

NUMERICAL STUDIES OF ROUGH SURFACE SCATTERING MODELS

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Shallow-Water Acoustics

LONG-TERM GOALS

To understand the effects of the rough air-sea interface and ocean bottom on acoustic propagation.

OBJECTIVES

To develop and study existing approximate theoretical models for rough surface scattering. In particular, to ascertain their applicability and potential usefulness in practical models of acoustic propagation and scattering.

APPROACH

Our primary focus has been on the small slope approximation (SSA) which we have studied for a number of different problems, including acoustic scattering from the air-sea interface and from the ocean bottom. Recently, we have also begun an investigation of the nonlocal SSA (NLSSA) which is an extension of the SSA. Finally, we have been developing a Monte Carlo Finite-Difference Time-Domain (FDTD) technique for scattering from both the rough ocean surface and bottom. This "exact" technique can be used to benchmark approximate theoretical models for rough surface scattering and to study the effects of surface roughness on a propagating signal.

WORK COMPLETED

The second part of a study of the SSA was published in JASA in May 1997 [1]. It presented a detailed numerical study of the SSA for 2-D, Dirichlet surfaces with Gaussian statistics and a Gaussian roughness spectrum. Our initial study of the NLSSA has included derivation of the lowest-order scattering cross section and calculation of several examples for 2-D, Dirichlet surfaces with Gaussian statistics and a Gaussian roughness spectrum [2],[3]. Development of the FDTD method, done in collaboration with John Schneider, has resulted in an improved absorbing boundary condition for elastic wave problems [4] and Monte Carlo FDTD algorithms for scattering from pressure-release surfaces [5],[6] and from fluid-fluid interfaces [7].

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RESULTS

Our study of the SSA indicates that it may be a good replacement for small perturbation theory and the Kirchhoff approximation (KA) in many practical models. While the higher order SSA is too computationally costly, the lowest-order involves the same integral as does the KA; yet it is much more accurate at low forward grazing angles than the KA and no worse than lowest-order perturbation theory in the backscatter region, which does fairly well for power-law type spectra.

It is still too soon to draw conclusions about the NLSSA, but preliminary results are promising. Finally, the Monte Carlo FDTD algorithm results compare well with integral equation results found by Eric Thorsos. Thus, the technique can be extended to problems of greater complexity, beyond the limits of integral equation techniques, with some confidence in the results.

IMPACT/APPLICATIONS

The development of approximate models that accurately predict wave scattering from rough surfaces is important in a number of Navy applications. For example, rough surface scattering models are needed in the simulations used by torpedo guidance and control personnel to test torpedoes. Another application for which rough surface scattering is critical is the detection of underwater mines, especially those buried in soft sediments. Other applications include ship wake detection, communications, and anti-submarine warfare.

TRANSITIONS

Partly as a result of our work, Voronovich was motivated to develop the NLSSA, which introduces nonlocal effects into the same ansatz used to develop the SSA. Also, Darrell Jackson is trying to incorporate the SSA into his high frequency models for penetrable ocean bottoms. Finally, our acoustic animations of wave propagation in a shallow-water waveguide are available via the Web, and videos of these and other animations have been provided to ONR.

RELATED PROJECTS

This research is related to projects in propagation in a shallow-water waveguide such as the work of David Berman and the work of John Schneider, in high-frequency bottom scattering modeling such as the work of Darrell Jackson, in long range propagation, and in rough surface scattering such as the work of Eric Thorsos.

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