Three-Dimensional Scale-Model Tank Experiment of the Hudson Canyon Region

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LONG-TERM GOALS

The long-term scientific goal of this project is to advance understanding of three-dimensional (3D) acoustic propagation in range-dependent ocean waveguides by studying propagation in a scale-model laboratory environment.

OBJECTIVES

The objective of this work is to generate high quality acoustic data, measured in the laboratory, that will (1) provide a benchmark standard for 3D numerical models currently being developed, (2) allow researchers to carefully investigate 3D acoustic propagation in a controlled waveguide, and (3) assist ONR in planning for future experiments in ocean environments with slopes and canyons.

APPROACH

The development of fully 3D numerical acoustic propagation models is an area of ongoing research.[1–7] These models have the potential to be very accurate, but comparisons between data taken at sea and numerical predictions often suffer because of insufficient environmental inputs to the numerical model. This is already a problem for two-dimensional (2D) data-model comparisons and is likely to be a perpetual problem when trying to employ 3D numerical models to describe experimental data.

An alternative way to provide benchmark-quality data for numerical models is to conduct physical scale-model laboratory experiments. Scale-model experiments permit tight control over many of the variables affecting acoustic propagation, such as water temperature, bathymetry, source/receiver geometry, surface and seafloor roughness, and the geoacoustic properties of the modeled seafloor. Control over these variables allow for precise observation of 3D acoustic propagation effects such as horizontal refraction, shadow zones, multiple mode arrivals, and intra-mode interference.

Much of the prior work in scale-model experiments has employed flat or sloping bottoms or random rough surfaces.[8–15] While these experiments have been useful for their intended purpose, they represent idealistic bathymetries that are not found in the ocean. The approach employed in this work is to use actual bathymetric data in conjunction with computer numerical controlled (CNC) machining techniques to produce scale-model representations of actual ocean environments.

Figure 1 illustrates the technical approach. The scale-model bathymetry is suspended below the air-water interface of an indoor test tank on a mechanical support structure. An acoustic source is positioned at a fixed point in space and broadcasts acoustic signals. A computer-controlled positioning system accurately locates the listening hydrophone in three-dimensional space. An acoustic I/O system both generates the acoustic source signal and digitally acquires the acoustic data at the listening hydrophone. High quality acoustic data is acquired for various source and receiver positions over the scale model, including both along and across canyon propagation. High spatial sampling of the acoustic field could allow for data post-processing that includes both horizontal and vertical beamforming. Auxiliary measurements (such as water temperature, receiver position, and measurements of acoustic properties of the foam) are also recorded.

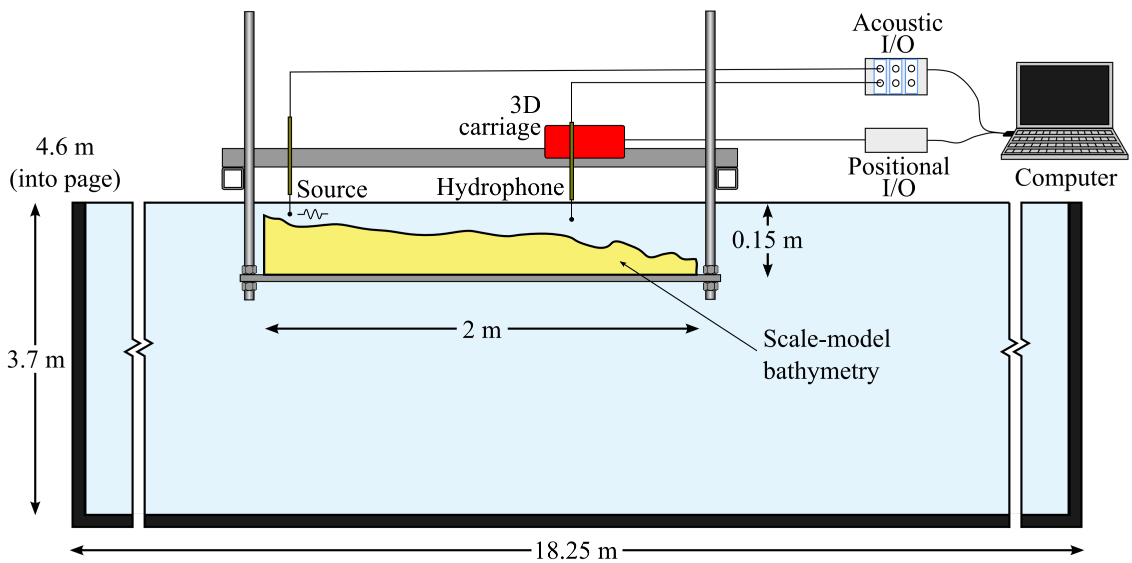

Figure 1: Illustration showing the experimental apparatus.

WORK COMPLETED

The work completed includes designing the mechanical support structure, creating the computer-aided design (CAD) model of the bathymetric part, performing material selection for the bathymetric part, and completing formal quotations for the mechanical, electrical, and acoustical components.

RESULTS

The mechanical support structure is shown in Fig. 2(a) and consists of a cradle that holds the bathymetric part and is suspended from the I-beams that comprise the floor of the indoor tank room. The design allows for both gross and fine alignment of the bathymetric part relative to the water-air surface, provides sufficient rigidity to prevent deformation of the bathymetric part, and provides a secure platform to which the linear positioning equipment can be secured (not shown).

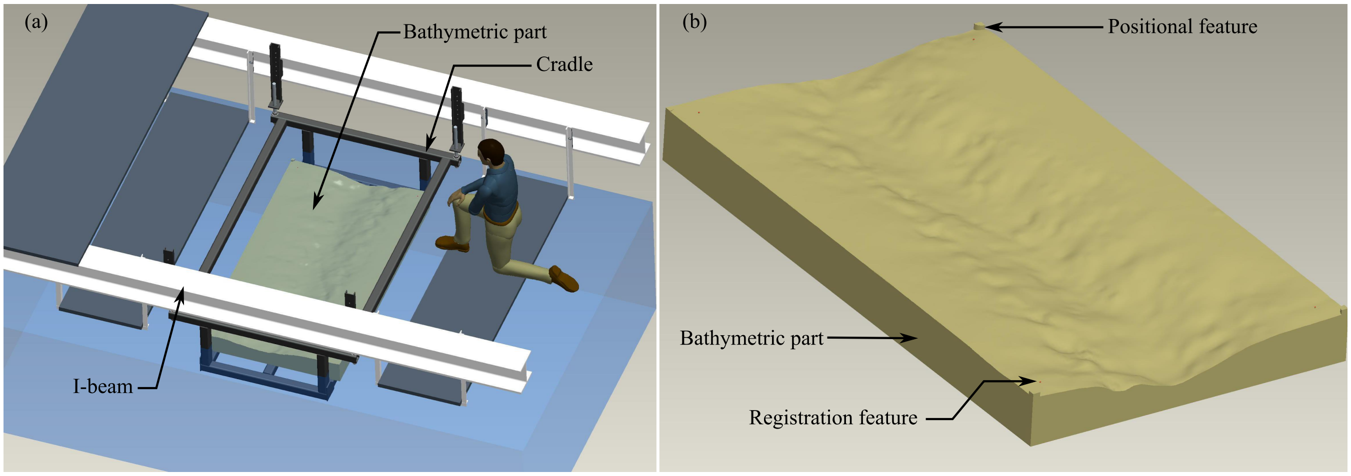

Figure 2: Mechanical design of (a) experimental support structure and (b) scale-model canyon.

The CAD model of the bathymetric part is shown in Fig. 2(b). The construction of the model involves importing into ProE data points from a bathymetric database, creating successive bathymetric cross-sections, and then utilizing the swept-blend feature of ProE to create a smoothly varying surface. Such a procedure is required for the practicality of CNC machining. Positional and registration features were also added to aid with alignment relative to the water-air interface and registration of the linear actuators relative to the bathymetry, respectively.

The material choice for the scale-model bathymetric part is important. A material is sought which a) approximates a pressure-release boundary (to maximize signal level in the experiment), b) does not support shear waves (for simplification of data/model comparison), c) possess homogeneous density and sound speed, d) has sufficient rigidity to not deform when submerged, e) does not become water saturated over time, and f) is amenable to CNC machining. A Reflection Coefficient Measurement (RCM) apparatus,[16] shown in Fig. 3(a), was constructed to measure the ultrasonic reflection coefficients of candidate materials, of which some of the measurements are shown in Fig. 3(b).[17] The material selected was RS20, a 20 lb/ft^3 rigid polyurethane foam machining board sold under the trade name Renshape 5030, which exhibited a $|R(\theta)|$ greater than 0.9 for angles between 10° and 90°. A 7-month submersion test also revealed that the RS20 material does not absorb water nor change dimension as a function of submersion time.

Finally, formal quotations were obtained for all of the major system components. The purchasing of materials and construction of the apparatus will commence when funding from a DURIP award becomes available.

IMPACT/APPLICATIONS

The impact of this research is understand the importance of 3D acoustic propagation induced by bathymetric features and to provide a benchmarking opportunity to newly developed acoustic propagation models.

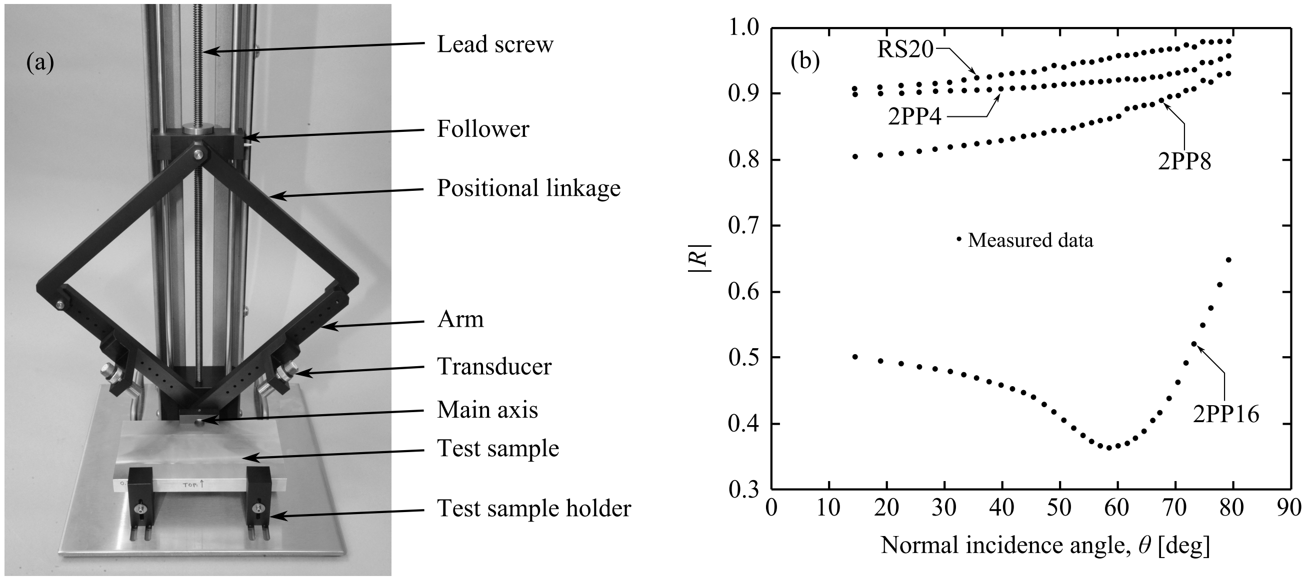

Figure 3: (a) RCM apparatus, (b) magnitude of the reflection coefficient for several candidate polyurethane foams.

TRANSITIONS

The primary transition for this project is to make direct reports on the scale model experiment and to make available the experimental data to principal investigators who develop numerical propagation models.

RELATED PROJECTS

Recently recovered acoustic data from the Gulf of Mexico are being investigated for evidence of 3D acoustic propagation. Analysis of the measured acoustic data suggests that horizontal refraction from canyon walls occurs for certain source ranges. Collaboration with Dr. Megan Ballard (ARL:UT) is underway to numerically model the pressure time series in a low-frequency band.

Recently recovered acoustic data from the Gulf of Oman are also being investigated within a statistical inference methodology to infer information about seabed properties. This work is performed in collaboration with Dr. David Knobles (ARL:UT).

PUBLICATIONS

Peer-reviewed papers

J. D. Sagers, M. R. Haberman, and P. S. Wilson, "Ultrasonic measurements of the reflection coefficient at a water/polyurethane foam interface," J. Acoust. Soc. Am. **134**, EL271-EL275 (2013).

D. P. Knobles and J. D. Sagers, "Forward and backward modal statistics for rough surface scattering in shallow water," submitted to J. Comp. Aco. (2013).

Technical reports

J. D. Sagers, A. P. Hill, M. R. Haberman, and P. S. Wilson, “Ultrasonic reflection coefficient measurement (RCM) apparatus,” Technical Report ARL-TL-EV-13-72, Applied Research Laboratories (2013).

J. D. Sagers and M. S. Ballard, “Sediment structure near the Church Stroke III exercise region, including the Catoche Tongue,” Technical Report ARL-TL-EV-13-69, Applied Research Laboratories (2013).

J. D. Sagers, “Time series extraction of SUS waveforms from the ACODAC array during the Church Stroke III experiment,” Technical Report ARL-TL-EV-13-56, Applied Research Laboratories (2013).

Conference presentations

D. P. Knobles and J. D. Sagers,“Influence of rough seabed surface on statistics of modal energy flux,” J. Acoust. Soc. Am. **133**, 3252 (2013).

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