High-Frequency Scattering from the Sea Surface and from Bubbles in Shallow Water

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LONG-TERM GOALS

The long term goal of this research is an improved understanding of (**1**) high-frequency scattering from the air-sea interface and from bubbles near this interface, and (**2**) high-frequency propagation and scattering in bubbly media characteristic of surf zone conditions.

OBJECTIVES

For studies involving the air-sea interface, the objective is to model bistatic sea surface scattering measurements based on simultaneous measurements of the wind and directional wave fields.

For studies on acoustic propagation and scattering in the surf zone, the objectives is to extract attributes (e.g., void fraction, spatial and temporal scales) of a surf zone bubble field, and interpret these vis-à-vis
the coastal oceanography and their impact on high-frequency acoustic systems.

APPROACH

The approach is based heavily on modeling and interpretation of experimental data taken by the Principal Investigator. Data for bistatic scattering studies is from an experiment conducted in 1995 off the Florida coast.

Data for surf zone studies is from the 1997 Scripps Pier experiment, involving a collaboration of NRL-SSC, APL-UW, IOS, and SIO. A plan for joint data analysis was agreed upon at the post-experimental meeting in early FY98.

WORK COMPLETED

A new model for bistatic surface scattering [1] that incorporates earlier research on the small slope approximation [2] was completed, with model results compared to integral measurements of bistatic scattering from the Florida experiment. Simultaneous measurements of wind-wave growth were also studied and reported on[3].

Data from the Scripps Pier experiment was analyzed, and estimates of spatial and temporal scales of bubble clouds in a surf zone derived and compared with those made by other Scripps Pier collaborators [4].

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RESULTS

Figure 1 (top) shows the dominant ray paths that compose the arrival structure for a measurement made in the Florida experiment. With the 1-ms pulse, the first few paths can be resolved (bottom plot); shown here are the direct path (D), surface-bounce path (S), bottom-bounce path (B), and surface--bottom bounce path (SB) in terms of ensemble averaged intensity. The smooth curve over the surface bounce path is a model result [1] that employs the small slope approximation (SSA). The bistatic scattering model has quite adequately predicted both the *calibrated* intensity level, and its temporal decay. Moreover, both large and small roughness scales have been accommodated by the SSA.

Figure 2 is an image of a bubble cloud constructed from acoustic measurements of bubble transport within the surf zone that were made during the Scripps Pier experiment [4]. The data were taken with one of four identical, upward-looking sonar units, collectively called the SALMON system (Shallow water Acoustic Lightweight MONitor). These units were strategically placed about a triangular frame with 10-m sides called the “Delta Frame”, designed by NRL-SSC and within which NRL-SSC and IOS made measurements.

The data shown in Fig. 2 were originally backscattering measurements, but in this figure they have been converted to attenuation estimates using the forward scattering theorem. Key to this conversion is an estimate of the bubble size distribution; here we use a distribution estimated by the research team from NRL-SSC led by Jerry Caruthers. The figure depicts a bubble cloud within the surf zone advecting seaward. The vertical dimension (labeled “true”) is derived from time delay in the acoustic return, while the horizontal dimension (labeled “estimated”) is derived from invoking Taylor’s (frozen turbulence) hypothesis (an independent estimate of current velocity was used here). The figure illustrates the complexity in shape that surf-zone bubble clouds can assume. (The white line shows the single cut in depth that Delta Frame-based measurements make, and thus how these measurements are complimented by those made with the SALMON system). Ultimately estimates of the 3-dimensional spectrum of bubble clouds are needed in order to access their impact on the performance of sonars that operate in this complex environment.

IMPACT / APPLICATIONS

Bistatic scattering from the sea surface is a key feature of the acoustic environment that determines the performance of sonar systems that operate either in shallow water or in the vicinity of the sea surface. The model presented in ref.[1] improves on our ability to predict bistatic scattering effects.

Results from the Scripps Pier experiment will impact the design of sonar systems that must operate in this very complex environment.

TRANSITIONS

This work relates directly to other ONR programs (both 6.1 and 6.2) that involve frequencies in the > 10 kHz range, and scattering from the surface and near-surface bubble layer. The results will be particularly useful forscattering models used in Torpedo and MCM system performance predictions.

RELATED PROJECTS

The work on bistatic sea surface scattering relates to basic research programs in scattering theory, such as the work on the small slope approximation by Thorsos and Broschat, and ONR 6.2 programs in modeling high-frequency acoustics.

The work on surf zone acoustics is an integral part of the ONR research program in this field being carried out by NRL-SSC, APL-UW, IOS and SIO-MPL.

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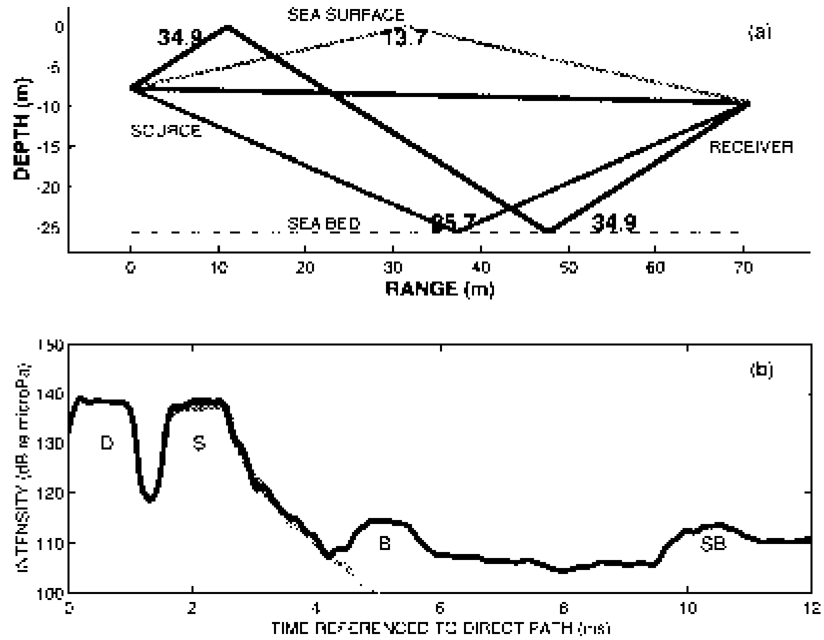

Figure 1: (Top) Dominant ray paths corresponding to experimental run 2 from ref.[1]. (Bottom) Ensemble averaged intensity showing the primary arrivals: direct (D), surface bounce (S), bottom bounce (B), and surface-bottom bounce (SB). The smooth curve is a simulation generated by the bistatic scattering model discussed in ref.[1].

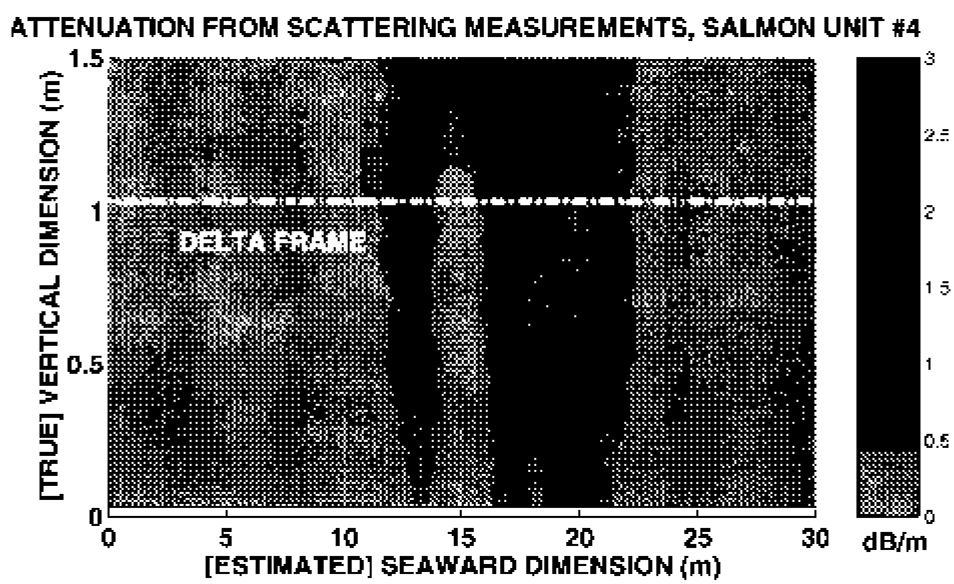

Figure 2: Image of a bubble cloud made during the Scripps Pier experiment. The vertical dimension is derived from time delay and horizontal dimension is derived from invoking Taylor's (frozen turbulence) hypothesis. The white line shows the single cut in depth that Delta Frame-based measurements make.