THE ERRORS CAUSED BY TEST SITE CONFIGURATION AT THE RADIATED EMISSION MEASUREMENT

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Summary Nowadays, it is very important to know and to keep uncertainty of EMC measurements at low value to ensure the comparability of measurement results from different laboratories. This paper deals with analysis of uncertainties caused by improper test site configuration – especially by receiving antenna positioning. The analysis is performed at frequency range which biconical broadband antenna works in and it is based on measurements. Nevertheless, it can be more simple to get results using theoretical analysis, but it does not include the test site properties.

1. INTRODUCTION

The radiated emission measurement is the most complicated measurement of all the electromagnetic compatibility (EMC) tests. It is also the most time-consuming, speaking not only about the time of measurement realisation but also about the time of measurement preparation. All the effort to hurry these processes is bound up with probability of measurement uncertainty increase [1]. Such a typical inaccuracy source at radiated emission measurement is the breach of proper test site configuration according to relevant EMC standards [2], i.e. incorrect geometrical positioning of the measuring antenna. The majority of errors is caused by using broadband antennas e.g. biconical, which are not isotropic, and therefore the accuracy of measurement depends on the proper alignment of the receiving antenna as well as its turning to set the antenna polarisation. Also, the directivity of receiving antenna influences the measurement results at breach of measuring distance.

Because every EMC test laboratory has to keep specific level of measurement uncertainty [3], it is important to analyse the influence of mentioned sources of errors to the total uncertainty. This analysis is performed theoretically as well as experimentally at EMC Laboratory FEI STU, where these measurements are performed routinely. The analysis is executed at frequency range 30MHz to 300MHz, which the biconical-receiving antenna is used in.

2. THEORETICAL ANALYSIS

To examine the influence of irregular positioning of measuring antenna we have to calculate the field strength at the point of this antenna over a metallic ground floor. In this case we consider a transmitting short dipole with a gain G. Antenna is fed by a matched source and the radiated power P_T. The free-space far-zone field strength E at a distance d is given [4]:

$$E = \frac{\sqrt{30 P_T G}}{d} e^{-\frac{j2\pi d}{\lambda}} = \frac{K}{d} e^{-\frac{j2\pi d}{\lambda}}, \quad (1)$$

where λ is the wavelength corresponding to the measuring frequency. Only ground-plane-reflected wave is present in addition to the direct wave (see Picture 1), so for this situation the total electric field for horizontally polarized dipoles in the point of measurement is given:

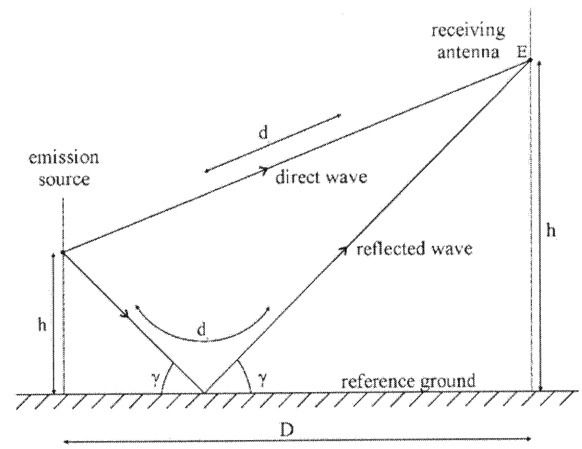

Fig. 1. Elm waves transmission over conductive floor.

$$E_h = E_d + E_r = K\left[\frac{1}{d_1} e^{-\frac{j2\pi d_1}{\lambda}} + \frac{|\rho_h|}{d_2} e^{-j\left(\frac{2\pi d_2}{\lambda} - \phi_h\right)}\right], \quad (2)$$

where E_d and E_r are the direct and ground-plane-reflected fields, respectively, d_1 and d_2 are lengths of direct and reflected ray trajectories; ρ_h is the reflection coefficient of the ground plane for horizontally polarized waves given by (3):

$$\rho_h = |\rho_h| e^{-j\phi_h} = \sqrt{\frac{\sin\gamma - (\varepsilon_r - j60\lambda\sigma_m - \cos^2\gamma)}{\sin\gamma + (\varepsilon_r - j60\lambda\sigma_m - \cos^2\gamma)}}, \quad (3)$$

where ε_r and σ_m are the ground plane parameters and γ is the angle of incidence. The magnitude of E_h is then obtained from (2) as:

$$|E_h| = \frac{K}{d_1 d_2}\sqrt{d_2^2 + d_1^2|\rho_h|^2 + 2 d_1 d_2 |\rho_h| \cos\left[\phi_h - \frac{2\pi}{\lambda}(d_2 - d_1)\right]} \quad (4)$$

Similarly, for a vertically polarised dipoles and a ground plane vertical reflection coefficient $\rho_v = |\rho_v| e^{j\phi_v}$ the electric field strength at a distance D from the radiating antenna can be shown to be:

$$|E_v| = \frac{KD}{d_1^3 d_2^3}\sqrt{d_2^6 + d_1^6|\rho_v|^2 + 2 d_1^3 d_2^3 |\rho_v| \cos\left[\phi_v - \frac{2\pi}{\lambda}(d_2 - d_1)\right]} \quad (5)$$

Using equations (4) and (5) we are able to calculate the field strength values at any points over metallic ground plane.

Also, some numerical method can be used to calculate the same task as it is showed before. Numerical methods offer powerful and flexible tool to solve electromagnetic problems and even save our time necessary for calculation. The most suitable numerical method for open area problems is method of moments (MoM), which offers a wide variety of three-dimensional electromagnetic problems analysis [4]. MoM employs transformation of complex integral equations to the system of simple linear equations that can be solved using matrix techniques. MoM works in a frequency domain. In Fig. 2 comparison of electric field results along the receiving antenna movement achieved by theoretical calculation, numerical simulation and measurement in case of horizontally polarised antennas is shown and as we can see we got very similar values using all of methods.

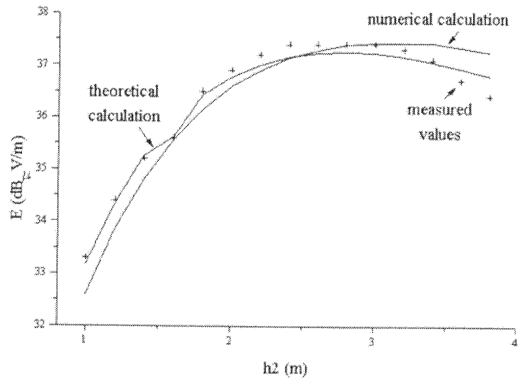

Fig. 2. Comparison of theoretical, simulated and measured values of electric strengths for 50 MHz.

Actually, during radiated emission measurement we do not use short dipoles as it was considered in previous theoretical analysis, but biconical antenna is used. This antenna is a broadband antenna that is usually specified for the use over the VHF frequency range (30-300 MHz mainly). Its structure consists of wire cages mounted either side of a support containing antenna balun (see Fig. 3). Each cone of the antenna is formed from six elbow-shaped wires arranged around a single straight wire along the central axis. The angle between each bent cone wire and the central wire is 30° and angle at each bend is 90°. This structure ensures the same properties of the antenna as thick dipole has [5].

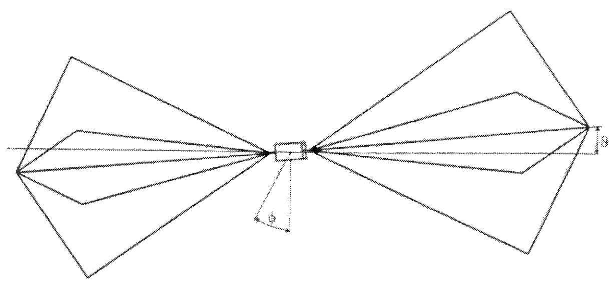

Fig.3. Biconical antenna with possible degrees of freedom.

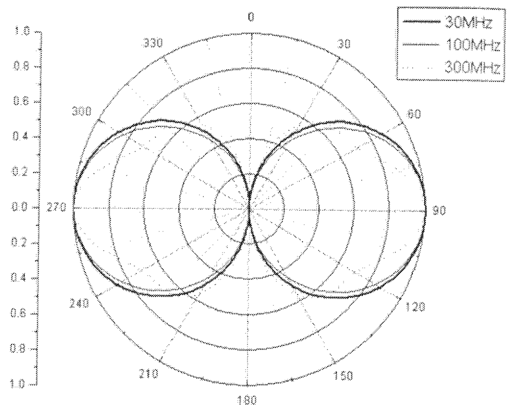

Fig. 4. Directivity pattern of biconical antenna at frequencies 30 MHz, 100 MHz and 300 MHz.

In Fig. 4 we can see the directivity patterns of the biconical antenna at three different frequencies that are obtained using MoM [6]. The directivity pattern is not ideal one for all the frequencies, it is a bit narrower for frequencies about 100 MHz and even at frequencies close to 300 MHz it is not very similar to figure-of-eight pattern, as we considered.

3. MEASUREMENT

The measurement was realised in semi-anechoic chamber of EMC laboratory FEI STU in Bratislava, where radiated emission measurements are performed routinely. A block diagram of the measuring system is shown in Fig. 5, the test place was arranged according to relevant standard [2]. As a radiator comb generator is used, which is situated on the 80 cm high nonconductive table. The measuring biconical antenna is situated in distance 3 m from the radiator and it changes its height in range from 1 m to 4 m. The semi-anechoic chamber provides the alternative to open area test site, however there are undesired reflections from absorbing walls that may depreciate the obtained results. On the other hand, these results characterise the real processes in our test site.

As it was mentioned before, comb generator was used as reference emission source. The output of comb generator is not stable over small time scales as its output level fluctuates slightly about its nominal value at any specific frequency. This was quantified by making repeated measurements through whole frequency range (30-300 MHz) using a spectrum analyser. By statistical approach [7] we get the experimental standard deviation of the mean value $\bar{x}$:

$$\sigma = \sqrt{\frac{1}{n(n-1)}\sum_{n}(x_n - \bar{x})^2} \quad (6)$$

Maximal variation is less than 0.12 dB in the analysed frequency range or uncertainty ±0.25 dB for a 95 % confidence level. If we assume that accuracy of measuring receiver is ±0.1 dB, we can consider that the output level of comb generator is stable.

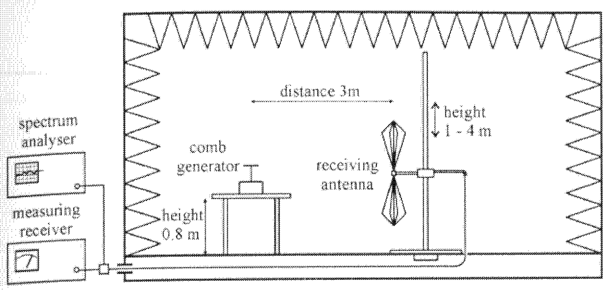

Fig.5. Radiated emission measuring system.

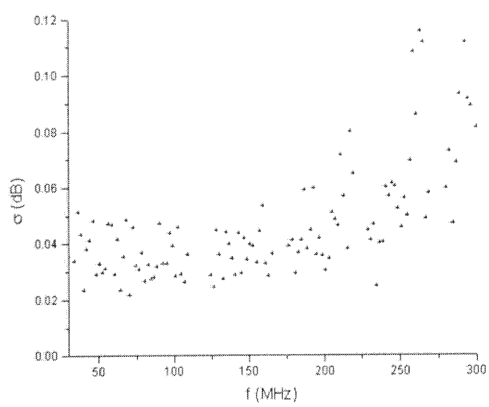

Fig.6. Variation of comb generator.

To examine the influence of receiving antenna geometrical positioning breach we performed the following measurements of radiated emission:

- dependency on measuring distance *D*;
- dependency on alignment of antenna ϕ;
- dependency on turning on antenna ϑ.

Just these factors are examined as they have some degree of freedom in positioning and can cause an error. Measurements were performed in the whole frequency range for both polarisations of antennas, horizontally as well as vertically and we recorded just the maximal values of measured field strengths *E* during receiving antenna movement in interval 1 to 4 m.

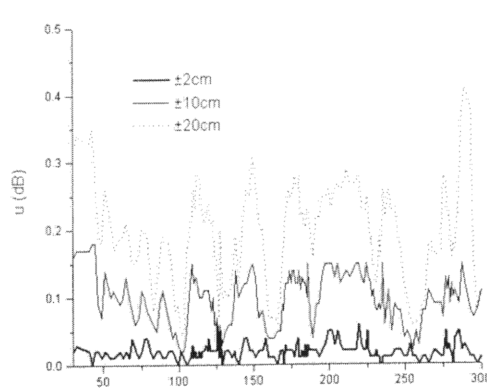

Fig. 7. Dependency of measurement uncertainty u on frequency f for horizontally polarised antennas for different estimated errors of measuring distance D.

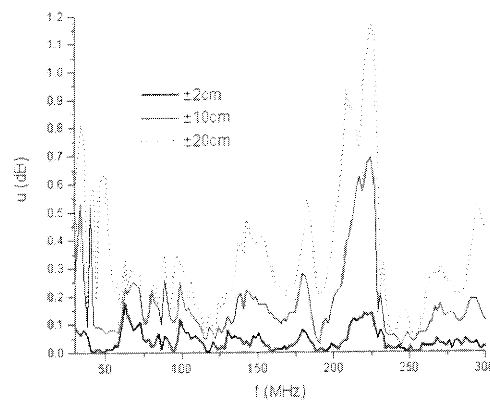

Fig. 8. Dependency of measurement uncertainty u on frequency f for vertically polarised antennas for different estimated errors of measuring distance D.

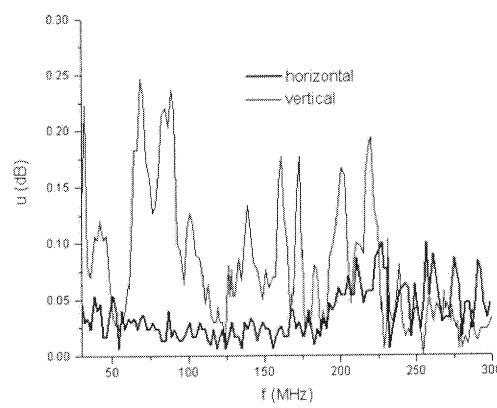

Fig. 9. Dependency of measurement uncertainty u on frequency f for errors of antenna alignment ϕ error ±10°.

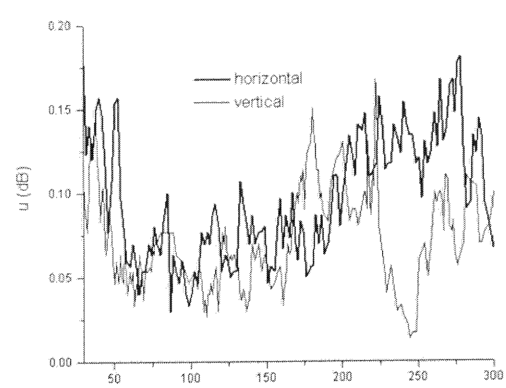

Fig. 10. Dependency of measurement uncertainty u on frequency f for errors of antenna turning ϑ error ±10°.

The maximal possible errors in improper alignment were estimated and the measuring errors z_{max} were obtained using measurement. Then the uncertainty caused by *i*-th effect can be calculated as:

$$u_i = \frac{z_{max}}{\chi}, \qquad (7)$$

where χ is the probability coefficient.
The results of measurement are showed in Fig. 6-9.

4. DISCUSSION

The best way in which we can examine the influence of irregular positioning of receiving antenna is performing of measurement at a specific test site. It is because theoretical analysis can redound into complicated solution, especially when we want to comprehend also the influence of receiving biconical antenna with its non figure-of-eight pattern in a frequency range 30 to 300 MHz. This could be avoided by numerical solution, which is the quickest and most comfortable form of analysis, but on the other hand it also does not include the properties of the test site. Therefore, the error analysis is based on measurement results mainly.
Using comb generator as equipment under test we obtain a stable level of radiated emission, which is very necessary for the error analysis. The stability of comb generator is just a bit worse than accuracy of the measuring receiver and comparable with spectrum analyser. However, the short-time stability is smaller than ±0.1 dB yet. The higher variation of generator output level might be caused by imperfections of test site, which was the semi-anechoic chamber.
The obtained values of uncertainties are shown in Fig. 7-10. The probability factor for Gaussian distribution $\chi=3$ was chosen, because there is higher probability that we prepare the test site configuration with high precision than with poor one. The maximal values of uncertainty are in case of measuring distance error ±2 cm: 0.07 dB for horizontally polarised antenna (HPA) and 0.16 dB for vertically polarised antenna (VPA); in case of antenna alignment error ±10°: 0.1 dB for HPA and 0.25 dB for VPA; and in case of antenna turning error ±10°: 0.18 dB for HPA and 0.17 dB for VPA. We can notice also from Fig. 7 and 8 that the error caused by breach of measuring distance increases almost linearly with increasing error of measuring distance.
The whole uncertainty caused by breach of positioning receiving antenna is 0.22 dB for HPA and 0.34 dB for VPA, respectively. The bigger error at VPA is caused by additional equipment, which is necessary for the measurement and it is also polarised vertically to the ground plane and therefore influences the measurement, e.g. antenna mast, cable. Big differences in uncertainty values for different frequencies are caused by undesired resonances and other imperfections of the semi-anechoic chamber.

5. CONCLUSION

From the previous analysis one can see that it is very important to keep high level of accuracy at geometrical positioning of receiving antenna inside the test side or ensure not to have many degrees of freedom. The second condition cannot be fulfill at Laboratory of electromagnetic compatibility FEI STU due to alternating using of chamber for emission or immunity testing respectively.
The presented method helps to obtain the real value of uncertainty and also if we know the sources of measurement error to reduce it. Afterwards, it depends just on the type of EMC test (scientific, commercial etc.), how big uncertainty can be accepted.

Acknowledgement
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