BOOK REVIEWS

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Experimental Acoustics Inversion Methods for Exploration of the Shallow Water Environment

A. Caiti, J.-P. Hermand, S. M. Jesus, and M. B. Porter (Editors)

Kluwer Academic Publishers, Netherlands, 2000.
293 pp. Price: $127.00 (hardcover), ISBN: 0792363051.

Shallow water acoustics, with the complexities caused by boundaries and variations in the water column, is a broad and fertile area for basic and applied research. The field has made exciting progress when theoretical work has met real data in shallow water environments. The greatest challenges may be inverse problems where the unknown and time-varying environments are estimated through acoustics signals as a means of remote sensing. Such inverse problems are, though complex, necessary because it is impossible to measure directly all relevant acoustic parameters in the vast spatial and temporal spaces of shallow waters. This title is truly welcome by anyone who has an interest in shallow water acoustics.

While shallow water acoustics inversion has been an area of active research, the subject is so diverse that no single book has been published to give a coherent treatment of its various subjects. Alternatively, this title provides a compilation of several interrelated subjects in the area under a single hardcover. It is a result of a workshop attended by about 20 researchers in the field, each covering their individual efforts relevant to the book title. Readers will find that actual shallow water conditions provide the focus for this publication, because all the papers are based on real data from shallow water regions.

The contents can be divided loosely into four subjects. They deal, respectively, with the effects of internal tides, source localization, effects of bottom vegetation, and inversion of sediment parameters.

The three papers concerned with the investigation of internal tides are all based on the same data sets, dealing with different aspects of the problem. Rodriguez *et al.* observes that in the presence of internal wave packets, propagation signals can occasionally experience a gain, possibly due to resonating effects. Their modeling of a particular internal wave packet and sound traveling through a packet is consistent with their assumption. To experimentally investigate such propagation gain effects as well as loss effects over range and frequency, it seems necessary to measure snapshots of internal wave fields.

Stephenan *et al.* report that variations observed in acoustic signals can be associated with different environmental effects. Specifically, they show that the influence of the bottom on their sound propagation data is sufficiently different from that of the internal tides so that simple, separate signal processing methods can be applied to deal with both problems.

Porter *et al.* bridge the subjects of internal tides and source localization. A notable feature here is that broadband signals over an extended period of time are used to investigate source tracking. The authors show that while narrow-band signals would have demonstrated large variations in arrival structures, broadband signals show stable arrival structure even in strong range-dependent scenarios. Also of interest is that fairly simple modeling, without considering all the complicated environmental variations, is shown to yield good tracking results.

On the subject of source tracking and localization, the paper by Ianniello and Tattersall analyzes experimental performance of a sophisticated multiline horizontal array system. Using simultaneously towed arrays at different depths, the authors report that both source range and depth can be determined using range-independent modeling. To achieve their results, they relied on the availability of good environmental data. Clearly, the range of applicability and the performance of such tracking arrays merit further study.

Two papers in the book cover acoustic interactions with vegetation on the sea bottom. Bozzano discusses the development and testing of a high-frequency backscatter system operating in the mega-Hz range. It also provides ample background and references on the subject of sea grass detection using high-frequency sonar. An interesting paper by Hermand *et al.* uses a simple experimental design to study sound propagation over sea grass. The goal of the investigation is to use sound as a remote sensing tool to monitor oxygen synthesis by sea grass. Contemporaneous measurements of temperature, sunlight, and CTD, as well as sound propagation, enable the authors to relate the abrupt and marked change in sound attenuation to the onset of photosynthesis in the sea grass. Furthermore, the authors are able to conclude that bubble layers formed from the photosynthesis are responsible for the sound attenuation and dispersion. Their work is an encouraging step forward to realizing the goal of using sound to monitor bubble concentration on the sea grass, hence providing a method to study photosynthesis of bottom vegetation.

The greatest number of papers in this collection concerns the inversion of sea bottom properties and parameters. Among all the uncertainties of the shallow water environment, the bottom is the more complex compared to the sea surface and the water column because of its diverse composition and the various processes controlling its variability. Therefore, it is not surprising that controversy continues concerning the appropriate governing equation used to describe the bottom as an acoustic medium. The theoretical paper by Buckingham argues for a viscous-fluid wave equation based on measured data showing that the sediment attenuation coefficient expressed in decibels has a linear relation to frequency. More details of the theory can be found in papers in the *Journal of the Acoustical Society of America*. Chotiros, however, argues for a poro-elastic model of sandy sediments. He discusses the sensitivity of reflection loss as a function of grazing angle and frequency to various Biot parameters within the poro-elastic model and concludes that there exists the possibility to invert for some of the Biot parameters, such as porosity and grain density, using measurements of reflection loss. The appropriate wave equation to describe the sea bottom is an area of intense interest; research continues and progress has been made on these questions since the publication of this book.

Several papers report the use of sound propagation in shallow water environments to invert for bottom parameters. The experimental techniques range from using a narrow band source combined with vertical line arrays, to broadband explosive sources, to drifting buoys. A common theme in all methods is to take advantage of the amplitude and phase information of the propagating field, combined with modeling of the forward field based on different approximations to the environment, to estimate certain bottom parameters. Chapman *et al.* use imploding light bulbs as sound sources and vertical line arrays to measure broadband propagation. Their inversion is based on matched field processing by applying ray tracing to short range data. It is encouraging to read that the researchers were able to use a relatively straightforward method to infer bottom properties.

Abawi *et al.* give a systematic comparison of several matched field processing methods based on a set of shallow water propagation data collected by a tilted line array from a towed narrow-band source. This investi-

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gation is timely and important in order to transition matched field research into applications.

Rogers *et al.* summarize many years of experimental study of the Yellow Sea. There have been several experiments in the same general area over a span of many years, representing a persistent effort to understand bottom properties in one particular shallow water environment. Of particular interest is the reported result on the nonlinear dependence of bottom attenuation coefficient expressed in decibels versus frequency. Clearly, in the frequency band below 1000 Hz, more investigation is needed on the frequency dependence of sediment sound speed and attenuation.

Hermand *et al.* report research on geoacoustic inversion with drifting buoys. Several types of drifting buoys are tested over different sediments. A controlled source is used to transmit to these buoys. The abilities of these buoys with large dynamic ranges are articulated. This reviewer wishes there were more space devoted to the details of their inversion methods and a discussion of the success or failure of the inversion.

The paper by Caiti and Bergem is an ambitious effort to invert for a large number of bottom parameters from normal incidence backscatter data using a parametric source. The inverted parameters include not only the mean properties of the bottom such as mean sound speed and density, but also parameters controlling interface roughness and subbottom heterogeneity. Normal incidence data are attractive because they can be obtained over long tracks. If reliable inversions can be obtained using normal incident data, towed systems, such as the reported parametric sonar or chirp sonar, will be able to provide a practical method to collect bottom parameters over long tracks or large areas. However, this paper can only be considered an initial effort toward that goal because it does not offer a convincing case for the validity of the inversion results. To demonstrate the validity of the inversion, it is important to (1) establish the soundness of the forward model for the environment concerned, (2) independently measure with adequate resolution environmental parameters, and (3) assess the accuracy and associated error analysis of the inversion technique. The authors have yet to achieve these goals. It should be emphasized that their work is in an important area where increased effort ought to be placed.

While this book is not an introductory text for students, it is a useful reference for scientists and engineers working in the field of shallow water acoustics; through it an appreciation of several important areas of active research is gained. Readers should be aware that because of the limited number of papers, the subjects covered are by no means exhaustive for the area of acoustic inversion methods in shallow water environments.

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