High Performance 10-meter EMC Chamber Design

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Abstract

In recent years, the need for a large, high performance EMC chamber is more and more pressing due to the increased likelihood of spectrum contaminates to the open area test site (OATS) environment. A high performance 10-meter EMC chamber with a 2 dB NSA design is discussed in this paper. It may be used for high precision radiated emission measurements and antenna calibration inside the chamber, in addition to traditional EMC measurements. Design and performance validation of the chamber are divided into two sections: the chamber only with ferrite tile and the chamber with hybrid absorber (ferrite tiles and pyramid foam absorber). Excellent agreement is shown between the measured and simulated data as detailed in the paper.

Keywords

10-meter EMC chamber, NSA, compact absorber

Introduction

A 10-meter EMC chamber is often preferred over an open area test site (OATS) for measuring radiated emission levels of a device under test (DUT) because of the lower ambient noise, especially at frequencies below 1 GHz. The net space for large DUT measurements is very important inside the chamber. It is also desirable in some cases to perform antenna calibrations in an anechoic chamber. The 10-meter EMC semi-anechoic chamber before refurbishing as described in this paper had been used for over 10 years; it was highly desirable to improve the RF performance and reverse performance degradation in the absorbers, cables, illuminating system and the turntable. The NSA deviation was just lower than 4.0 dB at the low frequency band for the chamber before refurbishment. Moreover, new test validation requirements in the international standards from the last 10 years added new challenges. Therefore, an extensive reconstruction was carried out to improve the performance of the chamber. Because of the relatively large size of the existing chamber, and the advances in the anechoic absorber designs, a high performance 10-meter EMC chamber with a 2 dB NSA deviation design was proposed. With such performance, the chamber can accommodate high precision radiated emission measurements and antenna calibrations. Design and performance validation of the chamber are divided into two steps: the chamber only with ferrite tile and the chamber with hybrid absorber (ferrite tiles and pyramid absorber). The measured and simulated data is presented for each phase. Excellent agreement results are obtained and shown in following sections.

Chamber Design

The shielded enclosure is 23.18 m × 16.88 m × 9.6 m with a raised floor, and there are dual turntables with diameters of 3.0 m and 1.2 m, respectively. The 3.0 m turntable will be used for large DUTs for high precision radiated emission and radiated immunity tests. The smaller turntable is planned for using during antenna calibrations. The objective is to achieve better NSA deviations than 2 dB at each turntable location at frequency range between 30 MHz to 1 GHz. Several aspects of the chamber design are considered, listed as following.

Absorber design

The absorb performance is a crucial aspect for the high performance chamber. Absorbers are used to suppress the metal shielding wall reflection and ambient noise interference inside the chamber. The reflectivity of the absorber at the frequency range and normal incident wave should be lower than −25 dB. If carbon-loaded foam pyramid absorber is used, the length of absorber will be exceedingly long, e.g., larger than 2.4 m for this frequency range. The decrease in the net available space inside the chamber would not be acceptable. Therefore, a new hybrid absorber is designed to be installed. The total absorber performance is the combination of the ferrite tile for magnetic field suppression and the pyramid foam absorber for electrical field suppression.

a) ferrite tile

Material properties and thickness of the ferrite tiles are critical. Tiles with a thickness of 5.3 mm have been selected for their RF properties and weight considerations.

b) Hybrid Absorber

With the contribution of ferrite tile, a compact foam absorber with a length of 1.8 m is designed for this chamber. The hybrid absorbers shown in Figure 1 are installed, which are not only space-saving, but more importantly achieve the challenging RF performance requirements.

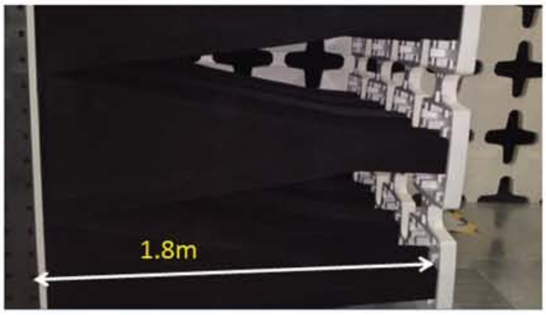

Figure 1 Compact hybrid absorber (ferrite tile + carbon-loadedfoam absorber).

Turntable and door design

In order to improve the usage flexibility of the chamber, the chamber will have two turntables to expedite product testing. Based on turntable requirement, these two turntables are aligned cross the width direction. The antenna calibration line is close to the inner side wall to achieve a better performance and avoid the effect of doors. Two doors are used for this chamber. The larger one is a sliding door with the size of 3 m × 3 m for large DUTs and the other door is a manually operated door for personnel access. The detailed arrangement is shown in Figure 2.

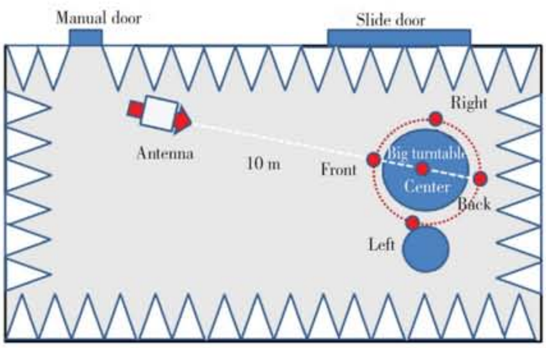

Figure 2 Door and turntable arrangement

Performance Validation and Analysis

In order to validate our design of this high performance chamber, two steps of NSA measurement were taken for the performance validation. Table 1 shows the equipment and components used in the chamber.

Table 1 Instruments used for site validation

Instruments	Company and Type
Vector network analyzer (VNA)	Agilent N5230C
Antenna	ETS-Lindgren 3110C/3148B
Software	ETS-Lindgren EMQuest™
Attenuator	Agilent/Weinschel 10dB
Antenna mast/ controller	ETS-Lindgren 2090/2070B

Figure 3 shows the test setup for the performance validation with only the ferrite tiles installed. Figure 4 shows the test setup for the performance validation, using the hybrid approach of ferrite tiles and foam absorber. The site validation measurements are based on the international standards [1-3]. Two pairs of broadband antenna,i.e., a pair of biconical antennas ETS-Lindgren 3110C and a pair of LPDAs ETS-L 3148B, were used for the site validation test. The antennas were first calibrated on the ETS-Lindgren OATS in Cedar

Figure 3 Test setup for the performance validation test with ferrite tiles only.

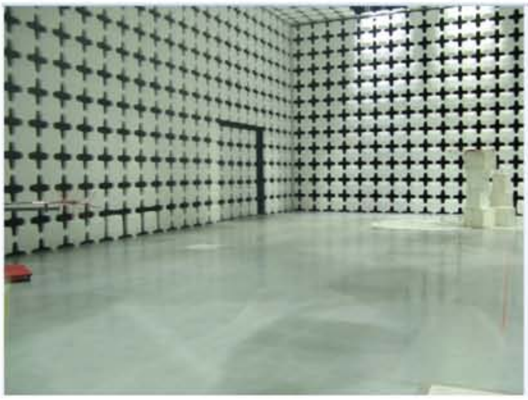

Figure 4 Test setup for the completed chamber performance validation, using the hybrid ferrite tile and foam absorber.

Park, Texas. The EST-Lindgren 2070B antenna tower was used to scan the receiving antennas from 1 m to 4 m. The Agilent VNA was used to measure the S_{21} parameter. The quiet zone size is 4 m in diameter which allows for some margin for EMC measurements on the 3 m turntable.

Results of the chamber with ferrite tiles

Figure 5 and Figure 6 show the simulation results of the deviation of NSA. At low frequency (about 30 MHz), the deviation of NSA is larger than 4 dB at horizontal polarization. As shown in these figures, the ferrite tiles alone are not sufficient to achieve the performance specifications.

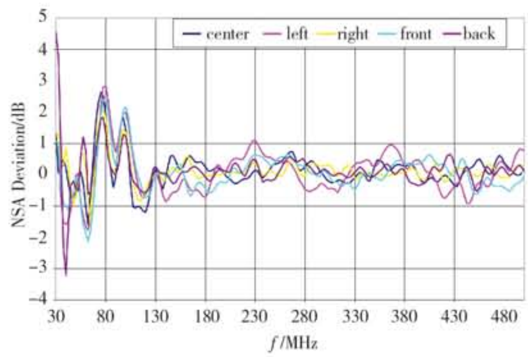

Figure 5 Simulated NSA deviation at horizontal polarization

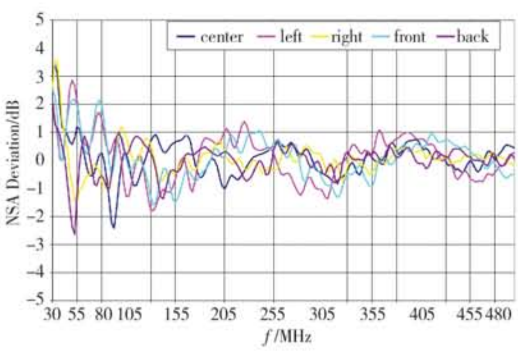

Figure 6 Simulated NSA deviation at vertical polarization

The NSA simulation is based on geometrical optics, i.e., a ray-tracing method. A ray representation is used to account for reflections from the chamber interiors. The plane wave reflection coefficient of the absorbers are computed based on the "homogenization" method [4-5], which produces both magnitude and phase information of the reflections. The fields that are incident at the reflection point are considered as local plane waves. The specular reflection of the EM wave from the chamber floor, walls and ceiling can be calculated at varying incident angles. To achieve better agreement with the measured results, four bounces are kept before the magnitude of a ray is considered negligible. The contributions from all rays are summed vectorically to calculate the site attenuation from transmitting antenna to receiving antenna. The deviation between the calculated chamber site attenuation and an ideal OATS is the deviation of the NSA.

Figure 7 and Figure 8 show the measured results of the deviation of NSA. At low frequency (about 30 MHz), the deviation of NSA is larger than 4 dB in the horizontal polarization. This matches with the simulated result. The worst position is the back position which is shown in Figure 2. The ferrite wall affected the performance with EM coupling. The comparison results of 30~300 MHz are shown in Figure 9. The agreement between the measured and simulated data is very good.

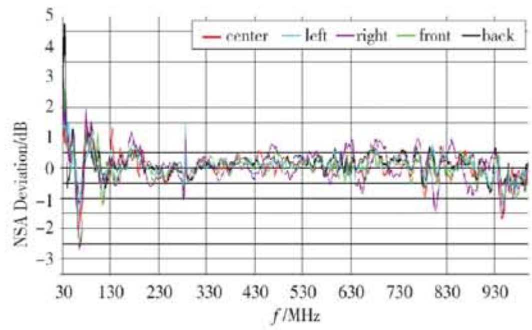

Figure 7 Measured NSA deviation at horizontal polarization

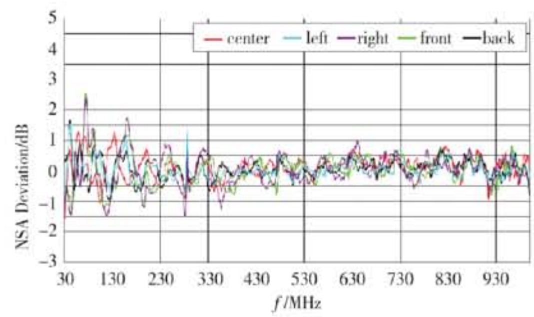

Figure 8 Measured deviation of NSA at vertical polarization

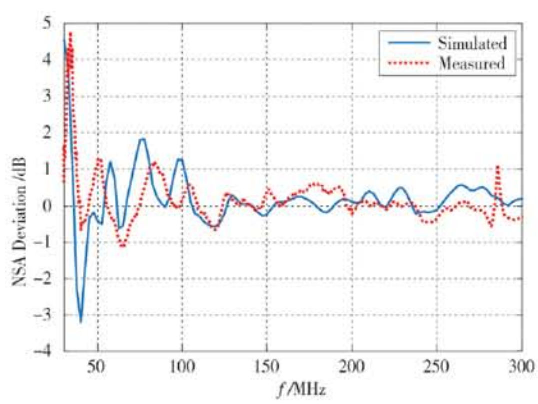

Figure 9 The worst results are shown at the back position in this detailed comparison of simulated and measured data

Results of the chamber with hybrid absorber

Figure 10 and Figure 11 show the simulation results of the NSA deviation of the chamber lined with hybrid absorber on walls and ceilings. The largest NSA deviation occurred at low frequency (at about 30 MHz) at horizontal polarization. The compact hybrid absorber performance ideally addresses the entire frequency range (30 MHz~1 GHz) and suppresses the undesired EM energy.

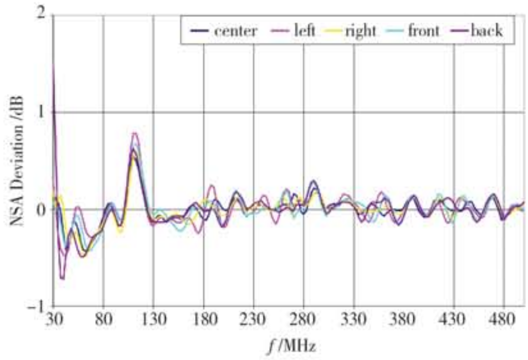

Figure 10 Simulated NSA deviation at horizontal polarization

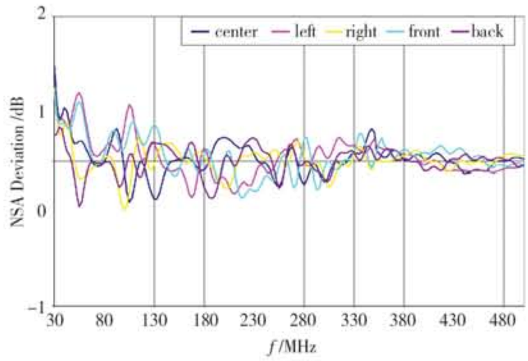

Figure 11 Simulated NSA deviation in vertical polarization

Figure 12 and Figure 13 show the measured results of the NSA deviation of the chamber with the hybrid absorber. At low frequency (at about 30 MHz), the deviation of NSA is largest at horizontal polarization. The vertical polarization results are better because of the optimal ferrite installation with the half piece staggered layout [6].

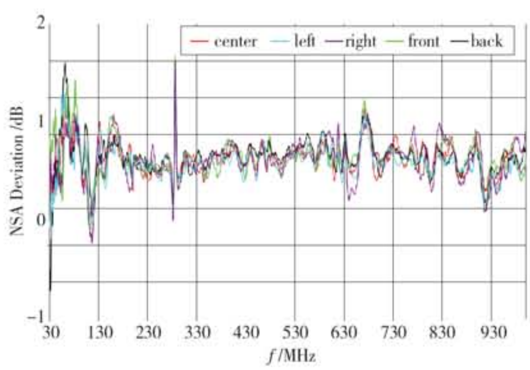

Figure 12 Measured deviation of NSA in horizontal polarization

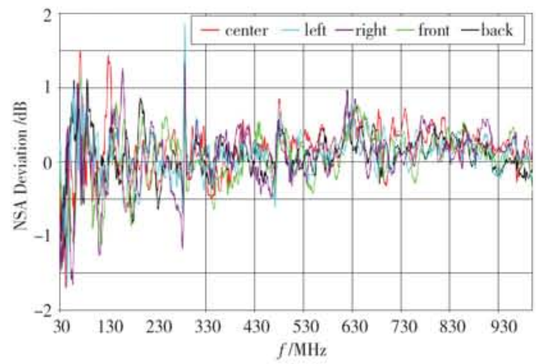

Figure 13 Measured NSA deviation in vertical polarization

It avoids the longer gap at vertical polarization and improves ferrite performance. It is unlike the usual case where vertical polarization results are worse because of the lower performance absorber with installation gaps.

Table 2 Results comparison summary

NSA/dB	Horizontal Polarization		Vertical Polarization	
	Simulated	Measured	Simulated	Measured
Ferrite	4.56 @30 MHz	4.75 @30 MHz	3.58 @30 MHz	2.47 @30 MHz
Hybrid absorber	1.514 @30 MHz	1.654 @30 MHz	1.314 @30 MHz	1.85 @282MHz

Table 2 shows the largest deviation occurs at the back position (from both simulation and measurement data). Except for the measured results at 282 MHz for vertical polarization, the largest deviations are concentrated at around 30 MHz. The NSA deviation results at 282 MHz are caused by an abnormal resonance of the log periodic dipole array (LPDA) antennas. As shown in Figure 14, a resonance at 282 MHz can be observed in the free-space dual antenna factors. A slight disturbance in the resonance frequency may cause a large variation in the NSA deviations. Even with the resonance behavior caused by the antennas, the NSA deviations of this chamber are well within the specifications. Good correlation

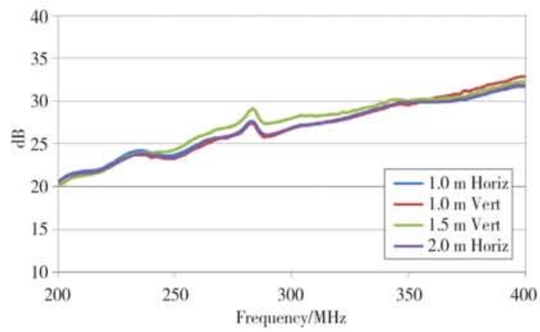

Figure 14 ETS-Lindgren Model 3148B antenna factor in a 10 m free space site

is shown between the simulated and the measured NSA results in this paper. The numerical simulation is an extremely valuable tool in guiding designs of these challenging high performance EMC chambers.

Conclusions

An existing 10-meter chamber lined with traditional foam absorber some 13 years ago is retrofitted with new hybrid absorber and achieves 2 dB NSA deviation. The performance of the chamber is measured with ferrite tiles only and with a combination of ferrite tiles and foam absorber, also known as hybrid absorber. The modeled or simulated performance is compared with the actual measured performance. Excellent agreement is shown. The replacement of the existing longer absorber with the new, shorter hybrid absorber increased test volume. Further, the chamber design change from one turntable to two different size turntables expedited test throughput and facilitated a wider range of products that could be efficiently tested. Existing chambers that have been in use for over 10 years should consider a retrofit to increase chamber performance and improve test productivity.

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