Generation and Measurement of Standard Electromagnetic Field inside TEM Cell

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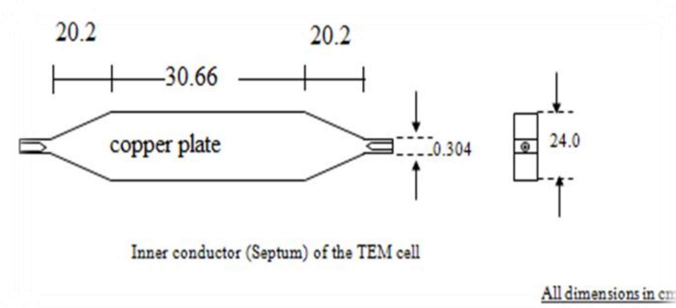
Abstract— **in this work, the design of a TEM cell for the measurement of standard electromagnetic field in HFSS has been proposed. To perform this measurement a waveguide system for the wave propagation system has been studied analytically. We have analyzed standard E- field (Electric-field) inside wave guide, a tapered slot has been incorporated in H plane of the wave guide. The proposed TEM cell has been designed to operate at GSM frequency i.e 2.4 GHz**

Keywords- Standard Electric Field, HFSS, TEM Cell, GSM frequency.

I. INTRODUCTION

A transverse electromagnetic cell [1] is basically a two port device which is made compatible with the 50Ω coaxial connectors so that the electromagnetic energy present b/w the inner and the outer conductor of the coax connector can be easily coupled to the tapered transition of the TEM cell. The TEM cell consist of a centre conductor also called septum which is made of copper, the centre part of the plate is rectangular in shaped while both the ends of the rectangular parts are made tapered. With respect to the septum there are two conductors equally spaced from septum, first one is the bottom outer wall and second one is the top outer wall both the walls are made of aluminum. The wave travelling through the cell has a free-space impedance of 377 Ω. A uniform TEM field is established inside a cell at any frequency of interest when RF energy is coupled to the line from a transmitter connected at the cell input port. As we know that the parallel surfaces support the waveguide modes at higher frequency so that there is possibility of the centre part of the TEM cell to support these modes also. The higher order modes are also possible at sharply defined frequencies which destroy the uniformity of the E-field inside the TEM cell.



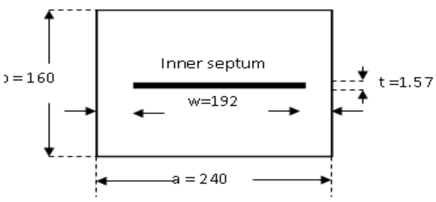


Fig.1 Housing of the TEM Cell (dimensions in mm)

II DESIGN PARAMETERS AND STRUCTURE ANALYSIS

As TEM cell is having a centre conductor of copper called septum and aluminum box enclosing the centre conductor so the whole assembly can be thought of as a shielded strip line. But here the designed TEM cell is having greater thickness than that of a strip line which is considered much thinner so we can say that it is an evolution of a shielded strip line to a rectangular co-axial line. As we know that the characteristic impedance Z_0 of the strip line is inversely proportional to the capacitance per unit length therefore we can say that more is the capacitance lesser is the impedance of the line (strip or rectangular co-axial). The design specifications of the TEM cell are Characteristic Impedance Z_0 = 50Ω, VSWR ≤ 1.1, insertion Loss ≤ 1.5 dB at upper cut off frequency, design frequency = 930 MHz. The design of the TEM cell is totally based on the characteristic impedance. Since the characteristic impedance of the cell must match with the 50 Ω connector at the input side. all the dimension of the cell must be chosen such that proposed structure could be compatible with the 50 Ω impedance so that the field uniformity can be maintained inside the TEM cell. The design should be made keeping in mind the following mentioned things

(a) Maximize usable test cross sectional area.

(b) Maximize upper useful frequency limit.

(c) Minimize cell impedance mismatch or voltage standing wave; and

(d) Maximize uniformity of EM field pattern characteristic of the cell.

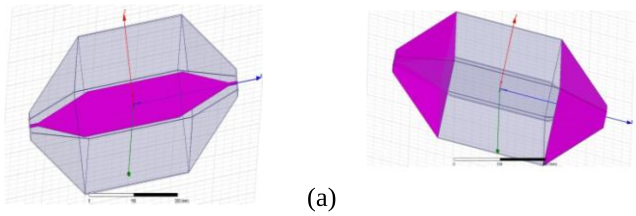
The design parameter of the TEM cell are characteristic impedance of the septum (Z_0), width of the septum made of copper. (w), length of the septum made of copper, width of the side, top and bottom wall made of aluminum (W), length of side, top and bottom wall , length of the tapered section of the septum and length of the tapered section of the walls. The first TEM cell was proposed by Crawford [2]. According to Crawford, the characteristic impedance of the septum depends on the following relation:

$$\frac{\boldsymbol{C_0}}{\boldsymbol{\epsilon_0}} = 4\left[\frac{a}{b} - \frac{2}{\pi}\ln\left(\sinh\frac{\pi g}{2b}\right)\right] - \frac{\Delta\boldsymbol{C}}{\boldsymbol{\epsilon_0}} \text{ .... (1)}$$

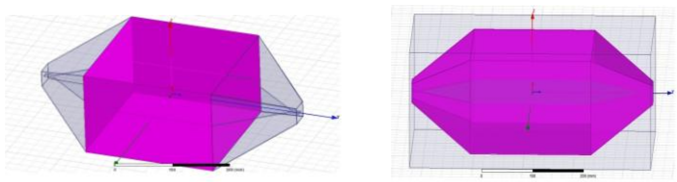
ε_r is the relative permittivity of the medium inside the cell, w is the width of the septum, b is the spacing between spacing between bottom and top wall of aluminum. The term $\Delta\boldsymbol{C}/\boldsymbol{\epsilon_0}$ relates to the fringing capacitance b/w the edges of the septum and the side walls. If $a/b \geq 1$ and $w/b \geq 0.5$ then $\Delta\boldsymbol{C}$ is negligible. The term $\Delta\boldsymbol{C}/\boldsymbol{\epsilon_0}$ is dependent on the location along the septum, because fringe capacitance in the taper is increasing resulting in a little larger impedance. If the ratios *a/b* and *a/w* are kept constant over length of the cell the impedance in the tapers will be approximately the same as that in the uniform cross-section of the cell. Also the Characteristics impedance of the TEM cell is given by….

$$Z_0 = \frac{\eta_0 \epsilon_0}{C_0} \text{.................. (2)}$$

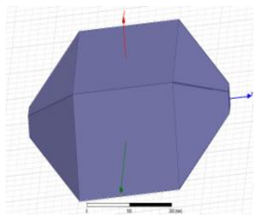
The designed structure of the TEM cell in HFSS [3] under different views is as follows:



(a)



(b)



(c)

Fig.2 (a) Central Conductor and Tapered section (b) rectangular section of aluminum box and the final assembly of the cell (c) assembly enclosed in aluminum box

III. RESULTS AND DISCUSSIONS

The various results obtained when the TEM cell was simulated in HFSS according to the theoretical calculations are as follows:

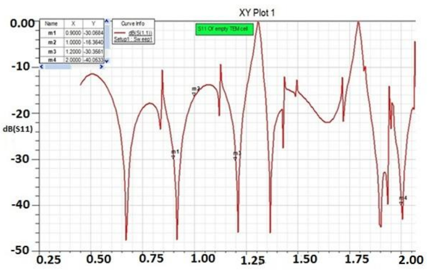


Figure-3 Return Loss

The return loss at the desired frequency of 900 MHz is -30.1 dB. The insertion loss of the cell obtained is -0.0048 dB as follows:

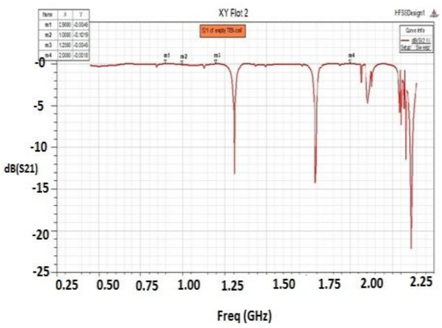


Figure-4 Return Loss

The VSWR plot of the TEM cell is way below 2 and is shown in the following figure:

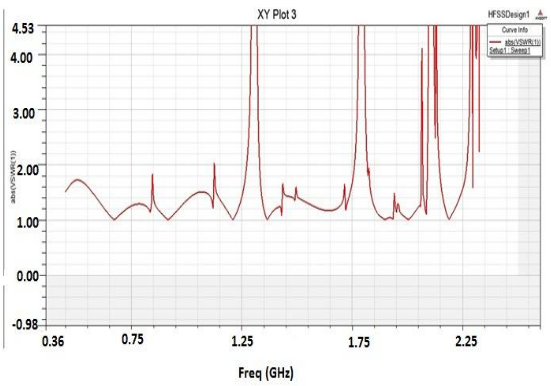


Figure-5 VSWR plot

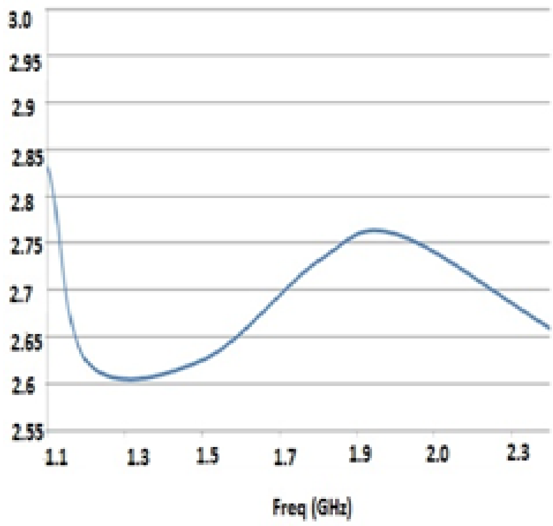


Figure-6 Frequency vs VSWR plot

Now given dimensions from figure-1 are as follows:

a = 240 mm

b = 160 mm

g (gap b/w septum and side wall of the TEM cell) = 24 mm &

w = 192 mm (Width of the septum).

Also $^{a}/_{b}$=1.5 > 1 & $^{w}/_{b}$ = 1.2 > 0.5 therefore $\frac{\Delta C}{\epsilon_0}$ i.e. fringing capacitance can be neglected. Therefore by putting all these values and neglecting the fringing capacitance we get the value of $\frac{C_0}{\epsilon_0} = 5.4$

Putting the value of $\frac{C_0}{\epsilon_0} = 5.4$ in $Z_0 = \frac{\eta_0 \epsilon_0}{C_0}$ and using free space impedance $120\pi\ \Omega$ we get the value of $\boldsymbol{Z_0} = 69.81\Omega$.

The E-field given by Crawford at the centre of the septum is given by the relation:

$$E_n = \sqrt{P_n R_c}/d \ \ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

Where $d = {}^{b}/_{2}$, P_n is net power transferred through TEM cell which is 1 mW and $R_c = \boldsymbol{Z_0}$ = Real part of char. impedance. Therefore the field calculated is given as:

$$\boxed{E_n = 3.3026 \text{ V/m}}$$

IV. CONCLUSIONS

After basic concept of TEM cell has been studied analytically, a simulation has been performed on the basis of existing TEM cell dimensions given by Crawford. Detailed studies based on the power of the TEM cell have been carried out. From VSWR, the simulated and theoretical results were compared and found in good agreement. E-field is also computed by simulation as well as by theoretical means.

V. REFERENCES

[1] Design of a TEM Cell EMP Simulator (U) by **"Peter Sevat"**

[2] Crawford, M. L., *"Generation of standard EM ¯fields using TEM transmission cells," IEEE* Transactions on Electromagnetic Compatibility, Vol. 16, No. 4, 189{195, Nov. 1974.

[3] Ansoft HFSS 14, Ansoft Corporation.