Electromagnetic penetration and scattering problems are difficult to treat with many analytical or numerical methods because of the inability of these methods to simply deal with the effects of structure materials, apertures, curvatures, corners, and internal contents. In previous programs, a new approach for the direct modeling of very complex electromagnetic interaction problems was studied: the finite-difference, time-domain (FD-TD) solution of Maxwell's equations. The FD-TD method has key advantages relative to available modeling approaches. These advantages permit it to accurately treat complex problems that are beyond the scope of solution by any other method. The goals of the present research program included the development of specific algorithms of high importance to help provide a flexible, simple-to-use, and highly accurate user-oriented FD-TD computer program. Five key improvements in the FD-TD algorithm were tested during this effort, including the following: (1) Total-field/scattered-field lattice division, (2) Variable angle of incidence, (3) Second-order accurate radiation condition, (4) Magnitude and phase computation condition for the sinusoidal steady state, and (5) Near-to-far field transformation.
The finite difference time domain method has long been one of the most widely used numerical methods for solving Maxwell’s equations due in part to its accuracy, explicit nature, and simplicity of implementation. Modern research interests have created a need for this method to be extended to handle multi-scale multi-physics problems where numerous physical phenomena are coupled with classical electrodynamics. These phenomena typically occur on vastly different spatial scales; however, the conventional finite difference time domain method requires a uniform spatial discretization across the entire simulation space. Additionally, the maximum time evolution that may be solved in a single iteration of the algorithm is proportional to the smallest discretization length. Consequently, properly resolving the smallest feature of a multiscale problem causes phenomena of a larger scale to be over-resolved, resulting in an unnecessarily large amount of memory and often an impractical number of computations required for simulation. The development of a capability for sub-gridding, where local domains of fine resolution may be incorporated into a simulation space of coarser resolution, is imperative to treat this issue. This thesis proposes a new algorithm to implement sub-gridding. The results of comprehensive numerical evaluations show promise for this algorithm to be of general use in solving multi-scale multi-physics problems.

Three-Dimensional Finite-Difference Time-Domain (3D FDTD) is a powerful method for modelling the electromagnetic field. The 3D FDTD buried object detection forward model is emerging as a useful application in mine detection and other subsurface sensing areas. However, the computation of this model is complex and time consuming. Implementing this algorithm in hardware will greatly increase its computational speed and widen its use in many other areas. We present an FPGA implementation to speed up the pseudo-2D FDTD algorithm which is a simplified version of the 3D FDTD model. The pseudo-2D model can be upgraded to 3D with limited modification of structure. We implement the pseudo-2D FDTD model and complete boundary conditions on an FPGA. The computational speed on the reconfigurable hardware is about three orders of magnitude faster than the software implementation. Understanding and predicting electromagnetic behavior is more and more needed in key electrical engineering technologies such as cellular phones, mobile computing, lasers and photonic circuits. After K. Yee first introduce the FDTD method in 1966, people began to realize its accuracy and flexibility for solving electromagnetic problems. The FDTD method provides a direct time-domain solution of Maxwell’s Equations in differential form by discretizing both the physical region and time interval using a uniform grid. Because this method can solve Maxwell’s equations on any scale with almost all kinds of environments, it has become a powerful method for solving a wide variety of different electromagnetic problems.

The efficiency of the conventional, explicit finite difference time domain (FDTD) method is constrained by the upper limit on the temporal discretization imposed by the Courant-Friedrich-Lewy (CFL) stability condition. Therefore, there is a growing interest in overcoming this limitation by employing implicit, unconditionally stable FDTD methods for which time-step and space-step can be independently chosen. Unconditionally stable Crank Nicolson method has not been widely used in time domain electromagnetics despite its high accuracy and low anisotropy. This work presents a novel three-dimensional frequency dependent fully implicit Crank Nicolson FDTD method. A modified frequency dependent alternating direction implicit FDTD (FD-ADI-FDTD) method, having better accuracy than the normal FD-ADI-FDTD method, is also presented.

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

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

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.

Abstract: Maxwell's equations represent govern the fundamental behavior of electromagnetic fields. Numerous efforts have been devoted to solve Maxwell's equations theoretically and numerically in complex media, such as anisotropic media and dispersive media. The Finite-Difference Time-Domain (FDTD) method is a powerful numerical technique for solving time-dependent Maxwell's curl equations in general media [1], [2]. The basic FDTD technique has been extended over the years to solve increasingly more complicated media and geometries. In particular, in the past few years, FDTD has been extended to accommodate non-diagonal constitutive tensors, but the work done so far has been limited to second-order accurate schemes in both time and space. Our goal in this thesis is to derive and study extensions of FDTD to achieve a scheme with higher order of accuracy in space for the study of electromagnetic wave propagation in homogeneous and inhomogeneous anisotropic media. The objective of attaining high order FDTD method is to reduce the overall truncation error and dispersion error of the finite-difference approximations, and increase the overall accuracy of the numerical results.

The Finite Difference Time Domain (FDTD) method is limited by memory requirements and computation time when applied to large problems, complicated geometries, or geometries with fine features. In this thesis, the nonuniform orthogonal FDTD method is presented and applied to a variety of electromagnetic problems. The nonuniform aspect of the method gives great flexibility in modeling complicated geometries with fine features. Furthermore, the variability of the mesh resolution also enables the user to move the boundaries of the computational domain farther away from the center of the problem without an undue increase in the number of cells. Most significantly, the orthogonality of the method preserves the speed of the conventional FDTD method. These three features of the nonuniform orthogonal FDTD method are demonstrated by means of numerical examples throughout the thesis. Grid dispersion error from the nonuniform mesh is analyzed and numerical examples are presented, demonstrating that small growth rates in mesh discretization lead to acceptably small errors. The issue of absorbing boundary conditions is addressed with the analysis and application of the dispersive boundary condition on nonuniform meshes. New techniques are also introduced for the efficient characterization of microstrip lines,
microstrip discontinuities, and coupled microstrip structures using FDTD data. A local mesh refinement technique is introduced for planar perfect electric conductor, and is shown to be three times more accurate than the staircasing approximation. The versatility of the method is demonstrated by the analysis of a balun-fed folded dipole antenna, the characterization of the transition of grounded coplanar waveguide to microstrip line, and the study of fields in lossy layered media.

The Finite Difference Time Domain (FDTD) method is an essential tool in modeling inhomogeneous, anisotropic, and dispersive media with random, multilayered, and periodic fundamental (or device) nanostructures due to its features of extreme flexibility and easy implementation. It has led to many new discoveries concerning guided modes in nanoplasmonic waveguides and continues to attract attention from researchers across the globe. Written in a manner that is easily digestible to beginners and useful to seasoned professionals, Computational Nanotechnology Using Finite Difference Time Domain describes the key concepts of the computational FDTD method used in nanotechnology. The book discusses the newest and most popular computational nanotechnologies using the FDTD method, considering their primary benefits. It also predicts future applications of nanotechnology in technical industry by examining the results of interdisciplinary research conducted by world-renowned experts. Complete with case studies, examples, supportive appendices, and FDTD codes accessible via a companion website, Computational Nanotechnology Using Finite Difference Time Domain not only delivers a practical introduction to the use of FDTD in nanotechnology but also serves as a valuable reference for academia and professionals working in the fields of physics, chemistry, biology, medicine, material science, quantum science, electrical and electronic engineering, electromagnetics, photonics, optical science, computer science, mechanical engineering, chemical engineering, and aerospace engineering.

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

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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.

Master's Thesis from the year 2014 in the subject Computer Science - Applied, grade: First, University of Manchester (School of Computer Science), course: Advanced Computer Science: Computer Systems Engineering, language: English, abstract: Due to recent advancement in technology, one of the popular ways of achieving performance with respect to execution time of programs is by utilizing massive parallelism power of GPU-based accelerator computing along with CPU computing. In GPU-based accelerator computing, the data intensive or computationally intensive part is computed on the GPU whereas the simple yet complex instructions are computed on the CPU in order to achieve massive speedup in execution time of the computer program executed on the computer system. In physics, especially in electromagnetism, Finite-Difference Time-Domain (FDTD) is a popular numerical analysis method, which is used to solve the set of Maxwell's partial differential equations to unify and relate electric field with magnetic field. Since FDTD method is computationally intensive and has high level of parallelism in the computational implementation, for this reason for past few years researchers are trying to compute the computationally intensive part of FDTD methods on the GPU instead of CPU. Although computing parallelized parts of FDTD algorithms on the GPU achieve very good performance, but fail to gain very good speedup in execution time because of the very high latency between the CPU and GPU. Calculation results at each FDTD time-step is supposed to be produced and saved on the hard disk of the system. This can be called as data output of the FDTD methods, and the overlapping of data output and computation of the field values at next time step cannot be performed simultaneously. Because of this and latency gap between the CPU and GPU, there is a bottleneck in the performance of the data output of the GPU. This problem can be regarded as the inefficient performance of data input/output (I/O) of FDTD methods on GPU. Hence, this project focuses on this aforementioned problem and addresses to find solutions to improve the efficiency of the data I/O of FDTD computation on GPGPU (General Purpose Graphics Processing Unit).

The finite-difference time-domain (FDTD) method has been shown in the last several years to be applicable to guided-wave photonics problems. The application of the method to diffraction gratings, intersecting and bending waveguides and Bragg mirrors has served to demonstrate that
method can solve a set of problems not tractable for more traditional techniques such as the beam propagation method. Although these papers have served to demonstrate the applicability of the FDTD technique, few papers have described the use of the FDTD analysis in a design environment. This paper will describe the use of the FDTD method in two design problems and show how specific engineering questions can be answered with the simulation technique. The first problem, a distributed feedback reflector for a graded index wave-guide laser, will demonstrate the ability of FDTD to model complex structures whose analysis would otherwise be virtually intractable. The second example, a multi-layer Bragg wave guide design, will show how the FDTD technique can be used to complement and extend other analysis methods.

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.

The study makes use of a variation of the Finite-Difference Time-Domain (FDTD) method as first proposed by Yee to simulate electromagnetic field distribution and propagation in an open waveguide structure. In order to prove that this new method is valid, a reflection coefficient is calculated with simulation data and compared to measurements. The agreement between measurement and simulation data, while not exact, is enough to establish the veracity of the new method. This study contains a detailed discussion of the discrepancies which were observed. Also presented are colour images of the simulation which give the reader an idea as to the nature and level of detail of the information which can be obtained from the simulation.

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 the.

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 3-dimensional finite-difference time-domain method is a numerical method for solving electromagnetic penetration and scattering problems. It uses a finite difference representation of the time dependent Maxwell equations. The object of interest is embedded in a lattice and the time is divided in discrete intervals. By applying the finite-difference equations for every time step the propagation and scattering of waves is simulated. In this report the 3-dimensional FD-TD method and its algorithms are explained. Results are presented for a perfectly conducting plate, cube and wedge and for a dielectric layered sphere. The calculated results agree with experimental and, exact theoretical results. Numerical computations, Finite difference method, Scattering of electromagnetic waves, Maxwell equation, Radar cross section, Time domain method, Boundary conditions.
This book introduces the powerful Finite-Difference Time-Domain method to students and interested researchers and readers. An effective introduction is accomplished using a step-by-step process that builds competence and confidence in developing complete working codes for the design and analysis of various antennas and microwave devices. This book will serve graduate students, researchers, and those in industry and government who are using other electromagnetics tools and methods for the sake of performing independent numerical confirmation. No previous experience with finite-difference methods is assumed of readers.

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.

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