ABSTRACT

STUDIES ON TRANSVERSE ELECTROMAGNETIC (TEM) CELL

Investigations have been carried out in this thesis on three major aspects of transverse electromagnetic (TEM) cells. These are: 1) effect of finite thickness of asymmetrically located inner conductor (septum) on characteristic impedance under TEM mode of excitation; 2) cut-off and resonance frequencies of higher-order TE and TM modes; and 3) technique of generating electromagnetic field having arbitrary impedance, defined by the ratio E/H, inside the cell.

The effect of finite septum thickness on characteristic impedance is analysed with three different mathematical formulations. In the first method, an appropriate Green's function is derived considering the septum thickness and the boundaries of an asymmetric TEM cell. An expression for characteristic impedance, valid for extremely low as well as high frequencies, is obtained in terms of distributed line parameters per unit length of the line. The inductance and the capacitance of the line are evaluated respectively from the magnetic and electric stored energies in the cell. The resistance and the conductance are evaluated from the power losses in the conductors and in the medium inside the cell, respectively. The integrals appearing in the expressions for the energy and loss calculations take into account the effect of finite septum thickness. Variations in
characteristic and wave impedances with frequency of operation are also studied. The electric field distribution in the cross-section for different asymmetric locations of the septum is also investigated. This formulation is applicable to small thickness of an asymmetrically located septum.

In the second formulation, the unknown electric charge distribution on the conductors is determined from a solution of Poisson's equation for electrostatic potential using moment method and Green's functions. The ratio of the total charge on the septum and its potential gives the characteristic impedance of the cell. The thickness of the septum appears in the impedance calculation through the segmentations of the outer periphery of the septum. The procedures allow wide latitude in the choice of subdomain sizes and do not require complicated treatment of edges and/or bends of the conductor. Numerical results giving electric charge distribution on the conductors, characteristic impedance, and distribution of normalised field components in the cross-section are presented. The region of uniformity of field in the cross-section is also found. The method is applicable to any thickness of an asymmetrically located septum.

In the third formulation, Schwarz-Christoffel transformation is used to take into account the effect of septum thickness of a symmetric TEM cell. The cross-section of the cell is transformed into a parallel plate configuration and the characteristic impedance is determined from the capacitance of these parallel plates. As the thickness of the septum increases, the spacing between the two parallel plates decreases from its value
corresponding to zero septum thickness. Consequently, the characteristic impedance decreases. The amount of reduction in spacing is chosen so as to give the correct thickness of the inner conductor for impedance calculation. Equating the real and imaginary parts of the incomplete elliptic integrals and associated complex quantities appearing in the transformation, equipotential contours around the septum are obtained. The thickness and width of the septum are found from the coordinates on the equipotential line which is coincident with the septum boundaries. Numerical results of the variation of characteristic impedance with septum thickness are presented and are found in good agreement with those obtained using both first and second methods.

The cut-off frequencies of higher order TE and TM modes in symmetric TEM cells are determined from the eigen values by solving the homogeneous wave equation in the cross-section of TEM cell using finite element method (FEM). FEM converts the wave equation into a matrix eigen value equation. The eigen values and the associated eigen vectors are determined by using eigen value-analysis computer package and applying appropriate boundary conditions which include the gap between the septum and the side walls of the outer conductor. The cut-off frequencies of a large number of higher-order modes are computed very accurately using the finite element method. The FEM results of higher-order mode cut-off frequencies agree well with those computed by using other methods reported in the literature. The resonance frequencies of the first few higher-order modes are calculated and experimentally determined. The calculated and measured values of these resonance frequencies show fairly good agreement.
The techniques of generating predominantly electric field or predominantly magnetic field or electromagnetic fields with arbitrary impedances defined by E/H ratios inside a symmetric TEM cell are described using transmission line theory. These fields are useful for intra-system EMI measurements of relatively small size printed circuit boards and electronic devices/components which require test environments not characterized by plane wave fields. The variations of electric field; magnetic field and the impedance along the length of the cell are studied to determine the size of the test region inside the cell over which the predominantly E or H field amplitude remains uniform within ±1 dB and the impedance variation is not large. The magnitudes of the fields with a wide range of E/H ratios are computed at the centre of the cell as a function of frequency and experimentally measured. Detection characteristics of a dipole probe in these fields are also studied experimentally as an example.