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Uncertainty Analysis on the Reconstruction of the Radiated Field in a Multiple Monopole Source Stirred Reverberation Chamber

A. De Leo, G. Cerri, P. Russo, and V. Mariani Primiani

Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche – Ancona – Italy

Abstract

In this paper a statistical analysis on the measurement uncertainties related to the radiated emissions of an Equipment Under Test (EUT) is reported. The measurement environment is a Reverberation Chamber (RC), where the EUT is placed inside its working volume and the electric field is sampled close to the RC's metallic walls. From these measurements the free space emission of the EUT is reconstructed. The RC is equipped for the Multiple Monopole Source Stirring (MMSS) technique, which requires an array of monopole antennas placed onto the walls; therefore, in the present paper, the same antennas are used to sample the orthogonal component of the electric field radiated by the EUT. Two uncertainties mechanisms are analyzed: the position of the monopoles onto the walls and the direction of the monopole, that in the ideal scenario are perfectly orthogonal to the walls, but in a more realistic scenario, they could be oriented slightly in a different way.

1 Introduction

Historically, in the Electromagnetic Compatibility (EMC), emission tests [1] are performed in Anechoic Environment (AE), at first the Open Air Test Site (OATS) and successively in equivalent environments as Anechoic Chambers (AC), Transverse Electromagnetic (TEM) or Gigahertz TEM (GTEM) cells [2]. In these structures, the electromagnetic field is analogous to a far field plane wave behavior.

More recently, RCs have been used as an alternative site for EMI test [3]: the nature of the electromagnetic field inside these structures has, on the contrary, statistical behavior; in other words it is, inside a subvolume called working volume, statistically uniform, isotropic and randomly polarized. Moreover the field behaves as an ergodic stochastic process.

This property can be achieved thanks to different stirring actions [4]: using one or more rotating paddles [5], moving [6] or vibrating [7] the RC's walls or varying the physical properties of the source of the electromagnetic fields inside the chamber, as in the source stirring techniques [8].

One of the possible ways to achieve the source stirring action is using a fixed array of antennas mounted onto the walls of the chamber. They are sequentially fed to stir the electromagnetic field inside the chamber. For this technique , monopole antennas can be used and in this case it is called Multiple Monopole Source Stirring (MMSS) [9] [10].

The same monopoles mounted on the walls can be used in receiving mode as electric field probes, to measure the normal component of the electric field.

Recently, a theoretical model [11] [12] was developed to reconstruct the electric field radiated in free space by an EUT, using its emission data measured inside the working volume of the RC by monopoles place on the RC's walls. This method has the advantage respect to the standard [3], to compute directly the electromagnetic emission without the estimation of the directivity of the EUT from its geometrical dimensions.

It is important to highlight that the evaluation of the emission consists of measuring the maximum field radiated by an EUT, one value only. For a complex object it is difficult to identify the direction of maximum radiation, and therefore in traditional measurement systems, the EUT is generally rotated in different positions. The use of a MMSS RC allows to avoid EUT movements, but in emission problems the field has to be reconstructed in a 3D space. In the present paper the analysis is extended to the radiation pattern to show the reconstruction capability of the method, that allow us to achieve the total 3D emission of the EUT, in order to identify the maximum radiation. Therefore, the method should not be understood as an alternative way of measuring the radiation pattern of an antenna.

The main aim of this paper is to evaluate the effect of the uncertainties on the reconstruction of the radiated emissions. In particular, two elements were considered: the uncertainty on position of the monopoles and the uncertainty on their orientation, perfectly orthogonal to the walls only in an ideal scenario.

The paper is organized as follows: section 2 describes the method, section 3 reports the scenario and section 4 some results of the statistical analysis are reported.

2 Method

The analytical method to reconstruct the free space electric field radiated by an EUT, using data collected when it is placed inside a RC is described in [13] [14].

The method firstly evaluates the electric field samples (the reference values), radiated by the EUT on the RC's

walls. In real situation the EUT field is unknown and so the field samples can be measured by the monopoles placed inside the MMSS. In this work, for sake of comparison, the EUT radiating structure is assumed to be known, and in particular consists of a combination of simple elements (dipoles, loops or apertures on ground planes) so their radiation both inside the RC and in free space, can be analytically determined.
Secondly, equivalent sources that can replaced the EUT inside the RC are determined. These equivalent sources are magnetic and electric currents regularly placed onto all the working volume of the RC and spaced by half-wavelength. The equivalent sources are determined by minimizing the difference between their field and the field reference values in the wall sampling positions
Finally the equivalent sources are placed in a free space scenario and their radiated emissions are computed (equivalent emissions).
To get a comparison, the chosen EUTs are placed in free space and the electric field radiated is computed (reference emissions).

3 The scenario

The scenario is a rectangular cavity (dimensions 0.8 m × 0.9 m × 1.0 m). In the analytical model, the walls have a finite conductivity that accounts for all the losses mechanisms. Its value is chosen in order to match the theoretical quality factor with the measured one. An array of 120 monopoles unregularly placed onto the RC's walls is used to sample the field. Figure 1 shows the scenario and in detail the i-th monopole.

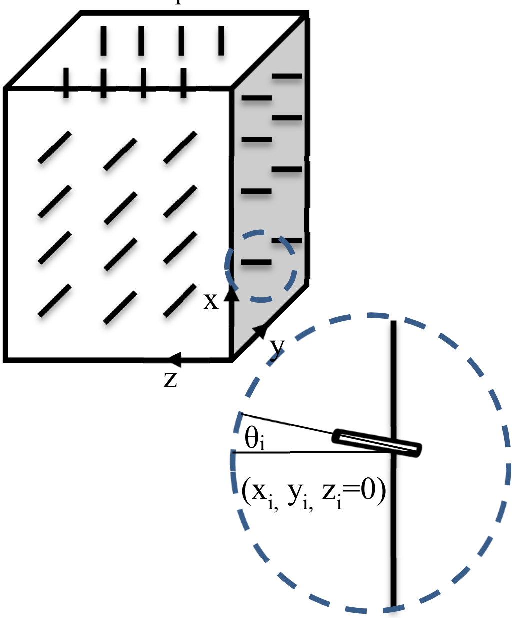

Figure 1. The MMSS RC, where the position and the orientation of the i-th monopole onto the RC's wall z=0 have been highlighted

Considering for example the i-th monopole placed onto the wall z = 0, its coordinates are (x_i, y_i) and its direction forms a θ_i angle with the normal to the walls.

We want to study the effect of the uncertainty on x_i, y_i and θ_i on the reconstruction of the electromagnetic emissions.
In particular, it can be assumed that these three parameters are affected by an uncertainty obtained from a rectangular distribution:

$$\begin{cases} x_i = \overline{x_i} \pm \Delta x_i \\ y_i = \overline{y_i} \pm \Delta y_i, \\ \theta_i = \overline{\theta_i} \pm \Delta\theta_i \end{cases} \quad (1)$$

where $\Delta x_i = \Delta y_i = 5\ mm$, $\overline{\theta_i} = 0°$ and $\Delta\theta_i = 10°$.

4 Results

In this section three different EUT are considered:

- a low directivity EUT, modeled by three dipoles and three loops having three orthogonal directions;
- A high directivity EUT, modeled by three loops having the same direction and spaced by half wavelength
- A slot on a metal plane.

These EUTs were chosen because their electromagnetic radiation can be analytically determined both in free space and inside the rectangular cavity. For each scenario, simulated at the frequency of 1 GHz, a set of 100 simulations were carried on to perform the statistical analysis on the estimated field values. For each simulation, a random function determines the values of the position and the orientation of the monopoles. Finally, for each direction, the average value (μ_E) and the standard deviation (σ_E) is computed and their value compared to reference values (E_{ref}).

3.1 Low directivity EUT

At first, let consider an EUT made by three dipoles and three loops placed at the center of the RC and directed along three orthogonal directions. Figure 2 shows the comparison between the actual electric field (reference) radiated in free space at distance of 10 m and the field reconstructed by the method. In particular, the two black lines represent the average reconstructed values plus and minus their standard deviation. The main parameter to check is the maximum of the electric field, because it is the physical quantity for an electromagnetic emission test. Table 1 shows that the difference between reference and reconstructed values is very small.

Max Electric Field [mV/m]	**E_{ref}**	**μ_E-σ_E**	**μ_E+σ_E**
EUT: 3 loops and 3 dipoles	11.5	11.2	12.0

Table 1. Maximum values of electric field radiated by 3 loops and 3 dipoles; reference (E_{ref}), minimum (μ_E-σ_E) and maximum (μ_E+σ_E) reconstructed values are reported.

The method is able to calculate the radiated emissions in all the directions to get their maximum absolute value; Figure 2 reports, as an example, the plane z = 0.

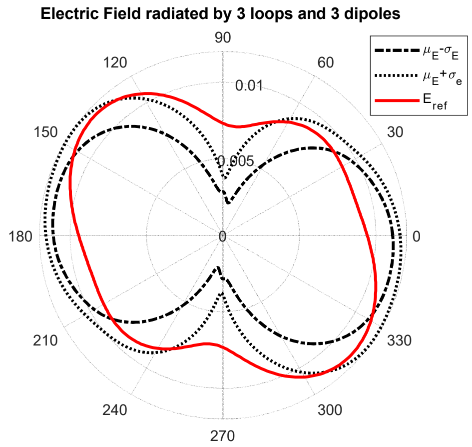

Figure 2. The electric field pattern radiated by 3 loops and 3 dipoles in the plane z = 0 at the distance of 10 m. Red line represents reference values; black lines represents upper and lower values returned by statistical analisys

3.2 High directivity EUT

The same analysis performed in previous subsection was repeated for a high directivity EUT, made by dipoles oriented along the z axis and spaced by half wavelength along y direction. As shown in Table 2 and Figure 3 respectively, also for this scenario, there is a good level of accuracy of the method and reference values are mainly bounded in the range $\mu_E \pm \sigma_E$.

Max Electric Field [mV/m]	E_{ref}	μ_E-σ_E	μ_E+σ_E
EUT: 3 dipoles	17.4	16.9	17.5

Table 2. Maximum values of electric field radiated 3 dipoles; reference (E_{ref}), minimum (μ_E-σ_E) and maximum (μ_E+σ_E) reconstructed values are reported.

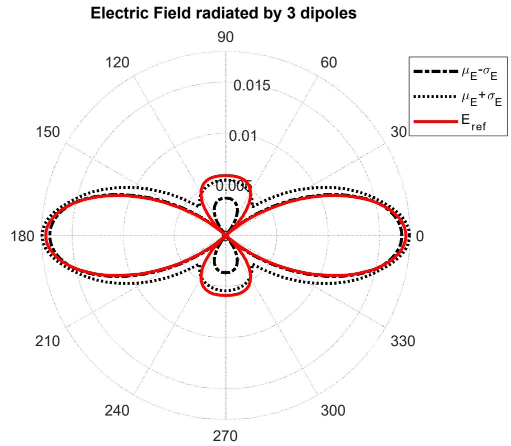

Figure 3. The electric field pattern radiated by 3 loops and 3 dipoles in the plane z = 0 at the distance of 10 m. Red line represents reference values; black lines represents upper and lower values returned by statistical analisys

3.3 Slot over a Ground Plane

Finally, the statistical analysis of the effect of the positioning uncertainties on the reconstruction of the radiated emission was performed on the case of an EUT having a slot on its metallic enclosure. To have an analytical solution of the scenario, a slot on a ground plane, with a TE_{10} aperture field distribution was considered

Also for this scenario the prediction of the maximum value of radiated emission (Table 3) and its radiation in all the direction (Figure 4) has a good reliability.

Max Electric Field [µV/m]	E_{ref}	μ_E-σ_E	μ_E+σ_E
EUT: slot on a ground plane	4.23	4.07	4.42

Table 3. Maximum values of electric field radiated by a slot on a ground plane; reference (E_{ref}), minimum (μ_E-σ_E) and maximum (μ_E+σ_E) reconstructed values are reported.

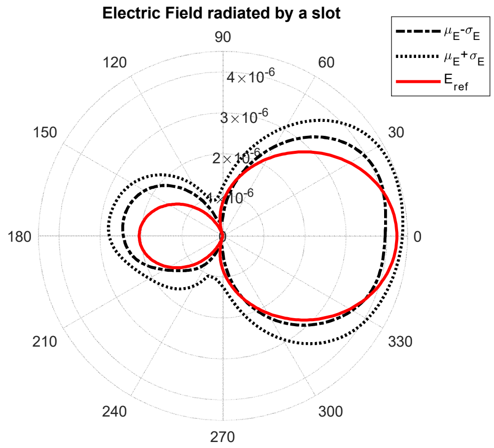

Figure 4. The electric field radiated by a slot on a ground plane in the plane z = 0 at the distance of 10 m. Red line represents reference values; black lines represents upper and lower values returned by statistical analisys

4 Conclusions

This paper presents the statistical analysis on the effect of the positioning of the monopoles on the reconstruction of the electric field radiated in free space by an EUT, using the electric field samples collected on the walls of a reverberation chamber where the multiple monopole source stirring technique is implemented.

To have a direct comparison with a free space environment, three simple EUTs are considered so that their radiation is analytically determinable.

The radiation emission determination in EMC is focused on the maximum value over all the directions, but also the statistical determination of the radiation intensity in every direction has been analyzed.

The results are very satisfactory and they encourage the research activities on the examined method.

5 References

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