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Probe calibration by using a different type of probe as a reference in GTEM cell above 1 GHz

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Abstract: Calibration of an electric field probe using a different type and size of probe as a reference is carried out in a GTEM cell from 1 to 6 GHz. We compared our results with those of calibration in an anechoic chamber to determine the effectiveness of the calibration. The difference between the calibration factors of the GTEM cell and the anechoic chamber increases when the probe is calibrated in an area in which the electric field distribution is nonuniform. Therefore, it is important to place the probe in an area with good uniformity or maintain the uniformity of the electric field in the GTEM cell when calibrating electric field probes with different dimensions.

Keywords: electric field probe, calibration factor, GTEM cell, electric field distribution, uniformity

Classification: Electromagnetic compatibility (EMC)

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1 Introduction

Generally, electric field probes are calibrated in an anechoic chamber [1, 2]. However, they cannot be calibrated from MHz to GHz at once and by the use of a single standard antenna. Hence, each frequency must be measured separately and several standard antennae are required for the calibration. Whenever an antenna is changed, it is necessary to access the anechoic chamber and align the position of the antenna. Accessing the anechoic chamber and aligning the antenna consume a lot of time and increase the factor of uncertainty. Recently, gigahertz transverse electromagnetic (GTEM) cells have been used as an alternative apparatus to anechoic chambers for calibrating electric field probes owing to the fact that they are less expensive and more convenient to use [3]. When the number of probes or calibrating frequencies is large, the use of a GTEM cell helps save considerable time, effort, and installation space when compared to an anechoic chamber. However, the electric field distribution in GTEM cells is not strictly uniform, as in conventional transverse electromagnetic (TEM) waveguides. At higher frequencies, the characteristic impedance and quasi-static field of GTEM may vary by up to approximately ± 4 dB [3] from the values given by asymmetric TEM cell theory [4, 5]. Therefore, to calibrate electric field probes at high frequencies in the GTEM cell, it is difficult to utilize the standard field method that is based on the asymmetric TEM cell theory. There have been very few studies investigating probe calibration in GTEM cells above 1 GHz and relationship between the calibration factors in an anechoic chamber and a GTEM cell. Our previous works [6] use one of the three elements of a probe as a reference antenna to calibrate a same type of probe in a GTEM cell. The calibration results agreed well with those in the anechoic chamber. However, when the types of probes are different, each type of probe is needed to calibrate one element in the anechoic chamber and used this element to calibrate the same type of probe in the GTEM cell. This process is time consuming. Furthermore, the electric field distributions in the GTEM cell become depleted when the frequencies increase [7]. It may be difficult to calibrate a probe using a different type and size of probe. In this paper, we calibrate a probe using a different type of probe as a reference in the GTEM cell. We then investigate on the relation between the uniformity of electric field in a GTEM cell and calibration factors.

2 Probe calibration using a different type of probe

In this section, we calibrate a probe using a different type of probe in the GTEM cell. Two types of electric field probes (E-probe A and E-probe B; Figs. 1 (a) and (b)) are chosen. We consider E-probe A to be much smaller

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than E-probe B and nonmetallic, except for the elements. Therefore, the electric field is barely affected by this probe in the GTEM cell. We use one of the elements of E-probe A as a reference antenna to calibrate E-probe B in the GTEM cell.

2.1 Calibration method and procedures

Fig. 1 (c) shows a schematic of the calibration system in which the GTEM cell is used to calibrate electric field probes. We control the net power P_{net} (2.5 W) to compare electric fields. The electric field probes are placed at a distance of 370 mm from the bottom wall; the distance between the bottom wall and septum is 740 mm (Fig. 1 (c)). The calibration factor (K_{GTEM}) of the electric field probe is determined using the reference antenna method, in which the difference between the electric field measured by E-probe A with calibration factor K_{AC} and the electric field measured using the electric field probe E-probe B in the GTEM cell is determined. The strength of the standard field ($E_{correct}$) measured using E-probe A in the GTEM cell and corrected by the calibration factor K_{AC} is defined as

$$E_{correct}\,[dBV/m] = 20\log_{10} E_{reference} - K_{AC} \tag{1}$$

where $E_{reference}$ is the electric field strength (in V/m) displayed on the control computer of the reference probe (E-probe A) in the GTEM cell. We use $E_{correct}$ as the standard field to calibrate elements of the electric field probe (E-probe B). Then, the calibration factor K_{GTEM} is defined as

$$K_{GTEM}\,[dB] = 20\log_{10} E_{GTEM} - E_{correct} \tag{2}$$

where E_{GTEM} is the electric field strength (in V/m) displayed on the control computer for elements of the electric field probe (E-probe B) in the GTEM.

2.2 Probe calibration using a different type of probe

We use one of the elements of E-probe A as a reference antenna to calibrate E-probe B in the GTEM cell from 1 to 6 GHz using the reference antenna method. First, we calibrate one of the three elements of E-probe A ($\text{Element}_{\text{refA}}$) in an anechoic chamber using the standard field method. Then, the calibration factors K_{GTEM} of the three elements (Elements 1, 2, and 3) for E-probe B are determined from the difference between the electric field of these three elements and the electric field of $\text{Element}_{\text{refA}}$, which is corrected using the K_{AC} in the GTEM cell. The difference D between the calibration factors of the GTEM cell and the anechoic chamber is defined as

$$D\,[dB] = K_{GTEM} - K_{AC\_B} \tag{3}$$

where K_{AC_B} is the calibration factor of the E-probe B that are calibrated in the anechoic chamber using the standard field method. Fig. 1 (d) shows the difference between the calibration factors of the GTEM cell and the anechoic chamber for the three elements of E-probe B. As a result, no significant differences are observed among the elements. However, we found that the

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difference in calibration factors is higher than 1 dB at certain frequencies. The maximum difference between the calibration factors of the GTEM cell and the anechoic chamber is 1.6 dB at 5 GHz, which may be caused by the nonuniform electric field distribution in the GTEM cell. Therefore, it is necessary to investigate the uniformity of electric field in the GTEM cell and find the relation between the uniformity of electric field and the calibration factor.

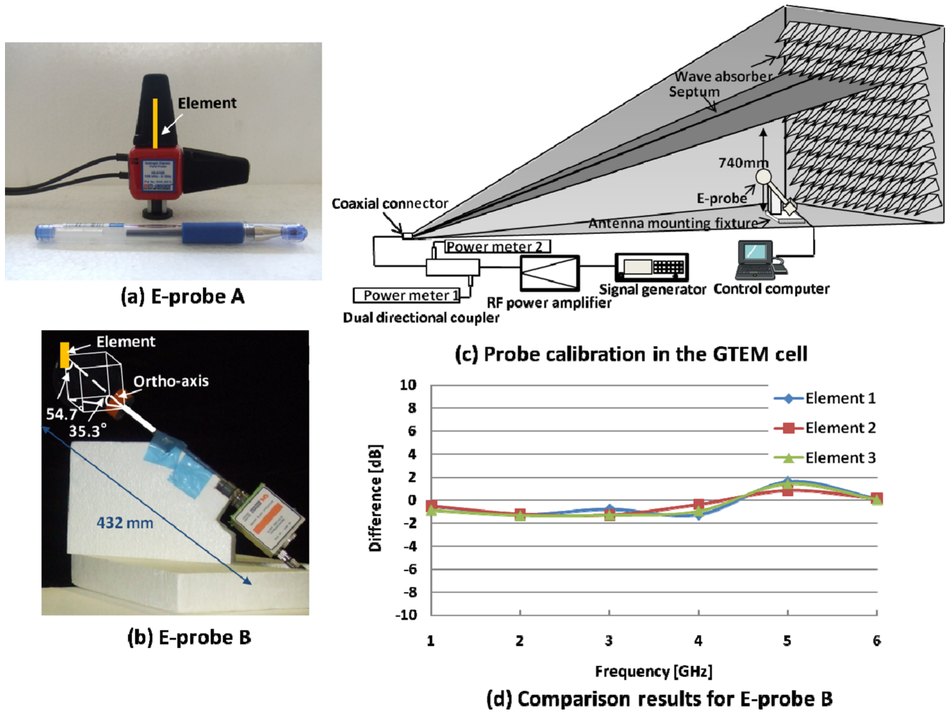

Fig. 1. Probe calibration using a different type of probe.

3 Uniformity of electric field in the GTEM cell

As described in section 2.2, the difference between the calibration factors of the GTEM cell and the anechoic chamber may be caused by the nonuniform electric field distribution in the GTEM cell. In this section, we measure the electric field distribution using E-probe A in the GTEM cell at 1 GHz and 5 GHz; the difference between the GTEM cell and anechoic chamber is relatively small (1 GHz) and big (5 GHz) at these frequencies when compared with the other frequencies, respectively (Fig. 1 (d)). Fig. 2 (a) shows the measurement system and the dotted lines indicate the measurement area of electric field, which is $200 \times 200\,\mathrm{mm}^2$. The center of the measurement area is defined as the origin position ($x = 0$, $y = 0$), which is 370 mm from the bottom wall and is used to calibrate the probe, as mentioned in section 2.1. The electric field strength is measured by $\mathrm{Element}_{\mathrm{refA}}$, which is corrected using the K_{AC} in the GTEM cell. The measurement interval is 20 mm in x and y directions. Figs. 2 (b) and (c) show measured results of the electric field distribution at 1 GHz and 5 GHz, respectively. As a result, we found that

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the electric field distribution at 1 GHz is relatively uniform at all positions, including the origin position. However, we also found that the electric field distribution changes significantly at 5 GHz. The value of the electric field strength measured by a probe corresponds to a spatially averaged value of the field-strength distribution near the probe. When the electric field distribution is not uniform, the field strength measured by two different probes may differ if the two probes have different dimensions or structures. As a result, the difference between the calibration factors of the GTEM cell and the anechoic chamber at 5 GHz will be greater than 1 GHz. Therefore, the probe calibration in the GTEM cell must be performed in an area of uniform electric field distribution when calibrating electric field probes with a different type of probe.

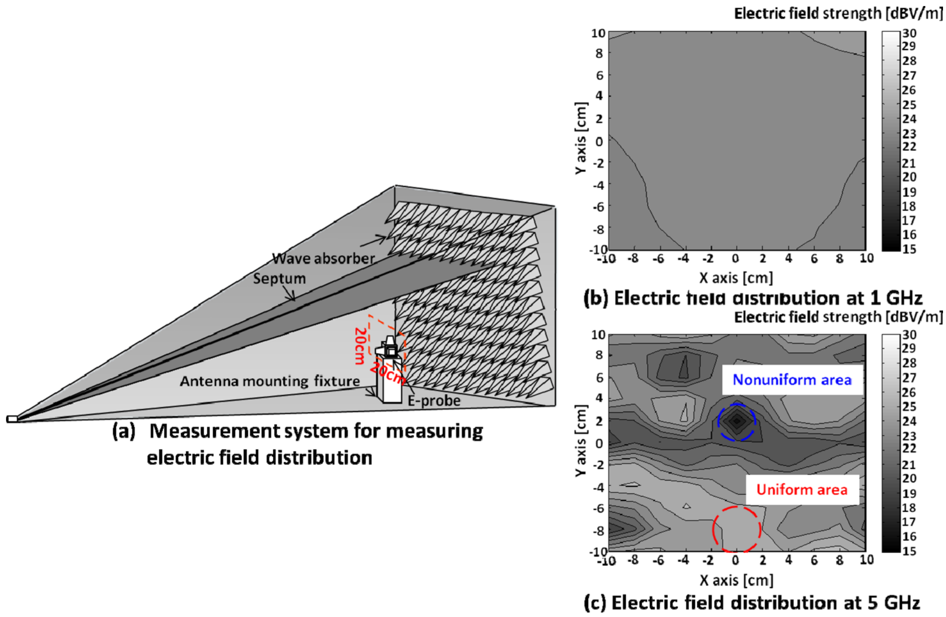

Fig. 2. Electric field distribution measured by $\text{Element}_{\text{refA}}$.

4 Probe calibration at different positions

Nonuniform electric field distribution in the GTEM cell was observed at 5 GHz. When calibrating the probe in the areas in which the electric field distribution is nonuniform, the difference between the calibration factors of the GTEM cell and the anechoic chamber may increase. In this section, we compare the difference between the calibration factors by performing calibration at different positions at 5 GHz. The evaluation method is as described in section 2.1. Fig. 3 shows the calibration position of the electric field probes. The electric field probes are placed at the origin position ($x = 0$, $y = 0$), where the distance between the bottom wall and septum is 740 mm, and the electric field is measured from -9 cm to 9 cm in the y direction (Fig. 3 (a)). The measurement interval is 1 cm in the y direction. Fig. 3 (b) shows the

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results of the difference between calibration factors during calibration at different positions. The maximum difference between the calibration factors of the GTEM cell and the anechoic chamber is observed at 3 cm, where the electric field distribution is relatively nonuniform and the electric field strength is weak, as shown in Fig. 2 (c). We also found that when the probe is calibrated at −9 cm to −6 cm, where the electric field distribution (Fig. 2 (c)) is uniform and the electric field is strong, the difference between the calibration factors of the GTEM cell and the anechoic chamber is less than 0.5 dB. Therefore, when calibrating electric field probes with a different type of probe, it is necessary to calibrate the electric field probes at the position where the electric field distribution is uniform in the GTEM cell.

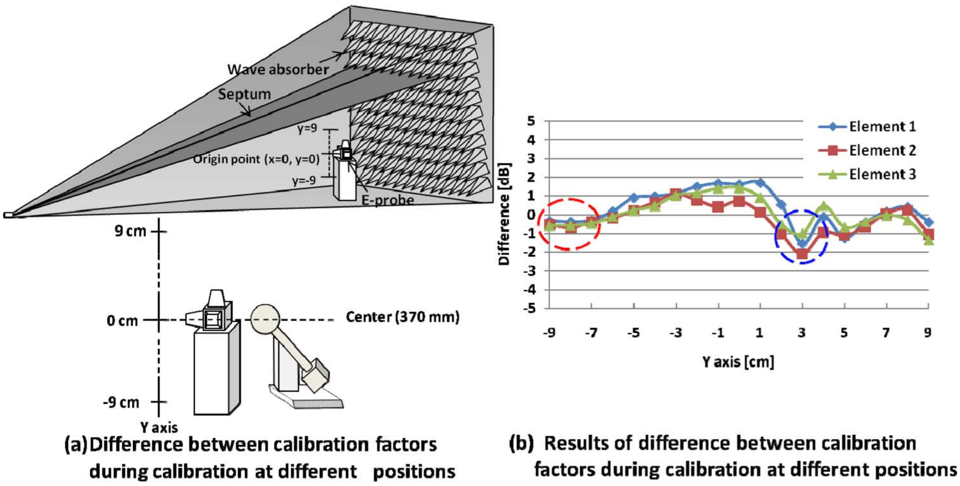

Fig. 3. Probe calibration at different positions.

5 Conclusions

Electric field probes are calibrated using a different type of probe in a GTEM cell in the 1–6 GHz frequency range by the reference antenna method. The electric field distribution in the GTEM cell is not strictly uniform. Therefore, the calibration results for the GTEM cell should be compared with those for the anechoic chamber to enhance the reliability of the calibration. First, we examined the use of one of the elements of the small probe (E-probe A) to calibrate the large probe (E-probe B) in the GTEM cell. As a result, the difference between the calibration factors is greater than 1 dB. This difference is caused by nonuniform electric field distribution in the GTEM cell, which may have been caused by the intrinsic characteristics of our GTEM cell. We also found that the difference between the calibration factors is relatively large when the probe is calibrated in an area of nonuniform electric field distribution. Therefore, it is important to place the probe in an area with good uniformity or maintain the uniformity of the electric field in the GTEM cell when calibrating probes with different sizes.

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