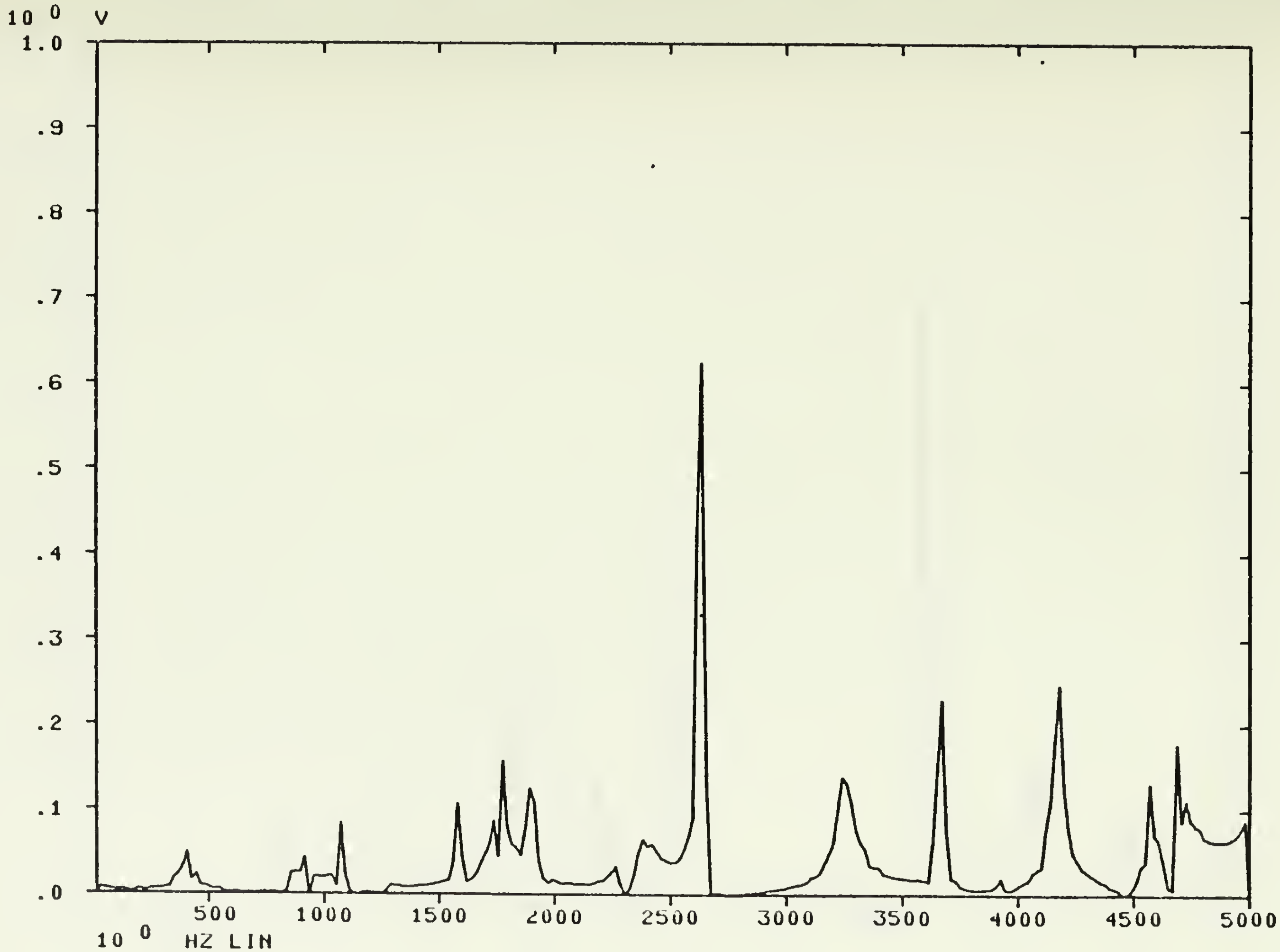

Figure 44. Baseband, 0 tc 5 KHz., EC #4, grid location 6.

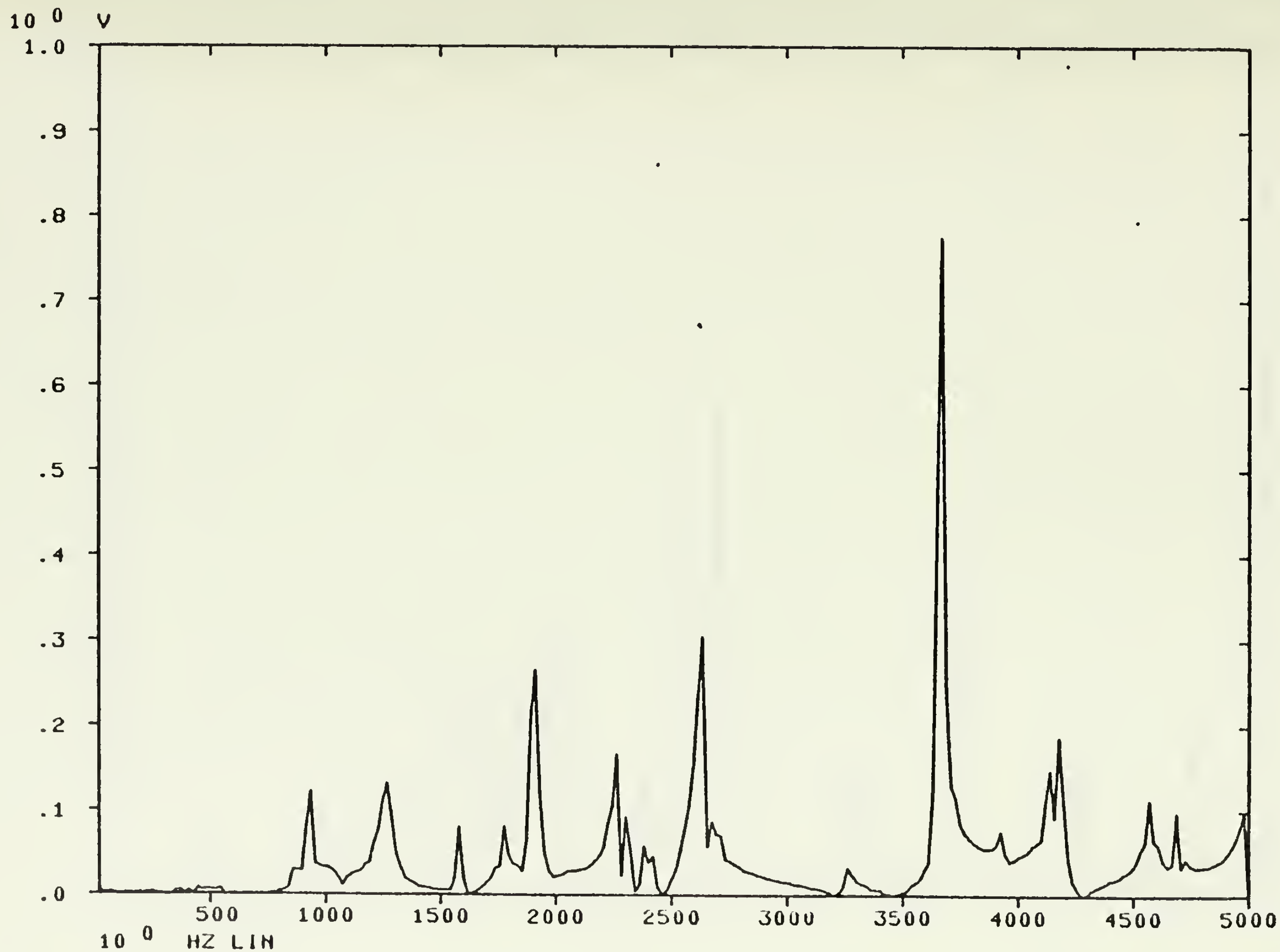

Figure #5. Baseband, 0 to 5 KHz., EC #4, grid location 14.

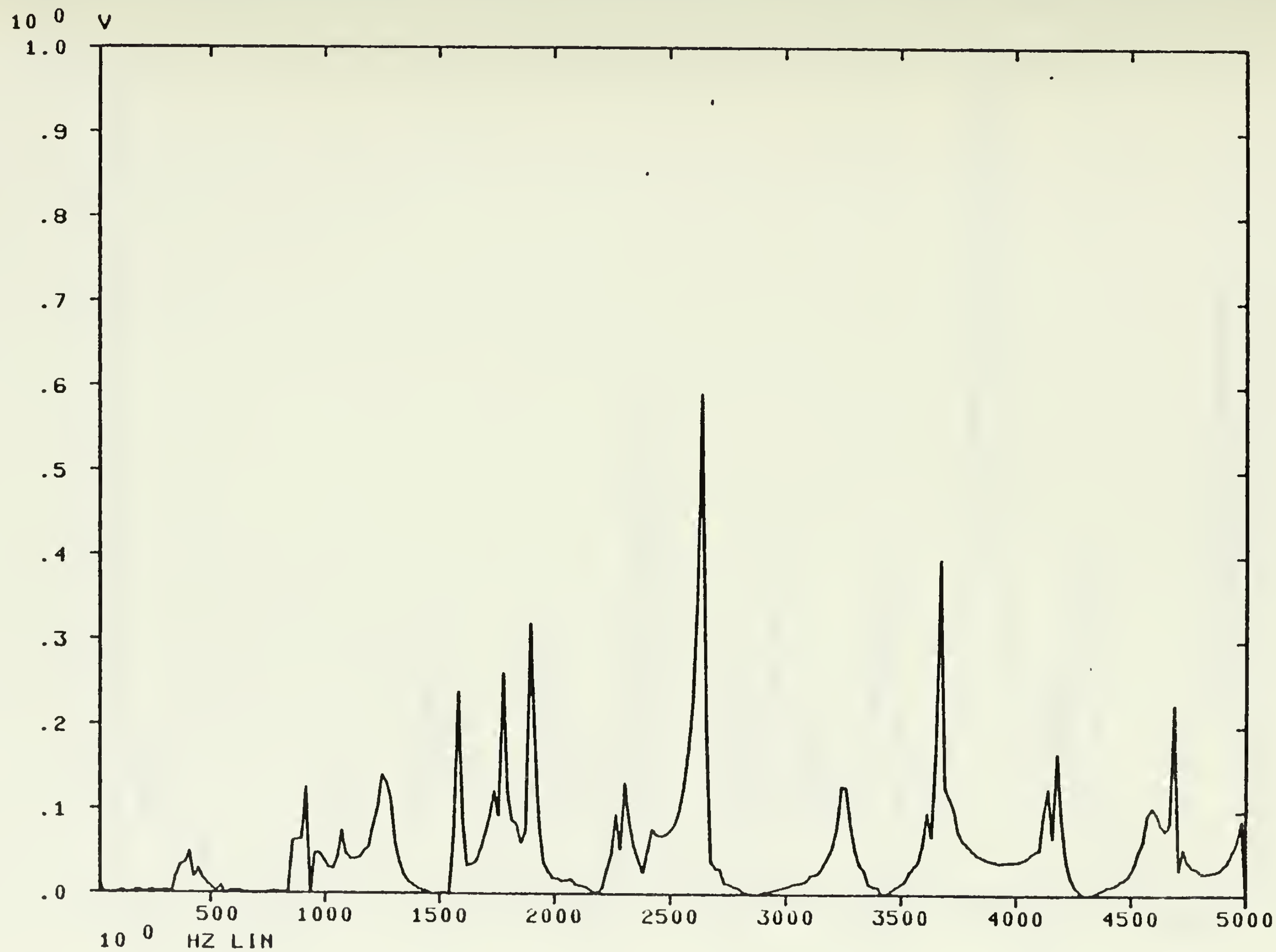

Figure 46. Baseband, 0 to 5 KHz., EC #4, grid location 20.

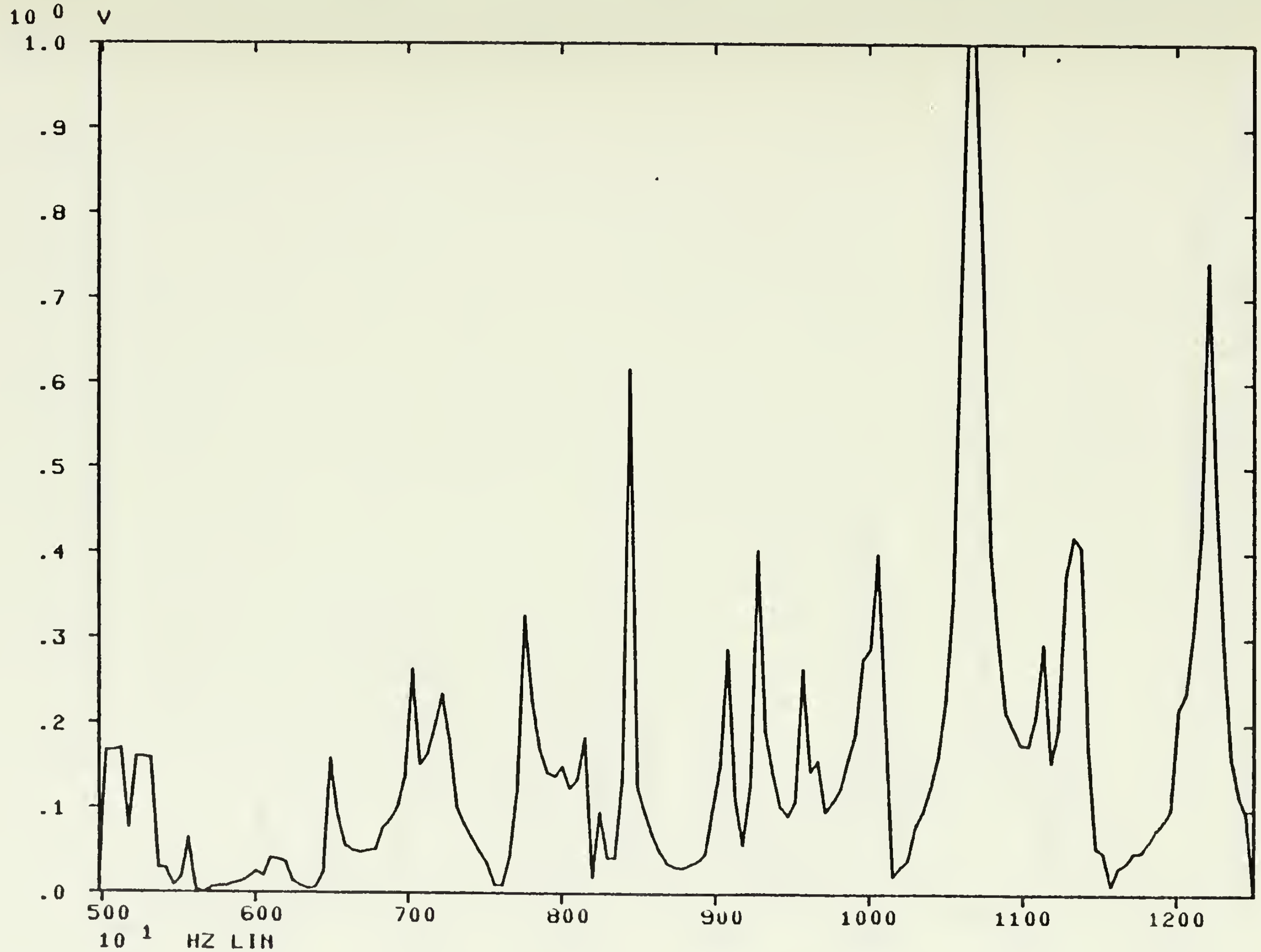

Figure 47. Baseband, 5 to 12.5 KHz., BC #4, grid location 3.

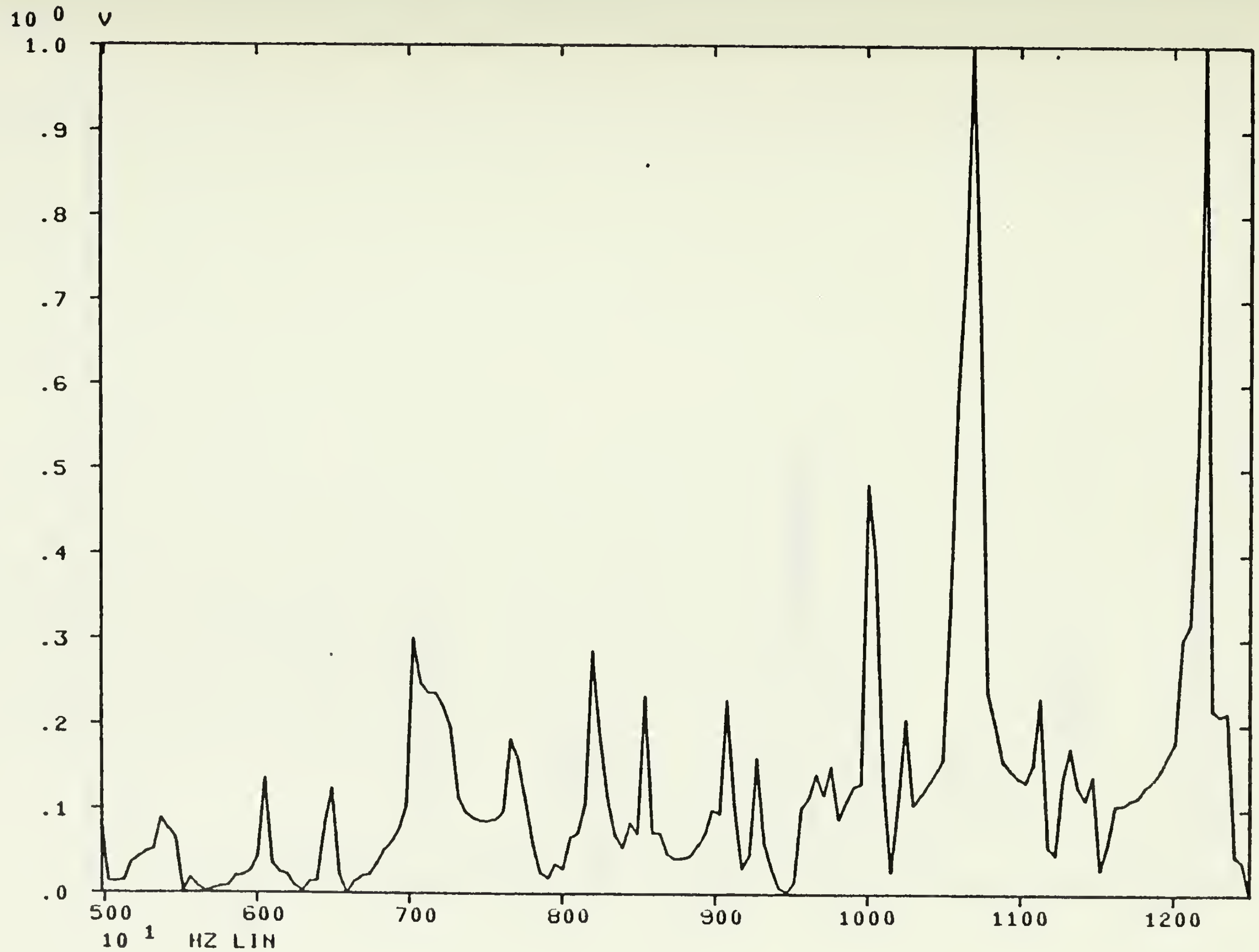

Figure 48. Baseband, 5 tc 12.5 KHz., BC #4, grid location 6.

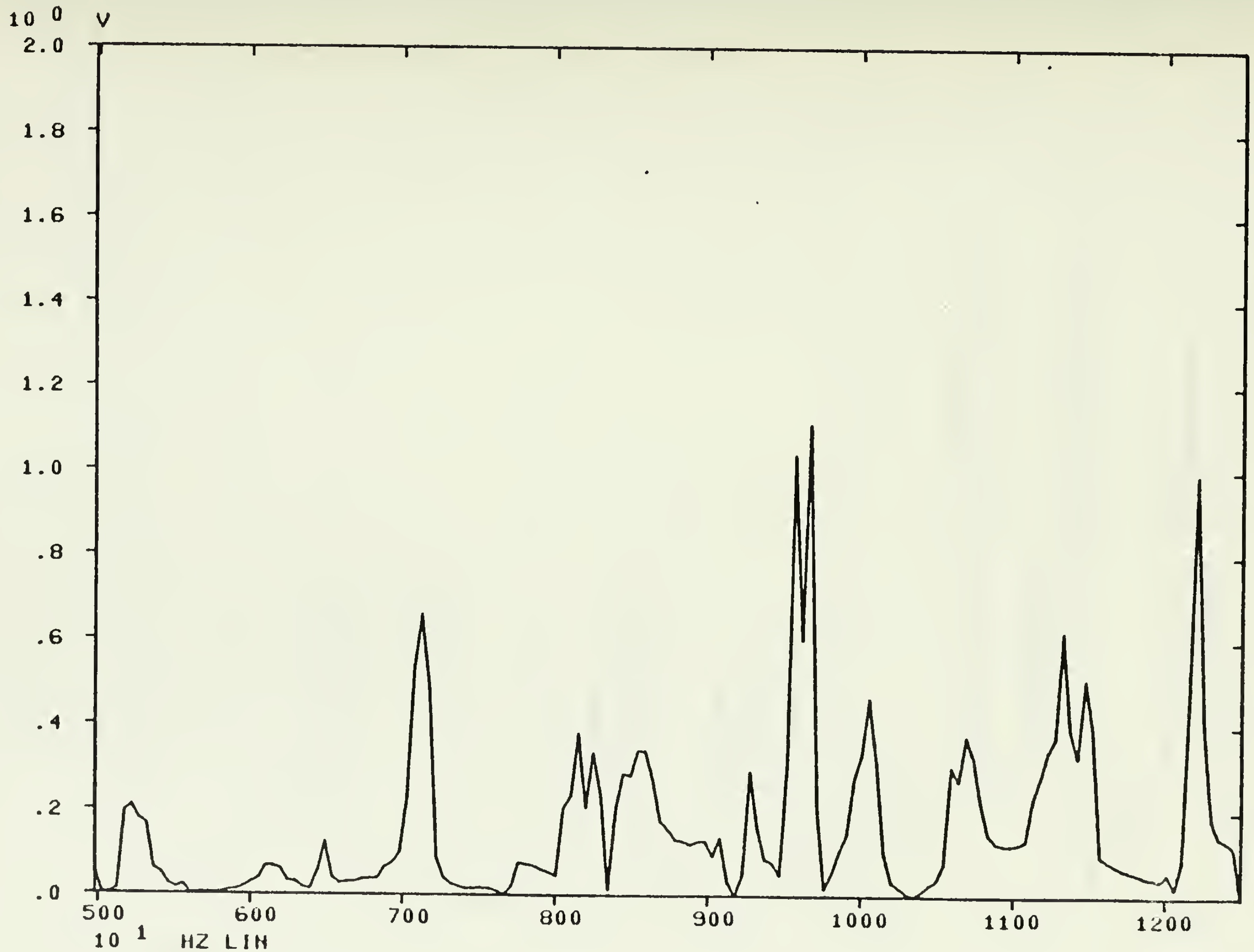

Figure 49. Baseband, 5 to 12.5 KHz., BC #4, grid location 14.

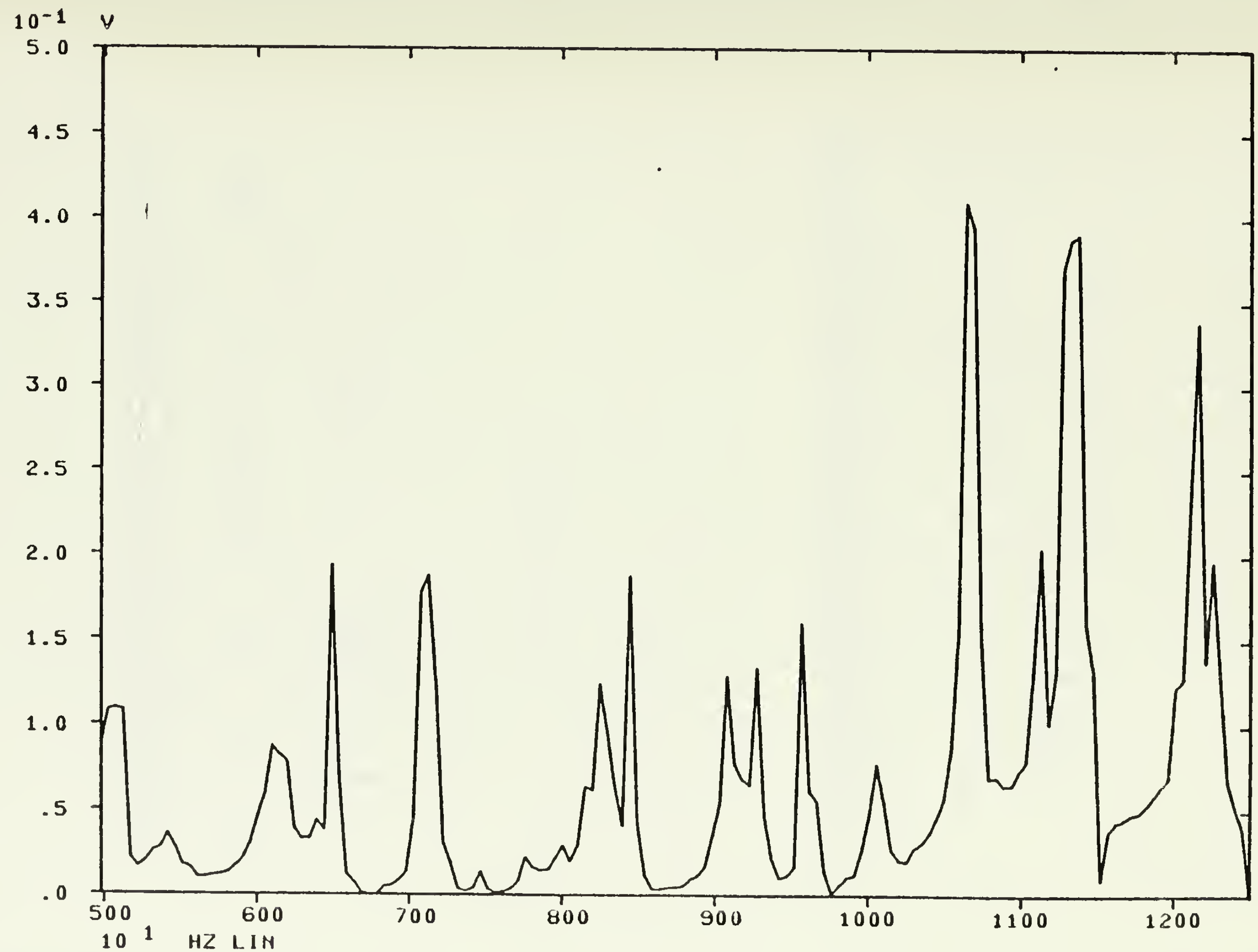

Figure 50. Baseband, 5 to 12.5 KHz., BC #4, grid location 20.

```
  1 L       -1                                     179 Y IF      43      1      2      0
  5 L        0                                     187 J       530      53
  9 L       10                                     192 J        12      -1
 13 Y     5838      1                              197 J       500      50
 18 Y _      32      1                             202 L        12
 24 Y _      30      0                             206 Y W       20      1
 30 Y W      11      1                             212 D
 36 Y W      12      1                             215 Y W       18      1
 42 Y _       1      0                             221 Y _        1      0
 48 Y _       2      1                             227 Y _        2      1
 54 J      100     59                              233 J       100     59
 59 Y _       1  2000D                             238 Y _        1  2000D
 65 Y IF      1      1      2     -2               244 Y IF       1      1      9      0
 73 Y      100      0     -2                       252 L        13
 79 J        9     -1                              256 Y W       19      1
 84 Y      100     99     -2                       262 Y _        1      0
 90 L        9                                     268 Y _        2      1
 94 J      100     58                              274 J       100     59
 99 L       11                                     279 Y _        1  2000D
103 Y W      16      1                             285 Y IF       1      1      1      0
109 Y _       1      1                             293 J        14     -1
115 Y _       2    500                             298 J        11     -1
121 J      100     59                              303 Y W       17      1
126 Y _      21  2000D                             309 Y _        1      1
132 Y W      13      1                             315 Y _        2    500
138 Y _       1      0                             321 J       100     59
144 Y _       2      1                             326 Y _       20  2000D
150 J      100     59                              332 MS       31    20D
155 Y _       1  2000D                             337 MS       21      6
161 Y IF      1      0      2      0               342 J        13     -1
169 J      510     51                              347 L        14
174 J       12     -1                              351 .
```

Figure 51. Locally developed keyboard user program, LABEL "1".

```
 1 L      -5
 5 L       0
 9 Y    5838      20
14 Y W        1        1
20 Y W        2       .1
26 Y R        1
31 Y W        3        1
37 Y R        2
42 Y    5821      35
47 Y    5809
51 Y    5814
55 Y    5829       0       10       20
62 Y    5815
66 Y    5816
70 Y    5817
74 .
```

Figure 52. Locally developed keyboard user program, LABEL "5".

```
  1 L      -10                       103 CL      10
  5 L        0                       107 MS      31      11
  9 Y     5838        1              112 MS      11
 14 Y W      16        1             116 Y       40   2000D   2001D
 20 Y R      10                      122 L       20
 25 Y     5838        2              126 Y       45       3       1
 30 Y W      25        1             132 SP       3       2       2
 36 Y R    2000                      138 #       20     10D       0
 41 Y W      26        1             144 CH       3       2       2
 47 Y R    2001                      150 X<       3
 52 Y W      27        1             154 X>       8
 58 Y      100        0      -2      158 X<       4
 64 D                                162 X>       1
 67 CL       1                       166 X<       5
 71 CL       2                       170 X>       2
 75 CL       3                       174 X<       6
 79 CL       4                       178 X>       3
 83 CL       5                       182 X<       7
 87 CL       6                       186 X>       4
 91 CL       7                       190 X<       8
 95 CL       8                       194 TR
 99 CL       9                       197 .
```

Figure 53. Locally developed keyboard user program, LABEL "10".

```
  1 L      -15                        95 Y W      32      1
  5 L        0                       101 Y P      10
  9 Y _        5       1             106 Y P      11
 15 L        2                       111 D
 19 CL       5D                      114 Y A-     10      10D     20
 23 Y A+       5       5D      1     121 Y _      13      1
 30 /        2       20      0       127 L      12
 36 Y     5838        2              131 X<     13D
 41 Y W       31       1             135 MS     31      10D
 47 Y R       10                     140 MS     21
 52 Y _       11       1             144 Y A+     10      10D      1
 58 L       10                       151 Y A+     13      13D      1
 62 MS      31       10D             158 /      12      20      0
 67 MS      11                       164 Y A-     10      10D      1
 71 X>      11D                      171 Y P      10
 75 Y A+      10       10D     1     176 Y W      33      1
 82 Y A+      11       11D     1     182 Y W      32      1
 89 /       10       20      0       188 .
```

Figure 54. Locally developed keyboard user program, LABEL "15".

```
  1 L      -16
  5 L        0
  9 Y     5838      2
 14 Y W      34       1
 20 Y R      10
 25 BS    1024
 29 MS      31     100
 34 MS      11
 38 BS     512
 42 Y      117
 46 Y      117      0       0
 52 Y      117      1       1
 58 Y      117      0       0
 64 L        1
 68 Y     5821     35
 73 Y     5881      3
 78 Y     5882
 82 Y       72      0
 87 Y W      35       1
 93 D
 96 L        3
100 Y     5881      4
105 Y     5882      2
110 Y       72      1
115 .
```

Figure 55. Locally developed keyboard user program, LABEL "16".

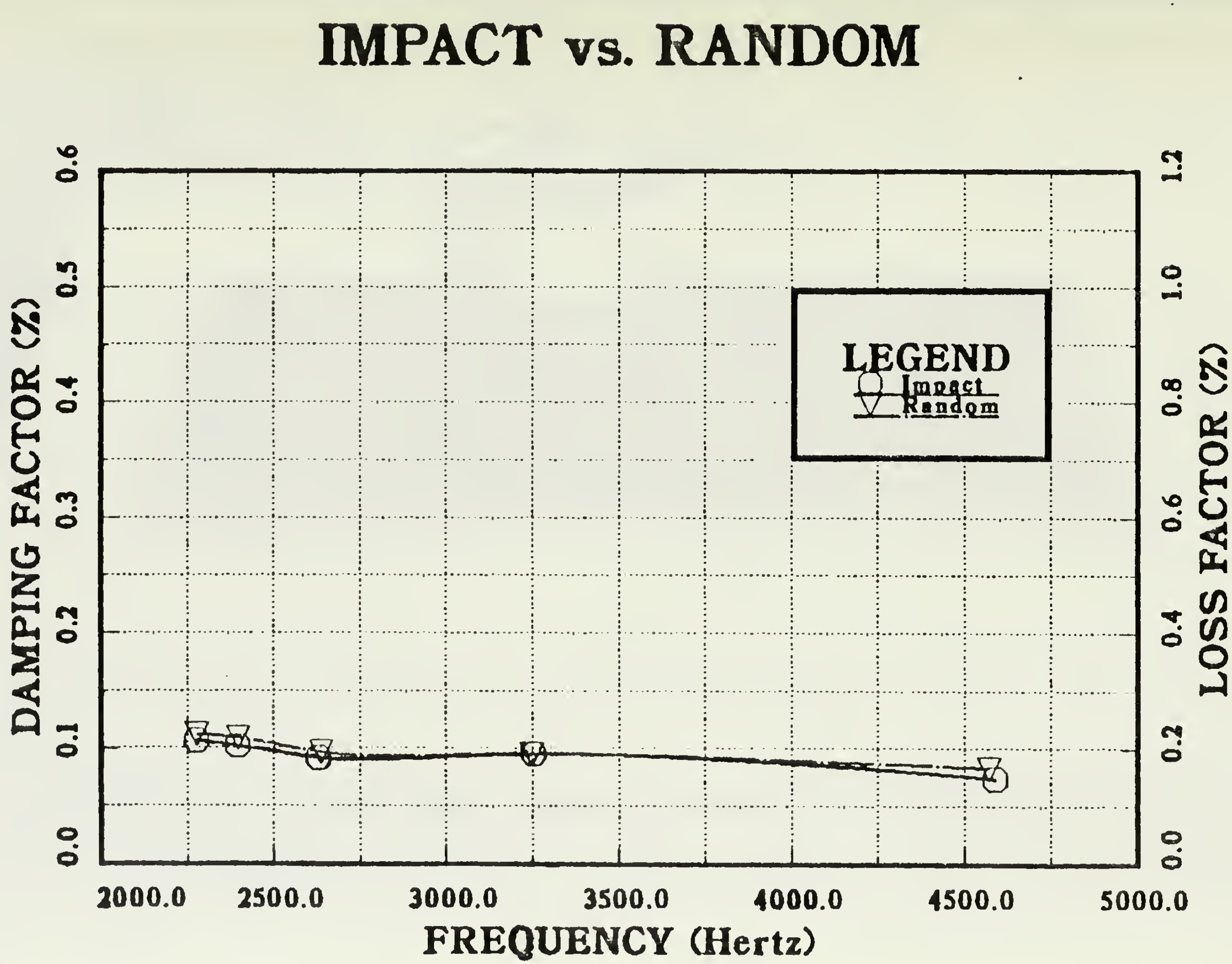

Figure 56. Damping Factor vs. Frequency, Impact vs. Random.

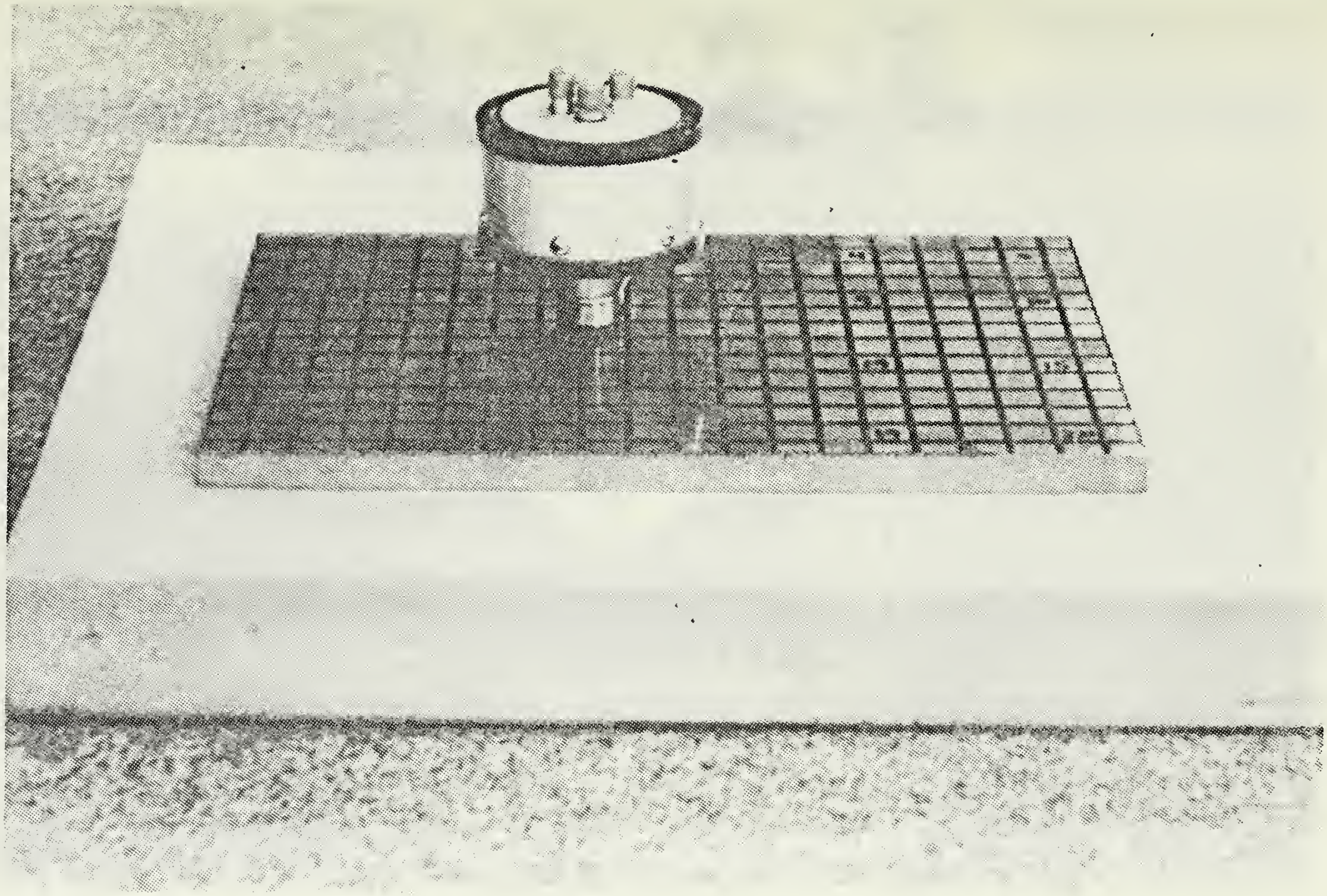

Figure 57. FOAM (pad), Boundary condition #1.

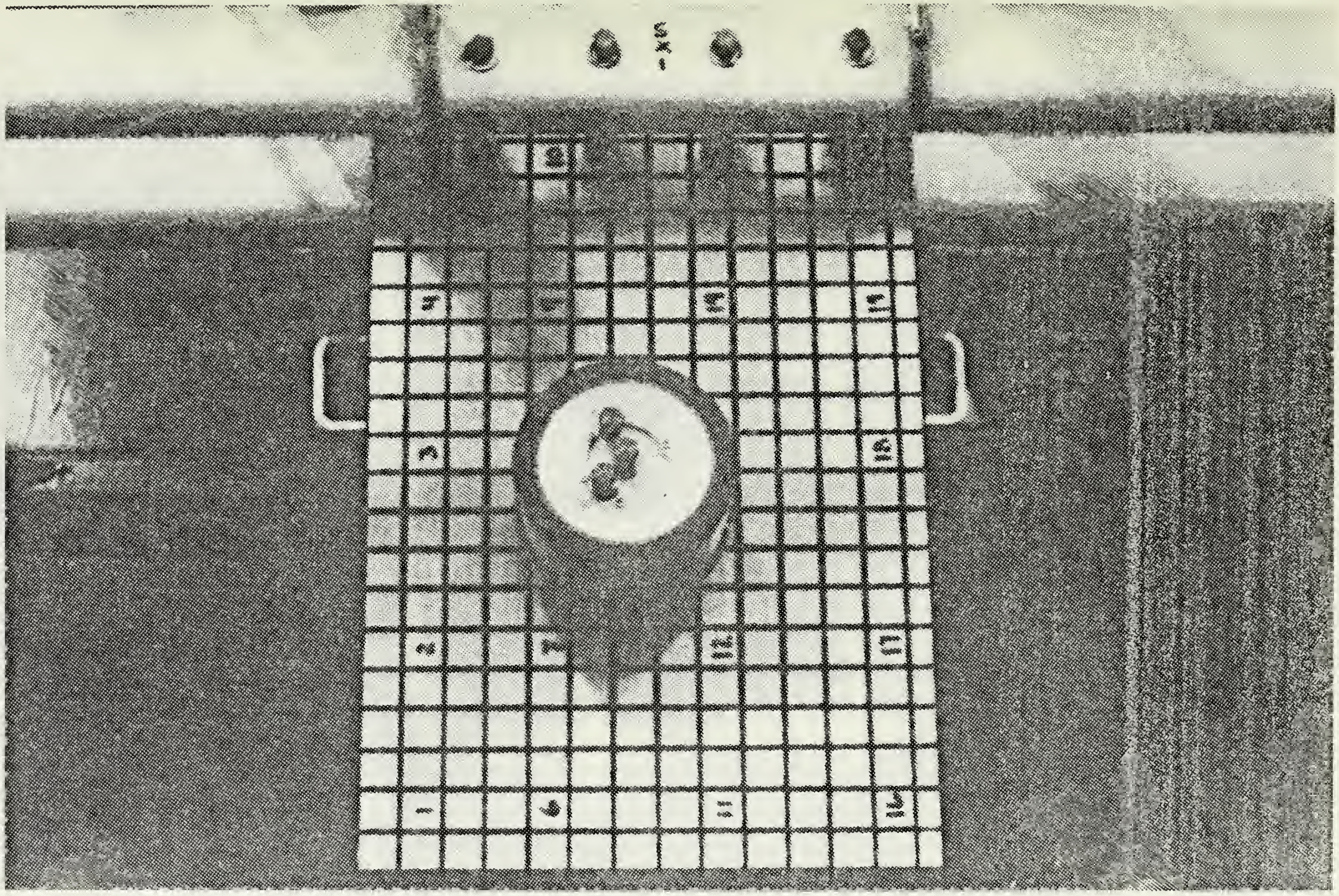

Figure 58. BOLTED (tank), Boundary condition #2.

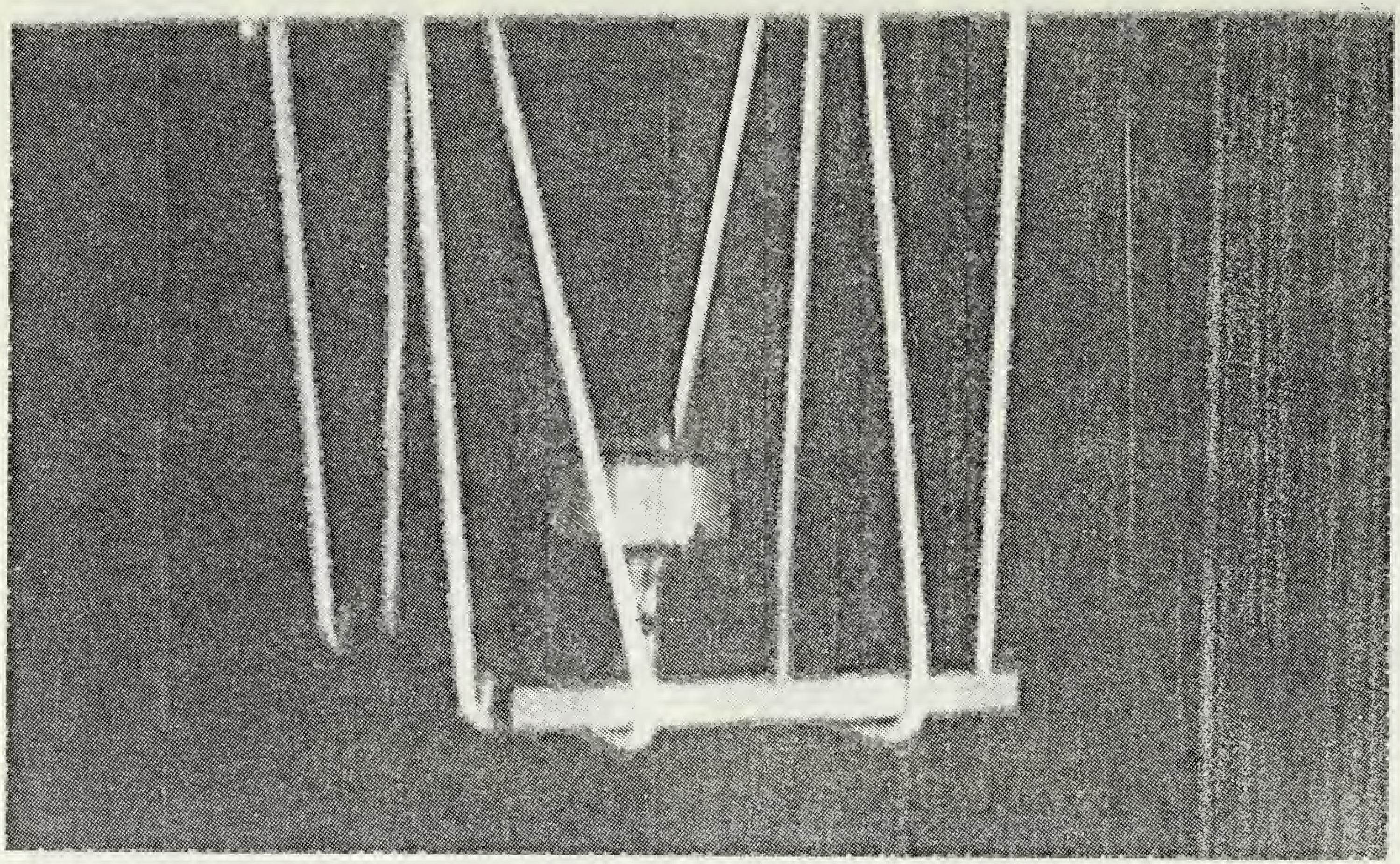

Figure 59. CHCBD (tank), Boundary condition #3, view 1.

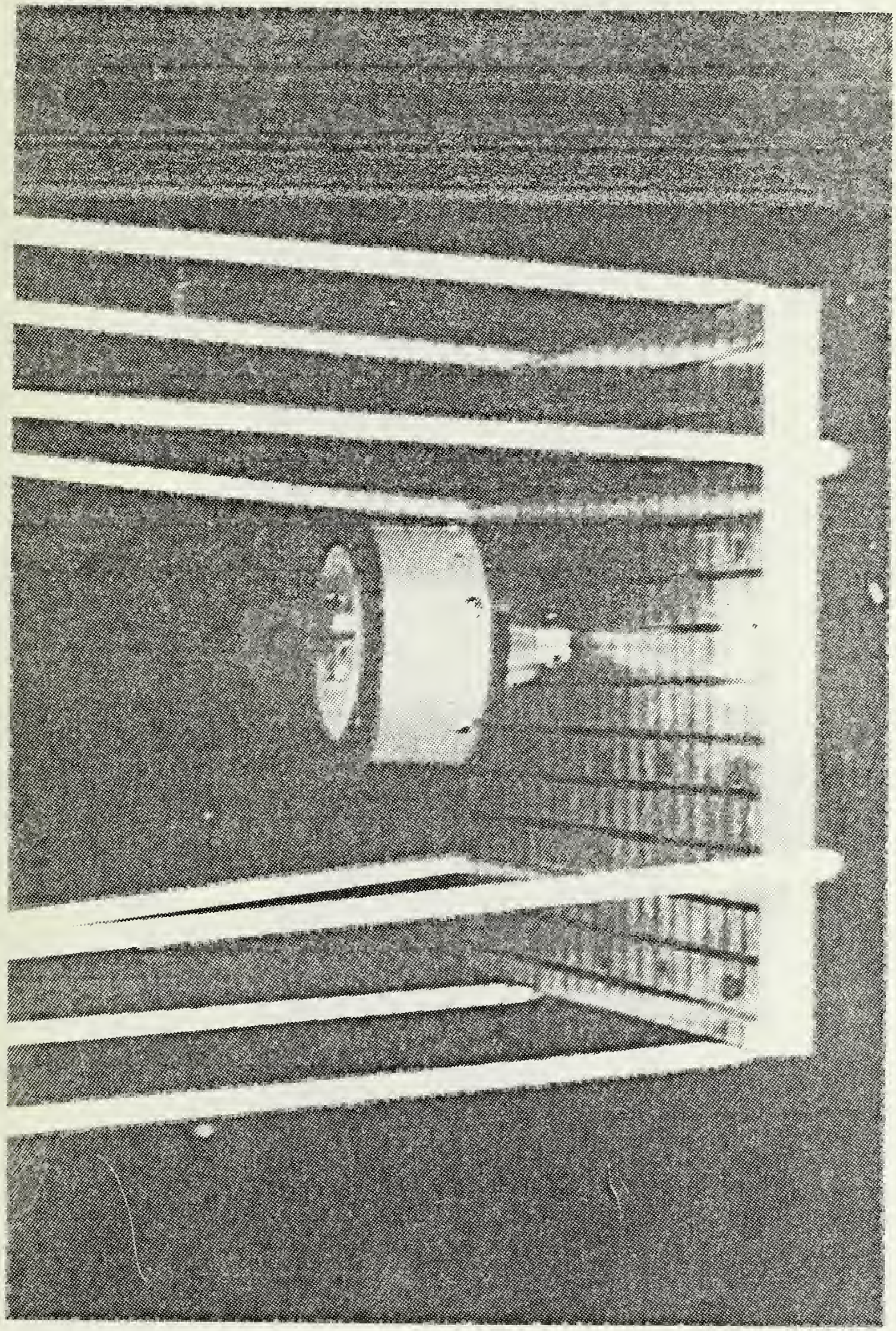

Figure 60. CHORD (tank), Boundary condition #3. view 2.

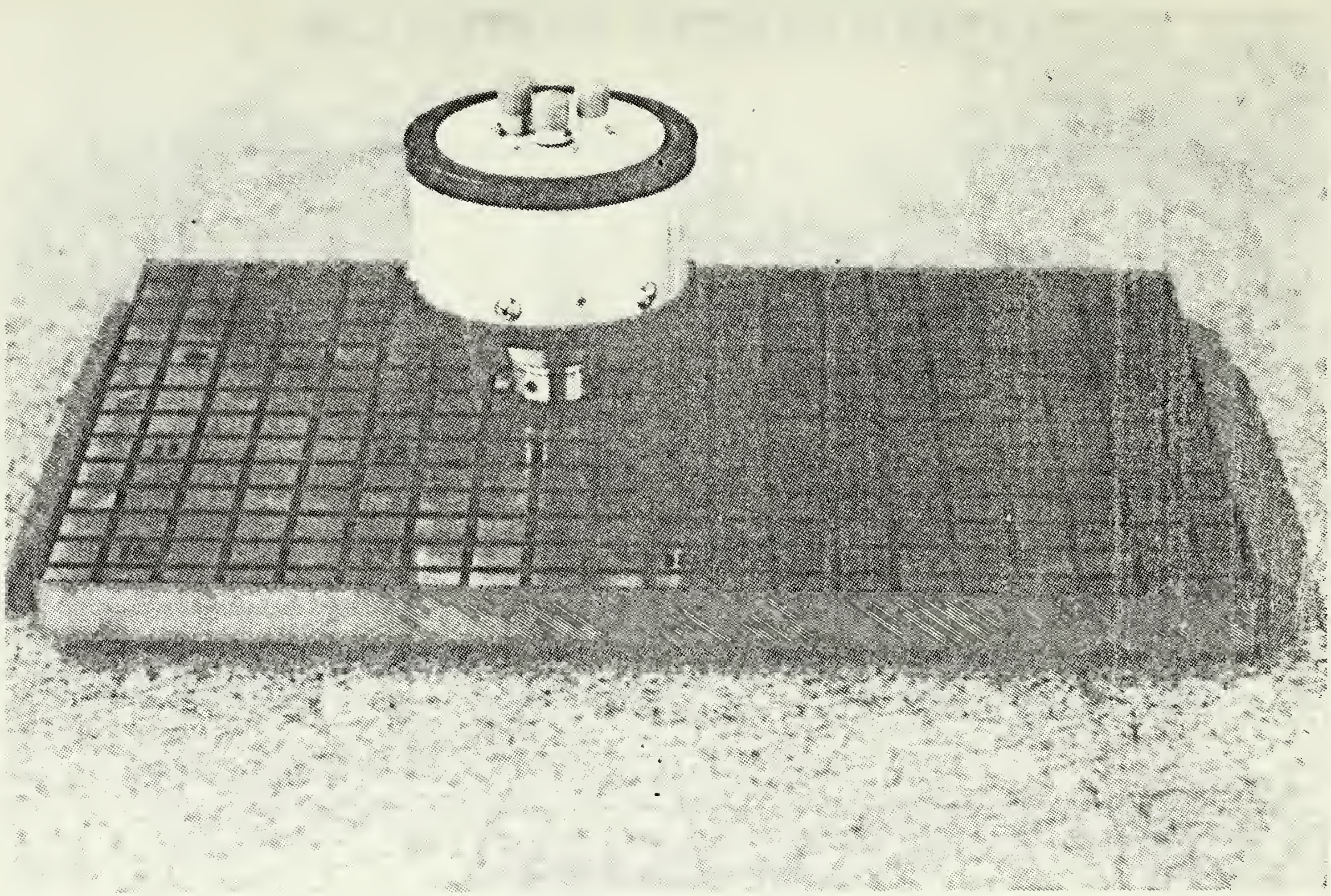

Figure 61. FOAM (ends), Boundary condition #4.

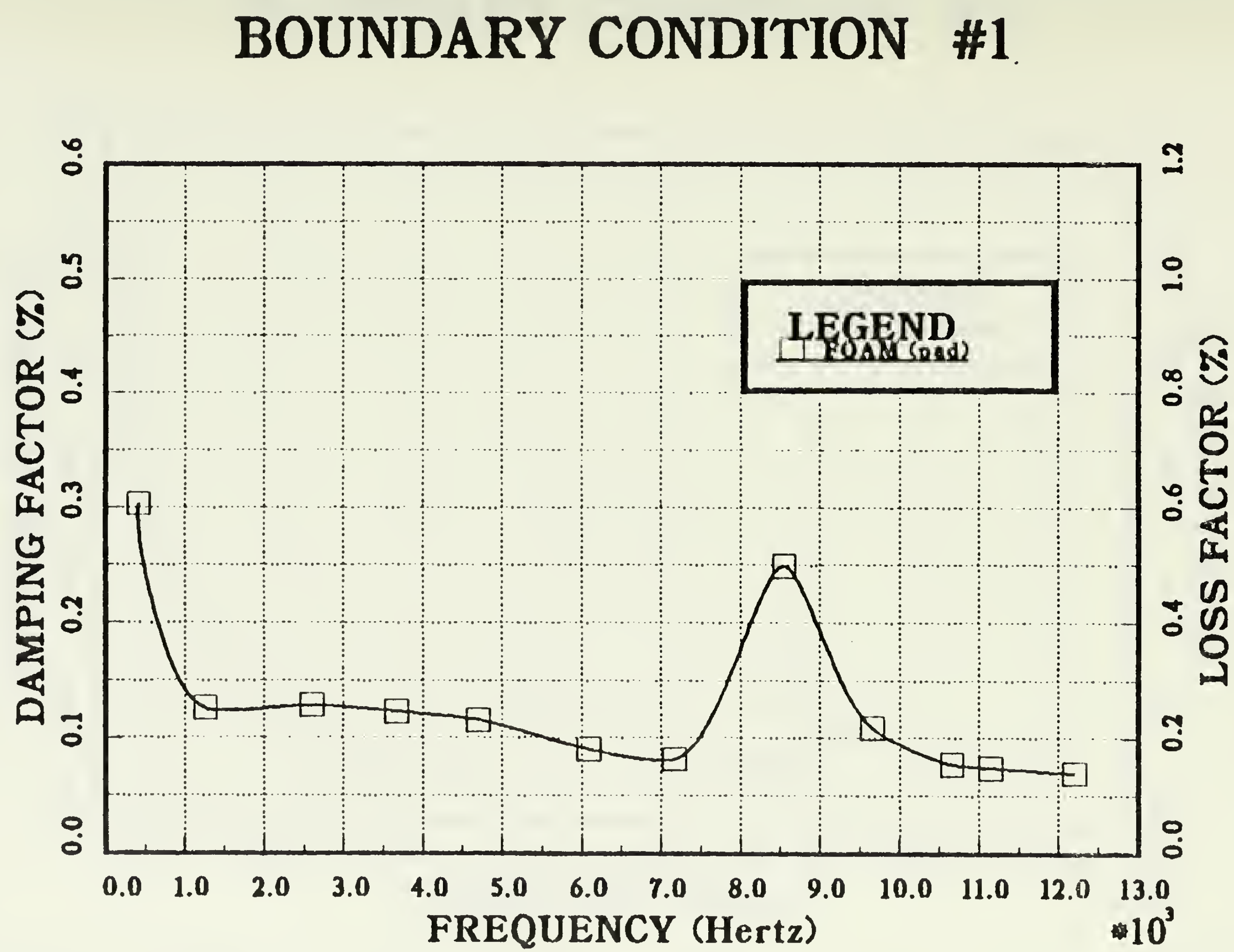

Figure 62. Damping Factor vs. Frequency, Boundary Condition #1.

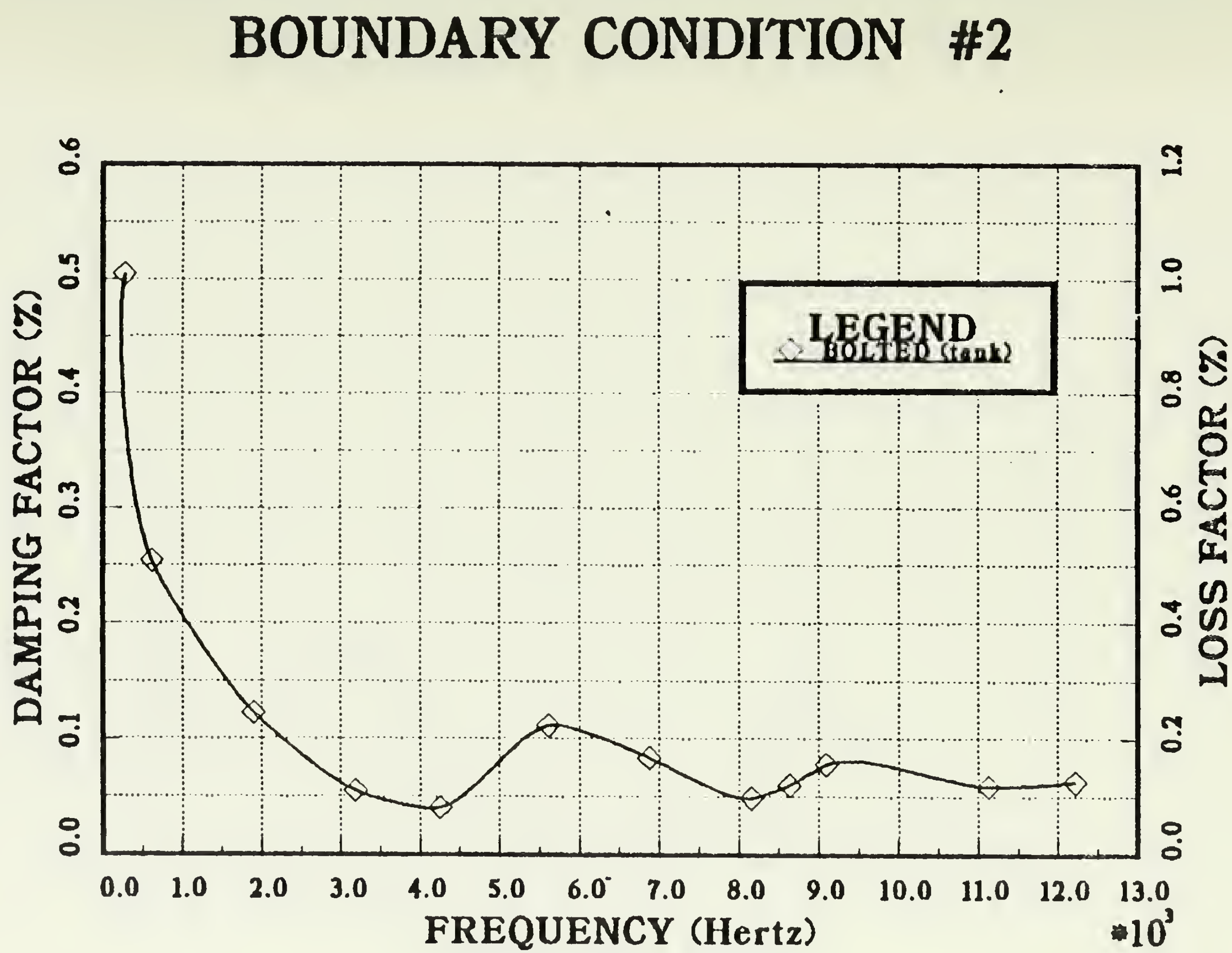

Figure 63. Damping Factor vs. Frequency, Boundary Condition #2.

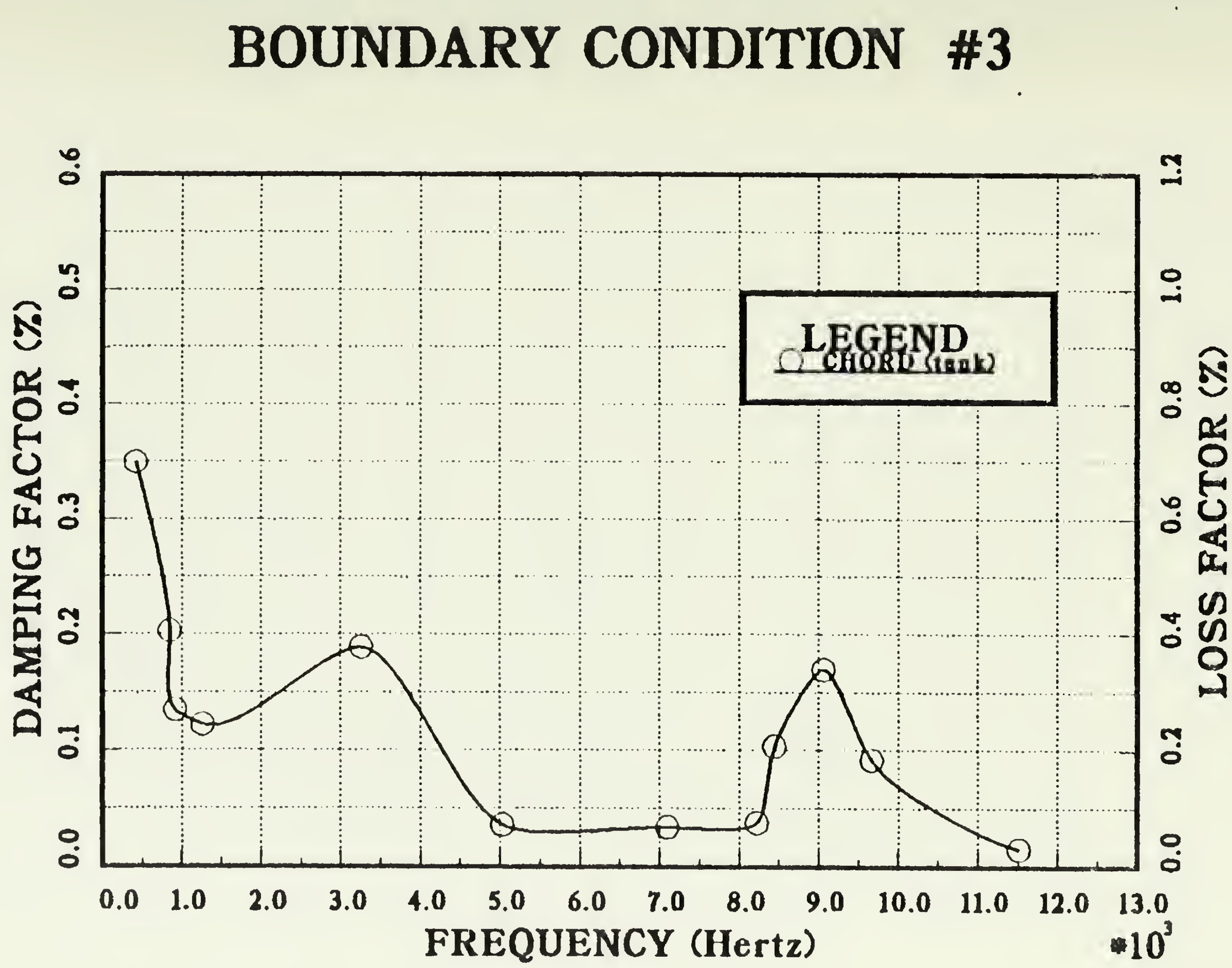

Figure 64. Damping Factor vs. Frequency, Boundary Condition #3.

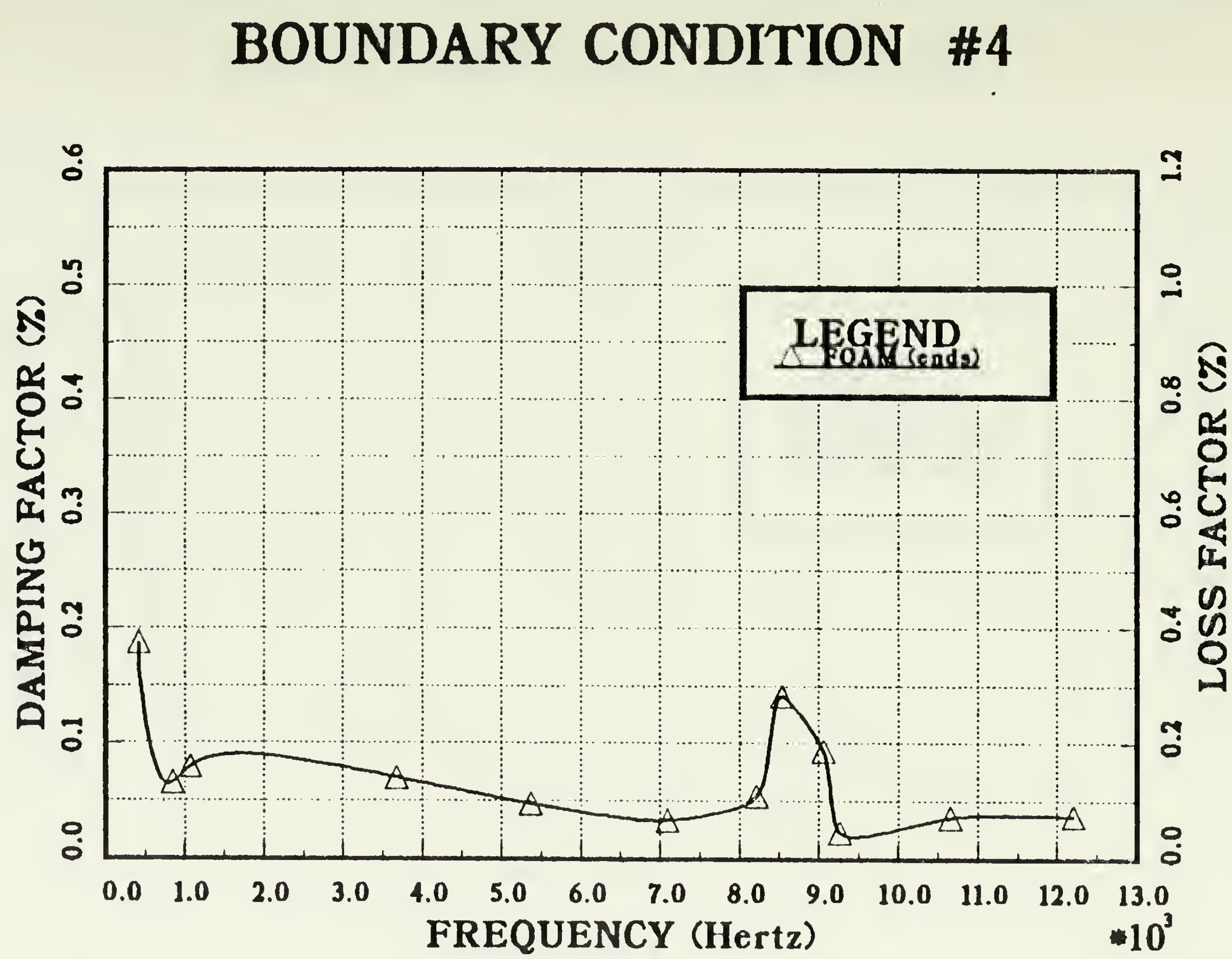

Figure 65. Damping Factor vs. Frequency, Boundary Condition #4.

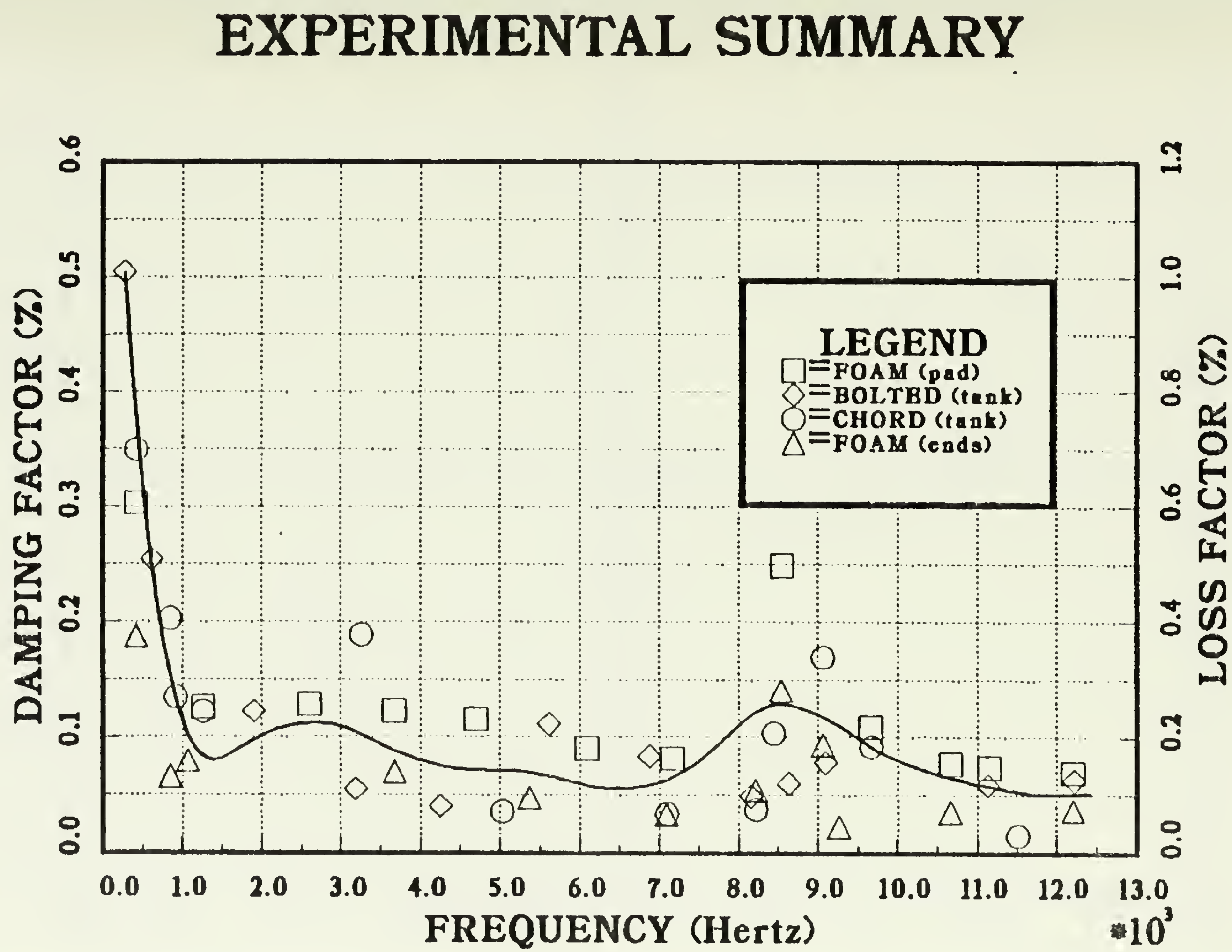

Figure 66. Damping Factor vs. Frequency, Experimental Summary.

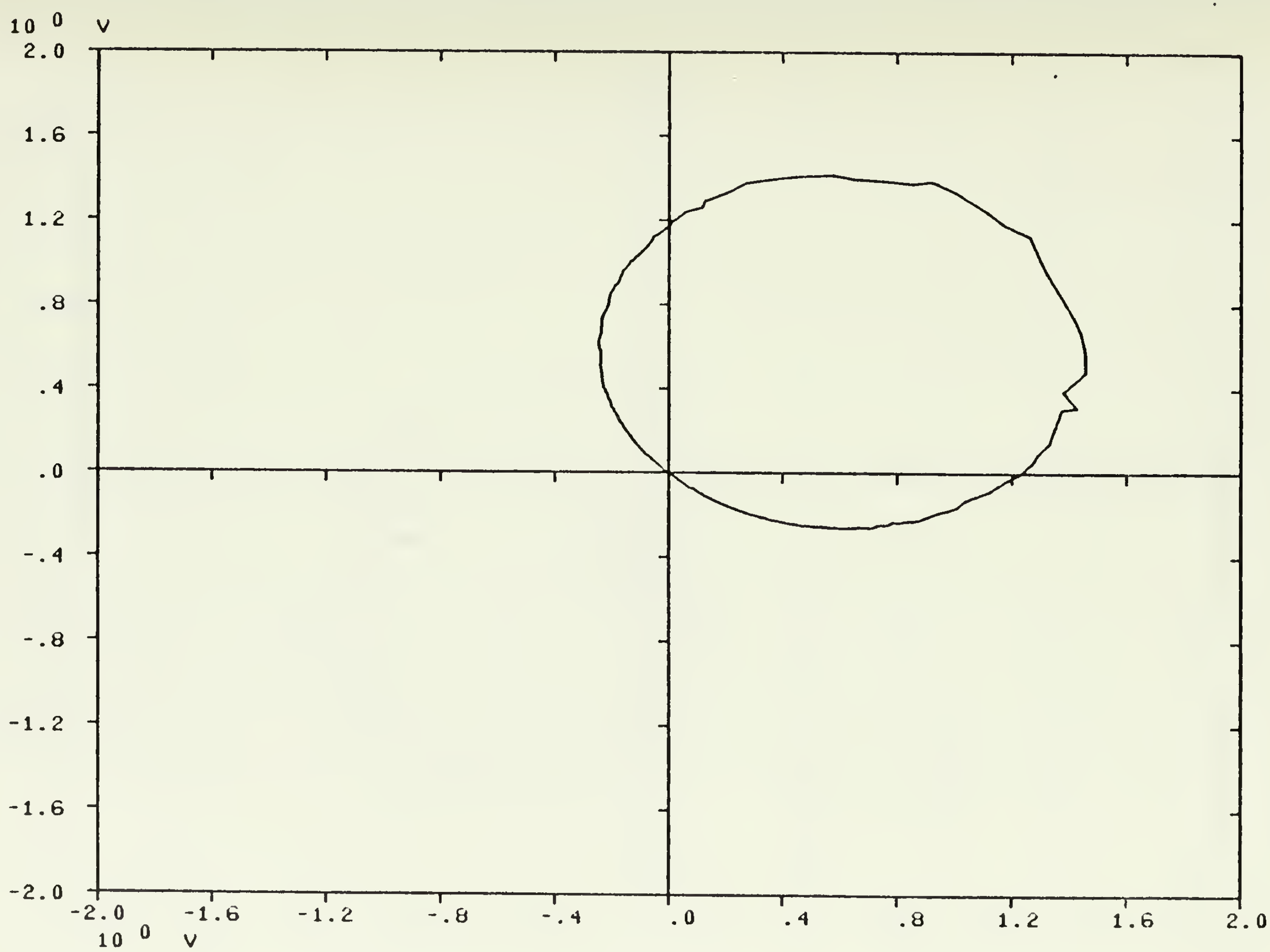

Figure 67. Nyquist plot, EC #3, CF=8221 Hz., grid location 1.

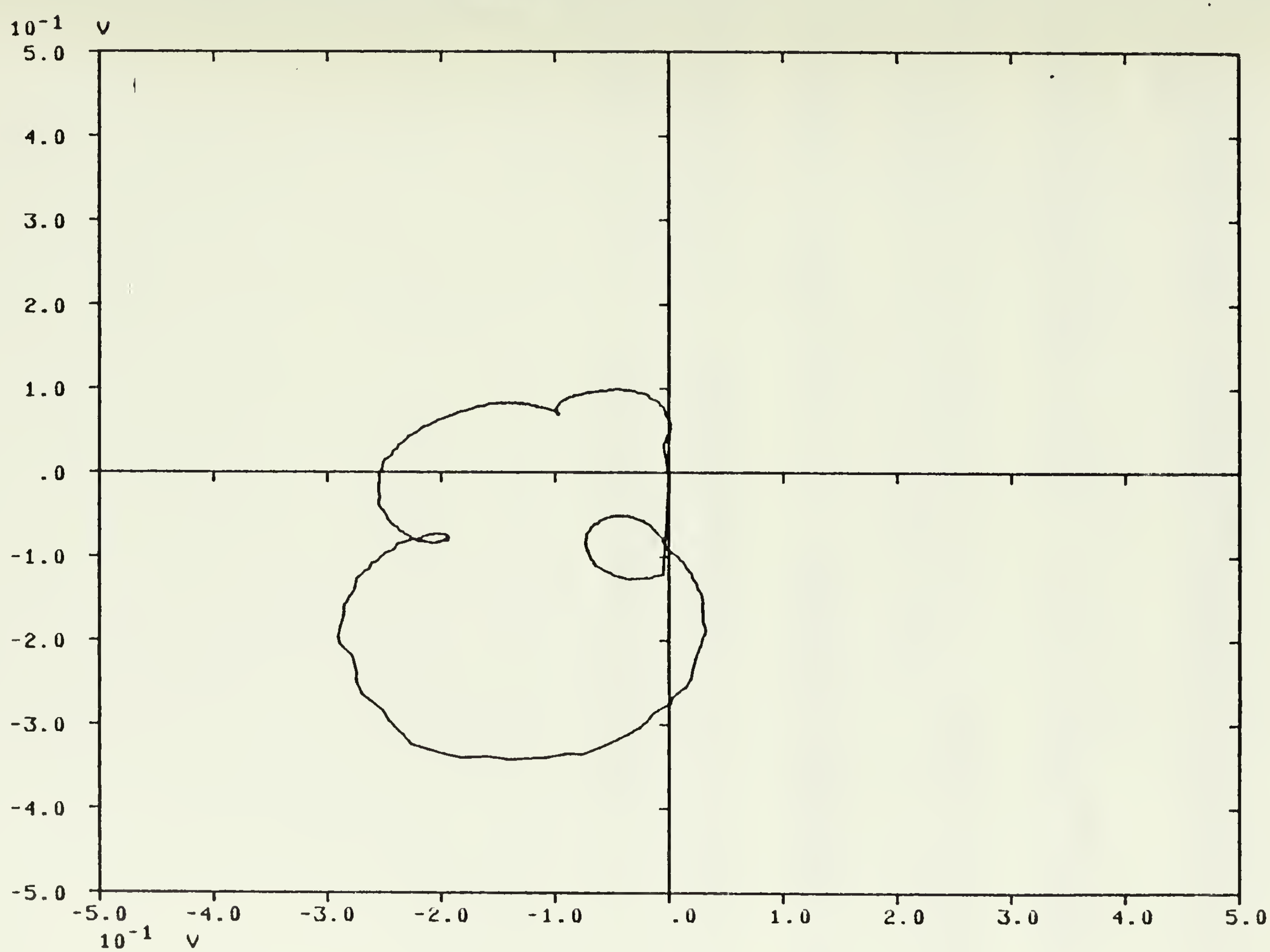

Figure 68. Nyquist plot, EC #2, CP=8152 Hz., grid location 1.

LIST OF REFERENCES

1. Heidgerken, R. A., The Design of a Test Procedure for the Measurement of Acoustic Damping of Materials at Low Stress, M.S. Thesis, Naval Postgraduate School, 1983.

2. University of Dayton Research Institute, Vibration Damping Short Course Note, Course Director: Drake, M. L., 1981.

3. Halvorsen, W. G. and Brown, D. L., "Impulse Technique for Structural Frequency Response Testing," Sound and Vibration, pp. 8-21, November 1977.

4. Ramsey, K. A., "Effective Measurements for Structural Dynamics Testing--Part II," Sound and Vibration, vol. 10, no. 4, 1976.

5. Crandall, S. H., Random Vibration, vol. 2, The M.I.T. Press, 1963.

6. Hewlett-Packard, Modal Analysis Option 402, vol. 1A, 1978.

BIBLIOGRAPHY

Hewlett-Packard Company, Fourier Analyzer Training Manual, Application Note 140-0.

McKinney, W., "Band Selectable Fourier Analysis," Hewlett-Packard Journal, pp. 20-24, April 1975.

Potter, R., "A General Theory of Modal Analysis for Linear Systems," Shock and Vibration Digest, November 1975.

Potter, R. and Richardson M., "Mass, Stiffness and Damping Matrices from Measured Modal Parameters," I.S.A. Conference and Exhibit, New York City, October 1974.

Ramsey, K. A., "Effective Measurements for Structural Dynamics Testing--Part I," Sound and Vibration, November 1975.

Richardson, M., "Modal Analysis Using Digital Test Systems," Seminar on Understanding Digital Control and Analysis in Vibration Test Systems, Shock and Vibration Information Center publication, May 1975.

Richardson, M., and Potter, R., "Identification of the Modal Properties of an Elastic Structure from Measured Transfer Function Data," 20th I.S.A., Albuquerque, N.M., May 1974.

Roth, P. R., "Effective Measurements Using Digital Signal Analysis," I.E.E.E. SPECTRUM, pp. 62-70, April 1971.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3.	Mr. Robert R. Hardy, Code 2803 David W. Taylor Naval Ship R&D Center Annapolis, Maryland 21402	5
4.	Dr. D. J. Vendittis, Code 196 David W. Taylor Naval Ship R&D Center Annapolis, Maryland 21402	1
5.	Mr. E. J. Czyryca, Code 2814 David W. Taylor Naval Ship R&D Center Annapolis, Maryland 21402	2
6.	Mr. V. J. Castelli, Code 2844 David W. Taylor Naval Ship R&D Center Annapolis, Maryland 21402	2
7.	Department Chairman, Code 69 Department of Mechanical Engineering Naval Postgraduate School Monterey, California 93943	1
8.	Professor Y. S. Shin, Code 69Sg Department of Mechanical Engineering Naval Postgraduate School Monterey, California 93943	3
9.	Professor R. E. Newton, Code 69Ne Department of Mechanical Engineering Naval Postgraduate School Monterey, California 93943	1
10.	Professor A. J. Perkins, Code 69Ps Department of Mechanical Engineering Naval Postgraduate School Monterey, California 93943	1

11. Lt. Ricky A. Heidgerken 1
RD 1, 649 Knights Pond Rd.
South Berwick, Maine 03908

12. Lt. Ferman Milster 2
1279 Spruance Rd.
Monterey, California 93940

13. Lt. Stephen T. Knouse 3
P. O. Box 9602
Anaheim, California 92802

14. Mr. and Mrs. Darrel T. Knouse 1
1220 Tari Drive
Colorado Springs, Colorado 80908

207036

Thesis
K682 Knouse
c.1

Effect of boundary conditions on the damping characteristics of a randomly excited cast nickel-aluminum bronze specimen at low stress levels.