12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25-27, 2002, Zagreb, Croatia

TEM-CELL FOR ELECTROMAGNETIC MEASUREMENTS

Kresimir Malaric, Roman Malaric, Antonio Sarolic

Faculty of Electrical Engineering and Computing, Zagreb, Croatia

Abstract - Use and application of the TEM-cell has been described. The cell can be used for calibrating small antennas, for immunity and emission testing. It has frequency response up to the first cut-off frequency, which in our case is 485 MHz, but can still have useful areas at higher frequencies (900 MHz). Laboratory experiments as well as commercial testing of the equipment such as cellular phone, IC boards, or small electronic devices up to 5 cm in height are possible. It provides homogenous electromagnetic fields with TEM (transversal electromagnetic mode) distribution, similar to the free space. It has a shield to prevent radiation from the outside, which would interfere with the measurement. Electric and magnetic field inside the cell can be accurately predicted using numerical methods. The measurements of TEM-cell, designed and made at the University of Zagreb, Croatia, of return loss and standing voltage ratio were done. Measurement setup and the method have been explained.

Keywords: TEM-cell, electric field, measurement.

1. INTRODUCTION

Transverse electromagnetic (TEM) transmission line cells are devices used for establishing standard electromagnetic (EM) fields in a shielded environment [1]. The cell consists of a section of rectangular coaxial transmission line tapered at each end to adapt to standard coaxial connectors (Fig.1.). They are usually $50\,\Omega$, but can be $75\,\Omega$ as well. TEM-cells are used for emission test of small equipment, for calibration of RF probes and for biomedical experiments. The cells are broadband having a linear phase and amplitude response from DC to the cell's cutoff frequency. With the increase in frequency, the cells must be smaller to avoid the cut-off frequency, which produces resonances, and destroy the homogenous EM field.

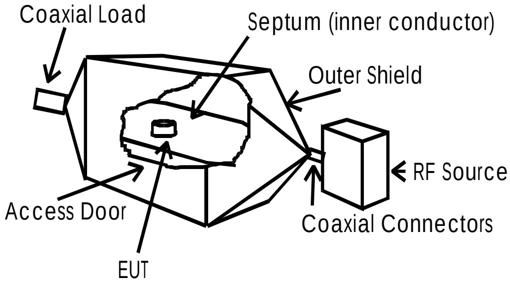

Fig. 1. TEM-cell

Finite element method (FEM) can be efficiently used in solving complex, nonlinear problems in electromagnetic compatibility [2]. The model contains information about the device geometry, material constants, excitations and boundary constraints. Applied mesh is shown in Figure 2. In each finite element, a linear variation of the field quantity is assumed. In order to have a unique solution, it is necessary to constrain the field strength at all boundary nodes. The metal box constrains the tangential electric field at all boundary nodes to be zero. The electrical and geometric properties of each element can be defined independently.

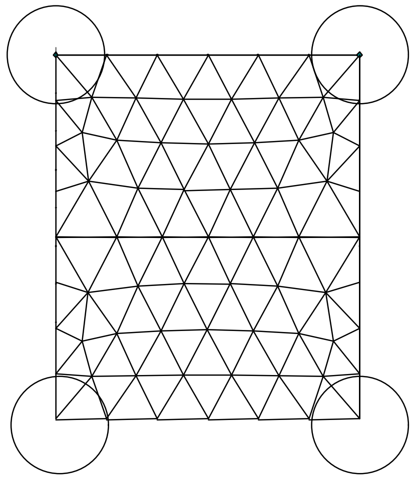

Fig. 2. FEM model

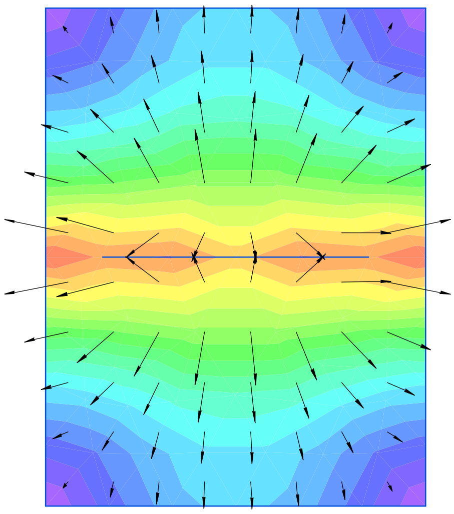

Fig. 3. Strength and vectors of **E**

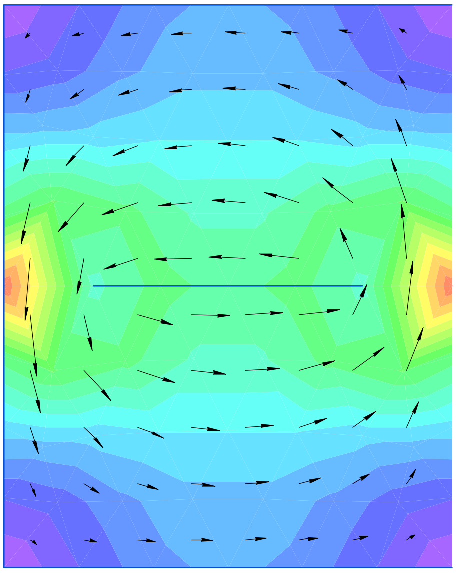

Fig.4. Strength and vectors of **H**

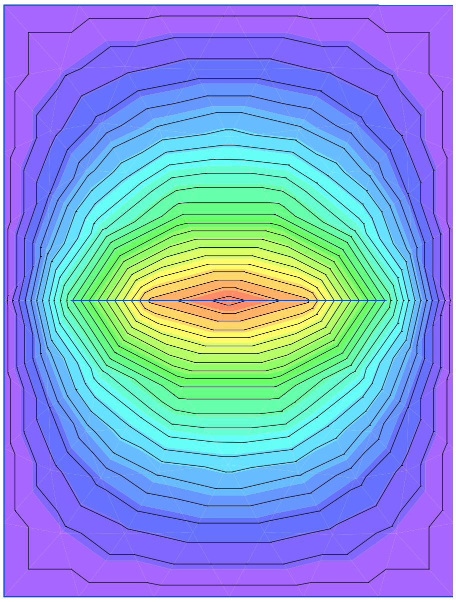

Fig. 5. Potential lines

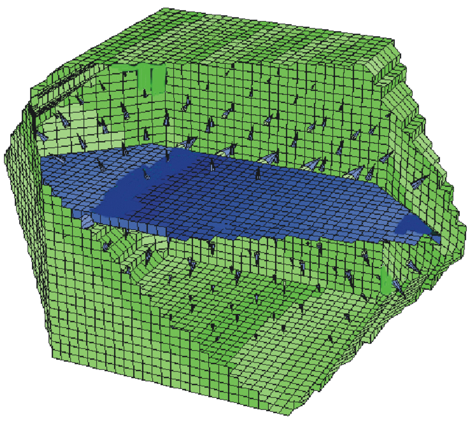

Fig. 6. Electric field 3D

Fig. 3. 4. and 5. are results of numerical modeling analysis. The electric field is stronger closer to the septum and is decreasing as we move to the outer shield. The area between septum and upper (lower) shield has homogenous electric and magnetic field in the middle (about 1/3 of height). This area is used for measurement and for Equipment under test (EUT). In our case the height of the object that can be inserted is 5 cm, without disturbing the homogenous electric and magnetic field. Both areas, above and below septum can be used for measurements. The EUT usually has to be placed on an insulator. The power applied to the TEM-cell can be up to 10 W without the need to cool it additionally.

Figure 6. shows the electric field distribution in 3D using "MAFIA" program. This model shows how vectors of electric field are placed in the space.

2. MEASUREMENT SETUP

The measurements were performed using HP 8720B Network Analyzer [3] and with gold plated N type connectors. Network Analyzer (Fig. 7.) can excite frequencies from 135 MHz up to 20 GHz. Measurement results are stored into the computer via software developed at our Department. The results are then processed in Microsoft Excel. For the TEM-cell it is not of utter importance to have laboratory free of outside interference as with other type of similar measurements, since the cell has an outer shield, so the impact of the surrounding fields have no effect on the measurements. The network analyzer itself can be under the influence of other fields that reside in the vicinity of the measurement setup. That is why the gold plated N type connectors have been used in the measurements to lower the signal loss and interference.

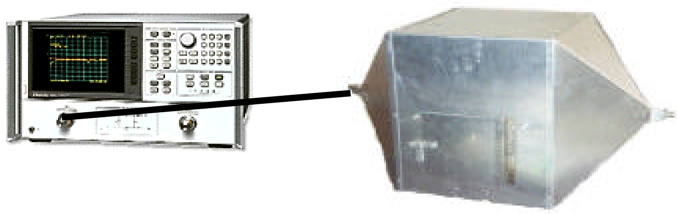

Figure 7. Measurement setup

3. MEASUREMENT RESULTS

The measurements were performed in Primary Electromagnetic Laboratory at the Department of Radiocommunications and Microwave Engineering. Voltage standing wave ratio (VSWR) and return losses are the parameters of TEM-cell that have been measured. VSWR shows how much is TEM-cell matched. If the value of VSWR is close to "1.0", then the cell is very well matched. Ideally, when VSWR is "1", that means that the cell is perfectly matched and that there is no reflection of the incident wave. In real life, this is never the case. The goal was to construct the cell to have small VSWR at the frequencies about 900 MHz for testing GSM. Return loss (dB) is related to the VSWR and shows the level of the reflected signal.

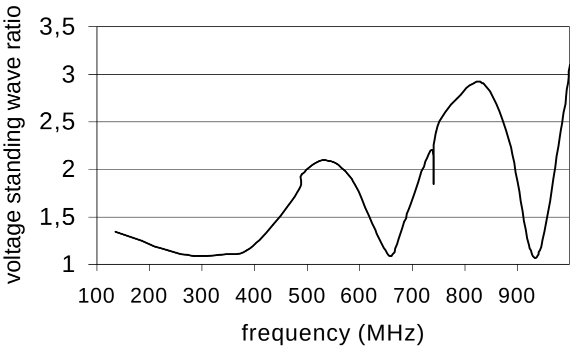

Fig.8. VSWR of TEM-cell

Figure 8 is showing VSWR up to frequencies of 1GHz. It can be seen that above app. 480 MHz, the value of VSWR rises over 3,5 and that the cell is quite well matched.

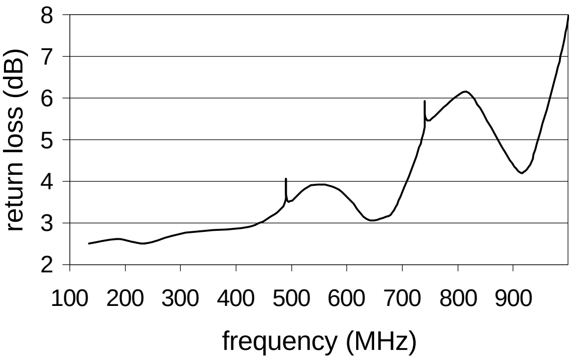

Fig. 9. Return loss of TEM-cell

Figure 9. shows the return loss in the ranges up to 1GHz. The lower the value (in dB), the weaker signal is reflected back from the end of the cell, which means that the cell is better matched.

The measured frequency goes up to 1 GHz because the BNC connectors are usable up to this frequency. Higher frequencies result in additional attenuation of the signal. Due to the geometry of the cell it can be expected that at 1800 MHz we would again have the similar situation as with 900 MHz, that is, the frequency area where the cell is well matched. The uncertainty of measurements in RF area is much higher than with lower frequencies or DC measurements. Here 1 or 2 dB, which is expected uncertainty is actually error from 30 to 60 %. If the uncertainty level of electric or magnetic field in the TEM-cell is less than 3 dB in frequency range from DC to the cell cut-off frequency, it is considered that the cell was designed very good.

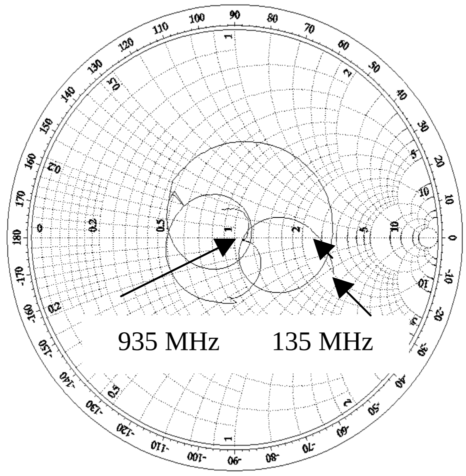

Fig. 10. TEM-Cell Smith Chart

Fig. 10. shows Smith Chart of the TEM-Cell. The closer the curve is to the center of the Smith chart, the more matched the cell is. The curve starts at 135 MHz and goes up to 1 GHz. The notches on the curve represent the cut-of frequencies at 475 and 740 MHz. At 935 MHz, the curve passes almost through the centre of the Smith chart.

4. CONCLUSIONS

TEM-cell was designed and modeled at the Faculty of Electrical Engineering in Zagreb. General outlines of the cell have been given with the reference to the previous work.

The results of the numerical analysis have been shown. The cell has been tested with the network analyzer HP 8720B. VSWR and return loss were measured and the obtained results showed that the TEM-cell can be used for the EMC measurements, the calibration of antennas, the immunity and emission testing as well as for biomedical exposure.

REFERENCES

[1] Kresimir Malaric, Juraj Bartolic "TEM-Cell with 75 Ω Impedance for EMC Measurements", *IEEE 1999 International Symposium on Electromagnetic Compatibility*, proceedings Volume 1, 2-6 August, 1999, Seattle, WA, SAD, pp. 234-238.

[2] Dr. Todd H. Hubing: "Survey of Numerical Electromagnetic Modeling Techniques", Report Number TR91-001.3, University of Missouri-Rolla, Electromagnetic Compatibility Laboratory, September 1, 1991

[3] HP 8720 Network Analyzer Operating Manual

Authors: Kresimir Malaric, Roman Malaric, Antonio Sarolic, Faculty of Electrical Engineering and Computing, Zagreb, Croatia. Tel.: +385 1 6129 789, Fax: +385 1 6129 717, E-mail: kresimir.malaric@fer.hr