Numerical Modeling of Acoustic Propagation
In a Variable Shallow Water Waveguide

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LONG-TERM GOALS

Random variability in shallow water will induce variability in a propagating acoustic field. The long-term goal of this research is to quantify how random variability in the ocean environment translates into random variability in the acoustic field and the associated signal processing algorithms. Particular emphasis is placed on the effects of time-varying shallow water internal waves.

OBJECTIVES

One objective under current support has been to describe the output from a horizontal array beamformer in terms of the waveguide invariant.

APPROACH

Theoretical predictions are first compared to numerical simulations and eventually to experimental data. In our current work, we have collaborated with Altan Turgut and investigators at the Naval Research Laboratory to use data from the ASIAEX experiment.

WORK COMPLETED

Under current support, the classic work on stochastic acoustic mode coupling developed by Dozier and Tappert [1978] was adapted for propagation through a realistic shallow water internal wave fields. Both the second- and fourth-moments of the acoustic mode amplitudes were calculated with the results presented at an Acoustical Society Meeting [Rouseff, 2003]. The method was also applied to study fluctuations in the so-called waveguide invariant. The waveguide invariant relates changes in acoustic intensity with range to changes with frequency [Brekhovskikh and Lysanov, 1991]. We previously showed how the waveguide invariant could be modeled as a distribution [Rouseff and Spindel, 2002]. Under current support, we used the Dozier-Tappert approach to relate the statistics of an internal wave field to the statistics of the waveguide invariant distribution [Rouseff, 2002].

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14. ABSTRACT

Random variability in shallow water will induce variability in a propagating acoustic field. The long-term goal of this research is to quantify how random variability in the ocean environment translates into random variability in the acoustic field and the associated signal processing algorithms. Particular emphasis is placed on the effects of time-varying shallow water internal waves.

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Also under current support we have related the output of a horizontal array beamformer to the waveguide invariant. Theoretical predictions were compared to numerical simulations and to data from the ASIAEX experiment [Rouseff and Turgut, 2003].

RESULTS

Figure 1 shows a synthetic LOFARgram. A LOFARgram displays the output of a beamformer in a particular look-direction as a function of time and frequency. In the calculation, a source moves along a track parallel to the horizontal array. The beamformer output exhibits the familiar "bathtub effect," a nested suite of seemingly parabolic striations. It is well known that the time when these parabolas are at a minimum corresponds to the closest point of approach (CPA) of the target. Superimposed on the figure are predictions made using a new formula derived under current support. Previous studies suggested that a numerical value for the waveguide invariant of 1.5 was appropriate for the summertime conditions used in the simulation. Good agreement is observed between the predicted striation pattern using 1.5 for the invariant and the numerical simulation. Using our formula, we were also able to predict the shape of the LOFARgram striations observed in the ASIAEX experiment. These results are significant because they connect the physics that produce the waveguide invariant effect to the output of a sonar system.

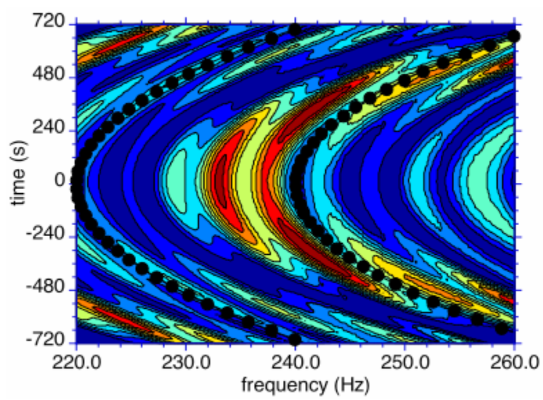

Figure 1. Synthetic LOFARgram. Output of the main beam in a conventional Bartlett beamformer plotted as a function of frequency and time as a source passes. Closest point of approach occurs at time equal zero. Water depth 70 m with typical summertime sound speed profile. Superimposed are predictions (circles connected by lines) made with waveguide invariant beta equal to 1.5.

IMPACT/APPLICATIONS

The concept of a waveguide invariant has enormous appeal. This parameter accounts for the dispersion properties of what could be a very complicated propagation environment. The present work has sought to relate this concept to the output of a beamformer.

RELATED PROJECTS

Various aspects of the waveguide invariant are being studied and applied by investigators at Scripps, MIT, NRL, Orincon and Neptune Sciences.

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