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TECHNICAL REPORT

MODIFICATION AND UTILIZATION OF AN/SSQ-41 SONOBUOYS FOR THE COLLECTION OF VOLUME REVERBERATION DATA FROM AIRCRAFT

NOVEMBER 1968

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FOREWORD

The widespread interest in the environmental and frequency dependent characteristics of volume reverberation resulting from marine organisms has produced a requirement for the rapid acquisition of volume scattering data. With the cooperation of the Naval Air Systems Command, Naval Ordnance Laboratory, and the Oceanographic Air Surveys Unit, the Naval Oceanographic Office has modified, tested, and determined the feasibility of using sonobuoys for collecting volume scattering data from aircraft and through this report has produced a guide for the utilization of sonobuoys for such measurements.

T. K. TREADWELL
Captain, U. S. Navy
Commander
U. S. Naval Oceanographic Office

ACKNOWLEDGEMENTS

The authors wish to thank Mr. R. J. Urick of the Naval Ordnance Laboratory under whose initial guidance this study was undertaken.

The authors also thank Mr. P. Rand of the Naval Ordnance Laboratory Acoustic Facility, Mr. H. Lawry and his associates at the Vocaline Corporation of American, South Bristol, Maine, for their assistance in the testing and modification of the prototype sonobuoys and LCDR E. Wilson, Commander of ASWEPS Aircraft "EL COYOTE" and his crew for their assistance in the field measurements.

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FIGURES (CONTINUED)

INTRODUCTION

Many experiments have been conducted to investigate the acoustic characteristics of biological scatterers located primarily in the deep scattering layers (DSL). These studies indicate that the dominant cause of volume reverberation from deep scattering layers results from resonant scattering from bathypelagic fishes possessing swimbladders. Present day advances in sonar technology have increased requirements for investigating the diurnal, seasonal and geographic variations of the volume scattering produced by the presence of the scattering layer.

Aircraft techniques using sonobuoys and underwater sound signals are ideally suited for the investigation and rapid acquisition of volume scattering data over large geographic regions. Earlier experimentation by Urick et al (1965) has demonstrated that acoustic data such as bottom reflectivity can be collected from aircraft using sonobuoys. Consequently, in the fall of 1966, an experimental research program was jointly undertaken by the Naval Oceanographic Office and the Naval Ordnance Laboratory to further develop airborne acoustic data collection techniques; particularly for collecting volume scattering information.

This report discusses the modifications, tests, calibration, and use of standard AN/SSQ-41 sonobuoys for the collection of volume reverberation data from aircraft. The results of the test and feasibility measurements using the prototype sonobuoys are also presented.

I. AN/SSQ-41 SONOBUOY

The AN/SSQ-41 sonobuoy is launched from an aircraft at speeds between 150 and 250 knots, and at altitudes between 500 and 10,000 feet. On contact with the water the sonobuoy deploys a shaded line hydrophone array and a preamplifier to a predetermined depth of 60 or 300 feet. The electronics system is capable of transmitting data as soon as a 10-volt sea water battery is activated.

Each hydrophone in the deployed array is omnidirectional. The four hydrophone elements are spaced and connected in a series parallel configuration to give a desired sensitivity and directionality.

The preamplifier is a single stage amplifier utilizing a field effect transistor to maintain low noise levels and for improving the low frequency response of the sonobuoy. This preamplifier has a constant gain of 14.2 dB, a flat frequency response between 0.02 kHz and 40 kHz, and a recovery time of approximately 60 milliseconds for high input levels. A limiter circuit in the preamplifier is used to protect the circuitry by clipping input signals above -14 dBv re 1 volt rms (dBv).

Additional amplification is obtained from an audio or sonic amplifier which consists of four stages. The gain of the audio stages can be adjusted and controlled by a variable potentiometer. This audio stage also contains an automatic gain control circuit (AGC).

The FM transmitter operates at carrier frequencies between 162 and 174 megacycles. The basic electronic components within the transmitter consist of a reactance modulator, crystal controlled oscillator, frequency quadrupler, a driver and final stage amplifier.

Each sonobuoy has a particular carrier frequency for transmitting to a standard receiver (ARR/52) onboard a monitoring aircraft. The sonobuoy receivers are capable of receiving and demodulating each frequency transmitted which enables monitoring of one or more sonobuoys simultaneously. Figure 1 shows a block diagram of the basic AN/SSQ-41 sonobuoy electronic system.

II. AN/SSQ-41 MODIFICATIONS

Several tests, adjustments, and modifications were made in order to make the AN/SSQ-41 sonobuoy suitable for volume reverberation measurements. These modifications involve frequency response, hydrophone directivity, AGC and gain controls, and the limiter circuitry in the audio amplifier stage. In addition, a calibration circuit was designed and added to the electronic system of the sonobuoy.

The first step in the adjustment and modification of the existing sonobuoy circuitry is to disconnect the AGC circuit. By disabling this circuit the sonobuoy amplifier gain is maintained at a constant level for any signal intensity. This enables analysis and interpretation of reverberation levels without considering variance in system gain. The circuit is disconnected at point A on the audio board shown in Figure 2.

Since volume reverberation is frequency dependent, an attempt was made to improve and extend the usable frequency response of the sonobuoy without major redesign or modification of any sonobuoy components. In order to determine whether it is possible to improve the frequency response of the sonobuoy at high frequencies three shunt capacitors in the audio amplifier (C208, C213, C216 in Figure 2) were removed. However, removal of these capacitors enhanced a hydrophone resonance occuring between 3.5 and 4.0 kHz. Since this resonance is undesirable at higher frequencies it was necessary to replace the capacitors and operate within the original response of the sonobuoy. The frequency response curves obtained for the audio amplifier with the AGC disconnected and with successive shunt capacitors removed are shown in Figure 3.

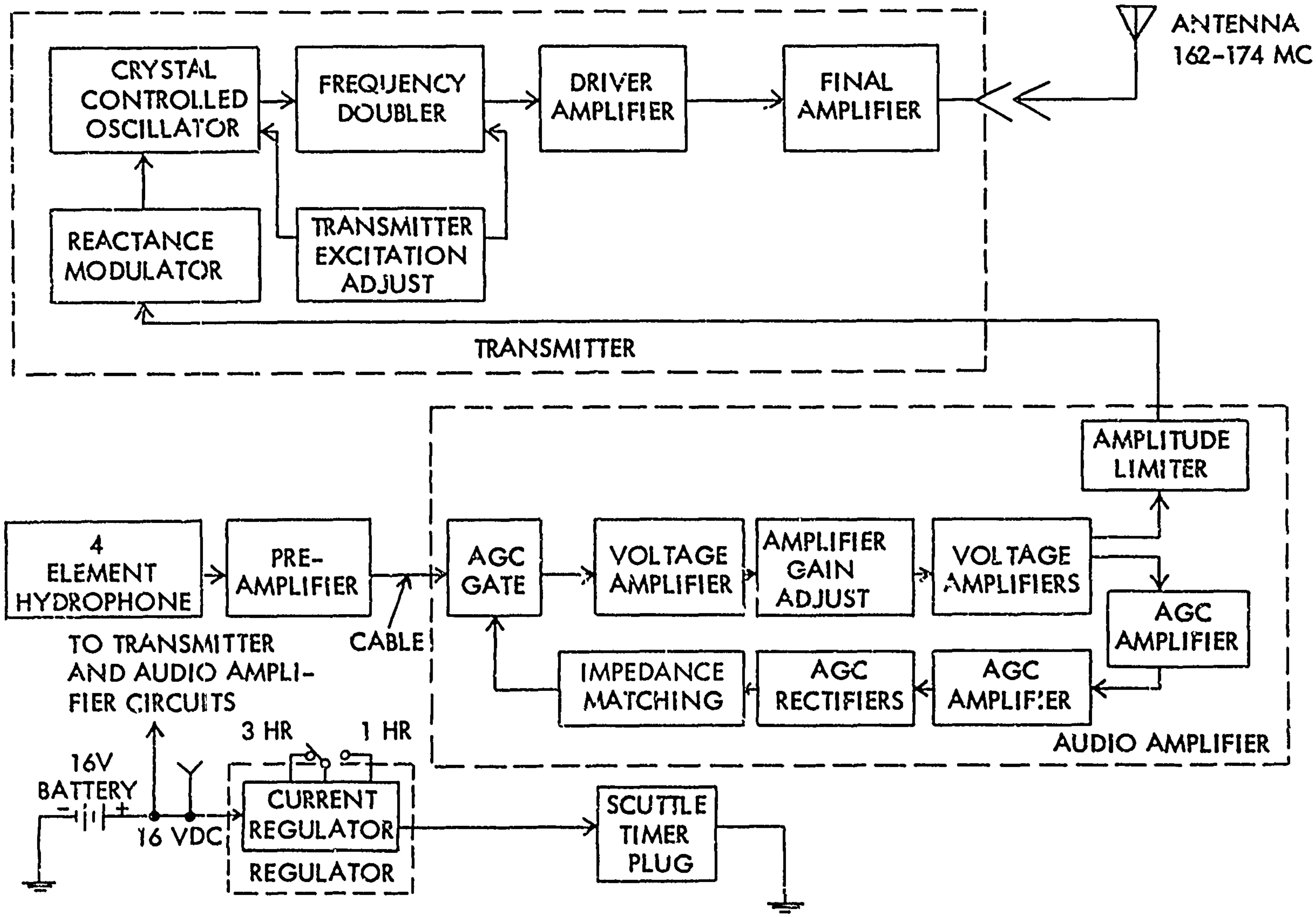


FIGURE 1. SONOBUOY AN/SSQ-41 BLOCK DIAGRAM

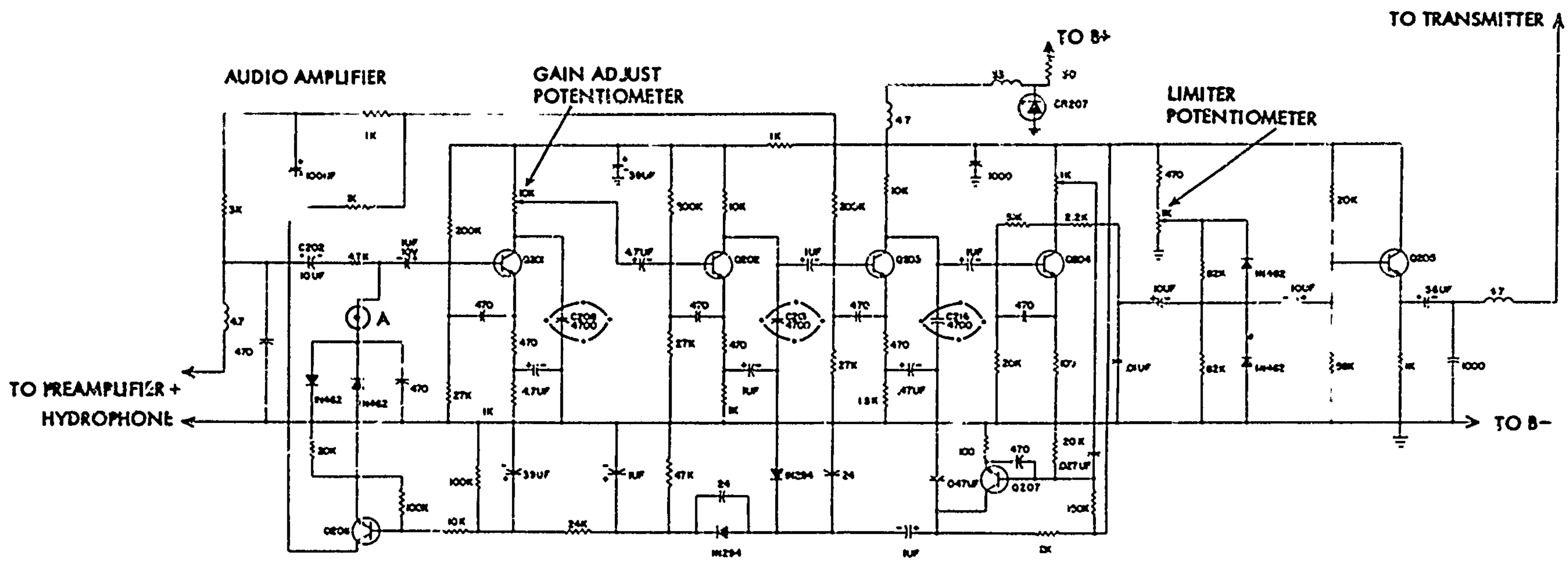


FIGURE 2. AUDIO BOARD SCHEMATIC

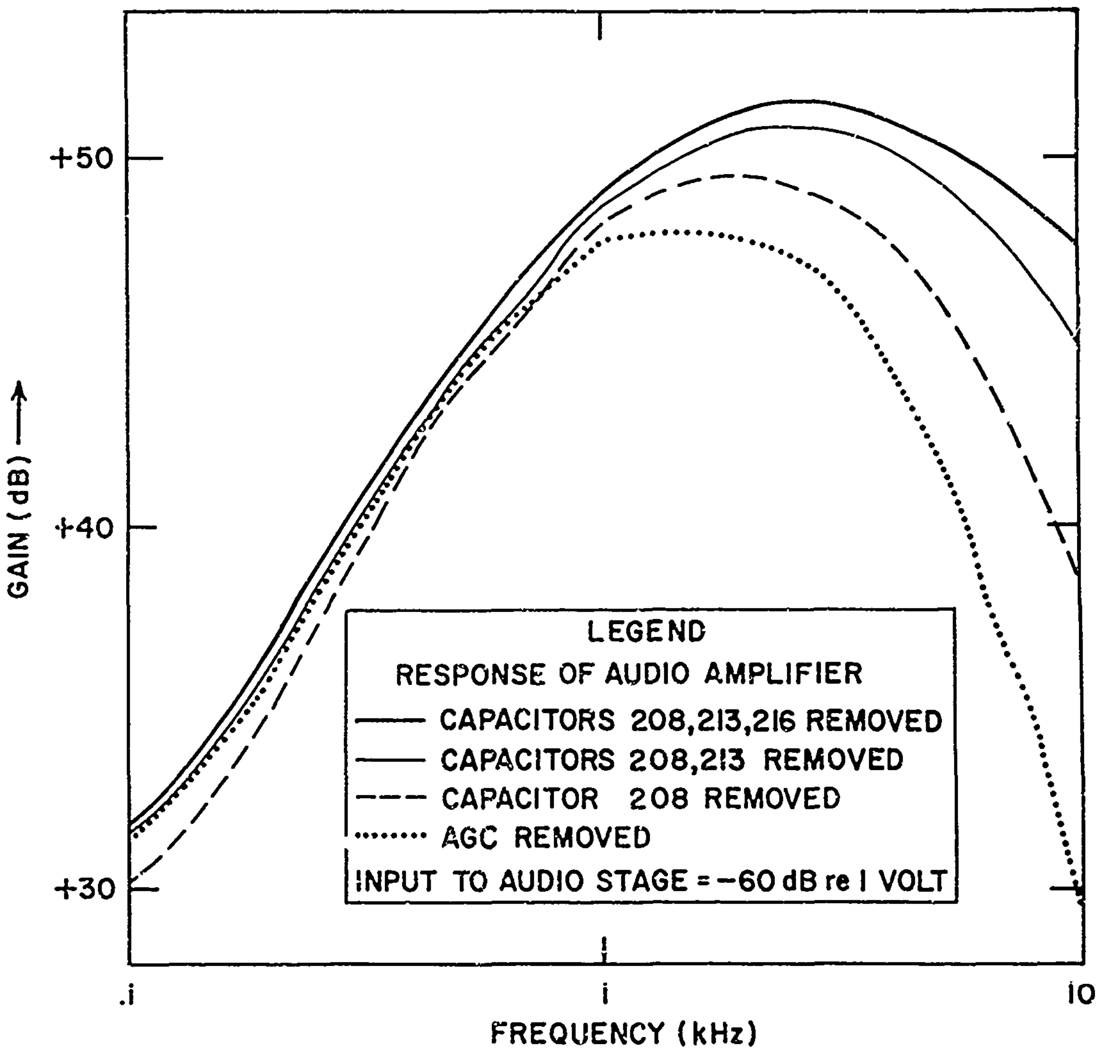


FIGURE 3. RESPONSE OF AUDIO AMPLIFIER

Conventional shipborne techniques for the collection of reverberation data have utilized omnidirectional sound sources and receivers. To make the sonobuoy receiver system comparable to shipborne systems the sonobuoy's shaded line hydrophone array, which has a preferential directional pattern at different frequencies (Figures 4 to 6), was modified to produce an omnidirectional hydrophone receiver pattern. Omnidirectionality was obtained by clumping together and binding the sonobuoy's four individual omnidirectional hydrophones and preamplifier securely within a plastic mesh. This technique produced the desired directivity pattern when tested. Also, one of a series of tests conducted at the U.S. Navy Sonobuoy Test Range at South Bristol, Maine, indicated that the hydrophones remained securely bound within the mesh and did not generate additional noise from rubbing or vibration during deployment. Figures 7 and 8 indicate the directivity pattern at frequencies of 2 kHz and 6 kHz after modification. Figures 9a and 9b show the hydrophone array before and after modification.

The frequency response of a typical sonobuoy with the AGC circuit disabled and with the modified hydrophone array was obtained relative to a calibration frequency of 2.35 kHz and is illustrated in Figure 10. This curve indicates the total sensitivity of the sonobuoy hydrophone, preamplifier, and audio stages. A relative curve was determined since the gain of each sonobuoy is changed during calibration (See Section III).

The transmitter portion of the sonobuoy does not require any adjustment or modification. In order to produce a calibrated pulse that is used to check system linearity as well as to determine absolute reverberation levels transmitted by the sonobuoy, a circuit was designed and inserted into the sonobuoy electronic package. The circuit utilizes a multi-vibrator that gates a phase shift oscillator and is designed to produce a two-level step, where the lower level is 20 dB below the maximum level. Each level is transmitted for approximately 100 milliseconds and the repetition rate of the step pulse is nominally 15 seconds. At each level, the phase shift oscillator has a frequency output of nominally 2.35 kHz. Any variations in calibration pulse parameters that occur are due to electronic component tolerance. A schematic and photograph of the circuit are shown in Figures 11a and 11b. Figure 12 is an example of the calibration pulse.

After the calibration circuit is inserted into the sonobuoy electronics, the maximum level is adjusted to represent +25 dB re 1 dyne/cm^2 of acoustic pressure (dBa). The low level step then represents an acoustic pressure 20 dB below this maximum.

III. CALIBRATION AND ELECTRONIC ADJUSTMENTS

Underwater sound signals detected by the modified hydrophone pass through an audio stage that is capable of frequency-modulating a VHF carrier

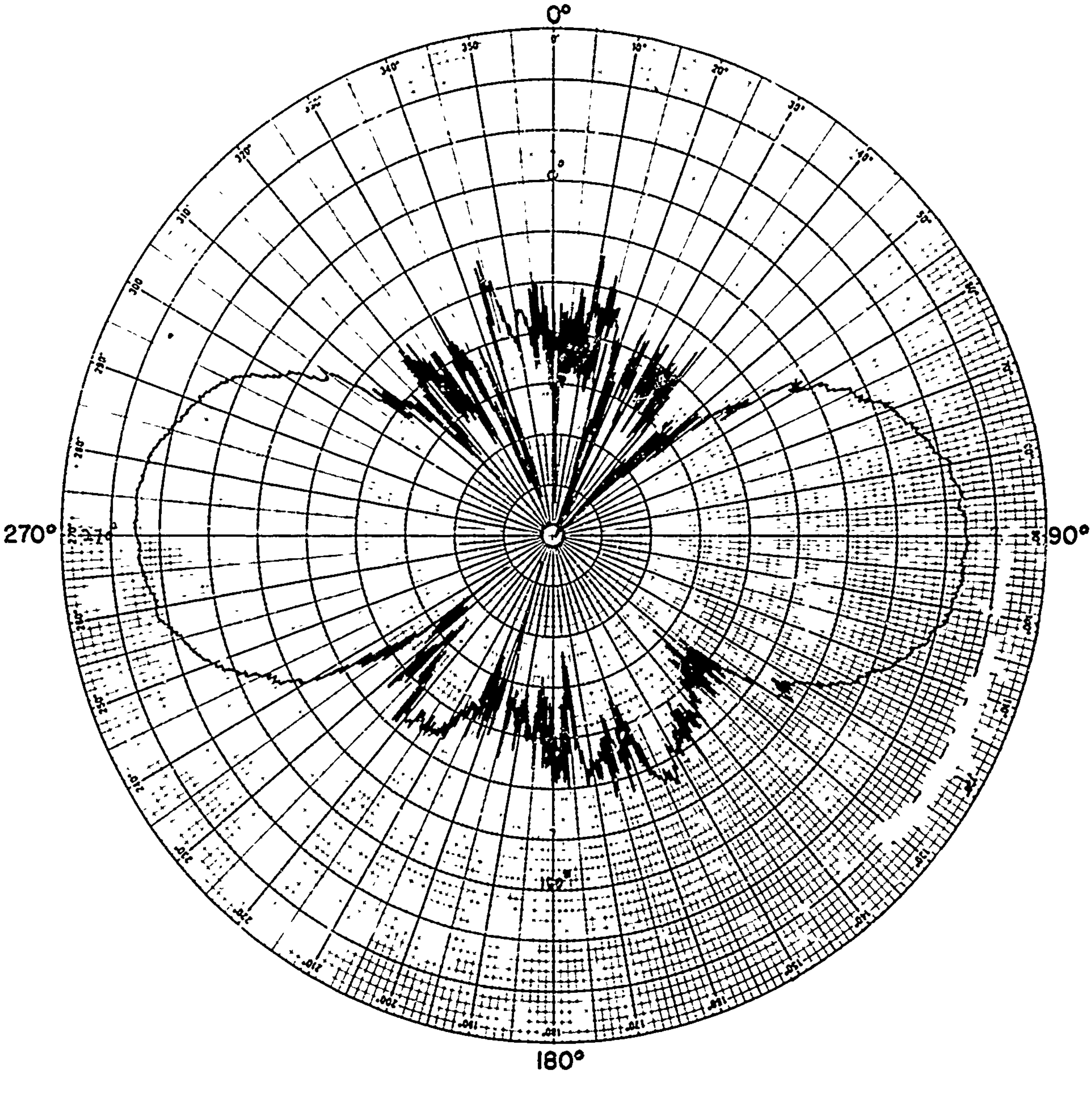


FIGURE 4. DIRECTIVITY PATTERN, 1.5 kHz, X-Y PLANE

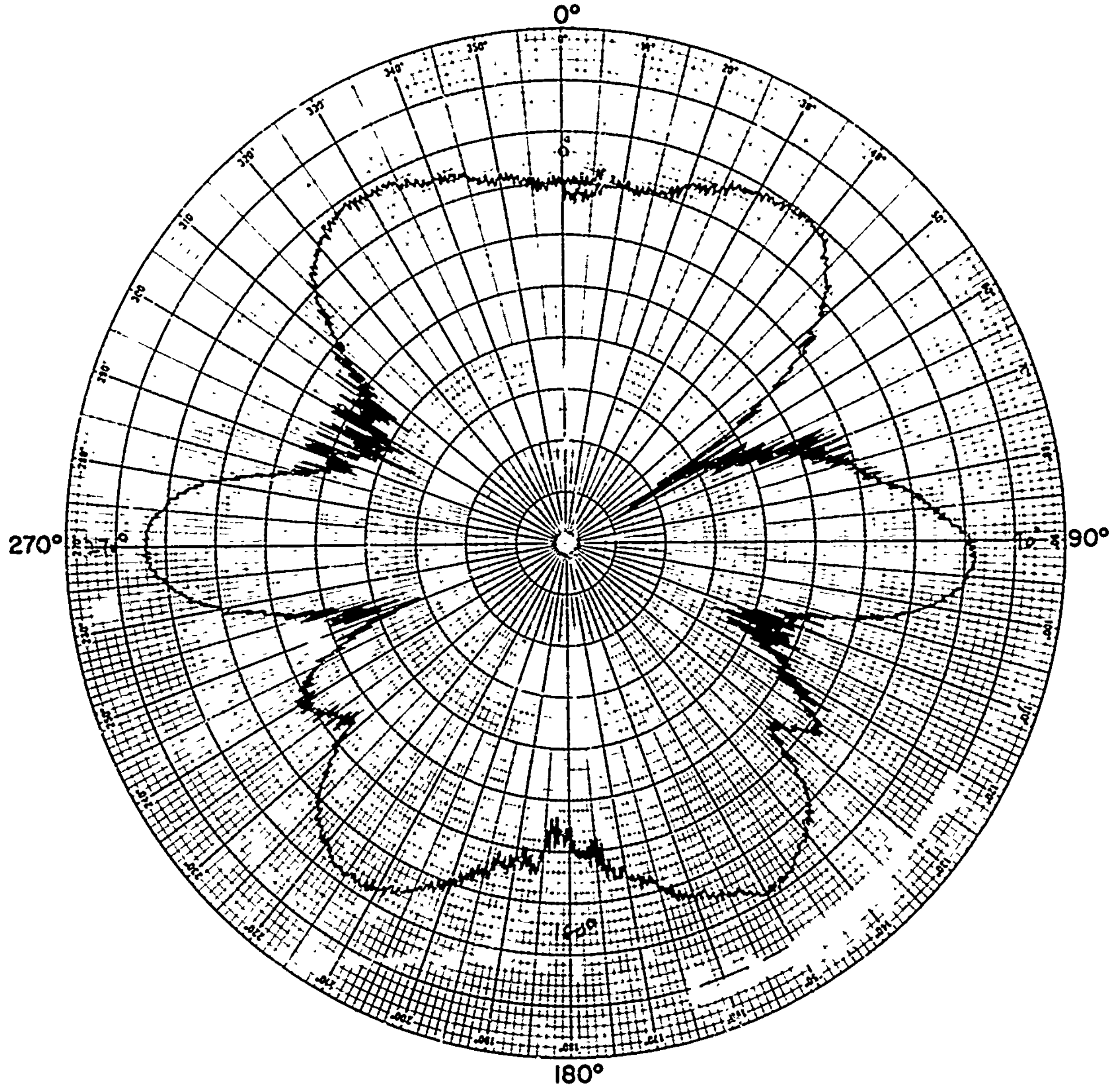


FIGURE 5. DIRECTIVITY PATTERN, 3.5 kHz, X-Y PLANE

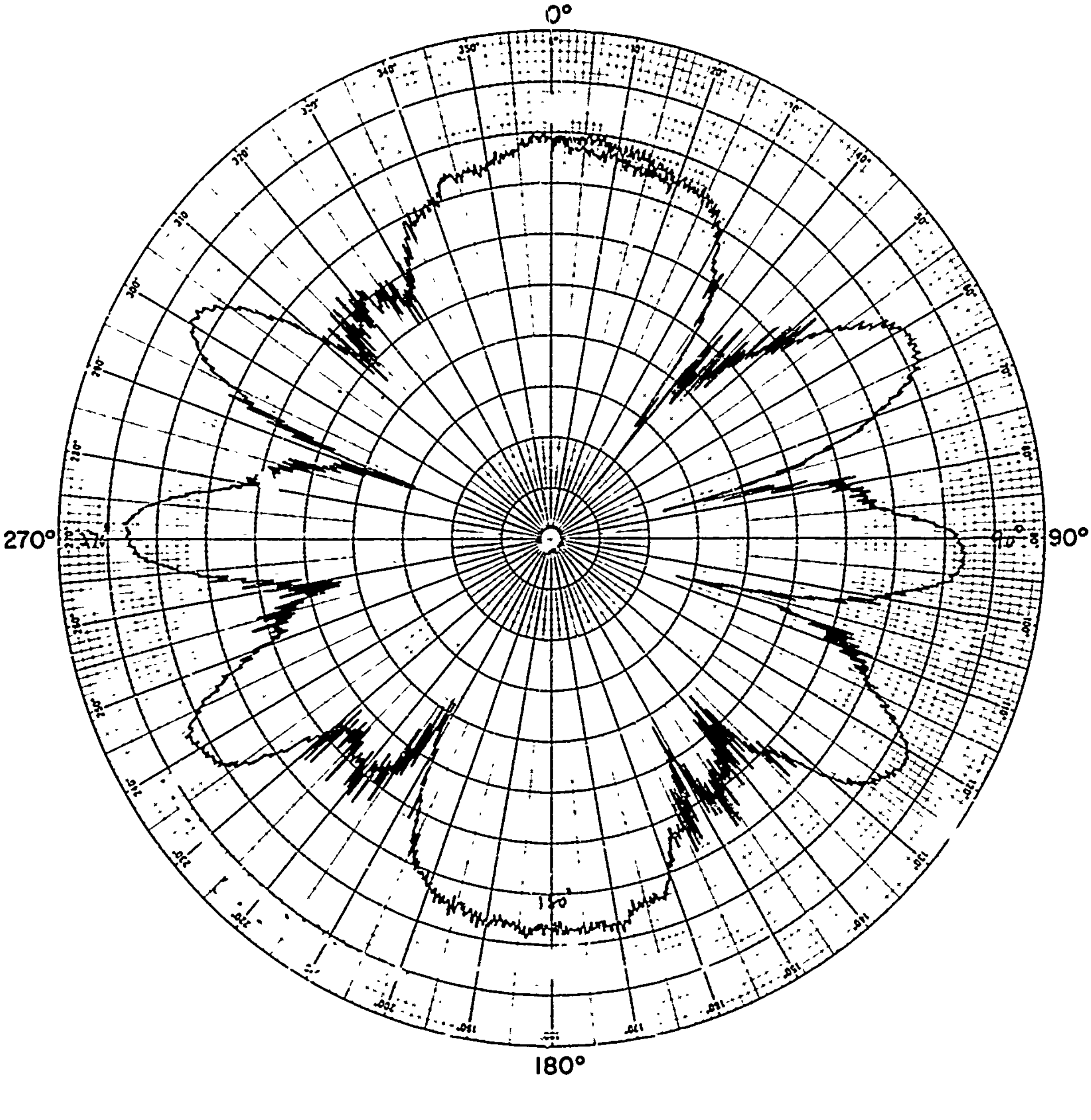


FIGURE 6. DIRECTIVITY PATTERN, 6 kHz, X-Y PLANE

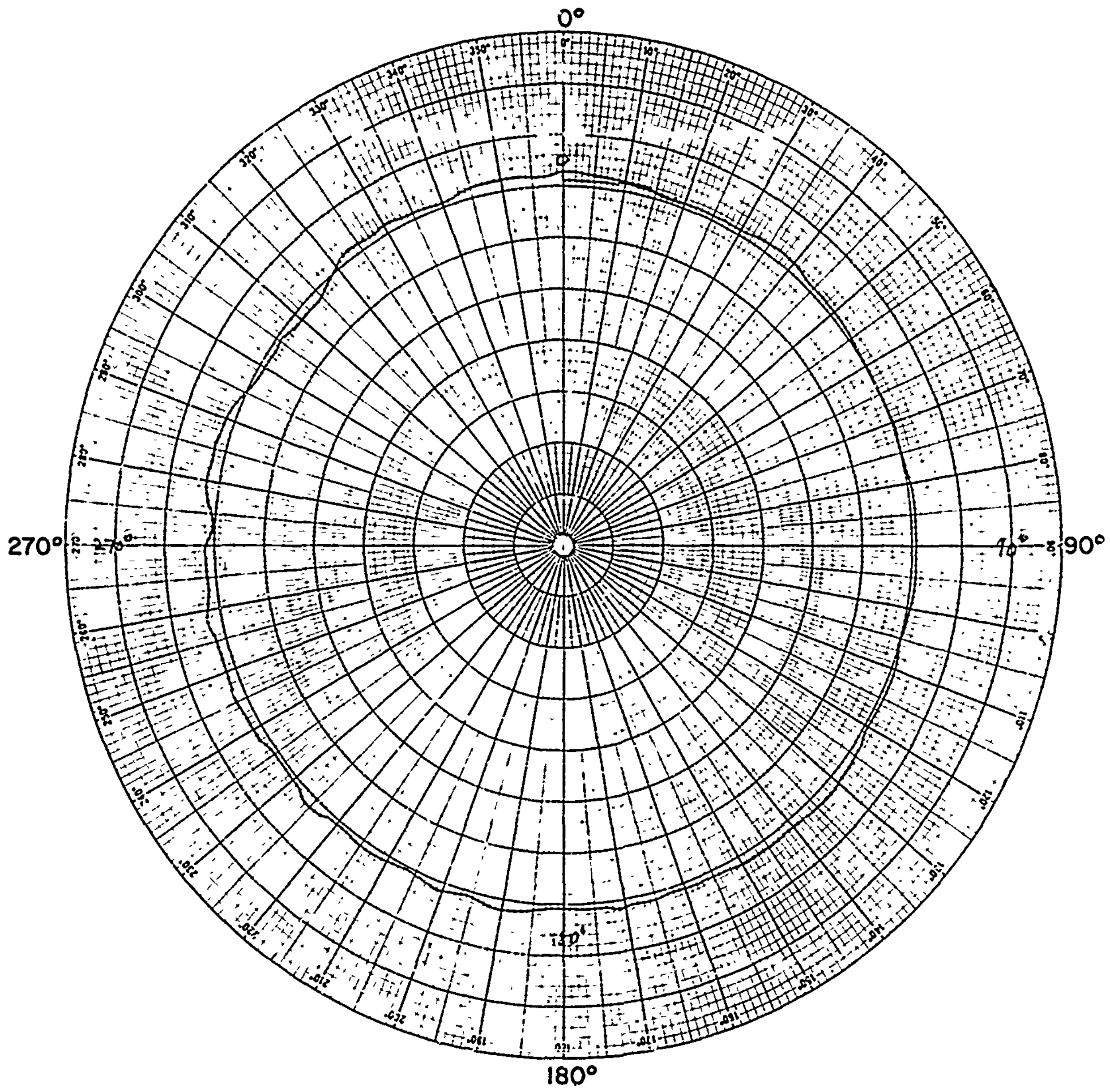


FIGURE 7. DIRECTIVITY PATTERN, 2 kHz, AFTER MODIFICATION, X-Y PLANE

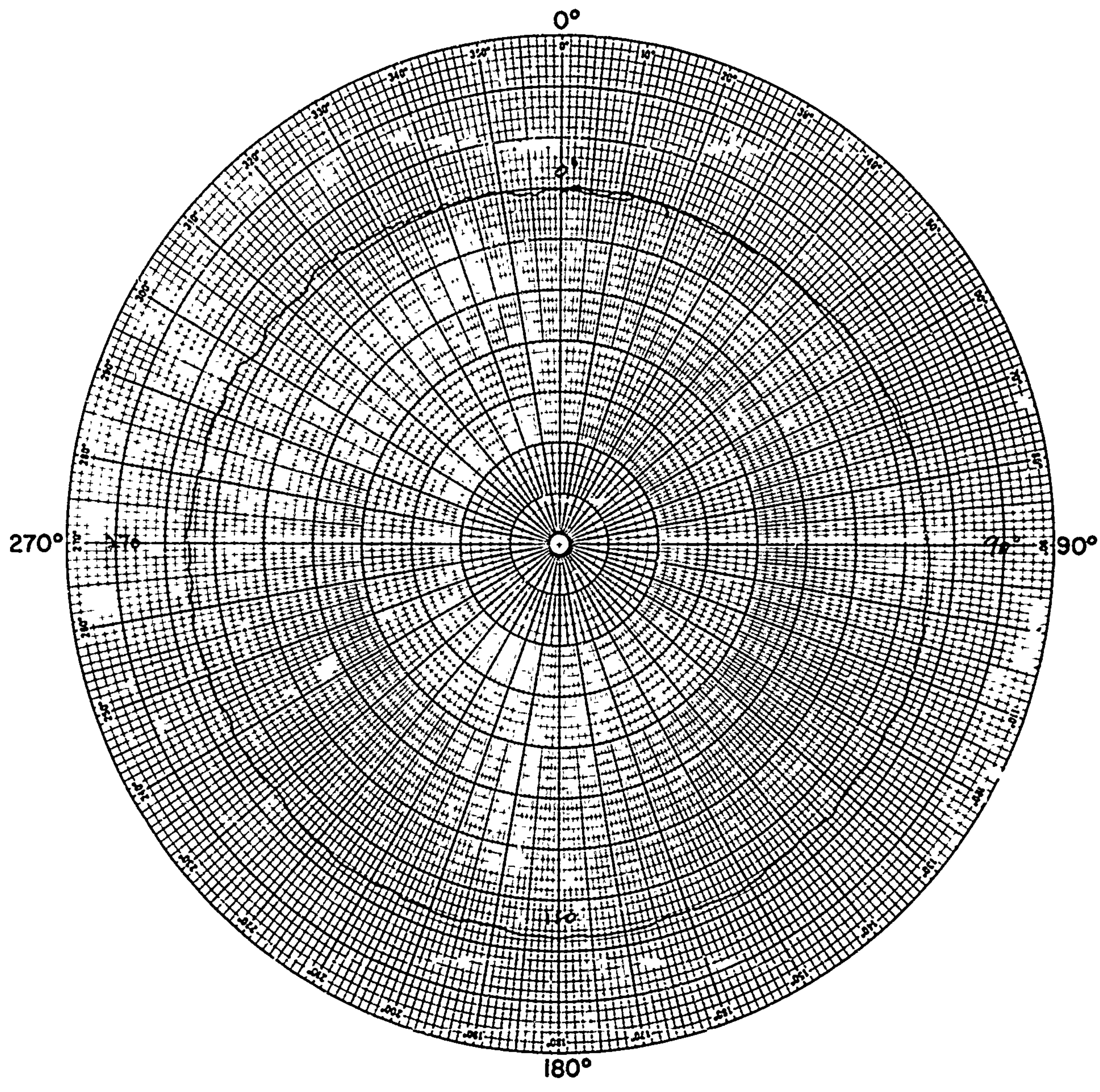


FIGURE 8. DIRECTIVITY PATTERN, 6 kHz, AFTER MODIFICATION, X-Y PLANE

FIGURE 9a. HYDROPHONE BEFORE MODIFICATION.

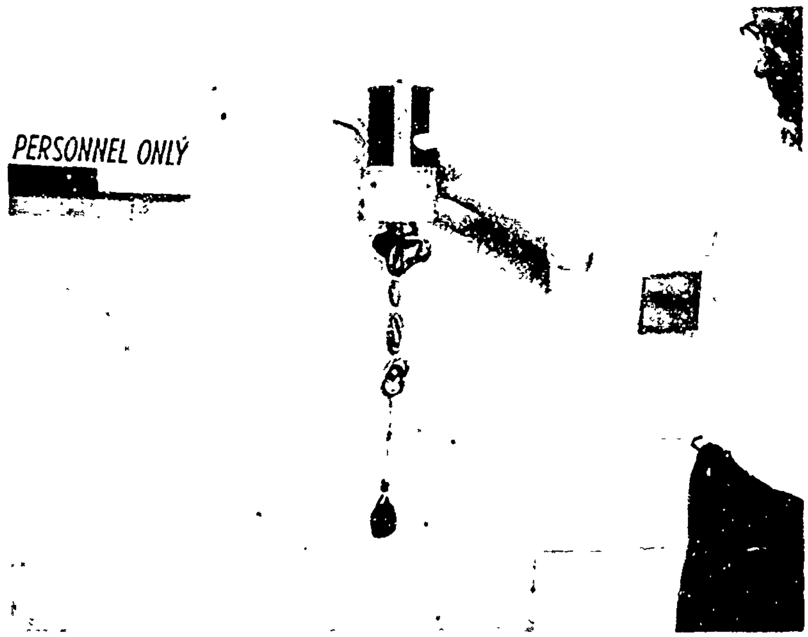


FIGURE 9b. HYDROPHONE AFTER MODIFICATION.

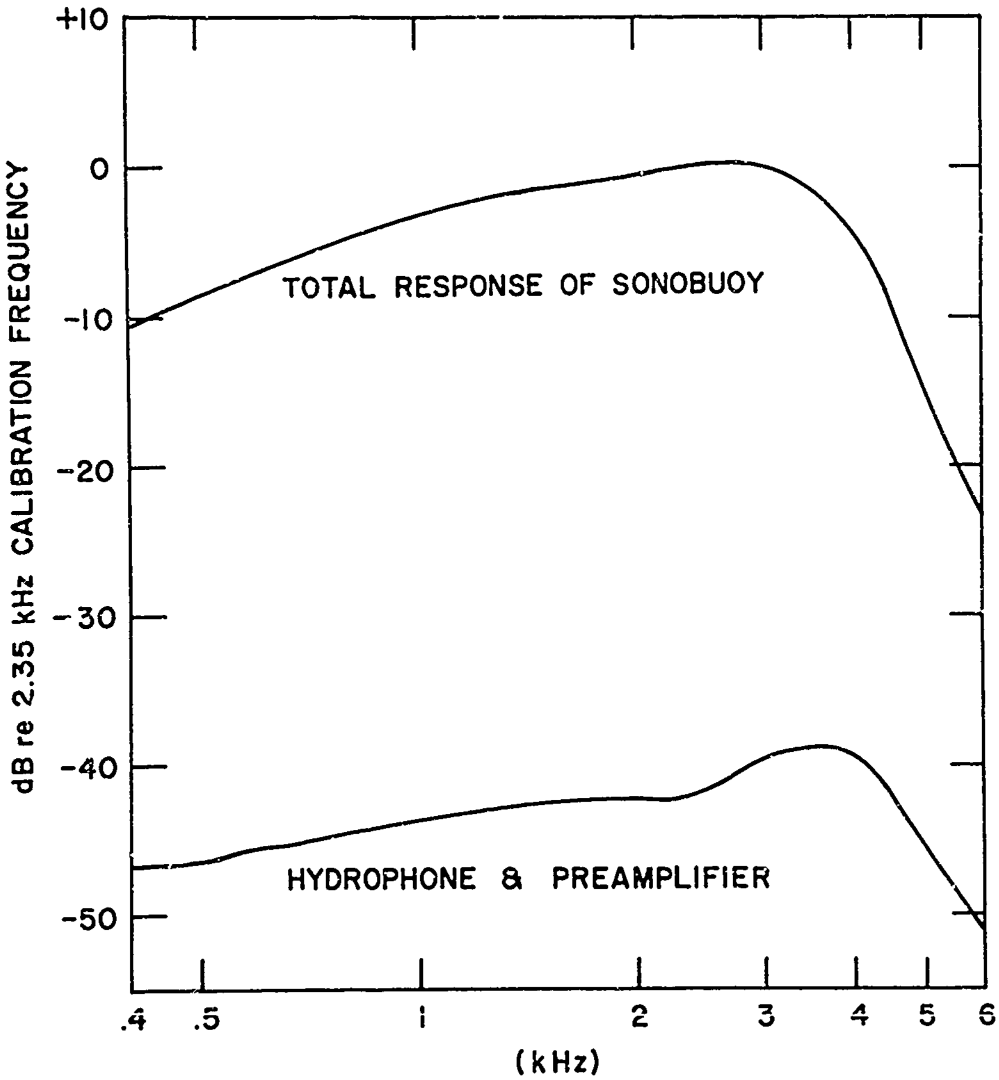
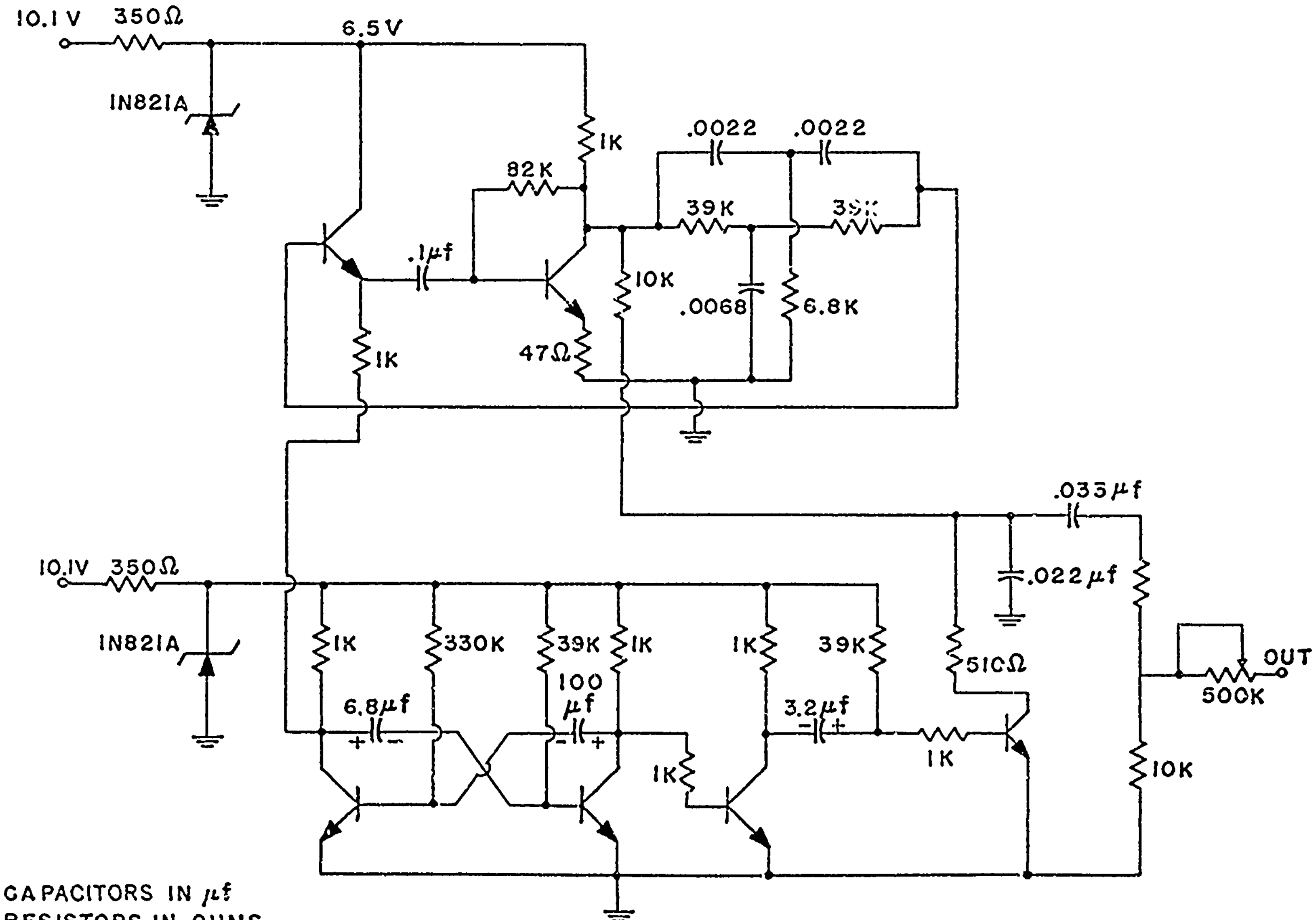


FIGURE 10. SONOBUOY RESPONSE CURVES



CAPACITORS IN µf
RESISTORS IN OHMS
TRANSISTORS MOTOROLA 2N3904

FIGURE 11a. TWO LEVEL CALIBRATION CIRCUIT FOR SONOBUOYS.

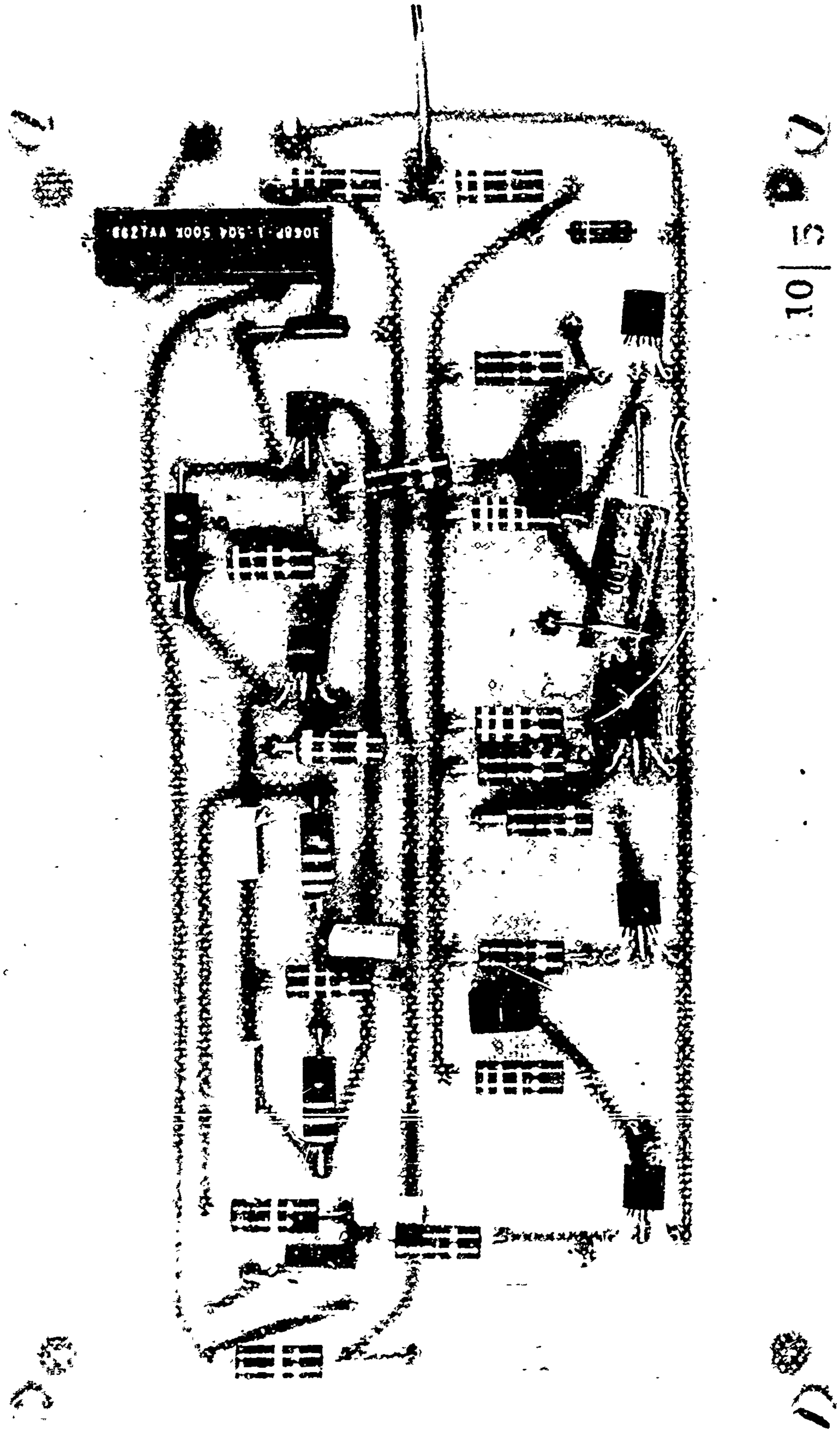


FIGURE 11b. CALIBRATION BOARD PART LAYOUT.

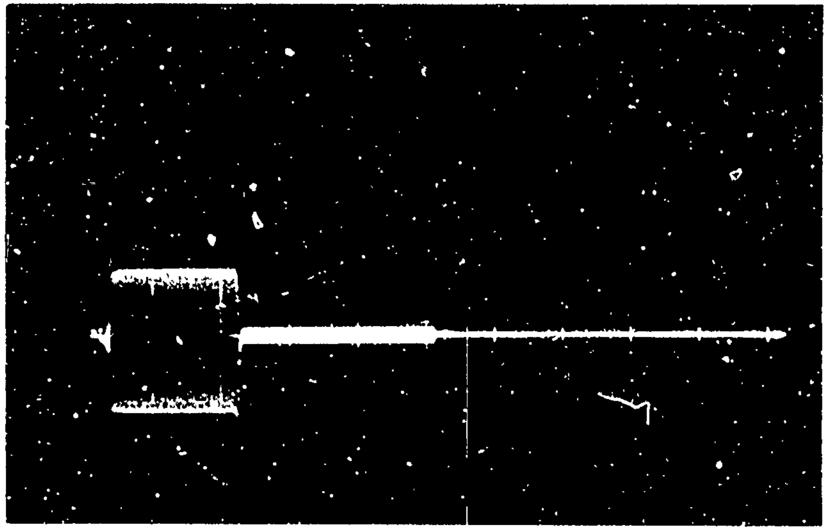


FIGURE 12. CALIBRATION PULSE.

that is transmitted to an aircraft receiver and demodulator. The amount of frequency modulation, expressed in terms of kHz deviation, depends upon the level of the acoustic pressure incident on the hydrophone. The frequency deviation available, for any input to the audio stage, is controlled by a limiter circuit consisting primarily of a potentiometer and two diodes. This circuit functions as a protective network that prevents damage to the reactance modulator in the VHF transmitter.

From previous reverberation data it is expected that a maximum acoustic pressure of +25 dBa and a minimum of -5 dBa are nominal levels to be recorded. This necessitates having an electronic system with at least a 30 dB dynamic range, which is well within the 50 dB dynamic range of the sonobuoy. Utilizing the nominal maximum level to be recorded, circuit adjustments were made so that an acoustic pressure level of +25 dBa at a calibration frequency of 2.35 kHz would produce a 75 kHz deviation at the output of the VHF transmitter. These adjustments are made while simulating a +25 dBa level at the input of the audio amplifier and monitoring the output of the transmitter with a deviation meter to insure that the proper frequency deviation is obtained. Figure 13 shows the instrument block diagram for adjusting to the proper deviation.

To calibrate the sonobuoy an equivalent acoustic pressure of +25 dBa is simulated and fed into the audio amplifier by using the output of a microvolter and feeding it to a dummy hydrophone-preamplifier package at the frequency of the calibration circuit phase shift oscillator. From the sensitivity and voltage output of the hydrophone, the level of the acoustic pressure is determined; or if the acoustic pressure is known, the voltage generated at the hydrophone preamplifier output can be obtained. For example, if the sensitivity of the hydrophone preamplifier package at 2.35 kHz is -66 dBv/μb/yd and the acoustic pressure is +25 dBa, the input to the audio amplifier should be -41 dBv. The microvolter can then be adjusted to produce the correct voltage level for the audio amplifier.

Once the input of the audio amplifier is determined the audio gain adjust potentiometer (R205) and a limiter potentiometer (R227) are adjusted to produce a 75 kHz deviation (see Schematic Figure 3) with the actual hydrophone and preamplifier in the circuit to maintain proper electronic loading. It was determined that neither the dummy hydrophone nor the actual hydrophone varied the circuit loading. Since a limiter circuit protects the reactance modulator in the transmitter stage, these adjustments must be performed carefully to insure that no damage to the modulator occurs. It was found that a 75 kHz deviation does not damage the reactance modulator in any way and observation of the signal wave form on an oscilloscope indicates no distortion occurs. Once the 75 kHz deviation is obtained, the variable potentiometers are fixed and locked in position.

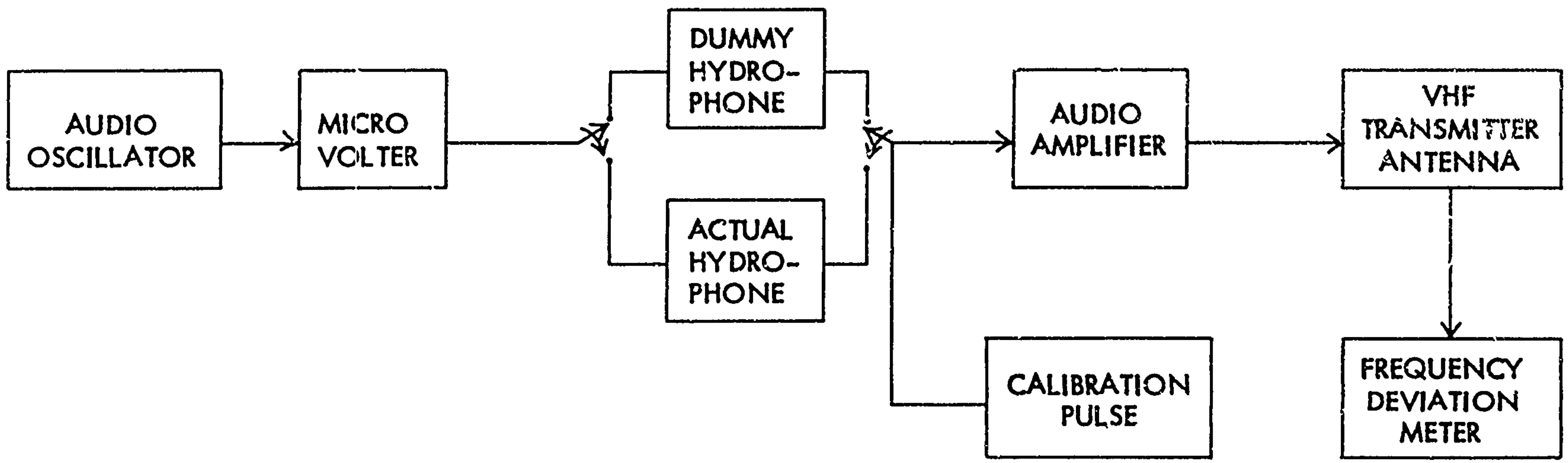


FIGURE 13. INSTRUMENT BLOCK DIAGRAM FOR DEVIATION ADJUSTMENTS

After the audio stage is adjusted for the proper deviation (+25 dBa at 2.35 kHz equivalent to a 75 kHz deviation), the calibration circuit is activated and fed into the input of the audio stage. Since the maximum calibration level is equivalent to +25 dBa, a deviation of 75 kHz should be displayed on the deviation meter or the level adjust potentiometer on the calibration board is adjusted until 75 kHz deviation is observed. The potentiometer is then locked and fixed in position.

The maximum deviation and acoustic level each sonobuoy can transmit at the calibration frequency, without distortion to the signal, was also determined. This distortion level was obtained by varying the output of the microvolter until visible distortion of the signal occurred on an oscilloscope monitoring the audio amplifier output. This level is the maximum level that can be recorded and transmitted undistorted by the sonobuoy electronics.

The output of the frequency deviation meter indicates the character of the pulse received by a sonobuoy receiver. Figure 14a and 14b show a comparison of the deviation meter output with the sonobuoy receiver output for transmission of the same calibration pulse. After correcting for different instrument gains, the deviation parameter of the calibration pulse varied by 0.7 dB. This is a check on the effect of the transmission link on a calibration pulse.

IV. FIELD TEST OF AN/SSQ-41 SONOBUOYS

A test drop of the prototype sonobuoys was made from an aircraft at the Sonobuoy Test Range. This test was made to determine the transmission charactersitics of each sonobuoy, deployment of the hydrophone package, impact test for electronic components, and centrifugal effects (due to sonobuoy rotation) on components after the sonobuoy is launched and descending to the water. The quality and efficiency of the hydrophone deployment was judged from the characteristics of the ambient noise signal displayed on an oscilloscope, and was determined to be of good quality. Each activated sonobuoy transmitted a calibration pulse at approximately 15 second intervals. The quality of the calibration pulse also determined if impact or centrifugal forces had broken or pulled apart any components in the sonobuoy.

Photographs were taken of several calibration pulses transmitted. Figure 15a indicates the quality of a good calibration pulse. Figure 15b is an example of a calibration pulse that may be produced by a damaged sonobuoy.

Since the calibration pulse passes through the same electronics as a detected signal, it is expected that variations experienced in deviation by the calibration signal would also be reflected in the recorded reverberation data.

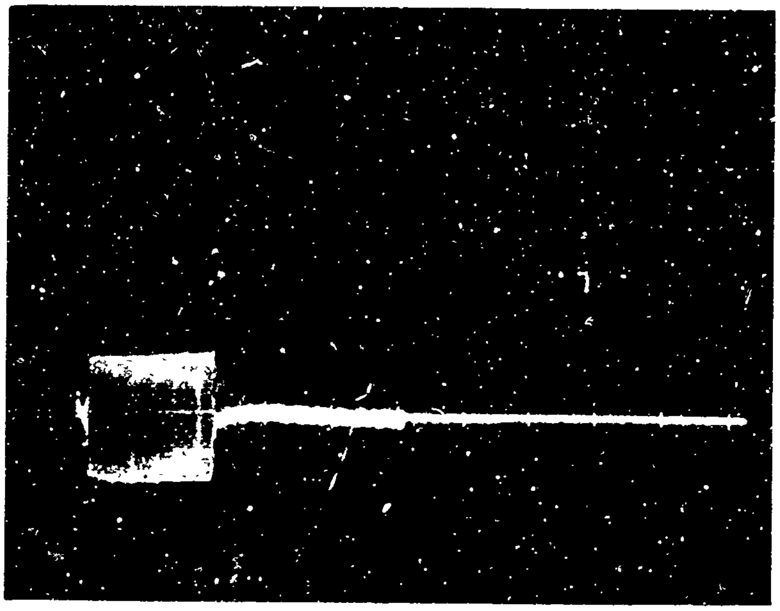


FIGURE 14a. DEVIATION METER OUTPUT.

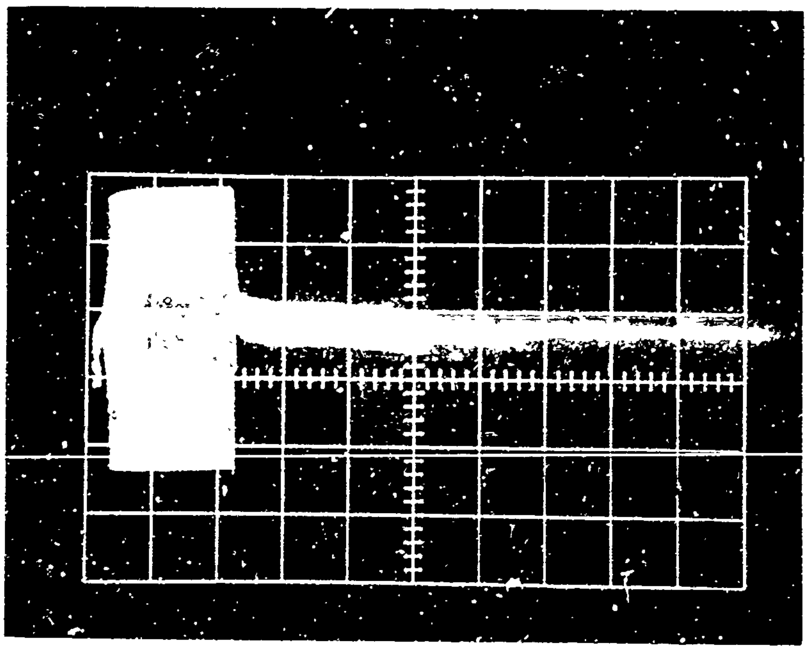


FIGURE 14b. TRANSMITTED CALIBRATION PULSE.

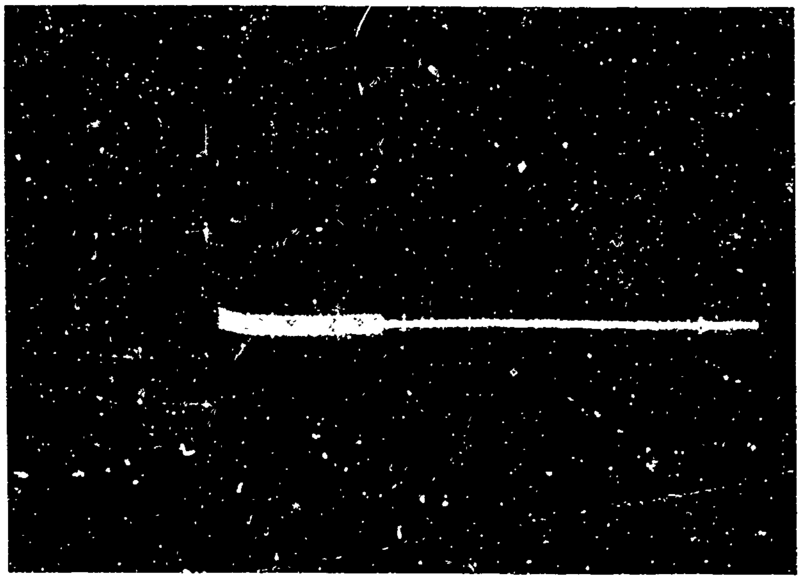


FIGURE 15a. CALIBRATION PULSE TRANSMITTED BY GOOD SONOBUOY

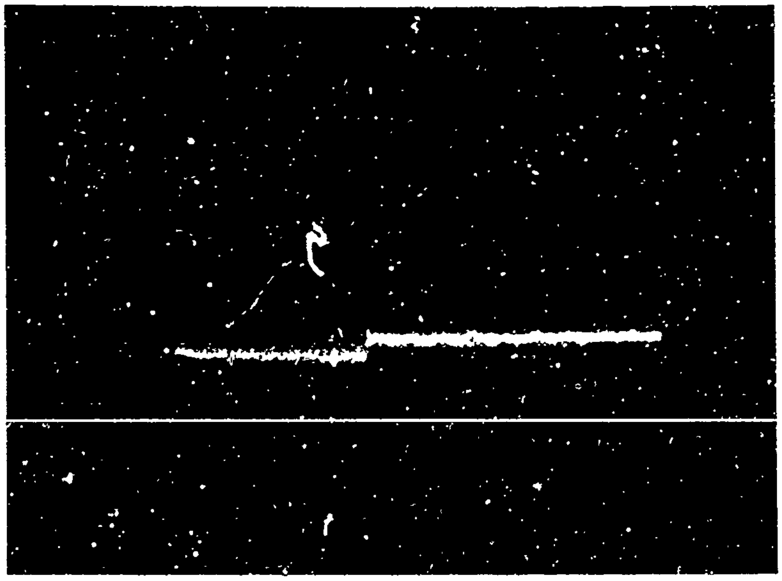


FIGURE 15b. CALIBRATION PULSE TRANSMITTED BY DAMAGED SONOBUOY

V. POST-FIELD TEST EXAMINATION OF SONOBUOYS

The sonobuoys were recovered at the test range and checked for damage and reliability of the electronic adjustments (discussed in Section III). The techniques used for the checkout procedure were the same as those used for initially setting up the sonobuoys. Bench tests indicated variation within ±0.5 dB of the original adjustments.

To determine the effect of fluctuating battery supply voltage on the electronic system, a power supply was substituted for the sea water activated battery. The power supply was varied between 6 and 12 volts and the associated frequency deviation measured. As long as the battery voltage is 10 volts or greater, the deviation will vary by a maximum of +0.25 dB. Figure 16 shows a curve of deviation versus voltage.

A temperature test was made on a representative sonobuoy battery (sea water activated) to determine if temperature variations effect its output. Figure 17 graphically illustrates voltage and frequency deviation as a function of temperature. The temperatures used were the minimum and maximum values expected during the actual field measurements.

Temperature tests were also performed on the sonobuoy components. A temperature range from 25°F to 120°F was applied to the audio stage. The gain and response varied by a maximum of +0.5 dB. A similar range of temperature was applied to the calibration circuit to determine if the calibration frequency and level would change. Figure 18 summarizes the results of the data.

VI. TEST AND FEASIBILITY FIELD MEASUREMENTS

Two sites were slected in the western North Atlantic for the test and evaluation of the modified sonobuoys. In February 1967, two modified sonobuoys were dropped at 25° 28.5'N and 72° 23'W (site 1). Later, in April, two additional sonobuoys were dropped at 31° 30'N and 75° 30'W (site 2). Figure 19 shows the location of the test sites.

A. Data Collection and Analysis

The AN/SSQ-41 sonobuoy is capable of detecting and transmitting reverberation levels in the frequency band between 0.8 kHz and 4.0 kHz. All reverberation levels were detected by the sonobuoy hydrophone set for a depth of 60 or 300 feet. The underwater sound signals utilized to produce the scattering energy were Mk 61 Mod 0 or Mk 51 Mod 0, containing 1.8 pounds of TNT and a 0.07 pound tetryl booster, detonated at 50, 60, 350, or 800 feet.

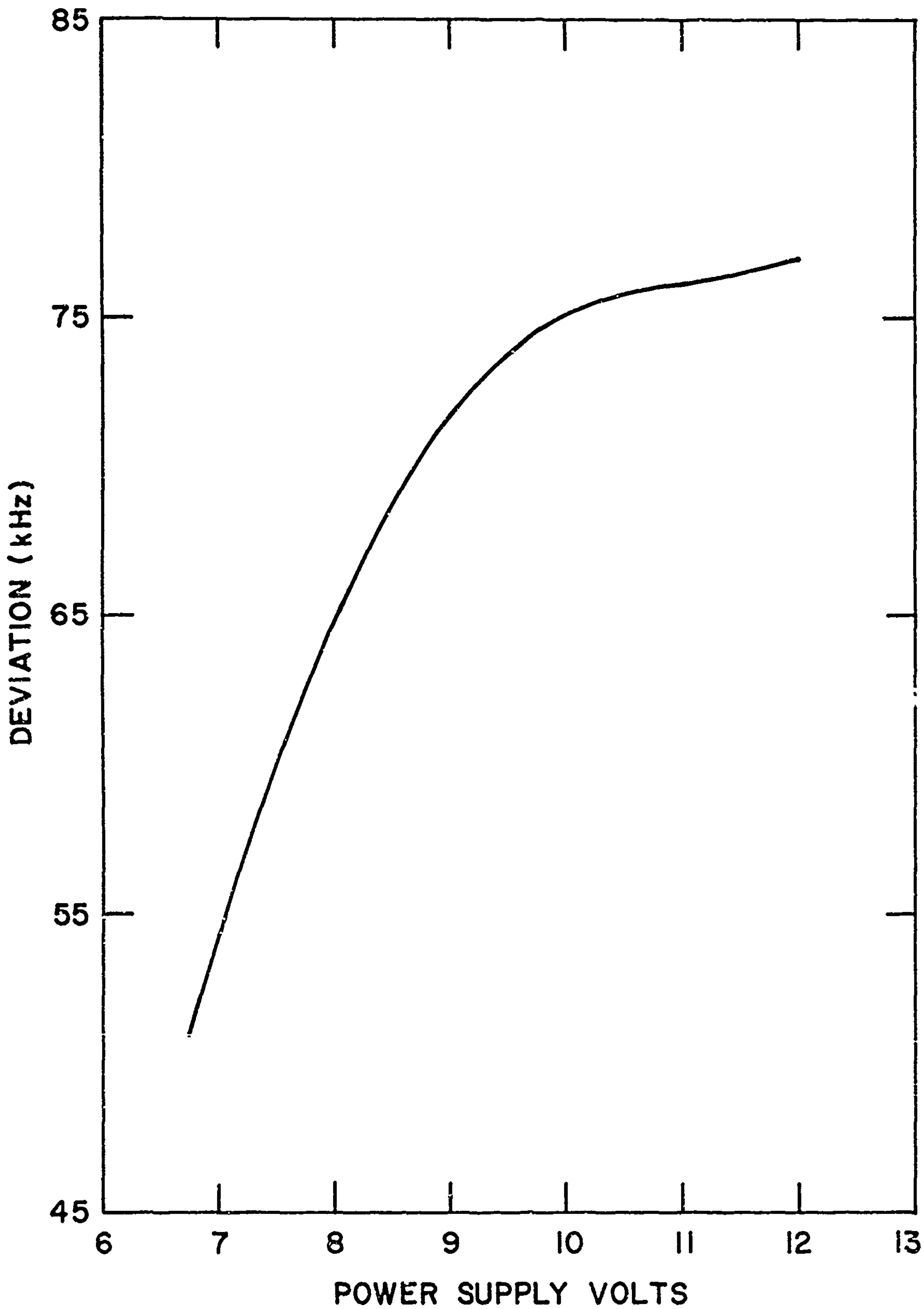


FIGURE 16. DEVIATION kHz VS. VOLTAGE

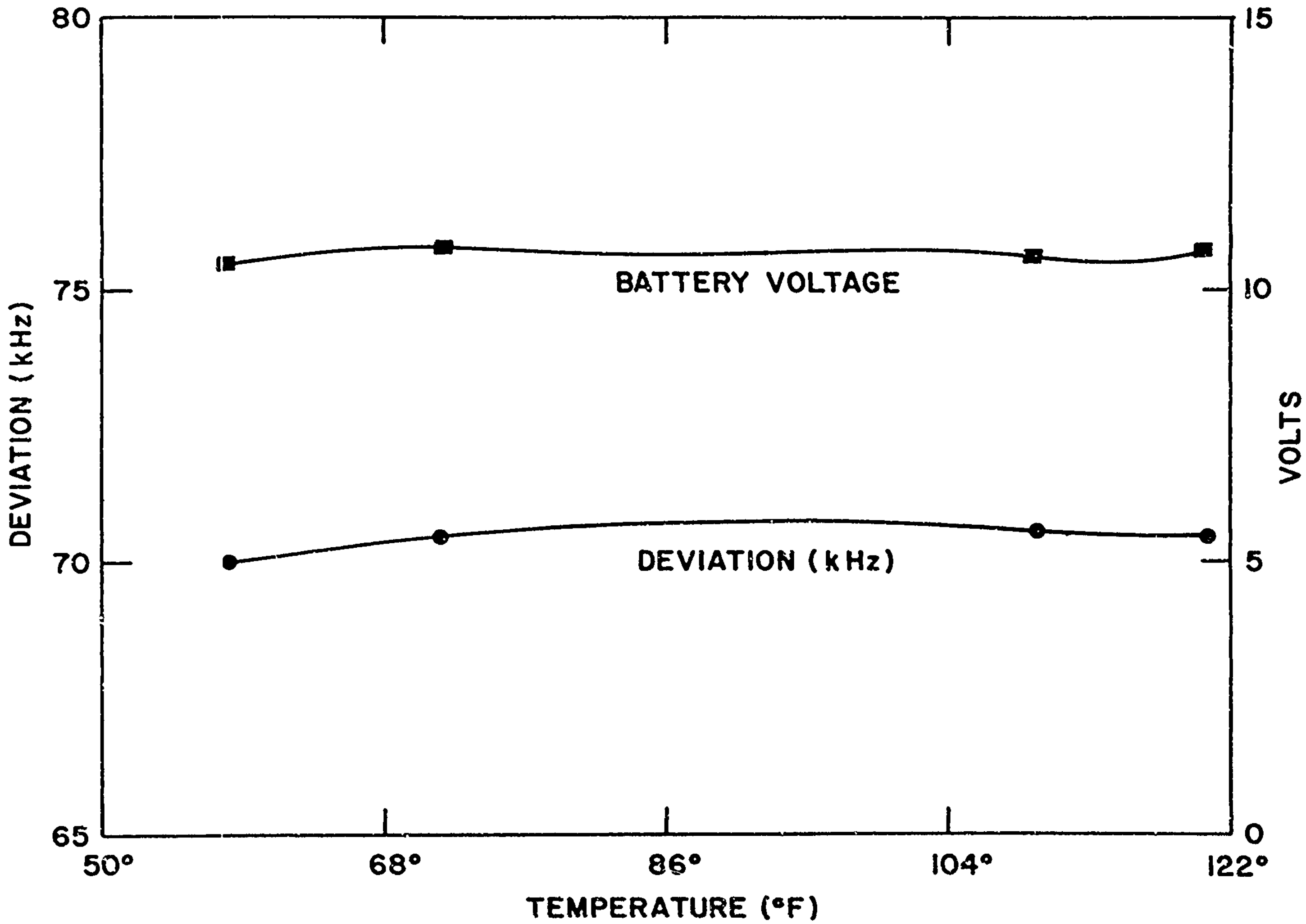


FIGURE 17. TEMPERATURE VS. DEVIATION kHz AND BATTERY VOLTAGE

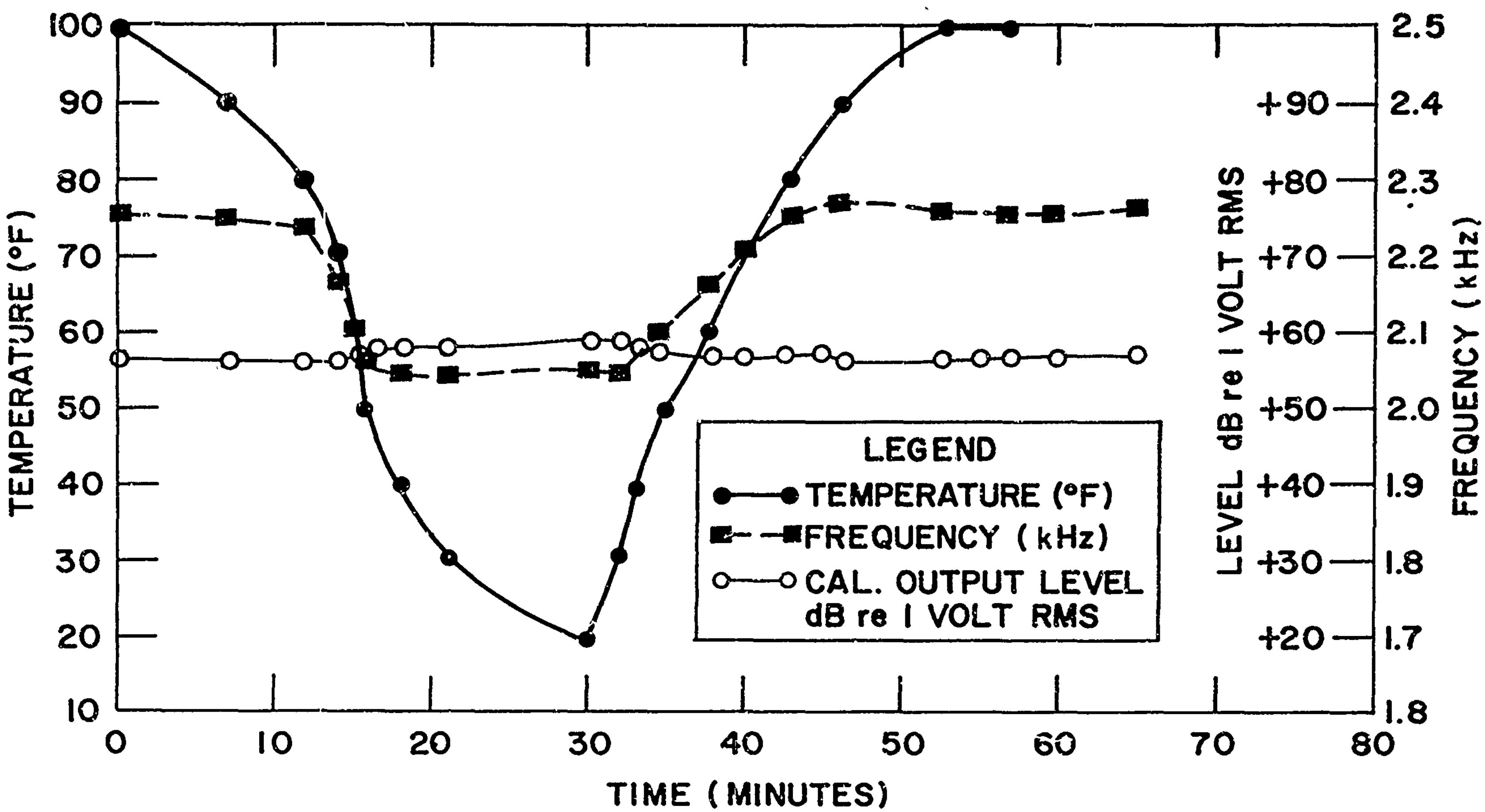


FIGURE 18. CALIBRATION BOARD TESTS

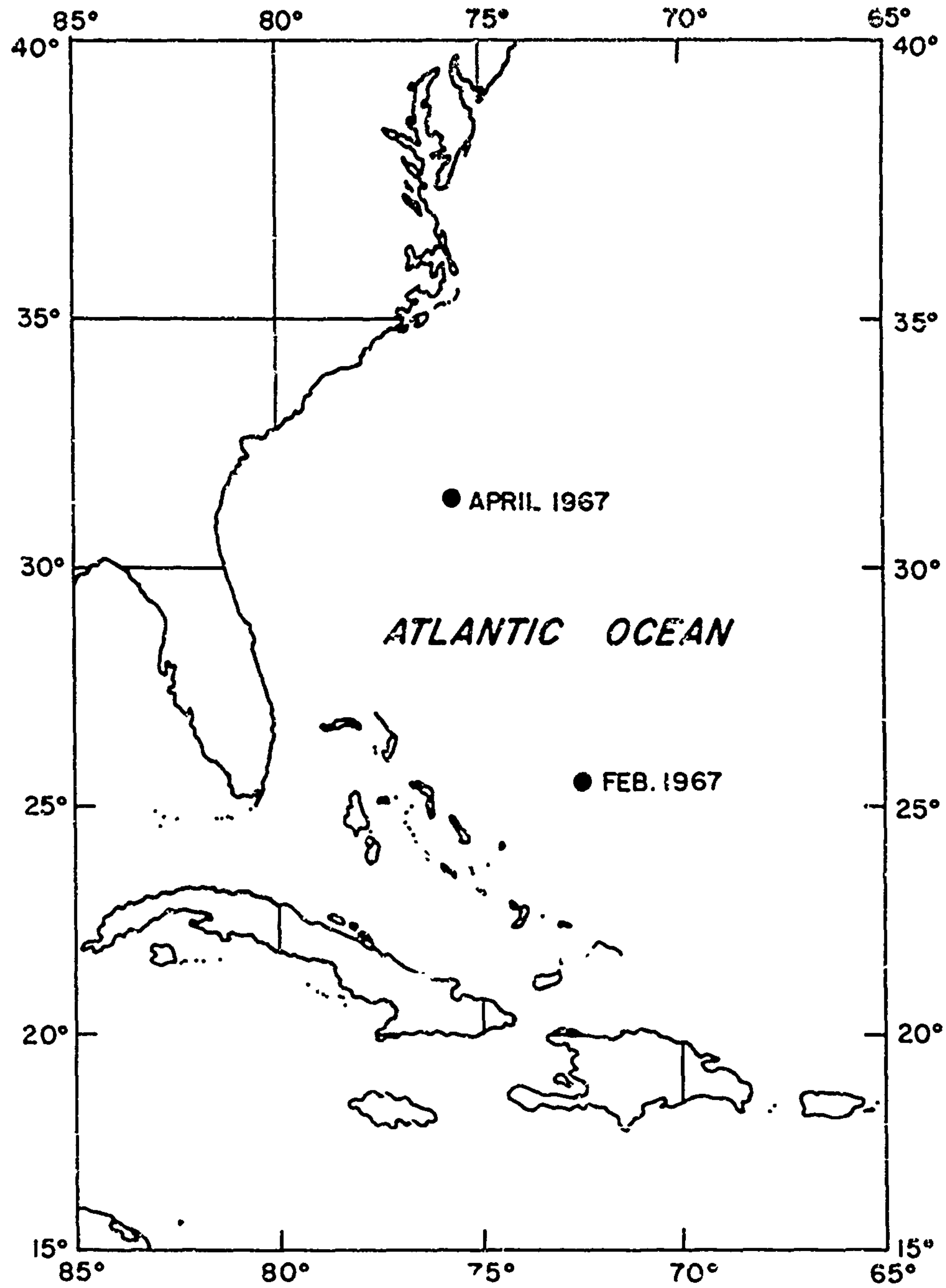


FIGURE 19. LOCATION OF SONOBUOY STATIONS

Volume reverberation data was simultaneously recorded on magnetic tape and displayed on a logarithmic Sanborn Recorder in the field. A typical record is shown in Figure 20 and events marked. The Sanborn record enables cursory examination of the data to insure that the results approximate a -30 log t decay curve predicted from theoretical considerations (Machlup, 1951; Marshall and Chapman, 1964). This decay is characteristic of scattering for a scattering layer at depth.

The magnetic tape data were analyzed in the laboratory using one-octave and one-third octave bandwidths. These data were displayed on a Sanborn Recorder producing a logarithmic reverberation level vs time curve from which scattering strength is computed. Absolute reverberation levels were determined from the calibration signal transmitted by the sonobuoy. Since this calibration step is for a single frequency (nominally 2.35 kHz), a correction factor is applied to the data for the sonobuoy response.

An overlay was applied to the reverberation level vs time curve for each analyzed band to determine if the data points lie on a -30 log t curve. Reverberation levels were determined at 0.5 second intervals after t = 0.5 second and were read until the signal-to-noise ratio was 3 dB. At signal-to-noise ratios of 10 dB or less, an appropriate correction factor is applied. Before t = 0.5 seconds the acoustic signals are clipped, since the levels exceed the maximum level that can be received by the sonobuoy (nominally 25 dB re 1 dyne/cm^2 at 1 yard). Bubble pulse and sea surface reverberation normally predominate at less than 0.5 second and data points before this time would not be used to determine a volume scattering strength.

The volume scattering strength equation has been derived by many investigators (Machlup, 1951; Urick, 1962; Chapman, 1964; Gold, 1966). The equation derived by Chapman (1964) was used to determine scattering strengths for the test reverberation data and is based on the following assumptions:

1. Isotropic sound source,

2. Isotropic scattering,

3. Source and receiver at same depth and same point,

4. Inverse square spreading law, and

5. Absorption is neglected.

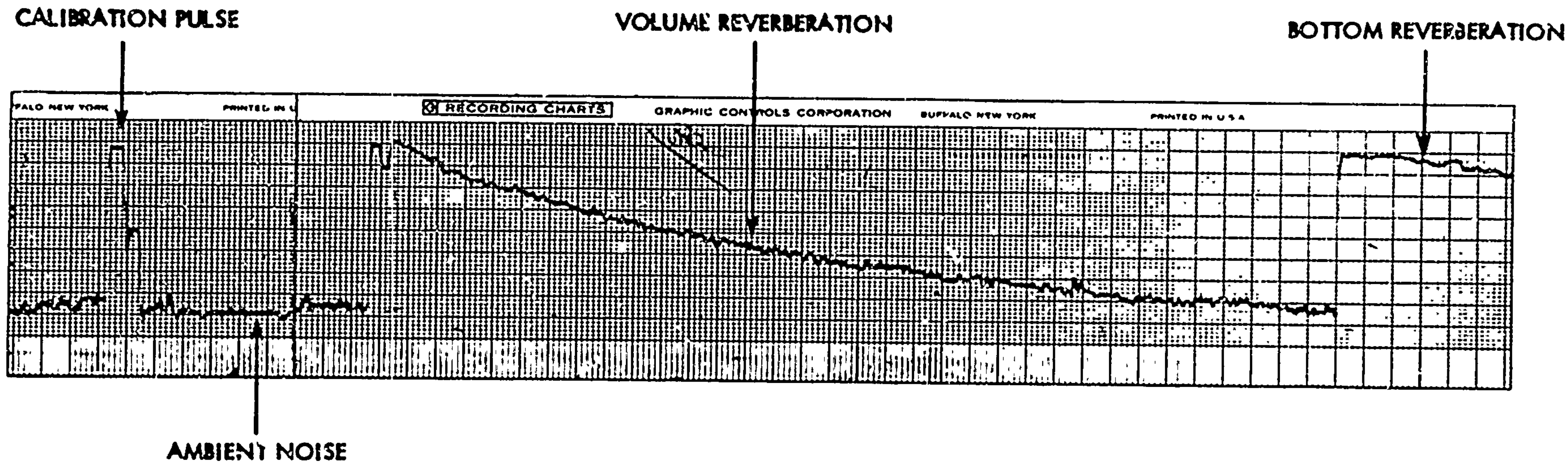


FIGURE 20. LOGARITHMIC RECORD OF VOLUME REVERBERATION VS. TIME.

In its final form the equation is:

$$(1)\quad 10 \log_{10} \int_0^z M(z)dz = 20 \log_{10} P(t) + 30 \log_{10} t - 10 \log_{10} E - 48.$$

$10 \log_{10} \int_0^z M(z)dz$ = Scattering Strength (dB),

$20 \log_{10} P(t)$ = Reverberation Level (dB) in the frequency band of analysis,

t = time (seconds),

$10 \log_{10} E$ = Energy per unit area measured at 100 yards from the sound source in the frequency band of analysis (ergs per square centimenter), and

48 = Constant containing correction for four paths of reverberation reaching hydrophone.

If the receiver and hydrophone are not at the same point, the $30 \log_{10} (t)$ term in equation (1) should be expressed as $30 \log_{10} (t + te)$ where te is the time it would take the direct signal to be incident on the hydrophone. Since detonation time cannot be measured accurately from an aircraft this may introduce some error in the computation of scattering strengths.

Scattering strengths were determined using equation (1) for one-octave and one-third octave analyses. Since scattering strength is frequency dependent a wide band analysis may introduce errors of several dB in its computation as well as masking the frequency dependence of the scattering strength. Figure 21 compares the scattering strengths for several shots using the two analysis bandwidths. The scattering strength was found to vary between four and ten dB for the shots analyzed. To avoid any frequency smoothing resulting from a one-octave analysis a one-third octave analysis was used on all subsequent data. Bandwidth smoothing was also noted by Lamperez (1967).

It should be noted that geometry is a factor that is not readily controlled from an aircraft. The reverberation levels displayed on the Sanborn Recorder actually indicate time after the direct signal is incident on the hydrophone. To convert the record time to actual time, detonation time would have to be known accurately. This variability of time due to geometry could result in errors of approximately two to three dB in scattering strength.

At Site I, two sonobuoys were released with hydrophone deployments set for 60 feet. The sonobuoys were approximately 100 feet apart and drift during the course of the tests produced a maximum separation of 200 feet over a period

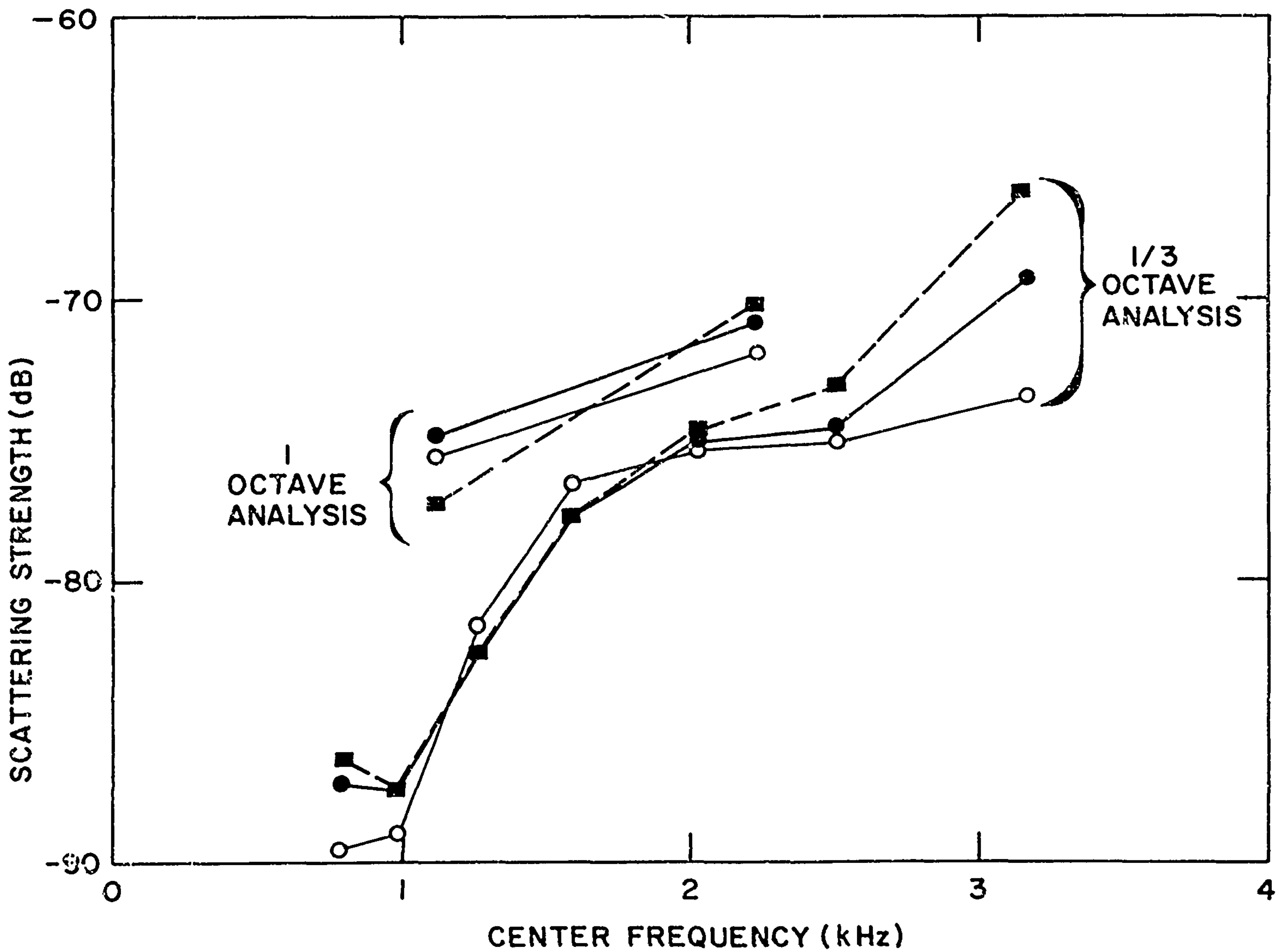


FIGURE 21. SCATTERING STRENGTH/OCTAVE ANALYSIS VS. ONE-THIRD OCTAVE ANALYSIS

of approximately three hours. Charges set for detonation depths of 60, 350 and 800 feet were released from several altitudes to vary the sonobuoy-charge geometry. By varying the aircraft altitude charges were dropped 50, 250, and 500 feet from the sonobuoy to study the effect of geometry on recorded reverberation levels. Since two sonobuoys were recording information from the same shots a check on the consistency of the recorded data was obtained.

The analyzed data are presented as envelopes since the geometries for the noted shots were varied and the measurements at each particular detonation depth were made in approximately 40 to 60 minute intervals. It should be noted that the sonobuoys recorded fairly consistent data and that the scattering strength increases with frequency with a knee or peak present between 1.0 and 2.0 kHz. Figures 22 to 24 graphically illustrate scattering strength vs frequency in one-third octave bands.

Figures 22 to 24 also show scattering strengths for winter and summer months obtained by conventional shipborne systems (Gold, 1965; Gold and Van Schuyler, 1966). The winter measurements are 6 to 12 dB higher than summer measurements and increase with increasing frequency. The present sonobuoy measurements generally increase with increasing frequency and fall approximately at the lower limit delineating the ship measurements.

At Site 2, two sonobuoys were released, one deploying a hydrophone to 60 feet and the other to 300 feet. After the sonobuoys were activated charges set for detonation depths of 50, 60, 350, and 800 feet were released and dropped within 100 feet of the sonobuoys. Ambient noise was recorded and ship observations in the test area indicated Sea State 3 conditions existed.

Sea state conditions are an important factor in the measurement of volume reverberation. At high sea states surface reverberation is increased and will predominate while volume reverberation is masked. This is especially true for deep charges and hydrophones. At Site 2, Figure 25, the analyzed data indicate the effects of surface reverberation. Figure 25 shows scattering strength vs frequency for a shallow charge and hydrophone, a geometry which produces a rapid decay of surface reverberation, and a deep charge and hydrophone where surface effects have produced higher reverberation levels.

A comparison of a 350 foot charge and a 60 foot hydrophone, with a 60 foot charge and 300 foot hydrophone, indicated interchangeability of source and receiver to produce similar reverberation levels. Figure 26 shows that scattering strengths computed for each geometry are very similar with the exception of one point at a frequency at 3.15 kHz.

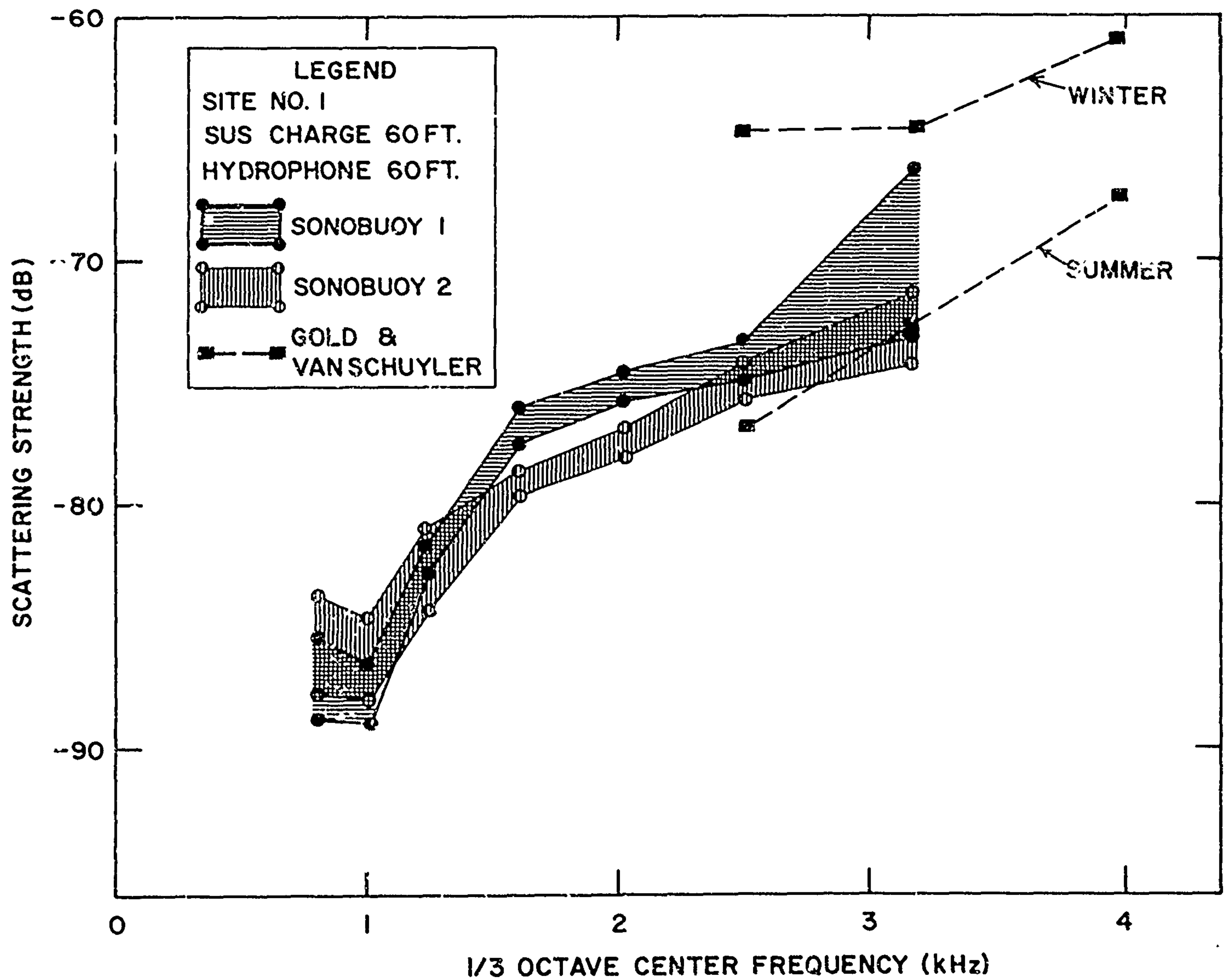


FIGURE 22. SCATTERING STRENGTH, SITE NO. 1

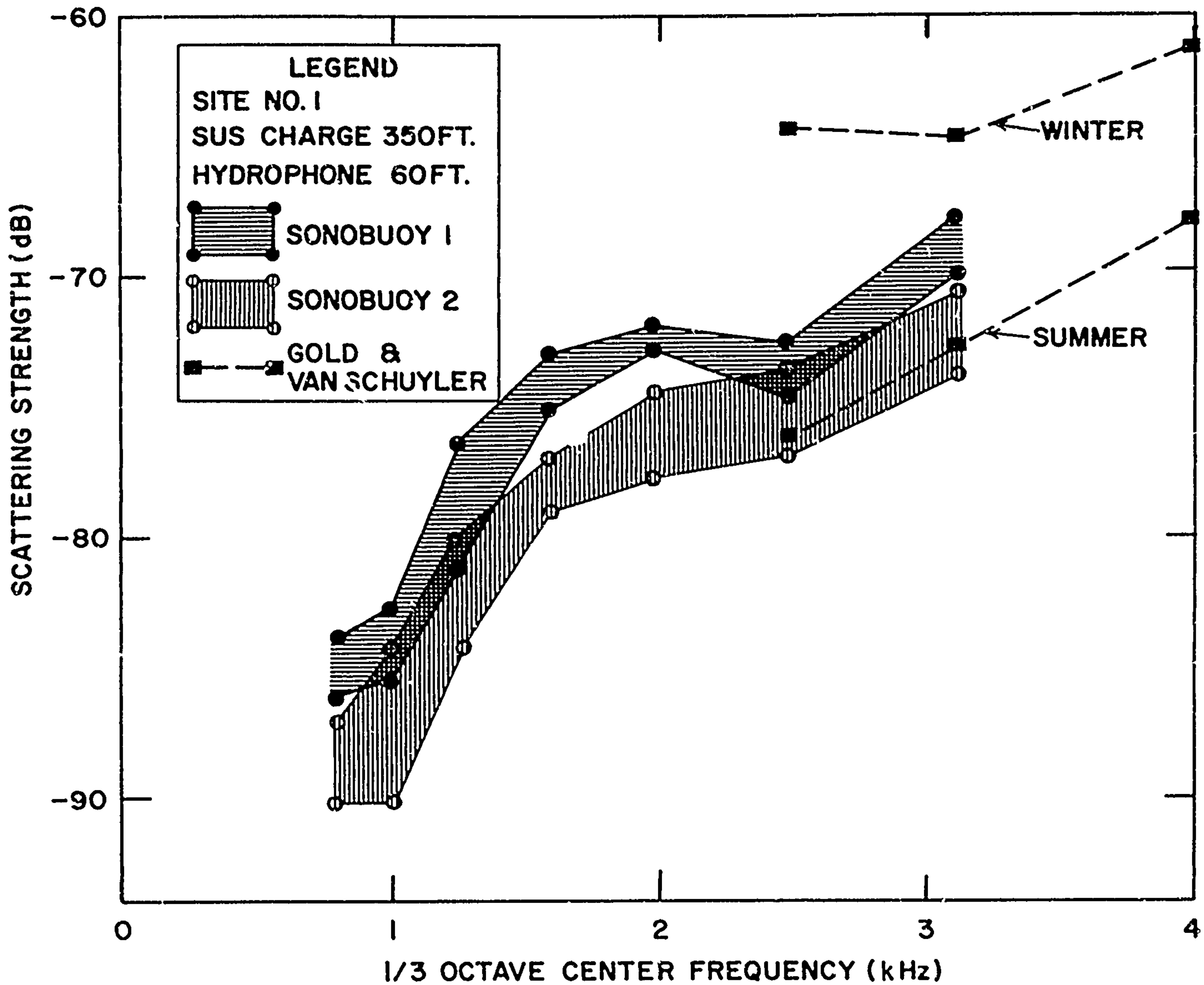


FIGURE 23. SCATTERING STRENGTH, SITE NO. 1

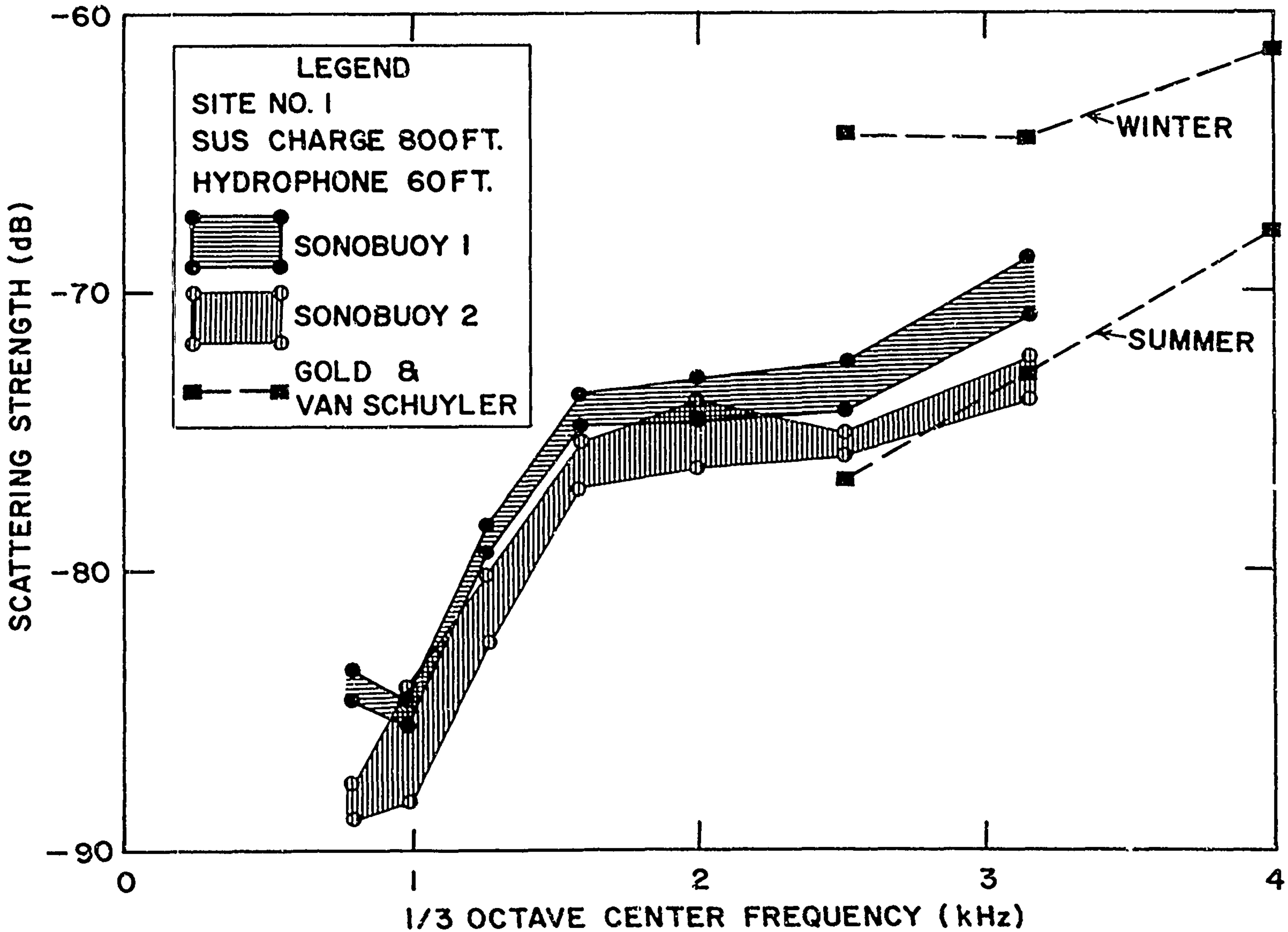


FIGURE 24. SCATTERING STRENGTH, SITE NO. 1

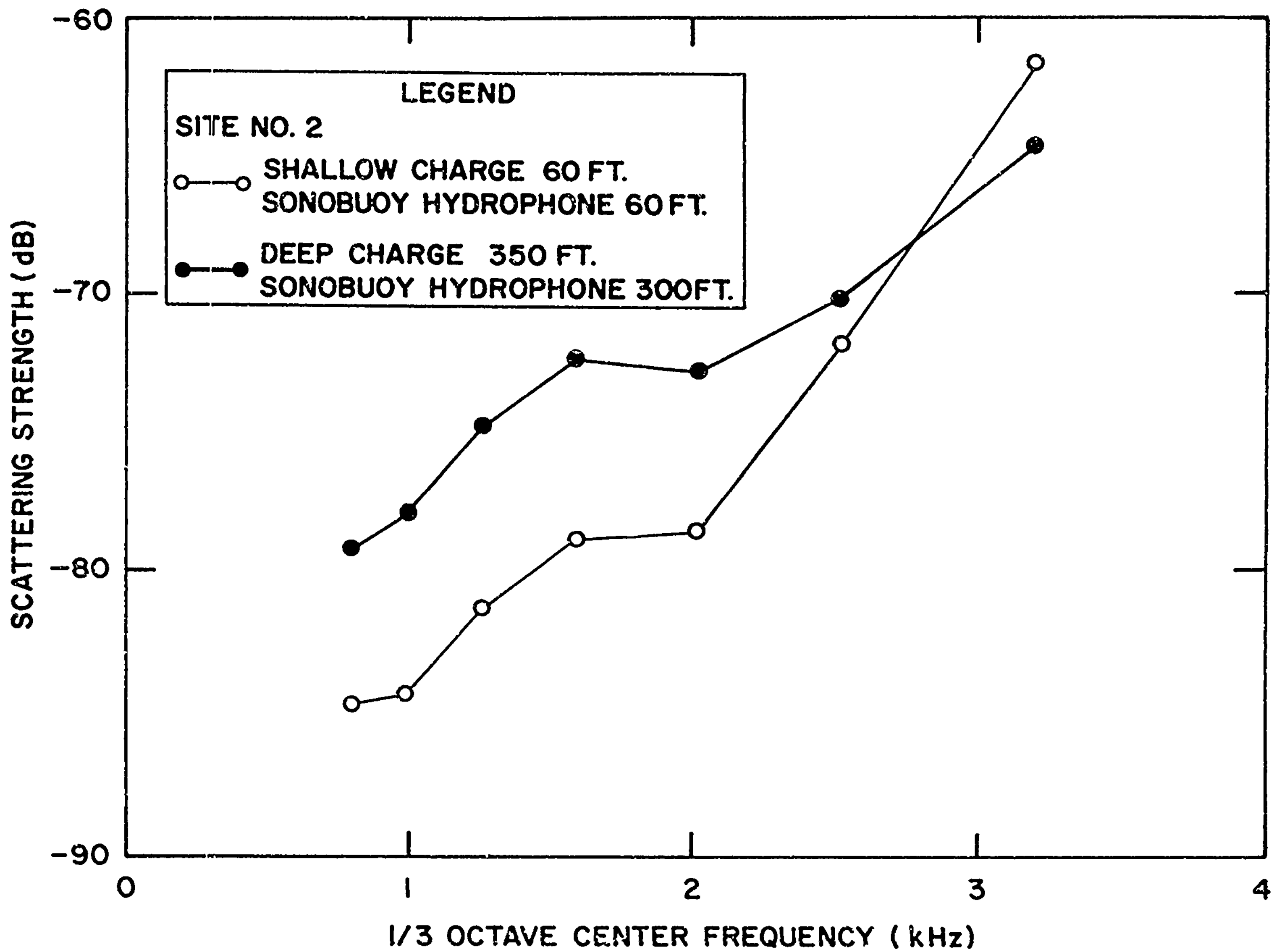


FIGURE 25. SCATTERING STRENGTH, SITE NO. 2

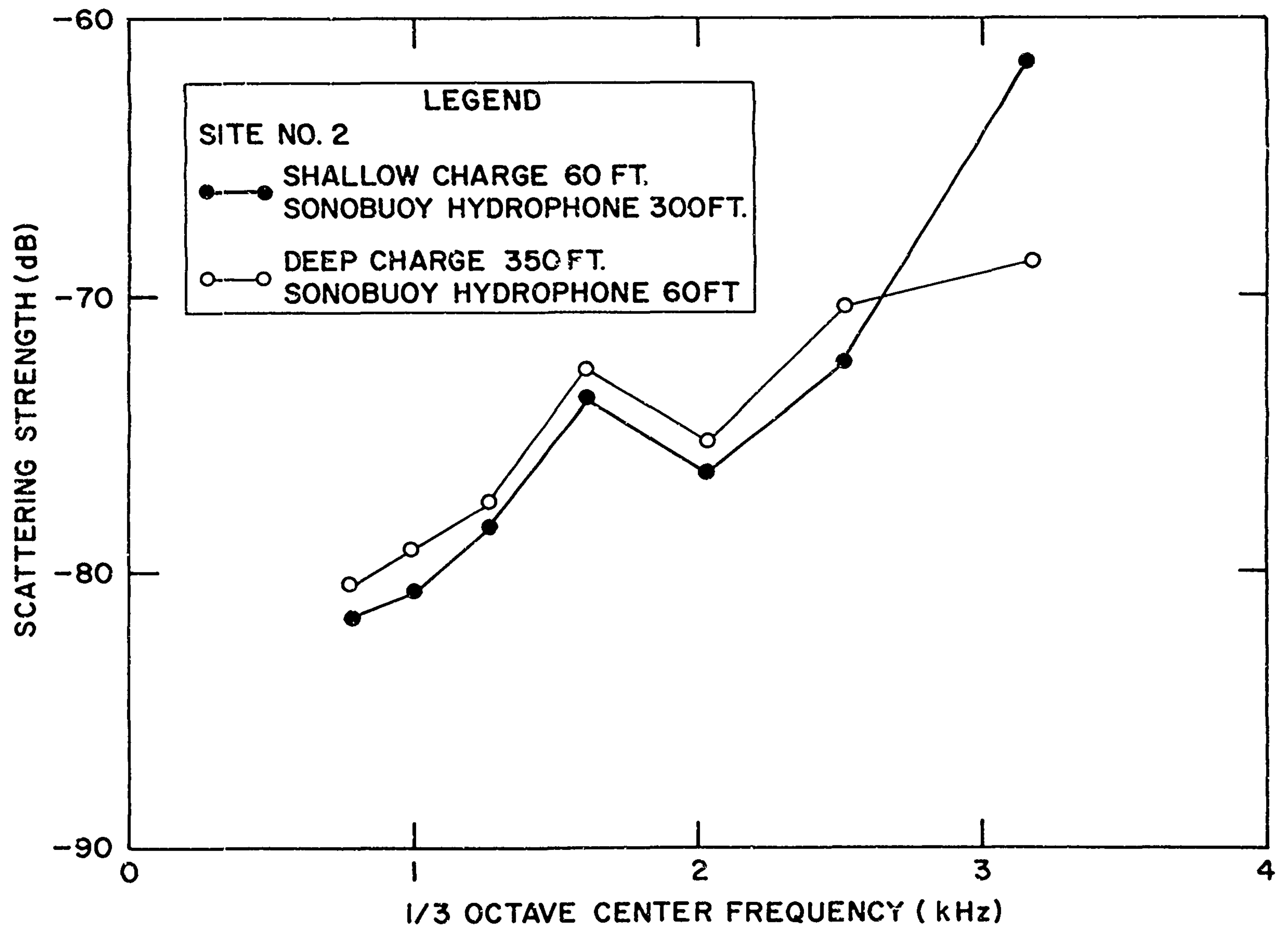


FIGURE 26. SCATTERING STRENGTH, SITE NO. 2

Figures 27 to 30 graphically display scattering strength vs frequency for several other shots. Variability was due to changing weather conditions and sea state during the test period. These changes may produce variations in scattering mechanisms and cause migrations or fluctuations of the scattering sources. As at Site 1, scattering strength generally increases with increasing frequency with a knee or peak present between 1.0 and 2.0 kHz.

VII. CONCLUSIONS

AN/SSQ-41 Sonobuoys were modified, calibrated and field tested for utilization in volume reverberation measurements. The frequency response of the modified sonobuoy is 0.8 to 4.0 kHz. Removal of an AGC circuit prevented gain fluctuation within the audio stages. A two-level calibration pulse was developed and is used for determining absolute reverberation levels and for checking the linearity of the recording and transmitting system.

Modified sonobuoys were used to collect data at two sites in the western North Atlantic. A one-third octave analysis was performed on the data to prevent bandwidth smoothing that may mask the dependence of scattering strength with frequency. Scattering strengths were found to increase with frequency with a knee or peak present between 1.0 and 2.0 kHz.

The test and feasibility studies have indicated that modified sonobuoys can be used to collect volume reverberation data.

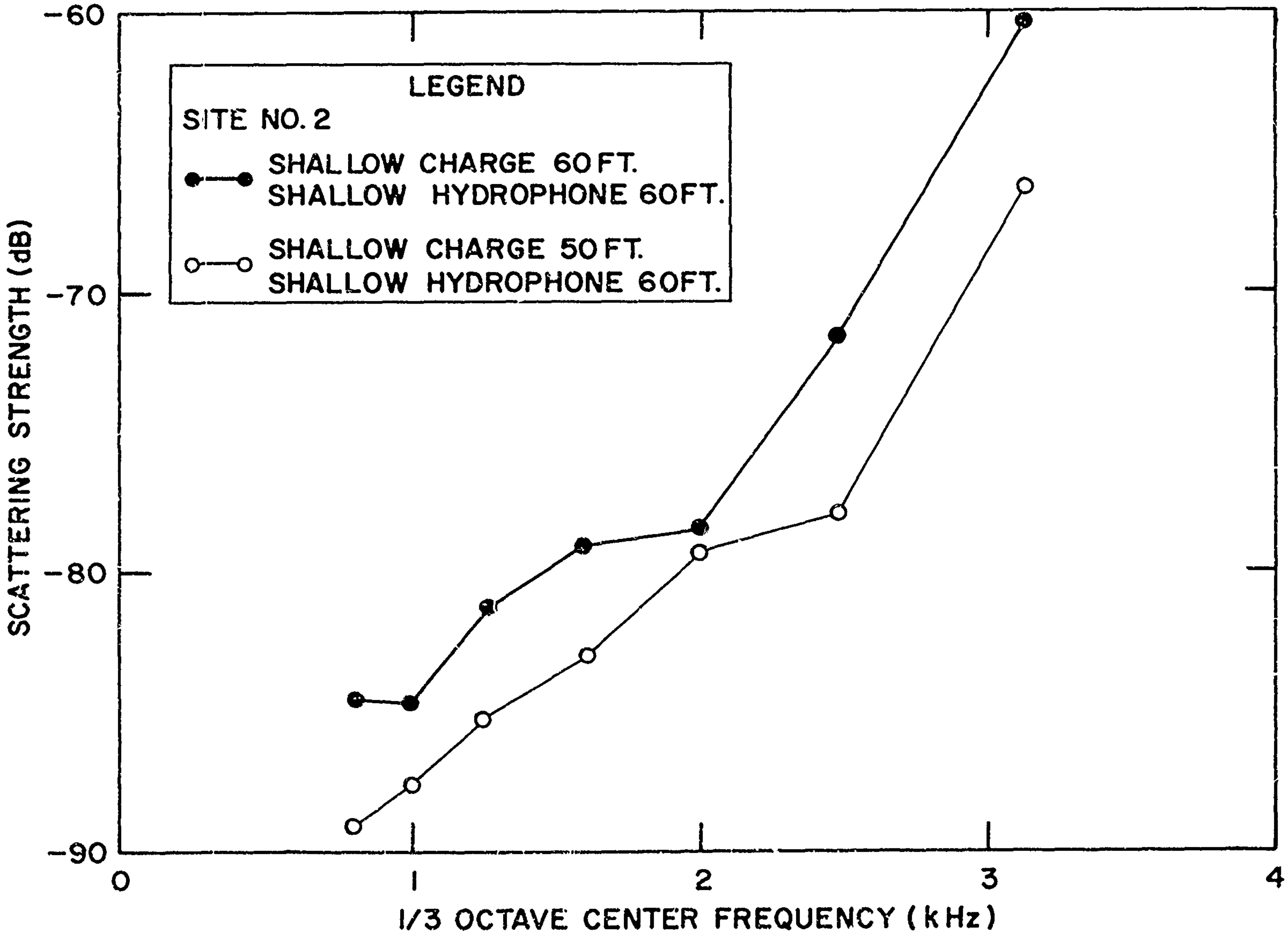


FIGURE 27. SCATTERING STRENGTH, SITE NO. 2

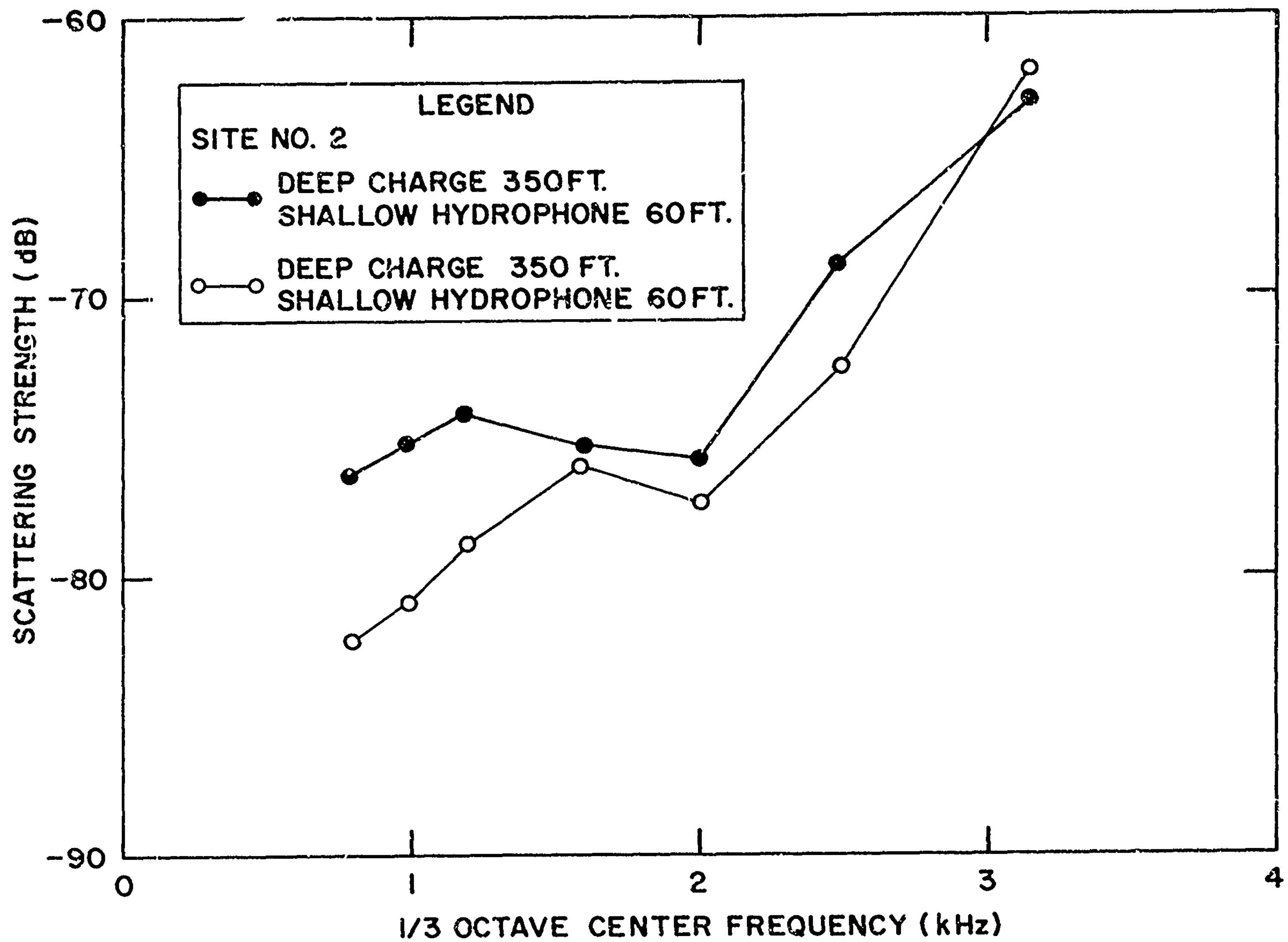


FIGURE 28. SCATTERING STRENGTH, SITE NO. 2

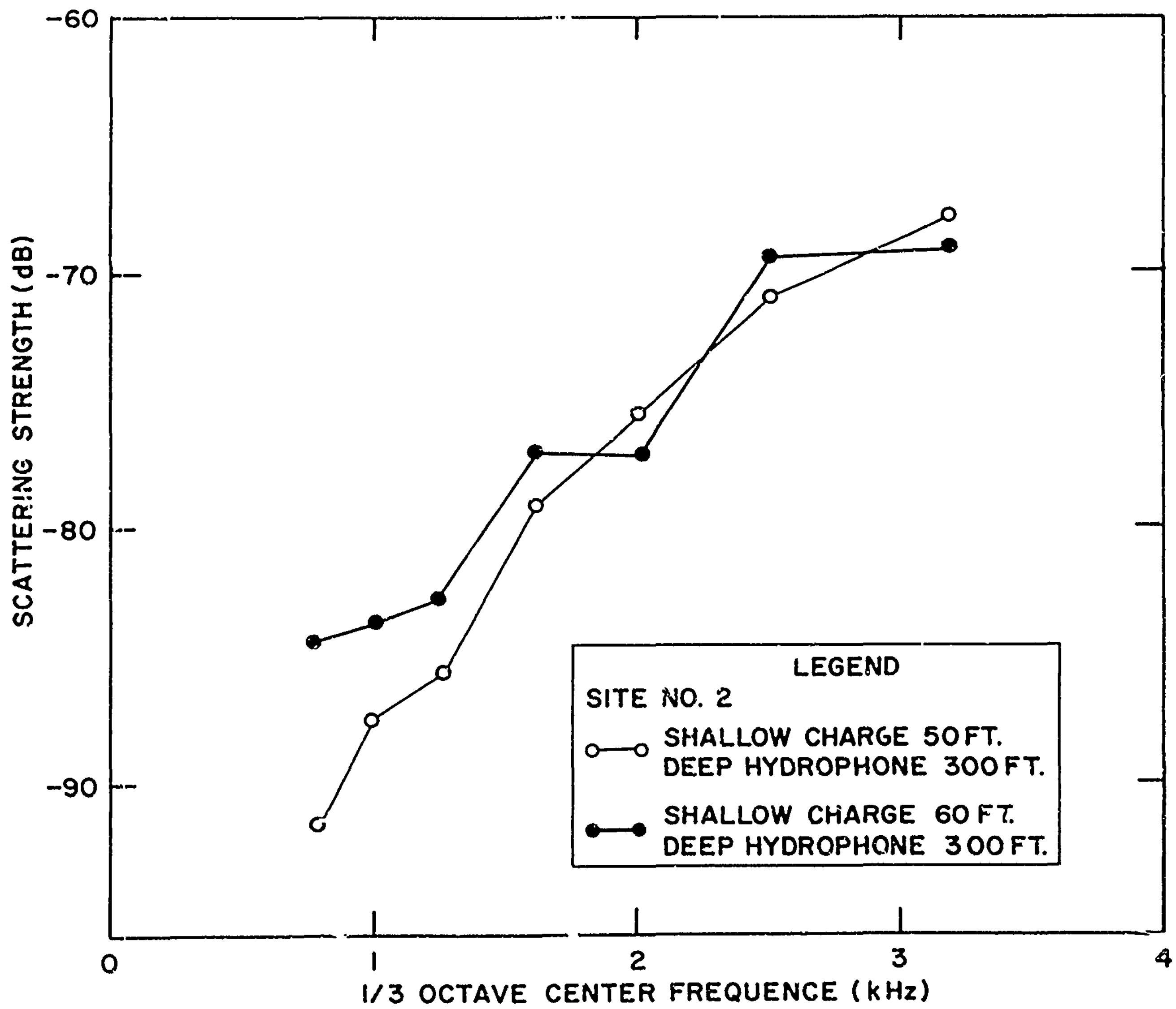


FIGURE 29. SCATTERING STRENGTH, SITE NO. 2

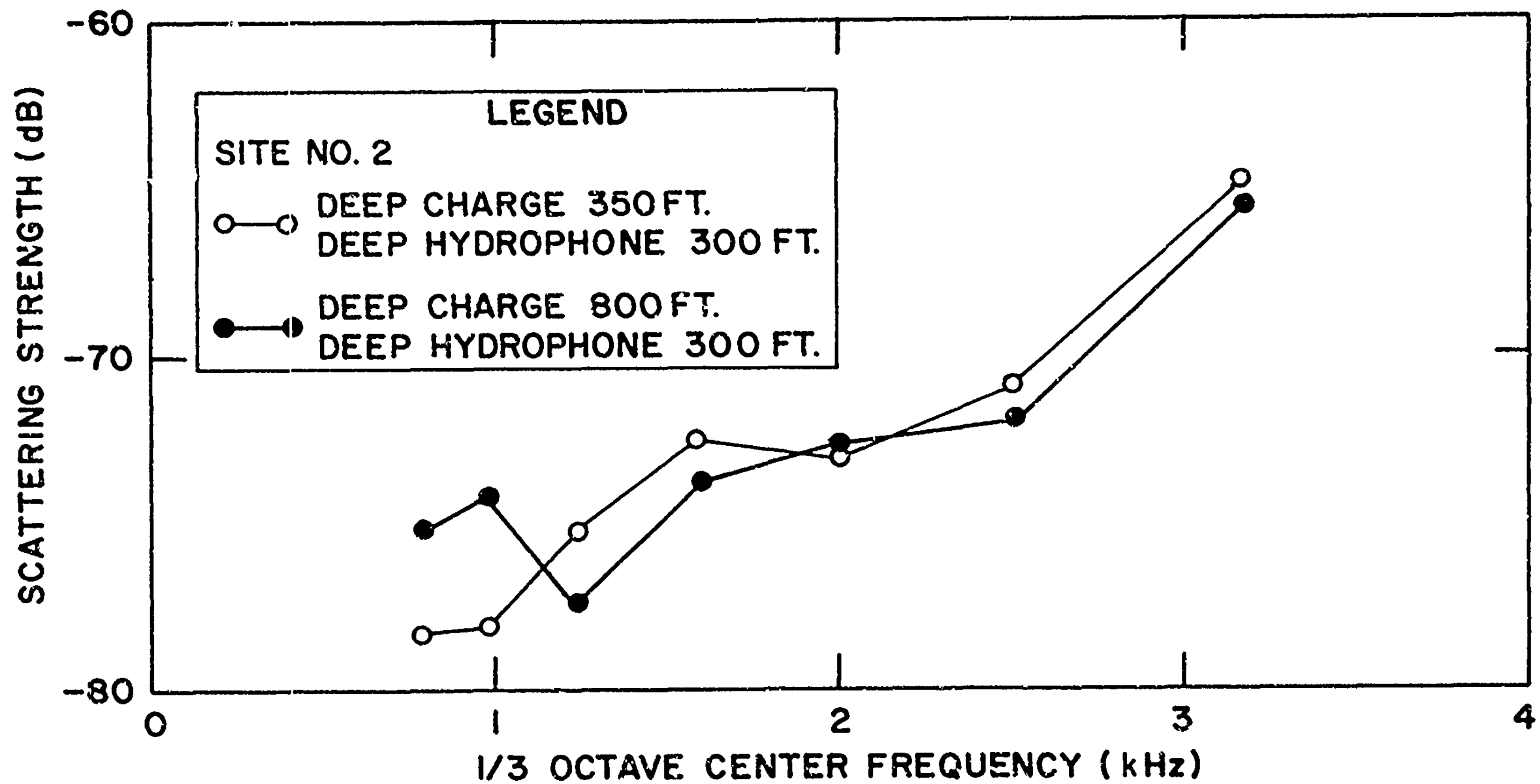


FIGURE 30. SCATTERING STRENGTH, SITE NO. 2

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13. ABSTRACT

AN/SSQ-41 Sonobuoys were modified, calibrated and tested for utilization in the collection of volume reverberation data from aircraft. The electronic modifications involved removal of an AGC circuit and gain adjustments in the amplifier stages. The sonobuoy hydrophone array was also modified to provide for omnidirectionality. A calibration circuit was added for checking system linearity as well as for direct reading of absolute reverberation levels from collected data.

Test and feasibility studies using the modified sonobuoys were conducted in the western North Atlantic. The acoustic data obtained in these studies were analyzed in one-third octave bandwidths in the frequency band between 0.8 and 4.0 kHz. Reverberation levels were determined by using a calibration pulse transmitted by the sonobuoy and a scattering strength computed. The results of the analyzed data indicate scattering strength generally increases with increasing frequency with a knee or peak occurring between 1.0 kHz and 2.0 kHz.

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