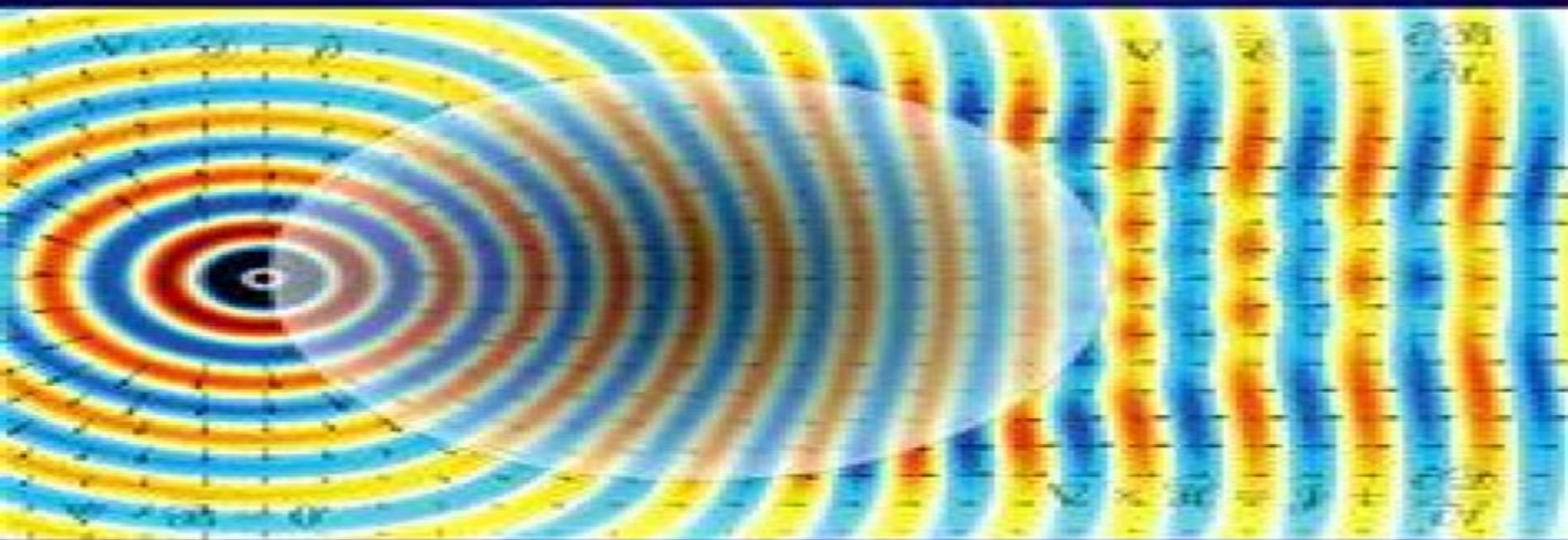


Numerical Electromagnetics

The FDTD Method



**Umran S. Inan
and Robert A. Marshall**

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W. Yu



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Numerical Electromagnetics Umran S. Inan, Robert A. Marshall, 2014-05-14 An introduction to the FDTD method for students and engineers without prior modeling experience *Computational Electromagnetics with MATLAB, Fourth Edition* Matthew N.O. Sadiku, 2018-07-20 This fourth edition of the text reflects the continuing increase in awareness and use of computational electromagnetics and incorporates advances and refinements made in recent years Most notable among these are the improvements made to the standard algorithm for the finite difference time domain FDTD method and treatment of absorbing boundary conditions in FDTD finite element and transmission line matrix methods It teaches the readers how to pose numerically analyze and solve EM problems to give them the ability to expand their problem solving skills using a variety of methods and to prepare them for research in electromagnetism Includes new homework problems in each chapter Each chapter is updated with the current trends in CEM Adds a new appendix on CEM codes which covers commercial and free codes Provides updated MATLAB code **Introduction to the Finite-Difference Time-Domain (FDTD) Method for Electromagnetics** Stephen Gedney, 2022-05-31 Introduction to the Finite Difference Time Domain FDTD Method for Electromagnetics provides a comprehensive tutorial of the most widely used method for solving Maxwell's equations the Finite Difference Time Domain Method This book is an essential guide for students researchers and professional engineers who want to gain a fundamental knowledge of the FDTD method It can accompany an undergraduate or entry level graduate course or be used for self study The book provides all the background required to either research or apply the FDTD method for the solution of Maxwell's equations to practical problems in engineering and science Introduction to the Finite Difference Time Domain FDTD Method for Electromagnetics guides the reader through the foundational theory of the FDTD method starting with the one dimensional transmission line problem and then progressing to the solution of Maxwell's equations in three dimensions It also provides step by step guides to modeling physical sources lumped circuit components absorbing boundary conditions perfectly matched layer absorbers and sub cell structures Post processing methods such as network parameter extraction and far field transformations are also detailed Efficient implementations of the FDTD method in a high level language are also provided Table of Contents Introduction 1D FDTD Modeling of the Transmission Line Equations Yee Algorithm for Maxwell's Equations Source Excitations Absorbing Boundary Conditions The Perfectly Matched Layer PML Absorbing Medium Subcell Modeling Post Processing Higher-Order FDTD Schemes for Waveguides and Antenna Structures Nikolaos V. Kantartzis, Theodoros D. Tsiboukis, 2006-12-01 This publication provides a comprehensive and systematically organized coverage of higher order finite difference time domain or FDTD schemes demonstrating their potential role as a powerful modeling tool in computational electromagnetics Special emphasis is drawn on the analysis of contemporary waveguide and antenna structures Acknowledged as a significant breakthrough in the evolution of the original Yee's algorithm the higher order FDTD operators remain the subject of an ongoing scientific

research Among their indisputable merits one can distinguish the enhanced levels of accuracy even for coarse grid resolutions the fast convergence rates and the adjustable stability In fact as the fabrication standards of modern systems get stricter it is apparent that such properties become very appealing for the accomplishment of elaborate and credible designs

Adaptive Mesh Refinement in Time-Domain Numerical Electromagnetics Costas D. Sarris, 2022-05-31 This monograph is a comprehensive presentation of state of the art methodologies that can dramatically enhance the efficiency of the finite difference time domain FDTD technique the most popular electromagnetic field solver of the time domain form of Maxwell s equations These methodologies are aimed at optimally tailoring the computational resources needed for the wideband simulation of microwave and optical structures to their geometry as well as the nature of the field solutions they support That is achieved by the development of robust adaptive meshing approaches which amount to varying the total number of unknown field quantities in the course of the simulation to adapt to temporally or spatially localized field features While mesh adaptation is an extremely desirable FDTD feature known to reduce simulation times by orders of magnitude it is not always robust The specific techniques presented in this book are characterized by stability and robustness Therefore they are excellent computer analysis and design CAD tools The book starts by introducing the FDTD technique along with challenges related to its application to the analysis of real life microwave and optical structures It then proceeds to developing an adaptive mesh refinement method based on the use of multiresolution analysis and more specifically the Haar wavelet basis Furthermore a new method to embed a moving adaptive mesh in FDTD the dynamically adaptive mesh refinement AMR FDTD technique is introduced and explained in detail To highlight the properties of the theoretical tools developed in the text a number of applications are presented including Microwave integrated circuits microstrip filters couplers spiral inductors cavities Optical power splitters Y junctions and couplers Optical ring resonators Nonlinear optical waveguides Building on first principles of time domain electromagnetic simulations this book presents advanced concepts and cutting edge modeling techniques in an intuitive way for programmers engineers and graduate students It is designed to provide a solid reference for highly efficient time domain solvers employed in a wide range of exciting applications in microwave millimeter wave and optical engineering

Electromagnetic Computation Methods for Lightning Surge Protection Studies Yoshihiro Baba, Vladimir A. Rakov, 2016-02-02 Presents current research into electromagnetic computation theories with particular emphasis on Finite Difference Time Domain Method This book is the first to consolidate current research and to examine the theories of electromagnetic computation methods in relation to lightning surge protection The authors introduce and compare existing electromagnetic computation methods such as the method of moments MOM the partial element equivalent circuit PEEC the finite element method FEM the transmission line modeling TLM method and the finite difference time domain FDTD method The application of FDTD method to lightning protection studies is a topic that has matured through many practical applications in the past decade and the authors explain the derivation of Maxwell s

equations required by the FDTD and modeling of various electrical components needed in computing lightning electromagnetic fields and surges with the FDTD method The book describes the application of FDTD method to current and emerging problems of lightning surge protection of continuously more complex installations particularly in critical infrastructures of energy and information such as overhead power lines air insulated sub stations wind turbine generator towers and telecommunication towers Both authors are internationally recognized experts in the area of lightning study and this is the first book to present current research in lightning surge protection Examines in detail why lightning surges occur and what can be done to protect against them Includes theories of electromagnetic computation methods and many examples of their application Accompanied by a sample printed program based on the finite difference time domain FDTD method written in C program

Adaptive Mesh Refinement in Time-Domain Numerical Electromagnetics Costas D.

Sarris,2006-12-01 This monograph is a comprehensive presentation of state of the art methodologies that can dramatically enhance the efficiency of the finite difference time domain FDTD technique the most popular electromagnetic field solver of the time domain form of Maxwell s equations These methodologies are aimed at optimally tailoring the computational resources needed for the wideband simulation of microwave and optical structures to their geometry as well as the nature of the field solutions they support That is achieved by the development of robust adaptive meshing approaches which amount to varying the total number of unknown field quantities in the course of the simulation to adapt to temporally or spatially localized field features While mesh adaptation is an extremely desirable FDTD feature known to reduce simulation times by orders of magnitude it is not always robust The specific techniques presented in this book are characterized by stability and robustness Therefore they are excellent computer analysis and design CAD tools The book starts by introducing the FDTD technique along with challenges related to its application to the analysis of real life microwave and optical structures It then proceeds to developing an adaptive mesh refinement method based on the use of multiresolution analysis and more specifically the Haar wavelet basis Furthermore a new method to embed a moving adaptive mesh in FDTD the dynamically adaptive mesh refinement AMR FDTD technique is introduced and explained in detail To highlight the properties of the theoretical tools developed in the text a number of applications are presented including Microwave integrated circuits microstrip filters couplers spiral inductors cavities Optical power splitters Y junctions and couplers Optical ring resonators Nonlinear optical waveguides Building on first principles of time domain electromagnetic simulations this book presents advanced concepts and cutting edge modeling techniques in an intuitive way for programmers engineers and graduate students It is designed to provide a solid reference for highly efficient time domain solvers employed in a wide range of exciting applications in microwave millimeter wave and optical engineering

Time Domain Techniques in

Computational Electromagnetics Dragan Poljak,2004 A state of the art review from invited contributors Subjects covered include time domain analysis of electromagnetic wave fields by boundary integral equation method and transient analysis of

thin wires and related time domain energy measures *Essentials of Computational Electromagnetics* Xin-Qing Sheng, Wei Song, 2012-05-15 *Essentials of Computational Electromagnetics* provides an in depth introduction of the three main full wave numerical methods in computational electromagnetics CEM namely the method of moment MoM the finite element method FEM and the finite difference time domain FDTD method Numerous monographs can be found addressing one of the above three methods However few give a broad general overview of essentials embodied in these methods or were published too early to include recent advances Furthermore many existing monographs only present the final numerical results without specifying practical issues such as how to convert discretized formulations into computer programs and the numerical characteristics of the computer programs In this book the authors elaborate the above three methods in CEM using practical case studies explaining their own research experiences along with a review of current literature A full analysis is provided for typical cases including characteristics of numerical methods helping beginners to develop a quick and deep understanding of the essentials of CEM Outlines practical issues such as how to convert discretized formulations into computer programs Gives typical computer programs and their numerical characteristics along with line by line explanations of programs Uses practical examples from the authors own work as well as in the current literature Includes exercise problems to give readers a better understanding of the material Introduces the available commercial software and their limitations This book is intended for graduate level students in antennas and propagation microwaves microelectronics and electromagnetics This text can also be used by researchers in electrical and electronic engineering and software developers interested in writing their own code or understanding the detailed workings of code Companion website for the book www.wiley.com/go/shengcem **Perfectly Matched Layer (PML) for Computational Electromagnetics** Jean-Pierre Bérenger, 2007-06-01 This

lecture presents the perfectly matched layer PML absorbing boundary condition ABC used to simulate free space when solving the Maxwell equations with such finite methods as the finite difference time domain FDTD method or the finite element method The frequency domain and the time domain equations are derived for the different forms of PML media namely the split PML the CPML the NPML and the uniaxial PML in the cases of PMLs matched to isotropic anisotropic and dispersive media The implementation of the PML ABC in the FDTD method is presented in detail Propagation and reflection of waves in the discretized FDTD space are derived and discussed with a special emphasis on the problem of evanescent waves The optimization of the PML ABC is addressed in two typical applications of the FDTD method first wave structure interaction problems and secondly waveguide problems Finally a review of the literature on the application of the PML ABC to other numerical techniques of electromagnetics and to other partial differential equations of physics is provided In addition a software package for computing the actual reflection from a FDTD PML is provided It is available here

Advanced FDTD Methods Wenhua Yu, 2011 *Advanced FDTD Methods* Parallelization Acceleration and Engineering Applications Contents Preface Chapter 1 Computational Electromagnetic Methods 1 1 FDTD METHOD 1 1 1 FDTD Update

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Parallel Finite-difference Time-domain Method Wenhua Yu,2006 The finite difference time domain FTDT method has revolutionized antenna design and electromagnetics engineering This book raises the FDTD method to the next level by empowering it with the vast capabilities of parallel computing It shows engineers how to exploit the natural parallel properties of FDTD to improve the existing FDTD method and to efficiently solve more complex and large problem sets Professionals learn how to apply open source software to develop parallel software and hardware to run FDTD in parallel for their projects The book features hands on examples that illustrate th

Optical Properties of Metallic Nanoparticles Andreas Trügler,2016-03-29 This book introduces the fascinating world of plasmonics and physics at the nanoscale with a focus on simulations and the theoretical aspects of optics and nanotechnology A research field with numerous applications plasmonics bridges the gap between the micrometer length scale of light and the secrets of the nanoworld This is achieved by binding light to charge density oscillations of metallic nanostructures so called surface plasmons which allow electromagnetic radiation to be focussed down to spots as small as a few nanometers The book is a snapshot of recent and ongoing research and at the same time outlines our present understanding of the optical properties of metallic nanoparticles ranging from the tunability of plasmonic resonances to the ultrafast dynamics of light matter interaction Beginning with a gentle introduction that highlights the basics of plasmonic interactions and plasmon imaging the author then presents a suitable theoretical framework for the description of metallic nanostructures This model based on this framework is first

solved analytically for simple systems and subsequently through numerical simulations for more general cases where for example surface roughness nonlinear and nonlocal effects or metamaterials are investigated [Microwave Circuit Modeling Using Electromagnetic Field Simulation](#) Daniel G. Swanson, Wolfgang J. R. Hoefer, 2003 Annotation This practical how to book is an ideal introduction to electromagnetic field solvers Where most books in this area are strictly theoretical this unique resource provides engineers with helpful advice on selecting the right tools for their RF radio frequency and high speed digital circuit design work **Advanced Computational Electromagnetic Methods** Wenhua Yu, Wenxing Li, Atef Elsherbeni, Yahya Rahmat-Samii, 2015-03-01 This new resource covers the latest developments in computational electromagnetic methods with emphasis on cutting edge applications This book is designed to extend existing literature to the latest development in computational electromagnetic methods which are of interest to readers in both academic and industrial areas The topics include advanced techniques in MoM FEM and FDTD spectral domain method GPU and Phi hardware acceleration metamaterials frequency and time domain integral equations and statistics methods in bio electromagnetics [Electromagnetic Simulation Using the FDTD Method](#) Dennis M. Sullivan, 2013-05-17 A straightforward easy to read introduction to the finite difference time domain FDTD method Finite difference time domain FDTD is one of the primary computational electrodynamics modeling techniques available Since it is a time domain method FDTD solutions can cover a wide frequency range with a single simulation run and treat nonlinear material properties in a natural way Written in a tutorial fashion starting with the simplest programs and guiding the reader up from one dimensional to the more complex three dimensional programs this book provides a simple yet comprehensive introduction to the most widely used method for electromagnetic simulation This fully updated edition presents many new applications including the FDTD method being used in the design and analysis of highly resonant radio frequency RF coils often used for MRI Each chapter contains a concise explanation of an essential concept and instruction on its implementation into computer code Projects that increase in complexity are included ranging from simulations in free space to propagation in dispersive media Additionally the text offers downloadable MATLAB and C programming languages from the book support site <http://booksupport.wiley.com> Simple to read and classroom tested [Electromagnetic Simulation Using the FDTD Method](#) is a useful reference for practicing engineers as well as undergraduate and graduate engineering students **Electromagnetic Simulation Techniques Based on the FDTD Method** W. Yu, 2009-09-15 Bridges the gap between FDTD theory and the implementation of practical simulation techniques This is the first publication that guides readers step by step through the implementation of electromagnetic simulation techniques based on FDTD methods These simulation techniques serve as an essential bridge between FDTD methods and their applications Moreover the book helps readers better understand the underlying logic of FDTD methods so that they can design FDTD projects using either commercial electromagnetic software packages or their own codes in order to solve practical engineering problems The book begins with two chapters that introduce the basic concepts of the 3 D

Cartesian FDTD method followed by discussions of advanced FDTD methods such as conformal techniques dispersive media circuit elements and near to far field transformation Next the book Presents basic concepts of parallel processing techniques and systems including parallel FDTD techniques and systems Explores simulation techniques based on FDTD methods Illustrates practical simulation techniques using engineering applications Introduces advanced simulation techniques Each chapter concludes with references to help readers investigate particular topics in greater depth Each chapter also includes problem sets that challenge readers to put their new FDTD and simulation skills into practice By bridging the gap between FDTD theory and practical simulation techniques this publication is an invaluable guide for students and engineers who need to solve a wide range of design problems in RF antenna and microwave engineering

Numerical Techniques in Electromagnetics, Second Edition Matthew N.O. Sadiku,2000-07-12 As the availability of powerful computer resources has grown over the last three decades the art of computation of electromagnetic EM problems has also grown exponentially Despite this dramatic growth however the EM community lacked a comprehensive text on the computational techniques used to solve EM problems The first edition of Numerical Techniques in Electromagnetics filled that gap and became the reference of choice for thousands of engineers researchers and students The Second Edition of this bestselling text reflects the continuing increase in awareness and use of numerical techniques and incorporates advances and refinements made in recent years Most notable among these are the improvements made to the standard algorithm for the finite difference time domain FDTD method and treatment of absorbing boundary conditions in FDTD finite element and transmission line matrix methods The author also added a chapter on the method of lines Numerical Techniques in Electromagnetics continues to teach readers how to pose numerically analyze and solve EM problems give them the ability to expand their problem solving skills using a variety of methods and prepare them for research in electromagnetism Now the Second Edition goes even further toward providing a comprehensive resource that addresses all of the most useful computation methods for EM problems

Advances in Computational Electrodynamics Allen Taflove,1998 Finite Difference Time Domain FD TD modeling is arguably the most popular and powerful means available to perform detailed electromagnetic engineering analyses Edited by the pioneer and foremost authority on the subject here is the first book to assemble in one resource the latest techniques and results of the leading theoreticians and practitioners of FD TD computational electromagnetics modeling

The Finite Difference Time Domain Method for Electromagnetics Karl S. Kunz,Raymond J. Luebbers,2018-05-04 The Finite Difference Time domain FDTD method allows you to compute electromagnetic interaction for complex problem geometries with ease The simplicity of the approach coupled with its far reaching usefulness create the powerful popular method presented in The Finite Difference Time Domain Method for Electromagnetics This volume offers timeless applications and formulations you can use to treat virtually any material type and geometry The Finite Difference Time Domain Method for Electromagnetics explores the mathematical foundations of FDTD including stability outer radiation

boundary conditions and different coordinate systems It covers derivations of FDTD for use with PEC metal lossy dielectrics gyrotropic materials and anisotropic materials A number of applications are completely worked out with numerous figures to illustrate the results It also includes a printed FORTRAN 77 version of the code that implements the technique in three dimensions for lossy dielectric materials There are many methods for analyzing electromagnetic interactions for problem geometries With The Finite Difference Time Domain Method for Electromagnetics you will learn the simplest most useful of these methods from the basics through to the practical applications

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