Shallow Water Reverberation and Low Frequency Seabed Scattering

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LONG-TERM GOALS

The long-term goal of this work is: (1) to develop a reverberation model for predicting the reverberation level and the echo-to-reverberation ratio in shallow water (SW) in a frequency band of 100-3000 Hz, and (2) to analyze the mechanisms of seabed scattering at low frequencies (LF).

OBJECTIVES

To set up a quality reverberation data base, to validate the SW reverberation model derived from the energy flux method , and to charaterize LF seabed scattering parameters.

APPROACH

Much progress has been made in the past three decades to improve our understanding of reverberation, including SW reverberation modeling and high frequency (HF) seabed scattering. However, these two research communities have not yet had enough communication each other. Different theoretical methods have been used to develop SW reverberation models. However, most of these models have not yet fully taken advantage of the progress made by the seabed scattering community. There remains a real scarcity of high-quality basic research data sets for testing those reverberation models and validating the suitability of the HF seabed scattering models at the low frequencies. New progress on the long-range reverberation modeling and the LF seabed scattering characterization requires three essential conditions: 1). A reliable reverberation model using a physics-based seabed scattering function, 2). Carefully calibrated broadband reverberation data, and 3). A ground truth about the seabed geoacoustic model.

Bridging the fields of reverberation modeling and the seabed scattering, we integrate the energy flux method for reverberation [1] with physics-based seabed scattering models [2], and use the LF field-inverted Biot geoacoustic model [3] and the quality reverberation data [4] for reverberation model-data comparisons and inversions.

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RESULTS

1. The energy flux method for SW reverberation, based on the W.K.B approximation to the normal-mode solution [1], has been integrated with the physics-based rough bottom scattering (RBS) model and sediment volume scattering (SVS) model [2].
2. The integration of the energy flux method with physics-based seabed scattering models directly and intuitively results in general expressions for SW reverberation in the angular domain and in the modal domain. The latter expression is same as the modal reverberation expression derived from the Green's function and boundary perturbation method by Tracey and Schmidt [5].
3. The integration also results in a simple relationship between the classic boundary scattering cross sections and the modal scattering matrix in SW waveguides.
4. Data-model comparisons show that the HF RBS model and the SVS model may directly be used for predicting low-frequency (LF) and long-range reverberation. Fig. 1 show the reverberation data-model comparison at the ASIAEX site for 1500 Hz using a set of seabed scattering parameters.
5. The LF data-model comparisons show that the reverberation level as a function of time at one single frequency cannot uniquely determine the seabed scattering parameters. The wideband reverberation data can uniquely determine a set of the bottom roughness spectra and the sediment volume scattering cross section as a function of frequency.
6. The LF seabed scattering parameters, derived from the broadband reverberation data, are different from those values often used for HF modeling or testing. For example, the HF roughness spectrum exponent is restricted to the range of $2 \le \gamma_2 \le 4$ with a mean of 3.0. But, the LF roughness spectrum exponent, inverted from the long-range reverberation, is much smaller. The HF sediment volume scattering cross section σ_V is generally assumed to have linear frequency dependence. However, the LF σ_V, inverted from the broadband long-range reverberation, exhibits much stronger frequency dependence. Figure 2 shows that using the Biot geoacoustic mode [3], the sediment volume scattering cross section at the ASIAEX site can be expressed by $\sigma_V \approx 0.0023(f/1000)^{3.822}$.

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PUBLICATIONS

J.X. Zhou and X.Z. Zhang, "Low-frequency seabed scattering at low grazing angles," J. Acoust. Soc. Am., **131**, 2611-2621 (2012).

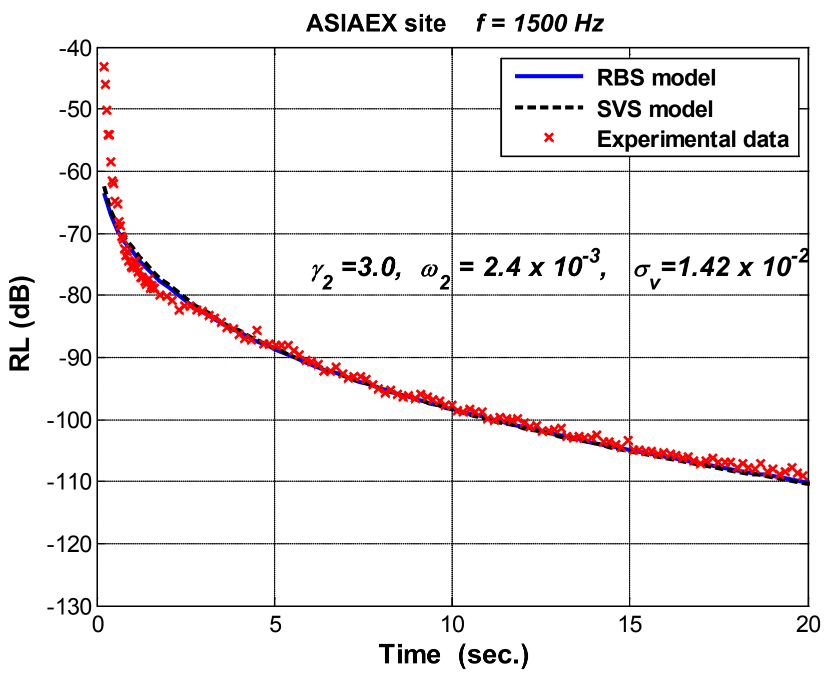

Figure 1. Reverberation model-data comparison at the ASIAEX site

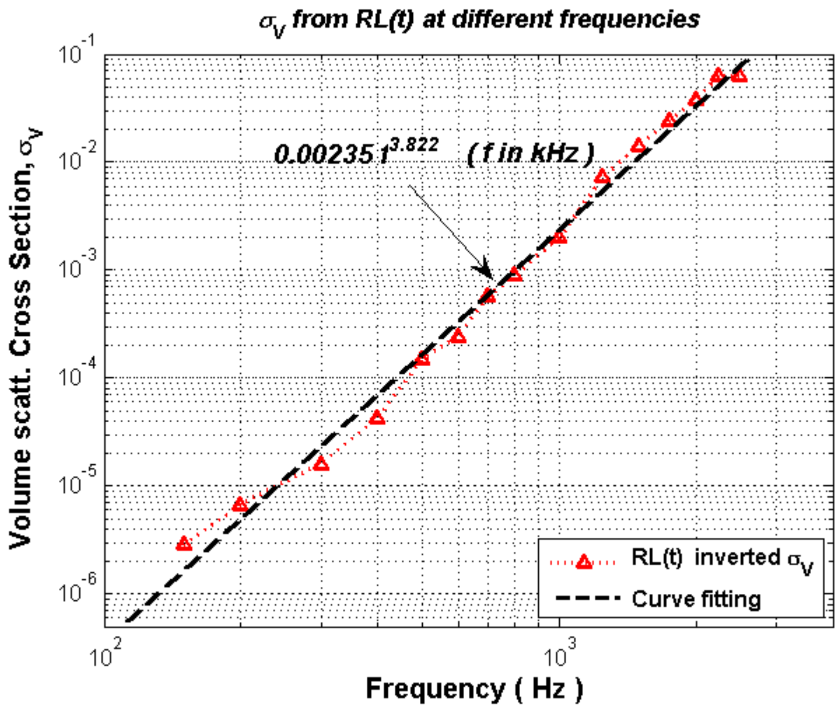

Figure 2. Reverberation-inverted sediment volume scattering cross-section vs. frequency