STUDY OF NON-LEAKY COPLANAR (NLC) WAVEGUIDE DISCONTINUITIES

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ABSTRACT

The discontinuities of non-leaky coplanar (NLC) waveguide is analyzed by using the extended spectral domain approach. It is found that the SMA-to-NLC transition will cause power leakage during experiment. Except for the small leakage, the theoretical and experimental results agree well.

I. INTRODUCTION

The conductor-backed coplanar waveguide (CBCPW) provides superior mechanical strength and heat sinking abilities than conventional CPW's. The inherent characteristic of power leakage in terms of the parallel plate wave makes, however, the CBCPW an impractical wave guiding structure[1]. It will cause the unwanted crosstalk and package effects. Therefore, how to suppress the power leakage is an important step to make the CBCPW practical and useful. Recently, some effort has been done to study the origin and leakage control of uniform CBCPW's [2]-[4]. The non-leaky coplanar (NLC) waveguide (Fig. 1(a)) proposed in [2] has the benefits of easy fabrication, good dimensional tolerance and high mechanical strength. The one with an additional bottom layer is especially suitable for MMIC's because it is easy to add the air-bridge if necessary.

In real circuits, the discontinuities of transmission lines are inevitable. The effects of discontinuities on those non-leaky structures should be evaluated. This paper is devoted to study the symmetrical and asymmetrical one port discontinuities of the NLC waveguide. The air-bridge is added to the asymmetrical structure to suppress the coupled slotline (CSL) mode. The extended three dimensional spectral domain approach is employed to simulate the circuit performance. Experimental results are compared with those of simulation.

II. NUMERICAL TECHNIQUE

The NLC waveguide discontinuity shown in Fig. 1(b) is analyzed by using the extended spectral domain approach. The substrate and metallization is assumed to be infinite in extent and the conductor loss is neglected. The three dimensional Green's function is derived first [5], and the air-bridge is modeled as two rectangular posts connected by a conductor strip with negligible thickness. Since the air-bridge is very small compared with the guide wavelength, the current flowing on it is assumed to be only the one dimensional lineal current. The z dependence of vertical current elements is integrated analytically and manipulated into decayed functions in spectral variables. Moreover both transverse and longitudinal slot field components are taking into account.

The method of moment is then used to generate a set of linear equations. From the solution of the deterministic equation, the scattering parameters and electrical field/current distributions can be solved. The CPW (even) mode is the one which can be launched and measured in our measurement setup. In addition to the scattered CPW mode, it will also, nevertheless, excite the CSL (odd) mode for the asymmetrical discontinuity. This excited CSL mode will be reflected back to the discontinuity by the SMA connector [6] and generates the CSL-to-CPW mode conversion. Therefore two independent excitations are needed to completely characterize the 2x2 S parameters of the asymmetrical circuit

$$\begin{bmatrix} S_{11}^{ee} & S_{11}^{eo} \\ S_{11}^{oe} & S_{11}^{oo} \end{bmatrix} \tag{1}$$

Here, for example, S_{11}^{ee} and S_{11}^{oe} are the S parameters of reflected even and odd modes due to the even mode excitation. The measured S parameter can be related to the theoretical ones by

$$S_{11} = S_{11}^{ee} - \frac{S_{11}^{eo} S_{11}^{oe}}{e^{-j\beta_o d} + S_{11}^{oo}} \tag{2}$$

where $\beta_o d$ is the phase delay for the CSL wave scattered from and reflected back to the reference plane.

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For the symmetrical discontinuity, only the S_{11}^{ee} is calculated since it will not excite the CSL mode for the CPW incident wave.

III. RESULTS

The tested circuits are symmetrical and asymmetrical perturbations of the NLC short circuit. Fig. 2 is the theoretical and measured S parameters of the symmetrical case. The trend for both curves is basically the same. The deviation of the power level is considered due to circuit loss. From the theoretical results, this discontinuity does not seem to cause leakage. However there are noticeable small ripples in the measured data. These ripples come from the leakage caused by some discontinuities most likely the SMA-to-NLC transition. This point will be clear in the subsequent experimental studies. Fig. 3 shows the calculated and measured S parameters of the asymmetrical NLC discontinuity with the air-bridge. It is evident that S_{11}^{oe} is much smaller than that of S_{11}^{ee} and S_{11}^{oo}. Therefore the contribution of the second term in Eq. (2) is so small that the measured S_{11} is close to S_{11}^{ee}. There are still some ripples in the measured data of Fig. 3.

To check if those measured ripples are caused by wave leakage, we measure these circuits with (marked as M) and without (marked as D) the surrounded absorbing material. Figs. 4 and 5 are measured results for the symmetrical and asymmetrical cases, respectively. It is clear that the ripples are eliminated after the absorbing material is applied to take away the small power leakage. Since the leakage is small, the phase term matches each other well for both situations. It is also observed that there are some common ripple positions for different measured circuits. Such ripples are considered to be caused by the same factor, i.e., the SMA-to-NLC transition. To verify this point, we measured that NLC through-line with and without absorbing material. Fig. 6 shows that this kind of transition does cause power leakage. Unless this leakage from the launcher is eliminated, it is not possible to characterize the NLC circuits exactly. Therefore different launching techniques should be studied to prevent the power leakage. By the comparison of Figs. 4, 5 and 6, we believe that most of the little leakage is caused by the SMA-to-NLC transition due to the field mismatch. However, since Fig. 6 is for a two port structure and the results depend on the line length, the locations of the ripples in this figure are not related to those in Figs. 4 and 5.

IV. CONCLUSION

The extended three dimensional spectral domain approach is used to characterize the NLC discontinuities. Except for small ripples, the theoretical and experimental data agree well. These ripples represent the little amount of power leakage most likely caused by the circuit discontinuities at the SMA-to-NLC transition. Therefore the SMA connector is not a good launcher for NLC structures since it will cause power leakage due to the field mismatch. Other launching techniques should be studied to prevent the power leakage.

ACKNOWLEDGMENT

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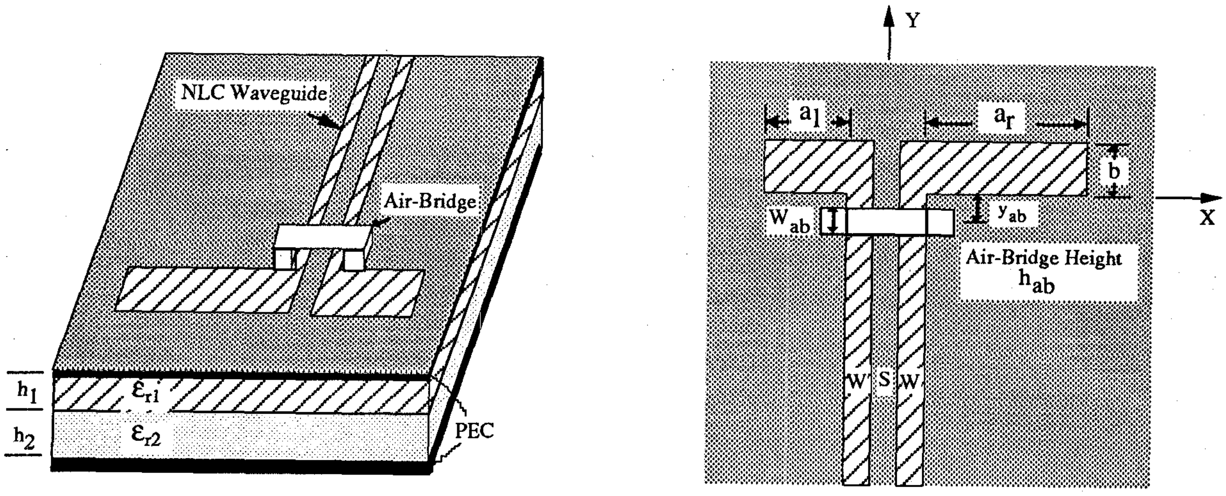

(a) (b)

Fig. 1. The non-leaky coplanar (NLC) waveguide discontinuity. (a) 3-D plot. (b) top view.

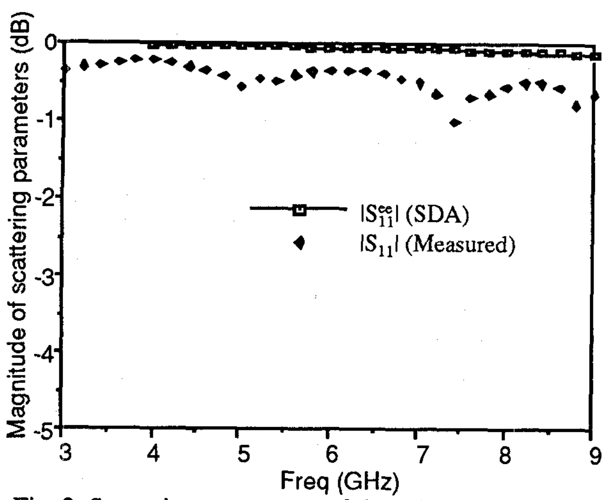

Fig. 2. Scattering parameters of the NLC symmetrical discontinuity. Circuit dimensions are $\varepsilon_{r1} = 10.8$, $\varepsilon_{r2} = 2.2$, $h_1 = 50$ mil, $h_2 = 125$ mil, s = 16 mil, w = 40 mil, $a_r = a_l = 76$ mil, b = 70 mil.

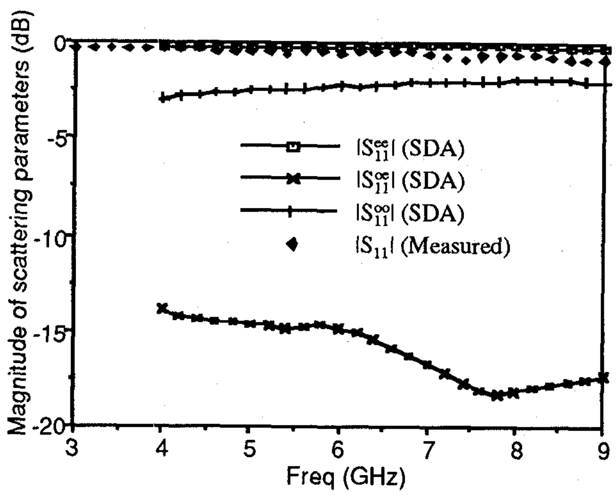

Fig. 3. Scattering parameters of the NLC asymmetrical discontinuity. Circuit dimensions are $\varepsilon_{r1} = 10.8$, $\varepsilon_{r2} = 2.2$, $h_1 = 50$ mil, $h_2 = 125$ mil, s = 16 mil, w = 40 mil, $a_r = 116$ mil, $a_l = 36$ mil, b = 70 mil, $w_{ab} = 20$ mil, $h_{ab} = 7$ mil, $y_{ab} = 10$ mil.

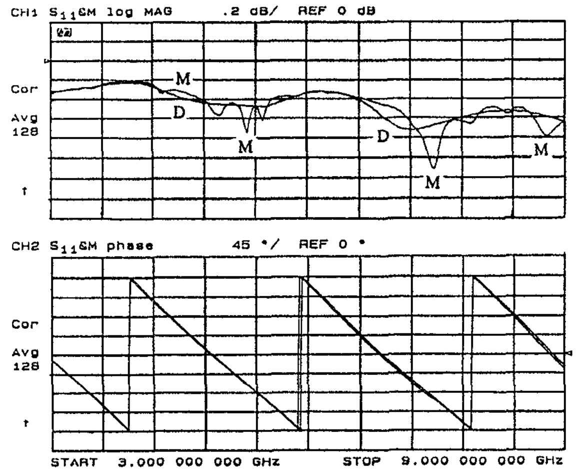

Fig. 4. Measured scattering parameters with (D) and without (M) the surrounded absorbing material for the NLC symmetrical discontinuity.

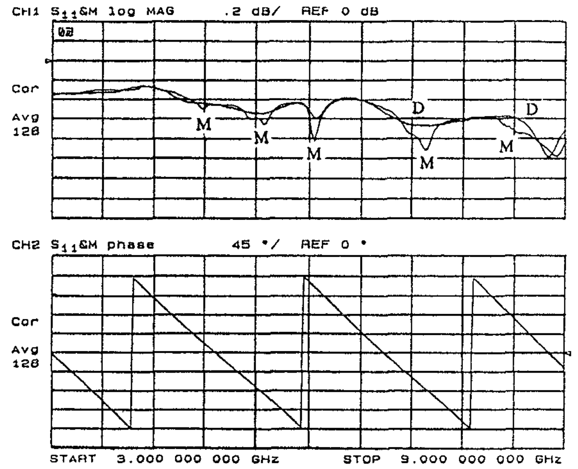

Fig. 5. Measured scattering parameters with (D) and without (M) the surrounded absorbing material for the NLC asymmetrical discontinuity.

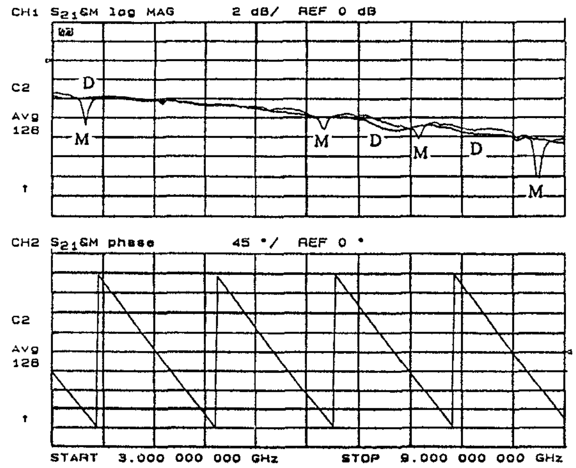

Fig. 6. Measured scattering parameters with (D) and without (M) the surrounded absorbing material for the NLC uniform through-line.