TITLE

IN-PLANE BISTATIC CALCULATIONS OF BOTTOM VOLUME REVERBERATION IN SHALLOW WATER

In-Plane Bistatic Calculations of Bottom Volume Reverberation in Shallow Water

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Abstract: Shallow-water reverberation calculations are compared for three bottom scattering functions: interface scattering using Lambert's rule, a simple bottom volume scattering formulation of Ellis, and a more realistic bottom scattering formulation by Hines. The dominant time dependence of the reverberation is due to transmission loss effects, but differences of several dB are due to the scattering functions.

INTRODUCTION

Even when the source and receiver are co-located (monostatic geometry), reverberation calculations involving bottom or surface bounces require information about the in-plane bistatic scattering function. A shallow-water reverberation model based on normal modes and ray-mode analogies has been previously developed (1), and is an extension of the work of Bucker and Morris (2). It uses normal modes for the propagation, with ray-mode analogies and a plane-wave scattering function at the interface. It was first developed for boundary scattering, and has been recently extended to handle volume reverberation in both the water and bottom (3). In this paper the model was adapted to use Hines' in-plane bistatic scattering function (4) as the scattering at the bottom. The scattering functions are described; then some sample reverberation calculations are presented to compare the effects of the various scattering formulations.

SCATTERING FUNCTIONS

The volume backscattering model of Hines is a perturbation model in which fluctuations in the acoustic impedance of the bottom are related to fluctuations in the porosity of the sediments. The scattering due to both the refracted and evanescent waves are calculated for the incident and scattered angles. The input parameters in the model are: water sound speed of 1500 m/s, density of 1.024 g/cm^3, sediment sound speed of 1600 m/s, density 1.64 g/cm^3, and attenuation 0.094 dB/m-kHz. The porosity was modelled as an exponentially decaying correlation function of the form $\exp(-r/r_o - z/z_o)$ with $r_o = z_o = 1$ m and a variance of 0.001. The scattering function (Fig. 1) was evaluated at 630 Hz from 2° to 30° in two-degree increments. Due to the finite ranges of the source and receiver and the nature of the calculations, the scattering function is slightly asymmetric in the incident and scattered angles; the two terms have been averaged to produce a symmetric function. Figure 2 compares the backscattering function (solid line) with Lambert's rule (dash-dots), $\mu \sin^2 \theta$, where $10 \log \mu = -27$ dB. Note the decrease in the scattering at the critical angle $\theta_c = 20°$; this results from including absorption in the bottom (5).

The volume scattering formulated by Ellis (3) is analogous to ray-based volume reverberation models for the water column. Since the mode functions extend into the sediment, the volume scattering can be extended into the bottom. The bottom volume scattering strength can be angle dependent as well as depth dependent, but for simplicity it is assumed to be isotropic.

REVERBERATION CALCULATIONS

The effects of the three scattering formulations are illustrated in two different environments. In the first example, the propagation environment (1) is a Pekeris model, 100 m of water, at 100 Hz, over a hard bottom with a critical angle of 30°. Figure 3 compares reverberation prediction for Lambert's rule (with a coefficient of −27 dB), Ellis' bottom scattering function (assuming a scattering strength of −50 dB//m^3), and Hines' scattering function of Fig. 1. The 2-degree grid of Fig. 1 is bi-linearly interpolated to obtain the scattering function at the mode angles.

The second example corresponds to Mediterranean (1) data from SACLANTCEN for a one-third octave band centered at 630 Hz, with a source spectral level of about 197 dB. The acoustic bottom parameters are as described for the Hines' scattering function. The sound speed profile and other details are described in (1). Figure 4 compares several reverberation predictions with the data (squares). Note the source and receiver were separated by 6 km (4 s in time), so the data are bistatic in range. A full bistatic model prediction (6) (short dashes) provides good agreement with the data over the entire range, with a Lambert coefficient of –35 dB adjusted to fit the data. However, predictions using our monostatic model (dash-dots), which includes the in-plane vertically bistatic returns, with the same Lambert coefficient, are in excellent agreement with the bistatic model for times greater than about 10 s; the calculation times for the monoststic model are also much shorter. The variance of the porosity in Hines' model was adjusted to 10^{-4} to facilitate comparison of its predictions (solid line) with the Lambert prediction (dash-dots) and the isotropic bottom volume scattering (long dashes).

As noted in Ref. 1 and elsewhere, propagation effects – especially bottom loss – are dominant in determining the overall levels and decay rate of the reverberation. The different scattering functions do, however, produce small differences (±2 dB) in the reverberation time dependence.

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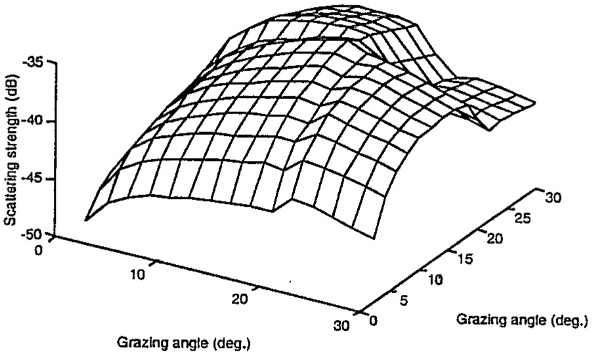

FIGURE 1. Hines' scattering function.

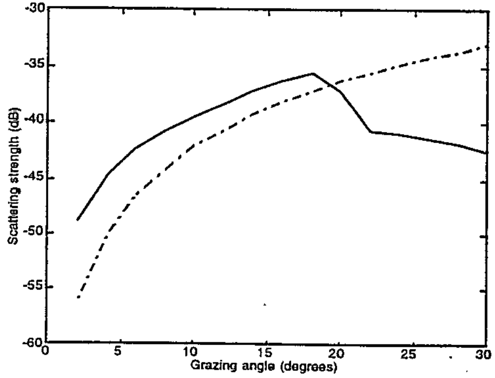

FIGURE 2. Backscattering function compared to Lambert's rule.

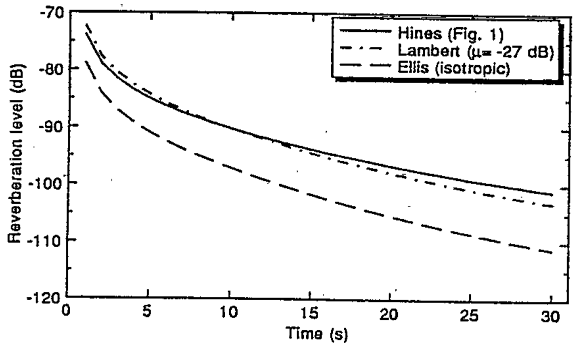

FIGURE 3. Predicted reverberation in Pekeris environment.

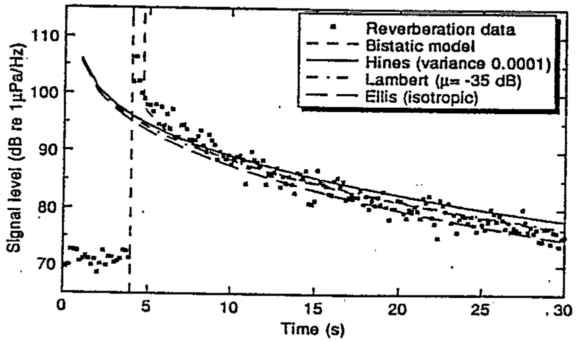

FIGURE 4. Model-data comparisons with measured data.

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