ACOUSTICS OF UNDERWATER SEDIMENTS

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LONG-TERM GOALS

The long-term goal of this research is to understand environmental effects on acoustic propagation to and scattering from a known object buried in the ocean bottom.

OBJECTIVES

Acoustic transmission into sediment at grazing angles shallower than critical is not well understood. In this regard, anomalous effects reported in the acoustics literature have received increasing attention lately. While work by researchers at the Applied Research Laboratory at the University of Texas [1] (ARL/UT) as well as at the Coastal Systems Station [2] (CSS) have confirmed the observation of unexpectedly high acoustic penetration at shallow grazing angles, the mechanism of the transmission is still unknown. So far, two mechanisms are being seriously considered by researchers: mode conversion into a Biot slow wave as suggested by ARL/UT and diffraction by small-scale roughness at the water/sediment interface as suggested by researchers at the Applied Physics Laboratory at the University of Washington [3] (APL/UW). The work described here has three goals: (1) to test the mechanism proposed by APL/UW in a controlled fashion; (2) to assess the temporal and spatial coherence of a signal transmitted through small-scale random roughness; and (3) to develop and test a theoretical model capable of predicting the effects of the roughness on the scattering response by a buried object.

APPROACH

The work summarized here represents the first year in a new effort to isolate and understand anomalous scattering effects at a rough interface using theoretical and experimental tools. The approach taken theoretically involved developing a scattering solution for a target buried in a layered fluid environment, including the effects due to surface roughness in an average fashion. This was done by incorporating a stochastic description of the rough surface based on Rayleigh-Rice perturbation theory [4] into transition-matrix scattering models developed in previous years at CSS. By ensemble

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averaging, the combined formulation yields expressions for both the "coherent" and "incoherent" components of the field scattered by a buried spherical target.

The laboratory experiments planned utilize an acoustic source mounted onto a movable platform that is fixed over a tank containing several hydrophones and two immiscible fluids. Roughness effects on propagation across the interface would be determined by floating beads at the interface between these fluids and detecting the field transmitted to an array placed in the bottom layer. The transmitted field would be analyzed with processing algorithms like those used by ARL/UT so that comparisons with their results could be made. The effect that roughness has on scattering by a buried object will be studied by suspending a target in the lower fluid.

WORK COMPLETED

A scattering solution for a sphere under a rough interface has been formulated for the average coherent field assuming a harmonic plane wave is incident from the fluid halfspace above. The solution is perturbative in the average roughness height and a FORTRAN program has been written to exercise the solution, including terms that are second order in the roughness height except when they are associated with rescattering effects. A solution for the average incoherent field has also been worked out but, because this solution is much more cumbersome, only the terms needed to study backscatter at shallow grazing angles have been incorporated into a FORTRAN program.

In regard to the proposed tank experiments, a laboratory scale measurement has been designed and set up in FY97. The set-up is depicted in Figure 1. A 4'x4'x7' tank with an overhead track for mounting a 100-150kHz source transducer was constructed. To mimic effects at a water/sediment boundary, vegetable oil and glycerin were chosen to fill the tank. Polystyrene beads of various sizes, which have a density intermediate between the two fluids, have been purchased and will be floated at the interface of the two fluids to produce a rough random surface for the diffraction experiments. To avoid reverberation problems when data are collected, processing software reproducing the algorithms used by ARL/UT was written and used to test and optimize hydrophone placement in the lower layer.

RESULTS

Figure 2 shows some results from the scattering solutions formulated over the past year for scattering a harmonic plane wave from an 11% thick spherical steel shell buried by 1.5a below a rough fluid-sediment interface. Here, a, the outer shell radius, is assumed to be 0.25m, the thickness is specified as a percentage of a, and the depth is measured from the median level of the interface to the center of the sphere. Two average roughness scales are considered, assuming Gaussian statistics: 1mm and 1.2cm root-mean-squared surface height. Both the predicted coherent and incoherent intensities are plotted over the flat interface result as a function of the scaled wavenumber of water, k.

Several notable features are displayed in these results at both roughness scales. As expected, roughness-induced departures from the flat interface calculation increase with frequency with the departures being greater and starting at lower frequencies with greater surface roughness. However, the backscattered intensity can exhibit a substantial enhancement even when the wavelength is an order of magnitude larger than the average roughness. Furthermore, it is interesting that the coherent part of the backscattered intensity also displays enhancement compared to the flat interface intensity. This contribution to the coherent field arises from the part of the field scattered by surface roughness down to the shell that follows a reversed path back to the source after scattering from the shell.

IMPACT/APPLICATIONS

In line with the desire to operate safely in littoral regions, the Navy requires an ability to quickly detect and classify underwater objects in order to avoid or clear mines. Although sonar has been used for this purpose for many years, it is still limited in its capabilities against bottom objects, especially if they are buried. This work will aid the development and optimization of bottom searching sonar for meeting the Navy's coastal missions, including mine-countermeasures, environmental reconnaissance/surveillance, and ordnance disposal.

RELATED PROJECTS

The present project was leveraged in FY97 by funding from the ONR Navy Laboratory Participation Program, the CSS Independent Research Program, and ONR's SPECWAR Program.

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