

UNCLASSIFIED

AD NUMBER

AD531451

CLASSIFICATION CHANGES

TO: unclassified

FROM: confidential

LIMITATION CHANGES

TO:
Approved for public release, distribution unlimited

FROM:
Distribution limited to U.S. Gov't. agencies only; Test and Evaluation; Aug 74. Other requests for this document must be referred to Director, Naval Research Lab., Washington, D. C. 20375.

AUTHORITY

NRL ltr, 3 Mar 2004; NRL ltr, 3 Mar 2004

THIS PAGE IS UNCLASSIFIED

✓
CONFIDENTIAL

NRL Memorandum Report 2876

**Submarine Target Strength
Estimates at 1 Khz**
[Unclassified Title]

CARL R. ANDRIANI
*Large Aperture Systems Branch
Acoustics Division*

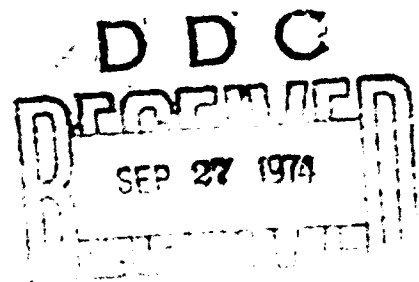
August 1974

AD531451

UNCLASSIFIED NATIONAL SECURITY INFORMATION
Unauthorized Disclosure Subject to Criminal Penalties



NAVAL RESEARCH LABORATORY
Washington, D.C.



CONFIDENTIAL

CONFIDENTIAL, classified by OpNav. 005510.72C
Exempt from GDS of E.O. 11652.
Ex. Cat. (3). Auto declass. cannot be predetermined.

Distribution limited to U.S. Government Agencies only; test and evaluation; August 1974. Other requests for this document must be referred to the Director, Naval Research Laboratory, Washington, D.C. 20375.

CONFIDENTIAL

NATIONAL SECURITY INFORMATION

Unauthorized Disclosure Subject to Criminal Sanctions.

CONFIDENTIAL

CONFIDENTIAL

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 2876	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SUBMARINE TARGET STRENGTH ESTIMATES AT 1 Khz (U)	5. TYPE OF REPORT & PERIOD COVERED Final report	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Carl R. Andriani	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NRL Prob. 81S02-24 Project No. XF52-552-700 62755N-52	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronics System Command Washington, D.C. 20360	12. REPORT DATE August 1974	
	13. NUMBER OF PAGES 10	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) CONFIDENTIAL	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE (See reverse side)	
16. DISTRIBUTION STATEMENT (of this Report) Distribution limited to U.S. Government Agencies only; test and evaluation; August 1974. Other requests for this document must be referred to the Director, Naval Research Laboratory, Washington, D.C. 20375.		
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) Submarine Target Strength		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (C) The 1 kilohertz monostatic and bistatic target strength for an attack class nuclear submarine is calculated based upon the extrapolation of a regression model, developed previously, from data on the .233 scale model submarine, KAMLOOPS. These calculations were made to support the active detection performance evaluation of Naval Undersea Center's (NUC) Expendable Sound Source surveillance system concept. The mean 1 khz. Monostatic target strength (Abstract continues)		

CONFIDENTIAL

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

15a.

NGDS (3). Auto declass. cannot be predetermined.

20. (Continued Abstract) (C)

averaged over all aspects is 19.7dB with a 24.9dB and 12.5dB beam and bow/stern aspect target strength, respectively. The 24.9dB beam aspect monostatic target strength agrees exceedingly well with a set of independent measurements made on KAMLOOPS. An expression for the calculation of the bistatic target strength is given.

CONFIDENTIAL

Submarine Target Strength Estimates at 1 Khz.

by

Carl R. Andriani

(C)The 1 kilohertz monostatic and bistatic target strength for an attack class nuclear submarine is calculated based upon the extrapolation of a regression model, developed previously, from data on the .233 scale model submarine, KAMLOOPS. These calculations were made to support the active detection performance evaluation of Naval Undersea Center's (NUC) Expendable Sound Source surveillance system concept. The mean 1 khz. monostatic target strength averaged over all aspects is 19.7dB with a 24.9dB and 12.5dB beam and bow/stern aspect target strength, respectively. The 24.9dB beam aspect monostatic target strength agrees exceedingly well with a set of independent measurements made on KAMLOOPS. An expression for the calculation of the bistatic target strength is given.

Problem Status: A final memorandum report on a continuing problem

Authorization: NRL Problem Number 81S02-24
Project Number XF52-552-700

Manuscript submitted July 26, 1974.

CONFIDENTIAL

INTRODUCTION

(C)The Naval Undersea Center (NUC) has developed an Expendable Sound Source (ESS)(1) which operates at 1 khz. The ESS development is part of a system concept for the active detection of submarines. The need for acoustic data to support the detection performance evaluation of ESS, in conjunction with various receiving arrays and source receiver geometries, resulted in a NUC proposal(2) to measure submarine target strengths and reverberation at 1 khz. In support of the proposed NUC measurements, NRL has made estimates of the 1 khz. target strength and reverberant field using models developed at NRL, and based upon the experimental goals and design parameters of NUC. The reverberation calculations are the subject of a separate NRL report(3) and encompass the greater part of the modeling effort. This memorandum report deals with target strength estimates at 1 khz. The objective of the NUC target strength measurements is "to provide submarine target strength for different aspects under controlled conditions" (2) at several bistatic angles.

(U)The proposed experiment, as outlined in reference 2 calls for a far-field measurement at bistatic angles of 0°, 16°, 45°, 90°, 135°, and 157.5°, at aspects of 0° to 90° and 180° to 270° in 15° increments. Based upon the physical symmetry of the target, this suite of aspects is believed to represent the 360° submarine target strength.

ESTIMATE OF 1 KHZ. TARGET STRENGTH

(C)In support of the NUC system evaluation requiring 1 khz. submarine target strengths, NRL has agreed to make target strength computations based on a regression model(4) developed from data taken on the .233 scale submarine model(5) KAMLOOPS (KAMLOOPS is a closely scaled model of the PERMIT and STURGEON class submarines). Those data are characterized by an expression of the form

$$TS = a_0 - a_1 \beta - a_2 \cos 2\theta, \quad \text{Eq. 1.}$$

where TS is the target strength in dB; β (degrees) and θ (degrees) are the bistatic angle and bistatic aspect, respectively, and are defined in figure 1. The coefficients are functions of acoustic frequency. The unit of a_0 is dB, a_1 is dB/degree, and a_2 is dB. The model data was taken over bistatic angles from 0° to 75° at 15° intervals, and bistatic aspects from 0° to 360° at 4° intervals. Evaluation of the coefficients leads to the target strength

CONFIDENTIAL

formulation

Eq. 2.

$$TS(f) = 20 + 2 \cos \left\{ \left[2 \frac{f-222}{206} + 1 \right] 180 \right\} - [.26 \log f - .60] \beta - 5.2 \cos 2\theta \pm 5.6,$$

where f is the acoustic frequency (hertz). The term ± 5.6 dB is the residual standard deviation to the regression curve. Equation 2 was developed from data covering 5 discrete frequencies: 244.7, 279.6, 314.6, 349.5 and 384.5 hz. These frequencies correspond to a full scale target equivalent of the KAMLOOPS model, as does eq. 2. The coefficient a_2 is an average over all f .

(C) In developing an expression for target strength at 1 khz. from eq. 2, the following assumptions (with some discussion) are made:

- 1) Since the second term in equation 2 is cyclical in frequency, an extrapolation of this term to 1 khz. is not unreasonable in that target strength estimates based on physical optics(6) also predicts an oscillatory variation. Thus, the first 2 terms are assumed valid at 1 khz. with the result

$$a_0 = 20 + 2 \cos \left\{ \left[2 \frac{f-222}{206} + 1 \right] 180 \right\} = 19.7 \text{ dB.}$$

- 2) The coefficient of the β term increases monotonically with f and extrapolation to 1 khz. ($a_1 = .18$ dB/degree) leads to dubious target strength results. It is assumed instead, that the best estimate for a_1 be determined by averaging the a_1 from the KAMLOOPS test data(4) over all frequencies sampled. The average a_1 is .048 dB/degree. The reasoning leading to this assumption follows. The dependence of a_1 on frequency may be seen by considering the submarine to be made up of several scattering centers. The scattering centers then (upon insonification) give rise to a complicated frequency dependent beam pattern. Thus, as the bistatic angle increases, the particular target strength observed will depend on the angle from which it is viewed for a given frequency. With reference to fig. 2, the increase in the value of a_1 (which is the slope of the target strength dependence on bistatic angle) with frequency suggests what in the simple case of a line array would be the narrowing of the main lobe width (increasing slope of main lobe) with increasing frequency. Thus, looking from some bistatic angle it would appear that the field

CONFIDENTIAL

intensity (hence the target strength) decreased with increasing bistatic angle at a given frequency; the decrease becoming greater with increasing frequency. Since the beam pattern for a submarine is more complicated than the example just given, one should not expect the simple monotonic form for a_1 given in eq. 2 to extend to 1 khz. Instead, a form which exhibits an oscillatory, but not periodic, behaviour due to the complicated frequency dependent main and side lobe structure should be expected. Since the author believes that the excursion of the oscillation is not large compared to the range of a_1 observed in the KAMLOOPS data, the mean value of the \bar{a}_1 is thought to be a best estimate for a mean a_1 in the frequency region about 1 khz.

- 3) The coefficient $a_2 = 5.2$ dB will be retained.
- 4) Since the KAMLOOPS data showed the residual variance to the regression curve to be independent of frequency and bistatic angle, the standard deviation of ± 5.6 dB will be retained at 1 khz.
- 5) A near-field correction calculation was performed in reference 6 for KAMLOOPS at a monostatic range of 260 feet. At 1 khz. (full scale) the near-field correction was negligible, therefore, a correction to far-field is not considered.

(C) Based on the above assumptions and discussion the expression for the 1 khz. average target strength for a full scale submarine similiar in hull design to the KAMLOOPS is

$$TS = 19.7 - .0488 - 5.2 \cos 2\theta \pm 5.6 \text{ dB} \quad \text{Eq. 3.}$$

(C) Equation 3 has been plotted in figure 3 for the monostatic case ($\beta=0$) with the mean target strength value (\bar{TS}) over all aspects given in the figure. The mean is $\bar{a} = 19.7$ dB. To obtain target strength at other bistatic angles, the mean of the monostatic value is adjusted by .0488 while maintaining the shape in fig. 3 for the aspect dependence. Since the regression model is based on data which does not exceed 75° in bistatic angle, it is not known whether or not $\beta=90^\circ$ is at a focus of symmetry. Symmetry is assumed here so that $\beta=22.5^\circ$ and 45° yield estimates for the proposed NUC measurements at 157.5 and 135° , respectively.

CONFIDENTIAL

COMPARISON WITH DATA

- (C) There is little reported data available at 1 khz. on nuclear attack submarines, to the author's knowledge, with which to test equation 3. A value of 24.8dB is reported in reference 6 for the 1 khz. monostatic beam aspect target strength of KAMLOOPS (the measurements were made by NUC). For $\beta=0$ and $\theta=90^\circ$, eq. 3 yields 24.9dB which agrees exceedingly well with the measured value.
- (C) There are some 1 khz. 10 ms pulse data(7) available on POLLACK (SSN 603), an attack submarine of the PERMIT class and similar in design to KAMLOOPS. The form in which this data is presented, and lack of the measurement and signal processing details make comparison of the data with eq. 3 difficult. However, when these data are averaged over aspect angles 75° to 105° (beam aspect) and over all aspects, target strength values of 24dB and 14dB, respectively, are obtained for the 10 ms pulse. The KAMLOOPS data used a 30 ms pulse.
- (C) The intent of the above extrapolation of eq. 2 to 1 khz. (eq. 3) is to provide an expression for bistatic target strength of attack class submarines suitable for system evaluation estimates in the absence of data at this frequency. Although eq. 2 is believed valid in the frequency region for which its synthesis was intended, and eq. 3 has some success in predicting the NUC measurement, the extrapolation to 1 khz. should be viewed with some caution until suitable measurements are made.

CONFIDENTIAL

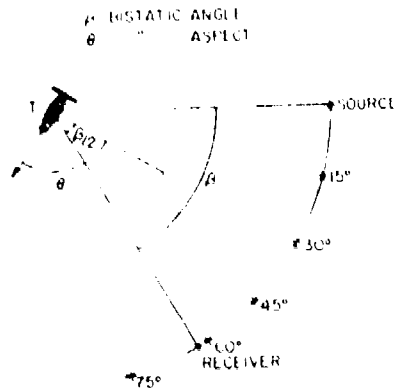


Fig. 1 (U) Bistatic geometry (U)

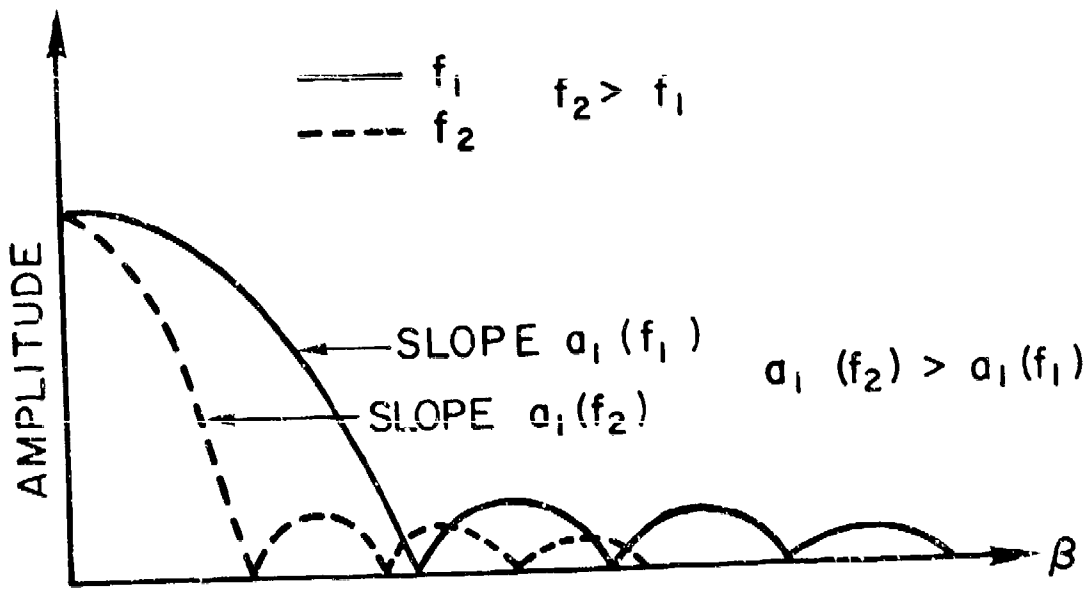


Fig. 2 (U) Beam patterns of a line array (U)

CONFIDENTIAL

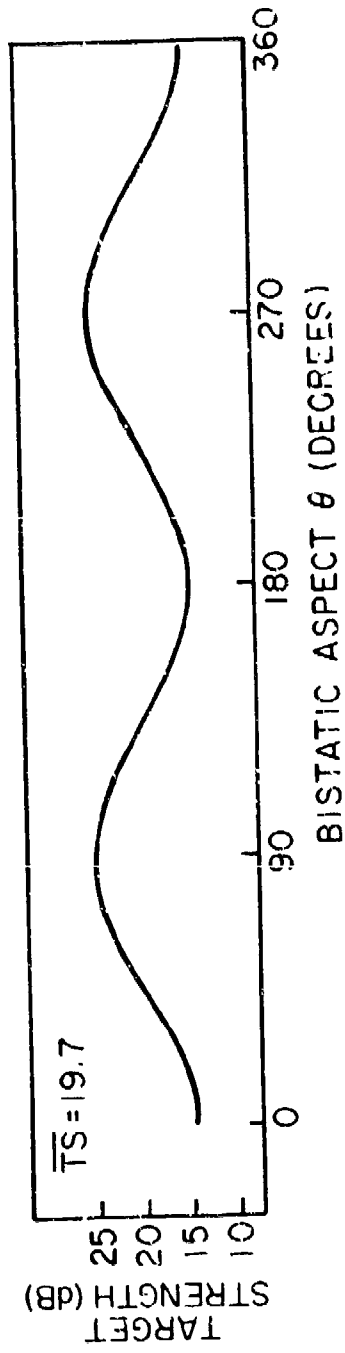


Fig. 3 (C) Plot of eq. 3 for $\beta=0$ (monostatic) (U)

CONFIDENTIAL

REFERENCES

1. M.R. Akers, J.W. Bond, M.K. Brandon, and J.L. Stewart, "Phase One Effort For Expendable Sound Source (ESS) Development Program" (U), NUC TN 806, San Diego, California, August 1972. Conf.
2. Morris Akers, "Proposed ESS At-Sea Test Program", (U), NUC, San Diego, California, January 1972. Conf.
3. J.T. Warfield and J.M. Griffin, "Medium-Range Bistatic Reverberation With An Expendable Sound Source", NRL report in preparation, Naval Research Laboratory. Conf.
4. Carl R. Andriani, "Low-Frequency Monostatic and Bistatic Target Strength of the KAMLOOPS Submarine Model", (U), Naval Research Laboratory, to be published in JUA, July 1974. Conf.
5. John R. Spina and Dale C. Intoluble, "Model Test Facilities and Procedures for Investigating Vibration and Radiation Properties of A Submarine Hull", (U) NRSDC, Washington, D.C. 26th Navy Symposium on Underwater Acoustics, 12-14 November 1968. Conf.
6. W.P. Melling, H.S. Ostrowsky, A.C. Charters, "Scale Model Target Strength Program", (U), Summary Report: APL CR.1-214, Prepared for Applied Physics Laboratory/John Hopkins Univ., by General Research Corp., June 1971. Conf.
7. T. Kooij, F.J. Keltonic, and S.P. Pitt, "Characteristics of Echo Frequency Responses Due to Internal Structures in Submarines" (U), A joint R & D report by NSRDC (report S-403R), NUSC (TR4499), ARL (TR73-8), March 1973.

Secret

UNITED STATES GOVERNMENT
Memorandum

7100-037
DATE: 26 February 2004

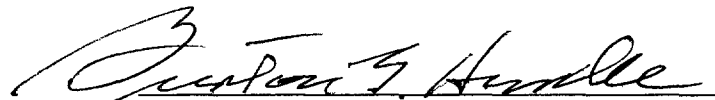
REPLY TO
ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Submarine Target Strength" (U), Carl R. Andriani, Acoustics Division, NRL Memo Report 2876, August 1974 (C)

1. Reference (a) describes an estimate of the 1 Khz monostatic and bistatic target strength of an attack class submarine.
2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical
3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions



BURTON G. HURDLE
NRL Code 7103

CONCUR:

Edward R. Franchi 3/1/2004
E.R. Franchi Date
Superintendent, Acoustics Division

CONCUR:

Tina Smallwood 3/3/04
Tina Smallwood Date
NRL Code 1221.1