FULL-WAVE ANALYSIS OF CASCADED JUNCTION DISCONTINUITIES OF SHIELDED COPLANAR TYPE TRANSMISSION LINE CONSIDERING THE FINITE METALLIZATION THICKNESS EFFECT

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ABSTRACT

A full-wave analysis of cascaded junction discontinuities of coplanar type transmission lines, coplanar waveguide (CPW) and finline, is implemented by mode-matching technique. Results of the frequency dependence and the transition-length dependence of the scattering parameters of the CPW-to-finline transition incorporating the finite metallization thickness effect are presented.

INTRODUCTION

For the monolithic microwave integrated circuit (MMIC) design, the coplanar type circuit is often more suitable than the double-sided circuit [1]. When the dimensions of MMIC circuit become smaller, the coupling effect between cascade discontinuities becomes significant.

The mode-matching technique has been applied to single CPW-finline discontinuities successfully [2]. In this paper, a more complex cascaded structure is analyzed by this technique. The transition-length dependence of the scattering parameters of CPW-to-finline transition is presented for the first time, with metallization thickness being considered.

MODE-MATCHING PROCEDURE

The eigenmodes of each transmission lines can be calculated by the extended spectral domain approach [3], which includes the finite metallization thickness of the coplanar type transmission line. The geometry of the problem is shown in Fig. 1. A CPW-to-finline transition consisting of cascaded discontinuities is shielded by a WR-28 rectangular waveguide. The tangential field continuity at both discontinuities, z=0 and z=Z_0, can be expressed as

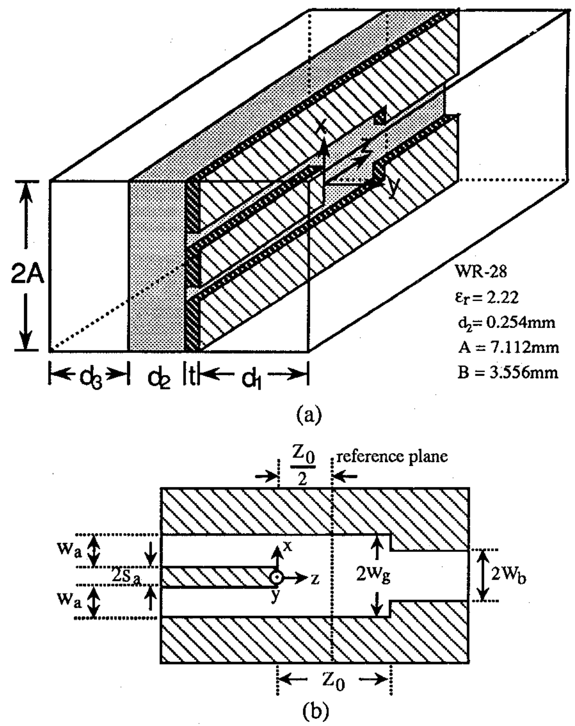

Fig. 1. (a) Shielded CPW-finline transition including the finite metallization thickness, (b) longitudinal section.

$$\mathbf{e}_1^a + \sum_{n=1}^{\infty} a_n \mathbf{e}_n^a = \sum_{n=1}^{\infty} c_n \mathbf{e}_n^g + \sum_{n=1}^{\infty} d_n \mathbf{e}_n^g \quad (1a)$$

$$\mathbf{h}_1^a - \sum_{n=1}^{\infty} a_n \mathbf{h}_n^a = \sum_{n=1}^{\infty} c_n \mathbf{h}_n^g - \sum_{n=1}^{\infty} d_n \mathbf{h}_n^g \quad (1b)$$

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$$\sum_{n=0}^{\infty} b_n \mathbf{e}_n^b e^{-\gamma_n^b z_0} = \sum_{n=0}^{\infty} c_n \mathbf{e}_n^g e^{-\gamma_n^g z_0} + \sum_{n=0}^{\infty} d_n \mathbf{e}_n^g e^{+\gamma_n^g z_0} \tag{1c}$$

$$\sum_{n=0}^{\infty} b_n \mathbf{h}_n^b e^{-\gamma_n^b z_0} = \sum_{n=0}^{\infty} c_n \mathbf{h}_n^g e^{-\gamma_n^g z_0} - \sum_{n=0}^{\infty} d_n \mathbf{h}_n^g e^{+\gamma_n^g z_0} \tag{1d}$$

a, g, b	: the left, center and right section of the cascaded discontinuity
a_n, b_n, c_n, d_n	: the expansion coefficient of each eigenmodes
$\mathbf{e}_n, \mathbf{h}_n$	: the normalized transverse vector electrical and magnetic fields

These simultaneous equations can be solved by carrying out power integration (3) over the cross section of the rectangular waveguide. This process results in a system of linear equations (2a-d). For the numerical computation, only a finite number of modes, Na,Nb and Nc are used.

$$\sum_{n=1}^{N^a} a_n I_{nm}^{ag} + 0 - \sum_{n=1}^{N^g} c_n I_{nm}^{gg} - \sum_{n=1}^{N^g} d_n I_{nm}^{gg} = -I_{1m}^{ag} \qquad m=1,\ldots,N^g \tag{2a}$$

$$\sum_{n=1}^{N^a} a_n I_{mn}^{aa} + 0 + \sum_{n=1}^{N^g} c_n I_{mn}^{ag} - \sum_{n=1}^{N^g} d_n I_{mn}^{ag} = +I_{m1}^{aa} \qquad m=1,\ldots,N^a \tag{2b}$$

$$0 + \sum_{n=1}^{N^b} b_n I_{nm}^{bg} e^{-\gamma_n^b z_0} - \sum_{n=1}^{N^g} c_n I_{nm}^{gg} e^{-\gamma_n^g z_0} - \sum_{n=1}^{N^g} d_n I_{nm}^{gg} e^{+\gamma_n^g z_0} = 0 \qquad m=1,\ldots,N^g \tag{2c}$$

$$0 + \sum_{n=1}^{N^b} b_n I_{mn}^{bb} e^{-\gamma_n^b z_0} - \sum_{n=1}^{N^g} c_n I_{mn}^{bg} e^{-\gamma_n^g z_0} + \sum_{n=1}^{N^g} d_n I_{mn}^{bg} e^{+\gamma_n^g z_0} = 0 \qquad m=1,\ldots,N^b \tag{2d}$$

where

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

NUMERICAL RESULTS

A computer code for the coplanar type transmission line cascaded junction discontinuities has been developed and checked with published results [4],[5] in Fig. 2. The necessary conditions, power conservation ($|S_{11}|^2+|S_{21}|^2=1$) and reciprocity ($S_{21}=S_{12}$), are both satisfied to within 0.001%. Six eigenmodes, i.e. Na=Nb=Nc=6, to make the results have 0.5 % convergence.

Fig 3. shows the transition-length dependence of the scattering parameters of CPW-to-finline transition, with a reference plane at $z=Z_0/2$. Although the transition-length variation makes small difference in the magnitude of scattering parameters, the phase has a linear relationship with

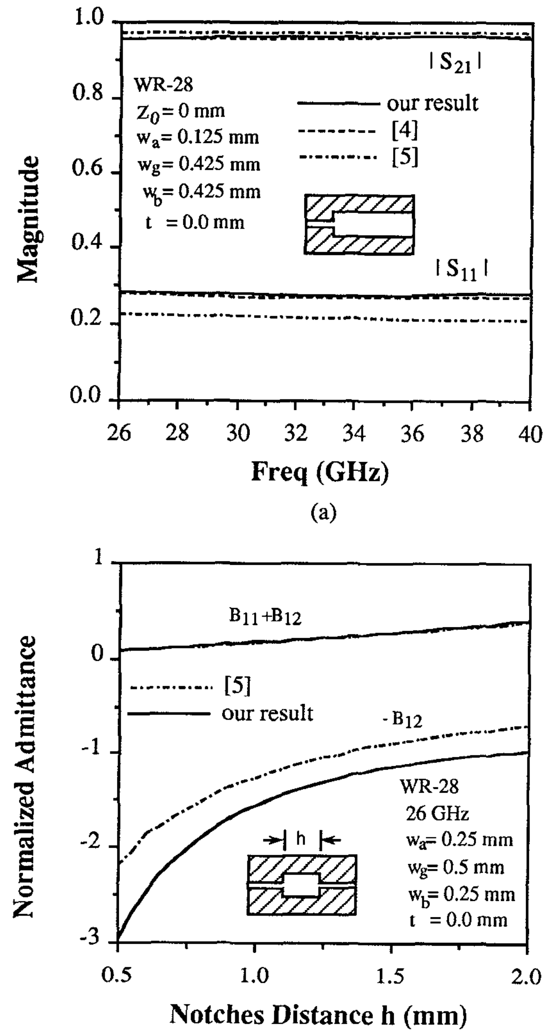

Fig. 2. Comparison of results for (a) finline step discontinuity [4],[5] and (b) inductive notches [5] with zero metallization thickness.

the transition-length. This phenomena is important for the impedance matching design. Fig 4. shows the frequency dependence of the scattering parameters. The linear phase variation is due to the electrical length variation at different frequencies. Fig 3 also shows an internal resonance inside the transition region and this resonance is magnified by the finite metallization thickness.

CONCLUSION

The transition-length dependence and the frequency dependence of the scattering parameters of the CPW-to-finline transition, made of two cascaded discontinuities, are presented for the first time, with metallization thickness being considered. This method can be applied to other coplanar type cascaded junction discontinuities, as CPW gap, inductive notch, capacitive strip, etc.

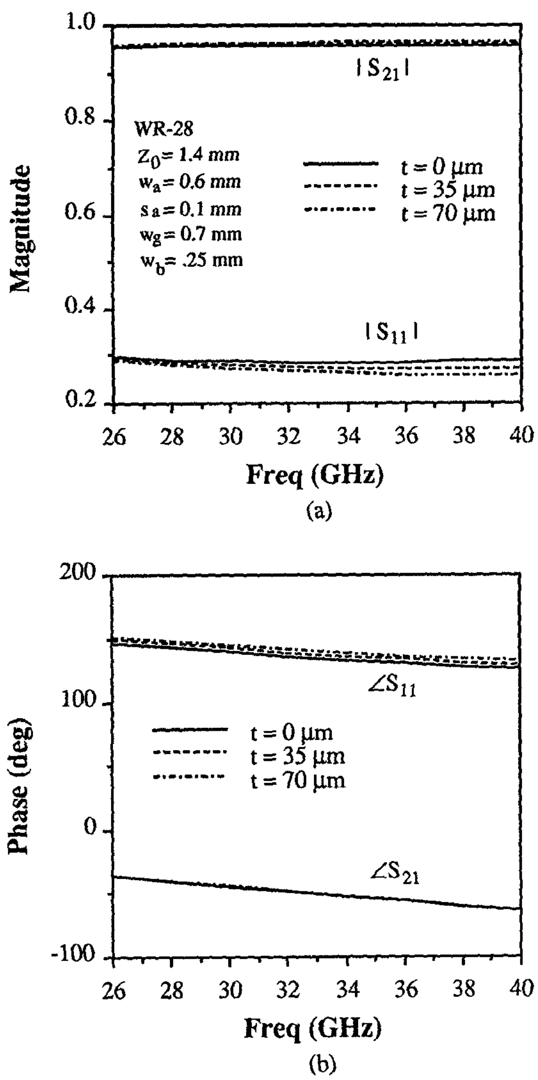

Fig. 3 Scattering parameters of a CPW-finline transition for coupled-slot mode incident at Z_0= 1.4 mm, (a)magnitude, (b)phase

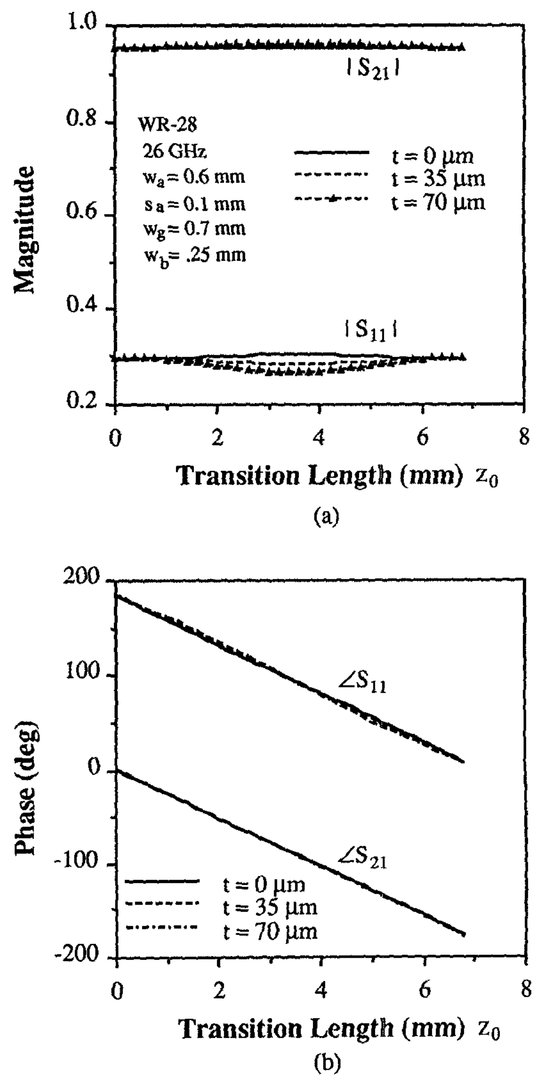

Fig. 4 Scattering parameters of a CPW-finline transition for coupled-slot mode incident at 26 GHz , (a)magnitude, (b)phase

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REFERENCE

[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] C.W. Kuo, T. Kitazawa and T. Itoh, "Analysis of shielded coplanar waveguide step discontinuity considering the finite metallization thickness effect", *IEEE MTT-S Int. Microwave Symp. Digest,* pp. 473-475, June 1991.

[3] 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.

[4] 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

[5] R. Sorrentino and T. Itoh,"Transverse resonance analysis of finline discontinuities", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-32, pp. 1633-1638, Dec 1984