

Multigrid Finite Element Methods for Electromagnetic Field Modeling



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Multigrid Finite Element Methods For Electromagnetic Field Modeling

Jian-Ming Jin, Douglas J. Riley



Multigrid Finite Element Methods For Electromagnetic Field Modeling:

Multigrid Finite Element Methods for Electromagnetic Field Modeling Yu Zhu, Andreas C. Cangellaris, 2006-02-03

This is the first comprehensive monograph that features state of the art multigrid methods for enhancing the modeling versatility numerical robustness and computational efficiency of one of the most popular classes of numerical electromagnetic field modeling methods the method of finite elements The focus of the publication is the development of robust preconditioners for the iterative solution of electromagnetic field boundary value problems BVPs discretized by means of finite methods Specifically the authors set forth their own successful attempts to utilize concepts from multigrid and multilevel methods for the effective preconditioning of matrices resulting from the approximation of electromagnetic BVPs using finite methods Following the authors careful explanations and step by step instruction readers can duplicate the authors results and take advantage of today s state of the art multigrid multilevel preconditioners for finite element based iterative electromagnetic field solvers Among the highlights of coverage are Application of multigrid multilevel and hybrid multigrid multilevel preconditioners to electromagnetic scattering and radiation problems Broadband robust numerical modeling of passive microwave components and circuits Robust finite element based modal analysis of electromagnetic waveguides and cavities Application of Krylov subspace based methodologies for reduced order macromodeling of electromagnetic devices and systems Finite element modeling of electromagnetic waves in periodic structures The authors provide more than thirty detailed algorithms alongside pseudo codes to assist readers with practical computer implementation In addition each chapter includes an applications section with helpful numerical examples that validate the authors methodologies and demonstrate their computational efficiency and robustness This groundbreaking book with its coverage of an exciting new enabling computer aided design technology is an essential reference for computer programmers designers and engineers as well as graduate students in engineering and applied physics

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

Electromagnetic Fields Jean G. Van Bladel, 2007-05-23 Professor Jean Van Bladel an eminent researcher and educator in fundamental electromagnetic theory and its application in electrical engineering has updated and expanded his definitive text and reference on electromagnetic fields to twice its original content This new edition incorporates the latest methods theory formulations and applications that relate to today s technologies With an emphasis on basic principles and a focus on electromagnetic formulation and analysis Electromagnetic Fields Second Edition includes detailed discussions of electrostatic fields potential theory propagation in waveguides and unbounded space scattering by obstacles penetration through apertures and field behavior at high and low frequencies

Circuit Oriented Electromagnetic Modeling Using the PEEC Techniques Albert Ruehli, Giulio Antonini, Lijun Jiang, 2017-06-19 Bridges the gap between electromagnetics and circuits by addressing electrometric modeling EM using the Partial Element Equivalent Circuit PEEC method This book provides intuitive solutions to electromagnetic problems by using the Partial Element Equivalent Circuit PEEC method This book begins with an introduction to circuit analysis techniques laws and frequency and time domain analyses The authors also treat Maxwell s equations capacitance computations and inductance computations through the lens of the PEEC method Next readers learn to build PEEC models in various forms equivalent circuit models non orthogonal PEEC models skin effect models PEEC models for dielectrics incident and radiate field models and scattering PEEC models The book concludes by considering issues like stability and passivity and includes five appendices some with formulas for partial elements Leads readers to the solution of a multitude of practical problems in the areas of signal and power integrity and electromagnetic interference Contains fundamentals applications and examples of the PEEC method Includes detailed mathematical derivations Circuit Oriented Electromagnetic Modeling Using the PEEC Techniques is a reference for students researchers and developers who work on the physical layer modeling of IC interconnects and Packaging PCBs and high speed links

The Nystrom Method in Electromagnetics Mei Song Tong, Weng Cho Chew, 2020-06-29 A comprehensive step by step reference to the Nystr m Method for solving Electromagnetic problems using integral equations Computational electromagnetics studies the numerical methods or techniques that solve electromagnetic problems by computer programming Currently there are mainly three numerical methods for electromagnetic problems the finite difference time domain FDTD finite element method FEM and integral equation methods IEMs In the IEMs the method of moments MoM is the most widely used method but much attention is being paid to the Nystr m method as another IEM because it possesses

some unique merits which the MoM lacks This book focuses on that method providing information on everything that students and professionals working in the field need to know Written by the top researchers in electromagnetics this complete reference book is a consolidation of advances made in the use of the Nyström method for solving electromagnetic integral equations It begins by introducing the fundamentals of the electromagnetic theory and computational electromagnetics before proceeding to illustrate the advantages unique to the Nyström method through rigorous worked out examples and equations Key topics include quadrature rules singularity treatment techniques applications to conducting and penetrable media multiphysics electromagnetic problems time domain integral equations inverse scattering problems and incorporation with multilevel fast multiple algorithm Systematically introduces the fundamental principles equations and advantages of the Nyström method for solving electromagnetic problems Features the unique benefits of using the Nyström method through numerical comparisons with other numerical and analytical methods Covers a broad range of application examples that will point the way for future research The Nystrom Method in Electromagnetics is ideal for graduate students senior undergraduates and researchers studying engineering electromagnetics computational methods and applied mathematics Practicing engineers and other industry professionals working in engineering electromagnetics and engineering mathematics will also find it to be incredibly helpful

Theory and Computation of Electromagnetic Fields in Layered Media Vladimir Okhmatovski, Shucheng Zheng, 2024-04-09 Explore the algorithms and numerical methods used to compute electromagnetic fields in multi layered media In Theory and Computation of Electromagnetic Fields in Layered Media two distinguished electrical engineering researchers deliver a detailed and up to date overview of the theory and numerical methods used to determine electromagnetic fields in layered media The book begins with an introduction to Maxwell's equations the fundamentals of electromagnetic theory and concepts and definitions relating to Green's function It then moves on to solve canonical problems in vertical and horizontal dipole radiation describe Method of Moments schemes discuss integral equations governing electromagnetic fields and explains the Michalski Zheng theory of mixed potential Green's function representation in multi layered media Chapters on the evaluation of Sommerfeld integrals procedures for far field evaluation and the theory and application of hierarchical matrices are also included along with A thorough introduction to free space Green's functions including the delta function model for point charge and dipole current Comprehensive explorations of the traditional form of layered medium Green's function in three dimensions Practical discussions of electro quasi static and magneto quasi static fields in layered media including electrostatic fields in two and three dimensions In depth examinations of the rational function fitting method including direct spectra fitting with VECTFIT algorithms Perfect for scholars and students of electromagnetic analysis in layered media Theory and Computation of Electromagnetic Fields in Layered Media will also earn a place in the libraries of CAD industry engineers and software developers working in the area of computational electromagnetics

Electromagnetic Modeling and Simulation Levent Sevgi, 2014-03-13 This unique book

presents simple easy to use but effective short codes as well as virtual tools that can be used by electrical electronic communication and computer engineers in a broad range of electrical engineering problems Electromagnetic modeling is essential to the design and modeling of antenna radar satellite medical imaging and other applications In this book author Levent Sevgi explains techniques for solving real time complex physical problems using MATLAB based short scripts and comprehensive virtual tools Unique in coverage and tutorial approach Electromagnetic Modeling and Simulation covers fundamental analytical and numerical models that are widely used in teaching research and engineering designs including mode and ray summation approaches with the canonical 2D nonpenetrable parallel plate waveguide as well as FDTD MoM and SSPE scripts The book also establishes an intelligent balance among the essentials of EM MODSIM The Problem the physics The Theory and Models mathematical background and analytical solutions and The Simulations code developing plus validation verification and calibration Classroom tested in graduate level and short courses Electromagnetic Modeling and Simulation Clarifies concepts through numerous worked problems and quizzes provided throughout the book Features valuable MATLAB based user friendly effective engineering and research virtual design tools Includes sample scenarios and video clips recorded during characteristic simulations that visually impact learning available on wiley com Provides readers with their first steps in EM MODSIM as well as tools for medium and high level code developers and users Electromagnetic Modeling and Simulation thoroughly covers the physics mathematical background analytical solutions and code development of electromagnetic modeling making it an ideal resource for electrical engineers and researchers

Electromagnetic Fields in Cavities David A. Hill, 2009-10-27 A thorough and rigorous analysis of electromagnetic fields in cavities This book offers a comprehensive analysis of electromagnetic fields in cavities of general shapes and properties Part One covers classical deterministic methods to conclude resonant frequencies modal fields and cavity losses quality factor mode bandwidth and the excitation of cavity fields from arbitrary current distributions for metal wall cavities of simple shape Part Two covers modern statistical methods to analyze electrically large cavities of complex shapes and properties Electromagnetic Fields in Cavities combines rigorous solutions to Maxwell's equations with conservation of energy to solve for the statistics of many quantities of interest penetration into cavities and shielding effectiveness field strengths far from and close to cavity walls and power received by antennas within cavities It includes all modes and shows you how to utilize fairly simple statistical formulae to apply to your particular problem whether it's interference calculations electromagnetic compatibility testing in reverberation chambers measurement of shielding materials using multiple cavities or efficiency of test antennas Electromagnetic Fields in Cavities is a valuable resource for researchers engineers professors and graduate students in electrical engineering

Automated Solution of Differential Equations by the Finite Element Method Anders Logg, Kent-Andre Mardal, Garth Wells, 2012-02-24 This book is a tutorial written by researchers and developers behind the FEniCS Project and explores an advanced expressive approach to the development of mathematical software The presentation spans mathematical

background software design and the use of FEniCS in applications Theoretical aspects are complemented with computer code which is available as free open source software The book begins with a special introductory tutorial for beginners Following are chapters in Part I addressing fundamental aspects of the approach to automating the creation of finite element solvers Chapters in Part II address the design and implementation of the FEniCS software Chapters in Part III present the application of FEniCS to a wide range of applications including fluid flow solid mechanics electromagnetics and geophysics

Multiforms, Dyadics, and Electromagnetic Media Ismo V. Lindell, 2015-02-20 This book applies the four dimensional formalism with an extended toolbox of operation rules allowing readers to define more general classes of electromagnetic media and to analyze EM waves that can exist in them End of chapter exercises Formalism allows readers to find novel classes of media Covers various properties of electromagnetic media in terms of which they can be set in different classes

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 **Finite**

Element Analysis of Antennas and Arrays Jian-Ming Jin, Douglas J. Riley, 2009-02-23 The Most Complete Up to Date Coverage of the Finite Element Analysis and Modeling of Antennas and Arrays Aimed at researchers as well as practical engineers and packed with over 200 illustrations including twenty two color plates Finite Element Analysis of Antennas and Arrays presents Time and frequency domain formulations and mesh truncation techniques Antenna source modeling and parameter calculation Modeling of complex materials and fine geometrical details Analysis and modeling of narrowband and broadband antennas Analysis and modeling of infinite and finite phased array antennas Analysis and modeling of antenna and platform interactions Recognizing the strengths of other numerical methods this book goes beyond the finite element method and covers hybrid techniques that combine the finite element method with the finite difference time domain method the method of moments and the high frequency asymptotic methods to efficiently deal with a variety of complex antenna problems Complemented with numerous examples this cutting edge resource fully demonstrates the power and capabilities of the finite element analysis and its many practical applications **Resonant Infrared Detectors And Emitters**

Kwong-kit Choi, 2024-05-24 This book is a sequel of The Physics of Quantum Well Infrared Photodetectors 1997 which covered the basic physics of QWIPs In the intervening 27 years QWIP properties pertinent to infrared detection are much

better understood and QWIP technology has become a mainstream widely deployed infrared technology. The main progress is the ability to know the QWIP absorption quantum efficiency quantitatively through rigorous electromagnetic modeling. The lack of theoretical prediction has impeded QWIP development for a long time. Generally an arbitrary choice of detector structures yields substantial variations of absorption properties and QWIP was regarded as a low quantum efficiency detector. With the advent of electromagnetic modeling quantum efficiency of any detector geometry can be known exactly and be optimized to attain a large satisfactory value. Consequently all properties of QWIPs are predictable not unlike prevailing silicon devices. This unique characteristic enables QWIP to be the most manufacturable long wavelength infrared technology in mass production. This book by K K Choi a co inventor of QWIPs will capture this exciting development. Based on the materials expounded in the book the reader will know key performance metrics in infrared detection in depth knowledge of QWIP material and structural designs array production its application and practical knowledge of electromagnetic modeling. In addition the book will describe using micro and nano structures to enhance the emission properties of active and passive optical emitters similar to detectors. The application of rigorous electromagnetic modeling to optical emitters is new to the optoelectronic community. The resonator pixel emitter structure with its modeling method will no doubt be able to attract substantial academic and industrial attention in years to come.

Adaptive Phased Array Thermotherapy for Cancer

Alan Jeffrey Fenn, 2009 From electromagnetic field theory for tissue heating to simulations of adaptive phased array thermotherapy for deep tumors of the torso to coverage of arrays for tumors in the head neck breast and chest wall this timely resource offers you expert guidance in this emerging area.

Electromagnetic Theory Julius Adams

Stratton, 2007-01-22 This book is an electromagnetics classic. Originally published in 1941 it has been used by many generations of students teachers and researchers ever since. Since it is classic electromagnetics every chapter continues to be referenced to this day. This classic reissue contains the entire original edition first published in 1941. Additionally two new forewords by Dr Paul E Gray former MIT President and colleague of Dr Stratton and another by Dr Donald G Dudley Editor of the IEEE Press Series on E M Waves on the significance of the book's contribution to the field of Electromagnetics.

Ultrawideband Phased Array Antenna Technology for Sensing and Communications Systems Alan J. Fenn, Peter

T. Hurst, 2015-04-10 Practical ultrawideband phased array technology used in airborne and ground based systems applications. Ultrawideband phased array antennas are an enabling technology for many ground based and airborne communications and radar systems. This book surveys electromagnetic theory and phased array antenna theory and provides examples of ultrawideband phased array antenna technology. It describes some of the research on ultrawideband phased arrays undertaken by the authors and their colleagues at MIT Lincoln Laboratory over the last ten years. The book focuses on experimental prototype ultrawideband phased array technology developed at Lincoln Laboratory for applications in the VHF and UHF bands from approximately 100 MHz to 1 GHz and addresses dipole monopole loop and other antenna array

elements It offers examples of antennas for both airborne and ground vehicle applications Most of the examples are developed in the context of rapid prototyping for quick assessment of communications and radar systems feasibility with measurements and numerical electromagnetic simulation results provided for many prototype examples The book is intended primarily for practicing antenna engineers radar engineers and communications engineers and for graduate students and researchers in electrical engineering Readers need no prior knowledge of ultrawideband antennas although some background in electromagnetic theory antennas radar and communications would be helpful

Electromagnetic Vortices Zhi Hao Jiang, Douglas H. Werner, 2021-12-09 Discover the most recent advances in electromagnetic vortices In *Electromagnetic Vortices Wave Phenomena and Engineering Applications* a team of distinguished researchers delivers a cutting edge treatment of electromagnetic vortex waves including their theoretical foundation related wave properties and several potentially transformative applications The book is divided into three parts The editors first include resources that describe the generation sorting and manipulation of vortex waves as well as descriptions of interesting wave behavior in the infrared and optical regimes with custom designed nanostructures They then discuss the generation multiplexing and propagation of vortex waves at the microwave and millimeter wave frequencies Finally the selected contributions discuss several representative practical applications of vortex waves from a system perspective With coverage that incorporates demonstration examples from a wide range of related sub areas this essential edited volume also offers Thorough introductions to the generation of optical vortex beams and transformation optical vortex wave synthesizers Comprehensive explorations of millimeter wave metasurfaces for high capacity and broadband generation of vector vortex beams as well as orbital angular momentum OAM detection and its observation in second harmonic generations Practical discussions of microwave SPP circuits and coding metasurfaces for vortex beam generation and OAM based structured radio beams and their applications In depth examinations and explorations of OAM multiplexing for wireless communications wireless power transmission as well as quantum communications and simulations Perfect for students of wireless communications antenna RF design optical communications and nanophotonics *Electromagnetic Vortices Wave Phenomena and Engineering Applications* is also an indispensable resource for researchers in academia at large defense contractors and in government labs

Discontinuities in the Electromagnetic Field M. Mithat Idemen, 2011-10-18 A multifaceted approach to understanding calculating and managing electromagnetic discontinuities Presenting new innovative approaches alongside basic results this text helps readers better understand calculate and manage the discontinuities that occur within the electromagnetic field Among the electromagnetic discontinuities explored in this volume are Bounded jump discontinuities at the interfaces between two media or on the material sheets that model very thin layers Unbounded values at the edges of wedge type structures Unbounded values at the tips of conical structures The text examines all the key issues related to the bodies that carry the interfaces edges or tips whether these bodies are at rest or in motion with respect to an observer In

addition to its clear explanations the text offers plenty of step by step examples to clarify complex theory and calculations Moreover readers are encouraged to fine tune their skills and knowledge by solving the text s problem sets Three fundamental classical theories serve as the foundation for this text distributions confluence and the special theory of relativity The text sets forth the fundamentals of all three of these theories for readers who are not fully familiar with them Moreover the author demonstrates how to solve electromagnetic discontinuity problems by seamlessly combining all three theories into a single approach With this text as their guide readers can apply a unique philosophy and approach to the investigation and development of structures that have the potential to enhance the capabilities of electronics antennas microwaves acoustics medicine and many more application areas *Computational Physics* Philipp O.J. Scherer,2017-09-07 This textbook presents basic numerical methods and applies them to a large variety of physical models in multiple computer experiments Classical algorithms and more recent methods are explained Partial differential equations are treated generally comparing important methods and equations of motion are solved by a large number of simple as well as more sophisticated methods Several modern algorithms for quantum wavepacket motion are compared The first part of the book discusses the basic numerical methods while the second part simulates classical and quantum systems Simple but non trivial examples from a broad range of physical topics offer readers insights into the numerical treatment but also the simulated problems Rotational motion is studied in detail as are simple quantum systems A two level system in an external field demonstrates elementary principles from quantum optics and simulation of a quantum bit Principles of molecular dynamics are shown Modern boundary element methods are presented in addition to standard methods and waves and diffusion processes are simulated comparing the stability and efficiency of different methods A large number of computer experiments is provided which can be tried out even by readers with no programming skills Exercises in the applets complete the pedagogical treatment in the book In the third edition Monte Carlo methods and random number generation have been updated taking recent developments into account Krylov space methods for eigenvalue problems are discussed in much more detail Short time Fourier transformation and wavelet transformation have been included as tools for time frequency analysis Lastly elementary quantum many body problems demonstrate the application of variational and Monte Carlo methods

Electromagnetic Radiation, Scattering, and Diffraction Prabhakar H. Pathak,Robert J. Burkholder,2021-12-21 Electromagnetic Radiation Scattering and Diffraction Discover a graduate level text for students specializing in electromagnetic wave radiation scattering and diffraction for engineering applications In Electromagnetic Radiation Scattering and Diffraction distinguished authors Drs Prabhakar H Pathak and Robert J Burkholder deliver a thorough exploration of the behavior of electromagnetic fields in radiation scattering and guided wave environments The book tackles its subject from first principles and includes coverage of low and high frequencies It stresses physical interpretations of the electromagnetic wave phenomena along with their underlying mathematics The authors emphasize fundamental principles

and provide numerous examples to illustrate the concepts contained within. Students with a limited undergraduate electromagnetic background will rapidly and systematically advance their understanding of electromagnetic wave theory until they can complete useful and important graduate level work on electromagnetic wave problems. Electromagnetic Radiation Scattering and Diffraction also serves as a practical companion for students trying to simulate problems with commercial EM software and trying to better interpret their results. Readers will also benefit from the breadth and depth of topics such as Basic equations governing all electromagnetic EM phenomena at macroscopic scales are presented systematically. Stationary and relativistic moving boundary conditions are developed. Waves in planar multilayered isotropic and anisotropic media are analyzed. EM theorems are introduced and applied to a variety of useful antenna problems. Modal techniques are presented for analyzing guided wave and periodic structures. Potential theory and Green's function methods are developed to treat interior and exterior EM problems. Asymptotic High Frequency methods are developed for evaluating radiation. Integrals to extract ray fields. Edge and surface diffracted ray fields as well as surface leaky and lateral wave fields are obtained. A collective ray analysis for finite conformal antenna phased arrays is developed. EM beams are introduced and provide useful basis functions. Integral equations and their numerical solutions via the method of moments are developed. The fast multipole method is presented. Low frequency breakdown is studied. Characteristic modes are discussed. Perfect for graduate students studying electromagnetic theory. Electromagnetic Radiation Scattering and Diffraction is an invaluable resource for professional electromagnetic engineers and researchers working in this area.

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