REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	30 April 1998	ONR Grant Final Report

4. TITLE AND SUBTITLE
Final Report, Measurement & Inversion of Acoustic Emission from Ice - Mechanical Processes in the Arctic

5. FUNDING NUMBERS
N00014-91-J-1296

6. AUTHOR(S)
Keith Von Der Heydt & Edward K. Scheer

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
Woods Hole Oceanographic Institution
AOP&E Department, MS 12
Woods Hole, MA 02543

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Office of Naval Research
Code 322HL
Ballston Tower One, 800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

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

19980508 041

13. ABSTRACT ***(Maximum 200 words)***
This project was in cooperation with investigators Schmidt and Baggeroer at the Massachusetts Institute of Technology for the period 1 January 1991 through 30 June 1996. The project was part of the Sea Ice Mechanics Initiative. Our focus was on the development of instrumentation and techniques for making seismo-acoustic measurements of ice crack events in the Arctic pack ice. Specialized autonomous data acquisition equipment with an emphasis on dynamic range and radio LAN telemetry was designed and manufactured. There was special emphasis on developing realtime beamforming and graphical display software for use in the field.

WHOI personnel participated in two extensive field programs, one in the Fall of 1993 and another the following Spring. Data acquired during these experiments was subsequently the focus of processing and analysis efforts through the end of the grant period.

14. SUBJECT TERMS
Ice Mechanics, Radio Telemetry
Seismo-Acoustic

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			UL

Final Report
MEASUREMENT AND INVERSION OF ACOUSTIC EMISSION FROM ICE-MECHANICAL PROCESSES IN THE ARCTIC
ONR Grant N00014-91-J-1296

Keith von der Heydt and Edward K. Scheer
Department of Applied Ocean Physics and Engineering
Woods Hole Oceanographic Institution
Woods Hole MA 02543
508 289-2223, FAX 508 457 2194
email: kvonderheydt@whoi.edu, escheer@whoi.edu

1 Description of work

The focus of this project, a cooperative effort with MIT colleagues Henrik Schmidt and Arthur Baggeroer, was to develop and adapt methods and instrumentation for making acoustic measurements as a means of inferring the mechanical properties of Arctic pack ice. This work was funded as a component of the **Sea Ice Mechanics Accelerated Research Initiative** and extended over the period 1 Jan 1991 through 30 June 1996. For our part, the program involved 3 components:

- We developed instrumentation and methods for acquiring seismo-acoustic data from ice-mounted geophones and hydrophones, in both "fixed" and quick response "mobile" configurations. We developed realtime beamforming software and the graphical means to assess these data in the field.
- We participated in 2 ice-camp based experiments involving various deployments of that instrumentation.
- Subsequently, we provided extensive support for processing and analysis of data recovered during these field efforts, as well as assisted with students advised by Schmidt and Baggeroer.

The objective of the Sea Ice Mechanics ARI was to develop a greater understanding of ice fracture mechanisms through direct measurement of natural and induced ice events and by inference using measurements of the elastic radiation from ice fracture events. The latter, our area of concentration, was founded on the hypothesis that elastic radiation is diagnostic of ice failure mechanisms and that appropriate environmental measurements, including use of arrays of geophones and hydrophones, would lead to a better understanding of stress-strain and fracture development in pack ice.

Our technical developments for the fieldwork were tailored to the following concept:

- Continuously monitor the acoustic emissions over an area of about 100 km^2. This was achieved by deploying a horizontal "X" shaped array of hydrophones at common depth. The data from this array were used to continuously monitor local ice activity as to intensity and location through use of an "acoustic radar" display achieved with realtime processing and display capabilities we developed.
- When persistent ice activity was observed and localized, 1 or more autonomous systems consisting of 3 axis geophones and hydrophones were deployed to the active site. Data from these systems were relayed in realtime via a radio LAN to the base camp, recorded and monitored.

During an experiment of approximately 2 week duration in the Fall of 1993 we tested techniques for quickly mobilizing geophone and hydrophone sensor systems equipped with radio data telemetry. Particular emphasis was placed on tests of algorithms for realtime beamforming and display of ice event data. A suite of 12 hydrophones and recording system were left in the field with the intention that the system would be run regularly over a 3 month period during the winter. Very little data was recovered from this exercise because snow accumulation in the hut caused a computer failure.

A 2nd and more extensive field program was conducted in the Spring of 1994. Enabling developments for which we were responsible were hardware and software associated with the Radio LAN Acquistion Modules (RLAM's) configured for use at ice event "hot spot" sites, a unique 8 channel, PC compatible 24-bit analog-to-digital converter board design and the adaption of a radio LAN product for data telemetry. An extensive software processing and display package using time and frequency domain beamforming techniques was developed for the acoustic radar implemented on a fast Unix workstation. This was crucial to realtime localization of random ice events.

Coincident with the ice event monitoring, data from the horizontal as well as a vertical hydrophone array were recorded as part of a long range acoustic propagation test known as the **Trans-Arctic Propagation (TAP)** experiment. This was achieved in cooperation with a Russian ice camp directly across the pole from us some 1000 km distant, where a low frequency source was deployed and operated.

Nearly 400 gigabytes of data were recorded over the course of the 1994 experiment. Following the field work, we were responsible for developing software used by us, students, Schmidt and Baggeroer for analysis of ice cracking events and the TAP data.

Of the publications listed which accrued as a direct result of our work, the first 4 are internal reports of a technical nature and the last was a paper by a student of Henrik Schmidt's who not only relied on data we collected but worked with with Ed Scheer on algorithmic issues.

2 Publications, Internal Reports

"A Report on Ice Event Localization in the Fall 93 SIMI experiment", E. Scheer, 1994; A summary with displays of all ice events detected in the SIMI-93 experiment, pertinent log book entries, combined with pertinent meteorological and navigation.

"Practical Guide to the Computational Environment of the WHOI-MIT Acoustics Group", E. Scheer, 1994; Continuously upgraded documentation for users of these systems with emphasis on available software, intricacies of data translation amongst hosts, etc.

von der Heydt, K, Eck, C.F., "Radio LAN Acquisition Module (RLAM), Recent Developments for High Resolution Data Collection Systems as Implemented for the ONR Sea Ice Mechanics Experiment, Spring 1994", Woods Hole Oceanographic Institution Technical Report #WHOI-95-09, May 1995.

von der Heydt, K., Baggeroer, A.B., "Fifteen Years of Arctic Acoustics and Ice Camps", Oceanus, Reports on Research at the Woods Hole Oceanographic Institution, Vol. 37, No. 2, Fall 1994.

K. LePage and H. Schmidt, Analysis of Spatial Reverberation Statistics in the Central Arctic, **J. Acoust. Soc. Am.**, 99, 2033-2047, 1996