PIER 2
Progress in Electromagnetics Research

Finite Element and Finite Difference Methods in Electromagnetic Scattering

PIER Progress in Electromagnetics Research
Jin Au Kong, *Chief Editor*
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Elsevier
New York • Amsterdam • London

Elsevier Science Publishing Co., Inc.
655 Avenue of the Americas, New York, New York 10010

Sole distributors outside the United States and Canada:
Elsevier Science Publishers B.V.
P.O. Box 211, 1000 AE Amsterdam, The Netherlands

This book is printed on acid-free paper.

ISBN 0-444-01518-3

ISSN 1043-626-X

Current printing (last digit):
10 9 8 7 6 5 4 3 2 1

Manufactured in the United States of America

PREFACE

This second volume of PIER considers recent advances in computational electromagnetics, with emphasis on scattering, as brought about by new formulations and algorithms which use finite element or finite difference techniques. Within the past few years, there has been a growing interest in using these "finite methods" within the electromagnetics research and development communities. A major reason for this new emphasis has been the need to solve ever more complex problems, requiring very large numbers of discrete unknowns.

Until recently, most open-region problems involving antennas and scattering have been approached using integral equations, which implicitly incorporate the far-field radiation conditions. On the other hand, numerical approximation of an integral equation usually results in global interactions between each and every discrete unknown. For the time-harmonic case, this gives fully populated system matrices, while time-domain solutions require causal updating of each unknown, as influenced by all other unknowns at each time-marching step.

In contrast, finite methods result in only local, nearest-neighbor, type interactions between discrete field values at the nodes of the spatial mesh or grid. Finite method use in solving closed-region boundary value problems in the frequency domain yields highly sparse system matrices. This can result in dramatic reductions in solution and fill times, as well as in required computer memory, when compared to dealing with a full matrix of the same rank. In the time-domain, similar efficiency is observed because explicit coupling only exists between nearest spatial nodes.

Although finite methods excel in numerical efficiency for field solutions in closed spatial regions, additional consideration is needed for the open-region case, in order to bound the spatial mesh while enforcing proper radiation conditions at infinity. This mesh termination problem is being approached by a variety of contemporary techniques, most of which are presented in detail in the eight chapters of this volume.

In Chapter 1, Morgan presents a comprehensive and fundamental overview of finite methods and their associated mesh termination techniques, both in the frequency- and time-domains. This first chapter is meant to provide basic reference and a tutorial review. A powerful finite element algorithm is discussed by Fleming in Chapter 2 where, using the unimoment method to enforce the far-zone radiation conditions, scattering by composite (metallic and dielectric) axisymmetric structures is considered. The boundary element method is used to terminate a 2-D finite element mesh and solve several complex scattering problems in Chapter 3, as authored by Wu, Delisle, Fang and Lecours. In Chapter 4, Mittra and Ramahi derive a variety of absorbing boundary conditions and then investigate their performance in bounding finite method meshes in 2-D and axisymmetric 3-D scattering problems. McCartin, Bahrmasel and Meltz develop a finite method, called the Control Region Approximation, in Chapter 5 and apply it to 2-D scattering problems using asymptotic boundary conditions to enforce proper radiation field behavior. In Chapter 6, Morgan presents a new finite element based formulation for representing time-harmonic vector fields in 3-D inhomogeneous media using two coupled scalar potentials. Transient field problems involving corners and wedges in 2-D and 3-D are considered by Cangellaris and Mei in Chapter 7, using conforming boundary elements and leap-frog time-marching. The finite-difference time-domain method is developed by Taflov and Umashankar in Chapter 8, where further consideration is given to the Yee algorithm, radiation boundary conditions and a wide variety of applications and validations.

Finite methods (so named by Professor K. K. Mei over a decade ago) will continue to evolve as problem complexity and computational resources both increase. It is hoped that this volume will serve as a useful reference for students and practitioners of computational electromagnetics who are, or will be, involved in this evolution.

Acknowledgments are given by individual authors at the end of their respective chapters. In addition, special thanks are given to Mrs. Karen Charnley for typesetting most of the book, to Mrs. Sue Syu for detailed editorial comments, and to Professor J. A. Kong, who suggested the creation of this volume.

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Monterey, California
May 22, 1989

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