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INVESTIGATION OF INFLUENCE OF RANGE DEPENDENT LAYERED BOTTOM ON PROPAGATION LOSSES IN THE SHALLOW WATER

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Experimental investigations and results on numerical modeling has shown, that simplified bottom models can't give adequate description of range-frequency dependence of acoustic field in the shallow water. In this report bottom structure and bottom parameters influence on range-frequency propagation losses was analyzed. Relation between optimal propagation frequency and parameters of layered bottom in the shallow water was investigated. Influence of range dependent layered bottom on propagation losses in the shallow water and on optimal propagation frequency were analyzed. It was shown that variability of bottom properties along path of sound propagation lead to modification of frequency dependence of propagation losses. Possibility of reconstruction of range-dependent bottom characteristics by frequency range-frequency dependence of propagation losses in shallow water was analyzed.

The evaluation of geoacoustic seafloor parameters with the use of acoustical data is an important problem with numerous applications in geophysics, oceanology, geology, and seismology. Parameters necessary for acoustical applications are the marine sediment density, sediment thickness, longitudinal and transverse velocities of sound, and loss coefficients of longitudinal and transverse waves. These parameters describe the layered seafloor and represent the necessary inputs for the solution of problems of direct underwater sound propagation. The effect of seafloor on the formation of an acoustic field is comparable with that of the stratification of the water column and the sea surface. In a shallow sea, this effect is most significant. As a rule, the seafloor model is selected in accordance with the problems to be solved during the investigation and the available software. The choice of bottom model is also influenced by the frequency range studied.

It is hard task to use geophysical bottom models for interpreting experimental data because of the difficulties associated with acoustic field calculations and the absence of detail data about the bottom characteristics in the region of interest. Sea sediments are noticeably inhomogeneous in their structure: different types of silt change one another in the horizontal plane. Parameters inside each sedimentary layer are either invariable or vary rather smoothly.

Accordingly, the model should be simplified so that with smaller number of parameters affecting sound propagation one could obtain a good fit of experimental and calculated acoustic fields. Therefore, we adopt the model with one liquid absorbing layer overlaying an elastic absorbing half-space.

In waveguides with a bottom formed by series of liquid absorbing layers with longitudinal sound velocity gradients in each layer overlying an elastic absorbing half-space, the acoustic fields were calculated with original program numerically realizing the method of adiabatic modes.

For a bottom model in the form of liquid sedimentary layer overlaying an elastic half-space we studied the effect of bottom characteristics and the sound velocity profile on the space-frequency dependence of losses in a shallow sea.

Calculations indicate a substantial influence of the layer of sediments on par with the elastic underlying half-space, on the acoustic field intensity. The layered bottom model is advantageous in predicting the variation of the optimal frequencies of sound propagation with the properties of sedimentary material and seasonal variation of the sound velocity profile. In order to study the effect of the characteristics of sediments and seasonal variation of sound velocity profile on the propagation of sound, we calculate the effect of losses on the propagation of sound in wide frequency range.

The calculations were conducted for a r=70 km long waveguide with depth H=200 m. The sound velocity profile corresponded to the summer period characterized by the strongest interaction of sound with the bottom. We calculate the losses for sound propagated in two trace with different sedimentary layers of depth d=20 m in the form of sandy silt or silty clay overlying the same elastic sandy half-space. Small-scale interference modulation of the intensity was smoothed by spatial averaging of the propagation losses. The results of these calculations are represented as equal loss lines on the frequency-range plane. A comparison of the propagation losses along these two tracks revealed a correlation between the type of sedimentary rock and the optimal sound propagation frequency in the shallow sea. For the layer of sandy silt, the optimal frequency was F_o=110 Hz (Fig.1 a), and for the layer of silty clay, F_o=60 Hz (Fig.1 b).

a) b)

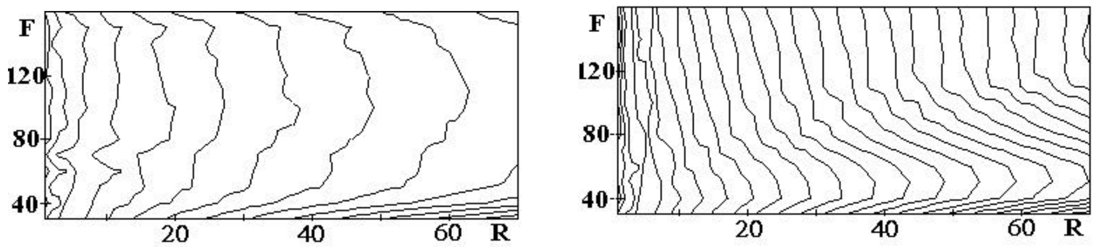

Fig. 1. Lines of equal propagation losses: a) layer of sandy silt overlying silty sand; b) layer of silty clay overlying silty sand.

Similar calculations for the same types of sedimentary rocks but under different hydrological conditions corresponding to the winter period also revealed an optimal frequency (F_o=80 Hz) that is weakly dependent on the type of sediment rock. This fact is associated with the presence of the winter subsurface channel that reduced the effect of the bottom on the optimal propagation frequency.

In waveguide sounding by monochromatic signals, as a criterion of the efficiency of bottom characteristic reconstruction, one can often uses the goodness of fit of the spatial dependence of measured losses with the results of numerical experiments. In [1] was suggested analyzing the space-frequency dependence of sound attenuation near an optimal propagation frequency to improve the reliability of bottom reconstruction and obtain a transparent proof of how efficiently a wide-band acoustic field can be described with the selected bottom model.

Numerical experiments indicates that the optimal propagation frequency in a shallow sea is a sensitive parameter that may be used as a criterion defining the efficiency of bottom structure modeling. In this respect, a goodness of fit of the optimal frequencies is the measure of “correlation” between the chosen and real acoustic model of the bottom. It should be noted that the sensitivity of this parameter to changes in the characteristics of sedimentary layer is rather high.

Although there seems to be no a one to one correspondence between the optimal frequency and a set of bottom parameters, with available data about the type of specimens in the region of interest, one can correct these data using the optimal frequency as a criterion of the goodness of fit of the model considered to real conditions. Thus to develop an acoustical bottom model in some frequency band one needs to invoke the geophysical data. With the successive chouse of bottom parameters, it is possibility to adequately describe the transmission of sound in a shallow sea in a wide frequency band close to the optimum frequency of sound propagation in the waveguide. The last circumstance is of the importance in solving tomography problems in a shallow sea.

Possibility of optimal propagation frequency use as a criterion of the goodness of fit of the model considered to real conditions was demonstrated on real experimental data [1]. Numerical modeling of range-frequency dependences of losses along with the geophysical information about the bottom type were used to select those bottom acoustic characteristics which provide the best agreement of the experimental measurements and the results of numerical analysis.

In recent time the problem of bottom parameters reconstruction in the range dependent waveguides became actual. Let us analyze influence of variability of bottom characteristics along the trace on space-frequency dependence of propagation losses and on optimal propagation frequency. Large number of bottom parameters which have influence on sound propagation complicate this analysis. Therefore we will only consider influence of sediment thickness on sound propagation in shallow sea. The results of numerical calculation of lines of equal transmission losses for two homogeneous waveguides with different sediment thickness shown in Fig.2.

a) b)

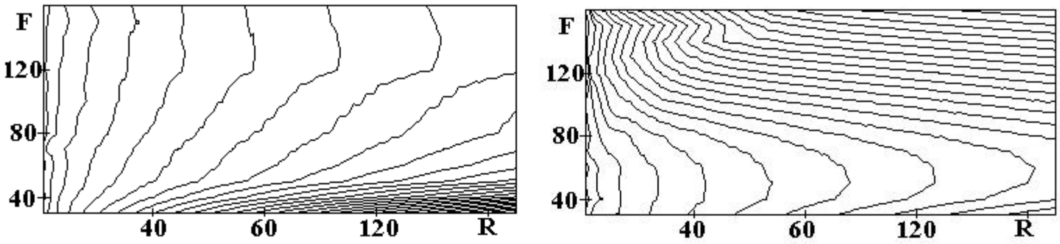

Fig. 2. Lines of equal propagation losses for layer of sandy silt overlying silty sand: a) d=10 m; b) d=40 m.

A comparison of the transmission losses for these two waveguides revealed essential influence of sediment thickness on optimal propagation frequency. For the sediment thickness d=10 m optimal propagation frequency is about 140 Hz. For the sediment thickness d=40 m optimal propagation frequency is about 60 Hz. We will use this strong frequency dependence of losses for qualitative valuation of possibility of range-dependent bottom parameters reconstruction. Let consider shallow water waveguide with sediment thickness varying from 10 m to 40 m. There are two different situations: sediment thickness under source d=10m, and sediment thickness under source d=40 m. The results of calculations are shown in the Fig.3. Fig.3 a indicates that optimal propagation frequency decreased with range from the source increased and with increasing sediment thickness. In this case we may make approximate conclusions about sediment thickness by optimal propagation frequency. Comparison between Fig.2b and Fig.3a shows that changes in optimal propagation frequency fall off from changes of sediment properties. Situation became essentially different if trace direction is changed (Fig.3 b) and sediment thickness decreased with range. In this case strong frequency dependence of losses formed on initial trace section can't be essentially modified despite of sound propagation conditions changed. Although one may note smooth increasing of optimal propagation frequency

a) b)

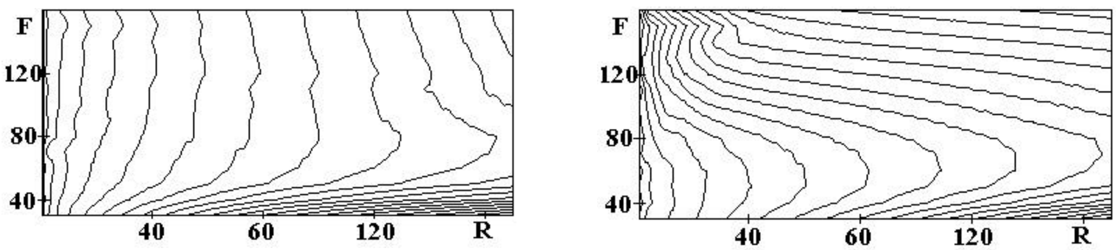

Fig.3. Lines of equal propagation losses for inhomogeneous waveguide:
a) sediment thickness increased along trace; b) sediment thickness decreased along trace.

along the trace, it remain behind from optimal frequency determined by local sediment properties. Comparison between Fig.3a and Fig.3b shows that local sediments properties determine modification in frequency dependencies of losses. Thus one may conclude that bottom parameters reconstruction in range dependent waveguides by frequency dependence of losses is possible. In this connection not optimal propagation frequency at fixed distance, but changes in frequency dependence of losses along the trace, must be taken into account. This work was partially supported by RFBR (№97-05-64712, №00-05-64956).

REFERENCES

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