DISPERSION CHARACTERISTICS OF DOMINANT AND HIGHER ORDER MODES FOR SINGLE AND COUPLED STRIP IN MULTILAYERED CYLINDRICAL DIELECTRICS USING TLM METHOD

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ABSTRACT

An inhomogeneous, multi-layered cylindrical stripline is analyzed using TLM method. Dispersion characteristics of dominant as well as higher order modes are obtained for single and coupled cylindrical stripline. Cylindrical stripline consists of circular arc strip placed between two cylindrical ground planes separated by multilayer dielectrics. Using flexible dielectric materials, it is possible to construct non-planar transmission lines that can be warped around with a cylindrical surface and used to excite conformal arrays mounted on a cylindrical object. A cylindrical transmission line is also useful for wide band power combining applications with considerable size reduction. The non-planar lines can also be used as a coaxial to planar transition adapters and baluns.

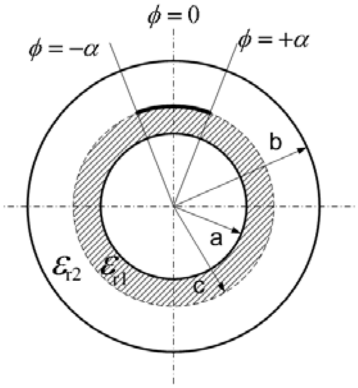


Fig.1. (a) Circular stripline

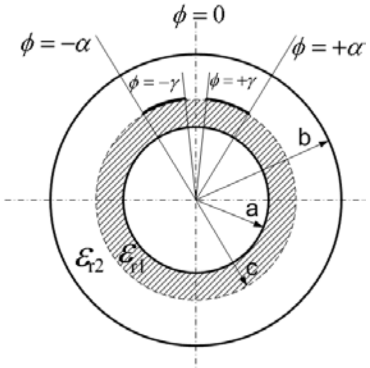


Fig.1.(b) Circular coupled stripline

INTRODUCTION

The TLM method is a space-time domain numerical technique to analyze arbitrary electromagnetic field problems .The space to be modeled is divided into discrete cells and the grid size is determined by highest frequency component of interest .The scattering properties of formation in each grid is modeled by transmission line node. In this paper, 3D Symmetrical condensed node (SCN) in 2D array is used to analyze the structure in time domain using Gaussian pulse excitation. Staircase approximation of circular boundary has been used for the structure.

THEORY

The TLM method models the electromagnetic field problem by simulating the guided structure through a three-dimensional transmission line mesh. Problem gets discretized both in space and time by scattering impulses away from the transmission line junction (node) and then transferring them from one node to the next in a fixed time step Δt. This procedure can be described by a scattering event S, relating incident impulses to reflected impulses at the time step $k\Delta t$ by

$${}_kV^i = S.{}_kV^r$$

Transferring event C, which relates reflected impulses to incident impulses in the adjacent node at the next time step $(k+1)\,\Delta t$, yields:

$${}_{k+1}V^i = C.{}_kV^r$$

where $_{k+1}V^i$ and $_{k}V^r$ are, respectively, vectors containing incident and reflected voltage at each node. S and C are the scattering and connection matrices. The solution procedure can be initialized by launching a primary impulse into one of the nodes. The output is taken at some points in the mesh. It consists of a series of impulses and contains the information of the structure analyzed. This is the general solution procedure for the TLM arbitrary electromagnetic field problems.

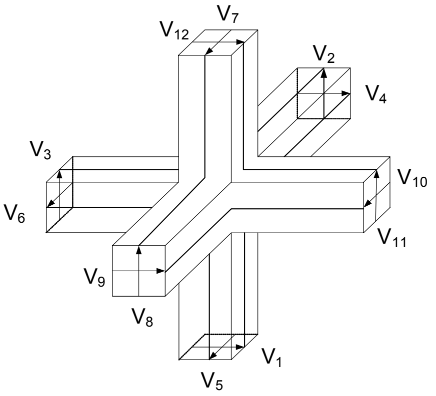


Fig.2. The symmetrical condensed node

3D SCN node (Fig. 1) consists of 12 transmission line having same characteristic impedance Z_o which also equals the characteristic impedance of free space.12 pulses on link transmission lines, incident upon the node, provides scattering into 12 reflected pulses. Scattering matrix of 3D SCN node is derived in [1,5] but a simpler and computationally more efficient approach is described in [2] and [3].

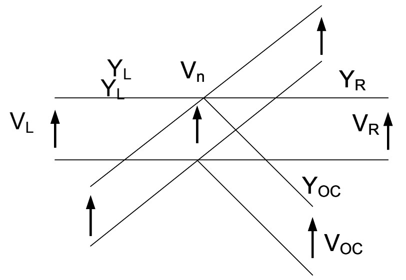


Fig. 3(a) Shunt circuit

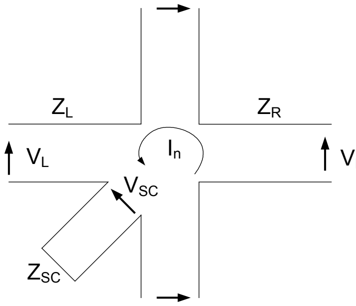


Fig. 3(b) Series circuit

According to this approach, TLM node can be represented by a set of equivalent shunt-only and series-only circuits, where the particular pair of transmission lines under consideration is common to both circuits (Fig 3). A nodal voltage V_n and loop current I_n can be determined for the shunt and series representation. For the transmission lines common to both representations the following equations are valid:

$$V_L^{\,r} = V_n + I_n Z_L - V_R^{\,i}$$
$$V_R^{\,r} = V_n - I_n Z_R - V_L^{\,i}$$
$$V_{OC}^{\;r} = V_n - V_{OC}^{\;i}$$
$$V_{SC}^{\;r} = I_n Z_R + V_{SC}^{\;i}$$

where $n \in x, y, z$.

The equivalent V_y and I_Z can be obtained as with the addition of capacitance due open circuit and inductance due to short circuit stubs to give

$$V_y = \frac{2}{4+Y_{OC}}(V_3^i + V_4^i + V_8^i + V_{11}^{\;i} + V_{OC}^{\;i} Y_{OC})$$

$$I_z = \frac{2}{Z_0(4 + Z_{SC})}(V_1^i - V_3^i + V_{11}{}^i - V_{12}{}^i + V_{SC}{}^i)$$

The conceptual TLM approach employs a 3D mesh. The memory space and CPU time required often become excessive, in particular for large and complicated structure. In [4], it is shown that 2D array of 3D SCN nodes instead of 3D array of 3D SCN nodes can be used to analyze guided wave structures. The concept is based on the fact that guiding structure is characterized by propagating modes, which are described by $\exp(-j\beta\Delta_z)$, where β is the propagation constant. Hence for a specific mode, the fields at plane $z = z_1$and $z = z_2$ have only a phase difference of $\beta(z_2 - z_1)$. So, the relation between reflected voltage impulse of the node at the time kΔt and the incident voltage impulse of the node at time (k+1)Δt on the line in z direction are given by

$$\begin{aligned}
{}_{k+1}V_8^i &= \exp(-j\beta\Delta_z)\,{}_kV_4^r \\
{}_{k+1}V_8^i &= \exp(-j\beta\Delta_z)\,{}_kV_4^r \\
{}_{k+1}V_2^i &= \exp(-j\beta\Delta_z)\,{}_kV_9^r \\
{}_{k+1}V_4^i &= \exp(-j\beta\Delta_z)\,{}_kV_8^r
\end{aligned}$$

Where, ${}_kV_4^r, {}_kV_2^r, {}_kV_9^r, {}_kV_8^r$ and ${}_{k+1}V_4^i, {}_{k+1}V_2^i, {}_{k+1}V_9^i, {}_{k+1}V_8^i$ are the reflected voltages at the time kΔt and the incident voltages at times (k+1)Δt, respectively, on lines 4,2,9,8 and Δ_z is unit cell spacing in z –direction.

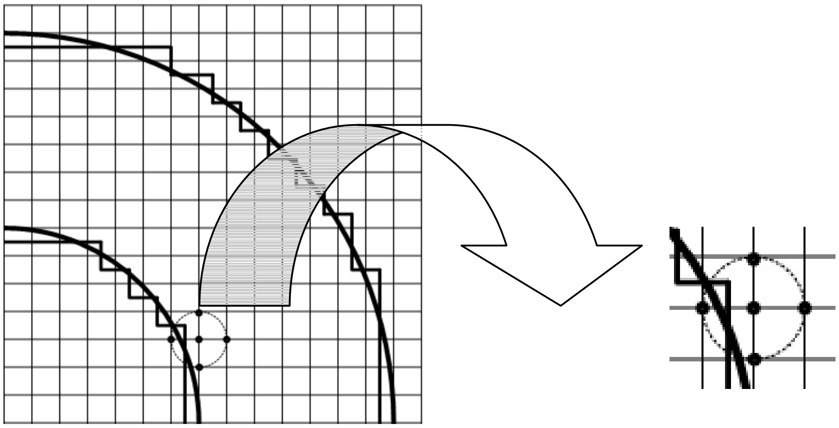


Fig. 4 Implementation of circular boundaries

The staircase approximation has been used in implementing circular boundary condition. The algorithm for applying boundary condition for coaxial line case has been explained in Fig.4. In this approach first of all, the positions of all the node point inside the ring is determined and then each node point (calling test node) inside the ring is examined if any link lines of the test node are crossing the circular periphery. This is achieved by calculating the distance of each of its 4 surrounding nodes from the centre. When the nodes whose distances from centre of the circle is less than radius of the circle, the boundary condition is required to apply between the link lines of these node and test node.

RESULTS AND DISCUSSION

To obtain dispersion characteristics of any structure, first of all a fixed value of propagation constant (β) is chosen and the corresponding frequencies of different modes is extracted from Fourier transform of time response. Modal spectrum of single strip line for beta =500 is shown in Fig, 5. Various peaks in the figure correspond to guided modes in the structure. Effective permittivity $(\beta / k_o)^2$ for dominant as well as higher order modes is plotted in Fig. 6 respectively. In case of coupled line, two modes (even and odd) will be propagating through the structure corresponding to magnetic wall & electric wall respectively.

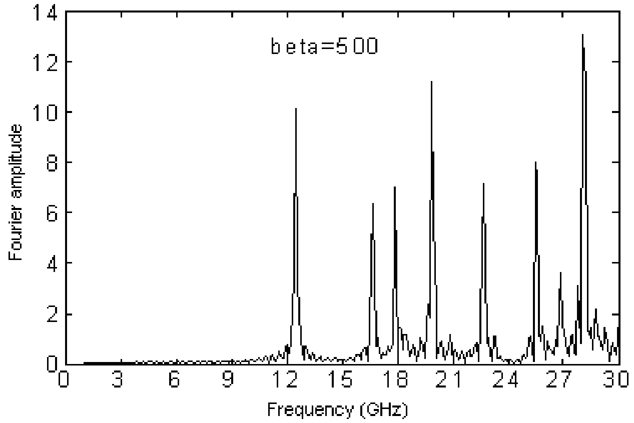
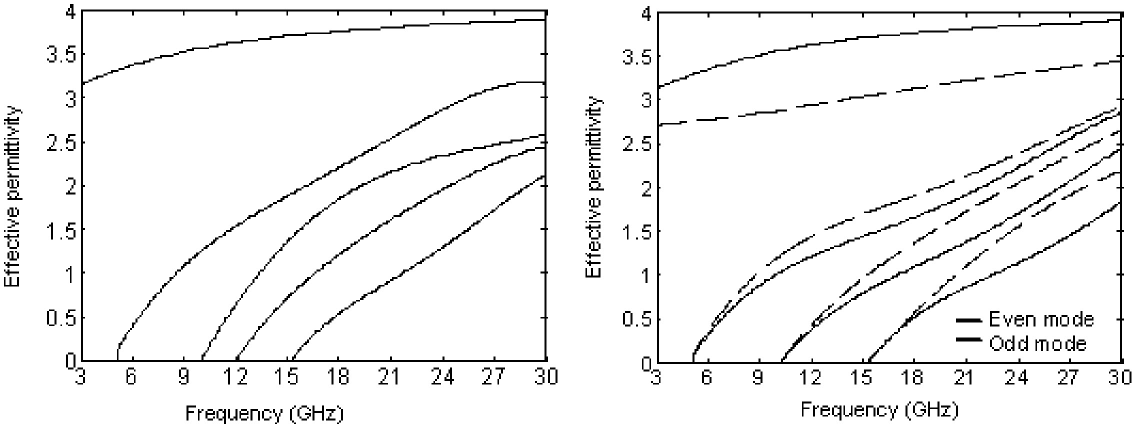


Fig.5. Modal Spectrum obtained by TLM code for single cylindrical stripline (beta=500).



(a) (b)

Fig.6. (a) Effective permittivity [(ß/ko)^2] for cylindrical single stripline (Fig.1a) a=0.5 cm, b=1.0 cm, c=0.7 cm, 2α=45°, ε_{r1}=4.0, ε_{r2}=1.0. (b) Effective permittivity [(ß/ko)^2] for cylindrical coupled stripline (Fig. 1b) a=0.5 cm, b=1.0 cm, c=0.7 cm, 2α=45°, 2γ=11.25°,ε_{r1}=4.0, ε_{r2}=1.0.

CONCLUSION

TLM method generates large amount of information in one single computation. The characteristics of the dominant as well as higher order modes corresponding to any arbitrary excitation besides the impulse response of the structure are accessible through Fourier transform. TLM program for analyzing single and coupled circular strip line in multi dielectric coaxial waveguide environment is developed. Dispersion characteristics for dominant and as well as higher order modes for the same are obtained.

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