Preface

The choice of topics in this book may seem somewhat arbitrary, even though we have attempted to organize them in a logical structure. The contents reflect in fact the path of 'search and discovery' followed by us, on and off, for the last twenty years. In the winter of 1970–71 one of the authors (C.A.), on sabbatical leave with L.R.O. Storey's research team at the Groupe de Recherches Ionosphériques at Saint-Maur in France, had been finding *almost* exact symmetries in the computed reflection and transmission matrices for plane-stratified magnetoplasmas when symmetrically related directions of incidence were compared. At the suggestion of the other author (K.S., also on leave at the same institute), the *complex conjugate* wave fields, used to construct the eigenmode amplitudes via the mean Poynting flux densities, were replaced by the *adjoint* wave fields that would propagate in a medium with transposed constitutive tensors, *et voilà*, a scattering theorem—'reciprocity in **k**-space'—was found in the computer output. To prove the result analytically one had to investigate the properties of the adjoint Maxwell system, and the two independent proofs that followed, in 1975 and 1979, proceeded respectively via the matrizant method and the thin-layer scattering-matrix method for solving the scattering problem, according to the personal preferences of each of the authors. The proof given in Chap. 2 of this book, based on the hindsight provided by our later results, is simpler and much more concise.

Further investigation revealed that the 'conjugate' problem, in which the scattering matrix was the transpose of that in the given problem, was no more than a reflection mapping of the the adjoint problem (i.e. of the original problem with transposed constitutive tensors). Later, when media with bianisotropic constitutive tensors were investigated, it was found that conjugate (reciprocal) media and wave fields could be formed by any orthogonal spatial mapping of those in the original problem after media and fields were *reversed in time*. The result was quite general and not limited to stratified systems.

The second line of development was to find the link between 'reciprocity in **k**-space' and Lorentz reciprocity, involving currents and sources in physical space. This was done for plane-stratified media by applying the scattering theorem to the plane-wave spectrum of eigenmodes radiated by one current source and reaching the second source. The reverse linkage, from Lorentz reciprocity to reciprocity in **k**-space, had already been found by Kerns (1976). Application of *restricted* time reversal as a means to obtain Lorentz reciprocity relations was the immediate generalization. (Dissipative processes are not 'time reversed', and so the time reversal is 'restricted'.)

The relation between time reversal and reciprocity is not new. It has often been discussed in the scientific literature. In the context of Lorentz reciprocity it has been applied by Deschamps and Kesler (1967), and possibly by others. We believe however that this is the first time that time reversal has been presented in a systematic and mathematically well-defined procedure to serve as a tool for solving problems of reciprocity and scattering symmetries (reciprocity in **k**-space). The use of time reversal gives rise to problems of causality when sources are present, but when the interaction between *two* systems is involved (Lorentz reciprocity) the non-causal effects are irrelevant.

The insight gained during these investigations has enabled us to present many of the earlier theorems and results, both our own and those of other workers, in a compact and unified approach. Much of the material is new. The generalization of Kerns' theorem in Chap. 7, for instance, had not yet been published at the time of writing of this book. We would like to hope that these ideas may prove stimulating to other workers in the field.

In conclusion, one of the authors (C.A.) would like to express his indebtedness to Professor H. Cory and Dr. E. Fijalkow for their contributions in developing the computer programs that revealed scattering theorems in the computer printouts, in the heroic days when programs were still punched on paper tapes and corrections inserted with scissors and glue. He is also indebted to Dr. A. Schatzberg for his important contribution in bridging the gap between reciprocity in **k**-space and Lorentz reciprocity in physical space.

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As this manuscript being prepared for press we learnt of the untimely death of Professor John Heading, the first managing editor of the series 'Developments in Electromagnetic Theory and Applications', and of this book in particular. We are indebted to Professor Heading for having invited us to contribute to the series and for his friendly encouragement and advice at all stages of this work. His contribution to the subject of wave propagation and reciprocity was considerable, and has influenced numerous workers in the field.

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