

Erroneous Electric Field Intensity Analysis in the Near-Field Regime due to Dipole and Waveguide as Measuring Probes

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Abstract— Rectangular waveguides were most former type of transmission lines employed to carry microwave signals and about which a great deal is known. In this paper, the electric field intensities of dipole probe and rectangular waveguide probe with infinite ground plane is analyzed and compared to that of no probe instance. A standard 2.296 x 1.016cm WR-90 open ended rectangular waveguide with infinite ground plane of operating frequency of 9GHz is used as a radiator. The dependency of normalized electric field intensity in the near field to the separation between the radiator and probes was observed. The effect of rotation of waveguide probe in the aperture plane (y-axis) was also studied. The simulations were performed using Ansoft's HFSS.

Key words: Near-Field Regime, Erroneous Electric Field Intensity Analysis

I. INTRODUCTION

Rectangular waveguides were most former type of transmission lines employed to carry microwave signals and about which a great deal is known. Today, they are extensively used in millimeter wave communication systems, especially airborne platforms, communication satellites, earth-stations and wireless base stations. The advantages such as high power handling and high Q-factor values revealed by waveguide cavities have qualified them for employment in such applications. However, they are less economic with bulky structures and calibration difficulties. The various conditions for propagation of waves through rectangular waveguides and coaxial cables were presented in [1], the electric and magnetic field within the structures were analyzed and them to be confined in space within the waveguides. Joo-Young Choi and Stepan Lucyszyn found modeling anomalies with the simulation of thin walled metal-pipe rectangular waveguides (MPRWGs) [2]. The attenuation in electrically thin MPRWGs is discussed with the aid of simulations using Ansoft's HFSS. The accurate electromagnetic field measurements using probes is always a challenging task and stimulates much research. Near-field measurements have significant errors due to reactive fields and exhibits large spatial variations. Novel techniques for accurate measurements are given in [3-4], discussing the influence on error induced by frequency, polarization, propagation direction and orientation of the probes. The various standard antennas for radio-frequency electric and magnetic fields were discussed in [5]. The dipoles and loops were qualified as a standard probes for E-field and H-field measurements respectively. A Moment Method estimation of the error induced by a compact measuring probe in the near field with comparison of electric field pattern without probe with co-pole voltage pattern in the scan plane is computed in [6]. The error induced in open ended rectangular waveguide with dipole as a measuring probe is

analyzed and discussed using HFSS simulator in [7] for different probe positions.

II. PROBE CONSTRUCTION

This section describes different probes for electric field measurement in the near field regime. The purpose of using probe is to transition of RF energy from one transmission medium to another. A standard 2.286cm x 1.106cm, WR-90 at 9GHz with aperture in the infinite ground plane excited in TE₁₀ mode was used as a radiator shown in Fig. 1.

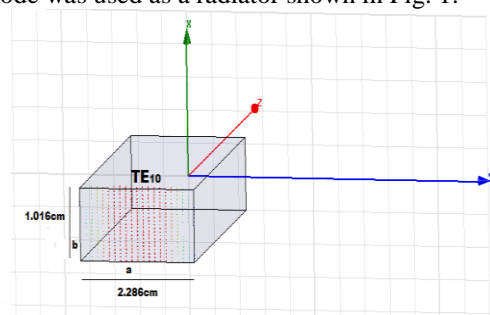


Fig. 1: Open ended rectangular waveguide simulated using HFSS

A. Open Ended Rectangular Waveguide with Dipole Probe

The dipole probe is discussed first. Dipole support sinusoidal current distribution and the useful frequency range of dipole are usually limited by its half wavelength resonant frequency [5].

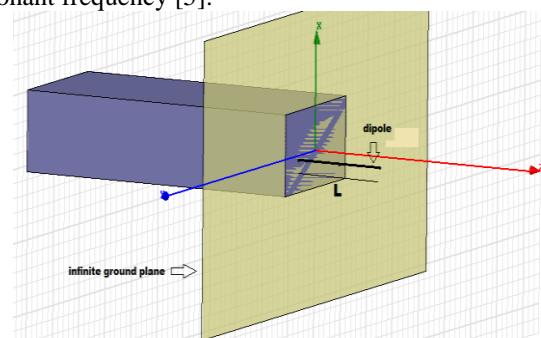


Fig. 2 Open ended rectangular waveguide with dipole probe at $z=0.25\text{cm}$ simulated using HFSS

The dipole of resonant length at 9GHz and radius 0.005λ used to measure near field electric field intensity of open ended rectangular waveguide is shown in Fig. 2. The values are measured by positioning the probe at 0.25cm, 0.5cm, 1cm in z-direction from the radiating aperture.

B. Open Ended Rectangular Waveguide with Waveguide Probe

Near field measurements can be made using rectangular waveguide. The waveguide probe patterns and gain for any frequency and aperture size is computed using mathematical model proposed by Yaghjian's [8].

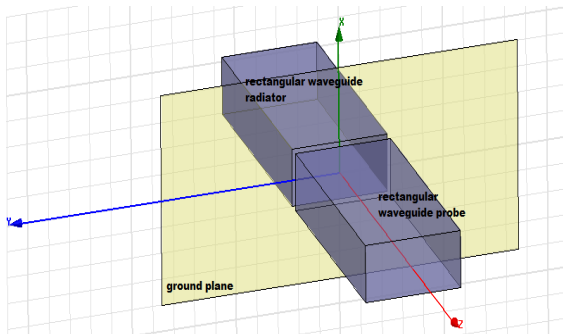


Fig. 3: Open ended rectangular waveguide with waveguide probe at z=0.25cm simulated using HFSS

A WR-90 open ended waveguide probe used to measure near field electric field intensity of open ended rectangular waveguide is shown in Fig. 2. The values are measured by positioning the probe at 0.25cm, 0.5cm, 1cm in z-direction from the radiating aperture.

III. NEAR FIELD ANALYSIS

The actual test range or an anechoic chamber does not accommodate far field distance and extends the necessity to perform near-field measurements. The radiator performance can be completely characterized by near field measurements. The equation describing the spatial dependence of electric field intensity was derived in [7] and mentioned below

$$E_x = \frac{-1}{2\pi} \nabla \times \int \int \epsilon_x e^j(k_x x + k_y y - k_z z) dk_x dk_y \quad (1)$$

$$E_y = \frac{-1}{2\pi} \nabla \times \int \int \epsilon_y e^j(k_x x + k_y y - k_z z) dk_x dk_y \quad (2)$$

$$E_z = \frac{-1}{2\pi} \nabla \times \int \int \epsilon_z e^j(k_x x + k_y y - k_z z) dk_x dk_y \quad (3)$$

Where, $k_x = \frac{m\pi}{a}$ and $k_y = \frac{n\pi}{a}$ are the separation parameters for m,n=1,2,3.....

The near-field to far-field transformation algorithm for planar scanning was proposed in [9]. The algorithm uses the fast Fourier transform (FFT) to derive the spatial frequency spectrum that is then mapped into the angular spectrum.

IV. SIMULATION RESULTS AND DISCUSSION

Near field region is a free space area within the radiator and far field region with inner radius $2D^2/\lambda$ where D is the main dimension of the antenna and λ is the wavelength in free space. For the waveguide probe the aperture size is used as the dimension for D. For the purpose of measurements both the dipole probe (resonant length-1.583cm, radius 0.01666cm at 9GHz) and the rectangular waveguide (standard WR-90) probe is positioned along z-axis. Normalized near-field electric field intensity was measured at 0.25cm, 0.5cm, 0.75cm, 1cm separations between the probes and the radiator. The simulations are carried out using commercially available software package from Ansoft company i.e. HFSS simulator.

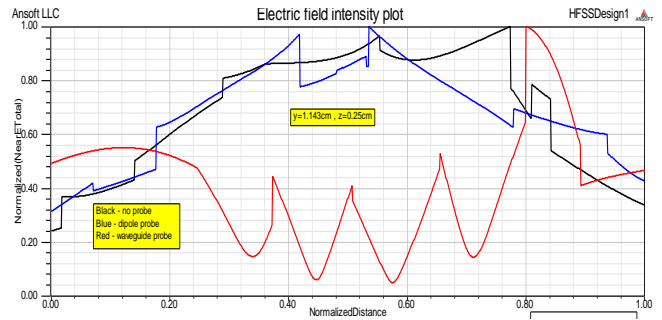


Fig. 4: Normalized Electric Field intensity plot in the near field region at z=0.25cm

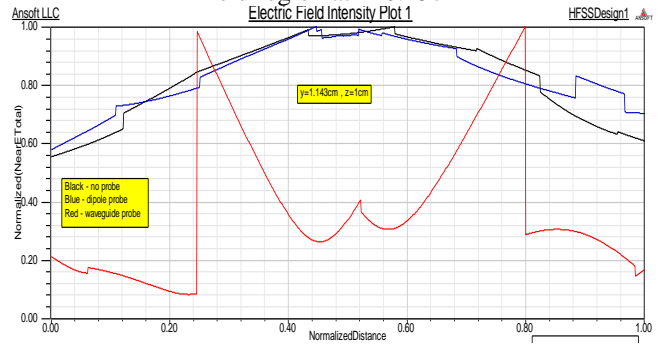


Fig. 5: Normalized Electric Field intensity plot in the near field region at z=1cm

The normalized electric field intensities in the near field region are shown in Fig. 4 and Fig. 5 for dipole and waveguide probes and were compared with no probe condition. The electric field intensity decreases with increased separation between radiator and probes. Also, the dipole probe measures electric field intensity with less error relatively to the waveguide probe. The deviation in values of waveguide probe is significant than dipole probe owing to waveguide aperture expanse leading to non zero error at the center in spite of normalized values taken.

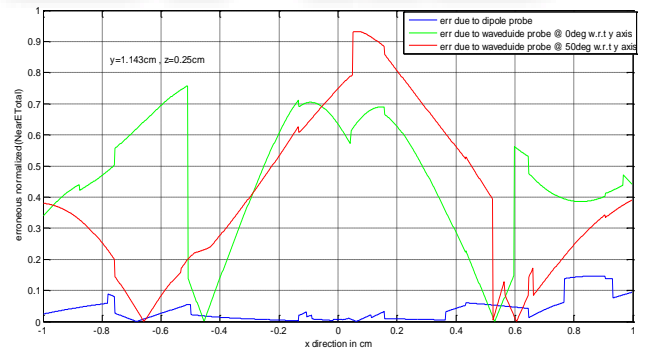


Fig. 6: Erroneous Normalized electric field intensity plot at z=0.25cm

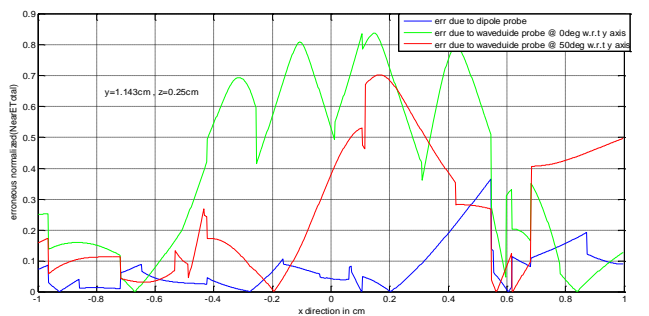


Fig. 7: Erroneous Normalized electric field intensity plot at z=0.25cm

The error in the normalized electric field pattern in the near field region is shown in Fig. 6 and Fig. 7. The difference in values for waveguide probe started diminishing when it was maintained at some angles w.r.t y-axis. Complying, the waveguide probe was kept at 250, 500, 750 w.r.t y-axis (aperture plane) and the resulting error in normalized electric field intensity is shown in Fig. 3 and Fig.4

V. CONCLUSION

Simulations were carried out using Ansoft's HFSS to measure the electric field intensities in the near field regime using dipole and rectangular waveguide probes and the results are compared with no probe condition. The existence of probes in the near field of the WR-90 rectangular radiator induces errors in the measurement because of multiple reflections between the radiator and probes. Spatial dependency of the electric field intensity was observed in the near field region and the values decreased with the increased separation between them. Also, significant deviation in the values of waveguide probe was seen due to aperture expanse which can be reduced slightly by rotation of the probe in the aperture plane. In future, the erroneous electric field intensity can be treated for accuracy in waveguide probe by using suitable techniques.

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