

# Preface

The present monograph discusses a number of mathematical and conceptual methods applicable in the analysis of electromagnetic fields. The leading tone is dyadic algebra. It is applied in the form originated by J.W. Gibbs more than one hundred years ago, with new powerful identities added, making coordinate-dependent operations in electromagnetics all but obsolete. The chapters on complex vectors and dyadics are independent of the rest of the book, actually independent of electromagnetics, so they can be applied in other branches of physics as well. It is claimed that by memorizing about five basic dyadic identities (similar to the well-known bac-cab rule in vector algebra), a working knowledge of dyadic algebra is obtained. To save the memory, a collection of these basic dyadic identities, together with their most important special cases, is given as an appendix. In different chapters the dyadics are seen in action. It is shown how simply different properties can be expressed in terms of dyadics: boundary and interface conditions, medium equations, solving Green functions, generalizing circuit theory to vector field problems with dyadic impedances, finding transformations between field problems and, finally, working on multipole and image sources for different problems.

Dyadic algebra is seen especially to aid in solving electromagnetic problems involving different linear media. In recent years, the chiral medium with its wide range of potential applications has directed theoretical interest to new materials. The most general isotropic medium, the bi-isotropic medium, has made electromagnetic theory a fresh subject again, with new phenomena being looked for. The medium aspect is carried along in this text. What is normally analysed in isotropic media is done here for bi-isotropic or sometimes for bianisotropic media, if possible. Especially new is the duality transformation, which actually exists as a pair of transformations. It is seen to shed new light on the plus and minus field decomposition, which has proved useful for analysing fields in chiral media, by showing that they are nothing more than self-dual fields with respect to each of the two transformations.

In Chapter 5, Green dyadics for different kinds of media are discussed and a systematic method for their solution, without applying the Fourier transformation, is given. In Chapter 6, source equivalence and its relation to non-radiating sources is discussed, together with certain equivalent

sources: point sources (multipoles) and surface sources (Huygens' sources). Everywhere in the text the main emphasis is not on specific results but methods of analysis.

The final chapter gives a summary of the work done by this author and colleagues on the EIT, exact image theory. This is a general method for solving problems involving layered media by replacing them by image sources which are located in complex space. The EIT is presented here for the first time in book form.

The contents of this monograph reflect some of the work done and courses given by this author during the last two decades. The results should be of interest to scientists doing research work in electromagnetics, as well as to graduate students. For classroom use, there are numerous possibilities for homework problems requiring the student to fill in steps which have been omitted to keep the size of this monograph within certain limits. The EIT can also be studied independently and additional material, not found in this text, exists in print (see referece lists at section ends of Chapter 7).

The text has been typed and figures drawn by the author alone, leaving no-one else to blame. On the other hand, during graduate courses given on the material, many students have helped in checking a great number of equations. Also, the material of Chapters 1 and 2 has been given earlier as a laboratory report and a few misprints have been pointed out by some international readers. For all these I am thankful. The rest of the errors and misprints are still there to be found.

This book is dedicated to my wife Liisa. A wise man is recognized for having a wife wiser than himself. I have the pleasure to consider myself a wise man.

*Helsinki*  
July 1991.

I.V.L.

For the second edition, the main text has remained unchanged except for a small number of misprints, which have been corrected. To assist in classroom use of the book, three new appendices have been added. Appendix A contains a collection of problems on the topics of Chapters 1 – 6 and Appendix B a set of solutions for most of these problems. Appendix C gives a collection of most useful formulas in vector analysis for convenience. Appendix A (Dyadic identities) of the first edition is now relabeled as Appendix D.

*Helsinki*  
March 1995.

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