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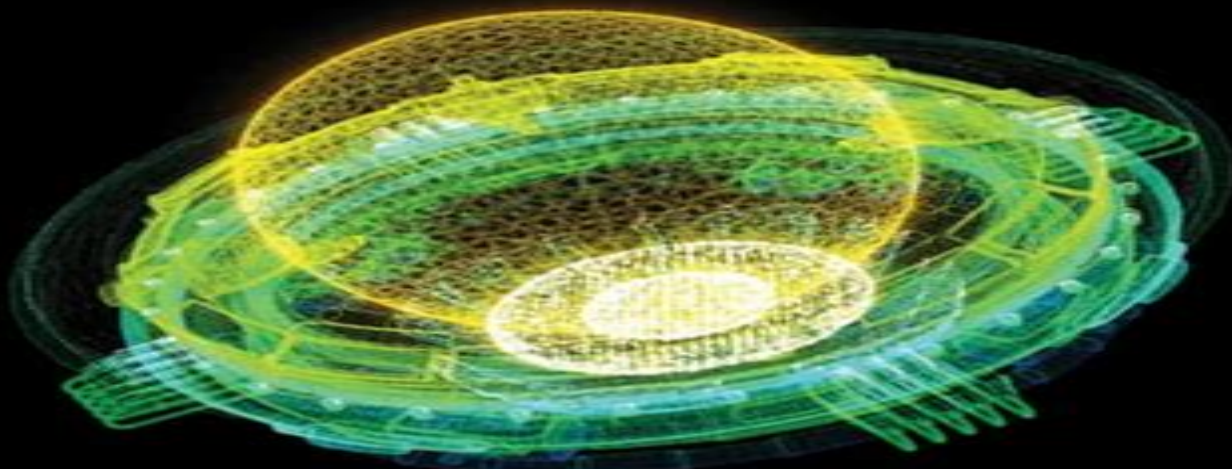
Electromagnetic Simulation Using the FDTD Method with Python

Jennifer E. Houle | Dennis M. Sullivan

Electromagnetic Simulation Using The Fdtd Method

Dennis M. Sullivan

Electromagnetic Simulation Using The Fdtd Method:

   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 Using the FDTD Method with Python** Jennifer E. Houle,Dennis M. Sullivan,2020-01-15 Provides an introduction to the Finite Difference Time Domain method and shows how Python code can be used to implement various simulations This book allows engineering students and practicing engineers to learn the finite difference time domain FDTD method and properly apply it toward their electromagnetic simulation projects Each chapter contains a concise explanation of an essential concept and instruction on its implementation into computer code Included projects increase in complexity ranging from simulations in free space to propagation in dispersive media This third edition utilizes the Python programming language which is becoming the preferred computer language for the engineering and scientific community Electromagnetic Simulation Using the FDTD Method with Python Third Edition is written with the goal of enabling readers to learn the FDTD method in a manageable amount of time Some basic applications of signal processing theory are explained to enhance the effectiveness of FDTD simulation Topics covered in include one dimensional simulation with the FDTD method two dimensional simulation and three dimensional simulation The book also covers advanced Python features and deep regional hyperthermia treatment planning Electromagnetic Simulation Using the FDTD Method with Python Guides the reader from basic programs to complex three dimensional programs in a tutorial fashion Includes a rewritten fifth chapter that illustrates the most interesting applications in FDTD and the advanced graphics techniques of Python Covers peripheral topics pertinent to time domain simulation such as Z transforms and the discrete Fourier transform Provides Python simulation programs on an accompanying website An ideal book for senior undergraduate engineering students studying FDTD Electromagnetic

Simulation Using the FDTD Method with Python will also benefit scientists and engineers interested in the subject

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   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 Equations 1 1 2 Stability Analysis 1 1 3 Boundary Conditions 1 2 METHOD OF MOMENTS 1 3 FINITE ELEMENT METHOD 1 3 1 Scalar Formulation 1 3 2 Vector Formulation 1 4 FINITE INTEGRATION TECHNIQUE References Chapter 2 FDTD Optimization and Acceleration 2 1 INTRODUCTION TO CPU ARCHITECTURE 2 2 SSE INSTRUCTION SET 2 3 CACHE OPTIMIZATION 2 4 TASK PARALLELIZATION AND BUNDLING 2 5 PREFETCH 2 6 READING OR WRITING COMBINATION 2 7 MATERIAL LOOP UP TABLE 2 8 NUMA OPTIMIZATION 2 9 IMPLEMENTATION OF VALU FDTD METHOD References Chapter 3 Parallel FDTD Method and Systems 3 1 PARALLEL FDTD METHOD 3 2 OPENMP FOR MULTICORE PROCESSORS 3 3 MPI TECHNIQUE 3 4 NETWORK CARD SWITCH AND CABLE References Chapter 4 Electromagnetic Simulation Techniques 4 1 MESH GENERATION TECHNIQUES 4 2 BASIC SIMULATION PROCEDURE 4 3 DIPOLE ANTENNA 4 4 VIVALDI ANTENNA SIMULATION 4 5 BANDED MICROWAVE CONNECTOR 4 6 PARALLEL LINES 4 7 TWO PORT ANTENNA 4 8 SLOT COUPLING 4 9 MICROWAVE FILTER 4 10 OPTIMIZATION AND PARAMETER SCAN 4 11 PERIODIC STRUCTURE SIMULATION 4 12 GROUND PENETRATING RADAR MODEL 4 13 MICROWAVE CONNECTOR References Chapter 5 EM Simulation Software Benchmarks 5 1 BASIC STEPS IN EM SIMULATION 5 1 1 HFSS 5 1 2 CST 5 1 3 FEKO 5 1 4 GEMS 5 2 HARDWARE PLATFORMS 5 3 PATCH ANTENNA 5 4 VIVALDI ANTENNA 5 5 SCATTERING OF

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   Computational Electromagnetics Raj Mittra,2013-08-20 Emerging Topics in Computational Electromagnetics in Computational Electromagnetics presents advances in Computational Electromagnetics This book is designed to fill the existing gap in current CEM literature that only cover the conventional numerical techniques for solving traditional EM problems The book examines new algorithms and applications of these algorithms for solving problems of current interest that are not readily amenable to efficient treatment by using the existing techniques The authors discuss solution techniques for problems arising in nanotechnology bioEM metamaterials as well as multiscale problems They present techniques that utilize recent advances in computer technology such as parallel architectures and the increasing need to solve large and complex problems in a time efficient manner by using highly scalable algorithms   **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

Electromagnetic and Photonic Simulation for the Beginner: Finite-Difference Frequency-Domain in MATLAB® Raymond C. Rumpf,2022-01-31 This book teaches the finite difference frequency domain FDFD method from the simplest concepts to advanced three dimensional simulations It uses plain language and high quality graphics to help the complete beginner grasp all the concepts quickly and visually This single resource includes everything needed to simulate a wide variety of different electromagnetic and photonic devices The book is filled with helpful guidance and computational wisdom that will help the reader easily simulate their own devices and more easily learn and implement other methods in computational electromagnetics Special techniques in MATLAB are presented that will allow the reader to write their own FDFD programs Key concepts in electromagnetics are reviewed so the reader can fully understand the calculations happening in FDFD A powerful method for implementing the finite difference method is taught that will enable the reader to solve entirely new differential equations and sets of differential equations in mere minutes Separate chapters are included that describe how Maxwell s equations are approximated using finite differences and how outgoing waves can be absorbed using a perfectly matched layer absorbing boundary With this background a chapter describes how to calculate guided modes in waveguides and transmission lines The effective index method is taught as way to model many three dimensional devices in just two dimensions Another chapter describes how to calculate photonic band diagrams and isofrequency contours to quickly estimate the properties of periodic structures like photonic crystals Next a chapter presents how to analyze diffraction gratings and calculate the power coupled into each diffraction order This book shows that many devices can be simulated in the context of a diffraction grating including guided mode resonance filters photonic crystals polarizers metamaterials frequency selective surfaces and metasurfaces Plane wave sources Gaussian beam sources and guided mode sources are all described in detail allowing devices to be simulated in multiple ways An optical integrated circuit is simulated using the effective index method to build a two dimensional model of the 3D device and then launch a guided mode source into the circuit A chapter is included to describe how the code can be modified to easily perform parameter sweeps such as plotting reflection and transmission as a function of frequency wavelength angle of incidence or a dimension of the device The last chapter is advanced and teaches FDFD for three dimensional devices composed of anisotropic materials It includes simulations of a crossed grating a doubly periodic guided mode resonance filter a frequency selective surface and an invisibility cloak The chapter also includes a parameter retrieval from a left handed metamaterial The book includes all the MATLAB codes and detailed explanations of all programs This will allow the reader to easily modify the codes to simulate their own ideas and devices The author has created a website where the MATLAB codes can be downloaded errata can be seen and other learning resources can be accessed This is an ideal book for both an undergraduate elective course as well as

a graduate course in computational electromagnetics because it covers the background material so well and includes examples of many different types of devices that will be of interest to a very wide audience   *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   **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 Electromagnetic Computation Dikshitulu K. Kalluri,2017-11-28 Advanced Electromagnetic Computation with MATLAB discusses commercial electromagnetic software widely used in the industry Algorithms of Finite Differences Moment method Finite Element method and Finite Difference Time Domain method are illustrated Hand computed simple examples and MATLAB coded examples are used to explain the concepts behind the algorithms Case studies of practical examples from transmission lines waveguides and electrostatic problems are given so students are able to develop the code and solve the problems Two new chapters including advanced methods based on perturbation techniques and three dimensional finite element examples from radiation scattering are included   **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

Comprehensive Nanoscience and Technology ,2010-10-29 From the Introduction Nanotechnology and its underpinning sciences are progressing with unprecedented rapidity With technical advances in a variety of nanoscale fabrication and manipulation technologies the whole topical area is maturing into a vibrant field that is generating new scientific research and a burgeoning range of commercial applications with an annual market already at the trillion dollar threshold The means of fabricating and controlling matter on the nanoscale afford striking and unprecedented opportunities to exploit a variety of exotic phenomena such as quantum nanophotonic and nanoelectromechanical effects Moreover researchers are elucidating new perspectives on the electronic and optical properties of matter because of the way that nanoscale materials bridge the disparate theories describing molecules and bulk matter Surface phenomena also gain a greatly increased significance even the well known link between chemical reactivity and surface to volume ratio becomes a major determinant of physical properties when it operates over nanoscale dimensions Against this background this comprehensive work is designed to address the need for a dynamic authoritative and readily accessible source of information capturing the full breadth of the subject Its six volumes covering a broad spectrum of disciplines including material sciences chemistry physics and life sciences have been written and edited by an outstanding team of international experts Addressing an extensive cross disciplinary audience each chapter aims to cover key developments in a scholarly readable and critical style providing an indispensible first point of entry to the literature for scientists and technologists from interdisciplinary fields The work focuses on the major classes of nanomaterials in terms of their synthesis structure and applications reviewing nanomaterials and their respective technologies in well structured and comprehensive articles with extensive cross references It has been a constant surprise and delight to have found amongst the rapidly escalating number who work in nanoscience and technology so many highly esteemed authors willing to contribute Sharing our anticipation of a major addition to the literature they have also captured the excitement of the field itself in each carefully crafted chapter Along with our painstaking and meticulous volume editors full credit for the success of this enterprise must go to these individuals together with our thanks for largely adhering to the given deadlines Lastly we record our sincere thanks and appreciation for the skills and professionalism of the numerous Elsevier staff who have been involved in this project notably Fiona Geraghty Megan Palmer and Greg Harris and especially Donna De Weerd Wilson who has steered it through from its inception We

have greatly enjoyed working with them all as we have with each other   Analytical and Computational Methods in Electromagnetics Ramesh Garg,2008 This authoritative resource offers you clear and complete explanation of this essential electromagnetics knowledge providing you with the analytical background you need to understand such key approaches as MoM method of moments FDTD Finite Difference Time Domain and FEM Finite Element Method and Green s functions This comprehensive book includes all math necessary to master the material   Subwavelength Optics Theory and Technology Yongqi Fu,2009 From the beginning of this century there has been a dramatic increase in interest in the study of surface plasmon polaritons based metallic subwavelength structures and learning This is a refreshing concise book on issues and considerations in designing   **Applied Mathematics, Modeling and Computer Simulation** Chi-Hua Chen,Andrea Scapellato,Alessandro Barbiero,Dmitry G. Korzun,2024-01-15 Applied mathematics modelling and computer simulation are central to many aspects of engineering and computer science and continue to be of intrinsic importance to the development of modern technologies This book presents the proceedings of AMMCS 2023 the 3rd International Conference on Applied Mathematics Modeling and Computer Simulation held on 12 and 13 August 2023 in Wuhan China The conference provided an ideal opportunity for scholars and researchers to communicate important recent developments in their areas of specialization to their colleagues and to scientists in related disciplines More than 250 submissions were received for the conference of which 133 were selected for presentation at the conference and inclusion here after a thorough peer review process These range from the theoretical and conceptual to strongly pragmatic papers addressing industrial best practice and cover topics such as mathematical modeling and application engineering applications and scientific computations and the simulation of intelligent systems The book explores practical experiences and enlightening ideas and will be of interest to researchers practitioners and to all those working in the fields of applied mathematics modeling and computer simulation
    Integrated Silicon-Metal Systems at the Nanoscale Munir H. Nayfeh,Ammar Nayfeh,2023-04-12 Integrated Silicon Metal Systems at the Nanoscale Applications in Photonics Quantum Computing Networking and Internet is a comprehensive guide to the interaction materials and functional integration at the nanoscale of the silicon metal binary system and a variety of emerging and next generation advanced device applications from energy and electronics to sensing quantum computing and quantum internet networks The book guides the readers through advanced techniques and etching processes combining underlying principles materials science design and operation of metal Si nanodevices Each chapter focuses on a specific use of integrated metal silicon nanostructures including storage and resistive next generation nano memory and transistors photo and molecular sensing harvest and storage device electrodes phosphor light converters and hydrogen fuel cells as well as future application areas such as spin transistors quantum computing hybrid quantum devices and quantum engineering networking and internet Provides detailed coverage of materials design and operation of metal Si nanodevices Offers a step by step approach supported by principles methods illustrations and equations Explores a range of cutting edge emerging

applications across electronics sensing and quantum computing **Radio Wave Propagation and Parabolic Equation Modeling** Gokhan Apaydin,Levent Sevgi,2017-10-16 An important contribution to the literature that introduces powerful new methods for modeling and simulating radio wave propagation A thorough understanding of electromagnetic wave propagation is fundamental to the development of sophisticated communication and detection technologies The powerful numerical methods described in this book represent a major step forward in our ability to accurately model electromagnetic wave propagation in order to establish and maintain reliable communication links to detect targets in radar systems and to maintain robust mobile phone and broadcasting networks The first new book on guided wave propagation modeling and simulation to appear in nearly two decades Radio Wave Propagation and Parabolic Equation Modeling addresses the fundamentals of electromagnetic wave propagation generally with a specific focus on radio wave propagation through various media The authors explore an array of new applications and detail various virtual electromagnetic tools for solving several frequent electromagnetic propagation problems All of the methods described are presented within the context of real world scenarios typifying the differing effects of various environments on radio wave propagation This valuable text Addresses groundwave and surface wave propagation Explains radar applications in terms of parabolic equation modeling and simulation approaches Introduces several simple and sophisticated MATLAB scripts Teaches applications that work with a wide range of electromagnetic acoustic and optical wave propagation modeling Presents the material in a quick reference format ideal for busy researchers and engineers Radio Wave Propagation and Parabolic Equation Modeling is a critical resource forelectrical electronics communication and computer engineers working on industrial and military applications that rely on the directed propagation of radio waves It is also a useful reference for advanced engineering students and academic researchers *One-Dimensional Nanostructures* Zhiming M Wang,2008-07-20 One dimensional 1D nanostructures including nanowires nanotubes and quantum wires have been regarded as the most promising building blocks for nanoscale electronic and optoelectronic devices Worldwide efforts in both the theory and the experimental investigation of growth characterization and applications of 1D nanostructures have resulted in a mature multidisciplinary field In this book a wealth of state of the art information offers the opportunity to uncover the underlying science from diverse perspectives Leading researchers elucidate the synthesis and properties of 1D nanostructures for various morphologies and compositions semiconductor metal carbon etc as well as their considerable impact on spintronics information storage and the design of field effect transistors *Practical Antenna Design for Wireless Products* Henry Lau,2019-07-31 This comprehensive resource covers both antenna fundamentals and practical implementation strategies presenting antenna design with optimum performance in actual products and systems The book helps readers bridge the gap between electromagnetic theory and its application in the design of practical antennas in real products Practical implementation strategies in products and systems will be addressed in order to design antennas in the context of actual product

environments including PCB layout component placement and casing design Practical design examples on wearable electronic products are presented with a systematic approach to designing antennas for actual products The book introduces antenna fundamentals to provide the basic concepts and necessary mathematics on electromagnetic analysis followed by advanced antenna elements The concept of electromagnetic simulation is presented The advantages and disadvantages of different numerical methods in antenna modeling are also discussed Several commercial antenna design and simulation tools are introduced allowing hands on practice of antenna modeling and simulation

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Table of Contents Electromagnetic Simulation Using The Fdtd Method

1. Understanding the eBook Electromagnetic Simulation Using The Fdtd Method
    - The Rise of Digital Reading Electromagnetic Simulation Using The Fdtd Method
    - Advantages of eBooks Over Traditional Books
2. Identifying Electromagnetic Simulation Using The Fdtd Method
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Electromagnetic Simulation Using The Fdtd Method
    - User-Friendly Interface
4. Exploring eBook Recommendations from Electromagnetic Simulation Using The Fdtd Method
    - Personalized Recommendations
    - Electromagnetic Simulation Using The Fdtd Method User Reviews and Ratings
    - Electromagnetic Simulation Using The Fdtd Method and Bestseller Lists

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