ASYMPTOTIC AND HYBRID METHODS IN ELECTROMAGNETICS pdf

1: ATI Computational Electromagnetics Course

The best, but now widely explored, solution for these problems is to combine various methods in so called hybrid methods. Asymptotic and Hybrid Methods in Electromagnetics is based on a short course, and presents recent developments in the field.

Hybrid Methods Many practical problems are too complicated to be solved accurately by a single numerical or asymptotic method. It is often advantageous to combine two numerical modeling techniques in a single field solver in order to take advantage of the strengths of each technique to solve problems that neither technique alone could model efficiently. For example, a finite element method can be combined with a boundary element method to form a more powerful hybrid numerical technique for analyzing both open-region problems and complex inhomogeneous objects. A full-wave numerical technique can also be combined with an asymptotic method to model very large objects with small features that require detailed analysis, such as an antenna mounted on an airplane. Hybrid methods are not simply two separate modeling codes with a common user interface. A hybrid method generally divides a problem into two parts and applies a different technique to each part while matching the currents or fields at the boundary to ensure a unique solution. Some hybrid codes solve one part first, and then use the boundary fields as the sources when solving the second part. Other hybrid codes solve both parts simultaneously allowing the solution of each part to influence the solution of the other. Formulations for many hybrid techniques have been developed and reported in the literature. Some of the more common and useful hybrid techniques are described in the following sections. Boundary element methods excel at modeling wires and unbounded geometries, but do not model complex structures that include a variety of materials well. The complementary strengths of these two methods make them ideal candidates for hybridization. The interior region is analyzed using a finite element method with unknown electric or magnetic surface currents establishing the boundary condition on the outer surface. The exterior region is analyzed using a boundary element method, with unknown electric or magnetic currents on the fictitious surface. Two sets of matrix equations are developed that share unknowns on the boundary between the interior and exterior volumes. By forcing the fields on both sides of the fictitious surface to be consistent with each other, the two matrix equations can be combined into one larger equation with a unique solution. In practice, it is relatively inefficient to generate one large matrix that is partly dense and partly sparse. Inward looking techniques repeatedly solve the finite element portion of the problem, while populating the boundary element method matrix. Outward looking techniques repeatedly solve the boundary element method portion while populating the finite element matrix. However, if large objects contain features that are too fine to be analyzed by an asymptotic method, it becomes necessary to employ hybrid methods that combine asymptotic techniques with numerically rigorous methods. Techniques that combine a moment method with an asymptotic method can be broadly categorized as either ray-based or current-based. Since GTD fails in regions where the field cannot be approximated by a local plane wave, uniform solutions have been developed that overcome some of the limitations of GTD. Physical optics is a current-based asymptotic method. Consequently, this hybrid technique has received considerable attention in the literature []. It has also been implemented in a commercial numerical code [23]. The hybridization of FEM and asymptotic techniques is described in []. Ra, "A hybrid finite element-boundary element method and its application to inverse scattering," Proc. Seidl, "A hybrid finite element and moment method for electromagnetic scattering from inhomogeneous objects," Proc. Jin and John L. Volakis, "Electromagnetic scattering by and transmission through a three dimensional slot in a thick conducting plane," IEEE Trans. Landstorfer, "A combination of current-and ray-based techniques for the efficient analysis of electrically large scattering problems," Proc. Balanis, "FEM-based hybrid methods for the analysis of antennas on electrically large structures," Radio and Wireless Conference,

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2: Asymptotic and Hybrid Methods in Electromagnetics : Frederic Molinet :

Asymptotic methods provide considerable physical insight and understanding of diffraction mechanisms and are very useful in the design of electromagnetic devices such as radar targets and antennas.

This 2-day course teaches the basics of CEM with application examples. Fundamental concepts in the solution of EM radiation and scattering problems are presented. Emphasis is on applying computational methods to practical applications. Students will then be able to identify the most relevant CEM method for various applications, avoid common user pitfalls, understand model validation and correctly interpret results. You will learn the importance of model development and meshing, post- processing for scientific visualization and presentation of results. Keefe Coburn is a senior design engineer with the U. In his job at the Army Research Lab, he applies CEM tools for antenna design, system integration and system performance analysis. He teaches graduate courses at the Catholic University of America in antenna and remote sensing. Contact this instructor please mention course name in the subject line What you will learn: A review of electromagnetics and antennas with modern applications. From this course you will obtain the knowledge to become a more expert user, use the best code for specific applications, interact meaningfully with colleagues, evaluate accuracy for practical applications, and understand the literature. Basic Concepts in Antenna Theory. Basic Concepts in Scattering Theory. Radar cross section frequency dependence. Various antenna types, array antennas, periodic structures and electromagnetic symmetry, and beam steering. Overview of Computational Methods in Electromagnetics. Introduction to frequency and time domain methods. Finite Element Method Tutorial. Mathematical basis and algorithms with application to electromagnetics adjusted to class mathematical background. Method of Moments Tutorial. Mathematical basis and algorithms adjusted to class mathematical background. Finite Difference Time Domain Tutorial. Mathematical basis and algorithm implementations adjusted to class mathematical background. Transmission Line Matrix Method. Scattering mechanisms and high frequency approximations. Overview and FEKO examples. Overview of parallel methods and examples. With emphasis on practical applications and intelligent decision making. Questions and FEKO examples. Adjusted to class problems of interest. This course is not on the current schedule of open enrollment courses. If you are interested in attending this or another course as open enrollment, please contact us at or at ati aticourses. ATI typically schedules open enrollment courses with a lead time of months. Group courses can be presented at your facility at any time. For on-site pricing, request an on-site quote. You may also call us at or email us at ati aticourses.

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3: Clemson Vehicular Electronics Laboratory: Hybrid Methods

Description Scope: Asymptotic methods provide considerable physical insight and understanding of diffraction mechanisms and are very useful in the design of electromagnetic devices such as radar targets and antennas.

Essentials of Computational Electromagnetics provides an in-depth introduction of the three main full-wave numerical methods in computational electromagnetics CEM ; namely, the method of moment MoM , the finite element method FEM , and the finite-difference time-domain FDTD method. Numerous monographs can be found addressing one of the above three methods. However, few give a broad general overview of essentials embodied in these methods, or were published too early to include recent advances. Furthermore, many existing monographs only present the final numerical results without specifying practical issues, such as how to convert discretized formulations into computer programs, and the numerical characteristics of the computer programs. In this book, the authors elaborate the above three methods in CEM using practical case studies, explaining their own research experiences along with a review of current literature. A full analysis is provided for typical cases, including characteristics of numerical methods, helping beginners to develop a quick and deep understanding of the essentials of CEM. This text can also be used by researchers in electrical and electronic engineering, and software developers interested in writing their own code or understanding the detailed workings of code. Companion website for the book: Francisco Saez de Adana Language: This practical book offers in-depth coverage of this area, showing how to apply these techniques to the analysis of complex electromagnetic problems in order to obtain results with an exceptionally high degree of accuracy. Focusing on two highly-effective methods - the uniform theory of diffraction UTD and physical optics PO , this book is unique in that it emphasizes how to solve real-world problems, rather than simply explaining theory like other books on the market. This first-of-its-kind resource show professionals how to apply this knowledge to a wide range of projects in the field, including antenna design, mobile communications, and RCS radar cross section computation. This authoritative book is supported with more than illustrations and over equations. Cambridge University Press Format Available: Lal Chand Godara Language: The move toward worldwide wireless communications continues at a remarkable pace, and the antenna element of the technology is crucial to its success. With contributions from more than 30 international experts, the Handbook of Antennas in Wireless Communications brings together all of the latest research and results to provide engineering professionals and students with a one-stop reference on the theory, technologies, and applications for indoor, hand-held, mobile, and satellite systems. Beginning with an introduction to wireless communications systems, it offers an in-depth treatment of propagation prediction and fading channels. It then explores antenna technology with discussion of antenna design methods and the various antennas in current use or development for base stations, hand held devices, satellite communications, and shaping beams. The discussions then move to smart antennas and phased array technology, including details on array theory and beamforming techniques. Space diversity, direction-of-arrival estimation, source tracking, and blind source separation methods are addressed, as are the implementation of smart antennas and the results of field trials of systems using smart antennas implemented. Finally, the hot media topic of the safety of mobile phones receives due attention, including details of how the human body interacts with the electromagnetic fields of these devices. Its logical development and extensive range of diagrams, figures, and photographs make this handbook easy to follow and provide a clear understanding of design techniques and the performance of finished products. Its unique, comprehensive coverage written by top experts in their fields promises to make the Handbook of Antennas in Wireless Communications the standard reference for the field. Johnson Jenn-Hwa Wang Language: Now available for the first time in print are the new concepts and insights developed over the last three decades in the broad class of computational techniques called the methods of moment. Designed to serve as both a professional reference and graduate-level textbook, it will be useful in calculations for electromagnetic problems related to, among others, antennas, scattering microwaves, radars and imaging. Also included are problems for students, with the solutions available.

4: Computational Electromagnetics | ElectroScience Laboratory

Asymptotic and Hybrid Methods in Electromagnetics is based on a short course, and presents recent developments in the field.

Asymptotic-Expansion Methods The techniques described in the previous sections are exact methods in that the error in the numerical solution only comes from the discretization. The numerical solution approaches the exact solution as the discretization is refined. However, as the number of unknowns grows, the demand for computer memory and calculation time also grows. This prohibits these methods from being applied to high frequency problems where the size of the object is much larger than the wavelength. They are high frequency methods that are only accurate when the dimensions of the objects being analyzing are large compared to the wavelength of the field. The asymptotic techniques introduced in the following sections include physical optics, geometrical optics, geometrical theory of diffraction, and uniform theory of diffraction. Physical Optics The Physical Optics PO approximation is a well known and efficient method for analyzing large scatters [1]. PO reduces the cost of memory and CPU-time by performing a high frequency approximation. It is a current-based method in which the physical optics approximation is used to obtain the current density induced on a surface. If the surface can be approximated as an infinite plane surface, then by image theory, 2 and Equation 1 reduces to 3 The electric and magnetic field radiated by the surface current on the illuminated side of the reflector can be determined by [3], 4 where. Equation 3 is exact only when the surface is infinitely large. The accuracy of the approximation depends on the transverse dimensions of the reflecting surface, the radius of curvature, location of edges, and the angle of the incident field. Generally, PO works well for large, smooth surfaces with low curvature. The implicit assumption for the physical optics approximation is that the incident field is treated as a locally planar wave. Also, it assumes that the reflector surface is perfectly conducting. It has been found that PO provides an accurate prediction of far-field patterns of reflected antennas in the main beam region and out to several side lobes [5]. The major disadvantage of PO is that the integration over the surface of the reflector may be quite complicated and time consuming when the feed is placed off-axis or the feed pattern is asymmetric []. Moreover, the radiation integral has to be evaluated each time the observation point is changed. Fast and efficient evaluation of the radiation integral was proposed using a fast series approach [5], incorporating a multilevel fast multipole method [6], or decomposing the scatterer into subdomains [7]. Initially applied in the frequency domain, PO has also been extended into the time domain [8]. In GO analysis, geometrical optics techniques ray tracing are used to set up equivalent currents on an aperture plane which is normal to the axis of the reflector. Then, the tangential aperture fields are constructed and used to determine the radiated fields utilizing the Fourier transform. Different formulations are obtained based on the use of aperture electric fields, magnetic fields or their combinations [10]. The relationship between GO and PO was demonstrated in [10]. It was shown that the PO integral can be represented as a summation of many Fourier transforms, such that the first few terms resemble the GO representation. Using the "extinction theorem" [3], the fields predicted by the integration of PO surface currents were shown to agree with the geometrical optics aperture fields on the aperture plane to within the local plane wave approximation. It was concluded that the accuracy obtained by the two methods is comparable. Geometrical Theory of Diffraction The approximations in both physical optics and geometrical optics are based on the following assumptions [3]: The current density is zero on the shadow side of the reflector The discontinuity of the current density over the rim of the reflector is neglected Direct radiation from the feed and aperture blockage by the feed are neglected. Both PO and GO ignore the edge diffractions which are highly dependent on the whether the edges of the reflector are flared, sharp, absorber lined or serrated. Thus, they cannot accurately predict the far fields beyond the first few side lobes. For predicting the patterns more accurately in all regions, geometrical diffraction techniques are required. The diffracted field is determined at the points on the surface where there is a discontinuity in the incident and reflected field. The value of the diffracted field is evaluated at these points with the aid of an appropriate diffraction coefficient. Usually, the coefficient is determined from asymptotic solutions of simple boundary-value problems with so called canonical geometries, such as a conducting wedge, cylinder or sphere. Since the solutions of these canonical problems are known, the object under investigation can be partitioned into smaller components, so that each component represents a canonical geometry. The ultimate solution is a superposition of the contributions from each component [2]. Two major advantages of GTD over other high frequency asymptotic techniques are that it provides insight into the radiation and scattering mechanisms from the various parts of the structure, and it can yield more accurate results. The method has attracted increasing attention; especially for applications to reflector antennas []. Unfortunately, GTD fails in the transition region adjacent to the shadow boundary, at caustics points through which all the rays of a wave pass , or in close proximity to the surface of the scatterer. In these zones, the field cannot be treated as a plane wave. Thus, ray techniques become invalid. To deal with this problem, a number of alternative approaches have been proposed: A comprehensive introduction to these methods can be found in [19]. It was initially proposed [28] to deal with the problem that GTD produces inaccurate results at the shadow boundaries. The uniform theory of diffraction approximates near electromagnetic fields as quasi-optical and uses ray diffraction to determine diffraction coefficients for each diffracting object-source combination. These coefficients are then used to calculate the field strength and phase for each direction away from the diffracting point. Eibert, "Modeling and design of offset parabolic reflector antennas using physical optics and multilevel fast multipole method accelerated method of moments," Multi-optic Conference, Deschamps, "Ray techniques in electromagnetics," Proc. Hutchins, "Asymptotic series describing the diffraction of a plane wave by a two-dimensional wedge of arbitrary angle," Ph. Kouyoumjian, "An analysis of the radiation from aperture on curved surfaces by the geometrical theory of diffraction," Proc. Mittra, "Asymptotic and hybrid techniques for electromagnetic scattering," Proc. Pathak, "A geometrical theory of diffraction for an edge in a perfectly conducting surface," Proc. Deschamps, "Asymptotic evaluation of high frequency fields near a caustic: Orlov, "Caustics, catastrophes and wave fields," Sov. Ufimtsev, "Elementary edge waves and the physical theory of diffraction," Electromagnetics, vol. Mittra, Y Rahmat-Samii, and W. Ko, "Spectral theory of diffraction," Appl. Pathak, "A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface," Proc.

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7: Clemson Vehicular Electronics Laboratory: Asymptotic-Expansion Methods

Abstract: Asymptotic and hybrid methods are widely used to compute the Radar Cross Section (RCS) of objects that are large compared to the wavelength of the incident wave, and the objective of this paper is to present an overview of a number of these methods. The cornerstone of the asymptotic.

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