Practical Papers, Articles and Application Notes

Flavio Canavero, Technical Editor

In this issue I propose to the readers two very different papers. The first paper is entitled "New Wall Modeling Method Substantially Reduces Time Required for Electromagnetic Simulation of Semi-Anechoic Chamber" by Gwenaël Dun and Paul Duxbury. In this paper, the authors show how they were successful in simulating the performance of large-size semi-anechoic chambers with precision, by means of a proper modeling of the ferrite tiles that cover the walls of the large empty volume of the chamber. A clever time segmentation makes affordable and feasible the virtual prototyping of large environments.

The second paper belongs to the "Education Corner" thread that I started a few issues ago. It represents the first of a two-part tutorial on "Scattering Parameters." The interest for scattering parameters is growing in the EMC community, due to the clear tendency toward higher frequencies in the applications, and the consequent wider use of measurement equipment such as Network and Vector Analyzers. I thought that a review of the physical meaning, of the basic properties, and of some subtleties related to the scattering parameters use would be useful for the practitioners frequently dealing with the measurement of such quantities. For this reason, I welcome the paper "A Primer on Scattering Parameters, Part I: Definitions and Properties" by I.A. Maio. This first part is a rigorous presentation of the basic theory and properties of the scattering representation of multiport systems and is enriched by several examples of high educational value. The second part will be published in the next issue and will be dedicated to more advanced issues (e.g. passivity) of scattering parameters and to the critical task of deriving meaningful and robust models of electrical systems characterized by scattering (real or virtual) measurements.

In conclusion, I encourage (as always) all readers to actively participate in this column, either by submitting manuscripts they deem appropriate, or by nominating other authors having something exciting to share with the EMC community. I will follow all suggestions, and with the help of independent reviewers, I really hope to be able to provide a great variety of enjoyable and instructive papers. Please communicate with me, preferably by email at canavero@ieee.org.

New Wall Modeling Method Substantially Reduces Time Required for Electromagnetic Simulation of Semi-Anechoic Chamber

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Modeling of the absorber on the walls provides a major obstacle in performing electromagnetic simulation of semi-anechoic chambers due to the very high permittivities and permeabilities. Simulation is critical in designing these chambers because near-field effects in the 30 to 200 MHz range cannot be determined by theoretical methods. The simulation model typically requires a very fine mesh in the area of the wall in order to accurately simulate the performance of an Open Area Test Site (OATS). The fineness of the mesh drives up simulation times, typically to the range of several months, delaying the design process.

We attempted to overcome this obstacle by modeling the ferrite absorbers used in the chamber walls as a boundary condition as opposed to incorporating them into the computational domain. This made it possible to increase the mesh size by a factor of 15, which in turn reduced the compute time to about 1% of normal value when biconical antennas are used and there is only a ferrite absorber. When hydrid absorbers are used, the compute time rises to between 3% and 5% of the normal amount. We were pleased that the simulation results correlated very closely with physical testing.

PHOTO: SIEPEL

Fig. 1. Picture of a semi-anechoic chamber.

Development of Semi-Anechoic Chambers

International regulatory agencies have greatly increased radio frequency (RF) emissions and susceptibility requirements since they were first introduced in the 1970s. Generally the standards on RF emissions are based on tests performed outside on an OATS but, these suffer from the effects of weather conditions and ambient noise.

To overcome the problem of weather conditions and ambient noise, semi-anechoic chambers have been developed as shown in Figure 1. The chamber is a RF shielded box with the walls and ceiling lined with materials that are highly absorbent of RF waves in order to provide conditions similar to an OATS. Today, regulatory agencies allow most products to be tested for EMC in semi-anechoic chambers rather than OATS. They require, however, that these chambers behave in a way that closely corresponds to OATS. The American ANSI C63.4 and the European EN50147-2 standards require that EMC testing be performed in a chamber where the Normalized Site Attenuation (NSA) deviates from an OATS by no more than ±4 dB.

The Design Challenge

Companies that build semi-anechoic chambers must be certain that their products meet this specification. Physical testing provides a poor solution because it is very expensive to build a prototype chamber and the physical testing required to evaluate the performance of the chamber over the full range of required frequencies and in all areas of the chamber would cost too much and take too long. Theoretical approaches provide good results for certain subsets of the problem but do not work for others. For example, at very high frequencies, typically above 1 GHz, the antenna geometry is not important so the electromagnetic field can be calculated based on the antenna radiation pattern and on the reflectivity of the wall. But this approximation does not apply to lower frequencies, where the geometry of the antenna is very important due to the near field effect and simulation is a must.

We felt that improving the simulation process was critical to optimizing the performance of chambers so we decided to carefully evaluate the leading electromagnetic simulation methods in terms of their ability in this area. Frequency Domain methods such as Method of Moments (MoM) do a good job of simulating the wire antennas used for the qualification of semi-anechoic chambers but cannot accurately simulate the walls of the chamber. In the simulation between 30 and 200 MHz, MoM CPU time for modeling a biconical antenna is reasonable. But in the case of a pyramidal absorber where an absorbing boundary condition cannot be used, memory and CPU time requirements are quite high.

On the other hand, traditional Finite Difference Time Domain (FDTD) methods work well for the walls but have difficulty in modeling wire antennas. The problem is that these software tools require a very fine mesh, typically 1 mm or less, to capture the geometry of the wires. Models with meshes this small typically have solution times measured in months, which is far too long to have a positive impact on the design process.

TLM Method Provides Accuracy and Speed

After a careful search, we turned to the Transmission Line Matrix (TLM) method for solving Maxwell's equations. The TLM method solves for all frequencies of interest in a single calculation and therefore captures the full broadband response of the system in one simulation cycle. A further advantage is that the TLM method creates a matrix of equivalent transmission lines and solves for voltage and current on these lines directly. This uses less memory and CPU time than solving for E and H fields on a conventional computational grid. The solver tolerates rapid changes in grid density, large aspect ratios of grid cells and localized gridding, enabling the mesh requirements to be kept to an absolute minimum. Finally, an intuitive easy-to-use graphical user interface, optimized meshing algorithm and parallel processing for increased speed, make the software suitable for solving extremely complex and electrically large problems.

We have found that MICROSTRIPES (a commercial implementation of the TLM method) provided the best mix of accuracy and computational efficiency for modeling EMC chambers with ferrite absorbers.

We found that the TLM method successfully modeled both the antennas and the chamber itself. We were able to create compact models of antenna structures that reduce the size of the resulting model while maintaining high levels of accuracy. We defined the transmission parameters by the scattering parameters of the balun and the simulation results of the wires. Because baluns can't be modeled easily, S-parameters were used which do not influence electromagnetic propagation. The use of a compact model to represent the antenna meant that the smallest element size required was 15 mm for the wire connection.

Special Boundary Condition Overcomes Problem

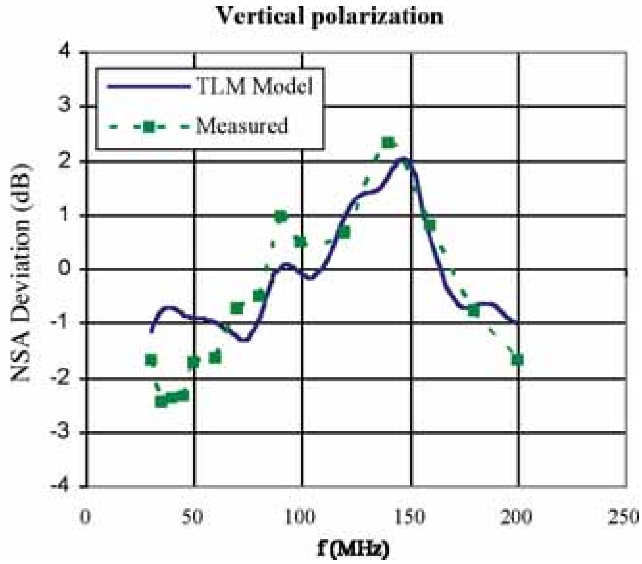
But we ran into a problem in modeling the walls of the chamber. The ferrite absorbers used in the chamber are only 6.7 mm thick, which meant that a mesh of 1 mm was needed. Reducing the mesh size to this level would require a 15 week simulation time. This was much too high so we worked with the TLM software developer to develop a special boundary condition that simulates the reflectivity of the ferrite absorbers, eliminating the need to include them in the model. The boundary condition was defined by the frequency dependent surface impedance of a one dimensional TLM ladder network and defined at the air-ferrite interface for the two polarizations of the E field parallel and perpendicular to the air/ferrite interface. This limit condition takes into account the incidence angle and the polarization of the electromagnetic wave.

The key advantage of making the walls into boundary conditions is the elimination of the need for the 1 mm mesh in this area. This means that the most critical area is the antenna connection which only requires a 15 mm mesh. The resulting increase in the mesh size reduced the computation time to only 1 week on a desktop computer, which was fast enough to serve as the primary evaluation tool during the design process. Five years ago without an absorbing boundary condition it would have taken 2.5 years to simulate a 3-meter measurement chamber. The boundary condition had no effect on the accuracy of the simulation. To validate the model, simulation and measurement results were compared for the two polarizations and two heights of the emission antenna. The deviation between the simulation and the measurements was in 99% of the cases lower than +/-1dB and in every case lower than +/-1.5dB, which was sufficient to optimize the performance of semi or full anechoic chambers.

The Result is a Successful Product

The new 3-meter EMC semi-anechoic chamber, developed with the aid of the simulation methods described herein, makes it possible to perform full compliance radiated EMI and EMS measurements, at 3 meters distance, according to the most commonly used international standards. The optimized design saves space inside the chamber, providing a comfortable work environment. In addition to the ferrite absorbers described above, the semi-anechoic chamber also uses a low-carbon loaded pyramidal absorber that is transparent in the low frequency band but preponderant above 1 GHz. Since the reception antenna is directional above 1 GHz, the pyramidal absorber only needs to cover the specular zone (optimized design). The pyramidal absorber is modeled by an anisotropic multilayer model with an error lower than 5% for frequencies up to 1 GHz as shown in Figure 2.

We can say that the key to the successful simulation in this application is the boundary condition for the modeling of the ferrite tiles which increases the time step that can be used. Being able to predict the performance of semi-anechoic chambers with precision makes it possible for the designer to evaluate many more alternatives during the design process without physical prototyping.



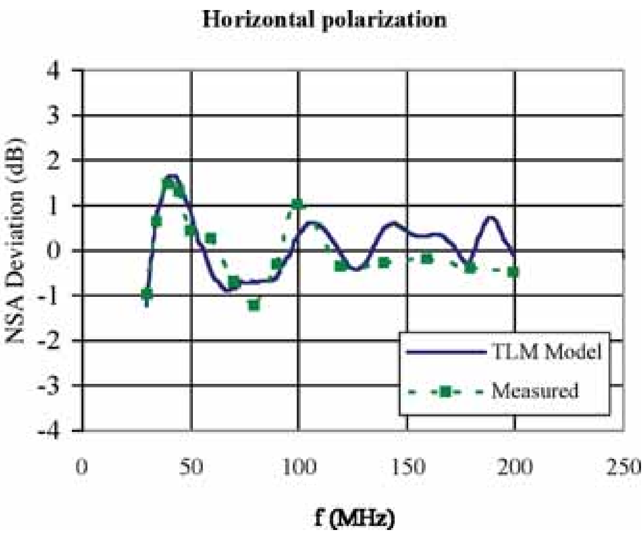


Fig. 2. Simulation vs. Measured Results.

About the Authors

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Paul Duxbury is a Senior Sales and Application Engineer with CST (http://www.cst.com) GmbH. He received a BEng(Hons) in Electrical and Electronic Engineering from Hertfordshire University in 1995. That same year he joined BSI, involved with EMC testing and the verification of BSI's OATS. In 1997, he joined IFR with responsibility for EMC test and design of their own products and the external commercial activities of the laboratory. Paul has been providing technical support since 2000 to users of MICROSTRIPES (www.microstripes.com) across Europe and the Asia/Pacific, with a particular emphasis on EMC applications. He also works closely with the product development team on developing product requirements.