

SMALL-SCALE OCEAN ACOUSTIC TOMOGRAPHY

Jerald W. Caruthers

Naval Research Laboratory

Stennis Space Center, MS 39529

Phone: (228)688-5438 fax: (228)688-5341 email: jwc@nrlssc.navy.mil

Award # N0001497WX40088

LONG-TERM GOALS

The goal of this project is to establish novel techniques in Ocean Acoustic Tomography.

OBJECTIVES

The objectives are to investigate and extend techniques in OAT based on evolving approaches pursued by Russian investigators and apply them to small-scale tomography of bubble plumes.

APPROACH

Russian scientists have taken a broader view of Ocean Acoustic Tomography (OAT) than has US scientists. Their view equates OAT with essentially any acoustical oceanography inverse problem based on a solution of a system of equations involving any set of acoustic measurements. US work has concentrated more on traditional travel-time and attenuation tomography. In our review of OAT, we have identified several new approaches that would be useful to pursue. We are exploring three applications to small-scale reconstructions involving bubble clouds in shallow water: emission tomography of bubble noise, diffraction tomography for bubble clouds, and non-reciprocity tomography for small-scale motion. The first two are conducted as a joint effort with Dr. Alexander I. Khilko of the Institute of Applied Physics, RAS (Russian Academy of Sciences) and the latter one with Dr. Oleg Godin of the Oceanography Institute, RAS.

The applications of tomography to small-scale reconstruction of bubble cloud properties are being studied in the context of a high-frequency acoustic, shallow-water bubble experiment conducted off the Scripps Pier in San Diego in March of 1997. Data for these efforts were taken using a device called the Delta Frame that measured acoustic properties at multiple frequencies over 16 paths within a 10-m equilateral triangle.

WORK COMPLETED

Application of standard (attenuation) tomography to reconstructing the bubble clouds has already been completed. A model has been developed for the application of emission tomography to the reconstruction of small-scale noise sources represented by bubble plumes formed just below the surface due to breaking waves. Several papers were presented on this topic. Diffraction tomographic algorithms have been developed. Numerous papers in each of the areas have been written and a draft book has been prepared. The book should go to press early next year.

Several approaches have been developed to extract the current-related information from travel times along not quite reciprocal paths in the Delta Frame experiment geometry. The

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 1997		2. REPORT TYPE		3. DATES COVERED 00-00-1997 to 00-00-1997	
4. TITLE AND SUBTITLE Small-scale Ocean Acoustic Tomography				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 Research Laboratory,Stennis Space Center,MS,39529				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					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

propagation paths are orders of magnitude shorter and the environment is much more volatile than in other reciprocal transmission experiments. Therefore, *a priori* there is a considerable uncertainty in what to expect from the data on non-reciprocity, particularly from not quite reciprocal paths. The approaches differ by the way effects of variations in sound speed are suppressed and (partially) separated from those due to fluid motion and are based on different assumptions about space- and time-scales of variations of the sound speed and density in the experiment.

RESULTS

Attenuation data from the Delta Frame have been processed and successfully applied in standard tomography. For the more elaborate techniques, data processing is not yet complete.

IMPACT/APPLICATIONS

New techniques in OAT have direct application to sensing the oceanic environments for numerous military and civilian applications.

TRANSITIONS

Techniques in emission, diffraction, and non-reciprocity tomography applied at the small scale are transitioning to applications of sensing bubble clouds in shallow water. Application of such work should be useful in MCM and special warfare.

RELATED PROJECTS

This project is jointly funded by the Ocean Acoustics Program of ONR and ONR Europe. Only Russian work is support here. Much of the work done under this project is in direct support of work conducted on the influence of bubbles on high-frequency acoustics in shallow water.

REFERENCES

- (1) I.P. Smirnov, J.W. Caruthers, and A.I., Khil'ko, "Multi-Scale Coherence of the Acoustic Field of a Noise Source in a Random Inhomogeneous Ocean," in the book: *The Forming of Acoustical Waves in an Oceanic Waveguide*, Inst. Appl. Phys., RAS, Nizhny Novgorod, (in press), 1997.
- (2) I.P. Smirnov, A.I. Khil'ko and J.W. Caruthers, "The Role of Weakly Divergent Bundles in Generating Regions with High Correlation in Oceanic Waveguides," in the book *The Forming of Acoustical Waves in an Oceanic Waveguide*, Inst. Appl. Phys. RAS, Nizhny Novgorod, (in press), 1997.
- (3) A.I. Khil'ko and J.W. Caruthers, *OCEAN ACOUSTIC TOMOGRAPHY: A Review with Emphasis on the Russian Approach*, a book in draft with submission to be published by the Inst. Appl. Phys., RAS.
- (4) I.P. Smirnov, A.I. Khil'ko and J.W. Caruthers, "Partially Coherent Acoustic Tomography in the Ocean," *Proceedings of the Third European Conference on Underwater Acoustics*, Crete, Greece, pp. 839-844, 1996.
- (5) D.I. Abrosimov, A.I. Khil'ko and J.W. Caruthers, "Method of Partially Coherent Tomography of Meso-scale Inhomogeneities in the Ocean," *Proceedings of the Third European Conference on Underwater Acoustics*, Crete, Greece, pp. 857-61, 1996.
- (6) I.V. Smirnov, A.I. Khil'ko, P.A. Elmore, and J.W. Caruthers, "Possibilities for Small-Scale Emission Tomography of Bubble Plumes in Shallow Water," *Proceedings of the High-Frequency Acoustics in Shallow Water*, SACLANTCTR, La Spezia, Italy, 1997.
- (7) D. Rouseff, F.S. Henyey, J.W. Caruthers, and S.J. Stanic, "Tomographic Reconstruction of Shallow-Water Bubble Field Observations in the Scripps Pier Bubble Experiment," to be presented at the 134th Meeting of the Acoust. Society Amer., abst. published in *J. Acoust. Soc. Am.*, v

102, 1997. (8) O. A. Godin, D. Yu. Mikhin, and D. R. Palmer, "Ocean current monitoring in the coastal zone," accepted for publication in Oceanography. (9) O. A. Godin, "Acoustic mode reciprocity in fluid/solid systems: Implications on environmental sensitivity and horizontal refraction," Proc. of the 3rd Intl. Conf. on Theor. & Comp. Acoust., Newark, N. J., in July 1997.