What is Antenna Factor?

I still remember the day when there was no internet or Google and I was searching antenna books to find the definition of the term “antenna factor”. The term was commonly used by all EMC engineers during radiated emissions testing, but then, they were not called EMC engineers, but referred to as RFI or EMI engineers. Even today, the subject of “Antenna Factor” is not commonly discussed in antenna theory or antenna design books. However, in the world of EMI or EMC testing (often called “EMI-EMC” testing), the concept of antenna factors is used as commonly as the antennas themselves. However, quite often, the concept of antenna factor is used without fully understanding its meaning, its limitations, the reasoning or the complexity behind this simple idea.

The antenna factor defines the relationship between the electric field strength E, around the antenna and the voltage output of the antenna V. To be more precise, in numeric terms, it is the ratio of the electric field strength E to the voltage V, induced across the antenna output terminals. So its units are volts/meter or microvolts per meter. However, the antenna factors are generally expressed in dB microvolts per meter (20 times the log of the numeric value of the antenna factors).

Rationale for the Use of Antenna Factors: At any given frequency, the relationship between field that the antenna is immersed in and the output voltage is linear (for passive antennas). Therefore, the antenna factor is a constant at a given frequency. So the antenna factor (in dB microvolts per meter) can be simply added to the value of voltage measured (in dB microvolts per meter) at the antenna output to determine the value of the measured field E (in dB microvolts per meter). This is very simple and convenient indeed. This is the main advantage of using the antenna factors while taking the emissions measurements for EMI-EMC testing. That is the reason for the exclusive use of the antenna factor as the main parameter during all radiated emissions testing for EMC compliance.

Limitations of Antenna Factor Concept: In order to get accurate and reliable data, one must watch out for the limitations of the tools used as well as the theory behind the methodology used. So we will examine the practical limitations behind this idea and also precautions to be taken during the radiated emissions measurements. That would include: (1) Uniform field (2) Effect of distance (3) handling of antenna (4) linearity of induced voltage (5) VSWR, etcetera.

Uniform Field: The definition assumes that the antenna under consideration is surrounded by an electric field that is uniform. In practice, the field surrounding the antenna is rarely if ever uniform. It is very difficult to get a uniform field even when we try to generate a uniform field as when we may want while calibrating the antenna. So we assume that the field is an average value over the volume of the antenna. One has to keep this in mind when using antenna factors. This fact creates most uncertainties during the calibration or the use of an antenna.

Effect of Distance: The direct impact of the non-uniform field is observed as the dependence of antenna factor on distance of calibration. The simple definition of antenna factor implies that the distance of the source of the field would have no impact on the value of the antenna factor but only the ratio of V and E. However, the uniformity of the field over the volume of the antenna depends on its distance from the source (the farther the source, the more uniform its field is likely to be over the entire body of the antennas). That is the reason why the antenna factors are likely to be different for distances.

Handling of Antennas: They are also used almost every day and possibly more than one shift by different engineers. They also require extensive handling due to changes for polarization as well as frequency bands. These antennas in an EMC laboratory are, therefore, designed for ruggedness and extensive use. However, their antenna factor is dependent on the shape and geometry of the antenna. Its integrity is completely dependent on the structure and shape of the antenna. So the antenna must be handled very carefully and they must be calibrated at regular intervals to verify that the antenna factors have not been affected by any mishandling. However, that is not enough because the yearly calibration may be too late to find out a serious out of calibration condition. Therefore, daily verification prior to beginning the test is highly recommended. See www.com-power.com/comb_generators.html.

Linearity of Induced Voltage: The receiving antenna used during emissions testing for compliance is not always passive and may include an amplifier to improve the output level. However, the amplifier may maintain its linearity only within a certain range. So, if an active antenna is used, one must be aware of this fact and make certain that the pre amplifier (and therefore the antenna) is in linear range trough out the test.

VSWR of the antenna: The measurement of the voltage at the antenna output terminals could be affected by any impedance mismatch. The mismatch in impedance would result in reflected energy at the antenna output and cause incorrect voltage reading. The EMC engineer should be aware of this fact and must verify that his antenna has a good impedance matching to his EMI meter. CISPR test methods require better than 2.0 VSWR.

The parameter used to define the antenna performance in basic antenna theory is antenna gain (G) and it can be converted into the antenna factor (AF) using the following expression for antenna aperture

$A_e = G.\lambda^2 / 4\pi$ … … Eqn. (I), where, λ is the wavelength at the signal frequency.

However, A_e is also defined as the ratio of power output (Po) of the antenna to the power density (P_d) at the antenna, so

$A_e = Po / Pd = (V^2 /50) / (E^2 / 120\pi)$ … … Eqn. (II), because $V^2 /50$ is the antenna power output into a 50 ohm load and $E^2 / 120\pi$ is the power density around the antenna.

Solving the two equations above and simplifying, we get

$AF = E/V = \sqrt{48/5}\,\pi / \lambda\sqrt{G}$ … … Eqn. (III) or

$AF = 9.7 / (\lambda\sqrt{G})$

This equation can be used to convert the antenna gain into the antenna factor at any frequency.

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