STANDARDS AND RECOMMENDED PRACTICES FOR CEM COMPUTER MODELING AND SIMULATION

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Abstract

The development of appropriate standards and guidelines for computational electromagnetics (CEM) computer modeling and simulation tasks has been a topic of much discussion within the electromagnetics community in recent years. This encompasses a broad range of applications such as the analysis of printed circuit board radiated and conducted emissions/immunity, assessing system-level EMC, predicting the radar cross section (RCS) of complex structures, and performing automated target recognition (ATR) and imaging simulations. In particular, there are concerns regarding the lack of well-defined methodologies to achieve code-to-code or even simulation-to-measurement validations within a consistent level of accuracy. This has been prompted by the development and use of new CEM computer codes mainly over the past twenty years. This article describes a project that is underway to guide the validation of CEM application models. The proposed standard is intended to address these concerns and provide a method for validating CEM codes and models.

INTRODUCTION

After hearing the concerns expressed by certain sectors of the electromagnetics community, the IEEE EMC Society's Standards Development Committee recently accepted to take the lead in sponsoring the development of a formal standard and recommended practice applied to CEM computer modeling and simulation. Although this is new territory for the Standards Development Committee and there is a great deal of support within the community to take serious steps in this direction, the idea of a "CEM standard" as such is not a new one. In fact, the need for a standard was realized over thirty years ago at a time when the development and use of computer tools for electromagnetics applications was emerging and just beginning to gain momentum. This was influenced by several factors: (a) the growing complexity and sophistication of military and commercial systems designs; (b) achieving requirements for a balanced, cost-effective electromagnetic environment effects (E^3) program in which computer analysis could effectively complement measurements; and (c) providing a means of developing consistent models and benchmarks to support life-cycle EMC code and measurement validations of actual systems. Important technological advancements in computer hardware and use of structured code only accelerated the arrival of CEM technologies and applications, as we know them today. The fast track CEM modeling and simulation trend continues today and will continue to grow as we further enter the age of high performance computing.

Fundamental Validation Issues

Practically speaking, there are both overt and subtle differences that CEM codes exhibit as a function of their underlying physics, mathematical basis functions, numerical solution methods, associated precision, and the building blocks (primitives) that are used to create models and analyze them. Although all CEM codes have their basis in Maxwell's equations of one form or another, their rate of convergence (relatively speaking) and "accuracy" depend on how the physics equations are cast (e.g., method of moments, uniform theory of diffraction, finite differences, or some other representation), what numerical solver approach is used (full or partial wave, non-matrix, etc.), inherent modeling limitations, built-in approximations, and so forth. The physics formalism, available modeling primitives (canonical surface objects, wires, patches, facets, etc.), analysis frequency, and time or mesh discretization further conspire to affect accuracy, solution convergence, and overall validity of the computer model. Here, we have just scratched the surface for there are even subtler, inocuous issues that affect the way the codes operate and how or even if they can be validly compared.

What has not been fully appreciated is the extent of the issue regarding model accuracy, convergence, and code validity. Simply put, concerns were raised when it was observed that the results of predictions using one type of CEM code did not agree favorably or consistently with the results of other codes of comparable type including measurement benchmarks. In some cases, noticable differences among analytically-based results over certain regions and for certain simulation states have been observed. Significant deviations between the analytical and empirical methods have been recorded as well. Differences are not unexpected, but the degree of disparity in certain cases cannot be readily explained nor easily discounted which leads to the question, "*...which result is correct?*"

While analysts may argue in favor of a given modeling approach, simulation technique or use of a particular CEM code there is no consistent methodology for comparing results among codes or against empirically-based methods in a truly valid, objective way. If a methodology exists, it does not appear to be universally practiced.

Furthermore, it is often difficult if not impractical to compare the results of certain codes even though they are based on Maxwell's equations. Of course, some exceptions to this can be cited, in particular, when one considers grouping and comparing the results of "similar" codes determined by their physics, solution methods, and modeling element domains. However, disparities even among "similar" codes have been observed, so oftentimes we are forced to go back to square one regarding the fundamental question.

Art Versus Science

Oftentimes the question has been asked "*Is CEM an art or a science*? By today's standards, one can make the case that it is nearly an even mix of both. The objective should be to emphasize the scientific aspects of modeling and simulation to ensure objectivity as a function of the overarching approach (modeling primitives, physics, problem to be solved) and the underlying scheme (physics, solver method, computation of observables). Obviously, the types of physics and solution method we use for a given problem and the desired observables are central to the issue.

No one will dispute the scientific basis and technical merit of CEM for solving complex problems. However, CEM is also something of an art from the perspective of the (expert) analyst. In practice, the expert is familiar with the code and the physics (i.e., the "canvas") and is proficient in applying the modeling tools and simulation/processing techniques (i.e., the brushes and colors). Unfortunately, this is also the root of the problem in that the process can introduce a certain degree of subjectivism and uncertainty. What seems appropriate to one expert analyst may be inconsistent or inappropriate to another, yet both may claim to be "correct" based on their preferred tools and applied techniques. Even though both approaches may be generally correct for a given problem, differences in results may arise. This again begs the question, "*...which result is correct?*"

In effect, we need to eliminate (or at least significantly reduce) potential uncertainty in the modeling and simulation process. The electromagnetic community clearly needs a benchmark methodology i.e., a *CEM standard* that can be used to assure consistency for objective modeling and simulation validations.

To achieve this we must rely on CEM experts as well as today's software savvy engineers and computer scientists familiar with the latest computerized simulation and hardware technologies. One of the goals should be to determine how generalized computer models are represented or generated, and how they can be effectively converted into efficient CEM models. One application that the DoD's High Performance Computing Modernization Program has investigated involves deriving high-fidelity CEM models from CAD databases. This implies an understanding of the typical ways to represent models possibly using a common language or via a universal set of descriptors, and then specifying methods to assure model and code validation utilizing these data.

Standards/Recommended Practices

To develop the standard and recommended practices, a balanced cross section of the CEM community must be being tapped. This includes the ACES community, the IEEE EMC Society's TC-9 Committee on CEM (co-sponsors of the proposed standard), the IEEE's Antennas and Propagation and Microwave Theory and Techniques Societies, ACES), Electromagnetic Code Consortium, and other international groups concerned with advancing and applying CEM technologies, for example, to RCS and ATR applications. Thinking somewhat "outside the box", we can also learn a great deal about relevant modeling and simulation technologies and techniques from the world of consumer video games.

There are two separate projects established to achieve the above concerns, issues, and goals. These are described next.

Project 1597.1: IEEE Standard for Validation of CEM Computer Modeling and Simulation

The scope of this four-year project is to develop a standard for the validation of CEM computer modeling and simulation codes in differing applications. The standard will provide a basis for analytical and empirical validation of CEM codes and configurations. Several key areas will be addressed, including:

- Validation by use of canonical models – This refers to the specification of canonical modeling elements (primitives) as a function of ensemble parameters (frequency, desired accuracy or fidelity, physics and numerical solution method, etc.). This is illustrated in Figure 1.
- Validation by simulation versus measurement - Included in the validations will be associated model-based parameter estimation (model- versus measurement-driven uncertainty estimates).

The purpose of this project is to guide the validation of CEM application models. The proposed standard is intended to address concerns over the lack of well-defined methodologies to achieve code-to-code or simulation-to-measurement validations within a consistent level of accuracy, and provide a method for validating CEM codes and models. An additional aspect of computer modeling and simulation for CEM considered here is aimed at studying radiation hazards and related safety issues.

Comparable work has been accomplished and continues to mature on behalf of other collaborative engineering disciplines such as computational fluid dynamics, thermal and structural/mechanical engineering. These will also be looked at for guidance and the development of a draft standard for CEM.

Project 1597.2: IEEE Recommended Practice for CEM Computer M&S Applications

The scope of this four-year project is to develop a recommended practice for use in CEM computer M&S applications to guide the EMC design of printed circuit boards to large, complex systems. Areas to be addressed include:

- General guidelines for creating CEM models.
- Development of modeling methodologies for small-to-large scale "canonical" systems, platforms or composite models.
- Methodologies for developing and applying collaborative, multi-disciplinary engineering modeling schemes.
- Computation of uncertainty for modeling applications.

This recommended practice will aid modelers and analysts in the selection and application of appropriate modeling and simulation methodologies, physics, and solution techniques to achieve accurate results and to complement measurements and EMC design tasks for a wide range of problems. As with its counterpart standard, a significant aspect of CEM computer modeling and simulation for electromagentic effects analyses will target the study of radiation hazards and related safety issues.

RELEVANT RESEARCH

This work will build upon prior analytical studies and research conducted by academic, government, commercial, and professional institutions and consortia [1, 2]. These include studies on the modeling and simulation of multi-disciplinary engineering problems pertaining to fluid dynamics, laminar flow, structural and thermal engineering applications [3]. Another key area of study is the development and use of analytical and measurement benchmarks.

SUMMARY

This paper discussed the development of appropriate standards and guidelines for CEM computer modeling and simulation A broad range of applications are considered ranging from the modeling of printed circuit board radiated and conducted emissions/immunity to analyzing large, complex system electromagnetic effects. Concerns have been raised regarding the lack of well-defined methodologies to achieve code-to-code or simulation-to-measurement validations within a consistent level of accuracy. To address these concerns, two IEEE projects are underway to guide the validation of CEM application models. The proposed standard and recommended practices to be developed under these projects are expected to provide a useful method for validating CEM codes and models. The progress on the development of these standards and guidelines will be reported upon periodically.

References

[1] B. Archambeault and J. Drewniak, "*EMI Model Validation and Standard Challenge Problems*", *http://aces.ee.olemiss.edu/.*

[2] Electromagnetic Code Consortium Web Site *http://www.asc.hpc.mil/PET/CEA/emcc/benchmark/benchmark.html*

[3] *CGNS, The CFD General Notation System Overview and Entry-Level Document,* CGNS Project Group, 15 May 1998.

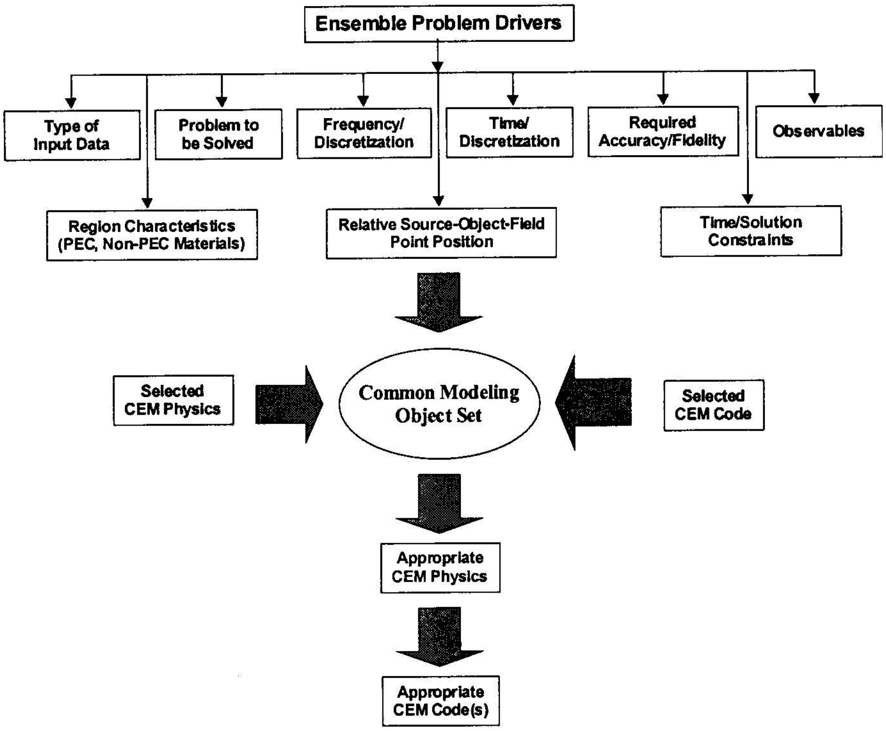

Figure 1. Ensemble Problem Drivers and Their Influence on the Selection of Appropriate CEM Physics and Codes for Validation Purposes