



# The Finite-Difference Time-Domain Method for Electromagnetics with MATLAB® Simulations

2nd Edition

Atef Z. Elsherbeni and Veysel Demir

# Finite Difference Time Domain Method For Electromagnetics

**Wenhua Yu**



## **Finite Difference Time Domain Method For Electromagnetics:**

**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

**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

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

Parallel Finite-difference

Time-domain Method Wenhua Yu, 2006 The finite difference time domain FDTD 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 the *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 Advances in Computational Electrodynamics Allen Taflov, 1998 Finite Difference Time Domain FDTD 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 FDTD computational electromagnetics modeling The Finite-difference Time-domain Method for Electromagnetics with MATLAB Simulations Atef Z. Elsherbeni, Veysel Demir, 2009 Helping students to construct a program with sufficient functionality to solve some basic problems this book presents the construction of equations accompanied by 3D illustrations It also explains the transformation of the concepts into programming *Electromagnetic Pulse Simulations Using Finite-Difference Time-Domain Method* Shahid Ahmed, 2021-04-14 *Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method* Discover the utility of the FDTD approach to solving electromagnetic problems with this powerful new resource *Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method* delivers a comprehensive overview of the generation and propagation of ultra wideband electromagnetic pulses The book provides a broad cross section of studies of electromagnetic waves and their propagation in

free space dielectric media complex media and within guiding structures like waveguide lines transmission lines and antennae The distinguished author offers readers a fresh new approach for analyzing electromagnetic modes for pulsed electromagnetic systems designed to improve the reader's understanding of the electromagnetic modes responsible for radiating far fields The book also provides a wide variety of computer programs data analysis techniques and visualization tools with state of the art packages in MATLAB and Octave Following an introduction and clarification of basic electromagnetics and the frequency and time domain approach the book delivers explanations of different numerical methods frequently used in computational electromagnetics and the necessity for the time domain treatment In addition to a discussion of the Finite difference Time domain FDTD approach readers will also enjoy A thorough introduction to electromagnetic pulses EMPs and basic electromagnetics including common applications of electromagnetics and EMP coupling and its effects An exploration of time and frequency domain analysis in electromagnetics including Maxwell's equations and their practical implications A discussion of electromagnetic waves and propagation including waves in free space dielectric mediums complex mediums and guiding structures A treatment of computational electromagnetics including an explanation of why we need modeling and simulations Perfect for undergraduate and graduate students taking courses in physics and electrical and electronic engineering Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method will also earn a place in the libraries of scientists and engineers working in electromagnetic research RF and microwave design and electromagnetic interference

**The Finite-Difference Time-Domain Method for Electromagnetics with MATLAB® Simulations** Atef Z. Elsherbeni, Veysel Demir, 2015-11-25 This is one of the best books on computational electromagnetics both for graduate students focusing on electromagnetics problems and for practicing engineering professionals in industry and government It is designed as an advanced textbook and self study guide to the FDTD method of solving EM problems and simulations This latest edition has been expanded to include 5 entirely new chapters on advanced topics in the mainstream of FDTD practice In addition to advanced techniques it also includes applications and examples and some tricks and traps of using MATLAB to achieve them Compared to the previous version the second edition is more complete and is a good reference for someone who is performing FDTD research This book is part of the ACES Series on Computational Electromagnetics and Engineering Supplementary material can be found at the IET's ebook page Supplementary materials for professors are available upon request via email to books@theiet.org

**Computational Electrodynamics** Allen Taflov, 1995 This work represents a university text and professional research reference on the finite difference time domain computational solution method for Maxwell's equations Sections cover numerical stability numerical dispersion and dispersive nonlinear and gain methods of FD TD and antenna analysis

**Electromagnetic Pulse Simulations Using Finite-Difference Time-Domain Method** Shahid Ahmed, 2021-04-13 Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method Discover the utility of the FDTD approach

to solving electromagnetic problems with this powerful new resource *Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method* delivers a comprehensive overview of the generation and propagation of ultra wideband electromagnetic pulses The book provides a broad cross section of studies of electromagnetic waves and their propagation in free space dielectric media complex media and within guiding structures like waveguide lines transmission lines and antennae The distinguished author offers readers a fresh new approach for analyzing electromagnetic modes for pulsed electromagnetic systems designed to improve the reader's understanding of the electromagnetic modes responsible for radiating far fields The book also provides a wide variety of computer programs data analysis techniques and visualization tools with state of the art packages in MATLAB and Octave Following an introduction and clarification of basic electromagnetics and the frequency and time domain approach the book delivers explanations of different numerical methods frequently used in computational electromagnetics and the necessity for the time domain treatment In addition to a discussion of the Finite difference Time domain FDTD approach readers will also enjoy A thorough introduction to electromagnetic pulses EMPs and basic electromagnetics including common applications of electromagnetics and EMP coupling and its effects An exploration of time and frequency domain analysis in electromagnetics including Maxwell's equations and their practical implications A discussion of electromagnetic waves and propagation including waves in free space dielectric mediums complex mediums and guiding structures A treatment of computational electromagnetics including an explanation of why we need modeling and simulations Perfect for undergraduate and graduate students taking courses in physics and electrical and electronic engineering *Electromagnetic Pulse Simulations Using Finite Difference Time Domain Method* will also earn a place in the libraries of scientists and engineers working in electromagnetic research RF and microwave design and electromagnetic interference

Scattering Analysis of Periodic Structures using Finite-Difference Time-Domain Method Khaled ElMahgoub, Fan Yang, Atef Elsherbeni, 2022-06-01 Periodic structures are of great importance in electromagnetics due to their wide range of applications such as frequency selective surfaces FSS electromagnetic band gap EBG structures periodic absorbers meta materials and many others The aim of this book is to develop efficient computational algorithms to analyze the scattering properties of various electromagnetic periodic structures using the finite difference time domain periodic boundary condition FDTD PBC method A new FDTD PBC based algorithm is introduced to analyze general skewed grid periodic structures while another algorithm is developed to analyze dispersive periodic structures Moreover the proposed algorithms are successfully integrated with the generalized scattering matrix GSM technique identified as the hybrid FDTD GSM algorithm to efficiently analyze multilayer periodic structures All the developed algorithms are easy to implement and are efficient in both computational time and memory usage These algorithms are validated through several numerical test cases The computational methods presented in this book will help scientists and engineers to investigate and design novel periodic structures and to explore other research frontiers in electromagnetics Table of Contents Introduction

FDTD Method and Periodic Boundary Conditions Skewed Grid Periodic Structures Dispersive Periodic Structures Multilayered Periodic Structures Conclusions      **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      **Computational Electromagnetics for RF and Microwave Engineering** David B. Davidson, 2010-10-28 This hands on introduction to computational electromagnetics CEM links theoretical coverage of the three key methods the FDTD

MoM and FEM to open source MATLAB codes freely available online in 1D 2D and 3D together with many practical hints and tips gleaned from the author's 25 years of experience in the field Updated and extensively revised this second edition includes a new chapter on 1D FEM analysis and extended 3D treatments of the FDTD MoM and FEM with entirely new 3D MATLAB codes Coverage of higher order finite elements in 1D 2D and 3D is also provided with supporting code in addition to a detailed 1D example of the FDTD from a FEM perspective With running examples through the book and end of chapter problems to aid understanding this is ideal for professional engineers and senior undergraduate graduate students who need to master CEM and avoid common pitfalls in writing code and using existing software

### **Numerical Electromagnetics**

Umran S. Inan, Robert A. Marshall, 2011-04-07 Beginning with the development of finite difference equations and leading to the complete FDTD algorithm this is a coherent introduction to the FDTD method the method of choice for modeling Maxwell's equations It provides students and professional engineers with everything they need to know to begin writing FDTD simulations from scratch and to develop a thorough understanding of the inner workings of commercial FDTD software Stability numerical dispersion sources and boundary conditions are all discussed in detail as are dispersive and anisotropic materials A comparative introduction of the finite volume and finite element methods is also provided All concepts are introduced from first principles so no prior modeling experience is required and they are made easier to understand through numerous illustrative examples and the inclusion of both intuitive explanations and mathematical derivations

### **The Finite**

**Element Method in Electromagnetics** Jian-Ming Jin, 2015-02-18 A new edition of the leading textbook on the finite element method incorporating major advancements and further applications in the field of electromagnetics The finite element method FEM is a powerful simulation technique used to solve boundary value problems in a variety of engineering circumstances It has been widely used for analysis of electromagnetic fields in antennas radar scattering RF and microwave engineering high speed high frequency circuits wireless communication electromagnetic compatibility photonics remote sensing biomedical engineering and space exploration The Finite Element Method in Electromagnetics Third Edition explains the method's processes and techniques in careful meticulous prose and covers not only essential finite element method theory but also its latest developments and applications giving engineers a methodical way to quickly master this very powerful numerical technique for solving practical often complicated electromagnetic problems Featuring over thirty percent new material the third edition of this essential and comprehensive text now includes A wider range of applications including antennas phased arrays electric machines high frequency circuits and crystal photonics The finite element analysis of wave propagation scattering and radiation in periodic structures The time domain finite element method for analysis of wideband antennas and transient electromagnetic phenomena Novel domain decomposition techniques for parallel computation and efficient simulation of large scale problems such as phased array antennas and photonic crystals Along with a great many examples The Finite Element Method in Electromagnetics is an ideal book for engineering students as well as for



professionals in the field      *An Investigation of the Finite-difference Time-domain Method in Electromagnetics* Jose Luis Chavez,1991      **Numerical Techniques in Electromagnetics with MATLAB** Matthew N.O. Sadiku,2018-10-08 Despite the dramatic growth in the availability of powerful computer resources the EM community lacks 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 This third edition of the 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 has added a chapter on the method of lines Numerical Techniques in Electromagnetics with MATLAB Third Edition continues to teach 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 Now the Third Edition goes even further toward providing a comprehensive resource that addresses all of the most useful computation methods for EM problems and includes MATLAB code instead of FORTRAN

*Bioengineering and Biophysical Aspects of Electromagnetic Fields* Ben Greenebaum,Frank S. Barnes,2018-10-03 Bioengineering and Biophysical Aspects of Electromagnetic Fields primarily contains discussions on the physics engineering and chemical aspects of electromagnetic EM fields at both the molecular level and larger scales and investigates their interactions with biological systems The first volume of the bestselling and newly updated Handbook of Biological Effects of Electromagnetic Fields Third Edition this book adds material describing recent theoretical developments as well as new data on material properties and interactions with weak and strong static magnetic fields Newly separated and expanded chapters describe the external and internal electromagnetic environments of organisms and recent developments in the use of RF fields for imaging Bioengineering and Biophysical Aspects of Electromagnetic Fields provides an accessible overview of the current understanding on the scientific underpinnings of these interactions as well as a partial introduction to experiments on the interactions themselves

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