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*Original Article*

# GTEM Cell-Based Immunity and Emission Test for Multi-Frequency Applications

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***Abstract*** - *In the modern communication world, all are connected with other members of the world through communication devices. The Gigahertz Transverse Electromagnetic (GTEM) cell is a versatile equipment for the measurement of conducting Electromagnetic Compatibility (EMC) with both emission and immunity testing in a free field environment. This paper mostly presents an analysis of GTEM-based testing for multi-frequency applications. The achieved results emphasized the GTEM cell performance to simulate electromagnetic conditions for various electronic devices. All these Electromagnetic emission devices are tested for compatibility prior to trade on the market. In this paper, the immunity and emission tests of different helical antennas and a wideband antenna at various frequencies are tested using a fabricated optimized GTEM cell. The fabricated optimized GTEM cell is validated for multi-frequency immunity, emission test using several helical microstrip and octagonal antennas. The developed antennas at various frequencies, 490 MHz, 800 MHz, and 2.4 GHz, are tested to validate the optimized GTEM cell.*

***Keywords*** - *Antennas, Septum, Immunity Test, Electromagnetic Compatibility, GTEM.*

## 1. Introduction

The recent economic growth relies mostly on emerging technologies like wireless communications, information technologies and military industries using Artificial Intelligence and Machine learning. All these technologies create Electromagnetic Interference measurement issues. EMC must test all RF communication devices to control the flood of EM radiation [1]. One way to reduce EMC is by proper EMI shielding. An asymmetric GTEM with an enclosed structure is more suitable for controlling radiated emissions and improving immunity or reducing susceptibility to external EMI. Nowadays, most electronic equipment uses RF devices.

Testing of all RF devices, a GTEM cell is designed and fabricated for immunity and emissions measurement. The GTEM is a more useful device for high-accuracy and versatile measurement. The upper frequency for TEM cells is limited by the resonance of propagating higher-order modes. The higher-order modes generated in GTEM are prevented with the use of a single taper and an absorber lined at the termination end. GTEM characterization depends on various parameters like: the size of Equipment Under Test (EUT), operating frequency, input power, septum height in cell, septum angle, septum material, thickness of cell material, termination wall material, etc. The proposed geometry of GTEM is shown in Figure 1.

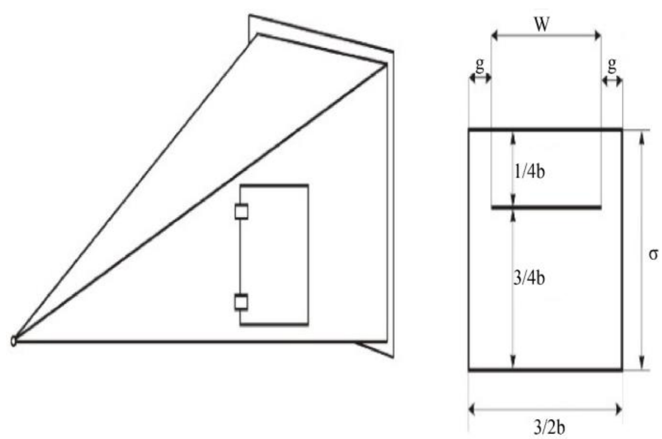



**Fig. 1 Basic GTEM geometry [2]**

The geometrical parameters of the GTEM cell can be determined from the GTEM cell characteristics [2]. The standard characteristic impedance ($Z_0$) of the GTEM cell equals 50 Ω and depends on the geometrical parameters of the structure, as shown in Figure 1. The septum is located at “3/4” of the cell height. The height/width ratio (b/a) of the inner GTEM cell is “2/3”. The intrinsic impedance ($\eta_0$) equals 377 Ω due to the free space inside the GTEM cell. The dielectric material must support the septum.

## 2. GTEM Model Analysis

GTEM characterization was analyzed as per the listed model:

1. Numerical model
2. Analytical model

GTEM works on a principle to convert a planar transmission line operating in the TEM mode to a free-space planar wave. A GTEM cell is a section of an asymmetric rectangular transmission line terminated with a hybrid termination at the other end. The other end, connected with the septum, is energized from an RF generator connected at the input and terminated with 50Ω resistor and an RF foam absorber at the output. The RF operation in a coaxial transmission line, in turn, contributes to the Electromagnetic field for the generation of higher-order modes [3].

### *2.1. GTEM Numerical Model*

The GTEM cell is designed to measure EMI/EMC tests for the EUT placed inside the GTEM. [3] Give the transmission line characteristic impedance of the GTEM.

$$Z_0 = \frac{\eta_0}{4\left[\frac{W}{b}+\frac{2}{\pi}ln\left(1+coth\frac{\pi a}{2b}\right)\right]} \tag{1}$$

Where $Z_0$ is the GTEM cell characteristic impedance, *a* is the width of the outer conductor, *b* is the height of the outer conductor, *W* is the septum width, and $\eta_0$ is the intrinsic impedance dependent on the dielectric permittivity and magnetic permeability of the material with the spacing between the inner and outer conductor.

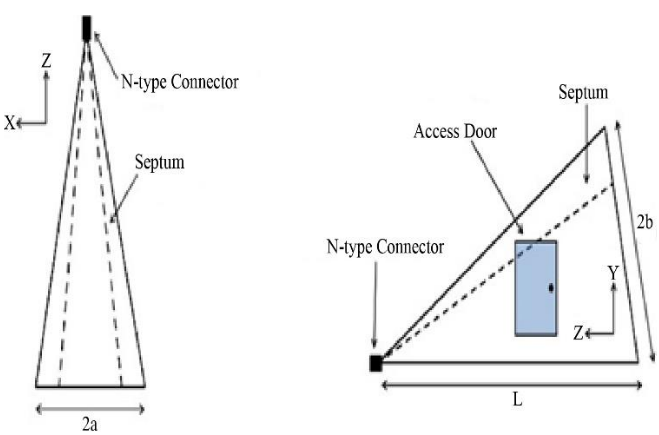



**Fig. 2 GTEM Structure parameters**

In the approximation method to find the $Z_0$, the capacitance of a rectangular coaxial transmission line with an infinitely thin and vertical offset septum is considered [4].

The septum angle is adjusted in such a way that GTEM provides a higher usable test volume and maintains constant characteristic impedance.

A parallel resistive board array of 50Ω match termination is connected at the output port via the septum. RF Foam absorbers are used to suppress unwanted reflections and ensure a uniform field inside the GTEM. The designed GTEM is analyzed in ANSYS HFSS 13.0 software operating at 1 1GHz to 5 GHz frequency, as shown in Figure 3.

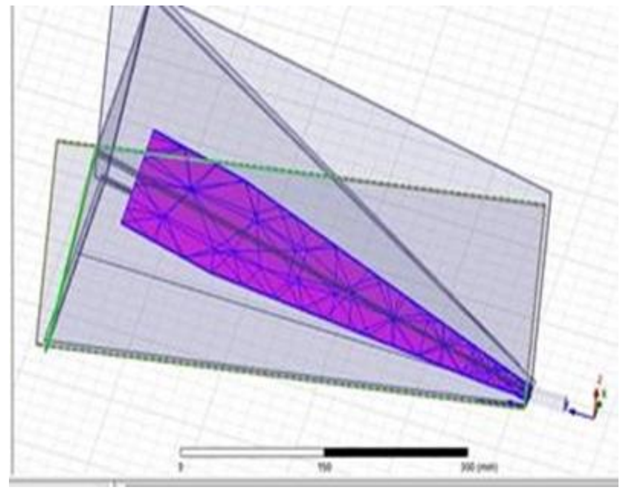


**Fig. 3 GTEM Simulation using ANSYS HFSS**

To avoid unwanted reflections from EUT, the GTEM cell must be terminated with a septum load of 50 Ω. At the septum termination, a flanged resistance is used for high-frequency operation. The septum is connected with the GTEM cell wall via parallel resistances and a ferrite wall.

To avoid unwanted reflections and the resistance effect, the concentrated elements are connected much closer to each other. They are separated with a minimum wavelength at maximum frequency smaller than λ/10 to avoid unwanted reflections [5].

### *2.2. GTEM Analytical Model*

Various electrical or electronic equipment operate at various frequencies of functional signals. So, the immunity of Integrated Circuits (ICs) is of major interest to researchers who test with GTEM [5].

For high-frequency immunity analysis, a GTEM cell is simulated for various parameters [6].

## 3. GTEM Design Specification

A tapered shape GTEM is designed to propagate the generated RF voltage inside the GTEM in a spherical manner with the matched field load termination. The GTEM is also an equivalent antenna transmission line model [6].

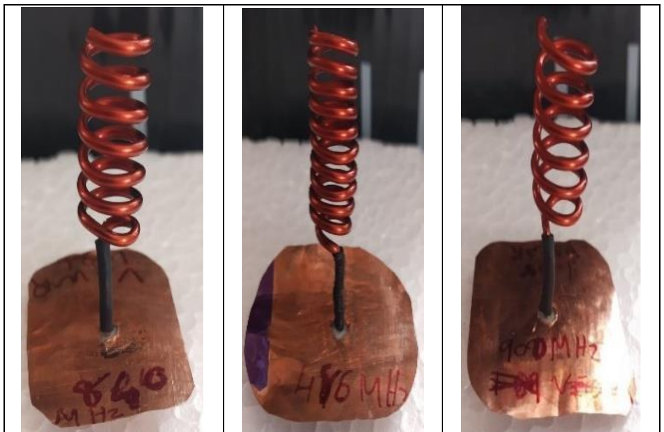
Table 1 shows GTEM cell dimensions. In the uniformity field area, the EUT is tested for radiated immunity (susceptibility). From the reciprocity theory, the radiated emissions test was also conducted in the GTEM.

**Table 1. GTEM cell dimensions**

| Parameters | Dimension |
|---|---|
| GTEM Length*width*height of | 510*260*180mm |
| Top flaring angle | 20 Deg |
| Septum length | 450 mm |
| Septum height | 100 mm |
| Septum angle | 10.3deg |
| GTEM material | Aluminum |

### *3.1. Antennas for Emission and Immunity Test*

A helical antenna was developed using copper wire at 900 MHz with a ground plane, as shown in Figure 4. Helical was developed and tested by connecting the SMA connector to a calibrated VNA. The following VSWR results were obtained, as shown in Figure 5. The helical antenna VSWR of 1.08 at 900 MHz is measured using a pocket VNA.



**(a) 840 MHZ** | **(b) 486 MHz** | **(c) 900MHz**

**Fig. 4(a) Helical antenna at 840 MHz, (b) Helical antenna at 486 MHz, and (c) Helical antenna at 900 MHz.**

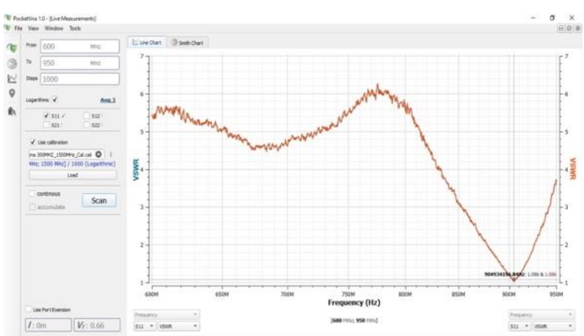


**Fig. 5 VSWR of helical antenna at 900 MHz**

An octagonal ring antenna was also developed for the Emission and Immunity test, as shown in Figure 6. An Octagonal ring antenna has also been developed using a copper polygonal-shaped microstrip patch antenna with FR4 substrate material with an operating frequency range of 3.1 to 10.6 GHz. The developed antenna is tested by connecting the SMA connector to a calibrated VNA, and the following VSWR results are obtained, as shown in Figure 7.

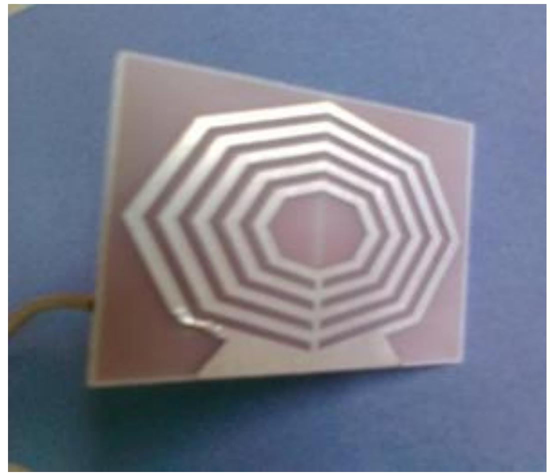


**Fig. 6 Octagonal ring antenna**

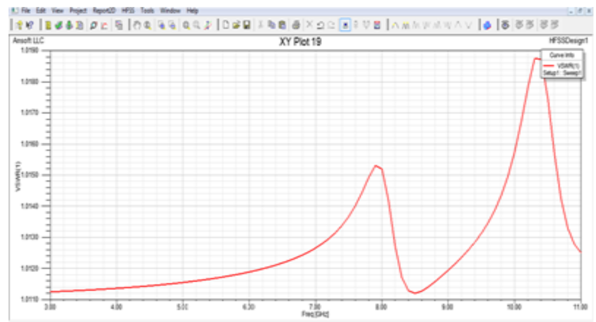


**Fig. 7 Octagonal ring antenna simulation results**

Various wideband frequency ranges, such as 490 MHz, 800 MHz, and 925 MHz, were also tested by connecting a signal source at the input, and the received VSWR results are mentioned in Table 2.

**Table 2. Antenna frequencies and S11 (return loss)**

| Sr. No | Frequency | VSWR |
|---|---|---|
| 1 | 490 MHz | 1.742 |
| 2 | 800 MHz | 1.31 |
| 3 | 925 MHz | 1.459 |
| 4 | 5 GHz | 1.0115 |

All the fabricated antennas get tested for immunity and emission, as shown in Figure 8.

**Fig. 8 Tx inside and Rx outside setup at 5 GHz**

**Fig. 9 Rx inside and Tx outside setup at 5GHz**

**Table 3. Uniformity test- Rx inside and Tx outside GTEM**

| Observation Point | dBm |
|---|---|
| Point#1 | -22.8 dBm |
| Point#2 | -23.0 dBm |
| Point#3 | -22.6 dBm |
| Point#4 | -22.4 dBm |

**Table 4. Emission and Immunity test output at multiple frequencies**

| No. | Frequency | Emission reading (dBm) | Immunity reading (dBm) | Difference reading (dBm) |
|---|---|---|---|---|
| 1 | 490 MHz | -23.1 | -22.7 | 0.4 |
| 2 | 800 MHz | -22.1 | -21.6 | 0.5 |
| 3 | 925 MHz | -19.6 | -19.8 | 0.2 |
| 4 | 5 GHz | -22.8 | -22.7 | 0.1 |

For the emission test, the fabricated octagonal antenna gets validated by placing the antenna inside the GTEM and connecting it with the receiver at the other port. Various helical antennas were validated for multiple frequencies with the arrangement of one end of the 490 MHz helical antenna connected with a signal generator at the transmitter side, and the other end N-type connected with the same frequency termination at the receiver side for emission test. For the immunity test, the signal generator of 490 MHz is connected to the N N-type input connector, and the antenna is placed inside the GTEM to receive the same frequency. The voltage (dBm) readings are measured for emission and immunity.

For multiple frequencies, tuned helical antennas were kept inside the GTEM and are fed with a signal source of various frequencies, like: 490 MHz, 800MHz, 925 MHz, at the receiver end. Voltage (dBm) was measured for the immunity test as shown in Table 4. The above table shows that for 490 MHz, 800MHz, 925 MHz and 5GHz frequencies, there is a very minor change in voltage, 0.4, 0.5, 0.2, and 0.1 dBm, respectively.

## 4. Conclusion

Various cost-effective helical and octagonal antennas are designed for 490 MHz, 800MHz, 925MHz and 5GHz frequencies. GTEM is tested for characterization at 1.0 GHz, 2.1 GHz, 2.34 GHz, 2.95 GHz, 490 MHz, 800MHz, 925 MHz, and 5GHz. The new promising GTEM fabricated design is developed for emission and immunity test with a 50mm*50mm RF device.

This design is more useful for research students in research and small-scale industries, to enhance proper knowledge in the field of EMI/EMC testing. Thus, a 0.5m GTEM was found to be a 20% usable area for the EMC test. These modern communication antennas are tested for immunity and emission for many multi-frequency applications.

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## References

[1] John D. Kraus, *Antennas and Wave Propagation*, 4th ed., Tata McGraw Hill Education, New Delhi, 2010. [Google Scholar]

[2] A.N Jaafar et al., "Analysis of Helical Antenna for Wireless Application at 2.4 GHz," *2019 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE)*, Melacca, Malaysia, pp. 1-5, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[3] Xueli Liu et al., "An Origami Reconfigurable Axial-Mode Bifilar Helical Antenna," *IEEE Transactions on Antennas and Propagation*, vol. 63, no. 12, pp. 5897-5903, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[4] K. Jimisha, and Santhosh Kumar, "Optimum Design of Exponentially Varying Helical Antenna with Non-Uniform Pitch Profile," *Procedia Technology*, vol. 6, pp. 792-798, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[5] Jiawen Nie et al., "The Effect of 2.45 GHz Electromagnetic Interference on a Microcontroller IC," *2017 Progress in Electromagnetics Research Symposium-Fall (PIERS-FALL)*, Singapore, pp. 2689-2694, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[6] M.Y. Zeain et al., "Design of Helical Antenna for next Generation Wireless Communication," *Electrotechnical Review*, vol. 96, no. 11, pp. 96-99, 2020. [CrossRef] [Google Scholar] [Publisher Link]