NUSL Problem No. 3900

NAVY UNDERWATER SOUND LABORATORY
NEW LONDON, CONNECTICUT

AN/SQS-26 INTERFERENCE: "FATHOMETER-TYPE" BOTTOM RETURNS (U)

By

B. F. Cole and H. R. D'Amelia

NUSL Technical Memorandum No. 2040-0155-69

11 December 1969

INTRODUCTION

In the various models of the AN/SQS-26 sonar, enough energy is transmitted and received via the vertical sidelobe response to allow these systems to receive discreet echoes from the ocean bottom. Such echoes are referred to as "fathometer" returns because their arrival times relate directly to multiples of the water depth. Although the AN/SQS-26 receives incoherent bottom reverberation returning via this same path, this discussion treats only the coherent "fathometer-type" returns. These returns are typically observed on the CW portion of the AN/SQS-26 storage display, and constitute regions of interference, the severity of which is a function of the water depth, the normal incidence bottom loss, and the specific SQS-26 equipment model. In this paper, the "fathometer-type" of interference is discussed generally, and some specific AN/SQS-26 (BX) and AN/SQS-26 (AXR) results from test area Bravo (a one degree square centered at 25.5°N, 72.5°W) are presented.

NUSL Tech Memo
No. 2040-0155-69

SOME GENERAL RELATIONS

Since the decay rate of this particular interference depends on the propagation loss suffered by the different order fathometer-type arrivals, it is desirable to review the expression for this loss. If loss is assumed to be zero for each surface contact, the 3.5kHz propagation loss can be given as a function of the arrival order (the number of bottom bounces undergone) as follows:

$$N_W = 20 \log 2D + 0.212 \times \frac{2nD}{1000} + nN_B + 20 \log n \qquad \text{eq. (1)}$$

where
D is the water depth in yards
N_B is the bottom loss in dB per contact
and n is the arrival order number.
For an omni directional source and receiver, this results in a received level given by

$$L_R = L_S - 20 \log 2D - 0.212 \frac{2nD}{1000} - nN_B - 20 \log n \qquad \text{eq. (2)}$$

where
L_R is the received level in dB//1 μ bar and L_S is the source level in dB//1 μ bar at one yard.
In the case of the AN/SQS-26, however, the received level of an arrival which returns from the bottom at an angle of θ (in the case of interest $\theta \simeq 90^\circ$) becomes:

$$L_R - \Delta RH(\theta) - \Delta RV(\theta) = L_S - \Delta SH(\theta) - \Delta SV(\theta) - 20 \log 2D - 0.212 \frac{2nD}{1000} - nN_B - 20 \log n \qquad \text{eq. (3)}$$

where $RH(\theta)$ describes the change in vertical receiving pattern, relative to the MRA, for different horizontal phasings of the array,
$RV(\theta)$ describes the change in vertical receiving pattern relative to on-axis, for different vertical phasings of the array,
$SH(\theta)$ describes the change in the transmitting pattern at the angle (θ) for different horizontal phasings, and
$SV(\theta)$ describes the change in the transmitting pattern for different vertical phasings of the array.

That is, the level of interference encountered by the AN/SQS-26 depends on the specific depression angle and mode in which the system is operating. However, if we agree, that for a given operating mode, $\Delta SH(\theta)$, $\Delta SV(\theta)$, $\Delta RH(\theta)$ and $\Delta RV(\theta)$ are constant over the minute angular difference between low-order fathometer returns, then the effective receiving response and source level for each of these arrivals is the same. In this case, equation (2) can be used to obtain an estimate of the normal incidence bottom loss despite the fact that no absolute measurements of ΔSV, ΔSH, ΔRH and ΔRV have been documented.

NORMAL INCIDENCE BOTTOM LOSS RESULTS

Some AN/SQS-26 (BX) and AN/SQS-26 (AXR) "fathometer" results from area Bravo have been reduced to yield the normal incidence bottom loss values shown in Tables I and II respectively. The (BX) results were obtained during the evaluation of the SQS-26 system on the USS WAINWRIGHT (DLG-28) in June 1966. The AXR results were obtained with the equipment on the USS GLOVER (AGDE-1) in May 1968. Since the ocean surface was extremely calm during both sets of trials, it has been assumed that the loss in energy associated with each surface reflection is negligible. Thus the difference between the 1st and 2nd order fathometer arrivals for the AXR and BX indicate a median normal incidence bottom loss of approximately 3.5 dB. While this value is considerable lower than the 6-10 dB normal incidence values that Alpine Geophysical reported for this area (reference (a)), it is reasonable in view of the bottom layering structure and the range resolution of the SQS-26 pulses (400 yds.). The SQS-26 pulses are actually integrating over all the sub-bottom reflections which were separately resolved by the Alpine measurements. When the Alpine values for the different layers are summed to approximate a total energy bottom loss value, the loss obtained is essentially the same as that experienced by the SQS-26 pulses.

SYSTEM DISCRIMINATION

The bottom loss value determined above can now be inserted into equation (3), and the total discrimination of the SQS-26 against these arrivals can be estimated. Since the median fathometer level received with the AXR in the convergence zone mode (zero tilt) was -2 dB, equation (3) yields:

$$\Delta RH(\theta) + \Delta RV(\theta) - \Delta SH(\theta) - \Delta SV(\theta) \quad [illegible] \text{ dB}.$$

The median level observed with the BX in the convergence zone mode (zero tilt) was -12 dB, which yields:

$$\Delta RH(\theta) + \Delta RV(\theta) - \Delta SH(\theta) - \Delta SV(\theta) = -60 \text{ dB.}$$

The poorer discrimination achieved with the AXR system on the AGDE-1 resulted from the bottom row of elements in the array being driven in phase, while the remaining elements of the array were being phased to transmit a 120 degree beam. This problem was subsequently corrected, but no "fathometer" return data was obtained with the repaired system. If the discrimination of the BX is assumed to be representative of that generally achieved with SQS-26 systems, then the GLOVER system had at least 10 dB less rejection against these arrivals than it should have had. This 10 dB degradation on the GLOVER AXR system proved extremely important and resulted in 4th and sometimes 5th order "fathometer-type" arrivals severely interferring with echo reception in the bottom bounce annulus at ranges of 24 and 30 kiloyards (reference (b)).

FREQUENCY CHARACTERISTICS

Since the "fathometer-type" returns observed during the AGDE-1 tests created heavy interference on the CW portion of the AXR VDR (Variable Depression Receiver) display, the ability of this interference to capture the OR circuits at the output of the CW doppler filter bank was investigated. Absolute levels were desired, hence the measurements were made by tapping the VDR SSI-SUM beam output off the system just after horizontal beamforming. A General Radio Type 1900-A wave analyzer was used as a tunable 10 Hz filter to simulate the 10 Hz doppler filters of the system. The output of the wave analyzer was displayed on a Bruel Kjaer recorder as a function of time for each filter band. The "fathometer return" levels obtained by sequencially scanning 10 Hz filter bands around 3500 Hz are listed in Table III, and are shown as a function of frequency in Figure 1. For these measurements, the SSI-SUM beam was steered at 000 degrees relative while the USS GLOVER was dead in the water (DIW). This procedure was followed to insure that the resulting "fathometer" frequency response was not interacting with the ODN (Own Doppler Nullification) function of the AXR. In practice, of course, the fathometer return should always be at about the same frequency in the water, but will shift into different CW doppler channels of the system for different receiving beams, depending on ships speed, the direction of the beam relative to ship's head, and the depression angle at which the main lobe of the beam is tilted.

~~CONFIDENTIAL~~

NUSL Tech Memo
No. 2040-0155-69

COMMENTS

On various occasions, it has been proposed that a line receiving array might be employed with systems like the SQS-26 and BQS-6 to provide better horizontal discrimination against reverberation and hence improve system echo-ranging performance via long range sound paths. In fact, John Hanrahan conducted an excellent study aimed at determining the feasibility of such an array, for bottom bounce echo-ranging (reference (c)). However, his study did not consider what the effect of multiple "fathometer-type" arrivals might be on such an array. When long pulse trains or long RDT transmissions are emitted at one frequency, the multiple fathometer arrivals can cause serious interference for large portions of the echo-ranging cycle. This point was vividly demonstrated by the results obtained with the AXR, when the array had 50 dB discrimination against these arrivals. The levels encountered in Area Bravo imply that, for a MDL of approximately -60, fathometer arrivals would be detectable on a line receiving array out to ranges approaching the first convergence zone! This clearly demonstrates the need for vertical directivity in any receiving array which is going to be used in conjunction with our long range active sonar systems.

B. F. Cole

R. R. D'Amelia

~~CONFIDENTIAL~~

REFERENCES

(a) Officer, C.B., W. T. McGuinness, J. Hirshman, A. Stockel, "Acoustic and Geophysical Survey of Bottom and Subbottom Reflectivity Area B - Part II - Final Report - Acoustic Data", Alpine Geophysical Associates, Inc., prepared for USNOO under contract N62306-1341, 17 Feb. 1964 (CONF)

(b) Hawkes, P. H., "Results of In-port and At-Sea Tests Conducted Aboard USS GLOVER (AGDE-1) April-May 1968", NUSL Tech Memo No. 2341-071-69, 4 April 1969 (CONF)

(c) Hanrahan, J. J., "The Expected Performance From the Use of an Auxiliary Receiving Array with the AN/SQS-26 (U)", NUSL Tech Memo No-905-046-66, 23 June 1966 (CONF)

TABLE I

AN/SQS-26 (BX) AREA BRAVO RESULTS

Bottom Bounce Track Mode
Depression Angle: 0 Degrees
Date: 18 Jun 1969
Run: 6A
Ship: USS WAINWRIGHT (DLG-28)
Water Depth: 3000 Fathoms
Frequency: 3.5kHz

First Order Fathometer Return Level $dB//(1\ \mu bar)^2$	Second Order Fathometer Return Level $dB//(1\ \mu bar)^2$	Bottom Loss From Relative Difference (dB)
-10	-21	2.5
- 5	-22	8.5
-12	-22	1.5
-11	-22	2.5
-12	-19	-1.5
- 6	-19	4.5
- 9	-24	6.5
-13	-23	1.5
-10	-23	4.5
-13	-2[illegible]	0.5
-10	-20	1.5

*Output of UNI Beam 6

TABLE II

AN/SQS-26 (AXR)
AREA BRAVO RESULTS

Convergence Zone Mode
Depression Angle: 0 Degrees
Rate: 19 May 1968
Run: 19 D2
Ship: USS GLOVER (AGDE-1)
Water Depth: 3000 Fathoms

First Order Fathometer Return Level $dB//(1\ ubar)^2$	Second Order Fathometer Return Level $dB//(1\ ubar)^2$	Bottom Loss From Relative Difference (dB)
-4	-13	0.5
-1	-15	3.5
0	-10	1.5
-2	-15	4.5
-1	-14	4.5
-2	-15	4.5
-4	-11	-1.5
-2	-12	1.5
2	-16	0.5
-1	-10	0.5
-2	-13	2.5
0	-13	4.5
0	-13	4.5
-3	-14	2.5
-2	-12	1.5
-5	-17	5.5
0	-15	0.5
-3	-15	3.5
-6	-16	1.5
0	-12	3.5
0	-14	5.5
-1	-13	3.5
-2	-14	3.5
-4	-17	[illegible]

TABLE II
(Con't)

First Order Fathometer Return Level dB//(1 ubar)[2]	Second Order Fathometer Return Level dB//(1 ubar)[2]	Bottom Loss From Relative Difference (dB)
-3	-15	3.5
-5	-16	2.5
-4	-17	4.5
-2	-12	1.5
-2	-12	1.5
-7	-12	-3.5
0	-14	5.5
-2	-15	4.5
-4	-16	3.5
-1	- 9	-0.5
-2	-13	2.5
-2	-17	6.5
0	-12	3.5
-3	-14	2.5

NUSL Tech Memo
No. 2040-0155-69

TABLE III

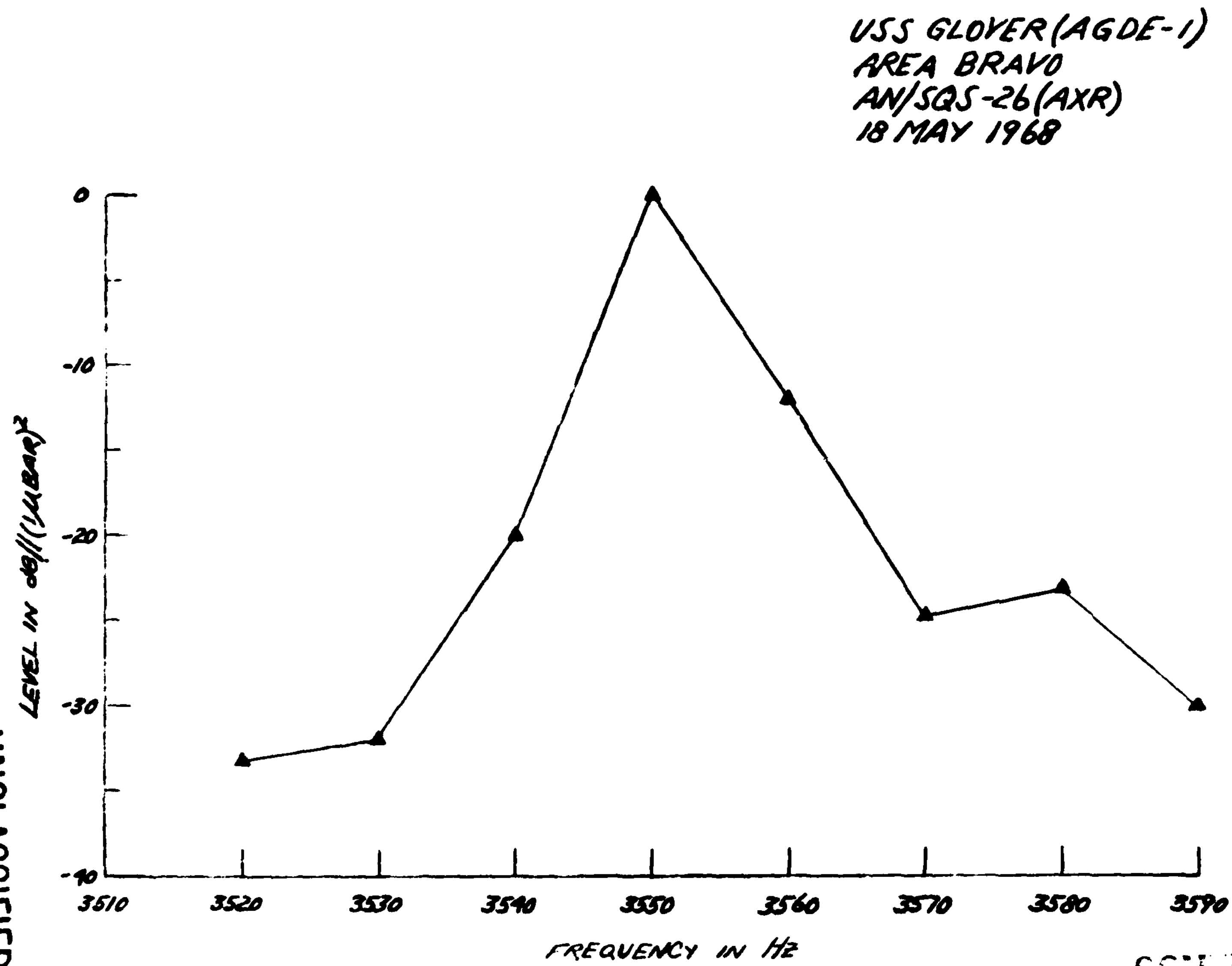
AN/SQS-26 (AXR) AREA BRAVO CW
FATHOMETER ARRIVAL LEVELS VERSUS FREQUENCY

Ship: USS GLOVER
Date: 18 May 1968
Depression Angle: 0 Degrees
Water Depth: 3000 Fathoms
Bottom Bounce Track Mode, FM Pulse Deleted

Filter Center Frequency	10Hz Band Level* dB//(1 μbar)^2
3520	-33
3530	-32
3540	-20
3550	0
3560	-12
3570	-25
3580	-23
3590	-28

*VDR SSI-SUM Beam output

UNCLASSIFIED



Fathometer Arrival Levels Versus Frequency

UNCLASSIFIED