Remote Seabed Sediment Classification and Sediment Property Estimation Using High Resolution Refection Profiles

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LONG TERM GOALS

The long term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing. In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Neural network and fuzzy logic techniques have been used to automatically detect subsurface layer interfaces and to find the boundaries between sediment layers. Signal processing techniques were developed to estimate vertical profiles of impedance and attenuation. The procedures for remotely estimating sediment properties are being verified using core data and insitu measurements. New signal processing techniques have been developed that allow several sources transmitting simultaneously in different bands to build a wideband FM pulse in the far field. That wideband data is being used to improve the accuracy of the sediment classification procedures and to provide the capability of measuring phase dispersion.

OBJECTIVES

1) Conduct chirp sonar surveys to provide imagery that will be used in High Frequency DRI site selection and to collect calibrated wideband reflection data during the DRI experiments

2) Expand the bandwidth of the chirp sonar from 1-15kHz to 1-45 kHz. A 40 kHz bandwidth will provide a vertical resolution in subsurface images approximately equal to 1 cm.

3) Compare remote chirp measurements of sediment properties with properties measured by other investigators conducting acoustic experiments and coring surveys.

4) Use the chirp sonar to measure a) the frequency dependence of the surficial reflection coefficient and subsurface reflectors b) the frequency dependence of compressional wave attenuation and c) phase dispersion and compare those measurements with the outputs of propagation models developed by other investigators.

APPROACH

A chirp sonar using multiband technology collects normal incidence reflection data over a band of 1 to 45 kHz while the towed vehicle emulates a point acoustic source. The point source is emulated using 3 piston sources that operate over different but overlapping frequency bands. Each single piston source has a wide beamwidth (greater than 40 degrees) over its band of operation. Multiple transducers can be driven simultaneously with chirp pulses with different bands to generate the wideband chirp pulse in the water that appears (in the far field) to emanate from a point acoustic source. Multiple rectangular receiving arrays of various sizes are used to control receiving beamwidth and scattering by spatial filtering. The bandwidth of the sonar provides subsurface imagery approaching 1 cm in vertical resolution. The enhanced bandwidth also improves the accuracy of attenuation and phase measurements needed for impedance inversion and dispersion measurements.

Phase dispersion is measured by measuring the arrival time of reflectors in bandpass reflection profiles. The raw FM data is passed through several bandpass filters to construct a sequence of images, each with a different center frequency. The difference in arrival time for the sediment-water interface and sediment-sediment interface reflections which is proportional to the change in sound speed is plotted as a function of frequency to obtain the phase dispersion measurement.

Dr. Schock supervises the research program including graduate and undergraduate students and at sea experiments. Earnest Arrizi, a graduate student, who attended at sea experiments, and processed the data sets, is writing his thesis on the frequency dependence of the reflection coefficient. Jim Wulf is the lead engineer on the project for expanding the sonar bandwidth.

WORK COMPLETED

During the past year, phase dispersion was estimated from chirp sonar data at the APL tower site using the method described above.

RESULTS

At the APL tower site off Fort Walton Beach, a sediment layer interface occurs approximately 4 meters under the a sandy seafloor. The phase of the reflection from the lower interface of the sand layer indicates that the 4 meter thick sand layer overlies a low impedance layer such as mud. The FM reflection data was filtered into 7 bands where the center frequency of the bands varied from 2.6 to 13.1 kHz. Images were constructed from the bandpass data sets. The two way travel time between the peaks of the sediment-water interface reflection and the sand-mud interface reflection were measured in each image. The travel time for each layer is plotted as a function of frequency. Each of the 50 curves in Figure 1a was generated by a single transmission. Figure 1b is the mean time travel of the 50 transmissions.

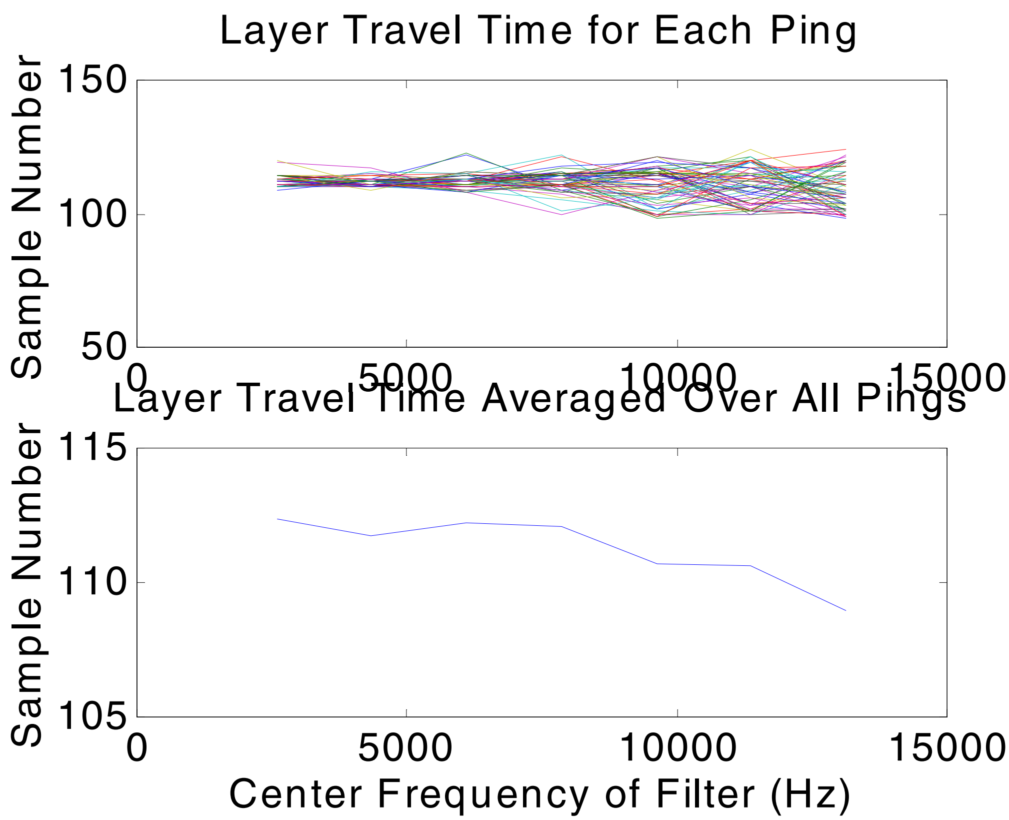

Figure 1 a) Two way echo travel time (in samples) as a function of frequency for 50 transmissions. The noisy measurements must be averaged to obtain an accurate estimate of phase dispersion. b) The graph of mean two way echo travel time as a function of frequency shows that travel time decreases with increasing frequency, or equivalently, sound speed increases with frequency.

Since sound speed is inversely proportional to travel time for a given layer thickness, phase dispersion or the change in sound speed with increasing frequency, can be calculated by normalizing the inverse of the time travel measurements as shown in Figure 2. The measurements show that sound speed increases by approximately 3% over the band of 2.6 to 13.1 kHz which roughly agrees with sound speed measurements and models presented at SAX-99 meetings.

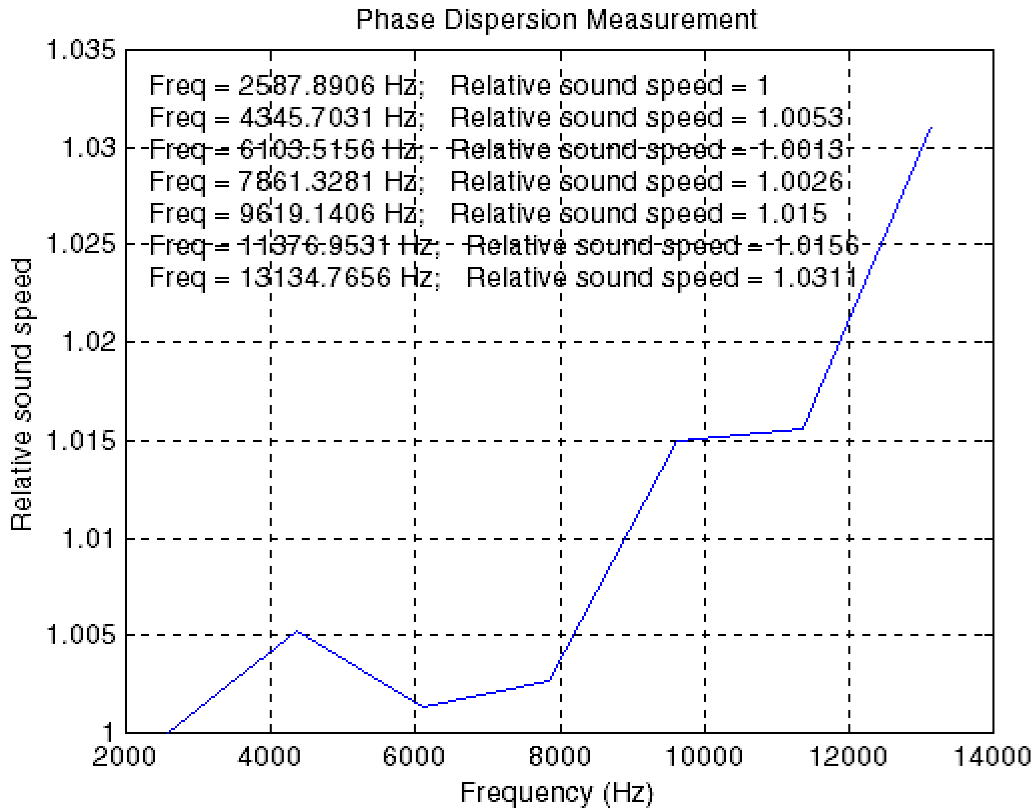

Figure 2. Relative sound speed as a function of frequency. The graph shows that sound speed increases by 3 % as frequency increases from 2.6 to 13.1 kHz.

IMPACT/APPLICATIONS

Instrumentation and sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying the top 20 meters of the seabed and obtaining vertical profiles of attenuation, acoustic impedance, volume scattering. From these acoustic property profiles, vertical profiles of physical properties such as bulk density, grain size, and porosity can be estimated.

TRANSITIONS

The chirp sonar, which evolved out of this program, was transitioned to industry in the early 1990s and has become the standard ocean industry instrument for conducting high resolution ocean surveys. Edgetech, Inc. is manufacturing multi-band chirp sonars, technology derived from this ONR research project.

RELATED PROJECTS

"Remote Sediment Property Estimation From Chirp Data Collected During ASIAEX," ONR G&G Grant. The chirp sonar is being used to remotely predict sediment properties in the East and South China Seas using the same techniques as described in this report.

PUBLICATIONS

1. Overview of SAX99: Environmental Considerations," Richardson, M. et al, IEEE J. of Oceanic Eng, 26 (1), January 2001, p. 26-52.

2. " The Development of Chirp Sonar Technology and Its Applications, " S. G. Schock and L. R. LeBlanc, AGU Abstract, Dec., 2000.

3. "Techniques for estimating sediment properties from chirp sonar data," S. G. Schock, JASA, Vol 109, No. 5, Pt 2, Chicago, May 2001 (invited paper).