# TEM-MODE E-FIELD UNIFORMITY IN A GTEM CELL

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## 1 Introduction

The GTEM cell was developed by D. Konigstein and D. Hansen in 1987. It is used for immunity testing up to the gigahertz frequency band[1]. Recently, various studies related to this cell have been reported [1] - [3]. In these studies, field distributions were measured extensively for frequencies up to 1GHz and calculated by using the FD-TD method.

However, the evaluation of the E-field characteristics in frequencies more than 1GHz is essential for immunity testing to simulate the field emitted from digital cellular such as PHS (personal handy phone system) and PDC (personal digital cellular).

Immunity testing in TEM waveguides such as GTEM cells have been discussed at IEC SC77B and CISPR/A. Recently, committee drafts (77B/265/CD and 77B/255/CDV) have been prepared by SC77B for the international standard, IEC 61000-4-20, and amendment to IEC 61000-4-3.

In this paper, TEM-mode electric-field (E-field) distributions and uniformity in a GTEM cell are evaluated by using a commercially-available E-field probe in a frequency range up to 3GHz. The fields are also measured by using an optical E-field sensor in a range up to 1GHz. The probe and sensor are calibrated to give precise measurements. In the measurement, the three axes (vertical, longitudinal, and transverse) are measured separately.

## 2 Experimental setup

The E-fields are measured on the transversal cross section of the GTEM cell at the place

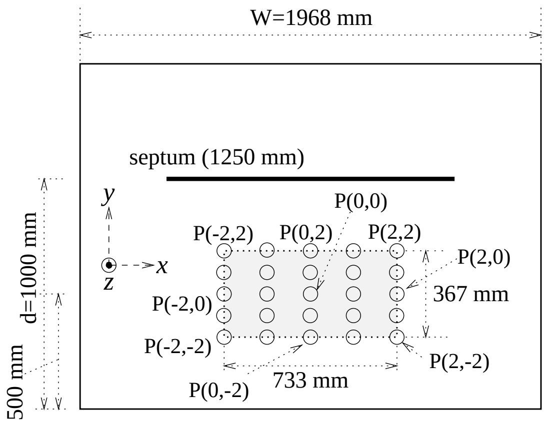


Figure 1: Cross section of a GTEM cell and measuring points

where the distance between the septum and the floor conductor $d$ is 1m. The measurement points on the cross section are shown in Figure 1. There are totally 25 of them. In the Figure, "$\circ$" represents a measuring point. The area inside the dotted-line (half-tone area) is the maximum EUT (equipment under test) size, about one-third of the cell width, $W$, and distance, $d$. The maximum EUT size is defined as the maximum size in which an EUT can be tested. This area is almost the same as that recommended by GTEM-cell manufacturers.

The three E-field components, (*i.e.* vertical ($E_y$), longitudinal ($E_z$), and transverse ($E_x$)) are measured by using an E-field probe and an optical E-field sensor. The vertical component is the primary E-field. The longitudinal and transverse components are the secondary ones. The experimental setups for the measurement are shown in Figure 2 (E-field probe) and in Figure 3 (optical E-field sensor). Since the optical sensor is more sensitive than the E-field

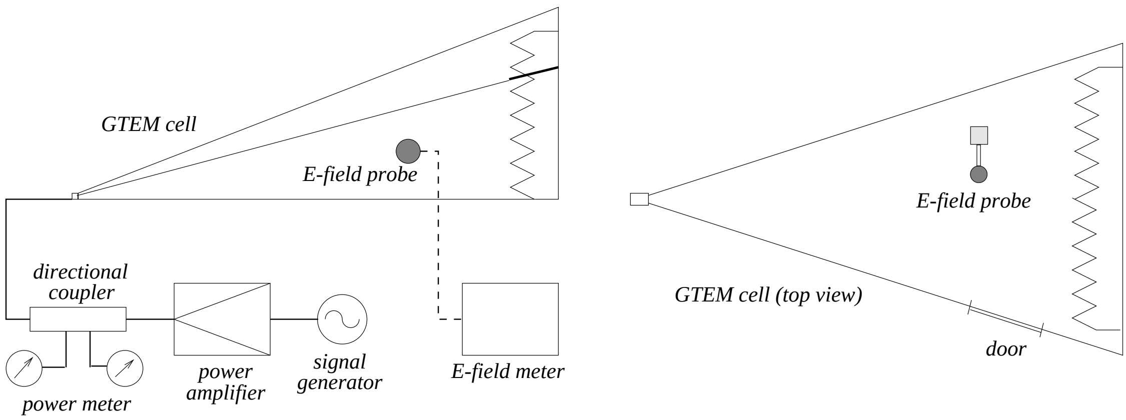


Figure 2: Experimental setup (E-field probe).

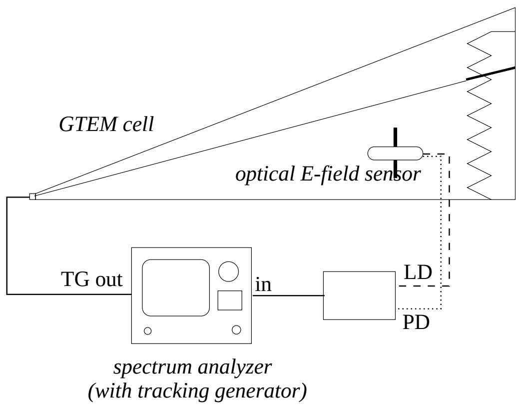


Figure 3: Experimental setup (optical E-field sensor).

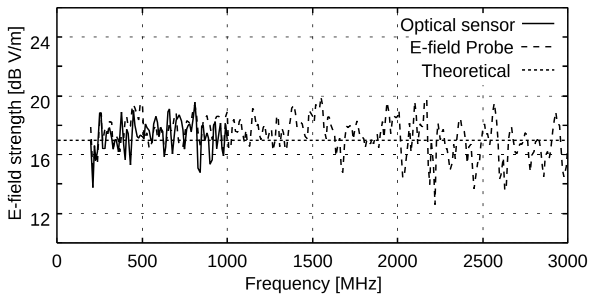


Figure 4: E-field variation at P(0,0) when input power was constant.

probe, it is not necessary to use a power amplifier. The E-field probe is an isotropic E-field probe (AR FP2083) that can measure three individual axis components simultaneously. The optical E-field sensor has a dipole element and a Mach-Zehnder interferometer. The length of the element is 160 mm.

The E-fields are measured at discrete frequencies of 10 MHz between 30 MHz and 3 GHz by using the probe and between 10 MHz and 1 GHz by using the sensor.

Both the probe and sensor are calibrated by using the reference antenna method in an anechoic chamber.

We used a 1100-type GTEM cell, manufactured by Elena electric Co. Ltd., in the experiment.

## 3 Measurement of E-field distribution

### 3.1 Frequency characteristics of E-field

The E-field variations at the center point, P(0,0), were measured while the input power $P_i$ to the GTEM cell was constant (1[W]). The results are shown in Figure 4.

The theoretical value of E-field at the center point is roughly

$$E_{th} = \frac{\sqrt{P_i Z_0}}{d} \,, \tag{1}$$

where $Z_0$ is the characteristic impedance of the TEM cell (50Ω). In this case, $E_{th}$ is about +17 dBV/m. The dotted line in the figure shows this value.

The probe measurements agree with optical-sensor measurements at frequency ranges between 200 and 400 MHz], 550 and 650 MHz, and at frequencies greater than 750 MHz. The variation (flatness) of both of measured results is about ± 3 dB compared with the theoretical value in less than 2 GHz. However, the variation range exceeds ±3 dB and the E-field strength decreases as the frequency increases in more than 2 GHz.

### 3.2 E-field distribution on the cross section

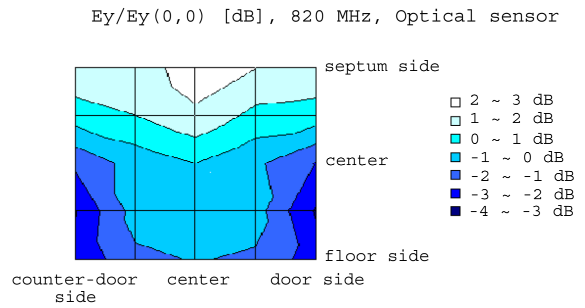


Figure 5: Distribution of primary E-field ($E_y$) strength.

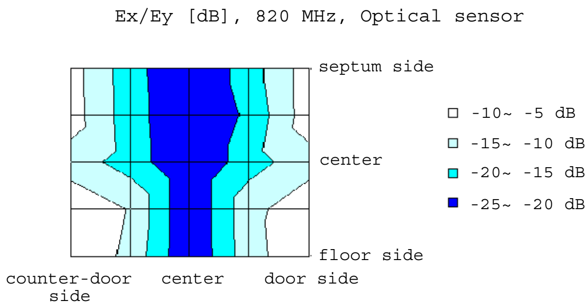


Figure 6: Distribution of transversal E-field ratio ($E_x/E_y$).

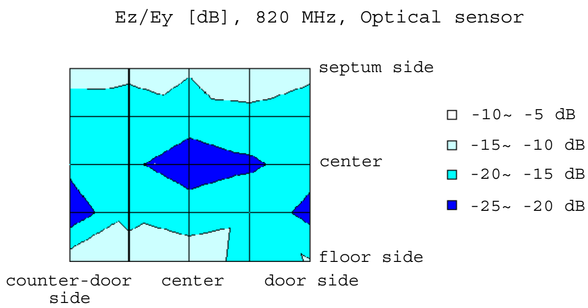


Figure 7: Distribution of longitudinal E-field ratio ($E_z/E_y$).

Figure 5 shows a contour map of the primary component ($E_y$) measured by the optical sensor at 820 MHz. Intersections of grid correspond to the measuring points of Figure 1. These values are normalized by the E-field strength at the center point. In Figure 5, the E-field near the septum is stronger than that near the floor conductor. The fields are especially weak at both sides of the bottom. Figures 6 and 7 show contour maps of the strength ratio of the secondary components, ($E_x$ and $E_z$) to $E_y$. The distribution of the strength ratios are almost symmetrical. This is reasonable considering the structure of GTEM cell.

Figure 6 shows that the ratio becomes larger as the calibration point is positioned nearer the side-wall conductors. This is because the electric lines of force tend toward the side-wall conductors, since the perpendicular component exists only on a conductor. The ratio of $E_x$ to $E_y$ is about $-6$ dB near the both sides of the maximum EUT size.

The ratio of the longitudinal component is smallest at the center point in Figure 7. By contrast it is large at the points near the septum. This is due to the geometrical structure of a GTEM cell. Since the septum is at an incline of 15 degrees to the horizontal, transversal cross section to the wave propagation in a GTEM cell do not agree with the cross section including the measurement points.

By comparing Figure 6 with 7, we see that the longitudinal component is larger than the transversal one near the vertical center line. However, the transversal component is larger than the longitudinal one at both side of the wall (door and counter-door).

### 3.3 Uniformity of the primary E-field

The maximum deviation of the primary E-field component for all points is shown in Figure 8. The solid and dashed lines denote the results from the E-field probe and the optical E-field sensor. The measured deviation from the optical sensor is larger than that from the probe in a frequency range of 1 GHz. However, the peaks occur at similar frequencies in both.

The committee draft outlines the following requirements for the calibration of E-field uniformity. The magnitude of the primary (intended) E-field component ($E_y$) over the cal-

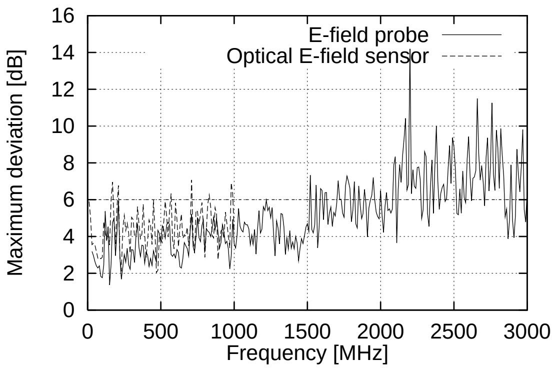


Figure 8: Uniformity of primary E-field component (all 25 points).

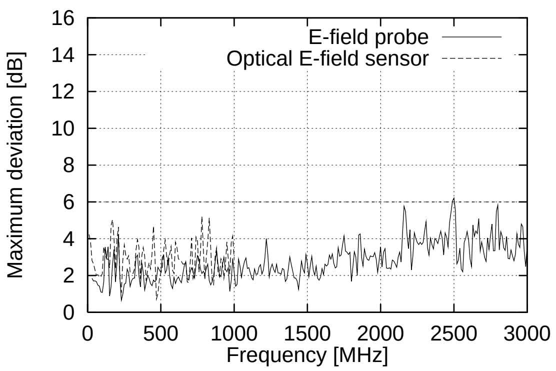


Figure 9: Uniformity of primary E-field component (19 of 25 points).

ibration area should be within −0 dB to +6 dB and the magnitudes of the secondary (unintended) E-field components ($E_x$ and $E_z$) should be at least 6 dB less than the primary component for 75% of all measurement points in the testing area.

The maximum deviation of the primary E-field component ($E_y$) for 19 points (more than 75% of the total) is shown in Figure 9. The committee requirements are satisfied for all the frequencies measured. However, the maximum deviation exceeds +10 dB at some frequencies near 2.2 GHz and 2.7 GHz when we consider all 25 points. The points outside the limits prescribed are mainly located near both sides of the lower points (P(2,-2) and P(-2,-2) in Figure 1).

## 4 Conclusion

E-field distributions and uniformity in a GTEM cell were measured in a frequency range up to 3 GHz. In the measurement, All three axis components in the cell were measured separately to evaluate the TEM field uniformity.

As the results:

- The variation in both of the measured results are about ±3 dB for the theoretical value roughly estimated up to 1GHz. However, the variation exceeds ±3 dB and the E-field strength decreases as the frequency increases in more than 2 GHz.
- The primary E-field near the septum is stronger than that near the floor conductor. The fields are especially weak on both sides of the bottom.
- The transversal component is larger than the longitudinal one on both sides of the wall.
- The committee-draft requirement regarding the deviation of the primary E-field is satisfied in all frequencies measured. However, the maximum deviation exceeds +10 dB at some frequencies beyond 2 GHz when we consider all 25 points.

Therefore, Attention should be paid to use the GTEM cell in more than 2GHz.

In future work, we will calculate the E-field distribution in the GTEM cell to confirm these results.

## References


[1] W. Liang, "Preliminary measurement on GTEM cell field distribution", Technical Report of NPL, No.OMS001, April 1997.

[2] D. Hansen and D. Ristau, "Sources of problems in the GTEM field structure and recommended solutions", IEEE Int. Symp. on EMC, 1996.

[3] W. A. Radasky and K. S. Smith, "Calculations and measurements of fast EM pulses in the GTEM cell", IEEE Int. Symp. on EMC, 1996.

[4] IEC 77B/265/CD

[5] IEC 77B/255/CDV