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Simplified Generation of Electromagnetic Field within EMC Immunity Test Area

Jozef Hallon, Karol Kováč*

Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology, Institute of Electrical Engineering, Ilkovičova 3, Bratislava 812 19, Slovakia

Abstract

For electromagnetic radiated immunity testing a homogeneous electromagnetic field within the test area is required. For this reason floor absorbers are obviously placed between the transmitting antenna and equipment under test. The paper analyses the possibility to fulfil homogeneity requirements without the absorbers only by changing the antenna height between two positions and by appropriate controlling of test field frequency. The paper demonstrates the possibility of this solution with full satisfaction of the field uniformity requirements.

Keywords: electromagnetic compatibility; immunity testing; field uniformity

1. Introduction

According to electromagnetic compatibility (EMC) standard requirements there are two basic measurements or tests which deal with radiofrequency (RF) electromagnetic fields. The first one is the radiated emission measurement, which is engaged in measuring the field intensity radiated from the equipment under test (EUT). For this operation a semianechoic chamber with reflecting floor is prescribed [1]. By this procedure the reflecting floor simulates the electromagnetic waves reflections from the real floor construction. The second one is the radiated immunity testing. In the frame of this test the homogeneous field is essential for objectivity and reproducibility of the testing. To maintain the field homogeneity the anechoic or modified semianechoic chambers with RF floor absorbers are required by standard. The absorbers have to be placed between the field source antenna and EUT [2]. Changing the floor arrangement between both procedures is cumbersome and requires additional space for storage of

*Corresponding author. Tel.: +421 2 60291 631; fax: +421 2 654 40 227.
E-mail address: karol.kovac@stuba.sk

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relatively large absorbers. So it would be beneficial to have possibility to perform the immunity test within the standard test configuration without necessity to use the floor absorbers.

The test of immunity against electromagnetic field is part of compulsory tests against disturbing EMC effects. It is prescribed by basic standard EN 61000-4-3 [1]. This standard creates the base for plenty of general and product specific standards, which are dedicated to EMC problem, consequently. The procedure of immunity testing is two step method. In the first step test area of homogeneous EM field, which is named in the standard as uniform field area (UFA), is calibrated in the testing chamber. By calibrating procedure the output levels of signal generator for required frequency points are obtained. In the second step the immunity test is performed using the signal levels collected during the calibration procedure. It is evident, that the calibration has to be performed relatively rarely e.g. once a year, or if the shielded chamber or the testing equipment is changed.

Enforceability of non-standard test conditions was studied by several authors. Their publications dealt with comparison of test results obtained in anechoic chamber and in the chambers with different characteristics [2, 3, 4, 5]. In the paper [6] the authors showed by only experimental measurements, that it is possible to keep the homogeneity within UFA in required limits also without the floor absorbers by changing the antenna height within the interval 1 – 2 m at 5 points. Their procedure needs computer control system, which performs relatively complicated calibration (5 times longer than standard) and it controls the antenna height depending upon the frequency during the test procedure.

The presented paper analyses the possibility to ensure the UFA homogeneity by simpler way even by maximum two transmitting antenna heights. For this purpose we analyzed the influence of the transmitting antenna height upon UFA homogeneity at first by numerical simulation. Consequently we verified the obtained results by measurement in the semianechoic chamber.

2. Field homogenity evaluation

For the calibration of EM field it is necessary to arrange a workplace according to Fig. 1. The electric field should be calibrated over a volume or surface in specified distance in front of the radiating antenna. The norm EN 61000-4-3 specifies the UFA, which is a hypothetical vertical plane of the field in which variations are acceptably small: at each frequency a field is considered uniform if its magnitude measured at 16 grid points (Fig. 1) is within -0/ +6 dB of the nominal value for not less than 75 % of all grid points (e.g. if at least 12 of the 16 measured points of an 1.5m×1.5m UFA are within the tolerance) [7]. Moreover the tolerance greater than +6 dB up to +10 dB, but not less than -0 dB, is allowed for a maximum of 3 % of the test frequencies.

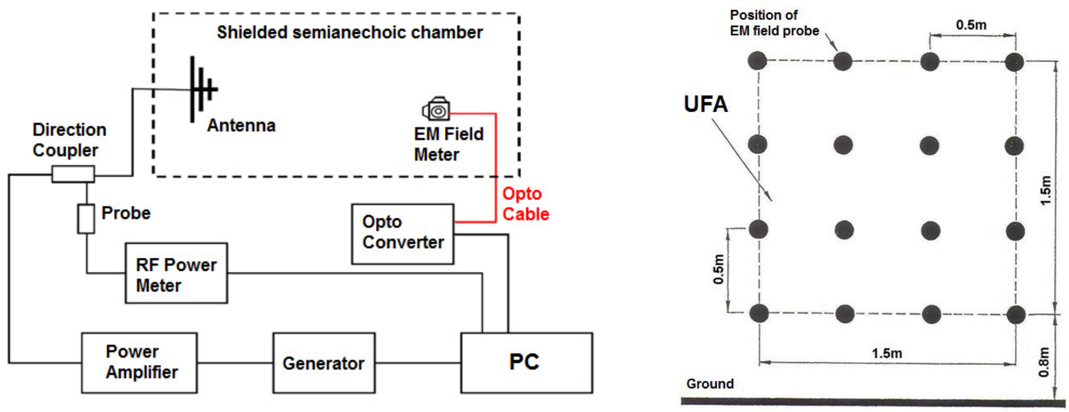

Fig. 1. (a) Setup of calibration procedure; (b) Specification of UFA.

In the calibration procedure specified in the standard it is stated that one has to measure the electric field at each one of the 16 grid points of the UFA at the selected frequencies. The forward power from the amplifier to the antenna shall be adjusted so that the field strength obtained is equal to the required calibration field strength E_u (electric field calibrated in the anechoic chamber). The norm specifies two calibration methods at both vertical and horizontal polarizations:

- Constant field strength procedure,
- Constant power procedure.

In the former procedure the 16 forward power readings shall be sorted into ascending order and then starting at the highest value one has to check if at least 11 readings below this value are within tolerance of -6dB/ +0dB of that value. In the latter the 16 field strength readings shall be sorted into ascending order and then starting at the lowest value one has to check if at least 11 readings above this value are within the tolerance – 0 dB/ +6 dB of that lowest value. According to this procedure it is clear that the allowed tolerance of + 6 dB extendible to + 10 dB for 75 % of all grid points permits a great variability of the electric field strength uniformity [7].

3. Analytical description of field intensity

The situation of the field generation in any space point of the UFA above reflecting floor is shown in the Fig. 2 on the example of vertical antenna polarisation. There are two radiated waves which participate in the field creation. They are the directly propagating wave and the reflected wave. It is evident that the length of wave propagation path is different for particular waves.

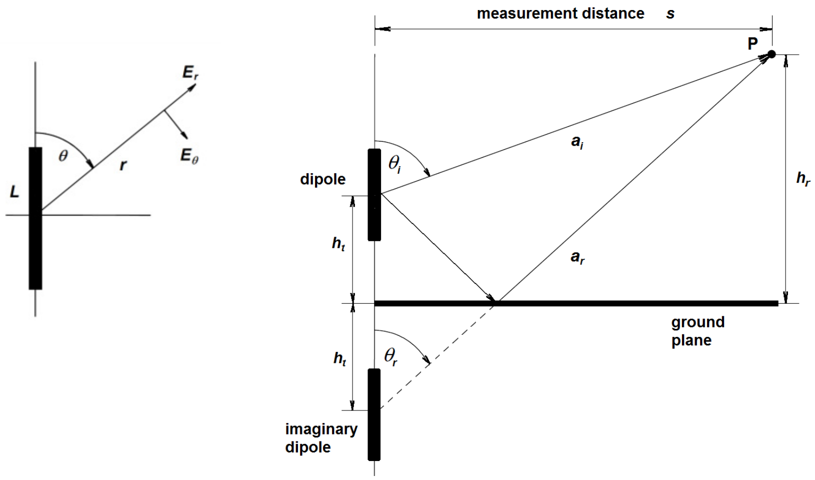

Fig. 2. Wave paths with the ground plane reflection.

The intensity of radiated field from a dipole with a constant current distribution over the full length can be expressed by the following equations [8]:

$$E_r = \frac{2jI_0L\beta^2\cos(\theta)}{4\pi\varepsilon_0 c}\left(\frac{-j}{(\beta r)^2}-\frac{1}{(\beta r)^3}\right)e^{j(\omega t-\beta r)} \quad (1)$$

$$E_\theta = \frac{jI_0L\beta^2\sin(\theta)}{4\pi\varepsilon_0 c}\left(\frac{1}{\beta r}-\frac{j}{(\beta r)^2}-\frac{1}{(\beta r)^3}\right)e^{j(\omega t-\beta r)} \quad (2)$$

The used constants and variables are defined as follows:

r - distance from the dipole to observation point
$\omega = 2\pi f$ - radian frequency
c - velocity of light in free space
I_0 - impressed current
L - length of the dipole
$\beta = \omega/c$ - phase constant

The electrical field at the observation point is the sum of the direct and reflected wave multiplied by the reflection coefficient ρ, which may be considered as equal to 1(for vertical polarization) or -1 (for horizontal polarization) as the floor is almost perfectly conducting :

$$E = E_i + \rho E_r \tag{3}$$

The distances from the dipole to the point of observation P can be calculated by equations (4) and (5). Where h_t is the height of the transmitting antenna and h_r is the height of the observation point P above the ground plane. s is the measurement distance, which is 3 m obviously. The angles θ_i and θ_r are expressed in equations (6) and (7).

$$a_i = \sqrt{h_t^2 - 2h_t h_r + h_r^2 + s^2} \tag{4}$$

$$a_r = \sqrt{h_t^2 + 2h_t h_r + h_r^2 + s^2} \tag{5}$$

$$\theta_i = \arctan((h_r - h_t)/s) \tag{6}$$

$$\theta_r = \arctan((h_r + h_t)/s) \tag{7}$$

There are several factors influencing the resulting intensity in the observation points within UFA. Generally the intensity of the wave is indirectly proportional to the length of propagation path of the wave i.e. distance between field source and observation point. So the reflected wave has significantly lower intensity than direct one. Then the phase shift between waves, caused by different propagation path length, significantly affects the resulting field intensity. Both factors, propagation path length and consequently phase shift, are dependent upon antenna and observation point heights. Due to the described interference of both waves the field intensity is significantly dependent upon frequency and as the propagation distance differs between UFA points, the field homogeneity is expressively changing up to more than 20dB at some frequencies.

4. Modelling of testing workplace

To study the EM field intensity distribution in all 16 points of the UFA within the whole frequency range is rather complicated task. So it would be advantageous to use numerical simulation tool to perform such study. It allows simpler analysis mainly in cases of complicated configurations. For this purpose we used software system FEKO based on method of moments.

The RF absorbing walls and ceiling of the test chamber where modelled by open area space border, the conducting floor by perfectly conducting space border of the model space. For simulation of EM field source we have created a model of our log-periodic and biconical antennas. The output points of simulation correspond with points of the UFA.

An example of simulation results in graphical form is shown in Fig. 3 for 155 cm antenna height, 425 MHz frequency and 10 V antenna feeding voltage. There is the model of log-periodic antenna visible and the distribution of intensity of EM within the UFA area. The fluctuation of field intensity caused by interference of direct and reflected waves is evident. The intensity is changing from 3.3 up to 11 V/m, which is more than 6 dB required by standard. The antenna height was 155 cm, which is generally required by the standard, but this height does not suit to our intention.

5. Execution of searching procedure

It was shown in Fig. 3 that the field intensity can significantly fluctuate within UFA. Although this fact we supposed that the minimum homogeneity for all antenna heights is lower than limit value of 6 dB. The principle of evaluating procedure was based upon this preposition. So we performed homogeneity analyses by numerical simulation in frequency bands 80 – 1000 MHz and 1000 – 3000 MHz with 2 MHz frequency step. The antenna height was changing in the range 1 – 2.1 m with 10 cm step. For each antenna position and each frequency point we stored the EM field intensity values in all 16 points prescribed by the standard. Then the dependence of UFA homogeneity upon frequency was calculated for each antenna height and for both antenna polarization.

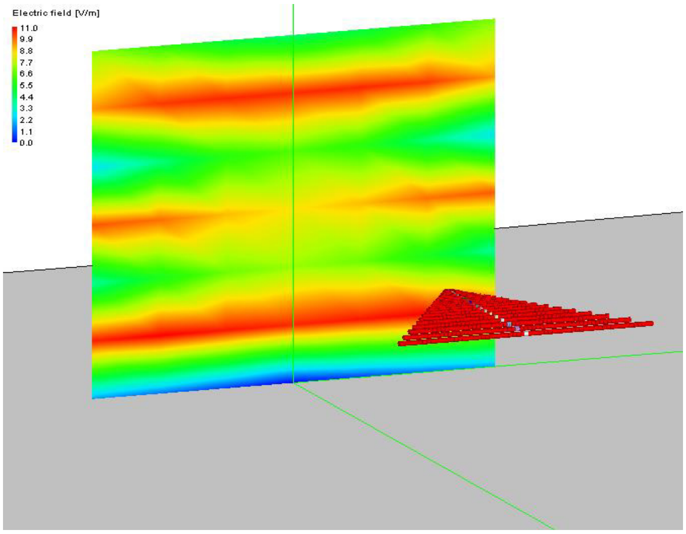

Fig. 3. Simulated EM field intensity over a reflective plane at the frequency 425 MHz.

After collecting of all necessary data the searching procedure could start. It took all combinations of two antenna heights and searched the minimal homogeneity at all frequencies. Then it counts the frequency points for which the minimal homogeneity is more then 6 and less than 10 dB. If the homogeneity is more than 10 dB, the combination is consider unacceptable. By this procedure we found out the best combination of antenna heights which were chosen for experimental verification by measurement in semianechoic chamber of our EMC laboratory. As the differences between the simulation and the measurement results are usually not negligible in EMC domain, we performed the measurements in some range around the chosen antenna heights. Device setup for calibration procedure corresponded with Fig. 1. The measurements were executed by automatic software system fully complying the standard requirements for the UFA calibration and the immunity test performance [9], [10]. On the measured data the minimal homogeneity was evaluated by the same procedure as on the simulation results.

Both the simulation and the measurement results of the whole process are shown in following diagrams. In Fig. 5 the simulated and measured values of homogeneity are shown for frequency range 80 – 1000 MHz and horizontal antenna polarization. It is evident from presented figures that required homogeneity is reachable by combination of two antenna heights – 130 and 200 cm. This combination allows reaching the best UFA homogeneity, when the 6 dB limit value was exceed less than 0.7 dB only in 1.73 % of total number of frequency values. By verification measurement the 6 dB value was exceeded by maximum 0.7 dB in 1.96 % of number of frequencies.

For vertical antenna polarization the same analysis was performed also. In this case the situation is much better as the floor reflection coefficient is positive, so the resulting field intensity is not changing so intensively. Our simulations showed that all heights above 140 cm comply with the requirements of the standard. During the measurements all heights above 180 cm were conforming as is evident on the 190 cm antenna heights example presented in Fig. 5.

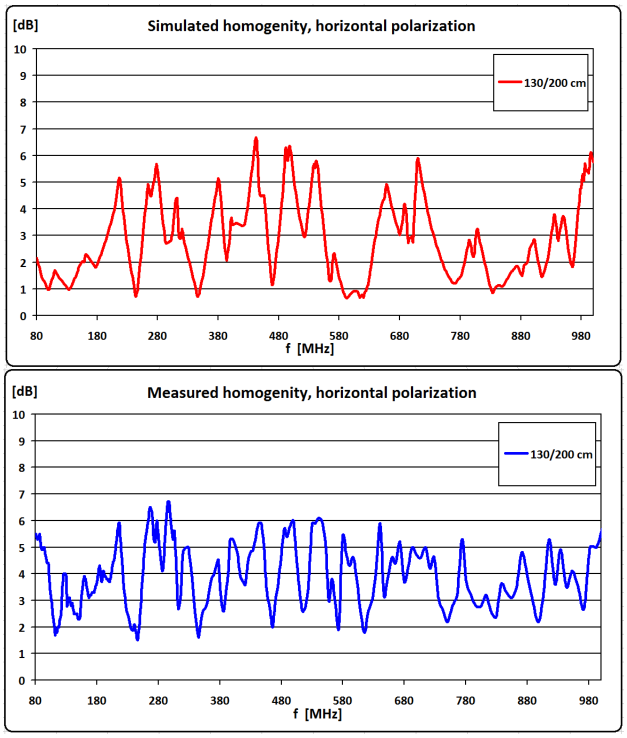

Fig. 4. (a) Simulated and (b) measured results in range 80 - 1000 MHz, horizontal polarization of LP antenna.

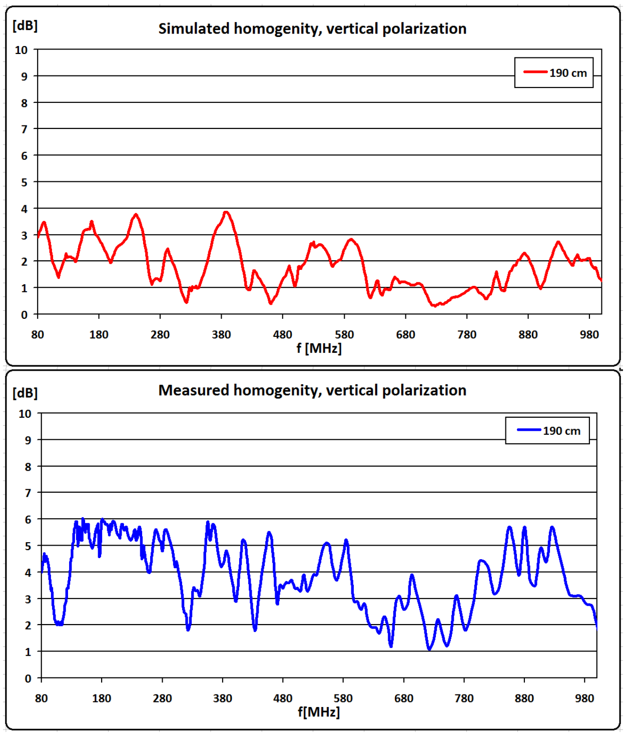

Fig.5. (a) Simulated and (b) measured results in range 80 - 1000 MHz, vertical polarization of LP antenna.

The analysis in 1 – 3 GHz range was performed only by simulation (Fig. 6). For horizontal polarization the homogeneity was conforming by combination of 190 and 200 cm antenna heights, when the limit values 6 dB was exceeded by maximum 1.2 dB only for 1.24 % of frequency points. For vertical polarization all heights above 110 cm are complying.

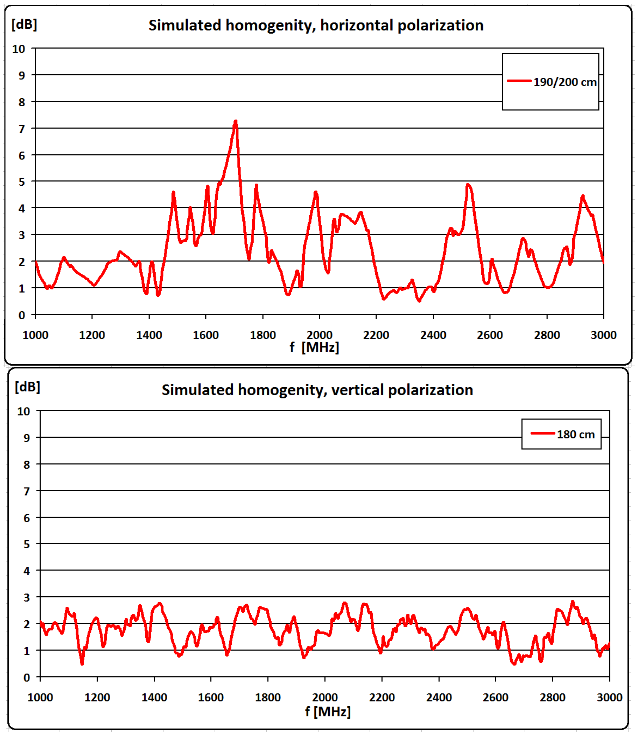

Fig. 6. Simulated results in range 1 - 3 GHz, (a) horizontal (b) vertical polarization of LP antenna.

The results obtained by numerical simulation and laboratory measurements in our semianechoic chamber showed adequate compliance. The resulting differences may be due to mild difference between our simulation model and real semianechoic chamber, which does not have perfectly absorbing walls and ceiling as was supposed by the modelling.

6. Conclusion

In the presented paper we found the possibility to fulfil the requirements of the EM field immunity test standard [1] without the floor absorbers placed between the transmitting antenna and the EUT by using only two antenna heights in the frequency range 80 – 1000 MHz. This simplifies the work organisation in the EMC laboratory which disposes of only one shielded chamber for both the radiated field intensity measurements and the field immunity test. By suggested technique it is possible to reconfigure the shielded room from the configuration of the radiated emission measurement to the configuration of the radiated immunity test practically by changing the antenna cables from the measuring receiver input to the power amplifier output. So the results of our work help to increase the effectiveness of any EMC laboratory operation.

Because each shielded semianechoic chamber has specific electromagnetic characteristics, it is not possible to fully generalize the results we presented. Our chamber has the dimensions of 8.9 x 4.9 x 4.9 m (L x W x H), its walls are fully covered by ferrite absorbers and partially by foam absorbers for frequencies above 1 GHz. So it is necessary to approve the proposed procedure for each chamber during its UFA calibration and to obtain the original data sets for the immunity test by the procedure we proposed.

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