APRIL 01 2000

Acoustics of Layered Media I: Plane and Quasi-plane Waves (Springer Series on Wave Phenomena Volume 5) Second, Updated Printing (softcover); *Acoustics of Layered Media II: Point Sources and Bounded Beams (Springer Series on Wave Phenomena Volume 10)* Second, Updated and Enlarged Edition

L. M. Brekhovskikh; O. A. Godin; David R. Palmer

J. Acoust. Soc. Am. 107, 1809–1810 (2000)
https://doi.org/10.1121/1.428553

Acoustics of Layered Media I: Plane and Quasi-plane Waves (Springer Series on Wave Phenomena Volume 5) *Second, Updated Printing (softcover)*

L. M. Brekhovskikh and O. A. Godin

Springer-Verlag, New York, 1998.
x+242 pp. Price: $59.95.

Acoustics of Layered Media II: Point Sources and Bounded Beams (Springer Series on Wave Phenomena Volume 10) *Second, Updated and Enlarged Edition*

L. M. Brekhovskikh and O. A. Godin

Springer-Verlag, New York, 1999.
xv+524 pp. Price: $139.00.

These two monographs, which we will refer to as ALM I and II, are revised versions of books first published in 1990 and 1992, respectively. The publisher does not actually refer to ALM I as a second edition but rather as a second, softcover, printing of the first edition. While the revisions to ALM I are minor, the revisions and additions to ALM II are extensive and resulted in a 33% increase in the number of pages.

The books originated from a single body of work devoted to a summary review of sound-wave propagation in inhomogeneous media. Since it clearly would not have been practical to publish the material in a single book, it was divided according to the nature of the acoustic source. In ALM I monochromatic plane waves, both homogeneous and inhomogeneous, are treated, as well as pulsed plane waves. ALM II treats point sources and bounded wave beams. There are other divisions as well. Elastic wave propagation is discussed in ALM I and propagation in a range-dependent waveguide is treated in ALM II. While the two books are self-contained, the material in the first three chapters of ALM II, devoted to the refraction and reflection of spherical waves, the reflection of bounded beams, and to an excellent discussion of lateral waves, has more in common with ALM I than with the rest of the material in ALM II. I have found that there is a degree of continuity and ease of reading if these three chapters are read after having read ALM I.

Any summary review of wave propagation in layered media must necessarily build on the material in Acad. Brekhovskikh's earlier books and at first glance, it might seem ALM I and II simply represent a more mathematical treatment of old topics. These books actually provide a comprehensive survey of contemporary research in acoustical wave propagation. Many of the citations are to material published in 1999. Older topics are treated, of course, but with such thoroughness and from such an original point-of-view that new, interesting results are often obtained.

Even though there is an emphasis on the authors' own research contributions, the treatment of topics is balanced and contributions by others are thoroughly discussed. In addition, summaries are included, with references, of topics not considered in detail. These summary paragraphs are a valuable feature of the books. The books do not treat several of the research themes that have preoccupied U.S. underwater acousticians during the last two decades including propagation through random media, ocean acoustic tomography, and global propagation problems. They do deal with some of the fundamentals upon which these subjects are based.

ALM I and II were written in English by the authors; they are not translations by a native English speaker of earlier Russian editions. Most of the minor language and typographical errors have been corrected in the new versions but a few remain. In general, they do not hinder readability.

Before surveying the material chapter by chapter, it is worthwhile mentioning some of the significant features of these books. They contain a detailed treatment of acoustic propagation in moving media. Throughout both books a topic is first studied for a medium at rest and then generalized to a moving one. The authors derive new equations for linear propagation in moving media that include, as special cases, many of the equations derived by others. Modal, geometric acoustics, and parabolic approximation descriptions of propagation in moving media are developed.

The Reciprocity Principle and the Flow Reversal Theorem are central themes of ALM II. These symmetry relations state that an acoustic quantity is invariant under interchange of source and receiver and, if the medium is moving, reversal of the flow. They are of both practical and theoretical importance. These relations are derived and studied for many different situations and used to obtain general constraints on propagation processes and to develop new, approximate, propagation models.

Chapter 8 of ALM II is new in this edition and contains a discussion of a new, fundamental reformulation of the theory of both acoustic and acoustic-gravity waves in three-dimensional, inhomogeneous moving media. The focus is the study of reciprocity and energy conservation using a hybrid Eulerian–Lagrangian description. This description, which has been used in a somewhat different form by other researchers, leads to simplified equations of motion and boundary conditions and is used to obtain, under very general conditions, the Flow Reversal Theorem as well as other conservation laws. A number of applications of this new approach have already been published.

These books are characterized by a high degree of thoroughness in the treatment of the topics considered. It is this thoroughness as much as anything else that allows the authors to discover interesting results even when they consider old topics. Two illustrative examples are the treatment of boundary conditions and of source terms. The authors not only consider the usual types of rigid boundary and interface conditions but also investigate, starting from first principles, how the conditions change when the medium is in motion or the boundary is deformable. As a consequence, some new results are obtained. In ALM II source terms are included from the beginning in the Euler and continuity equations is a form based on physical considerations. Because of this approach, the authors are able to show, for example, that the acoustic quantity invariant under interchange of source and receiver positions (Reciprocity Principle) depends on the nature of the source. If the authors had been less thorough in their treatment of source terms, they would have missed this fascinating result.

The lists of references is a valuable feature of the books. There are over 1700 citations in the two books. The majority of these are to material originally published in English (67%) or translated into English from Russian (15%). Another 15% of the citations are to references in Russian that have not been translated—typically books, conference proceedings, and older research articles. About 2% are to references published in German or French. The authors went to great effort to make the lists comprehensive, up-to-date, correct, and useful.

In Chapter 1 of ALM I the linear wave equations are derived for acoustic waves in an inhomogeneous moving media and for elastic waves in isotropic solids. This derivation is repeated in Chapter 4 of ALM II but there sound sources are included. We see in Chapter 1 the first example of a technique used throughout. The wave equation is transformed to some desirable form by introducing a new independent (vertical) variable and by scaling the field. In this case the equation for a plane wave in a medium with density and flow field stratification is reduced to a Helmhotz-like equation. The same technique is used to show the similarity between a horizontally polarized shear wave propagating in a layered solid and a sound wave propagating in a layered fluid. Chapter 2 considers monochromatic plane waves propagating in stationary and moving discretely layered media. The emphasis is on calculating the reflection and transmission coefficients. Chapter 3 considers exact solutions to the wave equation for continuously layered media. By transforming the equation to a general, solvable form, essentially all the possible solvable models are constructed and several are discussed in detail. In Chapter 4 reflection of waves from discretely layered solid media is studied. Various cases are considered—elastic media with free boundaries, two or more solids in contact with one another, and a solid in contact with a fluid. Rayleigh, Stonely, and other types of waves that can exist near the boundary of an elastic medium are also discussed.

Reflection of pulsed sound waves from discrete and continuous layered media is discussed in Chapter 5 based on the law of conservation of integrated pulse. We see here another characteristic of the books. Through their analysis the authors are able to clear up confusion resulting from errors in the literature. In this case, the error relates to the change in shape of a pulse as it propagates in a waveguide. Chapter 6 is an interesting chapter in which the universal properties of reflection and transmission coefficients are discussed—those properties that are independent of the detailed nature of the stratification. Chapter 7 considers viscoelastic media and absorptive fluids, anisotropic elastic media and fine layered media. The discussion of the case when the modulus of the reflection coefficient is greater than unity for two viscoelastic media in contact has been improved in this printing. Chapters 8 and 9 treat the WKB approximation, its range of validity, and methods for estimating the sound field when the approximation is not adequate. Chapter 10 discusses the determination of the reflection coefficient and the impedance for an arbitrary layered media. It is suggestive of Chapter 6 and contains some improvements over the first printing. The focus is on the use of equations satisfied by the reflection coefficient rather than those satisfied by the sound field.

Turning now to ALM II, we have already mentioned the material in its first three chapters and in Chapter 8. After deriving the linear equations that determine the sound field, Chapter 4 continues with a discussion of reciprocity relations and exact solutions to the wave equation. The discrete spectral (modal) representation of the field in layered media is derived. This is done not by using separation of variables and expanding the sound field in a complete set of eigenfunctions of the one-dimensional wave equation but by associating modes with the residue of poles in an integral representation of the field. This 40-page discussion is full of useful techniques and interesting results. For example, the discrete spectrum of the sound field of a point source in a moving medium cannot, in general, be represented in terms of a superposition of modes, unlike the case of a medium at rest. Chapter 5 develops the geometric optics approximation and Chapter 6 is devoted to a discussion of the sound field in the neighborhood of a caustic. This chapter is somewhat unsatisfying. The line diagrams are not particularly informative and the chapter is full of tedious algebraic details. This is certainly not the place to look if one is interested in learning about the geometric structure of caustics. On the positive side the chapter does discuss how to calculate the sound field in the vicinity of a few types of caustics and this, after all, is what is ultimately important.

Chapter 7, devoted to wave propagation in a range-dependent waveguide, is one of the more important chapters in the books. Representation in terms of local modes is discussed as is the use of horizontal rays and vertical modes. The section on rays in range-dependent waveguides centers about the use of the ray invariant. The last part of this chapter is devoted to parabolic equation methods. The introductory material is somewhat dated but the authors make up for this shortcoming in their discussion of the parabolic approximation for a field in a moving medium.

Appendix A reminds one of Chapter 4 of *Radiation and Scattering of Waves*, by Felsen and Marcuvitz (IEEE Press, 1994). It contains a useful discussion of the classes of integrals that are typically approximated by the method of steepest descent. These integrals are encountered throughout the text. Uniform asymptotic approximations are also discussed.

Appendices B and C are new with this edition and could have been included as separate chapters in the body of the book. Appendix B is concerned with a modal description of propagation in a waveguide having range-dependent boundaries or interfaces. This is a difficult and subtle problem because the boundary conditions satisfied by the acoustic field differ from those satisfied by the local modes. The series expansion of the field in terms of modes can be so poorly convergent that it is not always possible to interchange differentiation and series summation and substitution of the series into the wave equation leads to coupled-mode equations that are unphysical. The authors address this problem by using energy conservation and reciprocity rather than by using the wave equation. They are able to derive coupled-mode equations that correct or extend the work done by others.

In Appendix C parabolic equations are derived starting with the constraints imposed by energy conservation and reciprocity. The authors begin by rigorously defining what is meant by these concepts in the context of the parabolic approximation. Using an inductive rather than a deductive process, they develop improved, wide-angle parabolic equations. There are some gems here for aficionados of the parabolic approximation: for the case considered, energy conservation and reciprocity are equivalent; self-adjointness of the vertical operator in a parabolic equation generally leads to a conservation law that is different from and incompatible with the energy conservation law; and reciprocal, wide-angle parabolic equations typically require range-derivatives of the medium parameters in their coefficients.

With a very careful choice of topics to be covered, I think these books could be used as texts for an advanced graduate course. (The authors' statement that senior undergraduate courses were taught using the books refers to the Soviet system where an undergraduate was someone working toward a degree roughly equivalent to a MS degree.) It should be noted these books require a motivated reader; one does not gain much from a superficial reading.

For the researcher, these books could not only provide a valuable source of reference material and a useful introduction to the literature on a given topic, but could also be the source of new research ideas.

In summary, ALM I and II represent an impressive achievement on the part of the authors as well as a great deal of ordinary hard work. They are recommended for anyone interested in the theoretical aspects of wave propagation.

DAVID R. PALMER
Office of the Director
NOAA Atlantic Oceanographic and Meteorological Laboratory
Miami, Florida 33173