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

Magda El-Shewaee and Hai-Young Lee
Pacific States University
College of Electrical Engineering and Computer Science
E-mail: eerdeem@engunrv.unl.edu

"Aju University
School of Electrical and Electronics Engineering
Suwon, South Korea

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. 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 \( \Pi_0 \) and \( \Pi_1 \) which have only one component in the z-direction. The wave is assumed to propagate in the z-direction, see Fig. 1. Thus the fields are given by [1]:

\[
E = \frac{\nabla \times \nabla \times \Pi_0}{\epsilon_r(x)} - jk_0 \nabla \times \Pi_1
\]  

(1a)
and

$$\eta \cdot H = jk\cdot \nabla \times \Pi + \nabla \times \nabla \times \Pi$$  \hspace{1cm} (1b)

where \( k = \omega \sqrt{\mu / \varepsilon} \) and \( \eta = \sqrt{\mu / \varepsilon} \). The vector potential for the LSM modes is given by:

$$\Pi = \psi_s \frac{\exp(-jk_s z)}{k_s} a_s$$  \hspace{1cm} (2a)

and for the LSE modes is given by

$$\Pi = \psi_s \frac{\exp(-jk_e z)}{k_e} a_s$$  \hspace{1cm} (2b)

where \( a_s \) is unit vector in the \( z \)-direction. The propagation constant is given by \( k \). The scalar potentials \( \psi_s \) and \( \psi_e \) must fulfill the Helmholtz equation and the Sturm-Liouville differential equation, respectively, \([1]\) as:

$$\frac{d^2 \psi_s}{dx^2} + \frac{d^2 \psi_s}{dy^2} + (\varepsilon_s(x)k_s^2 - k_l^2)\psi_s = 0$$  \hspace{1cm} (3a)

and

$$\varepsilon_e(x) \frac{d^2 (1 / \varepsilon_e(x) \frac{d\psi}{dx})}{dx^2} + \frac{d^2 \psi}{dy^2} + (\varepsilon_e(x)k_e^2 - k_l^2)\psi_e = 0$$  \hspace{1cm} (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:

$$[Z] [J] = [0]$$  \hspace{1cm} (4)

in which the elements of the matrix \([Z]\) are functions of the frequency, the propagation constant \( k \), and the characteristics of the different dielectric layers. The vector \([J]\) contains the current densities on the metallic strips (\( J_{XM} \) and \( J_{XM} \)). The effective dielectric constant \((\varepsilon_{TE})\) is varied until the determinant of the system matrix \((4)\) vanishes. The eigenvectors of system \((4)\) (for each eigenvalue \( \varepsilon_{TE} \)) 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 \( \varepsilon_r = 10.5 \) (DI-CLAD 810 [3]). The widths of the metallic strips are \( W_1 = 1.2\text{mm} \) and \( W_2 = 2.0\text{mm} \). The separation between the strips is \( S = 1.0\text{mm} \). The normalized propagation constants of the dominant modes (\( \alpha \) and \( \pi \)-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 3 and 8, and the discretization distance is \( h = 0.266666\text{mm} \). 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 \( \varepsilon_{r,2} = 4.3 \) and it is assumed to be lossless [4]. The width of the overlay is chosen to be \( T = 4.5333\text{mm} \). 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 \( f = 1\text{GHz} \) 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 \( f = 1\text{GHz} \). 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 \( \alpha \) and \( \pi \)-modes is smaller when an overlay is used. This phenomena can be used to decrease pulse distortion in the coupled microstrip lines.
Acknowledgment

This work is supported by the Korean Science and Engineering Foundation (KOSEF) under a fellowship program. It is conducted in the Microwave Applications Laboratory, School of Electrical and Electronics Engineering, Ajou University, Suwon, Korea.

References


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 $\pi$-modes versus the frequency using the MoL (this work) and the SDA [3]. $W_1=1.2\text{mm}$, $W_2=2.0\text{mm}$, $S=1.0\text{mm}$, $H=H_1+H_2=1.3\text{mm}$, $\varepsilon_r_1=\varepsilon_r_2=10.5$ (D1-CLAD 810), $H_3=0.0$ (no overlay), and $H_4=20.0\text{mm}$.

Fig. 3. The effective dielectric constants versus the height of the FR-4 overlay ($H_3$). $W_1=1.2\text{mm}$, $W_2=2.0\text{mm}$, $S=1.0\text{mm}$, $H=H_1+H_2=1.3\text{mm}$, $\varepsilon_r_1=\varepsilon_r_2=10.5$ (D1-CLAD 810), $T=4.5333\text{mm}$, $\varepsilon_r_3=4.3$ (FR-4 composite), $H_4=20.0\text{mm}$, and $f=1\text{GHz}$. 
Fig. 4. The normalized phase velocities versus the frequency, \( W_1=1.2 \text{ mm}, W_2=2.0 \text{ mm}, S=1.0 \text{ mm}, H=H_1+H_2=1.3 \text{ mm}, \) 
\( \varepsilon_{r_1}^{\pi} \varepsilon_{r_2}=10.3 \) (DI-CLAD 810), \( H_3=0.65 \text{ mm}, T=4.5333 \text{ mm}, \varepsilon_{r_3}=4.3 \) (FR-4 composite), and \( H_4=20.0 \text{ mm}. \)

Fig. 5. The effective dielectric constants versus the width of the FR-4 overlay \( (T), h=0.266666 \text{ mm} \) (discretization distance), \( W_1=1.2 \text{ mm}, W_2=2.0 \text{ mm}, S=1.0 \text{ mm}, H=H_1+H_2=1.3 \text{ mm}, \varepsilon_{r_1}^{\varepsilon_{r_2}}=16.5 \) (DI-CLAD 810), \( H_3=0.65 \text{ mm}, \varepsilon_{r_3}=4.3 \) (FR-4 composite), \( H_4=20.0 \text{ mm}, \) and \( f=1 \text{ GHz}. \)
13th Annual Review of Progress in
APPLIED
COMPUTATIONAL
ELECTROMAGNETICS
at the
Naval Postgraduate School
Monterey, CA

March 17-21, 1997

CONFERENCE PROCEEDINGS
CONFERENCE PROCEEDINGS

VOLUME II

13th Annual Review of Progress in
APPLIED
COMPUTATIONAL
ELECTROMAGNETICS

at the
Naval Postgraduate School
Monterey, CA
March 17-21, 1997

TECHNICAL PROGRAM CHAIRMAN

Eric C. Michielsen

Sponsored by

The Applied Computational Electromagnetics Society
Naval Postgraduate School, DOE/LLNL, University of Illinois, University of Kentucky,
USAF, DOD AND DOE IN COOPERATION WITH IEEE, URSI, ASEE, SIAM AND AMTA

THE NAVAL POSTGRADUATE SCHOOL
SESSION 21: PLANAR ANTENNAS AND CIRCUITS  
Chairs: Guy Van Den Bosch and Niels Faché

"A Full-Wave Electromagnetic Simulation Technology for the Analysis of Planar Circuits"  
N. Faché ........................................................................................................... 1227

"Analysis of Metal Patches, Strips and Corrugations Inside Cylindrical Multilayer Structures by Using G1DMULT", Z. Šipuš, P.-S. Kildal and S. Raffaelli .................................................. 1235

"A Numerical Algorithm G1DMULT for Computing Green's Function of Multilayer Objects"  
P.-S. Kildal, Z. Šipuš and M. Johansson .......................................................... 1242

"Fast Moment Method Algorithm for Electromagnetic Scattering by Finite Strip Array on Dielectric Slab", B. Popovski, B. Spasenovski and J. Bartolic ........................................... 1250

"Optimization of Various Printed Antennas Using Genetic Algorithm: Applications and Examples", M. Hamdi and J.P. Daniel .......................................................... 1258

"Characterization of Asymmetric Microstrip Transmission Lines on Multilayers with FR-4 Composite Overlay", M. El-Shenawee and H.-Y. Lee .............................................. 1266

SESSION 22: SCATTERING  
Chairs: Jianming Jin and Atif Elsherbeni

"RCS and Antenna Modeling with MOM Using Hybrid Meshes"  
J.M. Putnam and J.D. Kolziiski ........................................................................... 1274

"Application of Moment Method Solutions to RCS Measurement Error Mitigation"  
J. Stach ............................................................................................................. 1282

"Scattering from Arbitrarily Shaped Cylinders by Use of Characteristic Modes"  
G. Amendola, G. Anguillì and G. Di Massa ...................................................... 1290

"A High Order Solver for Problems of Scattering by Heterogeneous Bodies"  
O.P. Bruno and A. Sen 7 ................................................................................. 1296

"Electromagnetic Scattering from Eccentric Cylinders at Oblique Incidence"  
H.A. Yousef and A.Z. Elsherbeni ....................................................................... 1303

"Iterative Technique for Scattering and Propagation Over Arbitrary Environments"  
O.M. Conde and M.F. Catedra ........................................................................... 1310


"Effects of Multiple Scattering in Photon Correlation Spectroscopy"  
V.I. Ovad, D.W. MacKowski, D.F. Nicoll and R. Firsty ..................................... 1326

"Fictitious Domain Method for Calculating the Radar Cross Section"  
F. Millot and F. Collina .................................................................................. 1342