



Allen Glisson

Dept. of Electrical Engineering
University of Mississippi
PO Box 1848
University, MS 38677-1848 USA
+1 (662) 915-5353
+1 (662) 915-2731 (Fax)
aglisson@olemiss.edu (e-mail)

Computational Electromagnetics for RF and Microwave Engineering, by David B. Davidson, Cambridge University Press, 2005, xix + 411 pages, \$75.00, ISBN 0-521-83859-2.

Computational Electromagnetics for RF and Microwave Engineering, prepared by David B. Davidson, is a good book. It is well structured, well written, and clear; only the title does not exactly reflect the content. The reader expects to see from the title much more RF and microwave applications than those included.

I must say that I like the idea behind, and the presentation philosophy of, this book, to introduce concepts of, and numerical issues related to, the well-known three methods: the Finite-Difference Time-Domain (FDTD), the Method of Moments (MoM), and the Finite-Element Method (FEM). The author has attempted to prepare the reader to use the commercial packages he chose by starting to discuss methods from the very beginning with simple, one-dimensional problems. This approach is effective if an electromagnetic problem is taken into account, step by step, from approximate representations of the simplified forms of real-world physical problems in an analog environment (e.g., by using Maxwell's equations and/or circuit theory) to numerical models in a discrete environment. Also, it is wise to discuss/include short simple scripts and examples in *MATLAB*, since this language has become a state-of-art computer language/tool in engineering.

I followed a quite similar approach in my book, *Complex Electromagnetic Problems and Numerical Simulation Approaches* (IEEE Press/John Wiley, 2003). I introduced fifteen different packages that can be used by the reader, from antenna simulations to radar-cross-section (RCS) calculations, microstrip circuit design to electromagnetic compatibility (EMC) and bioelectromagnetics (BEM), etc. The idea is to compare at least two of the presented packages at a time on a chosen canonical electromagnetic problem. I aimed to prepare and train the reader to attack complex electromagnetic problems by using the presented packages first. The claim was also that this approach would broaden the market for the commercial electromagnetic codes. The supplied source codes also allow the reader to improve existing modules, add new features, and even develop better novel codes. In-house prepared codes usually do almost everything that a commercial package does. Unfortunately, they may never (and the aim is not to) compete with the user-friendly nature of the commercial packages. Therefore, if a user starts with these simple scripts on simplified problems he/she can use those commercial packages more effectively and intelligently.

Dr. Davidson's approach is to let the reader first understand the theory behind the problem at hand, then write down and use simple scripts on some simple problems, and finally use any of the commercial packages. Therefore, Dr. Davidson's approach in his book would also broaden the market for the commercial codes.

The author presents the three methods in 10 chapters. Chapter 1 belongs to the general introduction of computational electromagnetics (CEM) and the FDTD, MoM, and FEM. The next two chapters (Chapter 2 and Chapter 3) are reserved for the FDTD Method. Chapters 5 to 8 present the MoM. The last two chapters (Chapter 9 and Chapter 10) belong to the FEM.

The author discusses one-dimensional FDTD in Chapter 2. After giving brief information about replacing partial derivatives with their finite-difference approximations in a discrete environment, the author directly discusses one-dimensional FDTD by using the well-known time-domain transmission-line (TL) equations, based on the equivalent-circuit approach. Actually, one-dimensional FDTD has been well discussed and documented in the literature (see, for example, major classical books listed by the author). There are also very nice lecture notes on the Internet (visit, for example, <http://www.engr.uky.edu/~gedney> for the lecture notes "EE699: FDTD Solution of the TR Line Equations" prepared by S. Gedney). On the other hand, if I were the author I would have discussed the one-dimensional FDTD problem by comparing one-dimensional FDTD TL equations against plane waves (1D-PW). By doing this, a wave theory versus circuit theory analogy would have been clearly established and presented numerically. Moreover, only the loss-free case is included in Chapter 2. It would have been much better if the author had discussed the lossy case and various terminations (e.g., inductive/capacitive loads, serial/parallel resonance terminations in transmission lines, which correspond to Dirichlet, Neumann, or Cauchy type boundary conditions in plane-wave representations) in this chapter. Two short *MATLAB* scripts – for example, one for the time-domain discretization of the transmission-line equations, and one for the time-domain plane-wave representations – allow the reader to understand and establish the analogy between these two well-known theories. Nevertheless, Chapter 2 is a good reference for all pioneering FDTD works, classical books, theoretical and practical aspects, such as discretization effects, accuracy, stability, and convergence, etc.

Chapter 3 is reserved for the two-dimensional and three-dimensional FDTD modeling. The author prepares the reader for

the modeling of a two-dimensional scattering problem by building a *MATLAB* script step by step, including some valuable programming and coding hints about using *MATLAB*. The perfectly matched layer (PML) termination is also discussed briefly in this chapter. The author prefers to use the *CST Microwave Studio*TM (MWS) commercial package for the three-dimensional FDTD discussions. Although the major issues related to FDTD modeling are covered in Chapters 2 and 3, I think it would have been better if near-to-far-field transformation, FDTD with various magnetic materials, etc., had been summarized to some extent.

The MoM uses the electric-field integral and magnetic-field integral equations (EFIE and MFIE). The theory behind one-dimensional MoM is well presented in Chapter 4. The commercial MoM code *FEKO* and the public-domain code *NEC2* are discussed in Chapter 5 for a few important antenna problems: the Yagi-Uda antenna, a log-periodic antenna, an axial-mode helix antenna, and a Wu-King loaded dipole. Therefore, this chapter is also important in terms of antenna information. Chapter 6 deals with methods of solving for currents on surfaces using MoM. Large EM problems, in terms of hybrid MoM/asymptotic techniques, and the Fast Multipole Method (FMM), based on the fast Fourier transform (FFT), are also discussed in this chapter.

Chapters 7 and 8 are the exposition of the EM scattering problems through stratified media. The MoM relies on an appropriate Green's function as the *field propagator*. Chapter 7 deals with the MoM modeling of stratified media, i.e., the problem of dielectric materials (such as layered microstrip circuits). First, a static analysis of a microstrip line is taken into account, and the spectral-domain Green's function is derived. Then, the dynamic analysis is introduced and Sommerfeld potentials are derived. Some practical applications are presented in Chapter 8, where microstrip-patch antennas and arrays are investigated by using the commercial *FEKO* package (MoM modeling of conductors and homogeneous dielectrics, together). It should be noted that the content of Chapters 4-8 forms a nice complete set in understanding the MoM approach in electromagnetics.

Chapter 9 describes the FEM (which has been successfully applied first in mechanics, and then in magnetostatics) for the Laplace equation, and variational and Galerkin weighted-residual formulations are outlined. The author did a nice job of discussing the *spurious modes* problem (e.g., eigensolutions of the Helmholtz equation with zero eigenvalues) in FEM. These are simply rejected as unwanted solutions in analytical investigations, but are taken into account by the variational method and are therefore computed numerically by FEM. Some advanced topics of FEM are given in Chapter 10. The hybrid FEM/MoM approach, using the best features of both for antenna radiation and radar cross section (RCS) problems, is also discussed in this chapter. The Appendix includes materials that the author thinks are necessary for completeness.

Although most of the text can be found elsewhere, this book is a good reference for all three methods, the FDTD, MoM, and FEM, since it brings almost every analytical and numerical detail of these methods. The book is also unique in several ways:

- It contains three well-known, widely used numerical methods: the FDTD, the MoM, and the FEM.
- It places the emphasis on model development, model justification, validation, and verification, which is one of the strongest points of the book.

- The mode of presentation and the chapters discussed are disparate from all classical books on computational EM in print today.

- The tutorial introduction to all three methods through hands-on simulations is extremely effective and useful.

- A few sample *MATLAB* codes are included for validation and verification, proof of modeling, and for the investigation of the limitations of a specific methodology.

Some of the weaknesses may also be listed, as follows:

- The author might better have listed major commercial packages for each method, and mentioned cons and pros in terms of basic simulation parameters, such as memory requirements, complexity, computation time, accuracy, stability, convergence, etc.

- It would have been better if the author had designed some canonical test scenarios where at least two methods can be compared to each other (e.g., FDTD vs. MoM, FDTD vs. FEM, MoM vs. FEM, etc.). For example, the six-element Yagi in Section 5.3 would be a good structure for the FDTD vs. MoM comparisons. It would have strengthened the book if the author had discussed how a time-domain simulator might be compared against a frequency-domain simulator (or vice versa).

- It would also have been better if the author had given a subsection in Chapter 4 (before the one-dimensional MoM section), and summarized the one-dimensional Sturm-Liouville equation and scalar Green's functions first, and their connection to the MoM representations.

- It would have been more attractive (especially for undergraduate students) if, for example, numerical modeling issues were more included for all three methods.

- I think the reader would have been much happier if the Transmission-Line Matrix (TLM) method had been covered to some extent.

- The author could have given more explanations about the *MATLAB* codes he included, which could be very important for beginners.

Dealing with CEM simulations today is very easy, because one can obtain commercial packages that do almost everything, all of which are user-friendly, all have self-checking routines for control, and all are calibrated. The user need not know the theory behind, nor worry about details such as convergence, accuracy, resolution, etc. He/she even does not even need to know, for example, the theory behind the microstrip lines in order to design broadband filters, couplers, and impedance transformers. On the other hand, the user will be in real trouble in research if he/she doesn't know what to do with the numbers obtained from the computer, or if he/she has no idea what to expect from the numerical simulation. Unlike common opinion, understanding the physics of the problem is a must in research, since the user may frequently be puzzled even with the simplest mathematical relations. In my

opinion, the information related to the FDTD, MoM, and FEM modeling in this book is not for the commercial package users (such as engineers in industry), as claimed by the author, since they don't care about these details: all they need is a kind of design, analysis, or synthesis (I've known university professors, engineers in companies, who use, for example *HFSS* or *FEKO*, but don't know whether they are based on FEM, MoM, or FDTD). On the other hand, it is a valuable reference book for engineering students, lecturers, and CEM researchers.

In conclusion, engineering problems addressed today are extremely complex, and the only way to begin comprehending their complexity is through the careful and systematic development of models of increasing complexity, indicating along the way the range of their applicability, as obeyed in this book. Electromagnetics is a well-established field with excellent textbooks available; therefore, as expressed by the author, this book is designed to complement, not to compete, with them. The design of the book is more theoretical and less numerical, and it targets at least graduate-level students/researchers and above. The author claims that the book is designed to serve as an introduction to CEM for radio-frequency applications. I believe that it is also a reference book in terms of many aspects, from complex contour integration, branch points, and branch cuts to discrete Fourier transformations, numerical integrations, etc. Modeling and coding hints, brief historical and mathematical explanations, and philosophical discussions make the book valuable and unique.

If you already are, or presumably will be, involved in CEM in one way or another, I think you should buy this book. While progressing from *engineering electromagnetics* to *electromagnetic engineering* mainly because of the widespread use of powerful CEM techniques in complex, real-world engineering problems, every one of us should have one copy in our library as a reference source.

Reviewed by:

Levent Sevgi

Electronics and Communication Eng. Dept.

DOĞUŞ University, Istanbul

Turkey

Recent Books

The following is a list of recently published books that have been received by the Associate Editor since the last issue of the *Magazine* was published. Reviewers are sought for these books, so readers are encouraged to let the Associate Editor know if they are interested in reviewing a particular book.

Array and Phased Array Antenna Basics, by H. J. Visser (Wiley, 2005)

Boundary Element Methods for Electrical Engineers, by D. Poljak and C. A. Brebbia (WIT Press, 2005)

Computational Electrodynamics: The Finite-Difference Time-Domain Method, by A. Taflov and S. Hagness (Artech House, 2005)

Fundamentals of Wireless Communication, by D. Tse and P. Viswanath (Cambridge University Press, 2005)

Introduction to RF Propagation, by J. S. Seybold (Wiley, 2005)

Robust Adaptive Beamforming, by J. Li and P. Stoica (Wiley, 2005)

Wireless Communications, by A. Goldsmith (Cambridge University Press, 2005) (©)

