Alternative Approaches to Radiated Emission and Immunity Measurements

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Variations in field intensities produced by the mandated 10-m (civilian standards) and 1-m (military standards) antenna distances can be compared using computer simulations.

Introduction

The radiated emission measurements as defined in the European standards are based on an open area test site and the use of a conductive reference ground plane. Tuned dipoles are used as receiving antennas in vertical and horizontal polarizations. The height of the receiving antennas is varied between 1 and 4 m above the ground plane to receive the maximum signal, which is the sum of the direct and the ground-reflected signals. The theoretical maximum is calculated for an infinite ground plane and is used as the reference for the determination of the normalized site attenuation of a real test site. Figure 1 shows the geometry used, which can be found in ANSI C63.4 and prEN 50147-2.

The site attenuation expressed in terms of the antenna factors of the transmit and receive antennas and a ground wave propagation term is given as:

$$A = \frac{279.1\ AF_R AF_T}{f_M\ E_D^{max}}$$

where

f_M = Frequency in MHz
AF_R = Antenna factor of receiving antenna in dB/m
AF_T = Antenna factor of transmitting antenna in dB/m
E_D^{max} = Maximum electric field in receiving antenna height scan range $h_2^{min} \le h_2 \le h_2^{max}$ from a theoretical half-wave dipole with 1 pW of radiated power.

For horizontal polarization, E_D^{max} is given by:

$$E_{DH}^{max} = \frac{\sqrt{49.2}\left[d_2^2 + d_1^2 \,|\rho_h|^2 + 2d_1 d_2 |\rho_h| \cos\left(\Phi_h - \beta\,[d_2 - d_1]\right)\right]^{1/2}}{d_1 d_2}$$

maximized over the interval $h_2^{min} \le h_2 \le h_2^{max}$.

For vertical polarization, E_D^{max} is given by

$$E_{DV}^{max} = \frac{\sqrt{49.2}\,R^2\left[d_2^6 + d_1^6 \,|\rho_v|^2 + 2d_1^3 d_2^3 |\rho_v| \cos\left(\Phi_v - \beta\,[d_2 - d_1]\right)\right]^{1/2}}{d_1^3 d_2^3}$$

maximized over the interval $h_2^{min} \le h_2 \le h_2^{max}$.

Field Generation

Using the formulas given above, a three-dimensional representation of the generated fields is given in Figure 2 for a frequency of 500 MHz and a horizontal dipole at 1 m above the ground plane. With increased frequency, more and more lobes emit from the center, which grow up and squeeze the earlier lobes to the ground plane. Figures 3 through 9 show the vertical cross sections of shapes like that shown in Figure 2.

Variation of Field Intensities

10-M DISTANCE

For a height up to 10 m, the field intensities of a horizontal half-wave dipole fed with 1 pW have been calculated. Figure 3 shows the field intensities produced at four selected frequencies. At 30 MHz, the lowest frequency used in civilian standards, the maximum field intensity is at a height of 9.4 m. Remember that for civilian

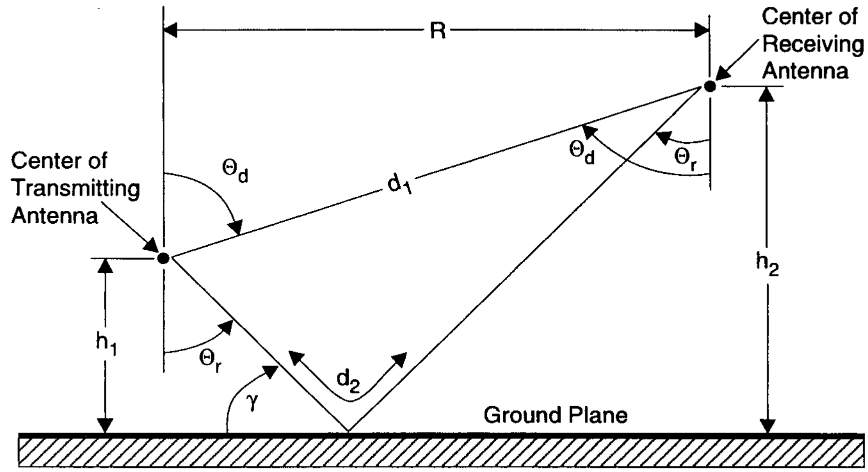
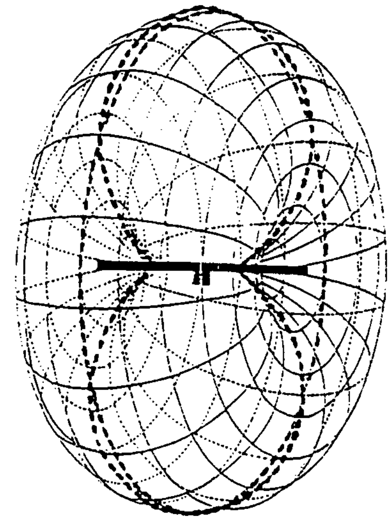


Figure 1. Site Attenuation Measurement Geometry.



standards, the antenna mast is only at a 4-m height. There, the first maximum, or peak, is seen at 189 MHz, where it can be measured. However, at 755 MHz this true maximum has come down to 1 m height and leaves the antenna height range. Consequently, only lower peaks can be measured at frequencies above 755 MHz.

The upper measurement frequency for civilian standards is 1000 MHz. There, the nulls between the lobes are about 30 dB below the maximum and two peaks (at 2.3 and 4 m) can be detected as the antenna height is adjusted. Figure 4 shows the field intensities for vertical polarization.

3-M DISTANCE

Using the same scale as Figures 3 and 4, Figures 5 and 6 show the field intensities for a 3-m distance. It can be seen that the lobes are closer to each other. The nulls are only 20 dB below maximum and no first, or true, maximum is above 4 m. The difference between the peak and the first maximum for frequencies above 239 MHz is about 2 dB. For horizontal polarization, there is always a null on the level of the ground plane, in contrast with the maximum for vertical polarization.

1-M DISTANCE

The calculations for 1-m distance reveal the consistency of the trends: the peaks are even closer to the ground plane and to each other. The amplitude differences between nulls and peaks are about 10 dB, as Figures 7 and 8 show for horizontal and vertical polarization respectively.

For ease of evaluation, Figure 9 shows the results for both polarizations on an enhanced scale. The biggest difference in amplitudes at a 1-meter height can be seen at 8 dB.

When aperture antennas are used, these differences can be minimized by integrating effects, and such an antenna could be used at a fixed height. The search for the maximum would be unnecessary, and the test time reduced.

Lobing and Ground Reference Plane Interactions

Using a shorter antenna distance eliminates the need to use the height scan to search for the maximum. Nevertheless, lobing still exists, and aperture antennas integrate these signals. However, the military test methods provide a solution to this problem: when the reference ground plane is put on top of the test bench, the radiating parts of the EUT are only 5 cm apart from the plane compared with 80 m when the ground plane is on the floor. The lobing is then transferred to higher frequencies where aperture

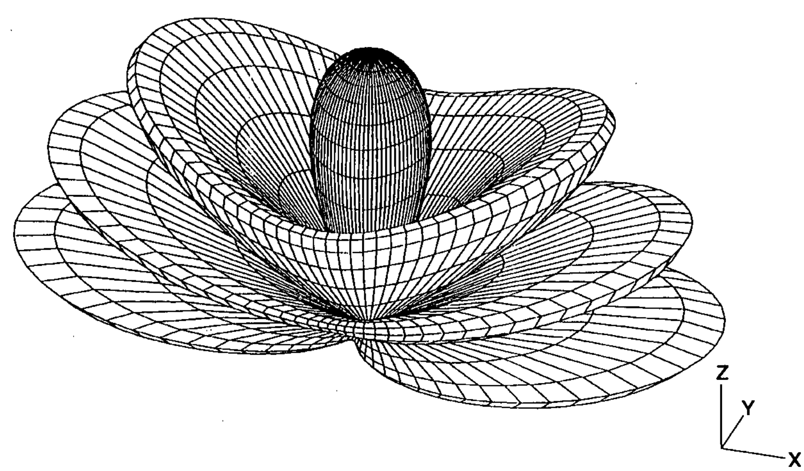


Figure 2. Field Generated at 500 MHz by a Horizontally-polarized Half-wave Dipole at 1 m above a Reference Ground Plane.

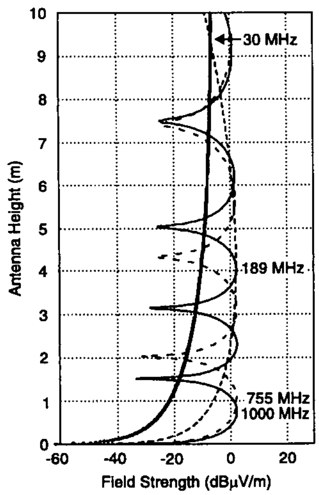


Figure 3. Field Intensity Distribution, Horizontal Polarization at 10 m.

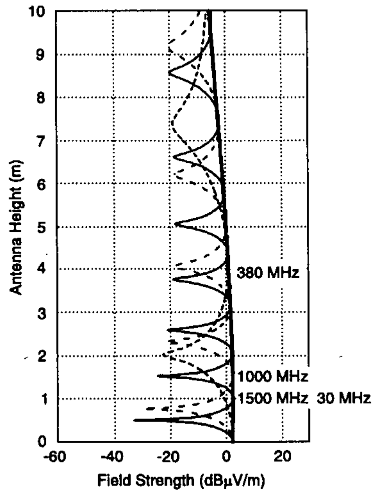


Figure 4. Field Intensity Distribution, Vertical Polarization at 10 m.

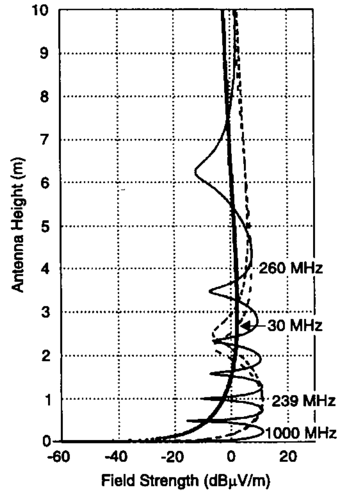


Figure 5. Field Intensity Distribution, Horizontal Polarization at 3 m.

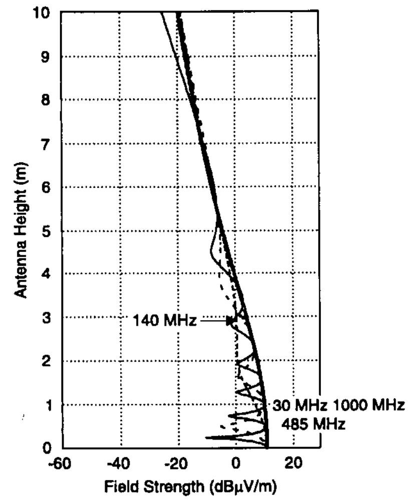


Figure 6. Field Intensity Distribution, Vertical Polarization at 3 m.

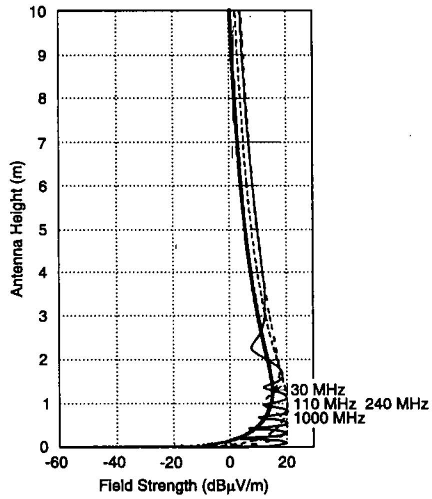


Figure 7. Field Intensity Distribution, Horizontal Polarization at 1 m.

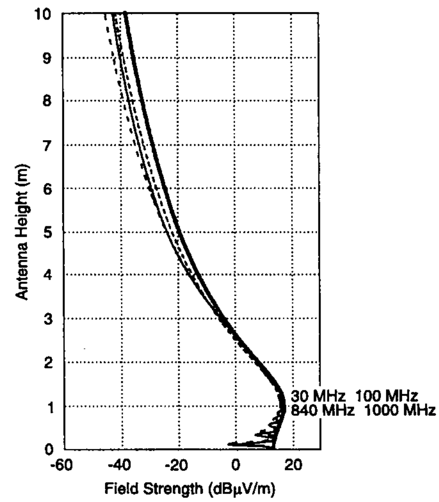


Figure 8. Field Intensity Distribution, Vertical Polarization at 1 m.

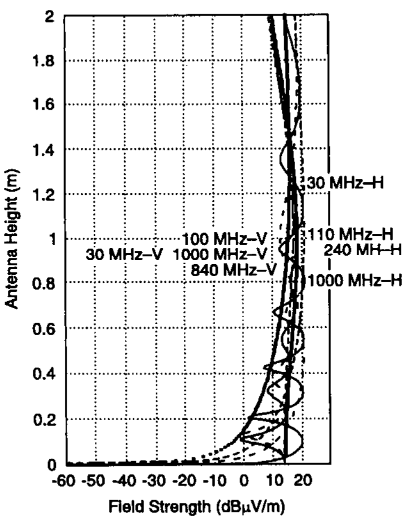


Figure 9. Field Intensity Distribution, Both Polarizations, Expanded Scale at 1 m.

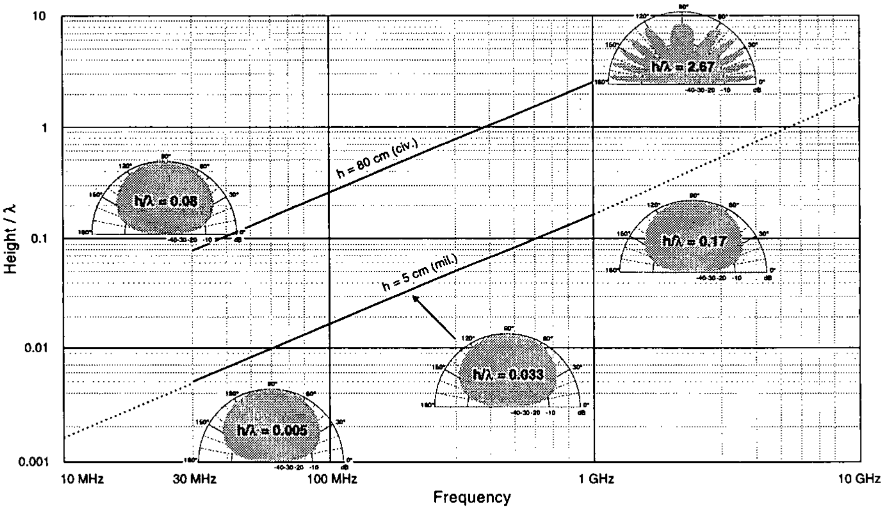


Figure 10. Influence of EUT Distance from Ground Plane on Lobing.

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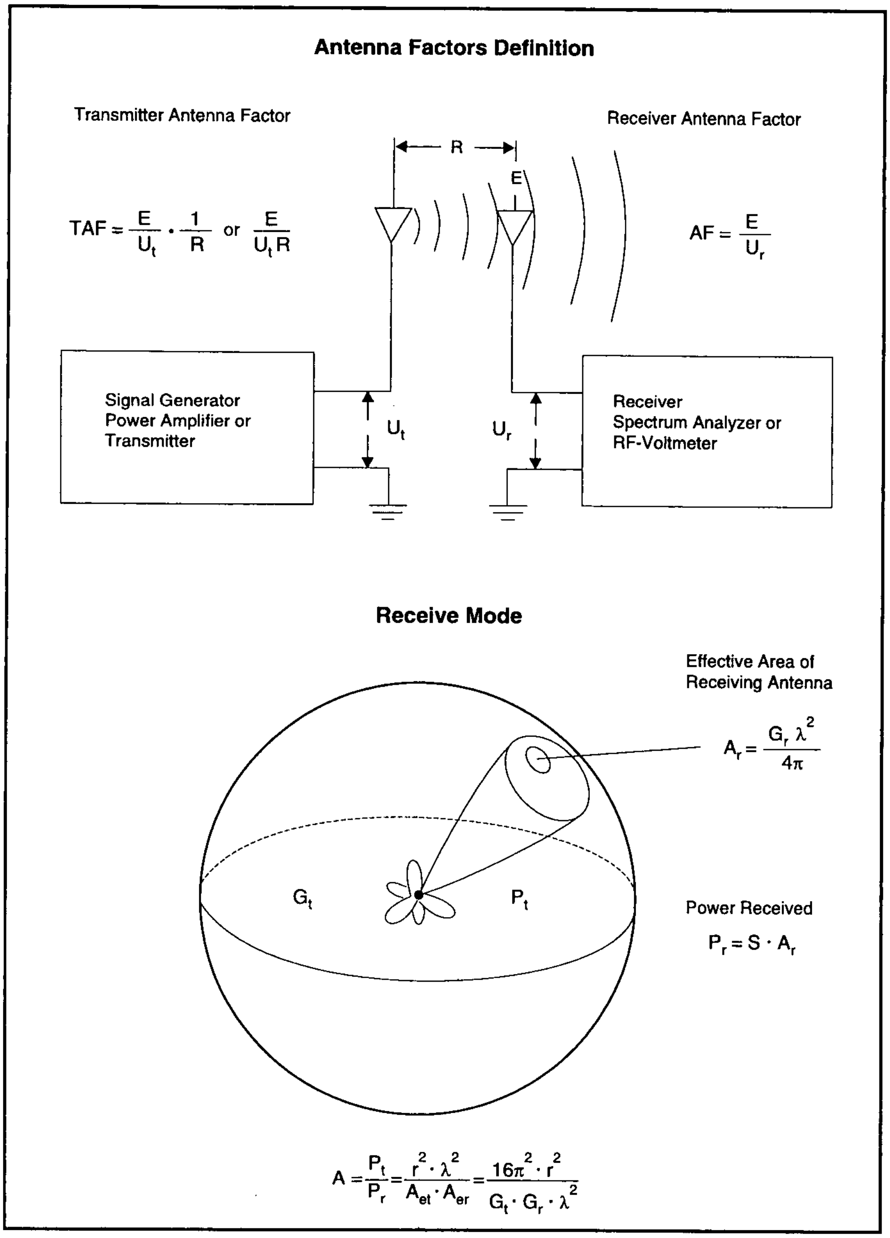

Figure 11. *Mathematical Relationships of the Military Test Method.*

COST FOR RADIATION MEASUREMENT			
	EN (10 m)	EN (3 m)	VG (1 m)
Absorber Lined Enclosure	5,000,000	750,000	250,000
Amplifier (10 V/m)	*	60,000	20,000
Antenna Mast	25,000	25,000	1,000
Controller for Mast	7,000	7,000	-
Antenna	7,000	7,000	12,000
Turntable	8,000	8,000	1,000
	5,047,000	857,000	284,000

Table 1. *Investments Required for Radiated Emission Test vs. Distance (Estimated Prices are in DM: 1$ U.S. = 1.7 DM). *Immunity measurements only required between 1- and 3-m distance.*

antennas are used for military testing. Figure 10 (page 108) illustrates this effect, which might be increased by further reducing the EUT height above the ground plane.

Results

The advantages of the test setup defined by military standards, i.e., 1-meter antenna distance, fixed antenna height, use of aperture antennas, and a reference ground plane on top of the test bench, can be proven with the mathematics used to define the civilian test setup. Furthermore, the antenna model used for military standards can easily be applied to susceptibility testing. The appropriate formulas can be found in Figure 11. It would be reasonable to use the military approach for a future harmonized test standard. This is underscored by an economic comparison of the required investments for both types of testing. The results can be found in Table 1.

Conclusion

Today, computer simulation techniques can be used to compare the field intensities at a 10-m distance from the antenna, a distance which is used in civilian standards, with those existing at the 1-m distance used in military standards. Advantages to test setups called out in military standards are clear. Similarly, the antenna model used for military standards can be used for susceptibility testing.

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