Numerical Techniques for EMI Source Modeling: A Review of Progress

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Abstract - This paper presents a review of recent progress towards using numerical modeling techniques to analyze sources of electromagnetic interference.

Electromagnetic compatibility engineers have witnessed the revolutionary impact that numerical electromagnetic modeling techniques have had in the fields of antenna engineering, microwave engineering, and magnetics. There is a great deal of interest in applying these same techniques to model sources of electromagnetic interference (EMI). Full-wave electromagnetic modeling of circuits and electronic systems could help to prevent unforeseen radiation and susceptibility problems, decrease product development time, and reduce the cost of meeting electromagnetic compatibility requirements.

Unfortunately, even relatively simple sources of EMI can be very difficult to analyze using a numerical technique. For example, analyzing a simple printed circuit board configuration requires a numerical technique capable of modeling,

- complex source geometries
- dielectrics
- thin metal surfaces
- tightly coupled, electrically small conductors
- thin, electrically long or resonant wires
- unbounded geometries.

In general, surface integral techniques such as the boundary element method have difficulty meeting the first three or four requirements. Finite methods such as the finite element method, FDTD, and TLM do not efficiently model large unbounded geometries or long wires.

In a paper presented at the 7th Annual Review of Progress in Applied Computational Electromagnetics [1], a very simple EMI source model was described. It consisted of a simple printed circuit board configuration with a partial metal enclosure and an attached cable. The EMI source model was a slightly modified version of the second canonical problem in *The ACES Collection of Canonical Problems, Set 1* [2]. At that time neither the EMI source model nor the canonical problem could be analyzed using any existing numerical technique. Apparently, this is still true today. However significant progress has been made in a number of areas. Major developments have occurred relating to each of the five techniques described below. Numerical codes based on each of these techniques may play a significant role in EMI source modeling in the coming years.

The Finite Element Method

The finite element method is well-suited for modeling complex source geometries. Nevertheless, the complexity of most EMI source configurations can be overwhelming even for a finite element model. Researchers at the University of Ottawa [3], the Naval Underwater Systems Center [4], and others have been working on the problem of matching the capabilities of finite element methods to the complexity of EMI source models.

Two weaknesses of the finite element method have been vector parasites and problems modeling three-dimensional radiation problems. Perhaps the most significant development in the past year for finite element modelers was the publication of two papers by Paulsen and Lynch [5,6] that help code developers to understand and eliminate vector parasites. Thanks to this work, vector parasites can no longer be considered a major problem with the finite element method. One solution to the three-dimensional radiation modeling problem is the development of adequate three-dimensional *infinite elements*. This is an area of research that has received a lot of attention recently. Infinite elements were the subject of at least 7 papers at the 1991 IEEE Antennas and Propagation Society symposium.

Method of Moments

Three-dimensional moment method techniques have no trouble with far field radiation calculations and they can usually model thin wires very effectively. In the past, they have not been effective for modeling complex source geometries with inhomogeneous dielectrics. Researchers at the T. J. Watson Research Center however, have overcome this limitation and are using a modified boundary element method to model EMI source configurations with volume dielectrics [7-9]. Their approach makes it possible to model a number of source configurations that previously defied numerical modeling.

Finite Difference Time Domain

Researchers at a number of institutions including Pennsylvania State University, MIT, and Digital Equipment Corporation [10] are applying FDTD to printed circuit card geometries. FDTD is a relatively young technique and a number of researchers are working on its development. An enhancement to FDTD known as the finite-volume time-domain method [11] eliminates the requirement of maintaining a uniform grid spacing. FDTD and FVTD are sure to play an important role in future attempts to model EMI source configurations.

Generalized Multipole Technique

The Generalized Multipole Technique (GMT) is essentially a moment method with expansion functions that are analytic solutions of the fields generated by sources located some distance away from the surface where the boundary condition is being enforced. The expansion functions are spherical wave field solutions corresponding to multipole sources. By locating these sources away from the boundary, singularities on the boundary are avoided. There is little difference in the way dielectric and conducting boundaries are treated. Configurations with multiple dielectrics and conductors are more readily modeled by GMT than with other general purpose moment-method techniques.

Researchers at the Swiss Federal Institute of Technology and other institutions have been making steady progress with this relatively new technique [12-14]. As new expansion functions are developed and introduced, the number of configurations that can be analyzed by this technique is growing rapidly.

Hybrid Techniques

A number of hybrid techniques that combine the features of two existing methods have been introduced in the past two years [15-24]. So far, none of them have been developed specifically for EMI source modeling and none of them are capable of modeling basic EMI source configurations like the canonical problem [2]. However, work is continuing. Hybrid techniques are certain to play a major role in future attempts to model sources of EMI.

Summary

Although many simple EMI source configurations still defy analysis by existing numerical codes, a lot of progress has been made just in the past year. New or enhanced finite element methods, moment methods, and FDTD techniques have been applied to basic printed circuit card geometries with some degree of success. The progress that has been made in the development of each of the techniques described above indicates that codes based on these techniques will ultimately be used to analyze a variety of EMI source configurations.

Given the current rate of progress, it is very possible that by next year there will be one or more codes that are able to model the second canonical problem in the *ACES Collection of Canonical Problems, Set 1*. Any code with this capability will be a valuable tool for electromagnetic compatibility engineers and is likely to have a tremendous impact in this field.

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