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# ELECTROMAGNETIC FIELD DISTRIBUTION OF A WIRE-RHOMBIC ANTENNA FOR IMMUNITY TESTING OF LARGE TELECOMMUNICATION EQUIPMENT

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## Abstract

Radio-frequency immunity testing equipment which can irradiate large equipment with both vertical and horizontal electric field at low frequencies which uses wire-rhombic antenna is described. The relationship between antenna size and electric field distribution is analyzed using static electric field approximation. An antenna that is 12.0m long, 4.5m wide and 3.5m high is constructed in a semi-anechoic chamber, and the electric field distribution is measured. The results show that the deviation between calculated and measured value is within 1 dB for the vertical electric field and within 3dB for the horizontal field. The field strength of 10V/m is obtained when the antenna is fed with about 8W of power for the vertical field and 250W for the horizontal field.

## 1. INTRODUCTION

Errors can be induced in telecommunication equipment by powerful electromagnetic waves. Therefore it is necessary to test immunity electromagnetic waves. The TEM cell [1][2] and Stripline [1][2] have been developed for this purpose, but these devices cannot easily irradiate large equipment with a horizontal electric field. In this paper, a wire-rhombic antenna for electromagnetic pulse (EMP) immunity testing[3], can be applied to large equipment immunity test to irradiate both vertical and horizontal electromagnetic fields to the equipment under test (EUT) without tilting.

## 2. CONFIGURATION OF WIRE-RHOMBIC ANTENNA

The wire-rhombic antenna is composed of two wires, two poles, and two transformers (Fig.1). The signal from a generator is supplied to the wires via a transformer. The wires are stretched to a rhombic shape. The EUT is placed at the position where the two wires are furthest apart. When the antenna rests on perfectly conducting ground, and these wires can be assumed to be infinitely long and uniformly charged, the electric field distribution is expressed by the static electric field of four electric charges (Fig.2) using the following three functions.

$$E_x=\frac{1}{2\pi\varepsilon_0}\left\{\frac{x-a}{(x-a)^2+(y-b)^2}q_1+\frac{x+a}{(x+a)^2+(y-b)^2}q_2-\frac{x-a}{(x-a)^2+(y+b)^2}q_3-\frac{x+a}{(x+a)^2+(y+b)^2}q_4\right\} \qquad (1)$$

$$E_Y = \frac{1}{2\pi\varepsilon_0}\left\{\frac{y-b}{(x-a)^2+(y-b)^2}q_1 + \frac{y-b}{(x+a)^2+(y-b)^2}q_2 - \frac{y+b}{(x-a)^2+(y+b)^2}q_3 - \frac{y+b}{(x+a)^2+(y+b)^2}q_4\right\} \quad (2)$$

$$E_{total} = \sqrt{E_X^2 + E_Y^2} \quad (3)$$

Here $E_Y$ and $E_X$ are the vertical and horizontal electric fields, and $q_1$- $q_4$ are the electric charges on the wires. Usually these have the following relationships.

$$|q_1| = |q_2| = |q_3| = |q_4| = q \quad (4)$$

When the charges are related as

$$q_1 = q_2 = +q$$
$$q_3 = q_4 = -q \quad (5)$$

it is called "common mode excitation", and the electric field is as shown in Fig.3(a).

When the following relationships hold,

$$q_1 = q_4 = -q$$
$$q_2 = q_3 = +q \quad (6)$$

it is called "differential mode excitation", and the electric field is as shown in Fig.3(b).

Figures 3(a) and (b) show that this antenna can generate both vertical and horizontal electric fields by changing the excitation mode.

## 3. MEASUREMENT OF ELECTRIC FIELD DISTRIBUTION

An antenna 12.0m long, 4.5m wide, and 3.5m high is constructed in a semi-anechoic chamber to confirm the calculations. These dimensions are based on the electric field distribution which has an electric field strength deviation in a 1 m × 1 m × 1.8 m space of within ±3 dB and purity of electric field of more than 90 %. Here purity is defined as,

$$P(\%) = E_{req} / E_{total} \quad (7)$$

Here $E_{req}$ is electric field strength required for each excitation mode, and $E_{total}$ is the total electric field strength.

The set up for measuring electric field strength is shown in Fig.4. The signal from a signal generator is amplified and fed to the antenna. Electric field strength is measured at the center of the wire configuration, and at four points which are 0.5 m foreword, backward, right, and left from the center. These five points are measured at heights of 0.6m, 1.2m, and 1.8m above the conducting ground (Fig.1.) using an electric field probe with an optical fiber link.

Fig.5(a) shows the maximum deviation of the values measured at these points. The uniformity of the electric field is within 3 dB for common mode excitation and 6 dB for differential mode excitation. Figure 5(b) shows the difference between the calculated and measured deviations. The difference is within 1 dB for common mode excitation, and within 3 dB for differential mode excitation.

When the electromagnetic field is applied to EUT, the vertical and horizontal electric fields should be applied separately. The purity of the electric field is measured. The minimum purities for the two excitation modes are shown in Fig.6. The measured and calculated purities coincide up to 15 MHz. This means that the electric field of this antenna could be calculated using static electric field approximation.

## 4. MEASUREMENT OF RADIATION EFFICIENCY

It is desirable that electric field generators for immunity testing produce a high electric field with a low RF power. The input power required to excite an electric field strength of 10V/m as a function of frequency is shown in Fig.7. The maximum power for obtaining a 10 V/m electric field is about 8W for the common mode and 250W for the differential mode.

## 5. CONCLUSION

The wire-rhombic antenna can radiate both vertical and horizontal electric fields by changing the excitation mode. The difference between calculated and measured deviation is within 1 dB for the common mode and 3 dB for the differential mode excitation, and measured electric field purity coincides with the calculated value up to 15 MHz. Generation of a 10V/m electric field requires 8W input power in common mode and 250W in differential mode.

More work is needed to improve the radiation efficiency in differential mode excitation.

## REFERENCE


[1] IEC Publication 801-3 Draft4
[2] SISPR/SCG Draft publication
[3] C. Zuffada and N. Engheta : "Field uniformity criteria for the design of a two-wire EMP simulator", Electromagnetics 8:25-35,1988


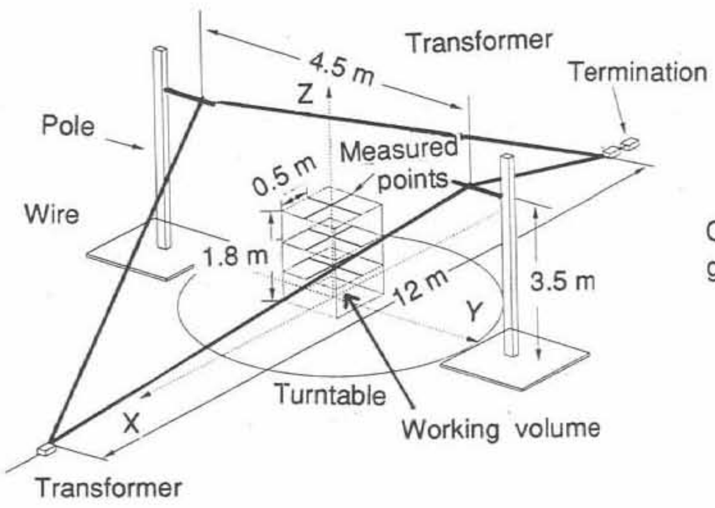


Fig. 1. Configuration of wire-rhombic antenna

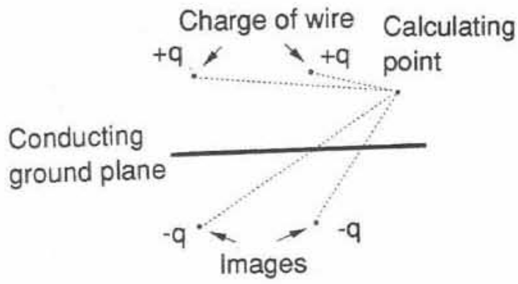


Fig. 2. Electric field analysis model

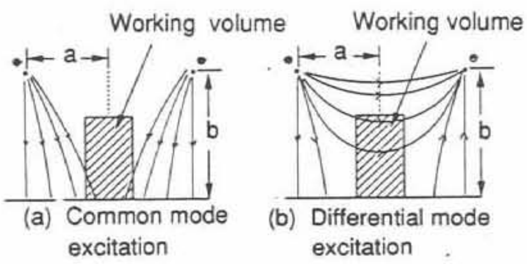


Fig.3. Voltage of wires and electric field

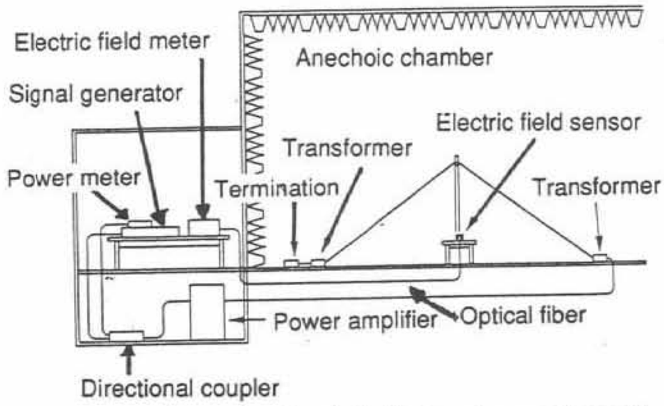


Fig. 4. Set up for electric field strength measurement

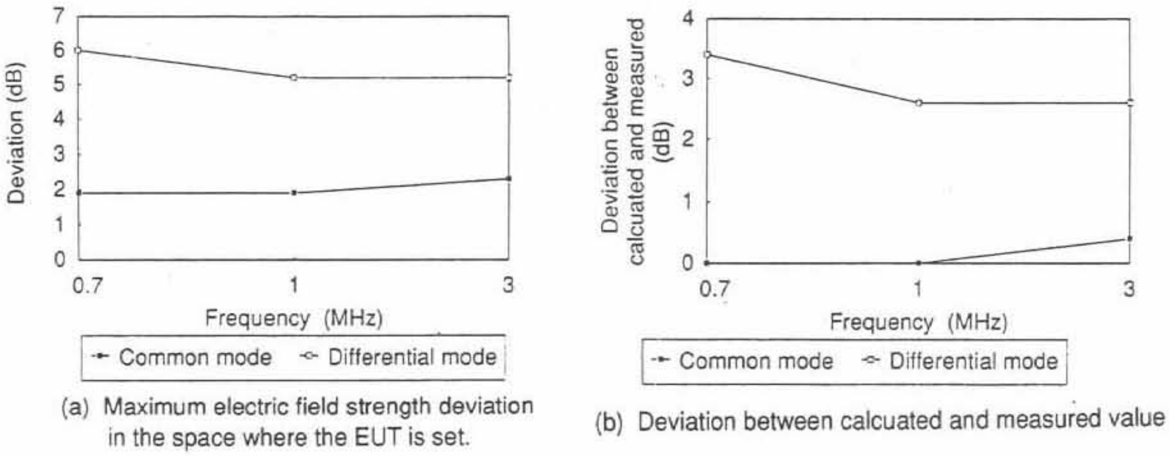


Fig. 5. Electric field strength measurement results

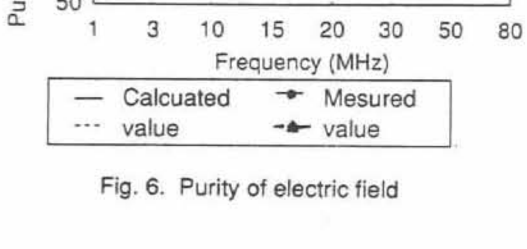


Fig. 6. Purity of electric field

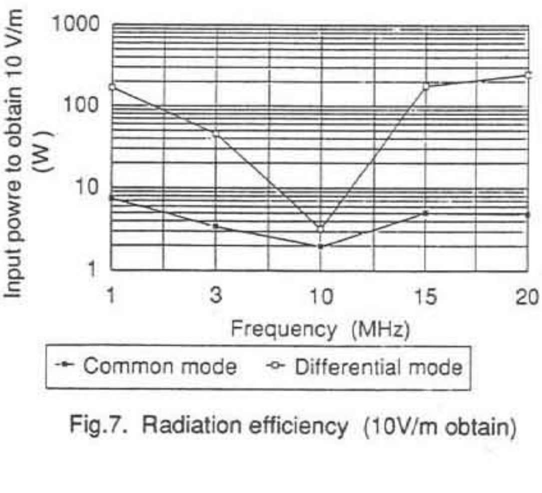


Fig.7. Radiation efficiency (10V/m obtain)