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Evaluation of the Electric Field Amplitude in a MSRC From Power Measurement with a monopole

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Abstract

The goal of the work presented in this paper is to demonstrate that the electric field inside a Mode Stirred Reverberation Chamber (MSRC) can be evaluated with short monopoles, mounted on the walls of the MSRC.
Indeed, the electric (E) field amplitude inside a MSRC can be deduced from power measurement realized with monopole if one takes into account the statistical laws followed by the power and the components of the E field.
The results obtained with this method are compared to measurements performed with conventional methods using E field probes (direct measurement) or matched antennas (indirect measurement) installed inside the working volume. The good agreement of these comparisons validates the proposed method.

1. Introduction

This paper deals with mode stirred reverberation chambers (MSRC), which are being increasingly, used for electromagnetic compatibility (EMC) measurements because they are less expensive than anechoic chambers. Our contribution is the study of alternative methods for characterizing the electromagnetic environment inside a MSRC. The developed method enables to check some field properties (statistical uniformity) in the uniform working volume (UWV) of the MSRC with electrically small sensors (wall-mounted monopoles). The advantages of such sensors (compared to conventional antennas and field probes) are their low cost and negligible loading effect. Moreover, they are very sensitive and do not need active components powered by batteries.
Previous works [1] have shown that there is a great correlation between the electromagnetic environment inside the WV and the one near the walls. More precisely, it has been demonstrated in [2] that the power received by a small electric dipole closed to the wall of a MSRC follows the same statistical distribution law that's the one inside the UWV.
In this paper we present a method to evaluate the electric field amplitude in the UWV from power measured through a small monopole installed on a wall of the MSRC.
We can remind that the standards (e.g. [3]) propose an alternative to the use of E field probes which consists in evaluating the E field from power measured with matched reference antenna placed in the UWV. With our method, the UWV becomes free of probes and antenna.

2. Evaluation of electric field from power

2.1 Power measured by a matched antenna

The mean power received over a stirrer revolution by an adapted antenna (log periodic, horn antennas) placed in the UWV of a MSRC is given by [4]:

$$\langle Pr \rangle = \frac{\lambda^2}{320\pi^2}\langle E_{x,y,z}^2 \rangle \quad (1)$$

Where λ is the wave length, $\langle P_r \rangle$ the mean power and $E_{x,y,z}$ corresponds to any electric field component E_x, E_y or E_z.
Taken into account the properties of the statistical distribution laws followed by the magnitude of one electric field component and its root mean square value, we can deduce:

$$\langle E_{x,y,z} \rangle = \frac{\sqrt{\pi}}{2}\sqrt{\langle E_{x,y,z}^2 \rangle} \quad (2)$$

Then, from (1) and (2), the electric field can be calculated from the power with the following equation (3):

$$\langle E_{x,y,z} \rangle = \frac{4\pi}{\lambda}\sqrt{5\pi\langle Pr \rangle} \quad (3)$$

2.2 Power measured by a monopole antenna

Let us consider an electric monopole of length h_m and a diameter d_m, perpendicular to a ground plane and immersed in an electromagnetic environment with E_i the incident field.

<u>General case:</u>
The voltage V_r measured at the base of the monopole can be modelled by figure 1 and given by the equation (4):

$$V_r = h_{ef} \cdot E_i \cdot \frac{Z_e}{Z_e + Z_m} \quad (4)$$

h_{ef} corresponds to the effective length of the monopole. Z_e and Z_m represent respectively the input impedance of the receiver and the monopole internal impedance.

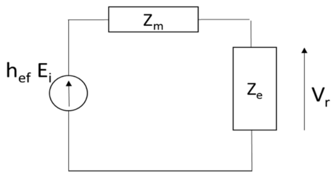

Figure 1. Equivalent circuit of the monopole.

Electrically short monopole:
If the monopole is electrically short, (i.e. $h_m \ll \lambda/4$), the radiating resistance can be neglected and then, its internal impedance is capacitive and the capacitor is defined by equation (5),

$$C_m = \frac{2\pi\varepsilon_0 h_m}{Log\left(\frac{4h_m}{d_m}\right)} \quad , \text{with } \varepsilon_0 = \frac{10^{-9}}{36\pi} \text{ (F/m)} \quad (5)$$

In this case, the input impedance of the receiver (usually equal to 50 Ω) can be neglected and the effective height h_{ef} evaluated to $h_m/2$.
Then, it can be demonstrated that the electric field component perpendicular to the plane can be deduced from the mean value of the receiving power by equation (6):

$$\langle E_Z \rangle = \frac{1}{2\sqrt{3 Z_e \pi}} \frac{\sqrt{\langle Pr \rangle}}{h_m C_m f_r} \quad (6)$$

With f_r the frequency in (Hz).

Electrically long monopole:
If the length of the monopole h_m is much greater than $\lambda/4$, this monopole is an oversized wire antenna and its behavior in MSRC can be considered as the one of an adapted antenna [5]. Even if this is not strictly rigorous, we consider that equation (3) can be used; this hypothesis has been experimentally verified. Indeed, the comparison of mean powers measured with a horn antenna in the UWV and with a monopole on the wall of a MSRC has shown that a monopole act as an adapted antenna if its length is greater than $\lambda/4$. [6].

3. Experimental results.

3.1 Experiments conditions

The dimensions of the used chamber are 5.6 m x 4m x 2.8m and the LUF is about 250MHz (figure 2). The working volume occupies 8m^3 and is located at a minimum distance of 80 cm from the walls.

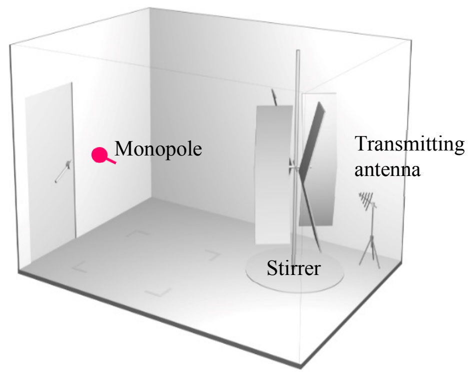

Figure 2. Drawing of the used MSRC.

For each tested frequency, the mean values are calculated for 90 power samples collected over a complete revolution of the stirrer.
A vector network analyzer is used for the emission and the reception, the emitted power is 0dB. Two standard antennas have been used: a log-periodic antenna (frequency band; 230MHz-3GHz) and a horn antenna (frequency band; 700MHz-18GHz). The frequency band of E field probe is 100 kHz-6GHz.
Then, the experimental frequency band have been divided into two parts:

- 300MHz - 2GHz: 45 measuring points
- 2GHz - 6GHz: 25 measuring points.

The monopole is 1.5 cm length. It is placed at a distance greater than 1m from the other walls in order to minimize their effects (as shown in figure 2). Previous measurements [6] have shown that a minimal distance of $\lambda/3$ must be used.

3.2 Electric field evaluation from power measurements

- Measurements at low frequency: 300MHz - 2GHz

Preliminary measurements at low frequency (300MHz-1.5GHz) where the monopole is electrically short, have shown a small difference between the electric field evaluated with the power measured with the log periodic antenna in the UWV and with the monopole on the MSRC wall, but the same shape.
Investigations have shown that it was due to a small difference between the capacitor C_m of the monopole

calculated with (5), which is very sensitive to geometrical parameters, and the real capacitor.
Indeed, from power measurements with the monopole in a TEM cell, we evaluated the capacitor C_m to 0.266 pF rather than 0.20 pF calculated with (5).
The experimental value was introduced in (6) and the electric field evaluated from power measurements is presented in figure 3.

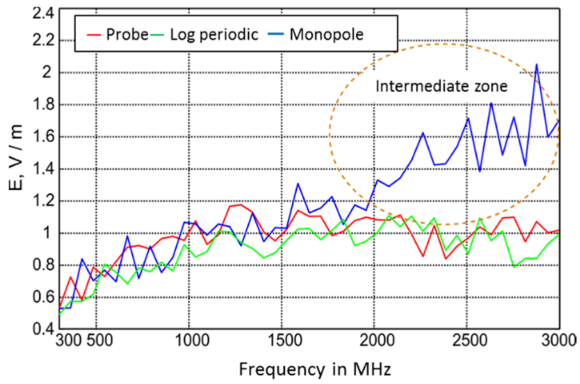

Figure 3. Mean electric field in the UWV (log-periodic and probe) and on the wall (monopole using correction factor)

The analysis of the figure 3 shows two zones:

- At low frequency , where the monopole length is lower than λ/10, (i.e.: lower than 2 GHz), the three spectrums are identical
- Over 2 GHz; where it is noted 'intermediate zone' in figure 2. This is due to the fact that the hypothesis of 'short monopole' is not valid above 2 GHz and the impedance is no more capacitive. This part will be studied in part 4.

<u>- Measurements at high frequency: 2GHz - 6GHz</u>

Figure 4 shows the electric field estimated from measurements of mean power with a horn antenna in the UWV (red curve) and the monopole on the wall (blue curve).

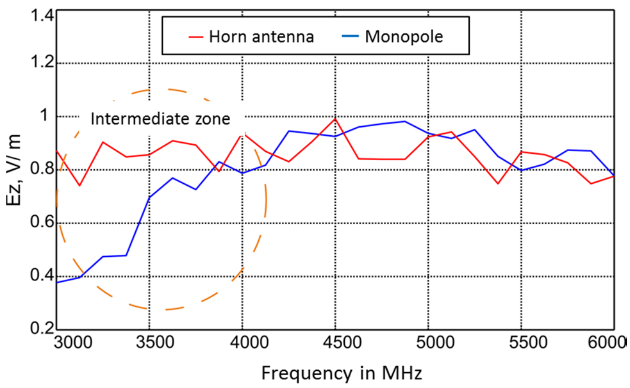

Figure 4. Mean electric field in the UWV (horn antenna) and on the wall (monopole)

As for the previous frequency band, there is two zones:

- Between 3 and 4 GHz, the monopole is not yet electrically long and thus, the curves are divergent.
- Above 4 GHz, the two curves are sensibly the same, the monopole act as an adapted antenna.

The two figures 3 and 4 show an intermediate zone between 2 GHz and 4 GHz, where the monopole is no more electrically short (thus equation 6 is not valid) and not yet electrically long (thus equation 3 either). The next part presents the study of this intermediate zone.

4. Study of the intermediate zone

In order to correct the intermediate zone we propose an experimental method, which consist in calibrating the monopole with the standard antenna: log-periodic and horn antenna.
The proposed solution is to use a correction factor Fc which is defined (7) as the difference between the power P_{mon} measured with the monopole and the power P_r measured with the reference antenna (log-periodic and horn antenna).

$$F_{C\ (dB)} = P_{mon\ (dBm)} - P_{r(dBm)} \tag{7}$$

Then, the mean power, measured with the monopole, can be corrected by this factor to define a corrected mean power Pc_{meas} with the equation (8).

$$Pc_{meas(dBm)} = P_{meas(dBm)} - F_{C(dB)} \tag{8}$$

And finally, this method allows now the use of equation (3) to evaluate the electric field from the corrected mean power Pc_{meas} in this intermediate zone.
Figure 5 shows the results obtained in the entire studied frequency band 300MHz – 6GHz, taken into account the correction of the intermediate zone.

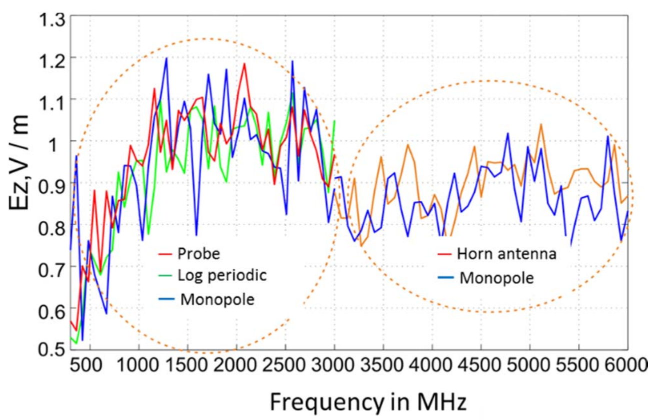

Figure 5. Comparison between the electric field spectrums issued from classical measurement and with the monopole using the correction factors.

We can observe that, now, the entire frequency band can be covered with the proposed method. The electric field inside the UWV can be evaluated with mean power measurements realized through a monopole on a wall of the MSRC.

5. Summary

A short monopole mounted on a wall of a MSRC and measuring the mean power can be used for evaluating the field inside the uniform working volume over a large frequency band, taken into account 3 zones:

- Low frequency band: the length of the monopole is lower than λ/10, the monopole is electrically short and its impedance is capacitive , equations (6) and (7)
- Intermediate frequency band: the length of the monopole is between λ/10 and λ/4 and its impedance is complex. A correction has to be done as described in part 4: equation (3) with a correction factor will be used to evaluate the electric field.
- High frequency band: the length of the monopole is greater than λ/4, the monopole can be considered almost as a matched antenna and the field can be evaluated with equation (3).

6. Conclusion

This paper has presented the study of an alternative method for characterizing the electromagnetic environment inside a MSRC. It has be demonstrated that the electric field inside the working volume can be evaluated from mean power measurements realized with a small dipole mounted on the wall of the MSRC over a large frequency band.

The developed method enables to check some electric field properties (statistical uniformity of the field or chamber load for example) in the uniform working volume (UWV) of the MSRC with electrically small sensors (wall-mounted monopoles). The advantage of such sensors (compared to conventional antennas and field probes) is their low cost and negligible loading. Furthermore, these sensors being permanently fixed on the wall of the chamber, performance degradations could be controlled during the EMC tests. The innovation of this approach consists in verifying a possible deterioration the uniformity of the field in the MSRC, with small sensors placed permanently on the walls of the chamber, without reference antenna and cable in the working volume.

6. Acknowledgements

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7. References

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