A Survey of Numerical Techniques for Modeling Sources of Electromagnetic Interference

Todd H. Hubing
University of Missouri-Rolla
Rolla, MO 65401

Abstract

This paper describes the preliminary results of a study to identify ways of using numerical modeling techniques to analyze sources of electromagnetic interference (EMI). First, two canonical EMI sources were developed that represent the type of configurations that need to me modeled. Then a number of numerical electromagnetic modeling techniques were evaluated to determine their suitability for analyzing these configurations. None of the currently available techniques appears to be a very practical approach, however hybrid techniques that combine a surface integral method with a finite method show considerable promise.

Introduction

Manufacturers of electronic equipment are taking more of an interest in the amount of electromagnetic radiation that emanates from their products. This is due to strict laws regulating electromagnetic interference (EMI) and the potentially high cost of shields, filters, and other EMI fixes required to make an otherwise noisy product meet these requirements. Many companies employ full-time EMI engineers who view every electronic system as an electromagnetic radiation source. By understanding how and why different configurations radiate, these engineers work at developing designs that meet the radiation requirements at the lowest possible cost.

Traditionally, EMI engineers have relied primarily on their measurement experiences, rules-of-thumb, and simple intuitive models to guide them in making design choices. Unfortunately, EMI rules-of-thumb that apply in some situations may not apply in others. Simple modeling techniques such as circuit, transmission line, or basic antenna models only work well when the source and all relevant current paths can be readily identified. Most EMI problems today however are not obvious enough to be predicted or analyzed using these simple techniques. Therefore, the only tools remaining for EMI engineers in most cases are measurements of the system or its components. Unfortunately, practical measurements can not be made without existing hardware and this is not usually available early in a product's development when critical design decisions are being made. Also, measured results in the absence of a theoretical model can be misleading and do not necessarily suggest how a design should be modified to minimize radiated emissions.

Numerical modeling techniques, which have revolutionized the fields of antenna and microwave system analysis, have had relatively little impact on EMI source analysis. Some work involving the modeling of components and cables has been done, but the scope of this work is limited and these techniques are not widely used by EMI engineers. The primary reason for this is that the types of problems that EMI engineers would like to model cannot be analyzed by available numerical techniques. In the following section, two configurations representing the type of problems EMI

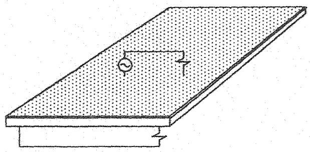

Figure 1: Canonical Printed Circuit Board Model

engineers need to be able to model are described and the extent to which numerical techniques can be used to model these configurations is discussed.

Canonical EMI Sources

Consider the configuration illustrated in Figure 1. It consists of two circuits mounted on opposite sides of a thin, dielectric-coated metal plate. This configuration is similar to a printed circuit board environment with components on one side of the board and traces on the other. A model like this might be used by EMI engineers to answer questions about possible problems with crosstalk between circuits. Prominent features of this configuration include its electrically small-to-resonant size, the presence of a dielectric, the thin metal plate with wires attached to both sides, the unbounded geometry, and the close proximity of the circuit leads to the plate.

Surface integral techniques based on the method-of-moments can be very efficient at analyzing electrically small-to-resonant radiation problems. However, they are not well-suited to modeling arbitrary configurations containing dielectrics or wires attached to opposite sides of a thin plate.

Finite techniques such as the finite element method, finite difference time domain, finite volume time domain and transmission line matrix techniques excel at analyzing complex, inhomogeneous configurations with both conductors and dielectrics. However, these techniques require that a 3-dimensional grid be constructed throughout the entire volume to be analyzed. For unbounded radiation problems, this grid quickly grows very large. A great deal of computation may be required even for relatively simple geometries.

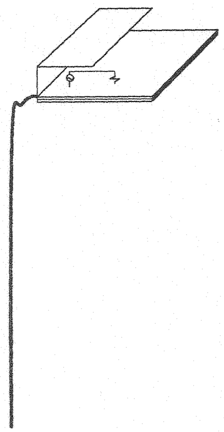

Figure 2: Canonical EMI Source Model

The configuration in Figure 1 is not large, but it is unbounded. It also requires a detailed grid in the vicinity of the wires because of their proximity to the plate. Because of these constraints, the author has not been able to locate a readily available computer code capable of analyzing this type of configuration efficiently. However finite techniques such as the finite volume time domain and finite element methods could theoretically be applied to this problem given sufficient computer resources.

Although the configuration in Figure 1 represents an important class of EMI problems, printed circuit cards rarely exist isolated from other sources or conductors. The configuration in Figure 2 is more typical of an EMI source configuration [1]. It consists of a printed circuit board configuration with a partial metal enclosure and an attached cable. Assuming that the cable is shielded, all of the currents contributing to the EMI can be assumed to flow on the outer surface and in most cases, the cable can be modeled with a solid wire. Like the model in Figure 1, this configuration contains dielectrics and thin plates with multiple wire attachments making surface integral techniques impractical. However, because of the presence of the relatively long thin wire, finite techniques are also impractical. This is because creating a grid throughout a volume large enough to contain the card, shield, wire, and the entire near field of the source results in a problem that is unmanageable from a computational standpoint. Although the model in Figure 2 represents a relatively simple EMI source, it cannot be analyzed effectively by any existing numerical techniques. This illustrates why numerical modeling techniques are not commonly used to model EMI sources.

Hybrid Techniques

Surface integral techniques such as most moment method techniques and the boundary element method are very efficient at analyzing long, thin wires and large conductive surfaces. Finite techniques are best at modeling complex, inhomogeneous regions. Therefore, it makes sense to combine a surface integral technique with a finite technique in order to take advantage of the best properties of each. A number of hybrid methods have been proposed that combine two existing techniques [2-6]. Generally, the configuration is divided into two or more regions. The numerical technique best suited to each region is applied in that region and boundary conditions are enforced at the interface between regions. For example, a hybrid moment method finite element technique might apply a finite element analysis within the small volume containing the card and inside surface of the shield in Figure 2. A moment method technique would simultaneously be applied to the surface defined by the wire, shield, and the boundary with the finite element region.

So far, no one has implemented a hybrid technique capable of analyzing the configuration in Figure 2 or most types of configurations of interest to EMI engineers. However progress continues to be made in this area. While most numerical methods appear to have fundamental limitations that will prevent them from ever being efficiently applied to most EMI sources, hybrid techniques have the potential to overcome these limitations.

Summary

EMI engineers have not yet benefitted significantly from the numerical techniques that have revolutionized the antenna and microwave engineering fields. The two simple configurations presented here illustrate some of the difficulties involved with applying numerical techniques to EMI source models. Hybrid techniques that combine a surface integral method with a finite method appear to be the best long-term approach, however more development of these techniques is required.

Hopefully, given the rate at which progress in this area is being achieved, an algorithm capable of accurately analyzing the configurations presented here is not far off. Once such an algorithm is implemented, it will likely become one of the most powerful tools available to EMI engineers.

Acknowledgement

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