



IEEE Standard for Validation of Computational Electromagnetics Computer Modeling and Simulations

IEEE Electromagnetic Compatibility Society

Sponsored by the
Standards Development Committee

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IEEE Standard for Validation of Computational Electromagnetics Computer Modeling and Simulations

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Abstract: A method to validate computational electromagnetics computer modeling and simulation techniques, codes, and models is defined in this standard. It is applicable to a wide variety of electromagnetic applications including, but not limited to, the fields of electromagnetic compatibility, radar cross section, signal integrity, and antennas. Validation of a particular solution data set can be achieved by comparison to the data set obtained by measurements, alternate codes, canonical, or analytic methods.

Keywords: antennas, computational electromagnetics, convergence, electromagnetic compatibility, electromagnetic interference, modeling and simulation, numerical techniques, radar cross section, rating scale, signal integrity, validation

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Introduction

This introduction is not part of IEEE Std 1597.1-2008, IEEE Standard for Validation of Computational Electromagnetics Computer Modeling and Simulations.

Since the mid-1960s, a number of computational electromagnetics (CEM) techniques have been developed and numerical codes have been generated to analyze various electromagnetic compatibility (EMC) and related electromagnetics problems. Whereas each is based on classical electromagnetic theory and implements Maxwell's equations in one form or another, these techniques and the manner in which they are used to analyze a given problem, can produce quite different results. Lacking is the availability of a well-defined, mature, and robust methodology for validating computational electromagnetic techniques within a consistent level of accuracy. Indeed, this has eluded the EMC community for many years and methods have been sought to address this deficiency. Concerns persist regarding the validity, accuracy, and applicability of existing numerical techniques to the general class of EMC problems of interest. Relevant problems include, but are not limited to, the following: printed circuit board radiated and conducted emissions/immunity, system-level EMC, radar cross section of complex structures, antenna radiation, large platform electromagnetic environment effects, and human body specific absorption rate.

Although these techniques and codes have been applied to a myriad of electromagnetic problems, uncertainty still exists and current validation practices have not always proven reliable. Computer predictions have been compared to measurements to provide a first-order validation, but there is also much interest in how the techniques, when applied to a given problem or a class of problems, compare to each other and the fundamental theory upon which they are based. Hence, additional efforts are needed to establish a standardized method for validating these techniques and to instill confidence in them.

Therefore, the purpose of this first-of-its-kind standard is to define the specific process and steps that shall be used to validate CEM techniques and to significantly reduce uncertainty as it pertains to their implementation and application to practical EMC problem-solving tasks. The standardized process, based on the Feature Selective Validation (FSV) method, is used to validate various techniques against each other as well as against measurement baselines, in order to determine the degree of agreement or convergence and to identify the potential error sources that would lead to divergent trends.

This standard is the first of a two-part family of standards on this subject. A companion, IEEE P1597.2™, Draft Recommended Practice for Validation of Computational Electromagnetics Computer Modeling and Simulation [B40],^a has been developed that provides examples and problem sets to be used in the validation of CEM computer modeling and simulation techniques, codes, and models. It is applicable to a wide variety of electromagnetic applications. The recommended practice, in conjunction with this standard, shows how to validate a particular solution data set by comparing it to the data set obtained by measurements, alternate codes, canonical, or analytic methods. The key areas addressed include model accuracy, convergence, and techniques or code validity for a given set of canonical, benchmark, and standard validation models.

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1. Overview

1.1 Scope

This standard defines a method to validate computational electromagnetics (CEM) computer modeling and simulation (M&S) techniques, codes, and models. It is applicable to a wide variety of electromagnetic (EM) applications including but not limited to the fields of electromagnetic compatibility (EMC), radar cross section (RCS), signal integrity (SI), and antennas. Validation of a particular solution data set can be achieved by comparison to the data set obtained by measurements, alternate codes, canonical, or analytic methods.

1.2 Purpose

This standard provides a formal mechanism for comparing the results of various CEM techniques, codes, and models in a repeatable way against a set of “golden” benchmarks, including standard validation and canonical problem sets. These data are based on theoretical formulations, or obtained as a result of performing high-quality measurements and, in certain cases, based on accurate analyses that have undergone and withstood peer validation.

1.3 Background

In general, CEM techniques and codes, and the manner in which they are used to analyze a given problem, can produce quite different results. These results are affected by the way in which the underlying physics

formalisms have been implemented within the codes including the mathematical basis functions, numerical solution methods, numerical precision, and the use of building blocks (primitives) to generate computational models.

Despite all CEM codes having their basis in Maxwell's equations of one form or another, their accuracy and convergence rate depends on how the physics equations are cast (e.g., integral or differential form, frequency or time domain), what numerical solver approach is used (full or partial wave, banded or partitioned matrix, nonmatrix), inherent modeling limitations, approximations, and so forth. The physics formalism, available modeling primitives (canonical surface or volumetric objects, wires, patches, facets), analysis frequency, and time or mesh discretization further conspire to affect accuracy, solution convergence, and overall validity of the computer model.

The critical areas that must be addressed include model accuracy, convergence, and techniques or code validity for a given set of canonical, standard validation, and benchmark models. For instance, uncertainties may arise when the predicted results using one type of CEM technique do not agree favorably or consistently with the results of other techniques or codes of comparable type or even against measured data on benchmark models. Furthermore, it can be difficult to compare the results between certain techniques or codes despite their common basis in Maxwell's equations. Exceptions can be cited, in particular, when comparing the results of "similar" codes grouped according to their physics, solution methods, and modeling element domains. Nevertheless, disparities even among codes in a certain "class" have been observed. Many examples can be cited where fairly significant deviations have been observed between analytical or computational techniques and empirical based methods. Differences are not unexpected, but the degree of disparity in certain cases cannot be readily explained nor easily discounted, which has led to the often asked-question, "*Which result is accurate?*" Annex B provides guidelines on how to apply the right CEM technique or code to the CEM M&S problem at hand.

2. Acronyms

For the purposes of this standard, the following terms and definitions apply. Annex C, *The Authoritative Dictionary of IEEE Standards Terms* [B38], and ANSI C63.14-1998 [B1] should be referenced for terms not defined in this clause.

ADM	Amplitude Difference Measure (depending on context)
CEM	computational electromagnetics
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EMI/C	electromagnetic interference/compatibility
FDM	Feature Difference Measure
FDTD	Finite-Difference Time Domain
FEM	Finite Element Method
FSV	Feature Selective Validation
GDM	Global Difference Measure
Mil-Std	military standard
M&S	modeling and simulation
MoM	Method of Moments
OATS	open-area test site
PCB	printed circuit board
PEC	perfectly electrically conducting
PEEC	Partial Element Equivalent Circuit
RAM	random-access memory (depending on context)
RLC	resistance, inductance, and capacitance
RCS	radar cross section
TLM	Transmission Line Method
VRS	Validation Rating Scale

3. Computational electromagnetics modeling and simulation validation process

3.1 General

The validation process for M&S results is dependent on exactly what is being validated and what data is available to support the validation. The preferred process is to validate the unknown case against a known reference. To this end, standard problems and other means of obtaining a reference are described in this standard together with a procedure to compare the resulting data sets. Where no suitable reference case can be obtained, validation is possible by using self-referencing schemes. While less encompassing, these schemes still permit a high level of confidence to be achieved. The flowchart shown in Figure 1 provides the route that is taken.

NOTE—The terms ‘modeling’ and ‘simulation’ can, in most places, be used interchangeably.¹

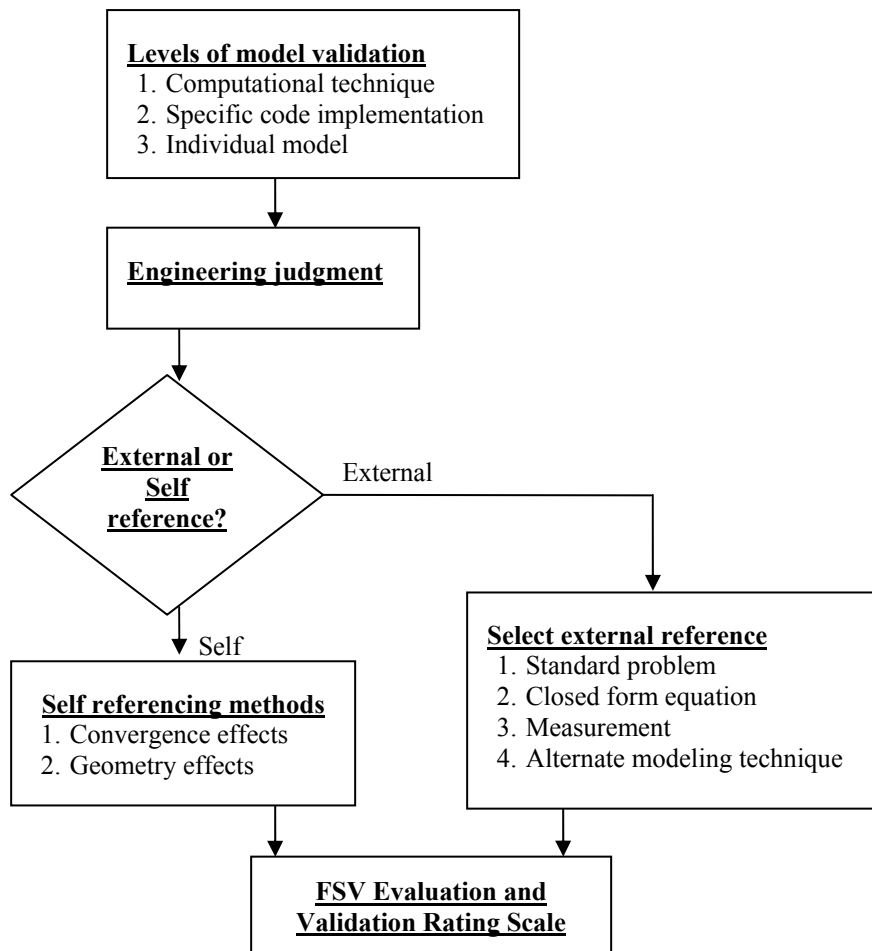


Figure 1—Validation flowchart

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