# ANALYSIS OF SHIELDED COPLANAR WAVEGUIDE STEP DISCONTINUITY CONSIDERING THE FINITE METALLIZATION THICKNESS EFFECT

Chih-Wen Kuo, Toshihide Kitazawa* and Tatsuo Itoh

Department of Electrical and Computer Engineering, The University of Texas at Austin, Austin, TX 78712
*Department of Electronic Engineering, Kitami Institute of Technology, Kitami, 090 Japan

ABSTRACT

The mode-matching technique is applied to analyze the shielded coplanar waveguide (CPW) step discontinuity. Effect of the finite thickness of the CPW center strip and ground planes is also considered. Results of the frequency-dependent scattering parameters of the shielded CPW step discontinuity incorporating the finite metallization thickness effect are presented for the first time.

## INTRODUCTION

The uniplanar transmission line structure based on the coplanar waveguide (CPW) has been proposed as a circuit structure for monolithic microwave integrated circuits (MMIC) and various circuits were developed [1]. One basic building block of these circuits is the change of width of center strip and the air gaps between the center strip and the ground planes of the CPW. Therefore, accurate analysis of the characteristics of these step discontinuities is important in designing the MMIC.

The mode-matching technique has been utilized by many researchers to analyze the step discontinuities of microstrips [2],[3] and finlines [4],[5]. With the success of the mode-matching technique in analyzing the discontinuity problems, this approach will be employed to formulate the boundary value problem of the CPW step discontinuity in this paper. Electromagnetic fields on both sides of the discontinuity are expanded by the eigenmodes of the shielded CPW. The accuracy of the mode-matching technique depends primarily on the accuracy of the eigenmodes. These eigenmodes (propagating and evanescent) are calculated by using the method in [6] which takes into account the finite thickness of the metallization and the edge condition.

Frequency-dependent scattering parameters of the shielded CPW step discontinuity is presented for the first time, with the finite metallization thickness being considered. Effect of the finite thickness on the scattering parameters is also studied.

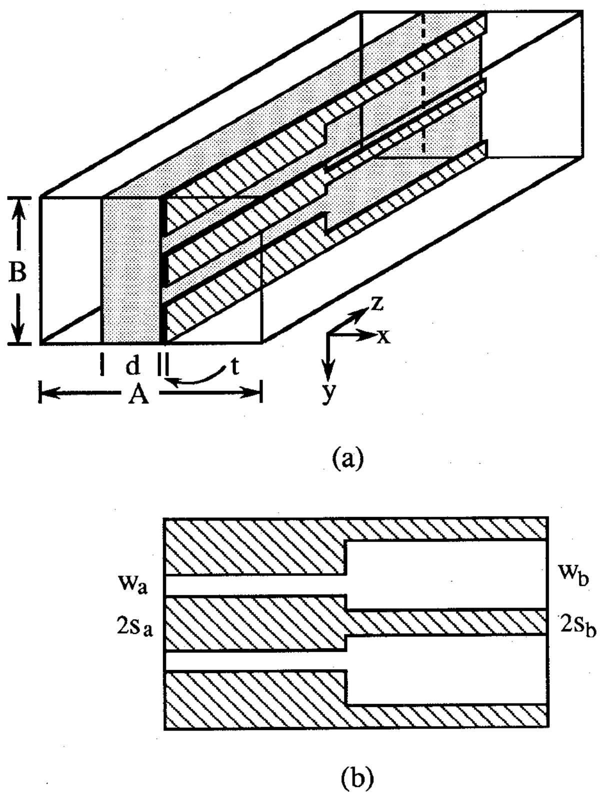


Fig. 1. (a) Shielded CPW step discontinuity including finite metallization thickness, (b) longitudinal section.

MODE MATCHING PROCEDURE

The mode-matching procedure will be described only briefly in this section. Details about the approach can be found in [7]. Fig. 1 shows the structure of the CPW step discontinuity inside a rectangular waveguide shielding. Electromagnetic fields to both sides of the discontinuity are expanded by using the eigenmodes of CPW. By matching the transverse electric and magnetic fields at the plane of discontinuity, z=0, one obtains

$$(1+\Gamma)a_1\mathbf{e}_1^a + \sum_{m=2}^{\infty} a_m\mathbf{e}_m^a = \sum_{m=1}^{\infty} b_m\mathbf{e}_m^b \qquad (1a)$$

$$(1-\Gamma)a_1\mathbf{h}_1^a - \sum_{m=2}^{\infty} a_m\mathbf{h}_m^a = \sum_{m=1}^{\infty} b_m\mathbf{h}_m^b \qquad (1b)$$

where superscripts a and b refer to the CPW sections to the left and right of the discontinuity, $\mathbf{e}_m$ and $\mathbf{h}_m$ are the normalized transverse vector electric and magnetic fields, $a_m$ and $b_m$ are the expansion coefficients of the CPW eigenmodes, and $\Gamma$ is the reflection coefficient of the dominant incident mode from the left side. Theoretically, an infinite number of modes need to be used on both sides to account for the discontinuity, however, in actual numerical computation, only a finite number of modes, $N_a$ and $N_b$ are used. With the boundary enlargement problem [7] according to the structure in Fig. 1, the corss products of (1a) with $\mathbf{h}_n^b$ and (1b) with $\mathbf{e}_n^a$ are integrated over the corss section of the rectangular waveguide shielding. The result is a system of linear equation (2a) and (2b) with $a_m$ and $b_m$ as the unknowns.

$$(1+\Gamma)I_{1n}^{ab} + \sum_{m=2}^{N_a} a_m I_{mn}^{ab} = \sum_{m=1}^{N_b} b_m I_{mn}^{bb}\ ,\ n = 1,..,N_b \qquad (2a)$$

$$(1-\Gamma)I_{n1}^{aa} - \sum_{m=2}^{N_a} a_m I_{nm}^{aa} = \sum_{m=1}^{N_b} b_m I_{nm}^{ab}\ ,\ n = 1,..,N_a \qquad (2b)$$

in which

$$I_{mn}^{fg} = \int_s \mathbf{e}_m^f \times \mathbf{h}_n^g \cdot \hat{\mathbf{z}}\, dS\ ,\ \ f,g \in \{a,b\} \qquad (3)$$

represents the interaction between different modes.

NUMERICAL RESULTS

The computer program based on the mode-matching procedure was developed. This program can analyze the CPW step discontinuity as well as the finline step discontinuity by simply changing the basis functions and symmetry from CPW to finline. In order to check the accuracy of the program, we first computed the data for the unilateral finline step discontinuity with zero metallization thickness and compared with the existing data. The result is plotted in Fig. 2. Agreement between our data and those in [5] is very good.

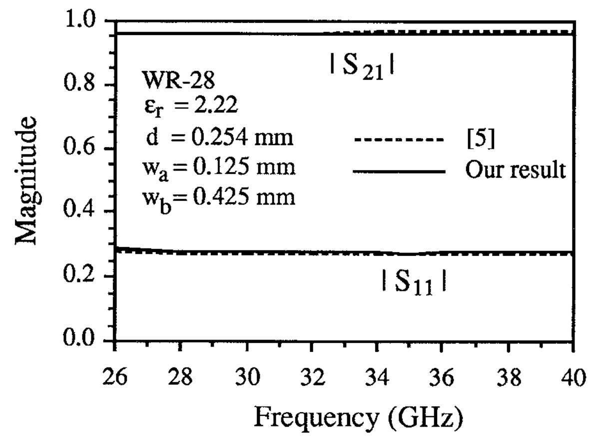


Fig. 2. Comparison of results for finline step discontinuity with zero metallization thickness.

Fig. 3 shows the scattering parameters of the shielded CPW step discontinuity. Extensive convergence tests were performed to verify the accuracy of the results. The data in the figures were all calculated with 6 eigenmodes, i.e., $N_a$=$N_b$=6. The relative error between the cases when 6 and 7 eigenmodes were used is only 0.5%. Power conservation ($|S_{11}|^2+|S_{21}|^2=1$) and reciprocity ($S_{21}=S_{12}$) conditions are both satisfied to within 0.01% error, although they are only the necessary conditions for the results to be correct. It is obvious from Fig. 3(a) that only at higher frequencies does the finite metallization thickness have noticeable effect on the scattering parameters. Interestingly, the reflection coefficient is found to be inversely proportional to the metallization thickness. This could be because that when the metallization thickness increases, more energy is transmitted along the air gap regions of the CPW instead of being reflected back.

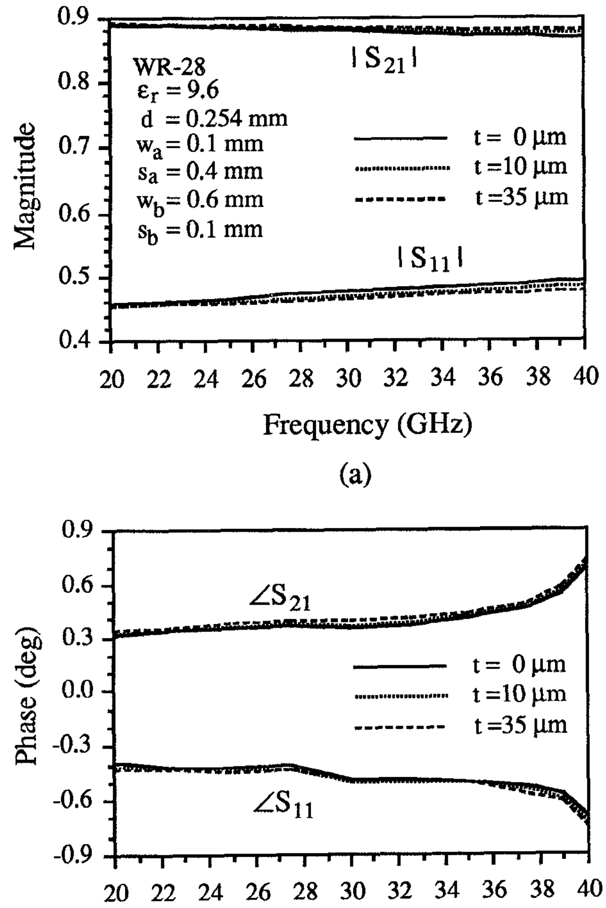


Fig. 3. Scattering parameters of a CPW step discontinuity, (a) magnitude, (b) phase.

## CONCLUSION

Frequency-dependent scattering parameters of the shielded CPW step discontinuity incorporating the finite metallization thickness effect are presented for the first time. The same approach can be applied to other type of CPW discontinuity problems as well as other planar circuit discontinuity structure, all with the finite metallization thickness being taken into account.


## ACKNOWLEDGMENT

This work was supported by the Army Research Office under contract number DAAL03-88-K-005.


## REFERENCES


[1] T. Hirota, T. Tarusawa and H. Ogawa, "Uniplanar MMIC hybrids: A proposed new MMIC structure", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 576-581, June 1987.

[2] N. K. Uzunoglu, C. N. Capsalis and C. P. Chronopoulos, "Frequency-dependent analysis of a shielded microstrip step discontinuity using an efficient mode-matching technique", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-36, pp. 976-984, June 1988.

[3] Q. Xu, K. J. Webb and R. Mittra, "Study of modal solution procedures for microstrip step discontinuities", *IEEE TTrans. Microwave Theory Tech.*, vol. MTT-37, pp. 381-387, Feb. 1989.

[4] H. El Hennawy and K. Schunemann, "Analysis of finline discontinuities", *Proc. 9th Eur. Microwave Conf.* (Brighton, England) 1979, pp. 448-452.

[5] M. Helard, J. Citerne, O. Picon and V. F. Hanna, "Theoretical and experimental investigation of finline discontinuities", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-33, pp. 994-1003, Oct. 1985.

[6] T. Kitazawa and R. Mittra, "Analysis of finline with finite metallization thickness", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 1484-1487, Nov. 1984.

[7] A. Wexler, "Solution of waveguide discontinuities by modal analysis", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-15, pp. 508-517, Sept. 1967.