Standard Electromagnetic Compatibility (EMC) Measurements, Feasibility of a Wide-Band Calculable Antenna

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Abstract

A wideband Bi-conical antenna is presented which its input impedance (without Balun) is matched to 50Ω for 100MHz to 2GHz. By its constant Gain and slight variation of radiation pattern for this frequency range, the antenna can be used as low-uncertainty calculable standard of E-Field. No need to impedance matching system together with the fixed-placed phase-center of the antenna can vanish two important uncertainty causes and improve the measurement accuracy. Preliminary results are reported.

1. Introduction

E-field measurement together with M-field measurement (principally for the very low frequencies) are the basis of every experimental study in the domain of EMC. Investigation at standard antennas had been in progress for EMC measurements. These tests require accurate calibration of antennas. For the reason of their simple and calculable radiating characteristics, the linear dipole antennas are often used for EMC tests. In this regard we have designed and simulated two standard dipoles in an open-field high quality site from 30 MHz to 2 GHz.
E-field measurement is essential in EMC both in far and near field areas especially for dosimetry, SAR evaluation and dielectric material characterization. Measurement devices of E-field usually consist of two main components: a small antenna or other pickup device that is sensitive to the presence of an E-field (in the case of radiation) and a detector to convert the signal to a form that can be registered on a readout device such as a meter (both for radiation and guided-waves). The standard antenna design is the most important challenge for these measurements. The Gain and Antenna Factor AF of a calculable antenna is determined without measurement but only by calculation. Therefore, the expensive and long calibration procedure is no more necessary. It is essential to evaluate the associated uncertainty of every calculated parameter, in this case.

2. Theory

The Antenna Factor (AF) is a very useful parameter for E-field measurements and is defined as the ratio of the electric field strength E of a plane wave incident on the antenna, to the detected voltage V_r :

$$V_r = AF(dB/m)\ .\ \mathbf{E} \quad (1)$$

The AF can be evaluated by using an open Standard Site which contains a high quality reflector plane. By installing two Tr & Rr antennas on the standard site, AF can be deduced by different methods. The Standard Site Method (SSM) [1] is one of the most used for the frequencies between 30 MHz to 2 GHz. For each AF test, the height of transmitting antenna (h_1) and the horizontal distance between the antennas (d) are fixed and the height of receiver antenna (h_2) is variable (Fig. 1). This configuration results the lowest uncertainty at an optimal height h_{2opt} where the detected voltage is maximum.

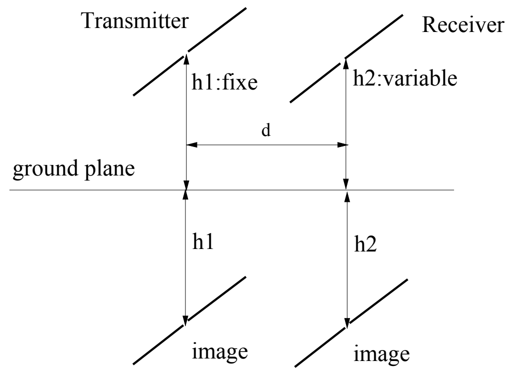

Figure 1: Standard Site Method SSM

In fact, the Standard Site method permits to calculate, in theory, the radiated E-field at every point on a perfect site supposing a well-known reflecting/diffracting environment surrounding the ground plane. In this case, the perfect open site is used as calculable primary reference.
A calculable dipole antenna can be used as primary standard, as well [2]. In this case, the calculable antenna is the primary standard itself, to calibrate other antennas by comparison and substitution.
Table 1 shows the comparative AF of a half wavelength dipole antenna by analytical methods, simulation and measurement in an open site configuration:

Table 1: AF of the half wavelength dipole; numerical, analytical and the measurement results in the standard site

f(MHz)	AF (dB/m) simulation	AF (dB/m) Analytic	AF(dB/m) Measurement
30	-0.6	-1.7	-1.1
60	4.0	4.1	4.6
100	8.5	8.4	8.8
300	18.3	18.5	18.7
500	22.5	22.5	22.6
700	25.9	25.9	25.7
1000	29.1	29.3	29.1
1500	33.0	33.2	32.4
2000	35.9	36.1	35.6

Uncertainty Evaluation: Radiated emission testing and calibrating of EMC test antennas is based on the electromagnetic waves propagation between device under test and antenna or between two antennas. For the higher frequencies a high quality anechoic chamber is generally used for far-field or near-field measurements. The uncertainty of AF evaluations for the half wavelength dipole antenna is generally equal or greater than 0.3 dB up to 1 GHz and greater than 0.5 dB up to 2 GHz. These uncertainties are transferred directly on E-field measurements and can cause 5% – 15% deviation. In the other hand, some random&systematic errors can affect seriously the E-field measurements, which the ground plan and other perturbation obstacles are the most important and can even cause a few dB deviation.
Half wavelength dipole has well-known calculable radiation characteristics and can be used as calculable standard for EMC measurements with low uncertainty level. Nevertheless, this antenna is not wideband and for different frequencies its length should be adjusted to resonant. This fact can reduce the application range of the dipole and rise the calibration time. A wideband Bi-conical antenna is proposed to avoid these problems.

2.1 Wide-Band Bi-Conical Antenna

The 3D solid Bi-conical antenna is a limited size model of the well-known frequency independent antenna: infinite conical radiator (Fig. 2). The radiation characteristics of the antenna depend on its the electrical length and flare angle. The feeding system can be a shielded internal coaxial line connected directly to the two halves of the antenna.

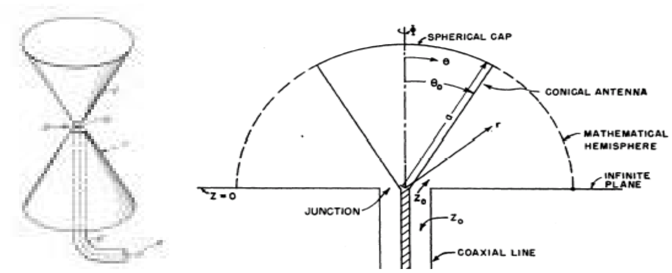

Figure 2: Conical and Bi-conical coaxial-fed antenna

By choosing the flare angle around 60-70 degrees and optimizing the antenna length, the input impedance is 50Ω [3]. Direct coaxial feeding system of antenna is advantageous because the uncertainties caused by the matching Balun can be eliminated. The antenna size is optimized to cover the frequency range 100MHz – 2 GHz . The antenna Gain is constant around 3-5 dB and the maximum directivity remains at horizontal axis.

3. Results

Theoretical curves of antenna input impedance are presented together with the first simulation results (Fig. 3,4). The antenna shows very good wide-band behavior where the input impedance is directly matched to 50Ω for the frequency range 100 MHz – 2 GHz. The optimal antenna height is ~40cm with its flare angle around 65 degrees.

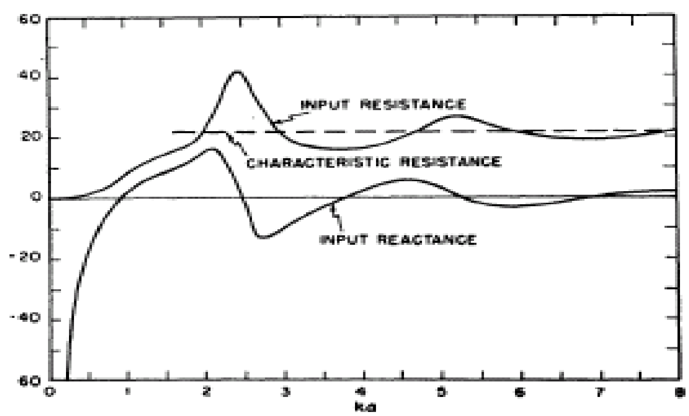

Figure 3: Analytical input impedance [3]

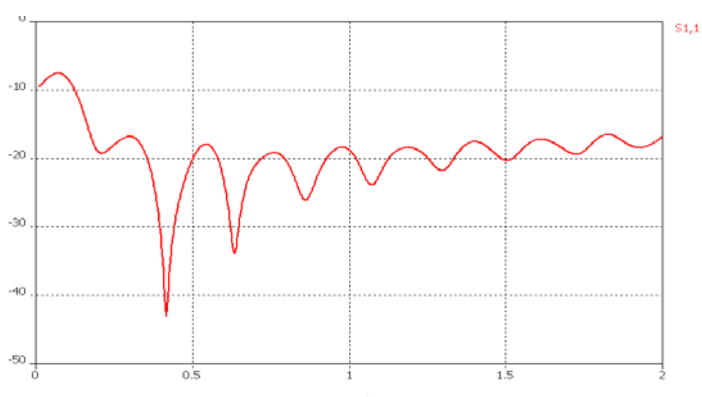

Figure 4: Return loss to 50Ω, numerical simulation

Numerical simulations show a quasi-constant Gain and Pattern for this frequency range. The analytical approach [3] is in good agreement with simulation results.
The AF of the wideband Bi-conical antenna can be evaluated by numerical simulation or directly by formula 2:

$$(\mathrm{AF})^{-1} \sim Le = \frac{\lambda}{\pi}\sqrt{\frac{GRr}{120}} \qquad (2)$$

As the input impedance of the antenna is remaining close to 50Ω for all the designed frequency range, then formula (2) can be presented as a direct relation between antenna Gain and AF :

$$(\mathrm{AF})^{-1} \sim \lambda\sqrt{G} \qquad (3)$$

Supposing a quasi-constant Gain, relation (3) is very similar to the analytical AF of a resonant dipole antenna (Fig. 5).

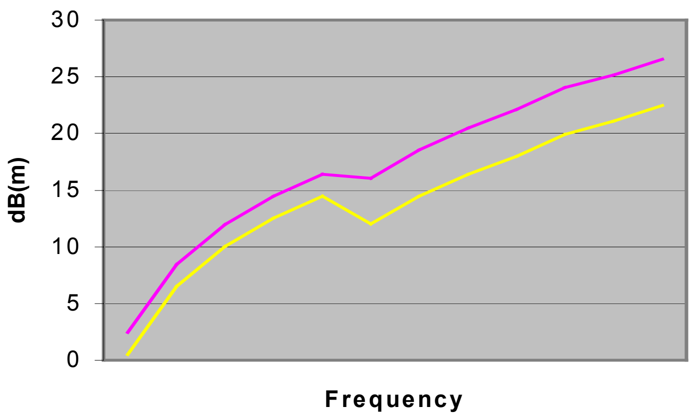

Figure 5: Schematic AF versus frequency, upper and lower margins for the Gain variations 3-5 dB

4. Conclusion

A direct coaxial-fed Bi-conical antenna is studied to establish wide-band calculable antenna for standard EMC measurements. Two main causes of measurement uncertainty can be vanished by this novel design :
1- Balun and matching system.
2- the most important advantage: fixed-placed phase-center of Bi-conical antenna for all the frequency range.
This is very important parameter to reduce the calibration uncertainties on the measurement site and to economize the calibration cost and time.

7. References

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