REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
29 June 1998

3. REPORT TYPE AND DATES COVERED
Final Report (1/1/95-12/31/97)

4. TITLE AND SUBTITLE
"Three-Dimensional Acoustic in Situ Imaging of Sediments" and continuation "Acoustic Imaging of Shallow Water Sediments Engineering Considerations"

5. FUNDING NUMBERS
N00014-95-1-0408

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

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

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Long-term goal: Measuring, imaging, and modeling centimeter-scale, three-dimensional, in situ sediment volum inhomogeneities using acoustic tomography.

19980702 108

14. SUBJECT TERMS
Sediment volume inhomogeneities, acoustic tomography, and shallow water

15. NUMBER OF PAGES
2

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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June 29, 1998

Dr. Jeffrey Simmen, Code 321OA
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Dear Dr. Simmen:

This letter constitutes the final report for ONR contract N00014-95-1-0408, entitled "Three-Dimensional Acoustic in Situ Imaging of Sediments" and a continuation of that grant entitled "Acoustic Imaging of Shallow Water Sediments Engineering Considerations."

Please let me know if you need any further information.

Sincerely,

Thomas C. Austin

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ACOUSTIC IMAGING OF SHALLOW WATER SEDIMENTS

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Category: High-Frequency Acoustics

LONG-TERM GOAL

Measuring, imaging, and modeling centimeter-scale, three-dimensional, in situ sediment volume inhomogeneities using acoustic tomography.

SCIENTIFIC OBJECTIVES

Sediment volume inhomogeneity on the centimeter scale has a major impact on the design and application of high-frequency sonars, especially when operated in shallow waters. Yet there is little information available on such inhomogeneities due to limitations on measurement techniques. We are developing an in situ probe system using acoustic tomography to image shallow water sediments to obtain sound speed and attenuation coefficient over space.

APPROACH

The in-situ sediment acoustic imaging system consists of an array of needle-like probes which may be pressed into the sediment, where each probe is a line array of acoustic transducers. The current system consists of three identical probes attached to a sturdy frame. Two probes are oriented vertically and pressed into the sediment about 1 meter apart, and the third is oriented horizontally, just above the seafloor, between the two vertical probes. Each probe contains 20 acoustic transducers, arranged as a line array with 5 cm spacing. Each transducer in every probe is capable of both transmit and receive. The transducers used are free flooded cylinders, with a resonant frequency of 100 kHz with approximately 40 kHz bandwidth. All possible raypath combinations between the probes are sequentially interrogated. The objective is to accurately estimate the travel time and amplitude from transmit to receive on each ray path.

WORK COMPLETED

Two data sets were processed. One is from a laboratory experiment and the other is from a field experiment. The tank experiment was conducted to evaluate the performance of the data acquisition system and inversion algorithms. During the tank experiment, a polyurathane (EN22) block of 14.1 cm in diameter and 7.5 in height was located near the center of the tomographic frame. The sound speed in the polyurathane block is 1816 m/s. The sound speed in water is 1507 m/s at 17 degrees C. The field experiment was conducted near Woods Hole, MA, in November 1996. The sediment is made of soft organic mud. A total of 1200 arrival times were obtained from 1200 transmit/receive combinations via post-processing program. The arrival times were picked in an interactive mode. There were 30 pings acquired for each ray path and the signals averaged. Typical standard deviations of the arrival time were less than 50 ns.

RESULTS

Sound speed inversion from the tank experimental data shows that the polyurathane block is clearly identifiable and its position was correctly located by the inversion algorithm. Spreading in sound speed due to diffraction is observed. Sound speed image of the field data shows a 10% variation in a 1 meter by 1 meter region. Attenuation coefficient inversion from the mud data reveals that the attenuation coefficient varies from 10 dB/m to 65 dB/m at 100 kHz. Comparison of the sound speed image with the attenuation coefficient image shows that some regions with higher sound speed correspond to lower attenuation coefficient while some other regions correspond to higher attenuation coefficient. It is found that gas bubbles might be present and multiple scattering effects could be important. Future modeling work will address this issue.

IMPACT/APPLICATION

Since this probe system can measure in situ sound speed and attenuation coefficient of sediments over two-dimensions, its advantage over coring is obvious. In addition to applications to high-frequency bottom acoustics, it can provide much needed information to the marine geology and biology communities.

RELATED PROJECTS

In the ONR-DRI on High-Frequency Sound Interaction in Ocean Sediments over the next five years, this system will be improved and updated to provide sediment volume inhomogeneity data in sandy as well as muddy bottoms.