Broadband Antennas Scanning Error as Contribution to Uncertainty of EMI Measurement

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Abstract. *Since the receiving antenna scans in range of 1 to 4 m to get the maximal interference there is no way how to make a correction to the effect of the ground plane. In this manner, error of antenna height variation and error of antenna directivity have to be included into the EMI measurement uncertainty. Based on choice of proper antenna models and numerical technique we investigated mentioned errors in this paper. We focus not only on their values but also how they vary with frequency of the received electromagnetic interference.*

Keywords: Broadband Antennas, Antenna Height Variation, Directivity, Uncertainty

1. Introduction

Broadband antennas - as log-periodic dipole arrays (LPDA) and biconical antennas are - have become very popular in electromagnetic compatibility (EMC) labs worldwide for electromagnetic interference (EMI) measurement mainly. Because there are no band breaks in given frequency ranges and test time are reduced. EMC engineers know the performance of these antennas - biconical antenna is used at lower frequency range, LPDA at higher frequencies. The question of higher measurement uncertainty due to antennas properties in such a case has opened.

During EMI measurement the receiving antenna varies its height over reference ground plane [1], which leads to another change of antenna's properties and also to another uncertainty contribution. Limited research has been conducted on the uncertainty contribution analysis of these broadband antennas [2],[3], mainly in their relation with reference ground plane. Therefore, we focus on the uncertainty contributions - errors of antenna - related to ground plane presence and varying height of antennas over the plane. The antenna height error and antenna directivity error in case of biconical antenna and LPDA are analyzed in this paper.

2. Broadband antennas and their models

To analyze the mentioned errors of broadband antennas numerical methods have to be executed – analytical methods are suitable just for simple problems, while measurement is always affected by surroundings. The most suitable method for antenna analysis are solver in frequency domain [4], method of moments was chosen to analyze the problems.

Typical representatives of the broadband antennas were examined:

- biconical antenna (see Fig. 1a) – 1300 mm long, with a cone radius of 260 mm created by 6 wires. Also a crossbar is in each cone. The frequency range of such antenna is from 30 MHz to 300 MHz;
- log-periodic dipole array (LPDA) (see Fig. 1b) - 760 mm long and 750 mm wide, with 14 pairs of dipole elements. The scale factor and the spacing factor of log-periodic dipole array elements are 0.85 and 0.126 (the longest dipole element is 750 mm long). The LPDA works in frequency range from 300 MHz to 1GHz.

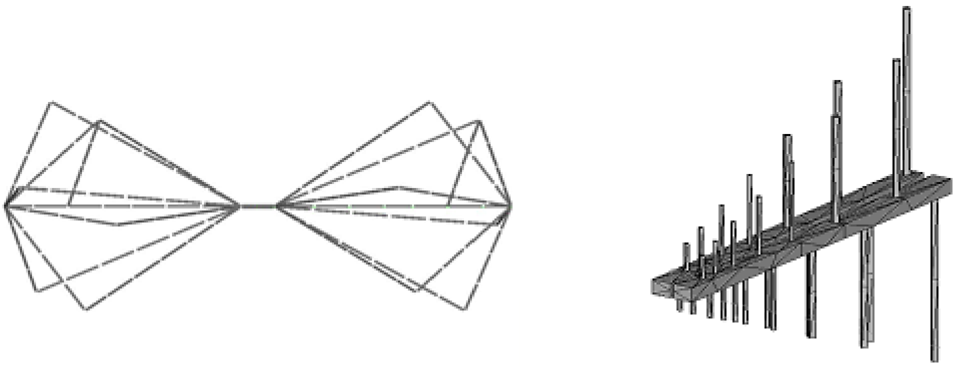

Fig. 1. Models of biconical antenna (left) and LPDA (right).

To use these models, at first we have to validate them. That means to verify if the obtained results copy sufficiently the properties of real antenna. Antenna factors (AF), input impedances, gains and directional patterns were compared in case of various models. The AF values are obtained by simulation where we placed a source of electromagnetic (EM) field e.g. short dipole antenna at adequate distance (ca. 100 m) away from the model of analyzed antenna. Then AF is given as ratio between known E field values and computed induced voltage at antenna output. Based on mentioned comparison [5] as the best model to represent real broadband antenna in simulation process is model, which consists of wire as well as surface elements (see Fig. 1).

3. Principles and methods

Antenna factor is mostly obtained when the antenna is in free space and the incident EM field is a plane wave. Such a free-space AF is an intrinsic property of the antenna which should not vary. However, the environment in which antenna is used may also affect the AF value. Since EMI measurement is performed over the conducting ground plane and actually antenna height over the plane is not constant. Hence, AF values may be changed depending on antenna polarization, height over the ground plane and also type of antenna, which may be different. Then the antenna height error relates to variable AF due to scanning the receiving antenna. AF was obtained using numerical simulation as it was mentioned above. However, conducting ground plane was replaced by a mirror image of the antenna situated in a double the distance as the height of the antenna under the original model to ensure homogenous plane wave.

The other important parameter of the antennas for our analysis is the radiation pattern. It refers to the directional dependence of radiation from the antenna. It is generally known that radiation pattern of an ideal half-wave dipole is constant in H plane, but in E plane it is a figure-of-eight pattern. So the directivity F given by sphere angles (θ,φ) can be expressed as:

$$F(\theta,\varphi) = \frac{\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)}{\sin\theta} = \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \qquad (1)$$

where k is wave number (k=2π/λ) and l is the length of the dipole (in case of half-wave dipole l=λ/2). Unfortunately, the radiation patterns of broadband antennas are not known. In addition they may vary with changing frequency. The variation of radiation pattern may be expressed also as the error of AF. If the source of radiation is not situated in front of analyzed antenna in direction of maximal radiation (zero angle-wise), but it is moved so that radiation from itself affects the analyzed antenna with angles (θ, φ), we obtain the real AF of antenna AF:

$$AF(\theta,\phi) = AF(dB) + F(\theta,\phi) \tag{2}$$

where AF(dB) is known antenna factor and F is directivity of analyzed antenna. Then the error, obtained by replacing the half-wave dipole antenna by broadband antenna, may be expressed as error of antenna factor ΔAF defined as:

$$\Delta AF(dB) = AF(\theta,\phi) - AF_D(\theta,\phi) - K \tag{3}$$

where AF and AF_D are antenna factors at the same angles of incidence given by angles (θ,φ). The parameter K is a correction for neglecting the difference between the values of antenna factors of these antennas.

Since the receiving antenna varies its height from 1 to 4 m (antenna has to scan), angles of incidence of disturbing electromagnetic waves on measuring antenna vary their values as well. For example, if tested object is assumed to be in 1 m height and the measuring distance is standard [1] recommended 10 m the angle of incidence of direct wave varies from 0° to 17°. In case of shorter distances these angles may increase to higher value. If we consider not only the direct wave incident on the antenna, but also the wave reflected from the reference ground plane, angles of incidence are from 0° up to 27° for 10 m measuring distance. Hence, it is necessary to rotate the source of radiation around the analyzed measuring antenna with these angles and to record the maximal variations as compared with a zero angle of incidence. To examine the ground plane affect the model of antenna was again extended by its mirror image, as it was mentioned above.

4. Results

Exact height of the antenna and also the angle of incidence are not known, therefore, we expect a maximum error obtained for antenna scanning in a given range by 10 cm. As the antennas vary its height above the ground plane, also their AF are changing. This variation ΔAF is shown in Fig. 2. The error is strongly frequency dependent and it is more evident for biconical antenna, maximally ±0.67 dB. In both cases the worse situation occurs for horizontally polarized antennas. The maximal variation of AF is mainly in case of the lowest height of antenna $h = 1$ m. It is the situation when the mutual coupling between the antenna and the ground plane is maximal. The LPDA causes not so great error due to height variation.

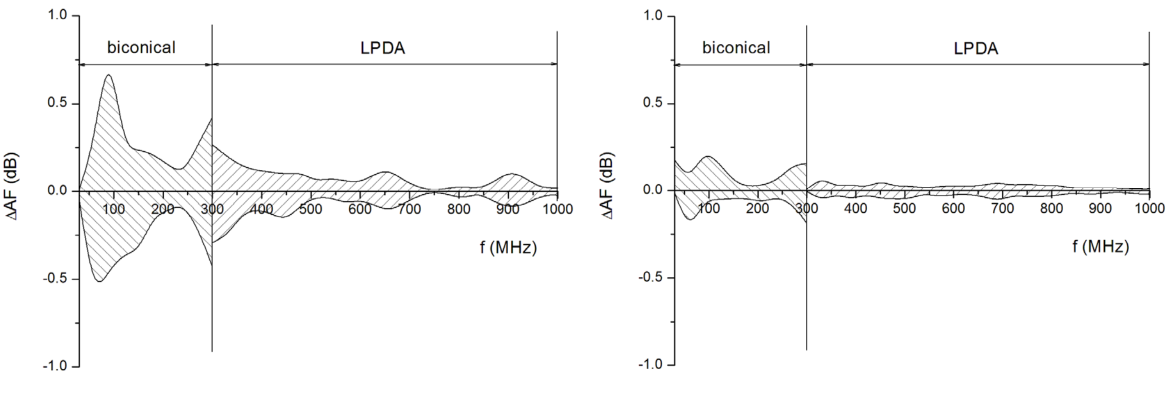

Fig. 2. Possible errors of AF for horizontally (left) and vertically (right) polarized broadband antennas caused by their antenna height variation.

The directional pattern of biconical antenna is similar to the pattern of the dipole. However, mainly in case of LPDA the main lobe of radiation pattern becomes more dominant with increasing frequency of radiation, so there is less similarity between radiation patterns of dipole and LPDA. Hence, there should be a higher probability that AF error caused is higher in case of LPDA. However, the ground plane presence nearby the antenna influences also its directivity pattern in addition. There are evident changes in directional patterns of analyzed antennas. While in case of LPDAs the main lobe of the pattern is just crinkled at low heights of antenna, in case of the biconical antenna one can say evident change of the directional patterns, which lead to higher errors. In Fig. 3 possible directivity errors of analyzed antennas are shown. These graphs represent of course the worst case error ΔAF.

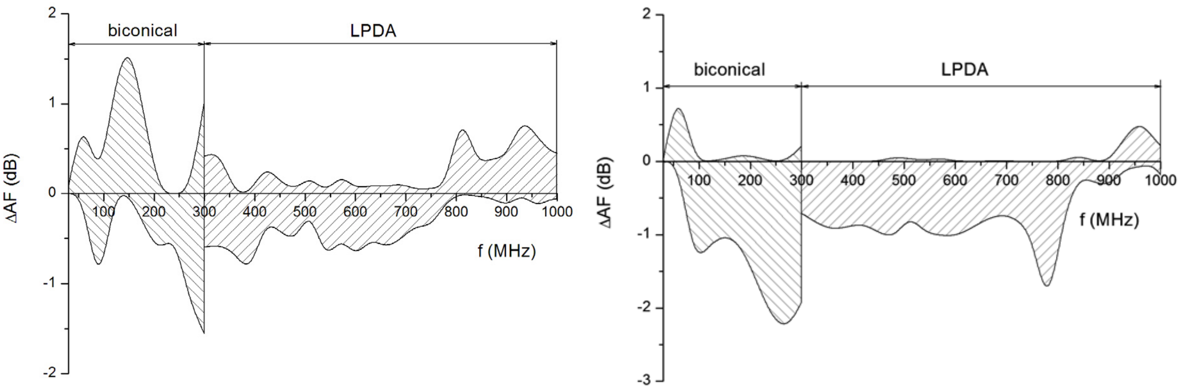

Fig. 3. Possible errors of AF for horizontally (left) and vertically (right) polarized broadband antennas caused by their directivity for distance 10 m.

It is necessary to mention that directivity error increases with the larger measuring distances because in those cases also the range of possible angles of incidence is larger.

5. Conclusions

Broadband antennas are more popular among EMC engineers in comparison with the half-wave dipole due to their benefits. On the other hand they may introduce additional errors into measurements which may lead to higher values of the measurement uncertainty because the correction is impossible due to unknown height of antenna. As it was seen above the vicinity of the ground plane impacts the AF value of broadband antennas as well as their directional patterns. In both cases biconical antenna introduces bigger error due to its bigger dimensions. The analyzed errors are strongly frequency dependent which may lead to evaluation of the frequency dependent uncertainty.

Acknowledgements

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References

[1] CISPR 16-1-4: Specification for radio disturbance and immunity measuring apparatus and methods - Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances. 3rd Ed., IEC, 2010.

[2] Chen Z., Foegelle M.D., Harrington T. Analysis of log periodic dipole array antennas for site validation and radiated emission measurement. In proceedins of the IEEE International Symposium on EMC, 1999, 618-623.

[3] Van Dijk, N. Uncertainties in 3-m radiated emission measurements due to the use of different types of receive antennas. *IEEE Transaction on EMC,* 47 (1): 77-85, 2005.

[4] Hajach P., Hartansky R. Resistively loaded dipole characteristics. *Radioengineering*, 12 (1): 23-27, 2003.

[5] Bittera M., Stih M. Modelling of wire antennas. In proceedins of the 12th International Conference on Mechatronics, 2009, 73-76.