Preface

The inverse scattering problem for electromagnetic waves is an area of major importance in applied mathematics. In particular, one can argue that the invention of radar is one of the most important inventions of the twentieth century. However, since radar is based on a weak scattering approximation and typically ignores polarization effects, it is of limited use for many target identification problems involving complex environments in which multiple scattering and/or polarization effects can no longer be ignored. For this reason considerable effort has been made in recent years to avoid the incorrect models inherent in the use of weak scattering approximations and instead to develop target identification algorithms without invoking such approximations. Initial efforts in this direction focused on nonlinear optimization techniques. However, although these techniques were successful in certain applications, it soon became apparent that they relied too heavily on strong a priori information about the scatterer and were numerically expensive as well. This then led to the search for target identification algorithms that, while avoiding incorrect model assumptions, were nevertheless easy to implement and required little a priori information. One result of this search has been the introduction of a class of methods collectively known as qualitative methods in inverse scattering theory (cf. [22]).

Qualitative methods in inverse scattering theory are characterized by the fact that, although they avoid the problems inherent in the use of weak scattering approximations or nonlinear optimization techniques, they typically recover less information than the latter two methods. In particular, with essentially no a priori assumptions about the material properties or geometry of the scatterer, the qualitative approach to the inverse scattering problem typically recovers the support of the scatterer as well as partial information on the scatterer's material properties. Furthermore, since the inversion algorithm is linear (even though the inverse scattering problem itself is nonlinear), the implementation of a given qualitative method is very rapid and easy to carry out (however, the implementation of a given qualitative method typically requires more data than the use of a nonlinear optimization scheme).

The oldest and most developed of the qualitative methods in inverse scattering theory is the linear sampling method (LSM), first introduced by Colton and Kirsch [49] in 1996 for the scalar case, and it is this approach (for the vector case) that will be the main focus of this book. For qualitative methods in electromagnetic inverse scattering theory other than the LSM, we refer the reader to Chapter 5 of the recent monograph by Kirsch and Grinberg [77] as well as to the article [69].

The basic material for this book was originally presented by one of us (Peter Monk) at the NSF-CBMS Regional Conference on Numerical Methods in Forward and Inverse Electromagnetic Scattering held at the Colorado School of Mines from June 3 to June 7 in 2002. Since that time the book [93] has appeared, which treats the forward problem in considerable detail. Hence in this book we have focused almost entirely on the inverse problem. In addition to the LSM, we have included in our presentation a discussion of uniqueness theorems and of the derivation of various inequalities on the material properties of the scattering object from a knowledge of the far field pattern of the scattered wave. Throughout our narrative the approximation properties of Herglotz wave functions and the behavior of solutions to a novel interior boundary value problem called the "interior transmission problem" play a central role.

It gives us considerable pleasure to acknowledge the long-term support of our research by the Air Force Office of Scientific Research, in particular the encouragement and guidance of Dr. Arje Nachman of the AFOSR and Dr. Richard Albanese of Brooks Air Force Base, San Antonio, Texas. Without their support this book would probably not have been written.

Monk would like to acknowledge the support of the National Science Foundation (NSF) under a grant to the Conference Board of the Mathematical Sciences (CBMS) for the NSF-CBMS Regional Conference on Numerical Methods in Forward and Inverse Electromagnetic Scattering held at the Colorado School of Mines (June 3–7, 2002). Particular thanks go to Professors Graeme Fairweather and Paul Martin for organizing the conference and for inviting a superb choice of participants.

Monk would also like to thank the Institute for Mathematics and Its Applications at the University of Minnesota for a visiting position in the fall of 2010 during the final stages of writing this book.