Experimental Investigations of CPW-Slotline Transitions for Uniplanar Microwave Integrated Circuits

Chien-Hsun Ho, Lu Fan and Kai Chang

Department of Electrical Engineering
Texas A&M University
College Station, Texas 77843-3128, USA.

ABSTRACT

Eight new coplanar waveguide (CPW) to slotline transitions using uniform and nouniform CPWs or slotlines will be discussed. These transitions are uniplanar and simple to fabricate. No via-holes are needed for ground connections, and integration with solid state devices are easy. A pair of broad-band transitions using CPW shorts and slotline radial stubs is demonstrated with a 1 dB bandwidth of more than 5.2 : 1.

INTRODUCTION

Coplanar waveguide (CPW) and slotline are the fundamental transmission lines in uniplanar MIC. They allow easy series and shunt device mounting and simple fabrication process. These characteristics make CPW and slotline important in MIC's and MMIC's designs [1]. To fully utilize the advantages of uniplanar structures the transition between CPW and slotline is necessary. Although several papers [2,3] introduce some intuitive approaches for designing CPW-slotline transitions, a systematic description of the design techniques is still lacking. This paper is intended to give a systematic approach to this problem based on experimental investigations. Figure 1 shows the eight new CPW-slotline transitions. The objective of developing the different transitions was to find a best combination of CPW short and slotline open circuits to generate broad-band matching from CPW to slotline. Compared with microstrip-slotline transitions [4], the CPW-slotline transitions presented in this paper have the advantages of being uniplanar and easy to integrate with solid state devices, and they require no via-holes for ground connections. Experimental results are given by measuring the insertion loss of one pair of coaxial-CPW transitions, CPW-slotline transitions and a 8mm length of slotline section.

NARROW-BAND CPW-SLOTLINE TRANSITIONS

The CPW-slotline transitions have 1 dB bandwidth of less than two octaves are classified as narrow-band transitions in this paper. Figures 1(a)-(e) are narrow-band designs of CPW-slotline transitions.

A. $\lambda_g/4$ Cross-Junctions

Figure 1(a) shows the $\lambda_g/4$ cross-junctions of two CPW-slotline transitions. The CPWs and slotlines are etched on the same side of the substrate, and they cross each other at right angles. The CPWs extend the $\lambda_g/4$ beyond the slotlines and terminate with open circuits. Similarly, the slotlines extend the $\lambda_g/4$ beyond the CPWs and terminate with short circuits. The extensions of CPW and slotline may act as tuning stubs to match the CPW to slotline. Figure 2 shows the experimental insertion loss of the two back-to-back transitions and a slotline section. The insertion loss of the two CPW-slotline transitions is less than 1 dB from 1.6 to 3.6 GHz, which is corresponding to a bandwidth of more than one octave.

B. $\lambda_g/4$ Slotline Shorts and (Virtual) CPW Shorts

Figures 1(b) and (c) show the CPW-slotline transitions using CPW shorts and CPW radial open stubs, respectively, with $\lambda_g/4$ slotline shorted stubs. The center conductor strip of the CPW in Figure 1(b) is connected to one side of the slotline to create the CPW short circuit. The experimental results of the insertion loss for the transitions of Figure 1(b) are shown in Figure 3. The 1 dB bandwidth is from 2.3 to 3.8 GHz. Figure 4 shows the insertion loss of the transitions in Figure 1(c). The 1 dB bandwidth is from 1.5 to 3.8 GHz.

C. Slotline Circular Opens and $\lambda_g/4$ CPW Opens

Figure 1(d) shows the CPW-slotline transitions using virtual slotline opens and $\lambda_g/4$ CPW open stubs. The virtual slotline opens use slotline circular opens. The

1993 IEEE MTT-S Digest

OF2

experimental results of the insertion loss are shown in Figure 5. The 1 dB bandwidth is from 1.1 to 3.9 GHz.

D. Slotline Circular Opens and CPW Shorts

Figure 1(e) shows the CPW-slotline transitions using slotline circular opens and CPW shorts. Figure 6 shows the experimental results of insertion loss. The 1 dB bandwidth is in the 1.6 GHz to 5.3 GHz frequency range.

BROAD-BAND CPW-SLOTLINE TRANSITIONS

The CPW-slotline transitions have 1 dB bandwidth of more than 2 octaves are classified as broad-band transitions in this paper. Figures 1(f)-(h) are broad-band designs of CPW-slotline transitions. Virtual CPW shorts and slotline opens are used to create broad-band matching conditions. The virtual slotline opens use slotline radial opens, and the virtual CPW shorts use CPW radial open stubs. When testing the transitions, we soldered bond wires to every discontinuity between the CPW and the slotline.

A. Virtual Slotline Opens and $\lambda_g/4$ CPW Opens

Figure 1(f) shows the CPW-slotline transitions using slotline 45° radial opens and $\lambda_g/4$ CPW open stubs. The experimental results of the insertion loss are shown in Figure 7. The 1 dB bandwidth is from 0.9 to 3.8 GHz, which is more than 2 octaves.

B. Virtual Slotline Opens and CPW Shorts

Figure 1(g) shows the transitions using CPW shorts and slotline 90° radial opens. The slotline radial opens are broad-band opens; therefore, the resulting CPW-slotline transitions should have broad bandwidths. One important feature of this transition is that the CPW and slotline are connected without bending the transmission structure. This makes the circuit layout more flexible and easier. Figure 8 shows the experimental insertion loss of the transitions using slotline radial opens. The insertion loss of less than 1 dB is from 1.1 to 5.7 GHz, which is more than 2.3 octaves. The transitions shown in Figure 1(g) give the best performance in bandwidth.

C. Virtual Slotline Opens and Virtual CPW Shorts

Figure 1(h) shows the CPW-slotline transitions using virtual CPW shorts and virtual slotline opens. Both of the CPW and slotline virtual terminations use broad-band radial open stubs. The angles of the CPW and slotline radial opens are both chosen as 45° to avoid interfering each other. The experimental results are shown in Figure 9. The 1 dB bandwidth is in the 1.5 GHz to 6.0 GHz frequency range, which is more than 2 octaves. By optimizing the angles and radii of the radial opens for CPW shorts or slotline opens, the usable bandwidth may be further improved.

CONCLUSIONS

Eight different circuit configurations of CPW-slotline transitions were proposed and the experimental results were presented. Table I summarizes the combinations and usable 1 dB bandwidth of different CPW short circuits and slotline open circuits. From the experimental results presented in the previous sections, we can conclude:

(1) The transition using CPW shorts and $\lambda_g/4$ slotline shorted stubs is the worse combination for the low loss and broad bandwidth applications.

(2) The transition using virtual CPW shorts (either quarter-wavelength or radial open stubs) has sharp gain slopes. This characteristic may be used in the design of band-pass filters.

(3) The transition using CPW shorts and slotline opens (either slotline circular or radial opens) can be designed without bending transmission structures. Circuit layout with these transitions is flexible.

(4) The transitions using slotline radial opens with (virtual) CPW shorts have broad bandwidths of more than 2 octaves. This means that: (a) slotline open circuits are the dominant factors of designing broad-band CPW-slotline transitions, (b) slotline radial opens are good candidates of designing broad-band slotline open circuits.

(5) The transition using CPW shorts and slotline radial opens is the best combination for the broad-band and low loss applications. The bandwidth of less than 1 dB insertion loss has been demonstrated more than 5.2:1. The designs and layouts of this type of transition are easy, compact and flexible. By choosing proper angles and radii for the slotline radial opens, the bandwidths of the transitions can be further improved.

ACKNOWLEDGMENTS

This work was supported in part by the Army Research Office and the State of Texas Higher Education Coordinating Board's Advanced Technology Program.

REFERENCES

[1] Y. H. Shu, J. A. Navarro, and K. Chang, "Electronically switchable and tunable coplanar waveguide-slotline band-pass filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-39, pp. 548-

554, March 1991.

[2] H. Ogawa and A. Minagawa, "Uniplanar MIC balanced multiplier-a proposed new structure for MIC's," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-35, pp. 1363-1368, Dec. 1987.

[3] T. Q. Ho and S. M. Hart, "A novel broadband coplanar waveguide to slotline transition," *IEEE Microwave and Guided Wave Letters*, vol. 2, pp. 415-416, Oct. 1992.

[4] K. C. Gupta, R. Garg and I. J. Bahl, *Microstrip lines and slotlines*, Artech House, Inc., Massachusetts, 1979.

Table I

Summary of combinations and 1 dB bandwidth of different CPW-slotline transitions.

	$\lambda g/4$ Slotline shorts	slotline circular opens	slotline radial opens
$\lambda g/4$ CPW opens	2.2 : 1 (Figure 1a)	3.5 : 1 (Figure 1d)	4.0 : 1 (Figure 1f)
CPW shorts	1.6 : 1 (Figure 1b)	3.3 : 1 (Figure 1e)	5.2 : 1 (Figure 1g)
CPW radial opens	2.5 : 1 (Figure 1c)	--	4.1 : 1 (Figure 1h)

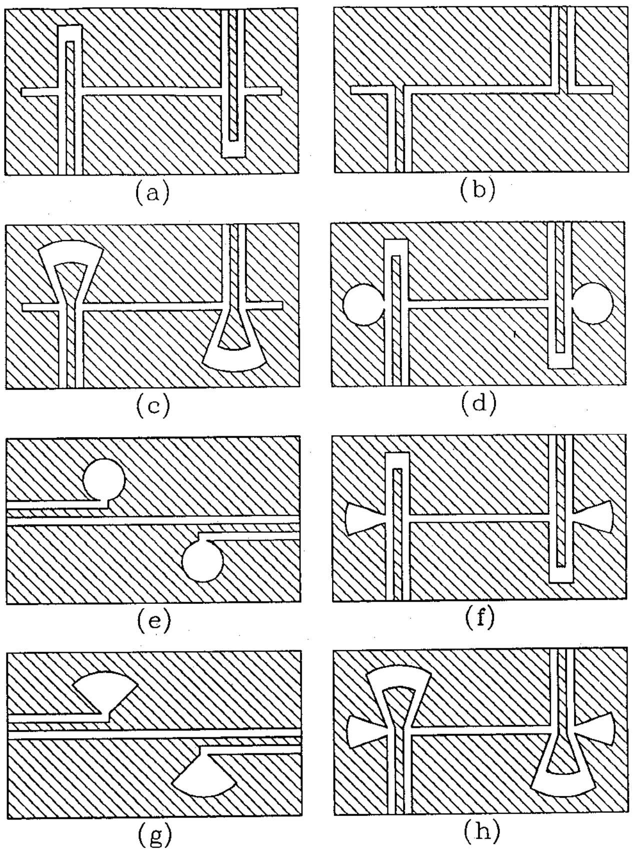

Figure 1 CPW-slotline transitions under consideration:
(a) $\lambda_g/4$ cross-junction.
(b) $\lambda_g/4$ slotline shorts and CPW shorts.
(c) $\lambda_g/4$ slotline shorts and CPW radial opens.
(d) Slotline circular opens and $\lambda_g/4$ CPW opens
(e) Slotline circular opens and CPW shorts.
(f) Slotline radial opens and $\lambda_g/4$ CPW opens.
(g) Slotline radial opens and CPW shorts.
(h) Slotline radial opens and CPW radial opens.

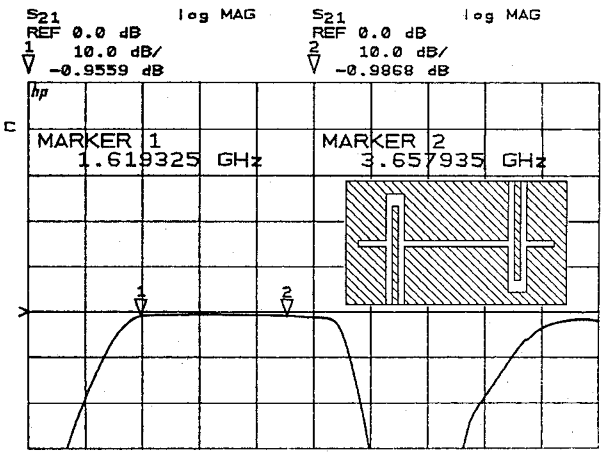

Figure 2 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(a).

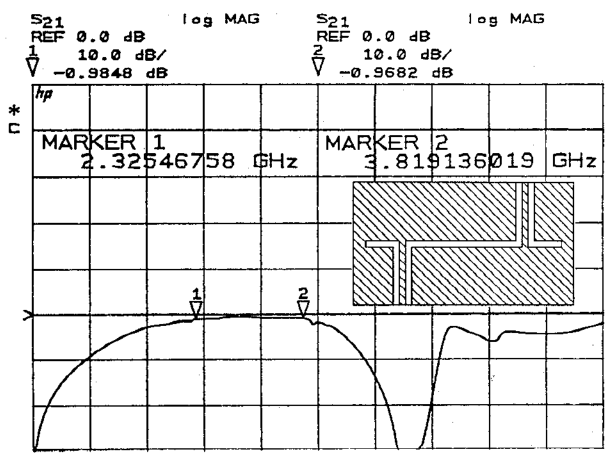

Figure 3 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(b).

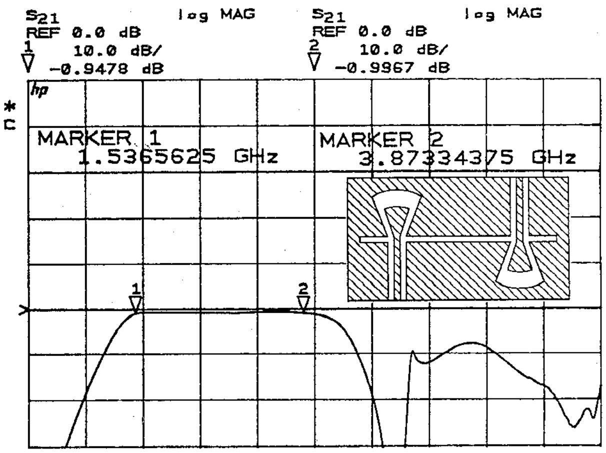

Figure 4 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(c).

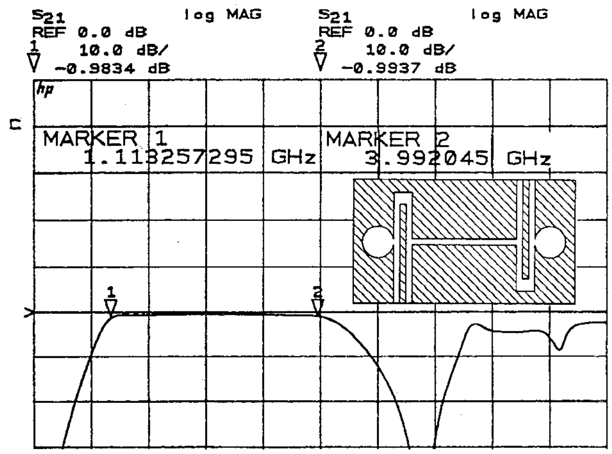

Figure 5 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(d).

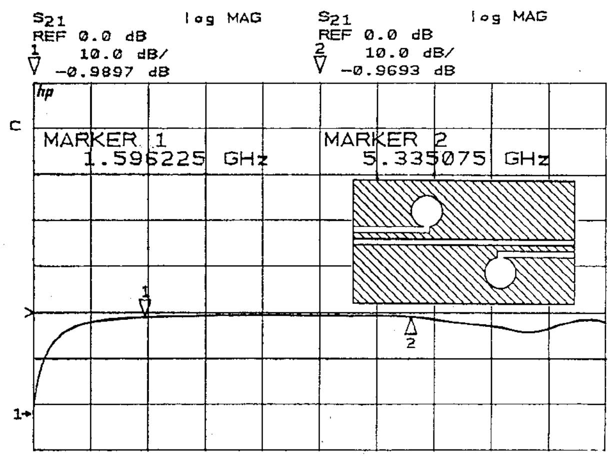

Figure 6 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(e).

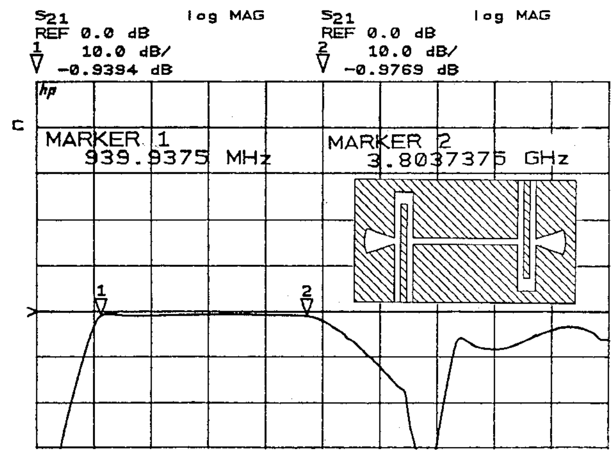

Figure 7 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(f).

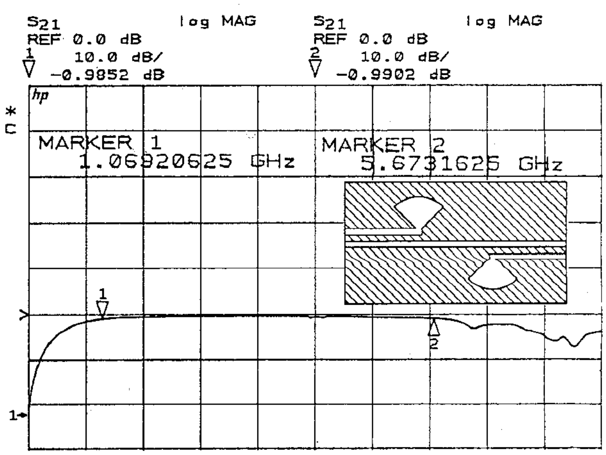

Figure 8 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(g).

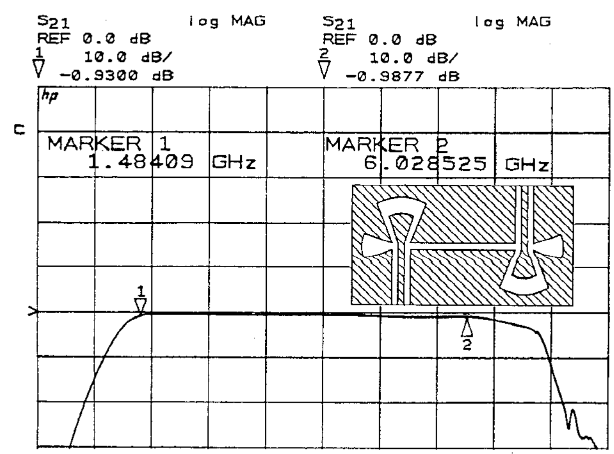

Figure 9 Measured insertion loss of one pair of CPW-slotline transitions in Figure 1(h).