Electromagnetic Interference assessment of small electronic devices with a TEM cell

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Abstract. Electromagnetic Compatibility deserves an increasing interest because as modern industry 4.0 searches for better results in productivity and efficiency, it is expected the presence of an increasingly number of more complex electronic devices, including portable devices. This paper shows how a TEM cell allows analyzing the effects of Electromagnetic Interference, in an easy way and at small cost, during the development phase of the product.

Keywords: TEM Cell, Electromagnetic, Electric Field, Immunity test

1. Introduction

Industry 4.0 uses modern technology for obtaining higher efficiency and productivity, with strong man-machine interaction. Factories work with more remote controlled equipment and this scenario indicates an increasing number of electronic devices such as smart sensors, tablets, microcontrollers, PLCs, actuators and data acquisition components.

Electromagnetic Interference represents a problem in equipment of various areas, including home appliances, industrial equipment and automotive vehicles, so that for every electronic equipment there is a concern about interference, related to its design and correct use.

When the electronic equipment meets the expectation for use in the described conditions, it can be considered as satisfying the restrictions of Electromagnetic Compatibility. For this analysis, various standards are applied, depending on the equipment category, but, in summary, two characteristics are verified: the electromagnetic emission of the equipment and its immunity to external electromagnetic fields, caused by other equipment [1].

Electromagnetic compatibility tests are normally performed in the so-called anechoic chambers [2]. They allow making a relation of the tests with OATS definition (Open Area Tests Site), that is, tests performed in unlimited area. In inhabited regions, an open area is difficult to find, so the use of an anechoic chamber avoids external interferences to affect the measurements and, in addition, minimizes the effect of reflections of the fields caused by the equipment, in emission tests. As already said, two main tests are performed in an anechoic chamber, related to radiofrequency emission and immunity.
Electromagnetic emission represents how much the equipment under test radiates to the environment in a given frequency range, and, depending on the application of the equipment, the corresponding standard establishes the frequencies and the limits of emission for approval.

Emission control has to be made at the equipment development phase, adopting adequate design procedures and making measurements to confirm that the desired results are obtained.

The experimental set-up for an emission test in an anechoic chamber can be seen in Figure 1, where the equipment under test is placed on a table (at left) that can be rotated, allowing the emission in any direction to be measured. The receiving antenna, associated to a measurement system, is at right in the figure.

On the other hand, the analysis of equipment immunity to an external radiation aims to evaluate the behavior of the equipment when external electric and magnetic fields are applied at specific levels and frequency ranges. This test verifies if the equipment functionality is susceptibility by radiation.

The set-up of this test in the anechoic chamber is presented in Figure 2, with the emitting antenna at right. Concerning this test, it can be quoted that for medical electrical equipment of general use, electric fields of 3 V/m are applied. In the automotive area, 200 V/m fields are used.

![Figure 1](image1.png)

**Figure 1.** Set-up for radiated emission test in the anechoic chamber of IPT - Institute for Technological Research of São Paulo.

![Figure 2](image2.png)

**Figure 2.** Set-up for radiated immunity test in the anechoic chamber of IPT - Institute for Technological Research of São Paulo.
2. Methodology
Taking into account the installation complexity and the high cost of an anechoic chamber, preliminary tests can be performed (as a guide to design optimization or a pre-compliance test, for example) employing a TEM cell, which consists on a coaxial rectangular transmission line with connectors adapted to its extremities, as shown in Figure 3 (a) and (b). Connecting a radio frequency generator to one of the extremities and a load to the other, an electromagnetic wave propagates in the cell, in the Transversal Electromagnetic mode (TEM). The electric field associated with the wave can be used to make tests on electromagnetic interference. Considering that the propagation occurs in the air, the wave impedance is 377 Ohms, as would be in the case of an open site test.

2.1. Construction of the TEM Cell
A large volume of literature has been published about the use of TEM Cells, being [3] an example, and the Cell construction depends basically on the definition of dimensions and materials. The TEM Cell presented in this work has dimensions defined according to [4] and was constructed using aluminum plates for the external conductors and a printed circuit board for the internal conductor (septum). Values of the dimensions indicated in Figure 3 (a) and (b) are presented in Table 1. Inside the usable test volume of the Cell an Equipment Under Test (EUT) is represented as box, being recommended that its maximum volume be defined by 0.6L x 0.6W x 0.33H.

![Diagram of TEM Cell](image)

**Figure 3.** TEM Cell. (a) Side view; (b) Front view. Adapted from IEC 61000-4-20:2010 [5]
Table 1. Values of dimensions indicated in Figure 3 (a) and (b).

| Dimension | Values (mm) |
|-----------|-------------|
| L         | 450.0       |
| L total   | 762.0       |
| L septum  | 750.0       |
| H         | 90.0        |
| W         | 214.0       |
| G         | 43.0        |
| A         | 300.0       |

Figure 4 presents a general view of the TEM Cell constructed for this work. In its interior, one can see a printed circuit board with electronic circuit under test.

2.2. Measurements in the TEM Cell

For TEM Cell design and construction validation, tests were performed, according to diagrams presented in Figures 5 and 6. A radio frequency generator covering the range 10 MHz to 200 MHz and voltages of 1 V, 3 V and 10 V was connected to one terminal of the Cell, while a resistive load of 50 Ohms/10 W was connected to the other terminal. An electric Field meter Manufacture by Narda, model EMR300 was used for the determination of the intensity of the electric field inside the usable test volume.

Figure 5. Connection of radio frequency generator and load to the TEM Cell.

Figure 6. Detailed view of electric field measurement inside the TEM Cell.
3. Results and Discussion

The results of electric field measurements at the central point of the Cell are shown in Table 2 and Figure 7. For a generator frequency of 100.0 MHz and voltage of 1.0 V, it was obtained an electric field with intensity equivalent to 20.4 dBV/m, which represents approximately 10.0 V/m. In the same frequency, with a generator level equal to 3.0 V, the measured electric field was 29.7 dBV/m, representing approximately 30 V/m. Finally, with 10.0 V, the measured electric field value was 39.9 dBV/m, which represents approximately 100.0 V/m. The procedure was repeated for frequencies in the range of the generator (10.0 MHz to 200.0 MHz), and table 2 presents the measured values organized in three columns, each one referred to one fixed generator voltage (1.0 V, 3.0 V and 10.0 V). Each column presents also a reference, which is the approximate value, given in V/m at 100.0 MHz. It is worth noting that a field of up to 100.0 V/m was obtained in the TEM Cell.

Table 2. Electric field intensity in dB V/m for three generator voltage values (1.0 V, 3.0 V e 10.0 V) and frequency range 10.0 MHz to 200.0 MHz. Reference value taken in 100.0 MHz and given in V/m.

| Generator voltage | 1 V | 3 V | 10 V |
|-------------------|-----|-----|------|
| Reference value (100 MHz) | 10 V/m | 30 V/m | 100 V/m |
| Frequency (MHz) | dB V/m | dB V/m | dB V/m |
| 10 | 17.8 | 27.0 | 37.2 |
| 20 | 17.9 | 27.2 | 37.3 |
| 30 | 18.3 | 27.6 | 37.8 |
| 40 | 19.0 | 28.2 | 38.3 |
| 50 | 19.4 | 28.7 | 38.8 |
| 60 | 19.8 | 29.1 | 39.3 |
| 70 | 19.7 | 29.0 | 39.2 |
| 80 | 19.9 | 29.2 | 39.3 |
| 90 | 20.5 | 29.8 | 39.9 |
| 100 | 20.4 | 29.7 | 39.9 |
| 110 | 20.4 | 29.8 | 39.9 |
| 120 | 20.2 | 29.4 | 39.6 |
| 130 | 20.1 | 29.4 | 39.5 |
| 140 | 20.2 | 29.5 | 39.6 |
| 150 | 19.6 | 28.9 | 39.0 |
| 160 | 19.1 | 28.3 | 38.3 |
| 170 | 17.8 | 27.3 | 37.3 |
| 180 | 17.2 | 26.6 | 36.6 |
| 190 | 16.7 | 26.1 | 36.1 |
| 200 | 16.2 | 25.6 | 35.5 |
Figure 7. Variation of field strength for nominal ranges 10 V/m, 30 V/m e 100 V/m.

The greatest variation from the reference values observed in the Table 2 is 4.4 dB V/m and this does not represent a problem for the tests in the Cell, because the value of generator voltage can be adjusted to obtain the desired value of electric field.

Taking into account the 50.0 Ohms load and the generator voltage of 10.0 V, it can be verified that the power supplied to the Cell was 2.0 W, obtaining a 100.0 V/m field.

In comparison, to obtain such electric field in an anechoic chamber, it is necessary an antenna associated to a generator and an amplifier, thus increasing the cost of the tests. The field $E$ radiated by an antenna can be calculated at a given point by [6]

$$E = \sqrt{\frac{30 \cdot P \cdot G}{d}}$$ (1)

Where $P$ is the power supplied by the generator, $G$ is the antenna gain and $d$ is the distance from the antenna to desired point. So, to obtain an intensity of 100.0 V/m in an anechoic chamber, at a distance of 1.0 m, and with antenna gain of 2.0 dB (which means a factor of 1.58), the generator should supply a power equal to 211.0 W, while in the case of the TEM Cell the power needed was only 2.0 W, as already seen.

With the present TEM Cell it is possible to perform immunity tests with devices occupying a volume of 27.0 cm x 12.8 cm x 3.0 cm. This size fits a great variety of printed circuit boards containing electronic control circuits, so that the designer could perform preliminary tests and evaluate the behavior of the device still in the development phase avoiding tests in an anechoic chamber. Therefore, for example, it is possible to assess the integrity of the signals in a micro processed circuit board when submitted to external electromagnetic fields and evaluate the performance of the structure and material used for shielding the device.

Although be possible the construction of the TEM Cell by the user, as is the case of the presented in this paper, specialized firms of the Electromagnetic Compatibility area can supply this kind of equipment with cost such as US$ 1,000.00. The frequency range of tests and the power required determine the particular type of Cell to be bought or built.
4. Conclusion
With the development of new technologies and consequently of new electronic equipment, it is mandatory that manufacturers be familiarized with the possible problems caused by electromagnetic interference and be prepared to correct them adequately. Therefore, Electromagnetic Compatibility must be issue for companies from the beginning of the equipment development and not left to the final product, when it will imply more resources and expenses. In this scenario the TEM Cell is a good tool allowing designers to make a previous evaluation of the electromagnetic immunity of the device projected.

Considering the results presented, it is interesting to point out that the variation of the field intensity observed in the Cell does not represent a problem, because the desired value in a test can be obtained by simply adjusting the generator voltage. Then, the only inaccuracy of the results will be due to the field meter.

Finally, from the above, it can be concluded that the TEM Cell, besides having a low cost is adequate for the analysis of the Electromagnetic Compatibility of small devices and, then, can be a tool for design optimization.

References
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