

SHALLOW WATER INVERSION BASED ON THE VERTICAL COHERENCE OF THE AMBIENT NOISE FIELD

Francine Desharnais and David M.F. Chapman

Defence Research Establishment Atlantic, P.O. Box 1012, Dartmouth, Nova Scotia, Canada, B2Y 3Z7

Past studies have shown how the spatial structure of the underwater ambient noise field can be linked to the acoustic properties of the ocean bottom. For example, Buckingham and Jones¹ have devised a way to estimate the compressional sound speed of the surficial sediment from the structure of the vertical directionality of the underwater noise field. Similar information can be obtained using the vertical noise coherence pattern.

This paper will present vertical coherence estimates from a shallow water model². The model derives the noise intensity within the ocean from wind and wave noise sources, which are modelled as a distribution of dipole sources at the ocean surface. The coherence between two vertically separated sensors is obtained with a Fourier transform of the noise intensity as a function of vertical angle. The model uses the bottom reflectivity equations of Brekhovskikh³ for a layered bottom. The ocean has an isovelocity profile.

The purpose of the study is to determine which ocean bottom parameters have a greater effect on the vertical noise coherence. For example, Fig. 1 shows the variation in reflection loss (as a function of grazing angle) for different bottom types. Bottom type A (solid line) represents a sand bottom typical of the Western Bank area south of Nova Scotia [compressional speed = 1650 m/s, shear speed = 260 m/s, compressional attenuation = 0.46 dB/ λ , shear attenuation = 1.3 dB/ λ , density = 1.8 g/cm³]. The type B bottom (dashed line) is the underlying tertiary bedrock [compressional speed = 2000 m/s, shear speed = 800 m/s, compressional attenuation = 0.08 dB/ λ , shear attenuation = 2.7 dB/ λ , density = 2.2 g/cm³]; type C (included for comparisons) is the same bottom as B, but with zero shear speed (long dashed line). All three bottoms were considered as half-spaces to produce Fig. 1.

The effect of the reflection loss on the vertical coherence pattern (real and imaginary part) is seen in Fig. 2 (the imaginary part is offset by -1). The line types are matched to those of Fig. 1. The coherence is plotted as a function of kd , where k is the wave number and d is the separation between sensors. The real part of the coherence is linked to the symmetrical component of the noise field, while the imaginary part is an indicator of large asymmetry in the vertical energy flux.

The effect of a change in compressional sound speed is seen by comparing the curves for bottom types A and C, for which the shear speeds are low. Since the harder bottom has a higher critical angle, the acoustic energy will be distributed over a wider range of angles in the vertical. At low shear speed, the imaginary part of the coherence is small, and the real part will decorrelate more quickly (over a shorter vertical distance) with a hard bottom.

The effect of the shear speed is seen by comparing the bottom types B and C. The difference is greatest over a specific range of low grazing angles (see Fig. 1). Over this range, part of the energy is converted from p-wave to s-wave, and the reflection loss gets stronger. This loss translates to a higher imaginary part of the coherence, and the real part decreases more quickly with vertical distance (or higher kd).

Changes in compressional or shear speed can have a strong effect on the vertical coherence pattern. Changes in attenuation, not shown here, have a much smaller impact on the coherence. The presence of layers in the bottom introduces a frequency dependence in the reflection loss and coherence patterns.

Some experimental data will be presented at the conference. It will be shown how the modelled coherence can be matched to the data to infer bottom structure.

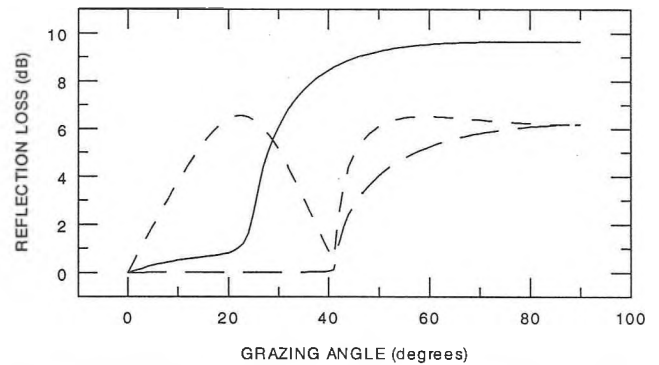


Figure 1 Reflection loss versus grazing angle for bottom type A (—), B (---), C (— — —).

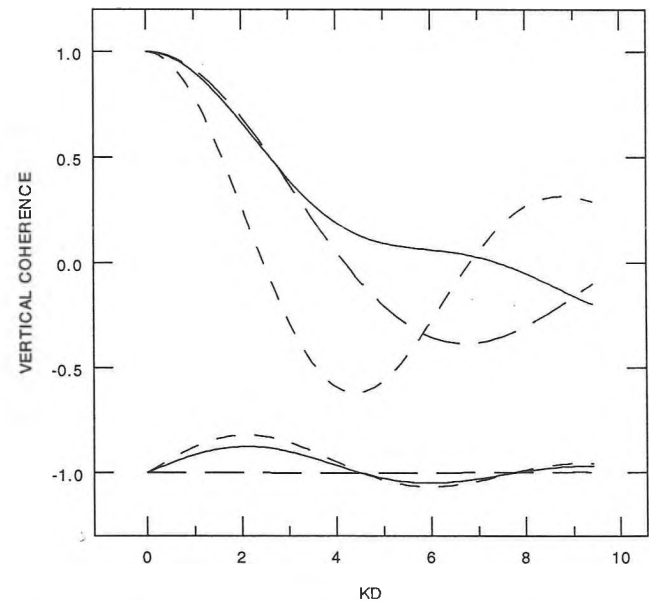


Figure 2 Real part and imaginary part (offset by -1) of the vertical coherence for bottom type A (—), B (---), C (— — —).

¹ M.J. Buckingham and S.A.S. Jones, "A new shallow-ocean technique for determining the critical angle of the seabed from the vertical directionality of the ambient noise in the water column," J. Acoust. Soc. Am. **81**, 938-946 (1987).

² D.M.F. Chapman, "Surface-generated noise in shallow water: a model", Proc. Inst. of Acoust. **9**(4), 1-11 (1987).

³ L.M. Brekhovskikh, Waves in Layered Media, 2nd edition, Academic Press, London (1980).