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AUTHORITY

NRL ltr dtd 30 Oct 96; NRL ltr dtd 30 Oct 96

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NRL REPORT 4012

A MONITOR FOR THE 10-KC LONG-RANGE SEARCH SONAR SYSTEM

L. C. Ricalzone and H. R. Baker

Sonar Systems Branch
Sound Division

July 22, 1952

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

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A MONITOR FOR THE 10-KC LONG-RANGE SEARCH SONAR SYSTEM, by L. C. Ricalzone and H. R. Baker, 10 pp. & figs., July 22, 1952.

The performance monitor is an integral part of the experimental 10-kc (LRS) sonar system installed in the USS GUAVINA (SSO-362). Its purpose is to provide, when required, simple and accurate information concerning the system's performance.

When used as a receiver, the monitor receives energy from the echo-ranging transducer and displays the pulse shape, pulse length, and waveform of the individual cycles making up the transmitted pulse. It also measures directly the pulse intensity on the axis

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1. Search sonar systems - Monitoring equipment

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As a transmitter, the monitor generates and transmits a calibrated cw signal for alignment of the echo-ranging receivers, simulated echoes of a known level and doppler shift, and calibrated multiple pulse for measuring noise, reverberation, and echo level. By using the monitor as a transmitter and the echo-ranging equipment as a receiver, the receiving beam pattern of the transducer may be plotted.

This monitor, while perhaps too elaborate for a fleet sonar system, has made it possible at all times to determine quantitatively the transmitting and receiving characteristics of the system.

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ABSTRACT

The performance monitor is an integral part of the experimental 10-kc (LRS) sonar system installed in the USS GUAVINA (SSO-362). Its purpose is to provide, when required, simple and accurate information concerning the system's performance.

When used as a receiver, the monitor receives energy from the echo-ranging transducer and displays the pulse shape, pulse length, and waveform of the individual cycles making up the transmitted pulse. It also measures directly the pulse intensity on the axis of the transducer beam and frequency of the echo-ranging driver oscillator. If a continuous signal is emitted by the echo-ranging transducer, the monitor will plot its beam pattern.

As a transmitter, the monitor generates and transmits a calibrated cw signal for alignment of the echo-ranging receivers, simulated echoes of a known level and doppler shift, and calibrated multiple pulses for measuring noise, reverberation, and echo level. By using the monitor as a transmitter and the echo-ranging equipment as a receiver, the receiving beam pattern of the transducer may be plotted.

This monitor, while perhaps too elaborate for a fleet sonar system, has made it possible at all times to determine quantitatively the transmitting and receiving characteristics of the system.

PROBLEM STATUS

This is a final report on the monitor for this equipment; work is continuing on the problem.

AUTHORIZATION

NRL Problem S07-12
RDB Projects NR 527-120 and NE 050-961-9

Manuscript submitted June 13, 1952

A MONITOR FOR THE 10-KC LONG-RANGE SEARCH SONAR SYSTEM

INTRODUCTION

Since sonar equipment performance depends upon equipment characteristics, self noise, target characteristics, and the nature of the medium, any one of which may change ~ ith time, it was decided early in the 10-kc sonar program to include instrumentation for continuously monitoring the performance of the experimental system. Design of the monitor began in November 1949, and it was installed in the forward torpedo room of the USS GUAVINA (SSO-362) along with other parts of the system in January 1951 (Figure 1).

The purpose of the monitor is to provide simple and accurate data on the performance of the Long-Range Search (LRS) Sonar System. This monitor is capable of measuring both the characteristics and efficiency of the driver and transducer and the receiving characteristics of the transducer and associated receiving equipment. Means are provided for measuring the acoustic pulse power output of the transducer as well as the transmitted pulse length and pulse shape. The transmitting beam pattern can also be plotted on a dark-trace tube. The frequency of the driver master oscillator is measured continuously. For receiving measurements, a number of signals are available for the calibration and evaluation of receivers. A 10-kc crystal-controlled signal and a signal variable 200 cycles each side of 10 kc, both of known intensity, are available for the accurate alignment and calibration of the receivers. A method of injecting false echoes of known strength, pulse length, and range, either directly or through the water, is available. Noise, echo, and reverberation levels can be measured by means of a series of equally spaced short pulses of a known level which can be injected either directly into the receivers or through the water on a known bearing. A receiving beam pattern can easily be plotted on a dark-trace tube.

The hydrophone* used with the monitor is a standard B-19H mounted on a life-line stanchion dead ahead and on the axis of the transducer at a distance of 21 feet, 11 inches. A second B-19H hydrophone is mounted on a life-line stanchion on the port side of the ship at a transducer relative bearing of 347° at a distance of 22 feet, 9 inches. This additional hydrophone is provided to make possible the calibration of the monitor hydrophone and LRS transducer by the reciprocity method.

The monitoring equipment also includes a tape recorder, a standard Magnecorder model PT6-A recording mechanism and model PT6-R amplifier (Figure 2). This can be used to simulate noise and other signals by playing the output of the recorder either through the water by way of the monitor hydrophone or directly into the receiving equipment by means of monitor direct injection. The level of these signals are known. Also either sonar information or speech can be recorded on the tape and played back through the speaker. This provides a fast and convenient means of gathering data for later analysis.

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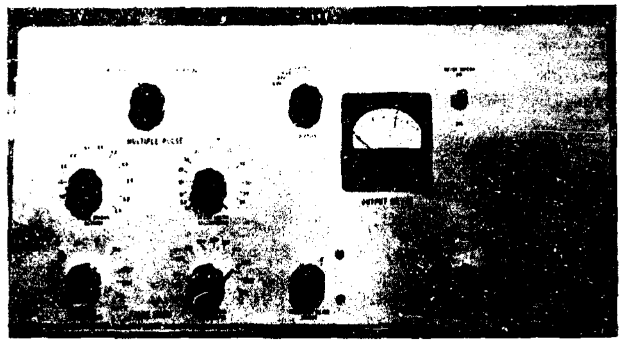
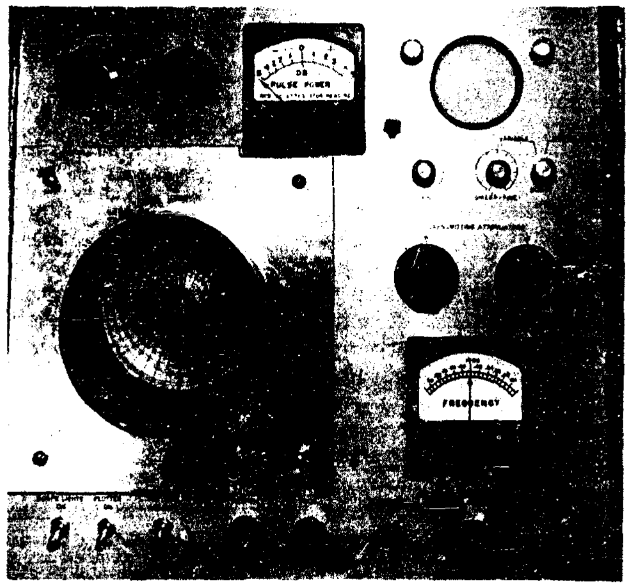
* The monitor transducer is referred to as a hydrophone in this text to avoid confusion with the echo-ranging transducer.

(a)



(b)



(c)

Figure 1 - Monitor rack in USS GUAVINA showing (a) the monitor rack with the bottom protective cover removed to show construction detail, (b) a close-up of the transmitting controls on the monitor panel, and (c) the position on the console panel of the dark-trace-tube beam-pattern plotter, pulse-power meter, frequency meter, 3-inch oscilloscope, and the various controls associated with these indicators.

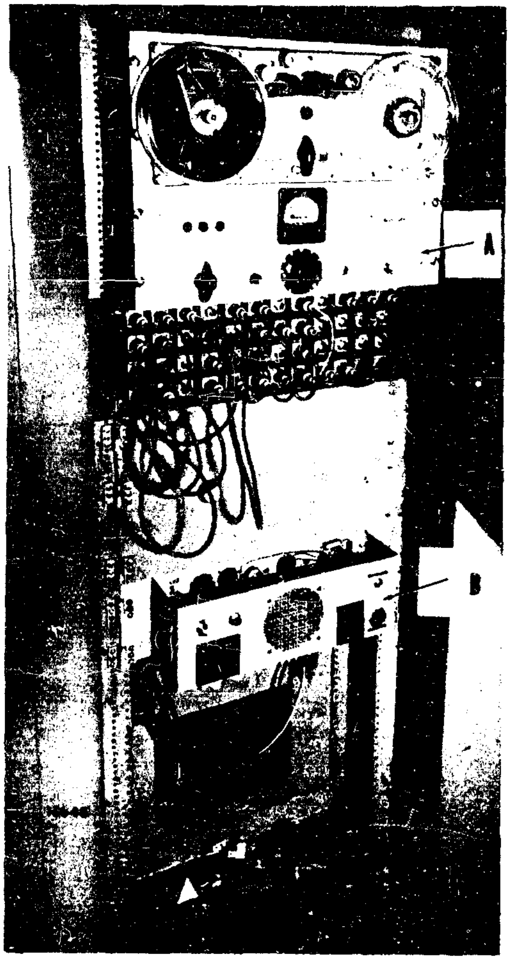


Figure 2 - Recorder rack in USS GUAVINA showing the tape recorder (A) and the recording and playback amplifiers (B). The two middle chassis shown are not a part of the monitor or tape recorder.

THEORY OF OPERATION

In operation, the monitor (shown in block diagram in Figure 3) is divided into two parts, a receiver and a transmitter. When receiving, the signal from the hydrophone is fed to a matching transformer which matches the low-impedance hydrophone to the 500-ohm receiving attenuator, a Hewlett-Packard model 350A covering a range of 110 db in 1-db steps. Between this transformer and attenuator are two relays; the transfer relay is used to switch the hydrophone from the receiver to the transmitter and the beam-pattern relay switches the receivers from the hydrophone to the LRS transducer. The signal now passes through another matching transformer which matches the 500-ohm attenuator to three separate amplifiers, a linear amplifier which operates the pulse-power meter, a logarithmic amplifier operating the beam-pattern plotter and an oscilloscope amplifier deflecting the 3-inch oscilloscope.

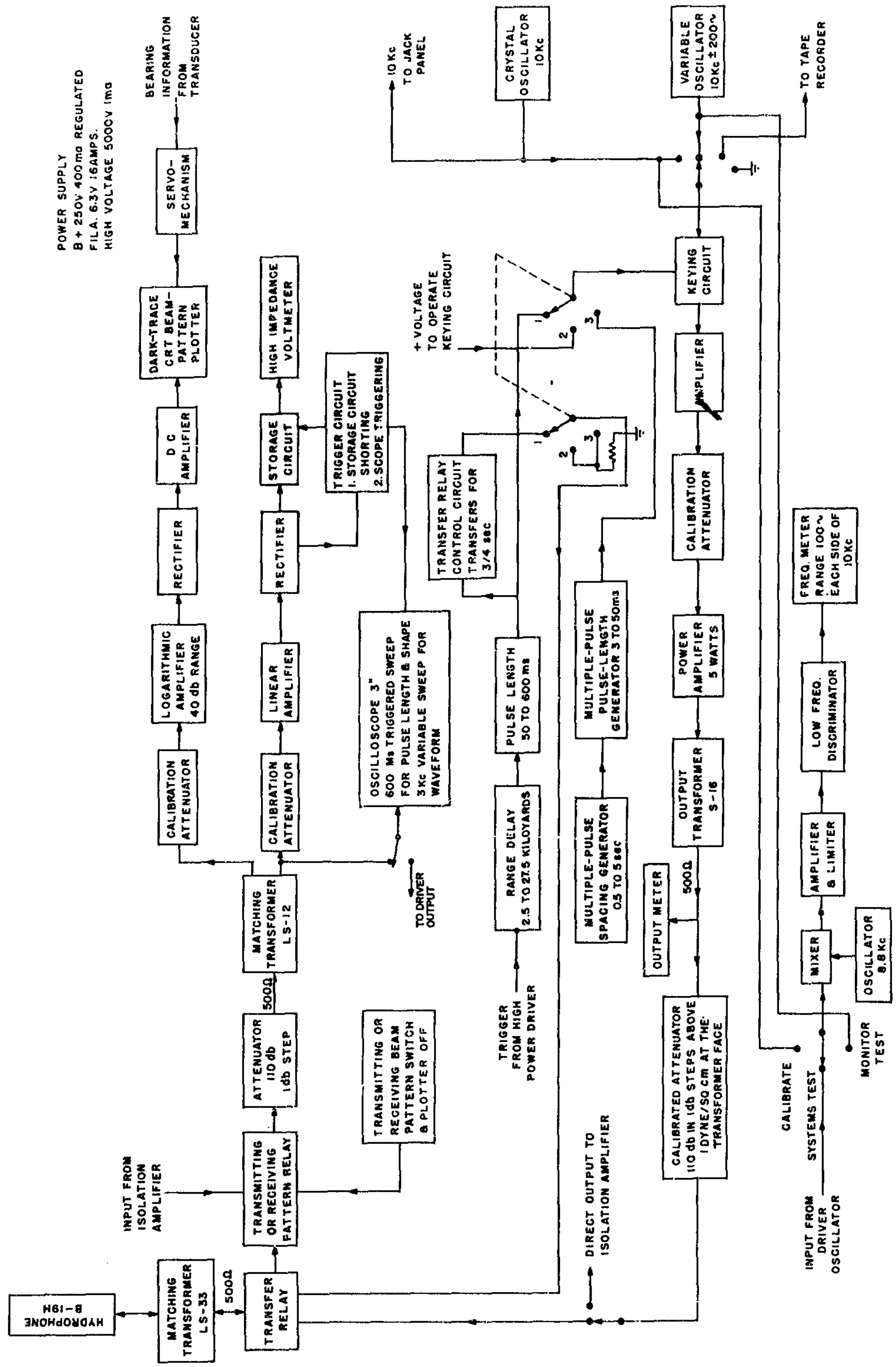


Figure 3 - LRS monitor block diagram

In the pulse-power circuit the signal passes through a calibration attenuator to a linear amplifier. The output of the linear amplifier is rectified and stored in a capacitor storage circuit. The voltage stored across this capacitor is read by a vacuum-tube voltmeter of sufficiently high impedance so as not to discharge the capacitor. In order to make this circuit responsive to pulses only, a trigger circuit is used to control the storage and voltmeter circuit. The storage capacitor is normally shorted. When a pulse passes through the rectifier, the trigger circuit is operated removing the short from the capacitor, allowing it to charge, and the voltmeter to read this charge. After a delay of a preset time of about 5 seconds, the trigger circuit returns to normal, shorting the capacitor and preparing it for the next pulse. The use of this storage system allows the reading of pulse power directly on a meter.

In the beam-pattern plotter, the signal passes through a calibration attenuator to a logarithmic amplifier having a 40-db range. This logarithmic amplifier is of the AVC type having short time constants. The output of the logarithmic amplifier is rectified and amplified by a dc amplifier. This information is used to deflect the dark-trace-tube electron beam radially. Bearing information is fed to a servomechanism which positions the electron beam in azimuth, thus plotting the beam pattern.

The signal applied to the 3-inch oscilloscope may come from either the matching transformer or directly from the LRS driver output. This signal is amplified and applied to the vertical deflection plates of the cathode-ray tube. This oscilloscope has two types of sweeps, a 600-millisecond triggered sweep used to observe pulse shape, and a sweep variable from 1 to 3 kc used to observe waveform. The triggered sweep is started by the pulse-power-meter trigger circuit.

When used as a transmitter the monitor will transmit three types of information: false echo, multiple pulse, and cw. The false-echo circuit is started by a trigger pulse from the LRS driver keying a trigger pulse from the LRS driver keying relay. As shown in Figure 3 this trigger pulse operates a range-delay multivibrator which in turn triggers a pulse-length multivibrator providing a range delay of from 2500 to 27,500 yards and a pulse length of from 50 to 600 milliseconds. The output of the pulse-length multivibrator is used to energize the keying circuit which allows a pulse of energy to be fed to the amplifier from either the crystal oscillator, variable oscillator, or tape recorder as determined by the signal-selector switch. The output of the pulse-length multivibrator also controls a transfer relay circuit which places the transfer relay in the transmit position at the beginning of the pulse and holds it there for 3/4 of a second, allowing the pulse to be transmitted through the hydrophone.

The multiple-pulse circuit consists of a spacing generator and pulse-length multivibrator. The multiple-pulse spacing generator consists of a free-running multivibrator providing a variable spacing of from 0.5 to 5 seconds. The output of this circuit triggers the pulse-length generator which in turn energizes the keying circuit when the selector switch is in position 3. In this mode of operation the transfer relay is held in the transmit position.

When used to transmit cw, position 2 of the selector switch, a constant positive voltage is applied to the keying circuit causing it to transmit continuously. The transfer relay is held in the transmit position.

The output from the keying circuit is amplified by a voltage amplifier and fed to a 5-watt power amplifier through a calibration attenuator. The output of this amplifier is converted to 500 ohms by an output transformer in order to match the 500-ohm 5-watt output attenuator. This attenuator is calibrated to read the sound intensity in db above

The shape of the pattern agreed closely with patterns taken on the laboratory's sound barge except for the pronounced lobe on the starboard side of the pattern which is believed to be caused by reflection from the submarine's capstan.

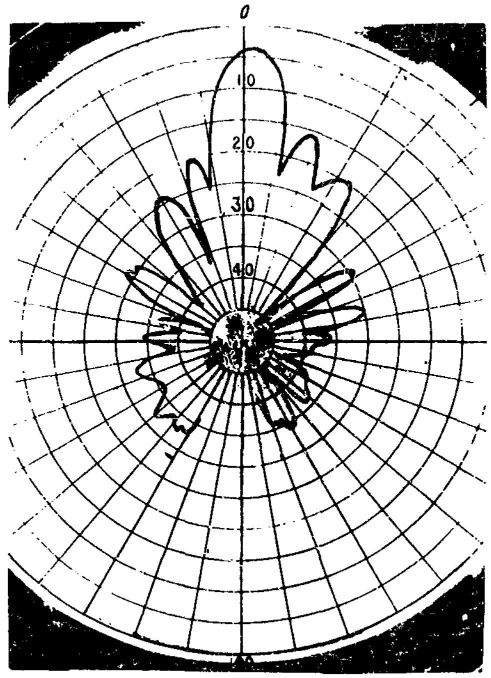


Figure 4 - Beam-pattern plot

Pulse-Power Meter

Using the figure of -68 db vs. 1 volt per microbar as the sensitivity of the transducer, a transmitting response of 106.2 db vs. 1 microbar per ampere at 1 meter is obtained from the formula:

$$\frac{M_T}{S_T} = J$$

or in the logarithmic form, using values in db

$$S_T = M_T - J,$$

where

$$M_T = -68, \text{ and}$$

at 10-kc,

$$J = -174.2. \text{ Thus}$$

$$S_T = -68 + 174.2$$

$$= 106.2 \text{ db vs. 1 microbar per amp at 1 meter.}$$

In the calibration of the pulse-power meter, the LRS transducer current was measured and using the calibration figure obtained above, the attenuators associated with the pulse-power meter were adjusted to cause the meter to read correctly. By the use of this device, the measurement of the pulsed acoustic output of the transducer became simple. All that was necessary was to train the transducer to 000 bearing and echo range. The settings of the attenuators necessary to cause the meter to read on scale plus the meter reading gave the pulse power directly in absolute units. This device was used to keep a constant check on the driver and transducer performance. By the combined use of the beam-pattern plotter, it is possible to isolate troubles in either the driver or transducer.

Monitor Oscilloscope

The monitor oscilloscope provided a convenient means for measuring pulse length, pulse shape, and waveform of the transmitted signal. Means were provided for observing the transmitted signal either through the water at a transducer bearing of 000 or directly from the driver output at any transducer bearing.

Functions of Monitor as a Transmitter

The ability of the monitor to transmit cw, multiple pulses, or false echoes, at a known and controllable level, proved to be its most useful feature. These signals were available injected either through the water by means of the starboard hydrophone or directly across the transducer leads. Of the two methods of injection, the direct injection across the transducer leads proved most useful since it could be used at any transducer bearing. The output attenuators controlling these signals were calibrated to read directly in db above 1 microvolt at the transducer output.

The crystal-controlled cw signal was used to accurately align the various receivers used in the LRS system to the same frequency, as well as to set the transmitting oscillator on the correct frequency. The use of the variable oscillator (10 kc ± 200 cycles) provided means for checking bandwidths and selectivity characteristics of the receivers. The multiple-pulse and false-echo signals were used in checking pulse response of the equipment. The use of these various signals injected through the hydrophone provided a convenient method for checking the phase response of the sector scan indicator equipment.

Measurement of Noise Level – Noise measurement and noise patterns vs. transducer azimuth angle and ship's speed were made using the crystal-controlled 10-kc signal. In these measurements a Ballantine Model 300 Voltmeter was used to measure noise level at the output of the LRS receiver. A cw signal was then injected directly across the transducer leads and its level adjusted to give a reading 3 db higher on the Ballantine voltmeter than that of noise level alone. The amplitude of the injected signal was then equal to the noise level and read directly off the calibrated attenuators. Figure 5 shows a typical pattern taken at a ship's speed of 1.9 and 5.1 knots. If it were desired to measure the amplitude of sharp noise spikes, the same technique was used with the exception that the noise spikes were compared with the multiple pulses on an A-Scan. Using these techniques, the effect of certain deck fittings on the noise level was studied and the ship quieted as much as possible.

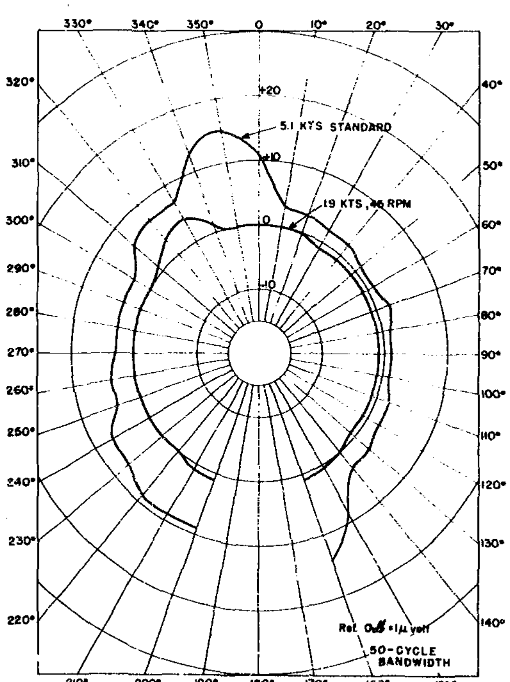


Figure 5 - Noise level measurements. Comparison of noise with calibrated cw signal injected across transducer leads.

Measurement of Reverberation Level – In the measurement of reverberation level, the multiple-pulse feature of the monitor was used. The reverberation was displayed on the A-Scan along with the multiple pulses injected directly across the transducer leads. The level of these pulses was adjusted until they stood 3 db above the reverberation level. The amplitude of the multiple pulses under these conditions equaled the reverberation level and was read directly in db above 1 microvolt on the calibrated attenuators. Using this method, reverberation level vs. range curves were made for various water depths and sea conditions. Figure 6 illustrates one of these curves giving the reverberation level for a particular set of conditions from 2500 yards to 12,500 yards.

Measurement of Echo Level — The monitor was used extensively for the measurement of echo level during this operating period. The procedure for this measurement was to adjust the monitor to inject a false echo at a range slightly greater than that of the true echo. This false echo was injected directly across the transducer leads in order to make the measurement possible on all transducer bearings. The real and false echoes were observed on the A-Scan and the level of the false echo was set

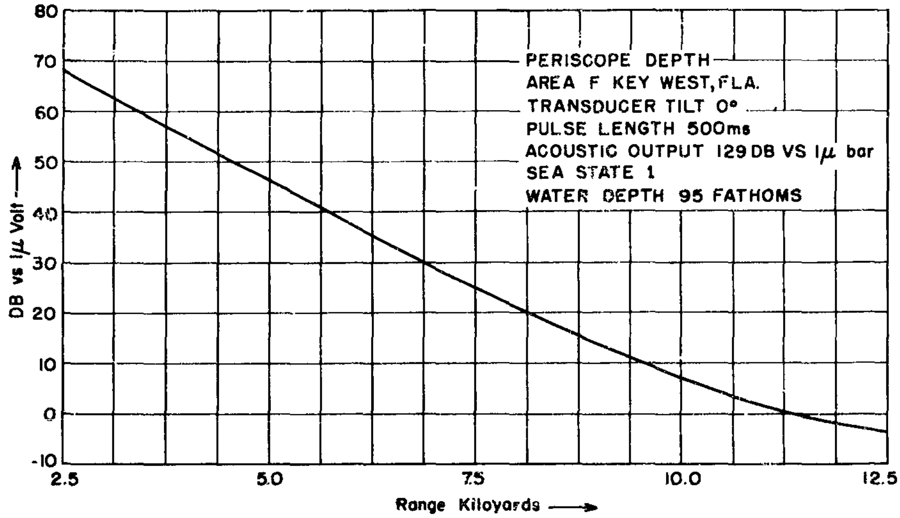


Figure 6 - Reverberation level by pulse comparison method

to equal approximately the level of real echo. Since the level of the false echo was accurately known, the level of the real echo could easily be obtained in microvolts. If the real echo appeared at a range where the TVG was still in effect, the false echo was placed close enough to the real echo in order that the gain change between the two was negligible. Figure 7 is a photograph of two echo-ranging intervals showing a real target at about 10,250 yards and a false echo injected at 13,750 yards. In the top photograph the real and false echoes are about equal (15 db above 1 microvolt). In the bottom photograph the target echo has a tapered shape, the leading edge being about 1 db and the trailing edge about 4 db below the level of the false echo, which has a level of 15 db above 1 microvolt. In both of the photographs, the TVG has completely decayed, having no effect on either the real or false echo.

Measurement of Frequency - A frequency meter was provided in the monitor which accurately measures frequency for 100 cycles either side of 10 kc. In use, the meter was calibrated by switching its input to the 10-kc crystal-controlled oscillator and by adjusting to read exactly 10 kc. After adjustment, either the frequency of the LRS driver oscillator or the variable monitor oscillator could be read to an accuracy of ± 2 cycles. This system provided a continuous and accurate check on the echo-ranging frequency of the LRS equipment and also provided a known frequency of 10 kc ± 100 cycles for measuring receiver responses and bandwidths.

OPERATIONAL PROBLEMS

During this 13-month operating period, very few problems were encountered in the operation of the monitor. The most serious problem was not attributed to the monitor console itself but to the frequent failure of the B-19H hydrophones used as the monitor transducer. This failure was not electrical but was caused by water leakage into the hydrophone cable. Under daily use, a hydrophone would normally last between $1\frac{1}{2}$ to 3 months before water forced its way into the cable causing a loss in hydrophone sensitivity of about 10 db. The leakage was probably due to small holes formed in the cable outer insulation

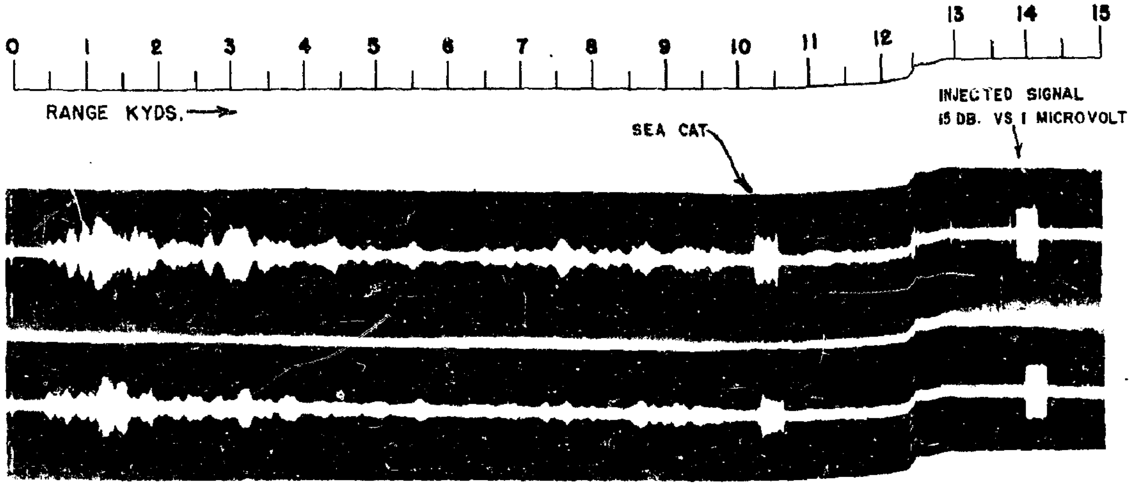


Figure 7 - Submarine echoes and false echoes

by the constant vibration and pressure changes occurring on the deck of a submarine. This could perhaps be corrected by a properly designed cable. Failure of the hydrophone did not render the monitor useless, however, as its direct injection features were still usable. Only the pulse-power meter and beam-pattern plotter were rendered useless.

Trouble was also encountered in the measurement of pulse lengths. The triggered sweep used for pulse-length measurement did not hold its calibration, and also the green P1 cathode-ray tube, did not provide long enough persistance for easy reading. These difficulties could be corrected by the use of a P7 tube and minor circuit changes. The only other failure during this period was that of two vacuum tubes.

CONCLUSIONS

1. Monitoring of the receiving and transmitting characteristics of the 10-kc experimental sonar system, has provided accurate information concerning all systems parameters which enter into the echo-ranging equations.

2. Frequent and accurate monitoring of equipment parameters has made it possible to measure more accurately, transmission loss, target strength, noise, and reverberation levels.

3. The monitoring facility has made it possible to quickly locate failures, or substandard performance in any part of the system. As a result of frequent monitoring, loss of operating time because of equipment failure was kept to a minimum.

4. The reliability and usefulness of this monitor with an experimental sonar system, suggests that a somewhat less elaborate monitor would be desirable for fleet sonar systems.

* * *

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Naval Research Lab., Wash., D.C.

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over

Detection (6) Sonar equipment

Acoustic (1)

(Copies obtainable from ASTIA-DSC)

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UNITED STATES GOVERNMENT

memorandum

7103/118

DATE: 30 October 1996

FROM: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF. (a) FOR DECLASSIFICATION

TO: Code 1221.1

VIA: Code 7100

REF: (a) NRL Confidential Report #4012 by L.C. Ricalzone et al, July 22, 1952 U)

1. Reference (a) is a report on the design and implementation of a monitor for the performance of the 10-kilocycle long-range search sonar system. The 10-kc active sonar was one of the phases in the reduction of the operating frequency of active sonars following World War II. The major frequency of sonars during World War II was 25 kHz. The research and development at NRL following the war progressed to 10 kHz, 5 kHz, and 2 kHz. This report includes the design of the system and at-sea test results.

2. This technology and equipment of reference (a) have long been superseded. The current value of this report is historical.

3. Based on the above, it is recommended that reference (a) be declassified with no restrictions.

Burton G. Hurdle

BURTON G. HURDLE
Acoustics Division

CONCUR:

Edward R. Franchi 11/4/96

EDWARD R. FRANCHI Date
Superintendent
Acoustics Division

Completed 1-11-00 [illegible]