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Finite Element Modeling and Characterization of a GTEM Cell

Alejandro Reckziegel[1], Hyun Ho Shin, Juan Carlos Cabral,Diego Stalder
Facultad de Ingeniería y Facultad Politécnica, Universidad Nacional de Asunción, Paraguay

Giga-hertz Transverse Electromagnetic (GTEM) Cells are instruments used in the field of electronics for the purpose of performing electromagnetic compatibility tests, which are necessary in order to verify that electronic equipment is immune to external disturbances and does not produce signals that disturb other equipment. As GTEM cells are derived from rectangular waveguides, their behaviour, including the characteristic impedance, is dependent on their dimensions [1]. The impedances of both the GTEM cell and the exciter line have to match in order to avoid reflections inside the chamber [2]. In this work, the impedance of a GTEM cell will be validated with the COMSOL Multiphysics commercial software package and the open source Fenics software. The dimensions of GTEM cell used in this work are based on a prototype constructed at our University (Figure 1) which lead to a characteristic impedance of 50 Ω.

In order to compute the characteristic impedance of the GTEM cell, the electrostatic field modelled by Poisson equation is solved using the Finite Element Method. The calculations are carried out on meshes with different refinements using both COMSOL and Fenics, and then, the results obtained are compared.

The Poisson equation for the electrostatic field is expressed as:

$$\nabla^2 \Phi = 0 \quad \text{in} \ \ \Omega \setminus (\partial\Omega \cup C), \tag{1}$$

where $\Phi : \Omega \to R$ is the electric potential inside the cell, and the domain of the cell is $\Omega = [-a/2, a/2] \times [0, b]$, where $a = 2.19$ m and $b = 1.49$ m, these values represent the constructive values of the prototype, being built at the Universidad Nacional de Asunción. On the boundary of the domain, $\partial\Omega$, homogeneous conditions are imposed, *i.e*, $\Phi(\partial\Omega) = 0$ V, and on the center conductor, C, which is located at $d = 1.04$ m from the lower boundary with the length $l = 1.53$ m, is imposed $\Phi(C) = 25$ V.

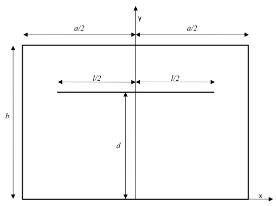

Figure 1: Geometry of the GTEM cell

From the electric potential Φ, the electric field $\vec{\mathbf{E}}$ is calculated by

$$\nabla \Phi = \vec{\mathbf{E}}. \tag{2}$$

Then we get the magnetic field $\vec{\mathbf{H}}$ by

$$\vec{\mathbf{H}}(x, y) = \frac{1}{\sqrt{Z_{TEM}}} \hat{k} \times \vec{\mathbf{E}}(x, y), \tag{3}$$

where $Z_{TEM} = 377\ \Omega$ is the impedance of free space.Then the Poynting vector is the power density which can defined as [3]:

$$\vec{\mathbf{S}} = \frac{1}{\mu} \vec{\mathbf{E}} \times \vec{\mathbf{H}}, \tag{4}$$

[1]areckziegel@fiuna.edu.py

where μ is the permeability of the medium through which the radiation passes, in this case air, so $\mu = 1$. This vector has the direction of $\hat{k}$ component where the waves in TEM mode are transmitted.

The maximum power(P_{max}) which flows through the GTEM is obtained by the surface integral:

$$P_{max} = \int_{\Omega} \vec{\mathbf{S}} \cdot \hat{k}\, ds. \tag{5}$$

Then the characteristic impedance is calculated by applying Ohm's Law:

$$Z_o = \frac{V^2}{P_{max}}. \tag{6}$$

Finally, the characteristic impedance was estimated using both, COMSOL and Fenics. In the case of Fenics, the equation (1) is solved using triangular elements with second order interpolation polynomial, and the UMFPACK lineal solver [4].

Figure 2 (left) shows the solutions, obtained in Fenics, for the electric potential Φ on the analyzed geometry. Figure 2 (right) shows the percent error on the characteristic impedance obtained as function of the element size, using the COMSOL best simulation as reference, which was obtained on the default settings using a mesh with 48000 elements.

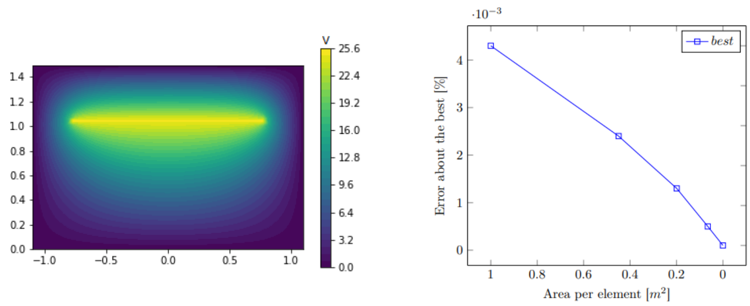

Figure 2: (left) Electric Potential Results. (right) Comparison Results.

The simulations also indicate that the prototype should have an impedance of 50 Ω, which is good to minimize reflections and match the exciter impedance. These results are the first steps to perform a 3d simulation of the prototype and characterize the frequency response of the GTEM using the Helmholtz equations.

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