FUNDAMENTALS OF OCEAN ACOUSTICS

Third Edition

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L.M. Brekhovskikh
Yu.P. Lysanov
Moscow, Russia

With 120 Figures

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Preface to the Third Edition

This is the third edition of our book *Fundamentals of Ocean Acoustics*, revised and supplemented, including much new material responding to the progress in the theory of sound propagation and scattering in the ocean over the last 10 years. New topics are devoted mainly to such questions as the intrathermocline lenses and their effect on sound fields in the ocean, weakly divergent bundles of rays, ocean acoustic tomography, coupled modes, invariants of an interference pattern in a range-dependent oceanic waveguide, sound scattering by random highly anisotropic volume inhomogeneities (fluctuations of the refractive index of the sea medium) with a fractal spectrum, fractal nature of low-frequency attenuation in the underwater sound channel, small-slope approximation in treating sound scattering from the rough sea surface (Voronovich's approach), sound scattering by an air bubble near the sea surface, collective bubble behaviour, etc. Both the direct and inverse problems are considered. Some recent experimental data are also added. More than 60 new references are presented. Some new references and figures are preceded by the letter A.

The book is intended for experts in acoustics and oceanology, engineers, postgraduates, and students of universities and institutes of geophysical and hydrometeorological profiles. Thus, it can be used as a scientific monograph and textbook of advanced type.

The authors are grateful to T.I. Tsyplakova for her great help in preparing the manuscript.

Moscow, Russia
December 2001

L.M. Brekhovskikh
Yu.P. Lysanov

Preface to the Second Edition

The general structure of this second edition remains the same as the first. However, the reader will find some new material in almost every chapter, for example, Snell's law for a range-dependent environment, the hybrid ray-mode method, invariants of an interference pattern in the coordinates of range and frequency, new considerations concerning the parabolic equation method, peculiarities of the correlation function of the field scattered by a sea surface, the new phenomenon of fore-reverberation, etc. New references have also been added. Errata of the first edition have been corrected.

Moscow, Russia
October 1990

L.M. Brekhovskikh
Yu.P. Lysanov

Preface to the First Edition

The continents of our planet have already been exploited to a great extent. Therefore man is turning his sight to the vast spaciousness of the ocean whose resources—mineral, biological, energetic, and others—are just beginning to be used. The ocean is being intensively studied. Our notions about the dynamics of ocean waters and their role in forming the Earth's climate as well as about the structure of the ocean bottom have substantially changed during the last two decades.

An outstanding part in this accelerated exploration of the ocean is played by ocean acoustics. Only sound waves can propagate in water over large distances. Practically all kinds of telemetry, communication, location, and remote sensing of water masses and the ocean bottom use sound waves. Propagating over thousands of kilometres in the ocean, they bring information on earthquakes, eruptions of volcanoes, and distant storms. Projects using acoustical tomography systems for exploration of the ocean are presently being developed. Each of these systems will allow us to determine the three-dimensional structure of water masses in regions as large as millions of square kilometres.

The rapidly extending applications of ocean acoustics require a manual where the theory of sound propagation in the ocean in its most fundamental form is systematically and rather completely presented. The authors have tried to write such a book. After looking through its contents the reader can see that all the most significant aspects of the theory are presented in this book. These include a deterministic theory of the underwater sound channel whose characteristics either are constant or change with distance, the theory of anti-channel, shallow water, the problems of sound reflection from the bottom, and so on. The stochastic aspects of the theory are also presented rather completely for sound scattering at the random ocean surface and at the bottom, propagation in the presence of internal waves, turbulence, etc.

The authors are thoroughly convinced that theory cannot be developed without close connection with experiment. Hence, a book on theoretical underwater acoustics should also elucidate principal experimental data. On the other hand, mixing theory and experimental facts in the presentation is undesirable since theory is more "fundamental" and steady in time as compared with the rapidly changing

experimental background. Solving this contradiction, the authors preface the main theoretical chapters with a rather bulky first chapter where the most interesting experimental facts are presented and the main characteristics of the ocean as an acoustical medium are considered. If it were possible to revise the book continuously after its publication, then the first chapter would have to be rewritten every other year or so, while the principal content of the theoretical chapters would have to be changed approximately every ten years.

The book is intended for students, postgraduates, researchers, and practical workers dealing with ocean acoustics.

The authors are sincerely grateful to V.M. Kurtepov for his critical reading of the book, V.V. Vavilova who had the main task of translating the book into English, and I.F. Treshchetenkova and E.A. Turina for their great help in preparing the manuscript.

Moscow, Russia
January 1982

L.M. Brekhovskikh
Yu.P. Lysanov

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