NSWC-PC Component of: Target Measurements to be Made as Part of a Full Spectrum Target Scattering Effort for MCM Applications

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Award Number: N0001407WX20546

LONG-TERM GOALS

The goal of this program is to advance the understanding of monostatic (backscatter) and bistatic scattering from targets. Results of this work may be used by modelers and Mine Countermeasures (MCM) signal processors to develop, assess, evaluate, and validate target scattering codes, classification algorithms, and sonar design codes.

OBJECTIVES

The objectives of this effort are as follows:

1. Advance the understanding of the physics of monostatic and bistatic buried target detection.

2. Determine the feasibility of using monostatic and bistatic scattering from targets for classification clues in a low frequency regime.

3. Investigate using the combination of monostatic and bistatic SAS imaging of targets for classification purposes.

4. Investigate the use of multi-aspect bistatic scattering over a wide frequency range for enhanced detection and classification.

APPROACH

The approach is to conduct three acoustic scattering efforts. These efforts focus on scattering from simple/generic shapes to more complicated mine-like targets. In the initial effort, free-field scattering measurements are to be conducted in the Naval Surface Warfare Center - Panama City (NSWC-PC) Acoustic Test Facility (ATF) using the simple/generic shapes. This first effort will focus on using projectors and receivers that operate in the 2 to 20 kHz frequency range. These free-field measurements are meant to provide a base line to carry out initial tests of target scattering codes and are a precursor to the two remaining efforts which are to be performed in NSWC-PC Facility 383, which is a 13.7-m deep, 110-m long, and 80-m wide test-pool with a 1.5-m layer of sand on the bottom.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2007**	2. REPORT TYPE **Annual**	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **NSWC-PC Component Of: Target Measurements To Be Made As Part Of A Full Spectrum Target Scattering Effort For MCM Applications**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center ? Panama City,Code HS11, 110 Vernon Ave.,Panama City,FL,32407**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
The goal of this program is to advance the understanding of monostatic (backscatter) and bistatic scattering from targets. Results of this work may be used by modelers and Mine Countermeasures (MCM) signal processors to develop, assess, evaluate, and validate target scattering codes, classification algorithms, and sonar design codes.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

In the second and third efforts, acoustic scattering measurements are to be carried out in NSWC-PC Facility 383 using the simple/generic targets as well as more complicated mine-like targets. In the second effort, the targets will be resting proud of the bottom, while in the third effort, the targets will be buried. In both cases, the measurements will be conducted in the frequency range of 1 to 30 kHz. The apparatus used for the second and third efforts will be a combination of two Synthetic Aperture Sonar (SAS) rail systems [one developed by NSWC-PC and the other by Applied Physics Laboratory - University of Washington (APL-UW)], which will be placed perpendicular to each other and oriented so as to look at the same region of the bottom. Contemporaneously with these bistatic measurements, backscattering measurements will be carried out by both rail systems. This strategy allows a particular target and environment configuration to be set up and studied for both monostatic and bistatic geometries. These measurements will form the experimental basis for evaluating and validating target scattering codes.

Key personnel participating in this effort include Joseph Lopes, Raymond Lim, David Burnett, and Carrie Dowdy of NSWC-PC as well as Eric Thorsos, Kevin Williams, and Steve Kargl of APL-UW. Lopes, Dowdy, and Williams are conducting the target scattering measurements and analyzing and interpreting data. Lim, Burnett, Thorsos, and Kargl are developing target scattering models.

WORK COMPLETED

In Fiscal Year (FY) 2006, simple/generic shaped targets were designed with the intent to evaluate/validate Finite Element Modeling (FEM) predictions generated by David Burnett. A contract was let for fabrication, and NSWC-PC received these targets in early FY 2007. Five simple/generic shapes were fabricated with 304 stainless-steel, and all five shapes have the same basic form. Each target is a closed cylindrical shell that has hemispheres on both ends and a plate partitioning the target in two. The wall thickness of the shell is 0.16 cm. Each shape has a length of about 61 cm and a diameter of approximately 15.2 cm, providing a length to radius ratio of 8 and a shell thickness to radius ratio of 2.1%. A port on each end is used for filling the partitioned chamber with either a fluid or material, and then sealing it from the surrounding environment. Figure 1 shows the different configurations for the five simple/generic shape targets. The first configuration is as described above. The second configuration is similar to the first except that a wax-like material is loaded in one of the chambers. The third, fourth, and fifth configurations are similar to the first configuration except that appendages such as a glide shoe, an eyebolt holder, and a glide wing are welded onto the shells. These configurations provide a basis in which scattering data and modeling can be compared in an incremental method while at the same time providing for more realistic target signatures.

In FY 2007, two sets of measurements were conducted. In the first measurement, free-field backscatter data were collected in the NSWC-PC ATF using the simple/generic targets. Figure 2 depicts the measurement setup employed for this first measurement. A simple/generic shape target was suspended in the free-field using a positioner that was also used to rotate the target. A source projected an acoustic signal toward the target, and a receiver located next to the projector was employed to record the signals backscattered by the target. Another receiver was also utilized in the measurement to record the incident signal transmitted by the projector. In the second set of measurements, backscatter and bi-static data were collected from targets resting on the bottom sediment in NSWC-PC Facility 383. Several targets utilized in this second set of measurements included: the simple/generic targets, a 0.6-m diameter spherical shell with a shell thickness to radius ratio of 5.1%, a solid aluminum cylinder with a diameter of 0.3 m and a length of 1.52 m, a 55-gallon drum, and more realistic shaped targets. Figure 3 illustrates the measurement setup showing the NSWC-PC and APL-UW rail systems and the location of the target with respect to the rail systems. Data were collected in three arrangements. In the first, backscatter data were collected using the source and receivers located on the APL-UW rail. In the second arrangement, bistatic scattering data were acquired by transmitting with a source on the NSWC-PC rail at a particular location (stationary) while receiving the scattered signal with the APL-UW receivers moving along the length of the APL-UW rail system. In the third arrangement, bistatic data were obtained by projecting an acoustic signal with an APL-UW source moving along the length of the APL-UW rail and employing a stationary receiver on the NSWC-PC rail system to record the scattered signal. In all three arrangements, the projectors and receivers on both rail systems were situated approximately 4 m above the bottom and their main response axes were directed at a 20^{o} grazing angle.

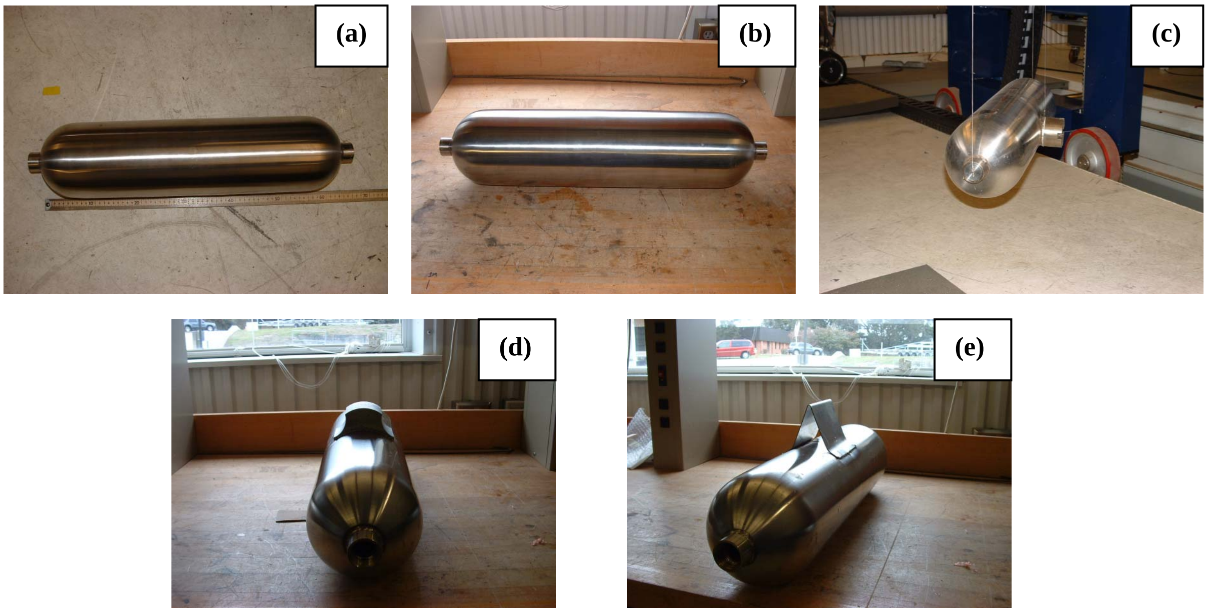

Figure 1. Simple/generic shaped targets. (a) Empty shell. (b) Shell with one side filled with wax-like material. (c) Empty shell with glide shoe appendage. (d) Empty shell with eye bolt holder appendage. (e) Empty shell with glide wing appendage. [Photographs of the five simple/generic shaped targets. Photographs show empty shell, empty shells with various appendages, and shell filled with material in one of the partitioned chambers].

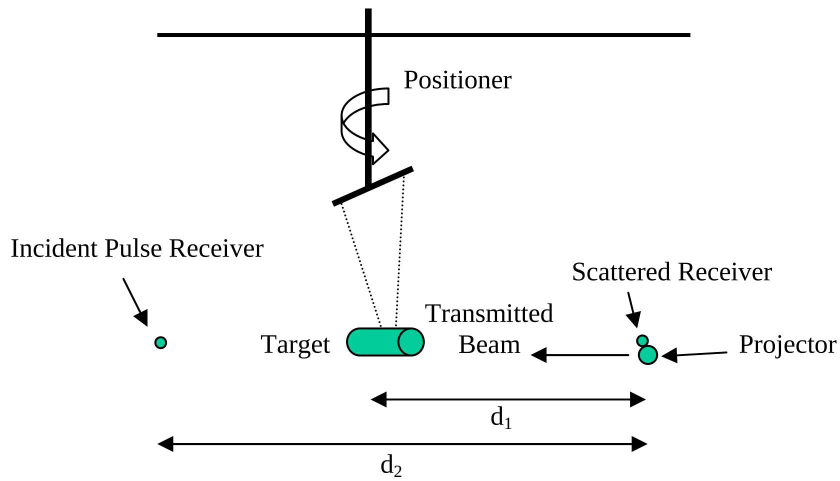

Figure 2. Free-field measurement setup. [Schematic showing the free-field measurement setup].

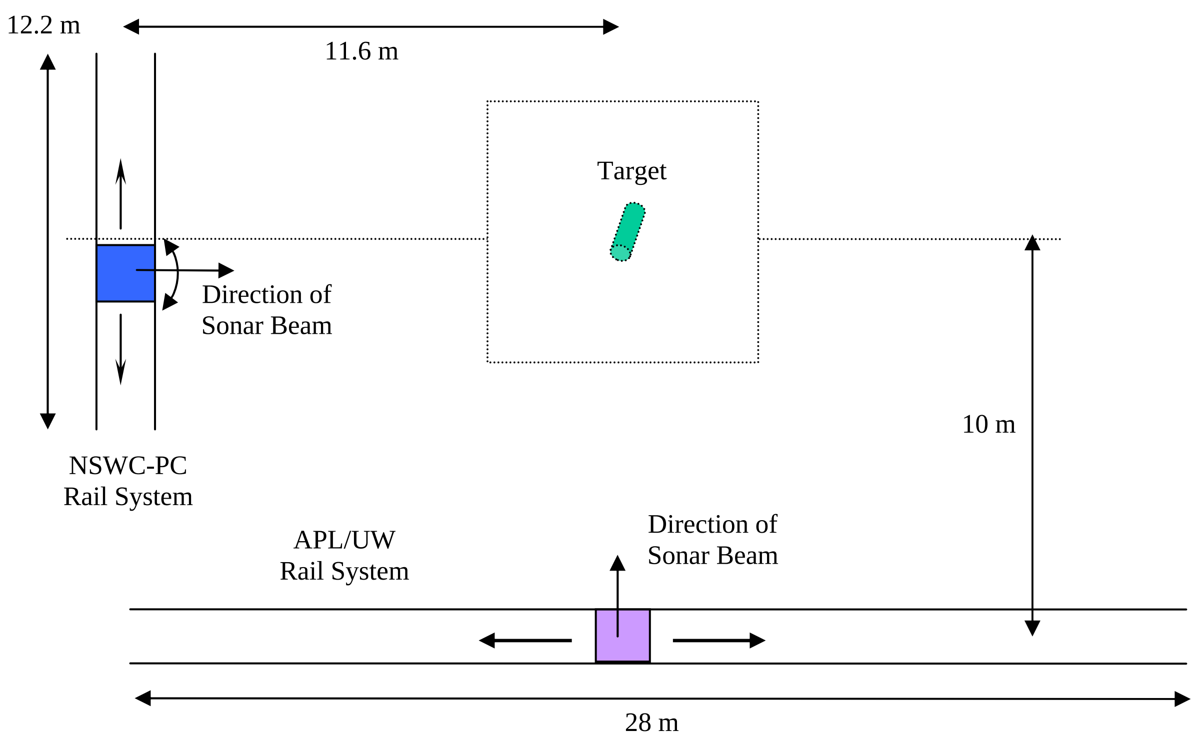

Figure 3. Proud target scattering measurement setup. [Schematic showing the NSWC-PC and APL-UW rail systems and the location of the proud target with respect to the rail systems].

RESULTS

Figure 4 depicts typical results obtained from data collected in the free-field. Both plots in this figure refer to the simple/generic target without any appendages and whose chambers were free-flooded with water. The plot on the left corresponds to a backscatter amplitude plot of ping time versus target aspect angle at a frequency of 20 kHz, while the plot on the right is a backscatter amplitude plot of frequency versus target aspect angle. In both instances, aspect angles of approximately 0^o, 180^o, and 360^o are associated with the target at an end-on orientation while aspect angles of about 90^o and 270^o refer to the target at an aspect of broadside orientation. For the end-on case (such as an aspect angle of 180^o), returns appear in the plot on the left that correspond to the front (ping time of 3.25 ms) and back (ping time of 4.1 ms) ends of the simple/generic target as well from the plate (ping time of 3.7 ms) that partitions the target in half. The plot on the right is a backscatter amplitude plot of frequency versus target aspect angle. Backscattered returns are clearly observed across a significant amount of the frequency band for a target aspect of broadside, while for an aspect angle of end-on, a geometrical interference pattern corresponding to the length of the target is seen in the plot. Figure 5 illustrates a comparison between predictions of Finite Element Modeling (FEM) and data for the end-on target orientation case. Overall, measured and FEM predicted levels are in moderate agreement with FEM predictions following the trends of the data in the frequency range of 9 kHz to 19 kHz. Work is being done to obtain a better agreement between the FEM predictions and data.

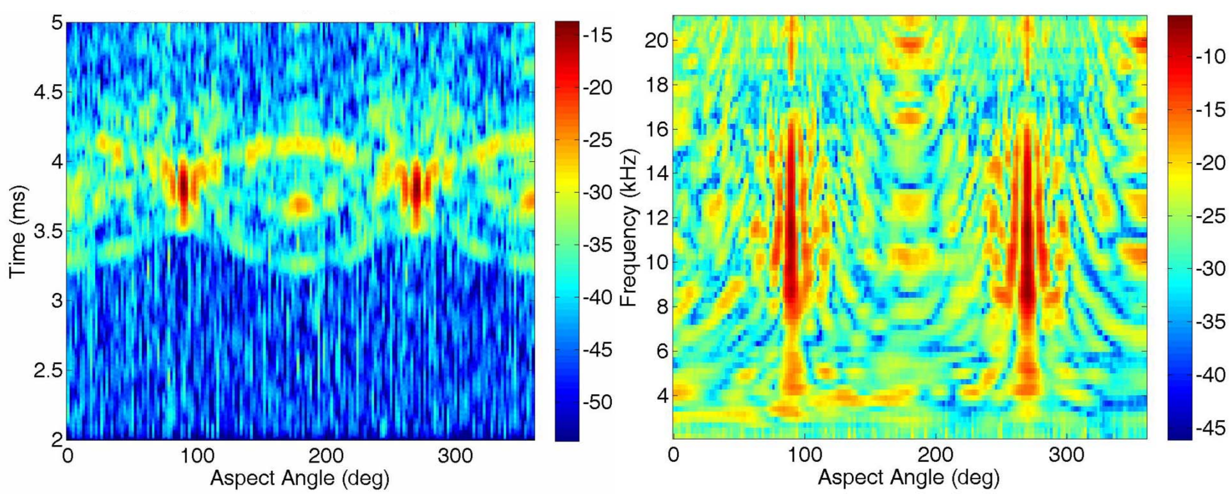

Figure 4. Amplitude levels of ping time versus target aspect angle (left) and frequency versus target aspect angle (right) for the simple/generic target without appendages suspended in the free-field. Both chambers are free-flooded with water. [The plot on left clearly shows returns from the front-end, back-end, and central partitioning plate of the shell. The plot on the right shows a geometrical interference pattern corresponding to the length of the target].

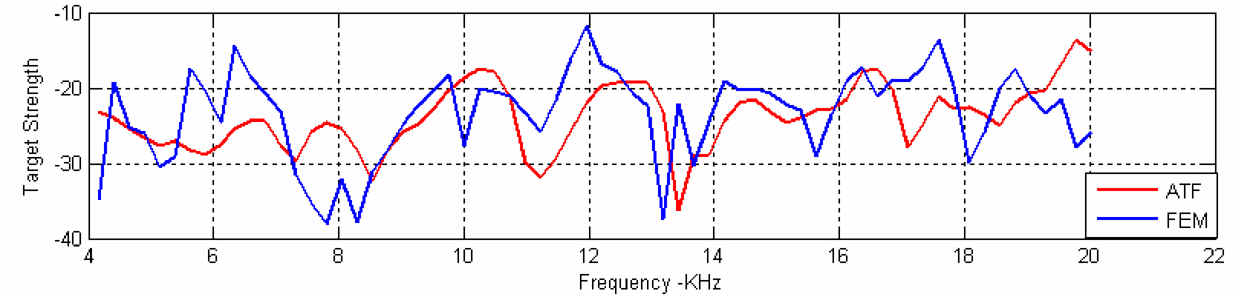

Figure 5. Comparison between FEM predictions (blue) and data (red) for the simple/generic target without any appendages suspended in the free-field at aspect angle of end-on. [The measured and FEM predicted levels are in moderate agreement with FEM predictions following the trends of the data in the frequency range of 9 kHz to 19 kHz].

Figure 6 illustrates typical examples of bistatic images generated by processing data using synthetic aperture sonar (SAS) methods. In each instance, the source on the APL-UW rail transmitted an acoustic signal in the 12 kHz to 28 kHz frequency range while it traveled the length of the rail, and the stationary receiver on the NSWC-PC rail system was utilized to record the scattered signals. The image on the left refers to the spherical shell, while the other two images correspond to the 1.52-m long solid aluminum cylinder. In the middle image, the cylinder was oriented broadside to the APL-UW rail and end-on to the NSWC-PC rail. In the image on the right, the cylinder is oriented at a 45^o aspect with respect to both rail systems. This figure demonstrates well focused SAS bistatic images. Data are still being processed and interpreted.

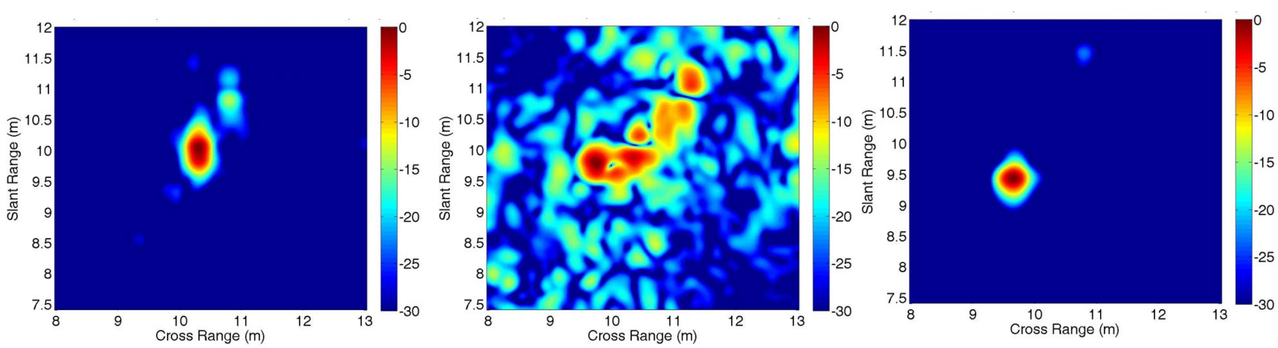

Figure 6. Bistatic SAS images of spherical shell (left), solid aluminum cylinder oriented broadside to APL/UW rail and end-on to NSWC-PC rail (center), and solid aluminum cylinder oriented at a 45^o aspect with respect to both rail systems (right). In each case, the source on the APL-UW rail transmitted an acoustic signal in the 12 kHz to 28 kHz frequency range, and the receiver on the NSWC-PC rail recorded the scattered signals. [This figure demonstrates well focused SAS bistatic images].

IMPACT/APPLICATIONS

This effort is envisioned as part of a coordinated program in which NSWC-PC, APL-UW, Washington State University (WSU), North Carolina State University (NCSU), and Brown University will conduct the necessary scientific research to directly address the Navy requirements of reducing false alarms and improving detection/classification. A goal of this coordinated program is to develop and experimentally test (in NSWC-PC facilities) target backscattering and bistatic scattering models. These models will then be incorporated into the Shallow Water Acoustic Toolset (SWAT). In turn, SWAT would be used to assess sonar design in terms of needed metrics predicting probability of detection and classification using acoustics. Such an "end-to-end" program of exact numerical models, approximate models to elucidate physics-based classification clues, classification algorithms, well-controlled, full-scale, laboratory quality experiments, and sonar design software is an important precursor to efforts that aim to simultaneously test not only the mine detection/classification physics but also Autonomous Underwater Vehicle (AUV) mine detection and classification technologies in real ocean settings.

RELATED PROJECTS

This task will monitor the efforts, utilize any applicable results, and exchange information to preclude any duplication of work in efforts that investigate: (1) target scattering models using FEM methods and approximate physical acoustics-based models, and (2) target scattering classification techniques and sonar design codes.