Nonlinear Underwater Acoustics

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Translated by Robert T. Beyer
Translation published in 1987; Originally Published in 1981

CONTENTS

Preface

Nonlinear phenomena, whose investigation is of interest for the solution of applied problems of modern underwater sound, are quite diverse in their physical nature. In their number we include cavitation, noise generation, acoustic streaming, and a series of other phenomena the description of which requires an account of the nonlinear terms in the equations of hydrodynamics. In recent years, there has been a great deal of attention paid to problems relating to nonlinear acoustics. The typical nonlinear effects-the distortion of a profile and the spectral composition of signals-are governed by the violation of the principle of wave superposition, which is common for all nonlinear problems.

Nonlinear wave effects are observed in the propagation of blast waves in the ocean. However, there is some difference between signals excited by electromechanical transducers and by blasts. The former depend on well-controlled parameters and allow us to carry out accurate spectral measurements, while pulsed blast signals are not, as a rule, reproduced experimentally, and measurements with their help yield lower accuracy. Therefore, effects due to an increase in the intensity of waves provided by acoustic methods are of interest at the present time.

The use of coherent acoustic signals of high intensity allows us not only to increase the range and resolutions of sonars but also to improve a number of other parameters of underwater sound apparatus.

At high levels of radiation, new effects appear which do not, in principle, exist in linear acoustics. Some of these effects are, in most cases, undesirable (such as, for example, the nonlinear damping and limitation of the signal level in water); many others, on the other hand, can be used to create new types of underwater sound apparatus.
The results of theoretical and experimental investigations of the interaction of nonlinear waves have been set forth in numerous papers and are correlated in monographs by R.T. Beyer, L.K. Zarembo and V.A. Krasil'nikov G.A. Ostroumov, and O.V. Rudenko and S.I. Soluyan. These works serve as a reliable foundation for practical applications. The annual number of publications on problems connected with the subject exceeded 250 in 1977. A significant number of publications have been devoted to the use of parametric arrays and instruments in underwater sound.
The information discussed in this increasing stream is more complicated in that investigators use different models and methods of calculation, and they publish experimental results carried out under strongly differing conditions and over different ranges of variation of the parameters. To a significant degree, this is due to the complexity of the investigated processes.

We call attention to the fact that an attempt is made in this book to consider the basic assumptions of nonlinear wave theory as applied to the solution of the problems of broadband directed radiation and detection of underwater signals from a single position.

The contemporary state of problems of the construction, application, and use of a new type of underwater sound apparatus-the nonlinear parametric apparatus is also set forth in this book.

The scientific achievements and the results of the development of nonlinear parametric receiving and transmitting arrays as well as underwater sound apparatus in which these arrays are used are correlated in this book. Necessary information on the interactions of one-dimensional waves is developed, and the basic results of the quasi-optical approximation of linear diffraction theory are given. A universal theory of parametric arrays is presented that allows us to investigate their characteristics with sufficient accuracy. Analytic relations have been obtained by the authors on the basis of the solution of nonlinear equations describing the behavior of acoustic beams in the quasi-optical approximation. Results have been obtained from these solutions in specific cases and calculated within the framework of the well-known models of Westervelt, Berktay, and others having limited regions of application.

Considerable space is given in this book to problems of distant, contact-free excitation of sound by means of the effective thermo-optical demodulation of light radiation in the surface layer of water.
Analysis of different working regimes of nonlinear underwater apparatus has been carried out with account of the real properties of the medium. A comparison is given of the theoretical and experimental data over the spatial distributions, frequency, amplitude, and phase characteristics of parametric transmitters and receivers. For convenience of engineering calculations, nomograms have been constructed that allow a great simplification in choosing parameters for the nonlinear arrays. A series of enlarged nomograms for the near, far and intermediate zones of the parametric array has been placed in the Appendix. The characteristics of a specific parametric apparatus are also given there.

The features of construction are developed, and the basic characteristics of foreign and domestic parametric arrays are given; small-size broadband measuring transmitters and receivers for tank and test stations, precision sonars, parametric fish detection apparatus, underwater sonars for shelf zones parametric apparatus for the transfer of broadband information in underwater sound channels, parametric Doppler sonars and acoustic recorders, parametric apparatus for geolocation acoustic cartography through a water layer, and so on.
The Conclusion and Chapter 1 were written by O.V. Rudenko and V.I. Timoshenko; Chapters 2, 4, 5, 8 and 9 by O.V. Rudenko; Chapters 3, 6, 7 and the Appendix by B.K. Novikov; Chapters 10,11 and 12 by V.I. Timoshenko.

The authors express their gratitude to C.A. Poyarkov, T.N. Kutsenko, and L.J. Timoshenko for their help on the preparation of the book.

Comments and remarks on the content of the book will be gratefully received by the authors.

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Leningrad, 1981