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J.-P. Fouque, J. Garnier, G. Papanicolaou, K. Solna: Wave Propagation and Time Reversal in Randomly Layered Media

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The development of the theory of any physical phenomenon starts by choosing an appropriate model of the environment in which the phenomenon takes place. The model should be a compromise between the complexity of nature and the feasibility (unfortunately, often rather limited) of solving the corresponding mathematical problem. When it comes to the propagation of waves in real media, the most advantageous and widely used model is the simplest, at the first glance even primitive, layered model. Incredibly enough, this oversimplified structure proved itself to be very efficient as a model of the great diversity of complex natural systems. The reason is that three basic substances—earth, water (ocean), and air (atmosphere and ionosphere), as well as the plethora of objects of much smaller scale, such as human tissue or the retina, often consist of a set of "pancakes" whose electromagnetic or elastic parameters change in one direction much faster than in the two other directions. Ignoring the latter leads to a one-dimensional problem, which, while being relatively simple and much easier studied mathematically, on the other hand, still preserves the most important features of real wave processes.

Although hundreds of original papers and reviews related to different aspects of wave propagation in layered media have been published during the past few decades, an excellent book of L. Brehovskikh written in 1957 (English translation: *Waves in Layered Media*, Academic Press, New York, 1980) still remains practically the only comprehensive textbook on this subject. Not to mention how much water has flown under the bridge since then, the book dealt solely with propagation in deterministic systems and did not touch on any effects of disorder.

Therefore, an up-to-date monograph written by highly regarded experts that presents in a modern way the generalities of the physics of randomly layered media and covers a broad range of applications has long been eagerly anticipated by mathematicians, physicists, and engineers.

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Being one of the Springer series on *Stochastic Modeling and Applied Probability* the book of J.-P. Fouque, J. Garnier, G. Papanicolaou, K. Solna is intended primarily for researchers and students in applied mathematics. These readers will find everything (or perhaps almost everything) they need to know in order to use the stochastic analysis of differential equations with random coefficients in solving various problems of modern wave physics, especially those problems related to time reversal.

The sweep of this book is broad and up-to-date. It ranges from classical problems of wave propagation in homogeneous and layered media, through disorder-induced localization, to time reversal, solitons, and disordered waveguides. Of course, putting all this material together coherently in a single whole is an ambitious undertaking, but the authors succeed brilliantly. The book is organized into twenty chapters. Following the introduction, the basic formalism and concepts of wave propagation in homogeneous and piecewise constant media are presented. Studying wave processes in disordered media is reduced to the asymptotic analysis of random differential equations with the corresponding boundary conditions, and the mathematical apparatus of partial differential equations and stochastic calculus needed for this analysis is introduced gradually and in a self-contained form. Using these tools and exploiting the idea of separation of scales, the authors give an extensive and exhaustive treatment of reflection and transmission in randomly layered media in ballistic and localized regimes, both in the time and frequency domains. About half the book is devoted to the rigorous quantitative analysis of the time reversal—a new, exciting, and still developing area with great potential for applications in acoustics and optics. Most of results in this part are new and presented for the first time.

Although 597 pages saturated by Lemmas, Propositions, and Theorems are not an easy reading and require certain mathematical background, I think the monograph will be appreciated and used not only by mathematicians but by a wide range researchers, including physicists and engineers as well. The book is encyclopedic, and one will most probably find between its covers the solution to any physical problem related to the propagation of waves in a layered environment. I doubt that an engineer will be able to go through mathematical technicalities and rigorous proofs that start from first principles, but he may not need to in order to use the final results. And one definitely will feel himself much more confident knowing that such a proof exists. I strongly recommend the book to graduate students and advanced researchers as a comprehensive and helpful source of information and excellent guide in the intriguing realm of random waves.

Of course, no book is perfect. The following comments are basically not a criticism of this edition, but rather suggestions for a second edition, which, I believe, the book is good enough for. The authors point out that the content of the book is multidisciplinary. However, one of the most important aspects of the physics of random wave processes—electromagnetic radiation in layered media—is omitted. This omission is particularly serious for the large community of scientists and engineers, who deal with optics, microwave technology, radar, communication, etc. and desperately need such a textbook. The underlying ideas and analytical methods used in the book are quite general and pertain equally to both scalar and vector fields. Moreover, a large portion of the results related to acoustic waves could be easily reformulated in terms of electrodynamics. Of course, this requires certain effort on the part of the authors, but they will be rewarded a hundredfold by the dramatic increase in the range of users who would benefit from it. My second concern is that Anderson localization receives disproportionally little attention in the book. The ability to localize radiation is the most important and exciting physical property of one-dimensional disordered media. Randomly layered configurations are unique objects in which strong localization of classical waves can be observed experimentally and studied theoretically at a mathematically satisfactory level of rigor. I think that this phenomenon should occupy a significant, if not a central, place in any modern book on waves in randomly layered media. And certainly the issue of resonances should not on no account be ignored.

Lest I appear to end on a negative note, let me reiterate that this is an excellent book which will be interesting, informative, and enjoyable for a wide circle of students, researchers, and engineers, demanding a place on their bookshelves.