Title: Seabed Acoustic Characterization

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LONG-TERM GOALS

The long-term goals of the research are (1) to quantify the frequency dispersion of the complex sound speed in marine sediments from low to mid frequencies, and (2) to understand the coupling of physical mechanisms in the water column and the seabed in complex range and azimuth dependent littoral waveguides.

OBJECTIVES

The main objective of the current research is to determine the frequency dependence of the sediment sound speed and attenuation in the 10-3000 Hz band in a littoral region that has extensive geophysical and real time supporting physical oceanography measurements. A secondary objective is to develop advanced signal processing methods that can be applied to the inverse problem of estimating waveguide properties from acoustic measurements.

APPROACH

Extensive narrowband and broadband acoustic measurements in the 10-3000 Hz band were planned with two L-arrays separated by approximately 20 km in the SW06 test area. The propagation track connecting the two arrays was to lie on an approximate isobath (~ 70 meters water depth). The specific locations of the L-arrays were chosen on the basis of prior geophysical measurements that indicated a nearly uniform high speed sandy sediment with a first layer thickness of about 20 meters. Geoacoustic inversion methods previously developed[1-2] will be employed to extract from the acoustic transmission data information on the frequency dispersion of the sound speed and attenuation within the seabed. The two L-arrays, with their horizontal apertures perpendicular to each other, offer a unique opportunity to apply advanced signal processing methods within an inversion methodology to transmission data that are received simultaneously on both arrays.

WORK COMPLETED

A 32 element L-shaped array and a 52-element L-shaped array were fabricated at the Applied Research Laboratories, The University of Texas at Austin (ARL:UT). The electronics for the computer system of the 32-channel data acquisition system were upgraded to sample at 6250 Hz with 16 byte recording capability. The two Shallow Water Acoustic Measurement Instrumentation (SWAMI) data acquisition systems were deployed by ARL:UT during Cruise 185 of the RV KNOOR during SW06. SWAMI-32 had 12 phones comprising its VLA aperture and 20 phones comprising its HLA aperture. The VLA aperture spanned the water column from about 10 meters beneath the surface to the seabed with

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equally spaced hydrophones. SWAMI-52 had 16 phones comprising its VLA aperture and 36 phones comprising its HLA aperture. Both HLA apertures were about 250 meters in length. The sampling rate for SWAMI-52 was about 2400 Hz. The distance between the two SWAMI arrays was about 20 km. SWAMI-52 recorded continuously from 236:15:27:00–249:16:50:00 GMT, about 13 days, while SWAMI-32 recorded from 236:22:36:00-240:16:35:00 and then from 242:22:45:26–248:23:10:00 GMT, about 11 days total.

RESULTS

The most important result for FY 06 was the successful completion of the acoustic measurements in SW06. It is expected that these data contain the required information to meet the research objectives. The value of the measurements will be determined by analysis of the data by ARL:UT and the other SW06 researchers.

1. The deployment of two L-arrays on an isobath with the HLA apertures of each array perpendicular to each other permits the development and testing of new inversion cost functions that employ the simultaneous receptions of acoustic signals. This may allow inversion techniques to be more sensitive to the values of seabed geoacoustic parameters. This in turn enhances the ability to quantify the dispersive properties of the seabed to a greater extent relative to the use of a single L-array.

2. Increasing the SWAMI-32 data acquisition system sampling rate from 2400 Hz to 6250 Hz coupled with the extension of the time of continuous recording permits the study of the frequency dependence of the propagation over a 3 kHz band for a large number of transmission experiments that included the mid-frequencies. It is hypothesized that if the Biot theory has a physical basis for describing the propagation of sound in marine sediments one may be able to observe a *transition frequency* where the sediment attenuation frequency dependence changes from f^2 to $f^{1/2}$. Independent of the question of the validity of the Biot theory is the main point that frequency dependence of the complex sound speed can in principle be extracted from the data in a model independent form.

3. The Combustive Sound Source (CSS)[3] deployed during SW06 represents a new capability for making broadband measurements (10-3000 Hz) of the impulse response of an ocean waveguide. The band limited impulse response may itself provide enough information to characterize the frequency dispersion of the seabed. While the deployment of the CSS is currently awkward and manpower intensive, the SW06 deployment provided realistic experience that can be translated to modifications of the hardware and experimental technique to significantly decrease the required manpower and increase the repeatability of the source waveform in future experiments.

4. The implosions of about 200 G-series light bulbs between the two SWAMI arrays may themselves provide estimates with high resolution of *coherent* seabed properties such as sound speed, sound speed gradient, and sediment thickness. The discovery that these nearly spherical glass spheres could produce highly repeatable source waveforms was an important contribution to the SW06 experiment. Once the coherent seabed properties are established from the low frequency acoustic data, properties such as the sediment attenuation can in principle be estimated.

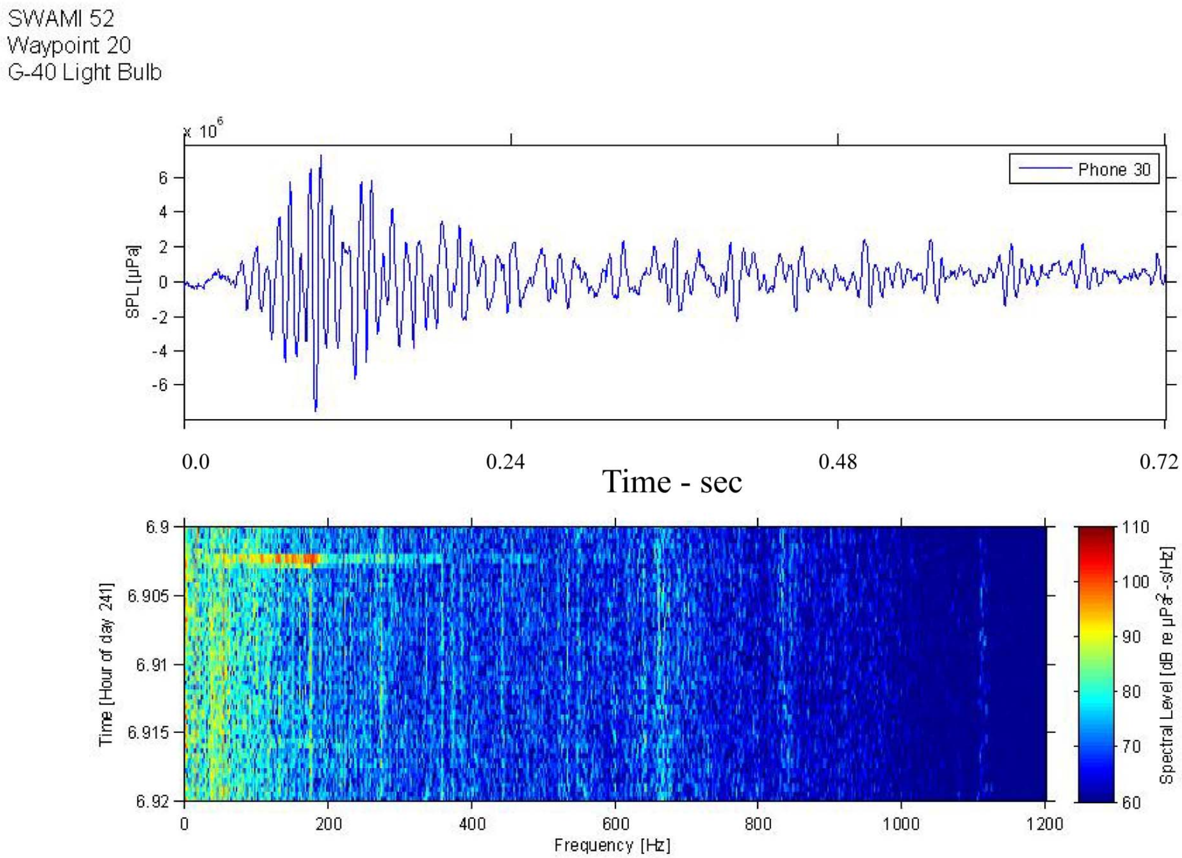

Figure 1: Received time series and spectra measured on SWAMI-52 from the implosion of a G-40 light bulb

Figure 1 contains an example of a light bulb implosion event measured on phone 30 of the SWAMI-52 array. The spectrum from the implosion time series shows frequency components out to about 500 Hz with the dominant part of the spectrum below 200 Hz. The received time series is about 0.7 seconds long and exhibits significant bottom interacting arrivals. An important point is that the source signature for each light bulb event was measured by a calibrated hydrophone whose distance to the source implosion was known within an error of less than 0.5 meters. Further, the source signatures from direct path propagation were measured in a lake environment prior to the SW06 experiment. The calibrated source signatures allow one in principle to model the received time series by convolving a simulated frequency response and the measured source spectra.

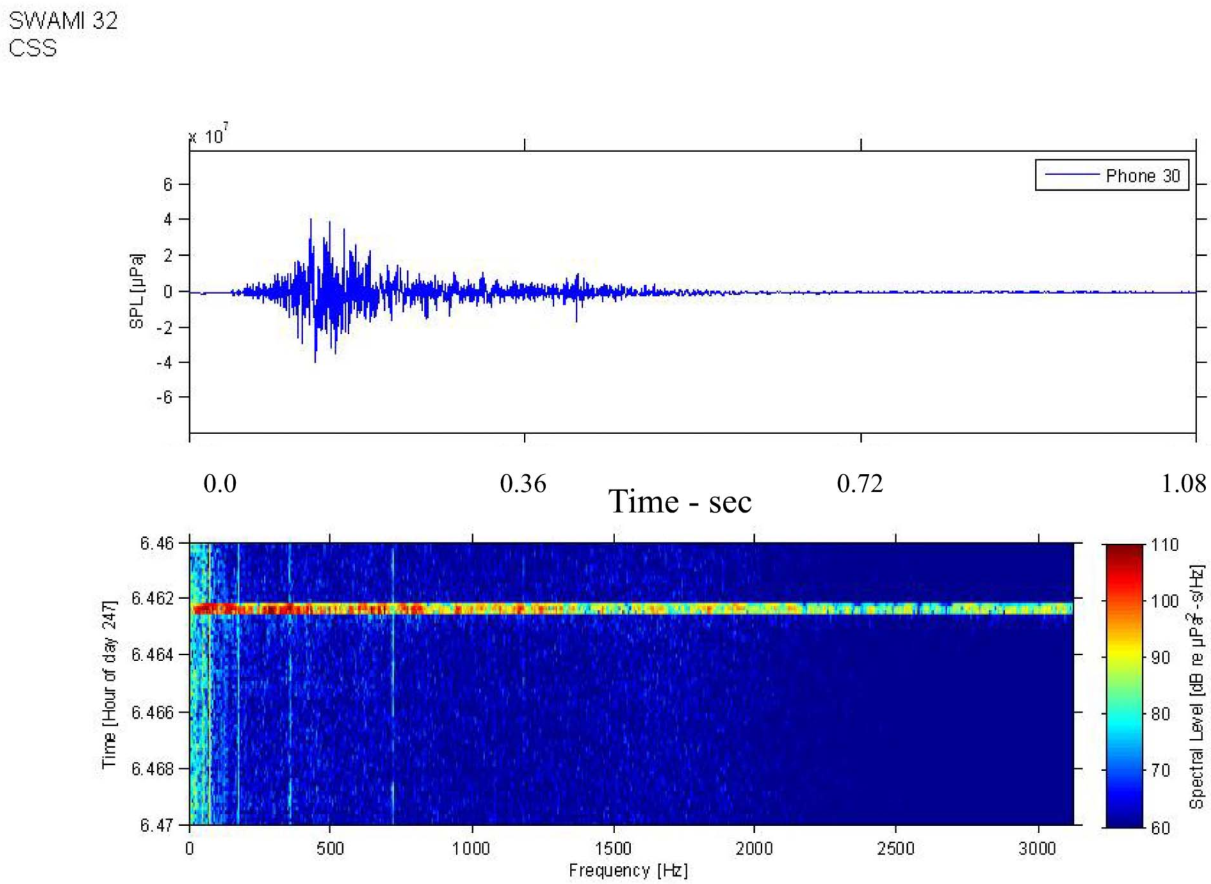

Figure 2. Time series and spectra of CSS event measured during SW06 on SWAMI-32 L-array

Figure 2 shows a received pressure time series and a spectrum from a CSS event recorded from phone 30 of the SWAMI-32 array. The bandwidth of the CSS event is significant, covering the entire recording bandwidth of the array (~3 kHz). The received time series is on the order of 0.4 seconds in duration. Since the source signature was measured on an independent calibrated system during the transmission, the wideband signature measured on the array offers a unique opportunity to examine the frequency dependence of the attenuation. Array processing will further enhance the SNR of the signal at the higher frequencies.

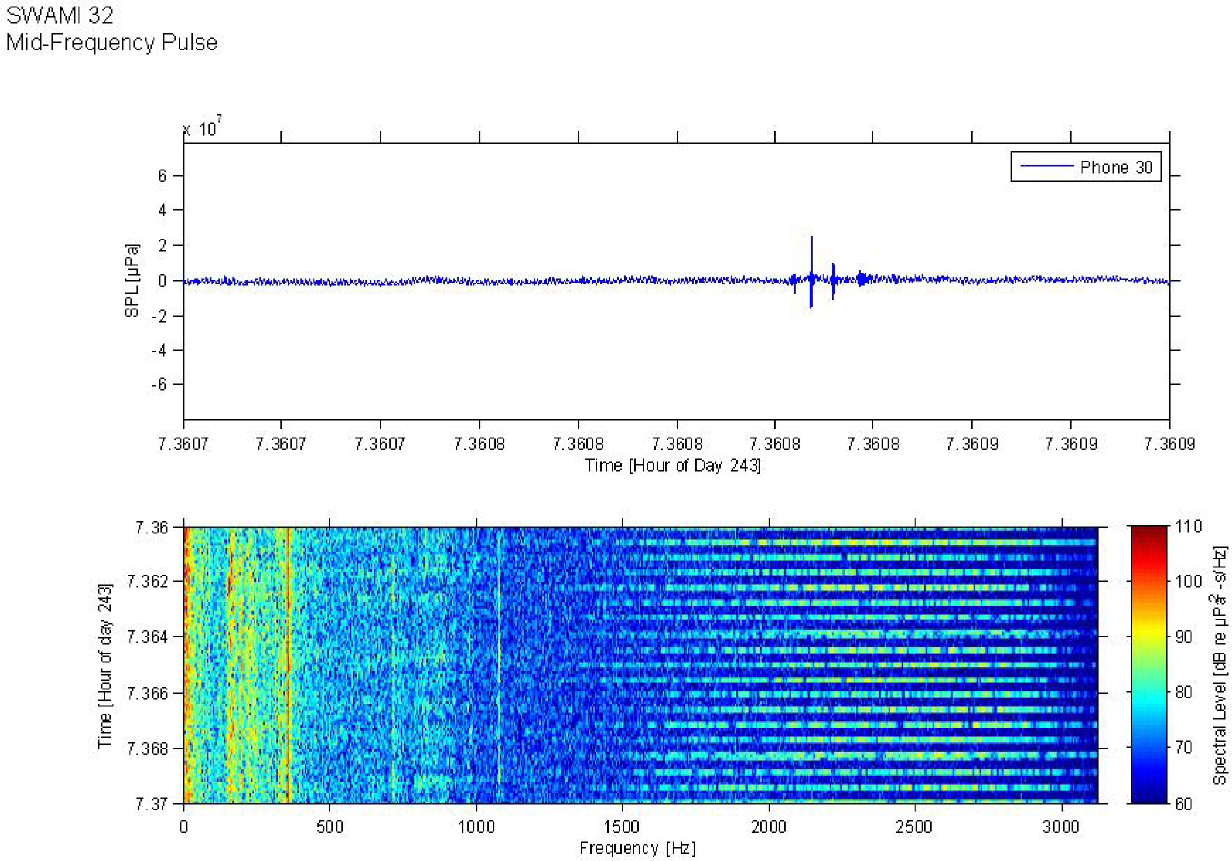

Figure 3. Example of broadband mid-frequency pulse data measured on SWAMI-32 array

Figure 3 shows data collected from the SWAMI-32 array. The source was an ITC 2050 towed source, provided by the Marine Physics Laboratory at SCRIPTS, that generated a broadband pulse in the 1500-3000 Hz band with a 2-second duty cycle. This permits the direct measurement of the band limited impulse response of the waveguide over a large vertical and horizontal spatial scale.

IMPACT/APPLICATIONS

The potential future impacts of this research include:

(1) Constraints on candidate physical theories of sound propagation in elastic seabeds.
(2) New signal processing schemes used for inverse problems in ocean acoustics.
(3) New, easily deployed broadband sources with highly repeatable waveforms that could replace/complement SUS.

RELATED PROJECTS

The PI of this ONR funded research has been tasked to use geoacoustic inversion methods to analyze light bulb implosion data taken in the PLUSNET Monterrey Bay experiment conducted in August 2006.

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