GTEM Cell: Alternative method for EMC testing of auto-electronic elements

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***Abstract* — This paper presents a validation of Electromagnetic Compatibility (EMC) tests performed in Gigahertz Transverse Electromagnetic (GTEM) cells as an alternative method to tests performed at Open Area Test Sites (OATS) or expensive anechoic chambers. These tests have been carried out with two different Equipment Under Test (EUT) provided by BOSCH Hungary.**

***Keywords*— EMC, GTEM cell, BOSCH**

I. INTRODUCTION

Rapid development of the technology and implementation of electrical and electronic parts in devices used on daily basic lead to evolution of numerous standards and legislations with aim to protect users and devices themselves from electromagnetic radiation. Market demands urge companies to create devices with wireless communication and charging which can result in interferences. High-speed digital and analogue circuits create direct radiation from their printed circuits boards (PCBs) becoming a major concern for electromagnetic compatibility engineers. Electronic systems of the future require higher bandwidth with lower power consumption to handle massive amount of data, especially for large memory systems, high-definition displays and high-performance microprocessors. A detailed review of the EMC analysis of PCBs is given in [1] by Er-Ping Li et al.

Electromagnetic Compatibility (EMC) is a concept of ensuring proper operation of different electric and electronic devices without mutual interference. EMC standards refer in many times to tests performed at OATS and in anechoic chambers. However, using a standard anechoic chamber for EMC tests can burden the manufacturer of the EUT with high costs and if a GTEM cell is available then it could offer an alternative method for these tests. Because they are less expensive, GTEM cells are convenient alternatives. GTEM cells are as accurate as anechoic chambers and can be used if the EUT is enough small to fit into the cell.

The work presented in this paper has been done on the basis of the relevant standard IEC 61000-4-20 issued by the International Electrotechnical Commission in 2010 [2].

This paper is organised as follows: Section II presents the related work. Section III describes the work and test results achieved with the GTEM cell. Finally, Section IV lists future works planned and concludes the paper.

Figure 1. The GTEM cell used with a spectrum analyzer connected

II. RELATED WORK

In the field of EMC numerous papers are presented, papers most relative to our work are shortly described in this section [3]. In [4] authors test RFID tag using GTEM cell and anechoic chamber and make a result analysis which shows correlation between results but future works have to be done for the use of GTEM cells as standardized EMC test equipment. A probe calibration of a GTEM cell is done in [5]. Different types of probe were tested in a frequency range of 1 to 6 GHz. Because of the distribution of the electric field in a GTEM cell the nomuniform calibration results have to be compared with the results of a reference method achieved in an anechoic chamber. GTEM cell is tested as alternative method for radiated immunity test in [6]. Work in [7] proposes an error compensation method for improving accuracy of the GTEM cell applied for radiated EMI measurements.

Although most of the work in the field of EMC using GTEM cells report on testing and improving GTEM cell accuracy, some works like [8] proposes a method for how to develop, simulate and construct cost-effective GTEM cells.

III. GTEM CELL MEASURMENT

A. The GTEM cell

A GTEM cell is a quadratic conical waveguide with angle of 20° in vertical direction and an angle of 30° in horizontal direction. Wave impedance of this line is 50 Ω.

Because of its construction there are no reflection inside, additionally ensured by the absorbing wall opposite to the peak of the cell. The conducting part of the waveguide is called septum with a resistance network at its end. The septum is a conductive metal plate, the width of which is 0.636 times of the width of the outer conductor. One end of the septum is a standard coaxial connector and its other end is connected to the back wall of the cell through a resistance network. Thanks to its quadratic conical construction only planar electromagnetic waves can be considered in its inside with a good approximation. Applying a GTEM cell both the electromagnetic emission and electromagnetic immunity (or susceptibility) can be tested but in case of immunity tests external generators are necessary to provide radio frequency interference (RFI) signals as disturbances. Scope of this paper is to give a validation of EMC emission tests performed in a GTEM cell as an alternative method to tests performed at OATS or anechoic chambers.

Structure of the GTEM cell is shown in Fig. 2 with the allowed location area for the Equipment Under Test (EUT). Supposing planar waves with intensity E of a homogeneous electric field and characteristic impedance Z_C of the TEM wave guide the power P at the height of h_{EUT} in the cell is

$$P = \frac{(E \cdot h_{EUT})^2}{Z_C} \tag{1}$$

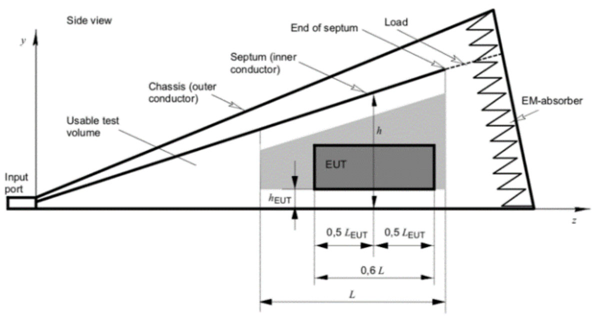

Figure 2 Structure of a GTEM cell

For achieving results appropriate to be compared with those obtained with the OATS method a test in a GTEM cell include three tests performed with three different positions of the EUT as shown in Fig. 3.

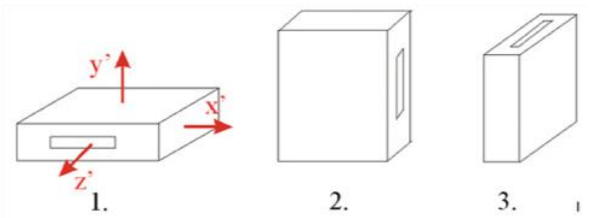

Figure 3. Applied EUT positions x, y, z of tested EUT

The referred standard distinguishes between so called ‘Small EUTs’ (the largest dimension of the EUT is shorter than the shortest wavelength of the measurement signal) and ‘Large EUTs’ (the largest dimension of the EUT is longer than the shortest wavelength of the measurement signal OR the EUT has external wire-connection).

In case of emission tests, the power emitted by the EUT is calculated from the test results obtained with three EUT positions as [9]

$$P = \frac{\eta_0}{3\pi} \cdot \frac{k_0^2}{e^2 Z_c} \cdot S^2 \tag{2}$$

where

$$S = \sqrt{V_X^2 + V_Y^2 + V_Z^2} \tag{3}$$

$$k_0 = \frac{2\pi}{\lambda} \tag{4}$$

$$\eta_0 = \sqrt{\frac{\mu}{\varepsilon}} = 120\pi \cong 377\ \Omega \tag{5}$$

and V_X, V_Y, V_Z are voltages measured in three EUT positions, S is the root-sum-square of these voltages, k_0 is the wave number, η_0 is the free open space impedance and e is the TEM mode field factor of the cell used in test and determined by the geometry of the cell.

To find the correlation with the OATS test results the EUT emissions over a ground plane can be simulated by assuming that the total radiated power, as estimated by the TEM waveguide tests, is the same as that emitted by a dipole replacing the EUT. Maximum field strength E_{max} on an OATS is given by

$$E_{\max} = g_{\max} \cdot \frac{\eta_0 \cdot k_0}{2 \cdot \pi \cdot e} \cdot \frac{S}{\sqrt{Z_C}} \tag{6}$$

where g_{max} is the geometry factor of the receiving antenna in the GTEM cell.

B. The standard IEC 61000-4-20

The standard IEC 61000-4-20 is an international standard defining emission and immunity test methods for electrical and electronic equipment with the help of various types of transverse electromagnetic (TEM) waveguides [9]. These types include open structures (for example striplines and electromagnetic pulse simulators) and closed structures (for example TEM cells). These structures can be further classified as one, two, or multiport TEM waveguides. The frequency range depends on the specific test requirements and the specific TEM waveguide type.

The objective of this standard is to describe

- TEM waveguide characteristics including typical frequency ranges and EUT-size limitations;
- EM waveguide validation methods for EMC tests;
- the definition of EUT;
- test set-ups, procedures, and requirements for radiated emission testing in TEM waveguides and

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Currently valid is the second edition of the standard published in 2010 since as technology improves standards need to keep up, thus working on the third edition is an ongoing process which is planned to be published in 2019.

C. EUTs

Thanks to BOSCH Hungary a couple of EUTs are provided for testing purpose with critical EMC requirements in practical applications. An EUT is a TPS54560 step-down converter produced by Texas Instruments. The tested EUT is a DC-DC converter which is designed to provide up to 5 A output current from an input voltage source. Input voltage can be in the range from 4.5 V up to 60 V. Detailed information about EUT is given in datasheet [10]. In Fig. 4 the photo of this EUT is shown.

EMC tests of these DC-DC converters has high importance in the automotive industry hence they are widely used in-board in cars for supplying the electronic and control units at different voltage levels. According to the standard described above EMC tests for these elements are necessary.

Figure 4. EUT (TPS54560EVM-515 Board)

D. Test results

Tests have been performed at the Faculty of Technology and Informatics of the University of Pécs in the laboratory of the Department of Electrical Networks taking into account every step listed in the standard IEC 61000-4-20.

The applied test receiver was a Rohde & Schwarz ESCI EMI spectrum analyser and for fetching, displaying and analysing the obtained data the software EMC32 has been used.

These tests have been performed in the frequency band of 30 MHz – 1 GHz with a resolution of 120 kHz. Measuring time for each point was 0.1 ms. Complete test results for a EUT are given in the followings.

The spectrums of measured voltages in X, Y and Z directions are given in Fig. 5, Fig. 6 and Fig. 7. The correlated calculated OATS spectrum is shown in Fig. 8.

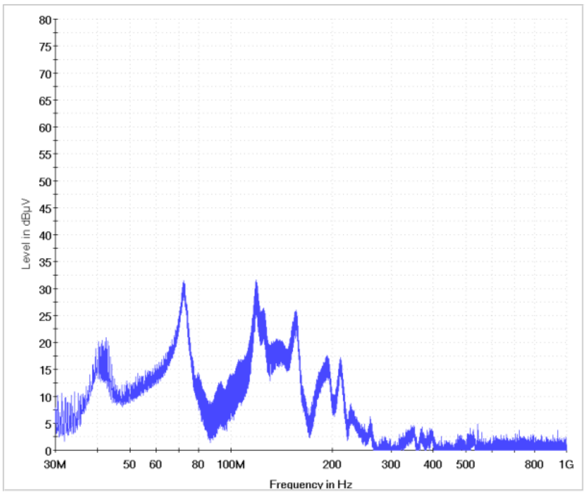

Figure 5. Measured spectrum for the direction X

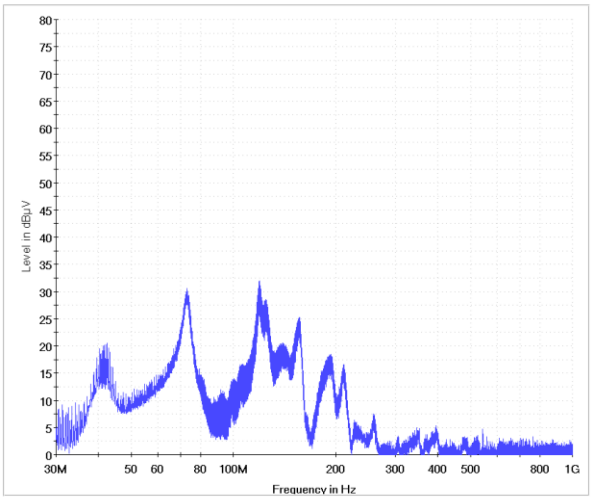

Figure 6. Measured spectrum for the direction Y

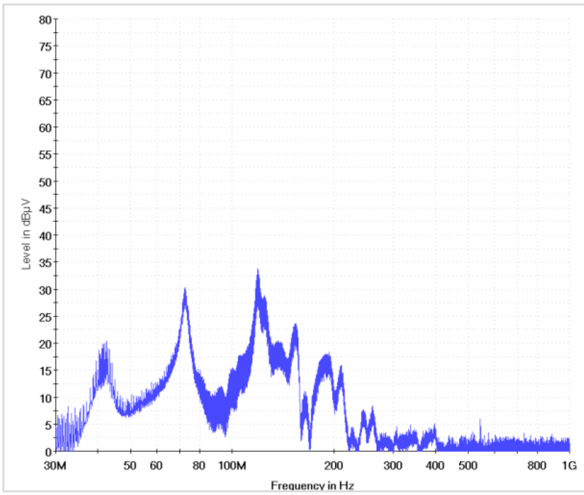

Figure 7. Measured spectrum for the direction Z

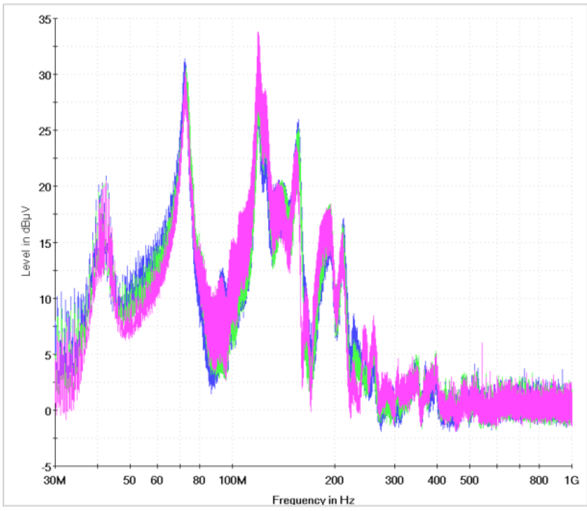

Figure 8. The correlated OATS result of the test

The electric field intensity, based on the OATS voltage spectrum, is given in Fig. 9.

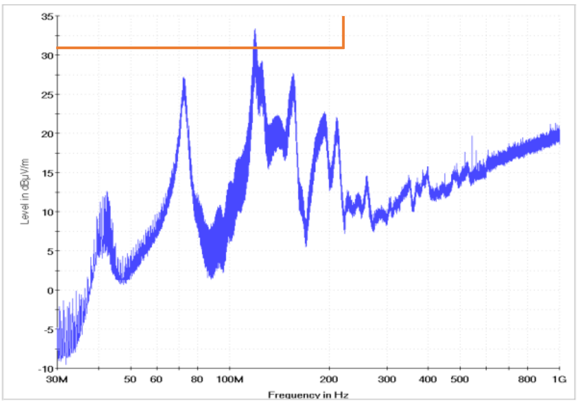

Figure 9. The correlated OATS electric field intensity spectrum with the limit required in EM55012

The limits valid for the automotive industry described in the standard EN55012 is drawn with red colour in Fig. 9. It can be noticed that the measured electric field intensity is over the limit at the frequency around 120 MHz. Interesting that if the same EUT is tested according to the EN55011 (CISPR11) standard, referred to IT industry, the intensity of the electric field is below the limit along the full frequency range.

IV. Conclusions and Future Work

During the last decade EMC testing with GTEM cells became more applicable due its lower cost and accuracy improvements. This paper gives an overview of the GTEM cell, the test methods and the relevant standard with test results achieved with two EUTs. Test results show correlation between test with a GTEM cell and those at OATS.

Future work will include comparison of our test data with reference data and developing new method for better accuracy of GTEM cell.

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