Measurements and Simulation of a Semi-anechoic Room Using Field Mapping as an Indication of Chamber Quality

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Abstract
In this paper we discuss the use of a field mapping approach for determining chamber quality. Both measurements and simulation results are used to illustrate this approach.

Introduction
The quality of a semi-anechoic chamber can be measured in a number of different ways. There are a few standard test methodologies, such as Normalized Site Attenuation for radiated emissions test chambers, and field uniformity tests for radiated susceptibility chambers [1,4]. However, these tests cover only a limited area within the chamber, and if a specific chamber is intended to be used for a variety of product testing, neither of the standard test methodologies may provide sufficient information for a more general use.

A useful way to characterize a general use chamber is to map the fields over a wide frequency range, and insure there are no resonant modes. This can be accomplished by a series of field measurements over the entire chamber. However, these tests are time consuming, and become a significant cost/time impact when a large chamber is to be evaluated. This paper describes the testing of a chamber, and the matching simulations of the same chamber. Since the simulation data are validated through the measurements, larger chambers can be evaluated using simulation techniques, without the need to perform the time consuming measurements. In fact, various absorber materials can be evaluated with the simulation technique, and an optimum chamber design can be developed before the chamber is built.

Measurements
A semi-anechoic chamber at an IBM site was shown to not meet the standard field uniformity test standards because of excessive reflections from the cones over much of the intended frequency range. The existing cones were to be removed, and the room re-lined with newer technology cones and tiles to improve the room’s performance. The room was intended to be used for a variety of standard commercial EMC and internal IBM quality EMC tests. So a more general quality evaluation was desired. Field mapping was determined to be a useful measurement technique for general chamber quality. This provided an opportunity to perform a field mapping before and after the room was refurbished.

A spherical dipole source\(^1\) (originally developed by NIST [5]) was used as a repeatable and physically small source. A block diagram of the system is shown in Figure 1. The spherical dipole antenna source was placed in the center of the room at a one meter height from the metal floor. The field mapping was performed over the inside of the chamber on a 0.6 m

![Figure 1 Precision Spherical Dipole Source Block Diagram.](image-url)

\(^1\) The Precision Spherical Dipole Source is manufactured by Applied EM Technology. The identification of commercial companies and equipment, implied or specific, does not represent a recommendation or endorsement of the companies or the product by NIST or NTIA.
A short (25.4 cm) dipole receive antenna was used to avoid field averaging by a larger antenna. The receive antenna was moved around the room and the field measured at each grid location. Various frequencies were measured over the frequency range of 30 MHz to 1 GHz. A discussion of the uncertainties of these types of EMC measurements is given in [6]. The vertical and horizontal polarization were both tested. For all receive locations, the transmit and receive antennas were aimed directly at each other for maximum reception. The room geometry is shown in Figure 2.

![Figure 2 Test Room Geometry.](image)

**Measurement Results**

The measurements were repeated for each grid location for the original chamber (old cones) and the refurbished chamber (ferrite tiles on the walls and ceiling). The original chamber measurement results showed significant modes at a number of frequencies where high and low field amplitude spots could be observed. When the ferrite tiles were installed, these modes were dramatically diminished and the fields more uniform across the room. Figure 3 shows an example of the field contour at 100 MHz with the original cone absorber and the new ferrite wall covering. Notice how the modal structure and magnitude of the fields have changed with the ferrite absorber.

![Figure 3 Measured Field Map for Vertical Polarization at 100 MHz. a) chamber with cone absorber and b) chamber with ferrite absorber.](image)
Simulations
The Finite-Difference Time-Domain (FDTD) technique was used to simulate the semi-anechoic chamber. In a previous paper [7], a FDTD modeling technique for analysis of anechoic and semi-anechoic electromagnetic test chambers was presented. The FDTD model presented in [7] discussed various aspects of time-domain modeling, including discussions of the methods used to eliminate the need to spatially resolve the fine detail of the absorbing structures and approaches for incorporating both frequency-dependent material properties (i.e., permittivity and permeability) into the time domain models. The model presented in [7] was validated by comparison to measured data, and demonstrated how time-domain techniques can be used to characterize chambers, predict chamber performance, and diagnose problems with both absorbers and chambers.

This model was used to simulate electric field impulse responses in a semi-anechoic chamber. The simulation was similar to the physical testing in that the source was placed in a 'central' location (i.e., from the perspective of someone standing in the chamber, on the (left-to-right) center-line of the cavity, at a (front-to-back) position that puts the transmitter approximately 3 m from the front wall), and the fields were determined throughout the chamber. The absorbing material was modeled using lossy material constants for the type and size of absorber material installed in this existing chamber. From our simulation, a set of field map plots was generated, which showed resonant modal effects similar to those observed in the measurements. Figure 4 shows the field maps (functions of position within the chamber) at 100 MHz. The figure shows contour plots of the magnitudes of the vertical electric field impulse response on a horizontal plane 1 m above the floor in this semi-anechoic chamber. The results shown in this figure have been normalized by the distance from the transmitter (source point) in order to reduce the dominant near-field effects in the vicinity of the source. As in the measurement results, two field contour maps are shown: one map for a chamber lined with poor absorber (urethane pyramids only) and one map for the same chamber but with better performing absorber (ferrite tile). Note that as in the measured results, the (cavity) modal behavior is less pronounced for the chamber with the better absorber. These results illustrate that a chamber's cavity resonances can be mitigated with better performing absorber.

Asymmetry: Spatial Variability
Another indication of room quality is the amount of asymmetry (spatial variability) in the chamber. In an ideal chamber (i.e., no reflections from the absorbing structures), at any location in the chamber with a set transmitter and receiver distance and receiver height, the fields would not vary throughout the chamber. However, no matter how good the absorbing structure is, some reflections will occur. The sum of all the reflected and direct waves (which have magnitude and phase) at any location in the chamber differs due to constructive or destructive interference. How these waves add together determines the spatial variability in the total field that is present at any location in the chamber. A chamber with good absorber material would have equal field strength at a given distance from the source, regardless of the direction from the source. Figure 5 shows an example of measured asymmetry of the chamber before the new absorber material was installed and Figure 6 shows the same analysis after the ferrite was installed. The maximum deviation across all frequencies was greatly reduced by the new ferrite absorber material.

Summary
Measurements and FDTD simulations were used to evaluate a semi-anechoic room before and after new absorber material was installed. The simulations and measurements agreed, indicating that further chamber evaluations (especially for large chambers) can be performed with simulations, thus saving significant testing time. These tests and simulations also showed a different way to analyze chambers that provides much more information about the performance of the absorber across the entire chamber than do traditional certification tests. With time- and frequency-domain techniques, we show here that the performance of chambers can be significantly altered with only small changes in the type of absorbing structure used, and we illustrate some examples of undesirable (cavity) modal field distributions which can occur inside a chamber when non-optimal absorber is used.
References


Figure 4 Example of FDTD Simulation Results at 100 MHz.
Variation in Received Levels for a Constant Distance Between Sphere Source and Receive Dipole Antenna (Vertical Polarization 8305 RES)

Figure 5 Field Variation Across Various Distances and Frequencies in Original Chamber.

Variation in Received Levels for a Constant Distance Between Sphere Source and Receive Dipole Antenna (with Ferrite Installed) Vertical Polarization

Figure 6 Field Variation Across Various Distances and Frequencies in Chamber with New Ferrite Absorber Materials.