Coupled Mode Problems for Bottom Interacting Sound and Coupled Mode Problems for Bottom Interacting Sound: Student Support (Assert)

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LONG-TERM GOALS

The long-term goal of this research is to improve our ability to model and predict VLF acoustic propagation in shallow water with particular emphasis on the range dependence of the medium and the geoacoustic properties of the bottom, and to quantify the various factors affecting the overall acoustic energy budget in shallow water propagation.

OBJECTIVE

Our scientific objectives are to incorporate the effects of sediment anisotropy, strong sediment attenuation, and the effects of both deterministic and stochastic medium properties into a local coupled mode propagation model, and to develop accurate theory and robust numerical algorithms for the shallow water propagation problem.

APPROACH

We are using an approach based on coupled local modes to carry out a systematic study of the effects of scattering, normal dispersion, anisotropy and intrinsic attenuation on a propagating shallow water acoustic signal with strong bottom interaction. The coupled mode theory is developed from the first order equations of motion for the stress and displacement rather than from the second order equations for a velocity or displacement potential. The later approach introduces coupling coefficients depending on the second-order derivatives with respect to the range coordinate of the local mode functions. These second-order coupling coefficients are an artifact of the formulation, and not present in the coupled mode theory based on the first order equations of motion.

WORK COMPLETED

We have investigated suppression of acoustic pulse broadening in shallow water waveguides with random heterogeneities due to mode diffusion. We completed modification of the general anisotropic elastic mode code of Park (1996) to include a layered ocean on the surface. This permits us to model a very general shallow water waveguide with anisotropic sediment layers of arbitrary symmetry axis orientation. This modified mode code has been fully integrated into our coupled mode code. Darin

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Soukup, supported by the AASERT, passed his General Exam, and has been admitted to candidacy for the Ph.D. in Geophysics. We completed assembly of a six node Beowulf parallel computer system, which will be used for our coupled mode computations. Two papers were completed and appeared in refereed journals (Park and Odom, 1998; Park and Odom, 1999).

RESULTS

An acoustic signal propagating in a range dependent shallow water waveguide is scattered and attenuated as a result of interaction with medium heterogeneities. An initial signal pulse consisting of a few modes will spread in time linearly with propagation distance as energy is redistributed among available modes due to mode coupling. Over longer propagation distances in a random waveguide, modal energy reaches equilibrium , and the average modal energy becomes constant. (The modes are of course subject to geometric spreading, attenuation and radiation losses, but it is assumed that all modes are equally affected so that locally, the energy per mode is a constant.) Energy propagates at a velocity that is an average of the group velocity for the individual modes. The pulse width grows more slowly now as the square root of the propagation distance, rather than linearly. This transition to square root broadening in randomly perturbed multi-mode fiber optic waveguides is well known and observed. Stronger coupling leads to a narrower equilibrium pulse width (EPW). Computations for a realistic shallow water waveguide indicate that the EPW for a signal propagating over a bottom with a 1^o slope is approximately ten times that of the EPW for signal propagating over a bottom with a 5^o slope. The way to measure weather the pulse spreading is being suppressed by mode diffusion is to plot the pulse width vs. propagation distance for a completely incoherent signal.

Computing modes in layered anisotropic elastic media is problematic due to degeneracy between the SH and SV components in the sediments for certain symmetry axis angles. Writing such codes is time consuming and fraught with pitfalls. We have adapted the anisotropic mode code of Park (1996) for use in a shallow water environment. The code is efficient and utterly stable. Where we were forced to use quadruple precision on a Sun SPARCstation with our previous mode code, we are now able to use double precision even for models with very low sediment shear speeds. This is a tremendous improvement. Where with our former code we had difficulty computing the modes for certain models at 20 Hz, we are now able to go as high as 100 Hz with no loss of accuracy. We are now really limited only by the ultimate size of the mode set. Park’s (1996) original code was for elastic layers only. Adding the capability to include fluid layers to model the ocean was a non-trivial modification requiring careful coding. We have compared the results with our existing code to ensure that coding was properly done and that we had correctly incorporated it into our coupled mode code. We are in the process of porting our code to our new six node Beowulf parallel system.

IMPACT/APPLICATIONS

Continued development of the mode diffusion model of Odom and Mercer (1996) through inclusion of pulse spreading effects and development of a new efficient mode code suitable for shallow water modeling indicate steady progress towards meeting our scientific objectives. This research is directly applicable to predicting the effect of a complicated shallow water environment on the acoustic field.

TRANSITIONS

Modal methods for modeling in random range dependent shallow water waveguides should provide important constraints on the most significant waveguide properties affecting propagation at low frequencies.

RELATED PROJECTS

Our research is directly related to other programs studying surface, volume and bottom interaction effects, including 6.2 and 6.3 efforts to quantify bottom backscatter and bottom loss effects in littoral regions.

REFERENCES

Odom, R.I. and J.A. Mercer, "Spectral diffusion of elastic wave energy," *Geophys. J. Int.*, **127**, 111-124, 1996.

Park, J., "Surface waves in layered anisotropic structures," *Geophys. J. Int.*, **126**, 173-183, 1996.

PUBLICATIONS

Park, M. and R.I. Odom, "Effects of elastic heterogeneities and anisotropy on mode and coupling and signals in shallow water," *J. Acoust. Soc. Am*, **104**, 747-757, 1998.

Park M. and R.I. Odom, "The effects of stochastic rough interfaces on coupled-mode elastic waves," *Geophys. J. Int.*, **136**, 123-143, 1999.