Coupling Between Slotlines Through a Conductor Backing

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***Abstract*— Leakage phenomena possible in conductor-backed slotlines were investigated through an analysis of coupled lines. Coupling between two slotlines with a finite width of conductor backing was examined. Obtained propagation constants for two modes of the coupled slotline confirm that coupling is caused by leakage through the conductor backing.**

I. Introduction

COPLANAR waveguides (CPW's) and slotlines have been attracting an increasing attention in recent years as basic elements for uniplanar MMIC's. Among their distinctive characteristics, leakage phenomena in conductor-backed CPW's or slotlines have drawn a significant amount of interest [1]–[4]. It has been reported that a propagation constant becomes complex for such an infinite structure and that attenuation occurs due to leakage in the form of a parallel plate mode .

It has not been reported, however, how such transmission lines couple each other. If any coupling between distant transmission lines are found, it will make another proof of leakage in the conductor-backed structures.

In this letter, two slotlines coupled by means of a leakage due to conductor backing are analyzed by means of the spectral domain method. As shown in Fig. 1, the conductor backing is provided only between the slotlines. Hence, the leakage in the form of a parallel plate mode is expected to exist only between the slotlines. Since the coupled-line as a whole is not leaky, the placement of two end walls at distances reasonably away from the slotlines would not affect significantly the analysis of the coupling phenomena by the leakage mechanism. The structure then becomes a shielded one for simplification of computation. On the other hand, if one intends to investigate a single conductor backed slotline, the shielded structure cannot be used for analysis, but a laterally open configuration must be used in order to account for the leakage phenomena which makes the propagation constant complex.

II. Analysis

The coupled structure analyzed here is shown in Fig. 1. Two parallel slotlines are located on one side of the substrate and

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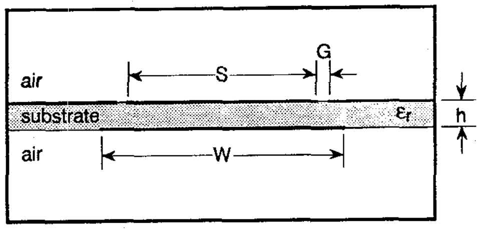

Fig. 1. Structure of coupled slotlines with a conductor backing.

they are backed by a strip conductor on the other side. This structure was analyzed using spectral domain approach [5]. Field equations used are

$$\begin{bmatrix} \tilde{J}_{x12} \\ \tilde{J}_{z12} \\ \tilde{E}_{x23} \\ \tilde{E}_{z23} \end{bmatrix} = \begin{bmatrix} \tilde{Y}_{xx} & \tilde{Y}_{xz} & \tilde{A}_{xx} & \tilde{A}_{xz} \\ \tilde{Y}_{zx} & \tilde{Y}_{zz} & \tilde{A}_{zx} & \tilde{A}_{zz} \\ \tilde{B}_{xx} & \tilde{B}_{xz} & \tilde{Z}_{xx} & \tilde{Z}_{xz} \\ \tilde{B}_{zx} & \tilde{B}_{zz} & \tilde{Z}_{zx} & \tilde{Z}_{zz} \end{bmatrix} \begin{bmatrix} \tilde{E}_{x12} \\ \tilde{E}_{z12} \\ \tilde{J}_{x23} \\ \tilde{J}_{z23} \end{bmatrix},$$

where E_{x12} and E_{z12} are electric field between the slots, J_{x23} and J_{z23} are currents on the conductor backing, E_{x23} and E_{z23} are electric field on the bottom of the substrate, and J_{x12} and J_{z12} are currents on the top conductor. Tildes ($\tilde{}$) indicate that quantities with them are Fourier-transformed.

The substrate used in the calculations are 0.635 mm in thickness and its relative dielectric constant is 2.5. Slotline width G is 0.2 mm. Line separation S was fixed at 20 mm, where there is almost no coupling without the backing conductor. The currents on the wide conductor, J_{x23} and J_{z23} , were expanded by five basis functions in Galerkin's procedure, while electric fields between the narrow slots were expressed by only one function.

III. Results

The difference of the effective dielectric constants of CPW and coupled slotline modes is used as an indication of the coupling. The difference is smaller if the lines are uncoupled and is larger if coupled. The structure in Fig. 1 can support several modes in addition to the CPW and coupled slotline modes as shown in Fig. 2. Mode 1 is a dominant microstrip mode while Mode 3 is the CPW mode. Modes 2 and 4 requires clarifications. They are formed by the coupling of the second microstrip mode for the limiting case of vanishing slots ($G = 0$) with the coupled slot mode in the limiting case of $W = 0$. Around $W = 14$ mm, they are coupled to form a pair of Modes 2 and 4. Note that the CPW mode do not take part in the coupling with second microstrip mode because their field symmetries are orthogonal. For $W < 14$ mm, Mode 2 has a characteristic of the coupled slot mode and Mode 4 has

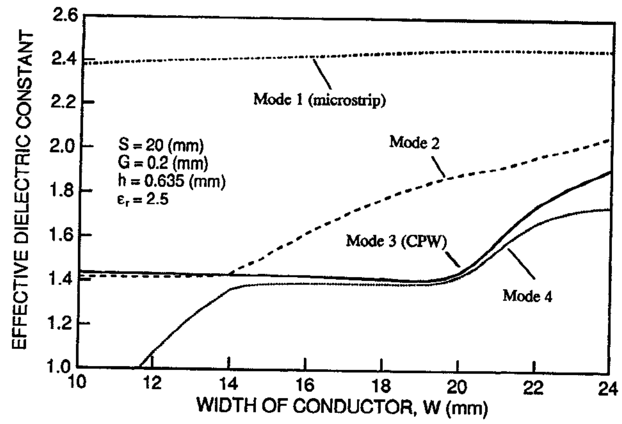

Fig. 2. Calculated effective dielectric constants for the conductor-backed coupled slotlines. Width of the backing conductor W is changed.

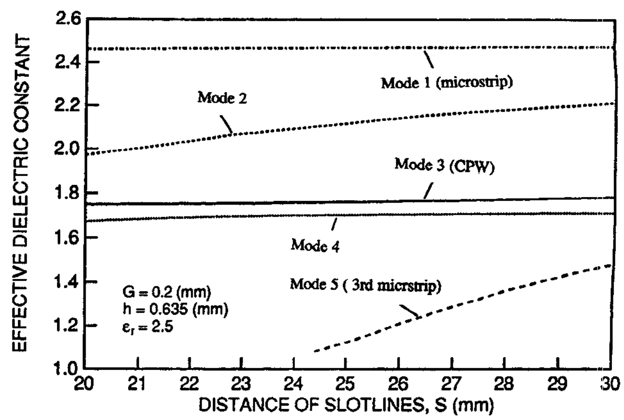

Fig. 3. Calculated effective dielectric constants for the conductor-backed coupled slotlines. Line separation S is increased keeping $W = S + 2$ (mm).

that of the second microstrip mode. On the other hand, for $W > 14$ mm, Mode 2 exhibit a characteristic of the second microstrip mode and Mode 4 that of the coupled slot mode.

According to this discussion, the effective dielectric constants of the CPW mode (Mode 3) and the coupled slot mode (Mode 2) are close to each other for $W < 14$ mm and hence the coupling between these two lines is small. On the other hand, for $W > 14$ mm, the difference of the effective dielectric constants of the CPW mode and the coupled slot mode (Mode 4) is small, indicating negligible coupling until W exceeds 20 mm when the effective dielectric constants of Modes 3 and 4 suddenly increase as well as their difference. Hence, for $W > 20$ mm, the two slotlines are coupled to each other. The coupling is due to the presence of the conductor backing extended to cover the two slots.

In Fig. 3, the line separation S is increased keeping the backing conductor width W larger by 2 mm than S. Note that the difference of effective dielectric constants for CPW mode and coupled slot mode is maintained even if line separation is increased. This clearly shows the coupling between the slotlines are not due to proximity effect but to the presence of the conductor backing.

In the structure shown in Fig. 1, the energy will leak to the other slotline through the parallel plate mode when one tries to excite one of the slotlines. The parallel plate mode traveling back and forth between the slotlines is the main ingredient of the microstrip type modes in the letter.

IV. Conclusion

Leakage phenomena in conductor-backed slotlines have been investigated by means of calculation of propagation constants for coupled slotlines. It has been shown that slotlines separated by a large distance couple each other when a conductor backing covers the area between two slots. It also has been found that the coupling does not get weakened by larger line separation. These results indicated the coupling is caused by leakage through the conductor backing.

The method used here to investigate leakage phenomena needs much simpler calculations than ever because only real propagation constants are dealt with.

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