CHARACTERIZATION OF ASYMMETRIC MICROSTRIP TRANSMISSION LINES ON MULTILAYERS WITH FR-4 COMPOSITE OVERLAY

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Abstract:
The method of lines (MoL) is used in this work to analyze two coupled asymmetric microstrip lines with an overlay. The material of the overlay is chosen to be FR-4 composite with relative permittivity of 4.3. The FR-4 composite is assumed to be lossless is this work. The height and the width of the overlay are varied to investigate their effect on the effective dielectric constants of the coupled microstrip lines. The normalized phase velocities of the dominant modes (c and π-modes) are shown as functions of the frequency up to 100GHz.

Formulation of the Problem

The detailed analysis of applying the method of lines (MoL) to the microstrip lines is given in [1]-[2]. In this work, the MoL is used to characterize two asymmetric coupled microstrip lines on dielectric multilayers with an overlay on the metallic strips, see Fig. 1. The method of lines is adapted to analyze inhomogeneous dielectric layers [1]-[2]. The procedure of the hybrid-mode analysis starts by solving the Helmholtz equation and the Sturm-Liouville differential equation [1]. The wave field can be determined from the two vector potentials Π_e and Π_h which have only one component in the x-direction. The wave is assumed to propagate in the z-direction, see Fig. 1. Thus the fields are given by [1]:

$$E = \frac{\nabla \times \nabla \times \Pi_e}{\varepsilon_r(x)} - jk_o \nabla \times \Pi_h \tag{1a}$$

and

$$\eta_o H = jk_o \nabla \times \Pi_e + \nabla \times \nabla \times \Pi_h \tag{1b}$$

where $k_o = \omega\sqrt{\mu_o \varepsilon_o}$ and $\eta_o = \sqrt{\mu_o / \varepsilon_o}$. The vector potential for the LSM modes is given by:

$$\Pi_e = \psi_e \frac{\exp(-jk_z z)}{k_o^2} a_x \tag{2a}$$

and for the LSE modes is given by

$$\Pi_h = \psi_h \frac{\exp(-jk_z z)}{k_o^2} a_x \tag{2b}$$

where a_x is unit vector in the x-direction. The propagation constant is given by k_z. The scalar potentials ψ_h and ψ_e must fulfill the Helmholtz equation and the Sturm-Liouville differential equation, respectively, [1] as:

$$\frac{\partial^2 \psi_h}{\partial x^2} + \frac{\partial^2 \psi_h}{\partial y^2} + \left(\varepsilon_r(x) k_o^2 - k_z^2\right)\psi_h = 0 \tag{3a}$$

and

$$\varepsilon_r(x) \frac{\partial}{\partial x}\left(\frac{1}{\varepsilon_r(x)} \frac{\partial \psi_e}{\partial x}\right) + \frac{\partial^2 \psi_e}{\partial y^2} + \left(\varepsilon_r(x) k_o^2 - k_z^2\right)\psi_e = 0 \tag{3b}$$

A comprehensive description and detailed formulation of the technique is given in [1]. The effective dielectric constants of the dominant modes are obtained by solving the following equation:

$$[Z]\,[J] = [0] \tag{4}$$

in which the elements of the matrix [Z] are functions of the frequency, the propagation constant k_z, and the characteristics of the different dielectric layers. The vector [J] contains the current densities on the metallic strips (J_{xm} and J_{zm}). The effective dielectric constant (ε_{re}) is varied until the determinant of the system matrix (4) vanishes. The eigenvectors of system (4) (for each eigenvalue ε_{re}) are the current densities on the strips for each mode. All the electric and magnetic field components can be calculated [1].

Numerical Results

The configuration of the two asymmetric coupled microstrip lines is given in Fig.1. The metallic strips are assumed to have zero thickness. The total height of the substrate is H=1.3mm and the relative permittivity is ε_r=10.5 (DI-CLAD 810 [3]). The widths of the metallic strips are W1=1.2mm and W2=2.0mm. The separation between the strips is S=1.0mm. The normalized propagation constants of the dominant modes (c and π-modes) are plotted versus the frequency in Fig.2. The total number of magnetic lines is 51, the number of magnetic lines on the strips are 5 and 8, and the discretization distance is h=0.266666mm. The results obtained using the MoL are compared with those obtained using the Spectral Domain Approach (Fig.3 in [3]). The results in Fig.2 show good agreement between the MoL and the SDA [3]. An overlay made of FR-4 composite is put on the two asymmetric microstrip lines, see Fig.1. The dielectric constant of the FR-4 is ε_{r3}=4.3 and it is assumed to be lossless [4]. The width of the overlay is chosen to be T=4.5333mm. The height of the overlay (H3) is varied from zero (no overlay) to 2H, (H=1.3 mm). The effect of varying the overlay height on the effective dielectric constants of the dominant modes at f=1GHz is shown in Fig.3. The results show that the effective dielectric constants of the dominant modes slightly change as the height of the overlay is about 2H. The normalized phase velocities of the dominant modes are plotted versus the frequency in Fig.4, where the height of the overlay is chosen to be H3=0.65mm. The difference between the phase velocities of the dominant modes is smaller when an overlay is used as shown in Fig.4. This difference is expected to get smaller as the height of the overlay is larger than the total height of the substrate H (H=1.3mm), see Fig.3. The width of the overlay is varied from zero (no overlay) to full layer of FR-4 composite with H3=0.65mm. In Fig.5, the effective dielectric constants of the dominant modes are plotted versus the width of the overlay at f=1GHz. The results show that the effective dielectric constants slightly change as the width of the overlay is about 30h, see Fig.5.

Conclusions

The overlay has significant impact on the phase velocities of the dominant modes of the two asymmetric coupled microstrip lines. The FR-4 composite is chosen as an overlay for its low cost. The results show that the difference between the phase velocities of the c and π-modes is smaller when an overlay is used. This phenomena can be used to decrease pulse distortion in the coupled microstrip lines.

Acknowledgment

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References

[1] R. Pregla and W. Pascher, "The Method of Lines," in Numerical Techniques for Microwave and Millimeter Wave Passive Structures, T. Itoh, Ed. New York: Wiley, pp.381-446, 1989.

[2] R. Pregla, M. Koch, and W. Pascher, "Analysis of Hybrid Waveguide Structures consisting of Microstrips and Dielectric Waveguides," Proceedings 17th European Microwave Conference, pp. 927-932, 1987.

[3] Y. Qian and E. Yamashita, "Characterization of Picosecond Pulse Crosstalk Between Coupled Microstrip Lines with Arbitrary Conductor Width," IEEE Trans. on Microwave Theory and Tech., Vol. MTT-41, pp. 1011-1016, No.6/7, June/July, 1993.

[4] B. C. Wadell, Transmission Line Design Handbook, Chapter 9, pp. 431-451, Artech House, Inc., 1991.

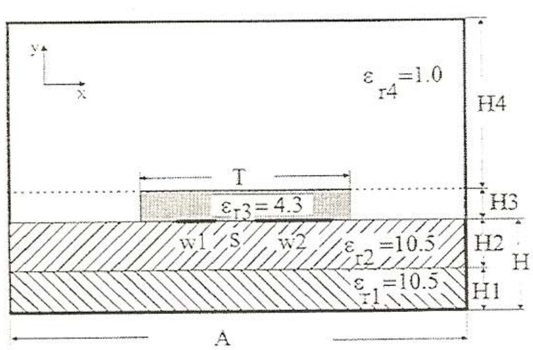


Fig. 1. Two asymmetric coupled microstrip lines with an overlay, W1 = 1.2 mm, W2 = 2.0 mm, S = 1.0 mm, H = H1+H2 = 1.3 mm, H4 = 20.0 mm, and A = 13.8666 mm.

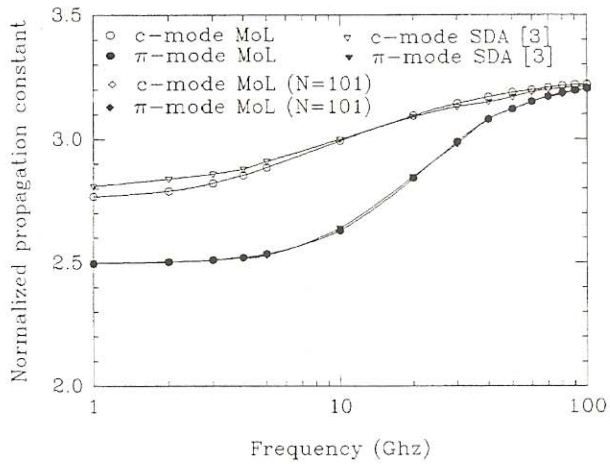


Fig. 2. The normalized propagation constants of the c and π-modes versus the frequency using the MoL (this work) and the SDA [3], W1=1.2mm, W2=2.0mm, S=1.0mm, H=H1+H2=1.3mm, $\varepsilon_{r1}=\varepsilon_{r2}=10.5$ (DI-CLAD 810), H3=0.0 (no overlay), and H4=20.0mm.

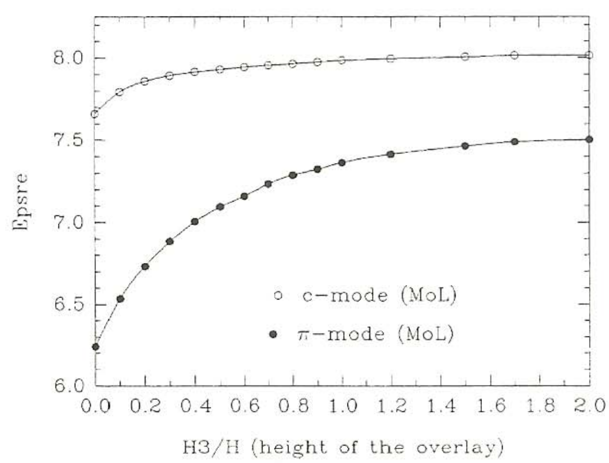


Fig. 3. The effective dielectric constants versus the height of the FR-4 overlay (H3), W1=1.2mm, W2=2.0mm, S=1.0mm, H=H1+H2=1.3mm, $\varepsilon_{r1}=\varepsilon_{r2}=10.5$ (DI-CLAD 810), T=4.5333mm, $\varepsilon_{r3}=4.3$ (FR-4 composite), H4=20.0mm, and f=1GHz.

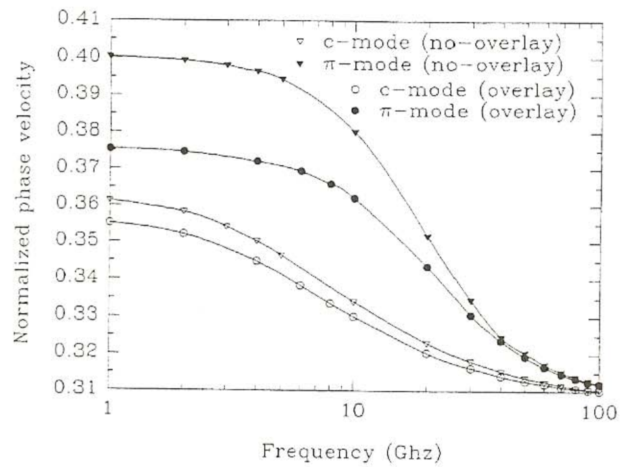


Fig. 4. The normalized phase velocities versus the frequency, W1=1.2 mm, W2=2.0mm, S=1.0mm, H=H1+H2=1.3mm, $\varepsilon_{r1}=\varepsilon_{r2}=10.5$ (DI-CLAD 810), H3=0.65mm, T=4.5333mm, $\varepsilon_{r3}=4.3$ (FR-4 composite), and H4=20.0mm.

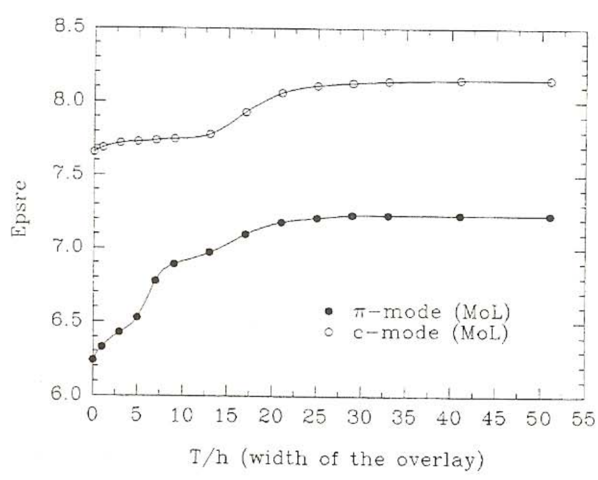
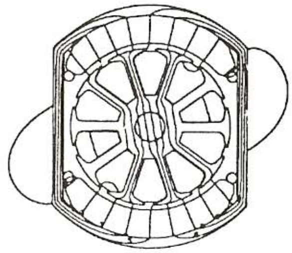
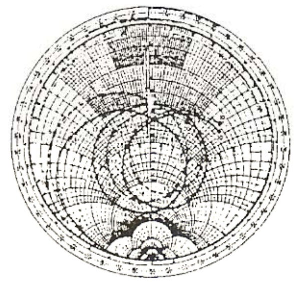
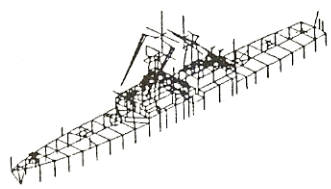
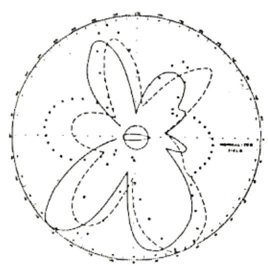


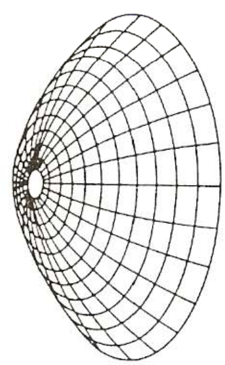
Fig. 5. The effective dielectric constants versus the width of the FR-4 overlay (T), h=0.266666mm (discretization distance), W1=1.2mm, W2=2.0mm, S=1.0mm, H=H1+H2=1.3mm, $\varepsilon_{r1}=\varepsilon_{r2}=10.5$ (DI-CLAD 810), H3=0.65mm, $\varepsilon_{r3}=4.3$ (FR-4 composite), H4=20.0mm, and f=1GHz.











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