THE EFFECT OF THE OCEAN BOTTOM ON SOUND PROPAGATION IN SHALLOW WATER

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ABSTRACT

The influence of various bottom parameters on propagation has been assessed through a parametric study carried out with an acoustic model based on normal-mode theory.

INTRODUCTION

For acoustic modelling in shallow water, the lack of information about the ocean bottom normally constitutes the major obstacle against obtaining reliable propagation predictions. Often, the only information available about the bottom in a given area is a rough classification of the uppermost layer in terms of sand, silt, clay, mud, etc. A reliable prediction can, however, be obtained in these cases provided that a careful consultation of the literature is done before assigning values to the various parameters. However, some pre-knowledge about the relative importance of various bottom parameters and about the acoustic penetration into the bottom certainly eases the task of providing reliable propagation predictions in cases of limited bottom knowledge.

This paper attempts, through a parametric study, to give a general picture of the effects of various bottom parameters on propagation in shallow water. The theoretical tool employed is a well-tested, normal-mode propagation model that allows for a realistic treatment of the ocean environment (Fig. 1).

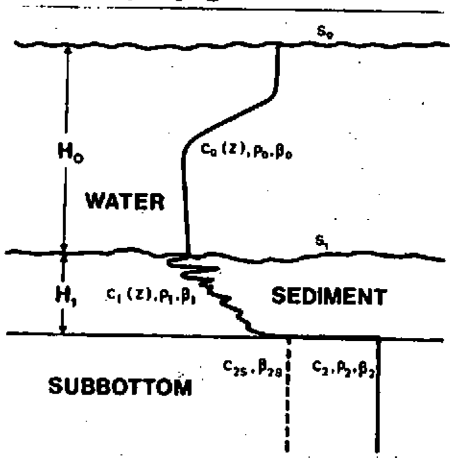

Fig. 1 Environment handled by normal-mode model

The environment is divided into three layers: a water column of depth H_0, a sediment layer of thickness H_1, and a semi-infinite subbottom. In the water the sound speed $c_0(z)$ is allowed to vary arbitrarily with depth, while density ρ_0 and volume attenuation β_0 are taken to be constant over depth. The sediment layer is treated in exactly the same way — an arbitrary sound-speed profile $c_1(z)$, a constant density ρ_1, and a constant volume attenuation β_1. The subbottom, on the other hand, is treated as a solid with depth-independent properties: c_{2S} is the shear speed and β_{2S} the shear attenuation; c_2 is the compressional speed, ρ_2 the density, and β_2 the compressional attenuation.

1 RELATIVE IMPORTANCE OF SOME BOTTOM PARAMETERS

First consider a fluid bottom, which means that the acoustic properties of the bottom are fully specified by the following three parameters: sound speed (c), attenuation coefficient (β), and density (ρ). By limiting ourselves to unconsolidated sedimentary bottoms, these parameters may, according to [1] take the following values: $c_B/c_W = 0.98-1.20$, $\beta_B = 0-1$ dB/λ, $\rho_B/\rho_W = 1-2$, where B stands for bottom and W for water. The unit dB/λ means dB per wavelength. By using this unit we are implying that the attenuation in dB/m increases linearly with frequency [1].

To show examples of extreme but realistic propagation conditions, the parametric study includes both a winter and a summer profile. Furthermore, two bottom types are considered (Fig. 2): 1) A soft bottom (S), where a sediment layer with a lower speed than the water is followed by a harder subbottom. 2) A hard bottom (H), where the sediment layer has the same properties as the subbottom. Propagation loss versus range was calculated for a broad range of frequencies, but to illustrate the main conclusions only results for 100 Hz will be shown here (Fig. 3).

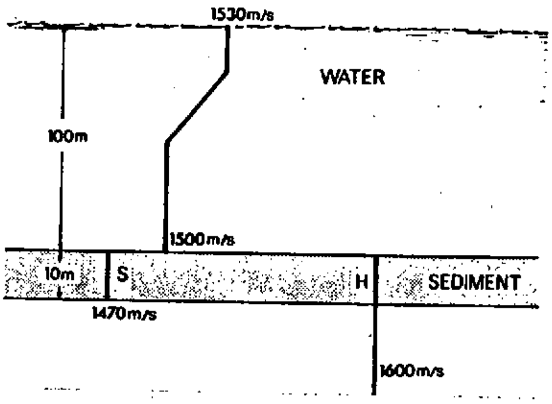

Fig. 2 Environment to study the relative importance of some bottom parameters

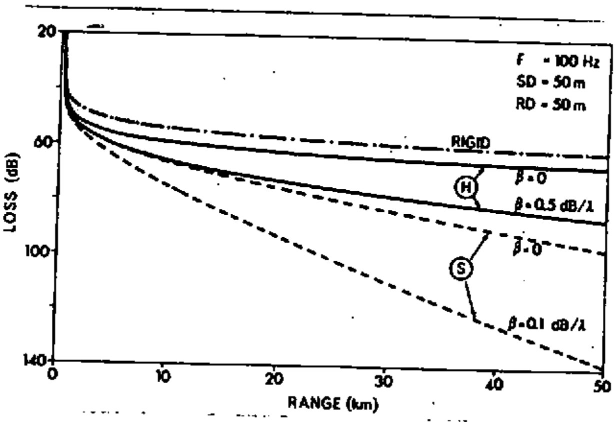

Fig. 3 Computed loss curves for different bottoms

For the hard bottom a density ratio of $\rho_B/\rho_W=2$ was chosen, and β_B was allowed to vary between 0 and 0.5 dB/λ. The parameters for the low-speed sediment layer were $\rho_B/\rho_W=1.5$ and $\beta_B=0-0.1$ dB/λ. Here the upper limit for β has been chosen as a realistic upper value for low-speed sediments (mud). As seen from Fig. 3, a change in speed from lowest to highest value gives rise to a much larger change in loss than does a change in β. Thus, for the 100 Hz case, a change in speed from lowest to highest value causes a change in loss of the order of 60-80 dB at a range of 50 km. On the other hand, by changing β from lowest to highest value the loss changes only 20-40 dB. The reason for the drastic change in propagation loss by changing the speed is that a low-speed sediment layer acts as a propagation channel that extracts energy from the water column. Finally, picking average values for c_B and β_B, and changing the density (not shown in Fig. 3), the change in loss is maximum 10-20 dB.

Comparing the above numbers, indicates that the bottom sound speed is clearly the most important bottom parameter. It is especially important whether the speed is higher or lower than the water speed. If c_B is lower, it is very important to know the thickness of the low-speed layer, as will be seen later. We see that the attenuation coefficient is more important than the density. Unfortunately, β is the most difficult parameter to assess and attenuation is therefore often neglected and β put equal to zero — a fact that most certainly leads to unacceptable prediction errors.

2 EFFECTS OF SHEAR WAVES

To assess the influence of shear waves on bottom losses we start by investigating the reflection coefficient at the interface between two homogeneous, semi-infinite media. With the compressional speeds (c_W and c_B) given in Fig. 4, the critical angle is 20.4°. Since energy propagating in a shallow water channel is associated mainly with bottom grazing angles less than the critical, we need only investigate the reflection coefficient between 0 and 20°.

Considering the bottom as a solid, three loss mechanisms exist: Excitation of shear waves (c_S), attenuation of compressional waves (β_C), and attenuation of shear waves (β_S). For a grazing angle of 10°, the influence of