RESEARCH ARTICLE

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CALCULATION OF REFLECTION AND TRANSMISSION COEFFICIENT OF MULTI STEP DISCONTINUITY OF DIELECTRIC WAVEGUIDE BY USING FEM SOLUTION OF TWO DIMENSIONAL HELMHOLTZ EQUATIONS

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ABSTRACT

Electromagnetic wave analysis in a dielectric waveguide has been theoretically analyzed in the light of Finite Element Method (FEM) solution of two dimensional Helmholtz equations. Various parameters related to electromagnetic wave propagation such as reflection coefficient (S_{11}) and transmission coefficient (S_{12}), Total transmission coefficient (T) and Power (P) by changing diameter and length of the waveguide model like multistep type waveguide discontinuity and also changing wave number by changing the wave frequency in each three different stages and results were discussed as per the existing theory through Perfect electric conductor (PEC) medium.

Key Words— Multistep, Finite element method (FEM), Reflection and Transmission coefficient, 2D Helmholtz equations and discontinuities

I.INTRODUCTION

Discontinuities in waveguides can be defined as imperfection in waveguide structure produced by two or more factious boundaries. These defects occur inevitably in many waveguide systems due to construction tolerance and misalignment in the component intersection [1] - [3].In this paper, the authors analyzed the behavior at discontinuities for step dielectric waveguides used in optical and millimeter components[4]. At discontinuities, the distribution of electric and magnetic fields varies resulting in power loss, which degrades the performance of the dielectric waveguides. By analyzing discontinuities in waveguides, the power loss of the signal propagated through the dielectric medium can be effectively estimated. Design and testing of waveguide components require a meticulous approach to overcome practical problems, such as impedance mismatch, losses, waveguide discontinuities (step, taper, and multi-step), abrupt discontinuities, planar waveguide discontinuities, and arbitrarily shaped discontinuities among planar dielectric waveguides with different thicknesses.

In this paper, FEM solution of 2D Helmholtz equations is applied to the analysis of waveguide model such as step type discontinuities of using three different cases and numerical results were compared. Physical mathematical model is explaining the exciting and classification of electromagnetic waves in an anisotropic waveguide in the three dimensional case. Finite difference techniques are used to find s-matrix parameter calculation of waveguide discontinuity problem [4].This paper explain the application of the generalized scattering matrix resemble to analyses of waveguide structure, in which the finite difference time domain (FDTD) method is use to find generalized s-matrix [5].Waveguide transitions containing ports where mode are in cutoff are analyzed by using cross section method and also coupling co-efficient for modes are solved [6].In 2004 D. Karkashadze et.al [7] has proposed accurate computation of reflection coefficient of waveguide discontinues in photonic crystals using Method of Auxiliary Sources (MAS) and compare with the rigorous connection technique obtained by the Multiple Multi pole Method (MMP).Mohamed Yahia et.al [8] has represented novel method a hybrid method that combines the FEM and the MVM, in which rectangular waveguide model is divided into triangular elements. The interpolation functions are obtained and which approximate the tangential electrical field within elements will use to build a new spatial basis function that replaces the model eigen function. Dmitry A. Bykov et.al [9] has invented a new procedure to computing the scattering matrix poles from Iterative method, in which consider the scattering matrix from the pole nearness and relies upon solving matrix equations with use of matrix decompositions. Carsten et al. demonstrated [10] the calculation of electromagnetic fields in the interior of 3-D structures with open waveguide ports from Galerkin finite element method (DG-FEM), this method is helpful to obtain frequency dependent scattering parameters.

II. BACKGROUND THEORY

Simulation of electromagnetic wave propagation is a very simple method in the two dimensional Helmholtz problem is also called in-plane wave propagation. TM wave propagation will be analyzed in a parallel plane waveguide structure with a 90 deg bend. Bend is an example of waveguide discontinuity and two dimensional simulations are useful for the design of three dimensional real life structures at next stage

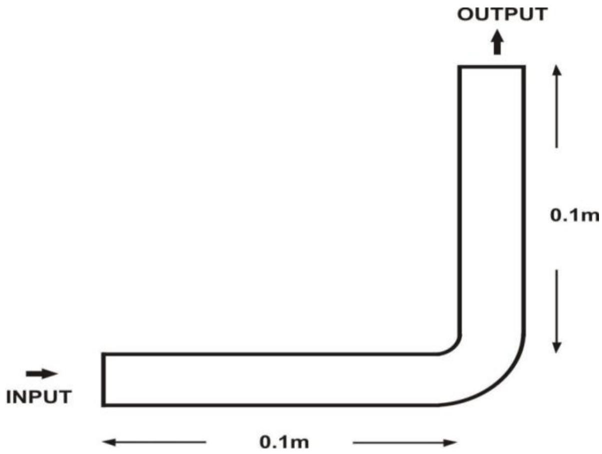


Figure.1

Important theory background of a TM in plane wave propagates in the x and y plane and there is no propagation in the z-direction. Therefore we have components E and H that is Ez(x,y), Hx(x,y) and Hy(x,y) are not equal to zero. Using two dimensional Helmholtz equation TM mode solutions can be obtained as follows [9].Consider two dimensional Helmholtz equations

$$\Delta_t E_z + \gamma^2 E_z = 0 \dots\dots.(1)$$

Where $\gamma^2 = \omega^2 \mu\varepsilon$ is the propagation constant $\mu = \mu_0, \ \varepsilon = \varepsilon_0$ material properties of the waveguides and the frequency f=9x109 Hz. Waveguide walls are made up of conducting materials that is perfect electric conductor (PEC) with following boundary conditions.

S-Parameters:

$$S_{11} = \frac{\int_{\delta_2\Omega}(E_z - E_{1z}).E_{1z}\,dl}{\int_{\delta_2\Omega} E_{1z}\,.E_{1z}\,dl} \quad (2)$$

$$S_{12} = \frac{\int_{\delta_3\Omega}(E_z\,.E_{2z}\,dl}{\int_{\delta_3\Omega} E_{2z}\,.E_{2z}\,dl} \dots\dots(3)$$

Components of electric field and magnetic field along x and y direction can be obtained solving above equation (1) and the S-parameters were calculated using the integrals equations (2) and (3).

III.RESULTS AND DISCUSSION

CASE:-01 Frequency and wave number remains constant, but diameter and length of the waveguide is varied

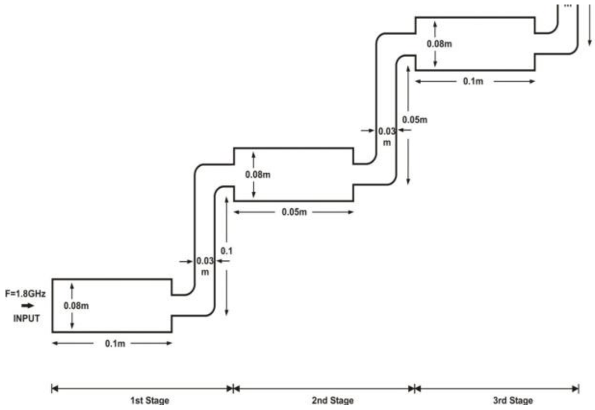


Figure.2

TABLE I

Frequency in GHz	Stage	Wave number	S_{11}	S_{12}	T	P = V^2/R
5GHz	Ist	103	0.0001	0.92	0.846	0.014 w
5GHz	2^{nd}	103	0.0187	1.022	1.044	0.021 w
5GHz	3^{rd}	103	0.03142	1.004	1.099	0.024 w

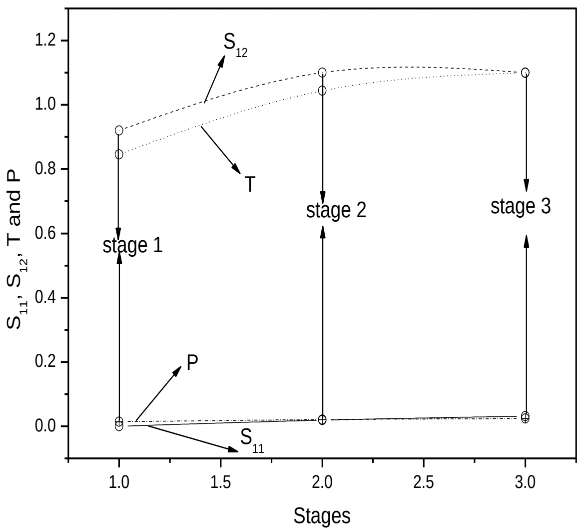


Figure 3

As the diameter and length of the waveguide is varying and frequency and wave number remains constant in three stages of waveguide model such step type discontinuity the following parameters are obtained: Reflection co-efficient (S_{11}) is decrease, Transmission co-efficient (S_{12}) and output power at slowly increase first stage to final stage as shown in Table I, because length and diameter is directly propositional frequency wave propagation in even mode propagation.

CASE:-02 Frequency is varied, by varying diameter of waveguide and wave number is varied by changing the diameter of waveguide and dl remains constant (x-axis and y-axis).

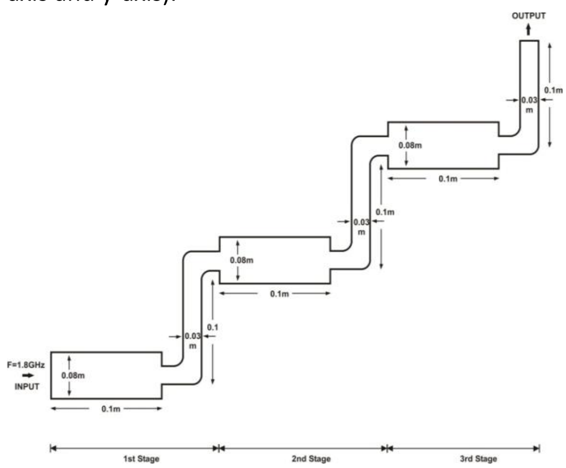
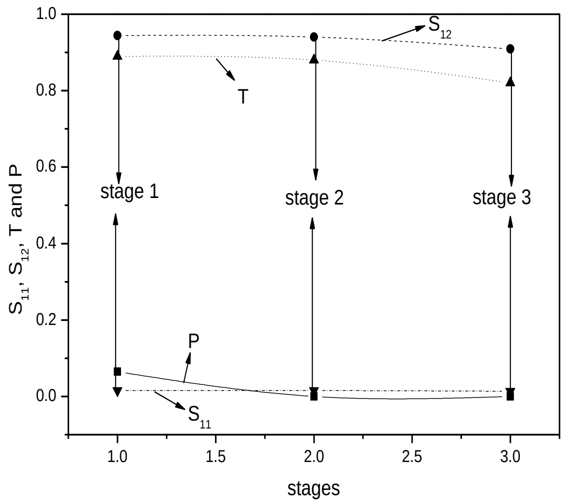


Figure.4

TABLE II

Frequency in GHz	Stage	Wave number	S_{11}	S_{12}	T	P = V^2/R
1.8GHz (S_{11}) and5GHz (S_{12})	Ist	38 and 103	0.0653	0.944	0.8951	0.015 w
1.8GHz (S_{11}) and5GHz (S_{12})	2^{nd}	38and 103	2.872x 10^{-32}	0.940	0.88	0.015 w
1.8GHz (S_{11}) and5GHz (S_{12})	3^{rd}	38and 103	3.0079 x10^{-32}	0.909	0.82	0.013 w

As the frequency is changing by varying diameter of the waveguide and wave number is varied by changing the diameter of waveguide and dl remains constants in three stages of waveguide model such step type discontinuity the following parameters are obtained: Reflection co-efficient (S_{11}) is decrease, Transmission co-efficient (S_{12}) and output power at slowly decrease first stage to final stage as shown in Table II, because length and diameter is directly propositional frequency wave propagation in even mode propagation



CASE:-03 Frequency is varied, depending on the diameter of the waveguide, wave number is varied with respect to diameter and dl is varying on x-axis and y-axis

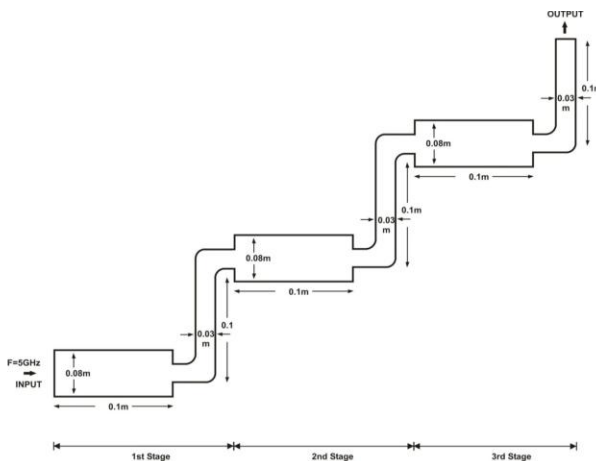
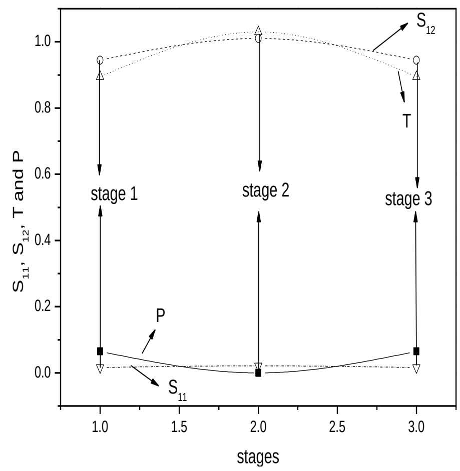


Figure.5

TABLE III

Frequency in GHz	Stage	Wave number	S_{11}	S_{12}	T	$P = V^2/R$
1.8GHz(S_{11}) and5GHz (S_{12})	Ist	38 and 103	0.0653	0.944	0.0891	0.0158
1.8GHz(S_{11}) and5GHz (S_{12})	2nd	38 and 103	3.954x 10^{-25}	1.017	1.034	0.0213
1.8GHz(S_{11}) and5GHz	3rd	38 and	0.0653	0.944	0.0891	0.0158



As the frequency is varied, by varying the diameter of the waveguide and wave number is varied with varying diameter and length of the waveguide is varied on x and y-axis in three stages of waveguide model such step type discontinuity the following parameters are obtained: Reflection co-efficient (S_{11}) is decrease, Transmission co-efficient (S_{12}) and output at final stage power acts as band pass signal as shown Table III, because length and diameter is directly propositional frequency wave propagation in even mode propagation

IV.CONCULSIONS

In this paper, a FEM solution of 2D Helmholtz equation method is proposed for the analysis of waveguide discontinuities by estimating reflection and transmission coefficients. Different parameter like S_{11}, S_{12}, S_{11}/S_{12} and power of each stage are tabulated of multistep discontinuities, by varying different parameters waveguide like length, diameter and frequency of wave of three different cases.

Case.1 frequency remains constant, S_{11},S_{12}, T and Power increase.Case.2 frequency varies, by vary diameter of waveguide S_{11}, S_{12} T and Power decrease and Case.3 frequency change, by changing diameter of waveguide S_{11}, $S_{12,}$ T and Power, slowly increases maximum and slowly deceases (band pass signal).

Final conclusion S-parameter and Power of waveguide depends on diameter and length of waveguide and also depends on frequency of EM wave. Similarly different model like sharp bend, taper and etc can be analyzed by using above mentioned method.

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