Broadband propagation over randomly varying, range-dependent sediments

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Abstract: Statistics of broadband signal transmission loss fluctuations are determined in terms of geoacoustic variability. Stochastic variations in geoacoustic fields are modeled by varying the vertical correlation length of measurements from Atlantic Generating Station site core profiles. Uncertainties in the geoacoustic fields change the coefficients of representations by empirical orthogonal functions which form the basis of a geoacoustic interpolation scheme. The fields are used in propagation modeling for both fluid and elastic sediments. Simulation statistics are compared with experimental data.

GEOACOUSTIC MODELING

Acoustic experiments conducted over different tracks at the Atlantic Generating Station (AGS) site have shown significant transmission loss (TL) variability. These fluctuations cannot be accounted for entirely by bathymetric and water volume variations. Consequently, as suggested by previous studies, geoacoustic variations must be responsible for significant portions of the variability.

A procedure for the generation of sediment sound speeds and attenuations has been developed [1], and we employ it here to investigate effects of sediment properties on TL. Sediment type, grain size, and layer thickness information, in conjunction with standard penetration test blow count values, are used to produce frequency-dependent compressional and shear sound speeds and attenuations and density profiles for 23 cores from the AGS site.

Uncertainties in the grain size characterization of sandy sediments can greatly affect both sound speed and attenuation profiles, with a larger sand grain size corresponding to both faster sound speeds and greater attenuations. The sound speed profiles for any specific core show little change with frequency over the spectrum of 75-1000 Hz. However, over the same frequency interval, the attenuations can vary significantly in sandy sediments but remain essentially constant in clayey sediments. For any particular selection of grain sizes, 23 core geoacoustic profiles are prepared. In order to accommodate large-scale range dependence, we employ an interpolation procedure based on empirical orthogonal functions [2] to produce geoacoustic input profiles for propagation codes for both fluid and elastic sediments. Representations of the propagation environment are obtained over eight tracks in the AGS region where broadband TL data is available.

Transmission loss versus frequency is calculated over the 75-1000 Hz spectrum for all eight tracks at 5 Hz increments using the RAM and RAMS PE models. Sediment properties such as layer grain size, thickness, and depth are adjusted until closest agreement between data and simulations is attained for all 8 tracks. The bold curve of Fig. 1(a) depicts the TL versus frequency for one of these tracks. Thin curves show data obtained from shots conducted along the track. Very close agreement is shown between the patterns of the computed results and the data. Uncertainty in TL due to range variability is demonstrated in Fig. 1(b). The bold curve depicts the mean of transmission losses calculated at locations within 15 meters of the range in Fig. 1(a), this interval being used because of shot range variability. The dotted curve represents the first standard deviation band about the mean. The mean captures the general features of the TL data, and the first standard deviation bands generally envelop the data.

STOCHASTIC UNCERTAINTIES

We seek to determine statistics of broadband signal TL fluctuations in terms of geoacoustic variability. We employ a stochastic procedure that efficiently incorporates smaller-scale variabilities in the core profiles for use in propagation modeling. Modifying the procedure of [3], we randomly perturb each core shear modulus profile according to different vertical correlation lengths. From the perturbed shear modulus profiles, we obtain the five geoacoustic parameters across the frequency spectrum of interest, giving the environmental parameters along any track. Examples of TL calculations from RAM, for 15 realizations of 1.5 meter vertical correlation length, are plotted as dotted curves against the shot data in Fig. 1(c). The results portray a strong similarity between the shot data and the realizations. The bold
FIGURE 1. Transmission loss versus frequency along Track 7 at depth 5 m showing comparisons between data and simulations. Thin curves are processed data from shots; bold curves are calculated results (Fig. 1(a)) or the means of calculations (Figs. 1(b), (d)); dotted curves are standard deviations (Figs. 1(b), (d)) or realizations (Fig. 1(c)).

The curve in Fig. 1(d) is the mean of the 15 realizations in Fig. 1(c) at each of the ranges in Fig. 1(b), and the dotted curves represent the first standard deviation band about the mean. The mean curve tracks the general TL features suggested by the data, and the smoothing is attributable to the TL fluctuations resulting from the geoacoustic and range uncertainties. The standard deviation bands in Fig. 1(d) encompass the shot data nearly everywhere except at the deep fades, and these bands are wider and smoother than those in Fig. 1(b) due to range uncertainties alone.

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