Modeling Approach for the Assessment of Field Distribution and Uniformity in Anechoic Chambers

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***Abstract*— The paper presents a modeling approach for assessing the properties of a generic anechoic chamber, taking into account wall and floor coatings, measurement table and antenna. Unlike previous approaches, the absorbing walls of the chamber are modeled as infinitely thin sheets rather than as volumetric objects, which leads to considerable improvement of the simulation performance. Given the uncertainty regarding the exact geometry of the pyramidal absorbers and especially of their material properties, a technique for determining the equivalent material properties from measured reflectivity data is presented.**

The large electrical size of the problem, its multiscale character, given by the large dimensions of a typical chamber on one hand and the fine details of the antenna on the other hand, as well as the complicated material parameters represent the challenges of such a simulation.

***Index Terms*— Electromagnetic compatibility, electromagnetic analysis, immunity testing, time domain analysis, anechoic chambers.**

I. INTRODUCTION

For specific electromagnetic compatibility (EMC) measurements, one of the characteristics of anechoic chambers prescribed in standards such as [1] is the field uniformity in the region of the device under test (DUT). The electric field is thereby measured in a defined number of points. In contrast, a simulation of the entire chamber, including the measurement setup, can provide *exhaustive* information about the field properties inside the chamber for that specific setup. Moreover, simulation can help taking a correct decision when changes of an existing chamber are planned, since the effect on the field of e.g. different new wall types from different suppliers can be assessed beforehand, without the need to actually mount them.

The simulation of absorbing materials and even of entire anechoic chambers has attracted a lot of attention in the last years [2]-[5]. In the simulation of entire anechoic chambers, either the actual 3D shape geometry of the absorber elements is modeled [2], [4], [5] or homogeneous *finite-thickness* layers with equivalent material parameters are used [3].

The abstract presents a modeling approach for assessing the properties of a generic anechoic chamber in the multi-GHz frequency range, taking into account wall and floor coatings, measurement table and antenna. Unlike previous works, the absorbing walls of the chamber are modeled as infinitely thin sheets, which leads to considerable improvement of the simulation performance. A comparison with measurement was performed and shows a good agreement. The electrical size of the problem (around 60 x 50 x 33 wavelengths at maximal frequency of interest, 3.5 GHz), its multiscale character, given by the large dimensions of a typical chamber on one hand and the fine details of the antenna on the other hand, as well as the complicated material parameters represent the challenges of such a simulation.

II. DESCRIPTION OF THE ANECHOIC CHAMBER MODEL

The model of the anechoic chamber is fully parameterized, in order to allow easy changes and investigation of “what-if” scenarios. Its initial dimensions corresponded to those of the anechoic chamber of the EMC Lab at Continental in Wetzlar, Germany. The inner dimensions of the chamber are 5.16 m x 4.36 m x 2.88 m. A measurement table made of wood with dimensions 2.5 m x 1.0 m and a height of 1.0 m was placed in the model and covered by a 1.5 mm thick metallic steel plate. The steel plate is grounded by electrically connecting it to the grounded wall by means of a variable (parameterizable) number of metal stripes. Several antenna types can be placed at a user-defined location within the chamber. The model can be thus easily adapted to various chamber sizes, table dimensions, antenna configurations, etc.

Fig. 1 depicts the simulation model of the chamber.

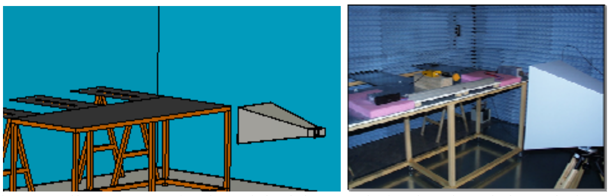

Fig. 1. Fully parameterized model of the anechoic chamber (left) and picture of the real anechoic chamber (right). Unlike the real chamber, the walls in the model are modeled as infinitely thin sheets with frequency-dependent material parameters.

The floor of the chamber is plated with ferrite tiles and can be fully or partially covered with a metallic plate. The walls have a multilayer structure, presented in the next section.

The materials of the walls and of the floor are parameterized as well. The walls of the anechoic chamber can be covered with various types of absorbant materials. In the case of the Wetzlar chamber, ferrite tiles (for low-frequency absorption) are fixed on wooden panels, and covered with pyramid absorbers (for high frequency absorption). Steel backing on the other side of the panels ensures that the entire chamber is properly grounded.

III. MODELING THE ABSORBING WALLS

As explained in the previous section, the absorbing walls of the chamber can have a complex structure, which could in principle be modeled in a 3D setting, but would lead to a very high computational complexity. For example, the chamber walls consist of no less than 21,200 pyramids. Both the pyramidal absorbers and the ferrite tiles placed behind them exhibit a frequency dependent behavior.

In the simulation, the wall configuration was taken into account by means of an infinitely thin equivalent material, whose parameters can be determined either by simulating one unit cell of the wall, or by fitting the model parameters to measurements. The latter has the advantage that it does not require the availability of reliable frequency-dependent material parameters. For the Wetzlar wall materials, measurements for the reflectivity were available. The parameters of the equivalent material model were determined by using the following procedure:

1) Smoothe/downsample the measured data.

2) Solve a nonlinear problem at each frequency point *f*, to determine the equivalent surface impedance of the wall Zs(*f*) which yields the same reflectivity as the measured result. These Zs parameters can be used directly in a frequency-domain simulation.

3) For a time-domain simulation, use a fitting procedure on the large number of Zs samples calculated in 1) to generate an analytical material model of the type

$$Z(\omega) = Z_\infty + j\omega L + \sum_{n=1}^{N} \frac{\alpha_n}{\beta_n + j\omega} + \sum_{n=1}^{M} \frac{\gamma_{0,n} + j\omega\gamma_{1,n}}{\delta_{0,n} + j\omega\delta_{1,n} - \omega^2} . \quad (1)$$

The model order N+2*M should be kept as small as possible for computational efficiency. In our case, we applied the automatic fitting procedure of the commercial software package CST MICROWAVE STUDIO [6], which was used for modeling the structure and in the subsequent simulations.

IV. SIMULATION RESULTS

The simulation results for the infinitely thin wall material are presented in Fig. 2.

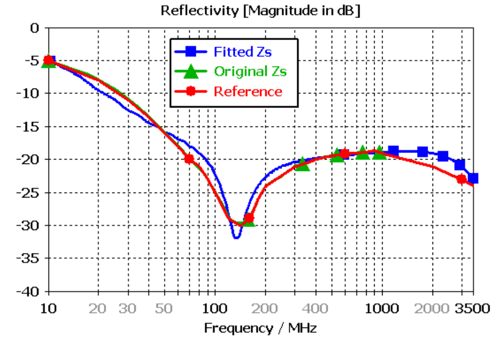

Fig. 2. Reflectivity of the anechoic chamber walls: comparison between measured data and results simulated with the original (unfitted) and fitted surface impedance models. The smoothed measured reflectivity is used as reference.

The calculation for the original Zs data obtained directly from measurements was performed with the finite-element frequency-domain (FD) solver, while the time-domain (TD) solver was used in conjunction with the analytical Zs model obtained by fitting. The simulation model includes the infinitely thin sheet, placed in front of a waveguide port. The used boundary conditions are equivalent to a plane wave excitation, and the reflection coefficient S11 at the port characterizes the wall reflectivity. It can be seen from Fig. 2 that, with the original, unfitted data used in the FD solver, the measured reflectivity can be perfectly reproduced. However, for large structures the FD solver might not be the most computationally efficient choice. The TD solver, which was used in the simulation of the entire chamber, requires the fitted Zs expression and is able to reproduce the trend of the measured result with very good accuracy.

Fig. 3 shows the vertical component of the electric field strength in a plane placed at the location of the device under test (DUT), for two configurations: in the actual test setup (table and chamber floor with groundplane) and in the setup for field uniformity measurement (empty chamber, absorbing floor). The range of values in the plot is limited to 0..-6dB relative to the maximum, thus giving an excellent visual indication of the field uniformity. The simulation time up to 2 GHz was of 37 minutes on a PC endowed with GPU-acceleration card.

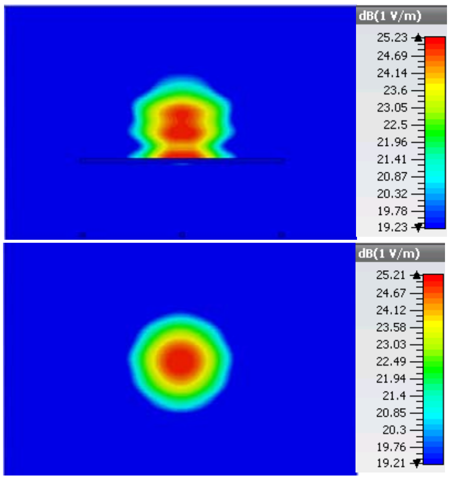

Fig. 3. Vertical component of the electric field strength at 1 GHz, at the DUT location: actual test setup (top) and empty chamber (bottom). Blue color indicates the limit of the 0..-6 dB field homogeneity area.

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