

Analysis and Simulation of Electric Field Intensity from a Half-wave Dipole Antenna in Open Area Test Site

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Abstract— Accurate measurement of electric field intensity is important in electromagnetic compatibility (EMC) field where the measured electric field emitted by an electrical or electronic product determines whether the product complies with regulation. To have valid measurement, the antennas used in the measurement must be calibrated accordingly. Both the measurement and calibration have to be done in a test site. Although there have been various alternative test sites available nowadays such as the anechoic chamber, legislative body such as the International Electrotechnical Commission (IEC) requires an open-area test site (OATS) as the reference for radiated emission measurement and antenna calibration. Therefore it is very important to understand the propagation mechanism in the OATS in order to design, evaluate and operate the OATS. This paper discusses the modeling and simulation of propagation mechanism in the OATS, starting with the basic propagation equation as a foundation, and the derivation of the electric field propagation model in an ideal OATS. The model uses a half wave dipole antenna as the transmitter. Simulations of the radiation of electromagnetic wave from a half-wave dipole antenna in the range of 30–1000 MHz have been performed in CST Microwave Studio[®] simulation software. The results of the calculation using the model were compared to the simulation. The average deviation was used to compare the result of the calculation using the theoretical model and the result of the simulation. The importance of height scanning of the receiving antenna was also elaborated. The results have proven that the theoretical model and the simulation are consistent and therefore the simulation validates the model.

1. INTRODUCTION

An open area test site (OATS) is a flat, outdoor open area, with conductive ground plane, free from overhead wires and nearby reflecting structures. The equipment under test (EUT) is placed on a non-metallic turntable and the electric field is measured for various orientations using an antenna. An ideal OATS has infinite ground plane made of perfect electric conductor [1, 2].

The knowledge on the propagation mechanism in the OATS is important to design, evaluate and operate the OATS. Therefore, this paper contributes to the understanding of the propagation mechanism by deriving the electric field propagation model in an ideal OATS and creating simulations to be compared with the theoretical model.

2. PROPAGATION OVER INFINITE GROUND PLANE

The electric field intensity at distance R from a non-isotropic transmitter is given by

$$E = \frac{\sqrt{30P_t g_t}}{R} \quad (1)$$

where P_t is the input power to the transmitter (W) and g_t is the gain of the transmitter [3–6].

If an infinite ground plane exists below the antennas, then the electric field intensity at the receiving antenna becomes the resultant between the electric field intensities due to direct and reflected waveforms as follows:

$$\mathbf{E} = \mathbf{E}_d + \mathbf{E}_r \quad (2)$$

where \mathbf{E}_d is the component of electric field intensity due to direct waveform and \mathbf{E}_r is the component of electric field intensity due to reflected waveform.

The electric field intensity due to reflected waveform can be analysed using mirror image of the transmitting antenna as shown in Figure 1 [7].

For sinusoidal waveform the electric field intensity becomes

$$E = \sqrt{30P_t g_t} \left(\frac{e^{-j\beta d_d}}{d_d} + \frac{\Gamma e^{-j\beta d_r}}{d_r} \right) \quad (3)$$

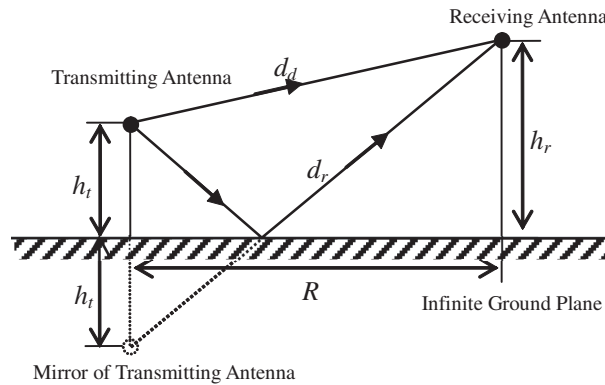


Figure 1: Geometry of electric field propagation over infinite ground plane.

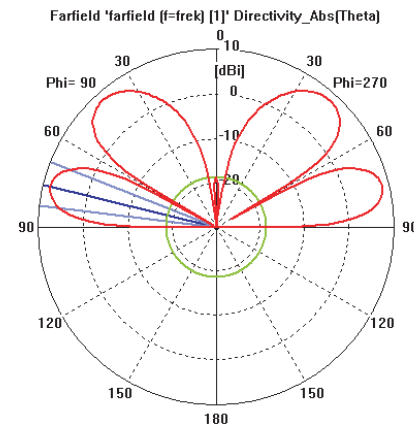


Figure 2: Radiation pattern of the half wave dipole over infinite ground plane.

Table 1: Height of receiving antenna versus electric field intensity.

RX height (m)	E (dBV/m)	
	Calculated	Simulated
1	12.15	11.82
1.5	4.94	6.01
2	0.91	0.18
2.5	8.40	8.40
3	10.02	10.09
3.5	9.81	9.66
4	8.79	8.42

where $d_d = \sqrt{R^2 + (h_t - h_r)^2}$, $d_r = \sqrt{R^2 + (h_t + h_r)^2}$, $\Gamma = e^{j\Phi}$ is the reflection coefficient, Φ is the phase shift due to the reflection and $\beta = 2\pi/\lambda$ is the free space wavenumber.

If the ground plane is a perfect electric conductor, the magnitude of the reflection coefficient is unity while its phase is shifted by 180° therefore Equation (3) becomes

$$E = \sqrt{30P_{tg}} \left(\frac{e^{-j\beta d_d}}{d_d} - \frac{e^{-j\beta d_r}}{d_r} \right) \quad (4)$$

3. SIMULATION RESULTS

The average deviation as given in the following formula will be used to compare the result of the calculation using the theoretical model and the result of the simulation.

$$D_{av} = \frac{\sum |d_n|}{n} \quad (5)$$

where $|d_n|$ is the absolute value of the deviation and n is the total number of data.

Simulations of the radiation of electromagnetic wave from a half-wave dipole antenna in the range of 30–1000 MHz have been performed in CST Microwave Studio[®]. The simulations were done for horizontal polarization only. In this simulation an infinite perfect electric conductor ground plane was included by setting the boundary condition at the ground plane to be electric ($E = 0$).

Due to effect of the ground plane the radiation pattern of the antenna have been changed into several lobes as shown in Figure 2.

A probe situated at the receiver was height scanned from 1 m to 4 m with 0.5 m increment. It was aimed to obtain the maximum electric field intensity. The simulation was done in the frequency of 300 MHz. The results were recorded in Table 1. The values obtained in the simulation were then compared to the calculated electric field intensity from Equation (4). The results in Table 1 are be visualized in a graph as illustrated in Figure 3.

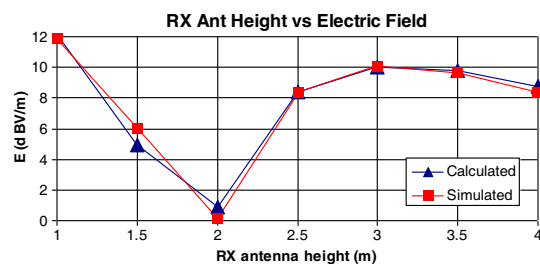


Figure 3: Height of the receiving antenna versus electric field strength.

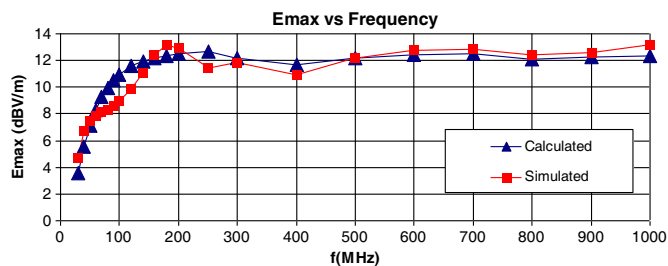


Figure 4: Maximum Electric Field Intensity at 30–1000 MHz.

Table 2: Maximum electric field intensity at various frequencies.

f (MHz)	RX height (m)	E_{\max} (dBV/m)		f (MHz)	RX height (m)	E_{\max} (dBV/m)	
		Calculated	Simulated			Calculated	Simulated
30	2.9	3.54	4.75	180	1.3	12.36	13.14
40	2.9	5.59	6.75	200	1.2	12.48	12.9
50	2.8	7.13	7.46	250	1.0	12.64	11.46
60	2.7	8.32	7.83	300	1.0	12.15	11.82
70	2.6	9.25	8.1	400	2.1	11.64	10.9
80	2.5	9.97	8.3	500	1.6	12.16	12.19
90	2.4	10.52	8.58	600	1.3	12.39	12.75
100	2.2	10.96	8.92	700	1.1	12.50	12.81
120	1.9	11.57	9.86	800	1.0	12.06	12.44
140	1.7	11.95	11.09	900	1.4	12.22	12.61
160	1.5	12.20	12.39	1000	1.3	12.32	13.15

As seen in Table 1 and Figure 3, the values of the simulated results are quite close to the calculated results. This is proven by the calculation of the average deviation which results 0.39 dBV/m.

To validate the model further, simulations were done in the whole frequency range at the calculated height obtained from Equation (3). The results are listed in Table 2 and visualized in a graph as illustrated in Figure 4.

Again, to compare the theory and simulation the average deviation was calculated. The result is 0.84 dBV/m. This indicates that the theoretical model and the simulation are consistent.

4. CONCLUSIONS

The electric field intensity at a distance from a transmitter is frequency independent. When a ground plane exists the electric field intensity becomes frequency dependent due to the reflection by the ground plane. The ground plane alters the radiation pattern of the transmit antenna. In EMC application, height scanning of the receiver is very important, because the maximum electric field intensity at different frequency is obtained at different receiver height. The electric field propagation model is valid as it has been proven conforms to the result of the simulations.

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