Selection of Antenna Factor for EMI Measurements

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Abstract. *The general and also the standard recommendation in the scientific community is to use a free-space antenna factor for electromagnetic interference measurements. This paper deals with the proposal of a "site" antenna factor which also includes, besides the free-space antenna factor the contribution of the imperfections of used test site. The relation between the "site" antenna factor and the site imperfections is examined based on a number of antenna factor measurements by the standard site method to confirm this proposal.*

Keywords: Antenna Factor, EMI Measurement, Normalized Site Attenuation, Test Site

1. Introduction

In electromagnetic interference (EMI) measurements it is necessary to obtain electric field strength for determining the compliance with the EMI standard requirements [1], [2]. The electric field strength of radiated emission is measured by a suitable receiving antenna connected to a measuring receiver. An antenna factor, the most important parameter of an antenna for EMI measurements, is seldom included among the antenna basic characteristics. The antenna factor is defined as a quantity relating the strength of the field in which is the antenna immersed to the output voltage across the load connected to the antenna; the field strength is then equal to the output voltage multiplied by the antenna factor. EMI antennas have characteristics that may be affected by a ground plane, e.g. the antenna factor of a tuned dipole for 30 MHz varies by about 6 dB when the height of the antenna above the ground plane is adjusted from 1 m to 4 m [4]. As EMI measurements require a single value of the antenna factor, standard bodies have decided to use the free-space value of the antenna factor in EMI measurement.

The free-space antenna factor is an antenna factor which is not influenced by adjacent objects. Standard [3] has also introduced a new set of terms and concepts, inter alia, near-free-space antenna factor and geometry-specific antenna factor. The same standard also describes three main methods of antenna factor calibration: the standard site method (SSM), the reference antenna method and the equivalent capacitance substitution method. Additional methods are described in [5]. However, low uncertainty of the antenna factor measurement does not explicitly mean low uncertainty of the EMI measurement due to imperfections of the test site where the measurement is performed. Then, an antenna factor including these test site imperfections may be used to reduce the EMI measurement uncertainty.

2. Problem description

The quality of test sites may be deduced from the difference of the theoretical normalized site attenuation (NSA) in the ideal test site and the measured NSA in a particular test site. Theoretical values of NSA, expressed in dB, are defined as [6]:

$$NSA = 48.92 - 20\log f - E_{\mathrm{Dmax}} \tag{1}$$

where f is the frequency and E_{Dmax} is the theoretically obtained maximum value of the electromagnetic field strength, also in dB, at the given frequency, measuring distance and polarization of the antenna.

Imperfections in a test site will yield practical site attenuation values which are different from the theoretical values. Practical test site normalized attenuation can be measured using an antenna setup shown in Fig. 2. Thus:

$$NSA = SA - AF_{\mathrm{T}} - AF_{\mathrm{R}} = V_{\mathrm{Rdir}} - V_{\mathrm{Rsite}} - AF_{\mathrm{T}} - AF_{\mathrm{R}} \qquad (2)$$

where *SA* is the site attenuation, V_{Rdir} is the voltage measured with the two antenna cables connected directly to each other, V_{Rsite} is the voltage measured with the two antennas in their locations while the height of the receiving antenna is adjusted to obtain the maximum reading. AF_{T} and AF_{R} are the free-space antenna factors of the transmitting and receiving antennas. All standards recommend a limit of ±4 dB for the residual imperfections.

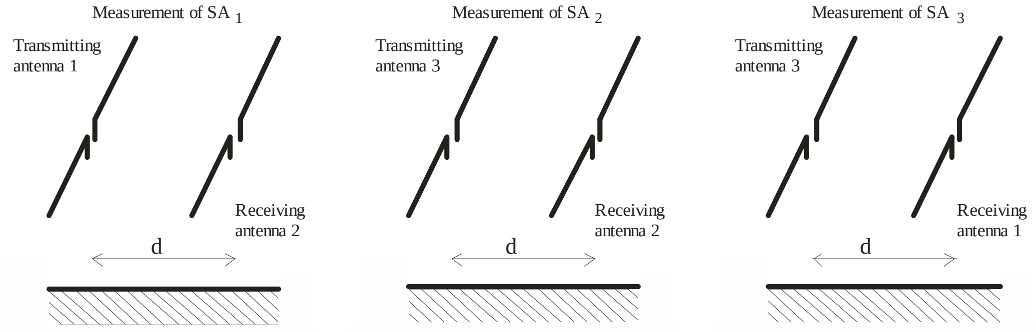

Fig. 1. Principle of measurement antenna factor [3]

For an antenna calibration over a conducting ground plane, the standard site method (SSM) is the most commonly used method. The standard site method requires three site attenuation measurements under the identical geometries, see Fig. 1, as well as using three different antennas taken in pairs. Three equations associated with these measurements of the site attenuation SA may then be obtained and from these equations the values of *AF* may be calculated:

$$\begin{aligned} AF_1 &= 0.5(SA_1 + SA_3 - SA_2) - 24.46 + 10\log f + 0.5E_{D\max} \\ AF_2 &= 0.5(SA_1 + SA_2 - SA_3) - 24.46 + 10\log f + 0.5E_{D\max} \qquad (3) \\ AF_3 &= 0.5(SA_2 + SA_3 - SA_1) - 24.46 + 10\log f + 0.5E_{D\max} \end{aligned}$$

In compliance with the geometry defined by [3], with the transmitting and receiving antennas 10 m apart the transmitting antenna in the horizontal polarization at the height of 2 m and the receiving antenna being adjusted in height from 1 m to 4 m, the resulting antenna factor, which is minimally affected by the test environment, is defined as the near-free-space antenna factor. The free-space antenna factor, necessary for EMI measurements, can be obtained in conjunction with the geometry-specific correction factors, known just for dipoles and biconical antennas [3].

Antenna characteristics are usually specified for far-field conditions. The far-field data is valid for arbitrary distances assuming that the measuring distance is very large compared to the antenna length. However, when the antenna length becomes comparable to the measuring distance, i.e. 3 m or shorter distances, additional correction factor should be added to the antenna factor value [3].

If such an antenna factor is used in EMI measurements, all these facts will lead to a higher uncertainty budget. Therefore, we propose the use of a “site” antenna factor instead of the free-space antenna factor. This antenna factor includes the test site imperfections, e.g. effect of the ground plane, and avoids, of course, the correction for near-field in which case two different antenna factors have to be obtained, i.e. for horizontal and vertical polarization.

3. Results

Since only one test site was at our disposal, twenty sets of antenna factor, as well as NSA, measurements were performed, for both polarizations, five distances from 2.25 m to 3.25 m with 0.25 m step and two heights of the transmitting antenna, 1 m and 2 m. The measurements were performed for 25 discrete frequencies logarithmically distributed in the range from 30 MHz to 1000 MHz. The measurement setup is given by standards [1], [3], see Fig. 2. The height of the receiving antenna was varied from 1 m to 4 m to get the maximum voltage V_{Rsite}. Three different antennas were used:

1) Bilog broadband antenna VULB 9161(transmitting & receiving);
2) Bilog broadband antenna VULB 9163 (receiving);
3) Set of biconical and log-periodical antenna VHBA 9123 & VPA 6108 (transmitting).

For these antennas, the free-space antenna factor is known. The correction factor C helps to reduce the uncertainty budget; its effect cannot be neglected, see Fig. 3. It is given as:

$$C = 20\log\left(\frac{d + P_{\mathrm{f}}}{d}\right) \qquad (3)$$

where d is the measuring distance from the source to a tip of the antenna and P_{f} is a phase-center position as a function of frequency. Also ideal values of NSA were calculated for every measurement geometry.

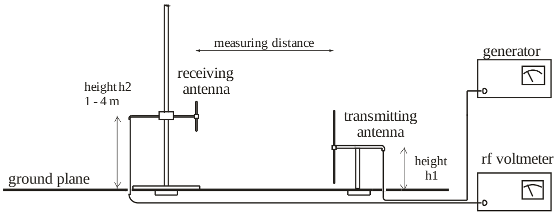

Fig. 2. Antenna factor and NSA measurement setup [2]

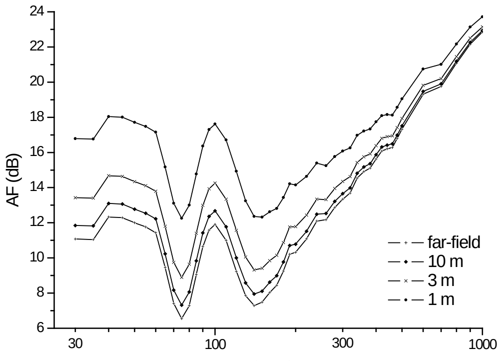

Fig. 3. Correction of antenna factor for Bilog broadband antenna VULB 9163

All the measured NSA values fulfill the ±4 dB criterion; in fact the maximal deviation does not exceed ±3.5 dB value, see Fig. 4. Better results were reached for horizontal polarization due to a negligible mutual coupling between the antennas and the orthogonal feeder, and the smaller ground screen edge reflections. Also the horizontally polarized ground reflections are less sensitive to differences in the ground plane material characteristics than the vertically polarized reflections [7].

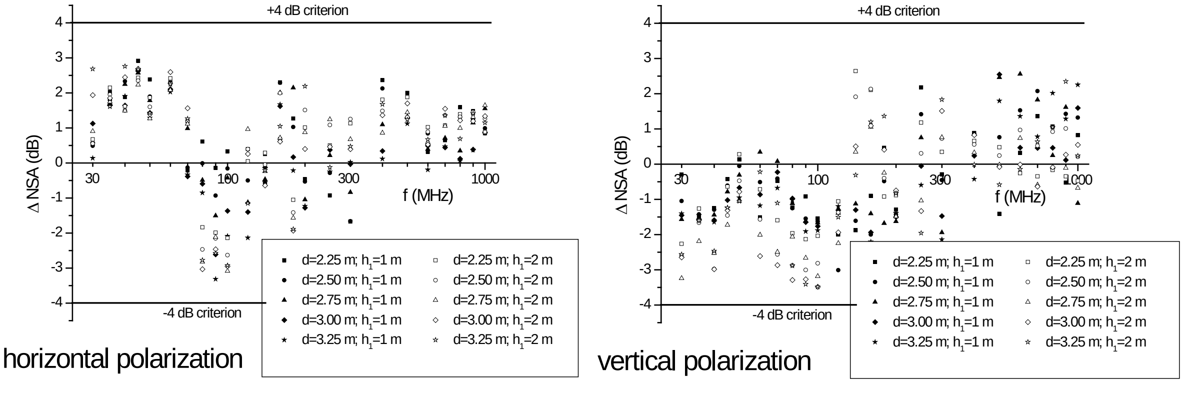

Fig. 4. NSA deviation data for various geometry using antennas “1” and “2”

Furthermore, “site” antenna factor values of used antennas were calculated, see Fig. 5. As it can be seen neither antenna factor deviation exceeds 1.6 dB. However, it is evident that the tendency of all the “site” antenna factor deviations copies the tendency of the NSA deviations. Correlations of these similarities were calculated as Pearson’s product moment coefficient. Values of correlation of 0.81 for horizontal polarization and 0.78 for vertical polarization indicate high dependency between these deviations.

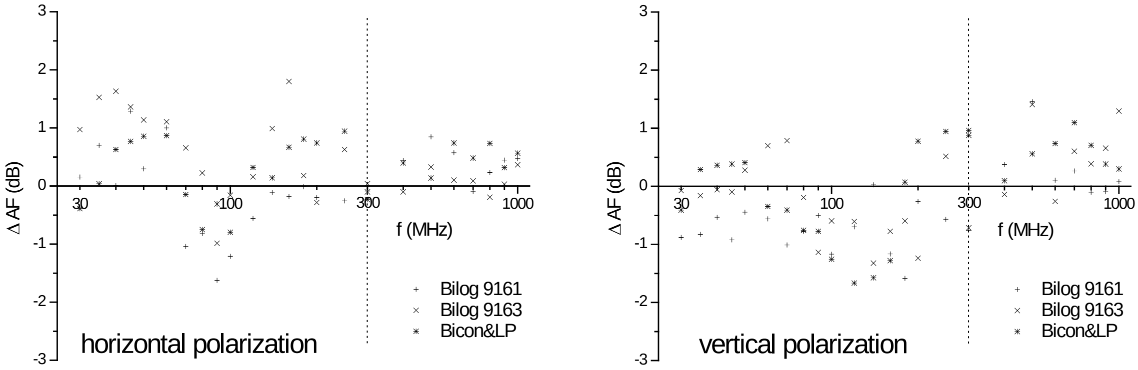

Fig. 5. AF deviation data of used antennas for 3 m distance and 1 m transmitting height

4. Discussion

The use of the “site” antenna factor for EMI measurements is proposed in this paper. Such an antenna factor measurement has to be performed in the same test site as is the EMI measurement itself. Then in contrast to the free-space antenna factor, the “site” antenna factor includes the test site imperfections, such as effects of the ground or any auxiliary devices. This antenna factor, when used for EMI measurements, leads to the measurement uncertainty reduction because there is no necessity to include the test site imperfections into EMI measurements uncertainty.

Acknowledgements

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