A NOVEL MICROSTRIP TO COPLANAR WAVEGUIDE TRANSITION FOR FLIP-CHIP INTERCONNECTION USING ELECTROMAGNETIC COUPLING

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ABSTRACT

A novel compact microstrip to coplanar waveguide (CPW) transition is proposed for flip-chip interconnection. Broadband performance of the transition is simulated and agrees well with measured results. A good interconnection between microstrip line on a motherboard to CPW on a flip-chip is accomplished without any vias. For 10dB return loss, the microstrip-to-CPW transition and the microstrip-to-flip-chip interconnection present 170% and 140% bandwidth, respectively.

INTRODUCTION

As the demand for high-density and high-functionality microwave and millimeter-wave circuits increases, new and innovative circuit architectures are needed such as three dimensional MMIC's, multilevel printed circuit boards (PCB), and flip-chips. One of the most promising the novel circuits, flip-chip structure is drawing attention for its several advantages: compactness, good heat sinking characteristics, small parasitic inductance and high yield rate. Because of the wide availability of microstrip (MS) circuit design technology and the necessity of flip-chip configuration, microstrip flip-chips are built on microstrip motherboards. However, since flip-chips are naturally suitable for CPW, the flip-chips based on microstrips entail inefficiency. In order to keep the advantages of both flip-chips and microstrip circuits, a very efficient microstrip-to-CPW interconnection is necessary.

Extensive work has been accomplished and suggests various microstrip-to-CPW (MS-CPW) transitions [1-5]. Some of the transitions have utilized vias which connects CPW on one plane to microstrip (MS) on another plane. However, vias cause considerable parasitic inductance which may deteriorate overall circuit performance [6]. In order to avoid this parasitic effect, other transitions have utilized electromagnetic coupling, and have been proven to be efficient in certain bandwidths [1-2].

In this work, an enhanced transition providing broadband characteristic is proposed which takes into account the finite ground effect. Additionally, a close investigation is made on the application of the proposed microstrip-to-CPW transition to the interconnection between a microstrip motherboard and a CPW flip-chips.

NUMERICAL AND MEASUREMENT RESULTS

The configurations of the two proposed transitions are shown in Fig. 1. The first transition has metallization tapering on the top CPW ground planes, and the second transition has tapering on both top and bottom ground planes. Both transitions have circularly tapered ground planes for a smooth conversion between microstrip line mode and CPW mode. The bottom tapering is a little longer by 0.1mm than the top tapering in order for the transition to start at the edge of the CPW ground plane and in order to have circular shape.

The performances of the both structures are predicted in Fig. 2 using the Finite-Difference Time-Domain (FDTD) method. The second transition with double tapered grounds performs better in return loss and bandwidth than the first one. The second transition shows about 170% bandwidth for 10dB return loss. The bandwidth of the transition has a very close relation with the transition length, which is the width of the CPW ground planes (W_{gnd}). Fig. 3 shows the bandwidth dependence on the transition length. If a variable, W_{CPW} is defined as $W+2G+2W_{gnd}$ as shown in Fig. 1, a relationship between the variable and the bandwidth is able to be built. A large dip in S_{21} in each graph is observed in Fig. 3, which mainly determine the bandwidths. The transition with W_{CPW}=11mm (W_{gnd}=5.0mm) has a large dip around 10GHz, and the transition with W_{CPW}=6mm (W_{gnd}=2.5mm) has a dip at 18.4GHz. Therefore, the dip frequencies are inversely proportional to the transition lengths, 6mm *18.4GHz = 11mm*10GHz.

Fig. 4 is the measured data for the structures of Fig. 3. Good agreement with simulated results is demonstrated. The ripples are attributed to the fabrication tolerances. Some alignment deviation of 200-300um between the top circuit and the bottom circuit is observed, which breaks the symmetry and thus degenerates the circuit performance.

As an application of this transition, a CPW flip-chip mounted on a microstrip line motherboard is investigated. The analyzed circuit consists of uniform microstrip line motherboard and a flip-chip with uniform CPW as shown in Fig. 5(a). Its performance is estimated using the Finite-Difference Time-Domain (FDTD) method. The transition with W_{CPW}=11mm (W_{gnd}=5.0mm) is employed. Due to the discontinuity between CPW line on the motherboard and the flip-chip, the overall return loss is increased by around 4-5dB over the whole frequency range as shown in Fig. 5(b). However, this performance degeneration is anticipated from the fact that the usual return loss of a single flip-chip interconnect is around 10-20dB at 5-20GHz [7].

CONCLUSION

A novel microstrip-to-CPW transition without via connection is proposed and its application to microstrip-to-flip-chip interconnection is studied. Broadband characteristic of the transition is achieved with circular tapering of microstrip ground plane as well as the CPW ground planes, and simulation result agrees very well with the measured data. When the transition is integrated with flip-chip interconnection, the performance of the entire circuit still keeps close to the transition itself. This transition would help designers to incorporate microstrip circuit design technology and flip-chip advantages.

ACKNOWLEDGMENT

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REFERENCES

[1] G. Strauβ, P. Ehret, and W. Menzel, “On-Wafer Measurement of Microstrip-based MIMICs without Via Holes" IEEE MTT-S Int. Microwave Symp. Dig., 1996

[2] D. Williams and T. Miers, “A Coplanar Probe to Microstrip Transition”, IEEE Trans. Microwave Theory Tech., vol. MTT-36, pp.1219-1223, July 1988.

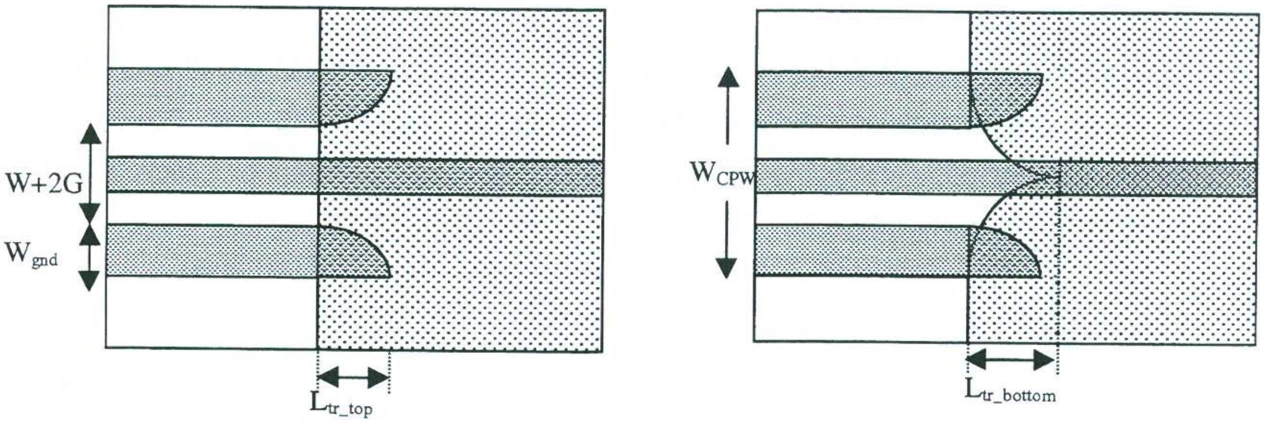
[3] N. Dib, R. Simons, and L. Katehi, “New Uniplanar Transitions for Circuit and Antenna Applications”, IEEE Trans. Microwave Theory Tech., vol. MTT-43, pp.2868-2873, Dec. 1995.

[4] H. Jin, R. Vahldieck, J. Huang, and P. Russer, “Rigorous Analysis of Mixed Transmission Line Interconnects Using the Frequency-Domain TLM Method”, IEEE Trans. Microwave Theory Tech., vol. MTT-41, pp.2248-2255, Dec. 1993.

[5] J. Burke, R. Jackson, “Surface-to Surface Transition via Electromagnetic Coupling of Microstrip and Coplanar Waveguide”, IEEE Trans. Microwave Theory Tech., vol. MTT-37, pp.519-524, March 1989.

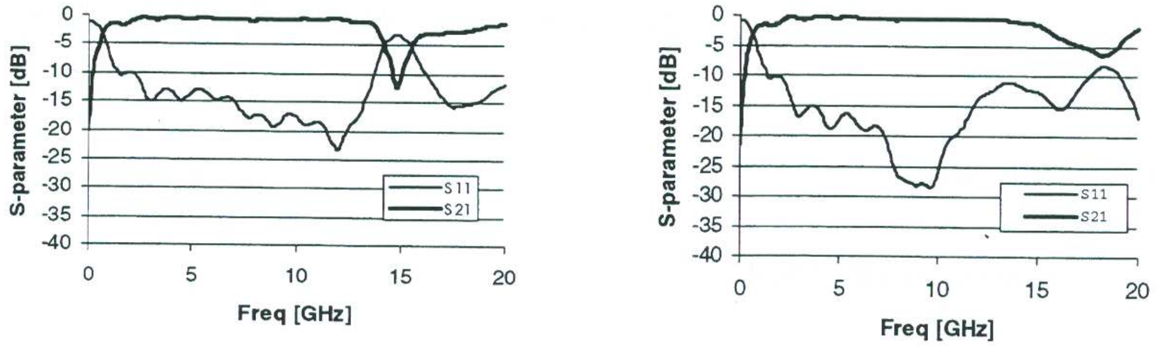
[6] D. Koh, H. Lee, and T. Itoh, “A Hybrid Full-Wave Analysis of Via-Hole Grounds Using Finite-Difference and Finite-Element Time-Domain Methods”, IEEE Trans. Microwave Theory Tech., vol. MTT-45, pp.2217-2223, Dec. 1997.

[7] J. Kim, D. Koh and T. Itoh, "A novel broadband flip chip interconnection", in IEEE 6th Topical Meeting on Electrical Performance of Electronic Packaging, pp.199-202, Oct. 1997.



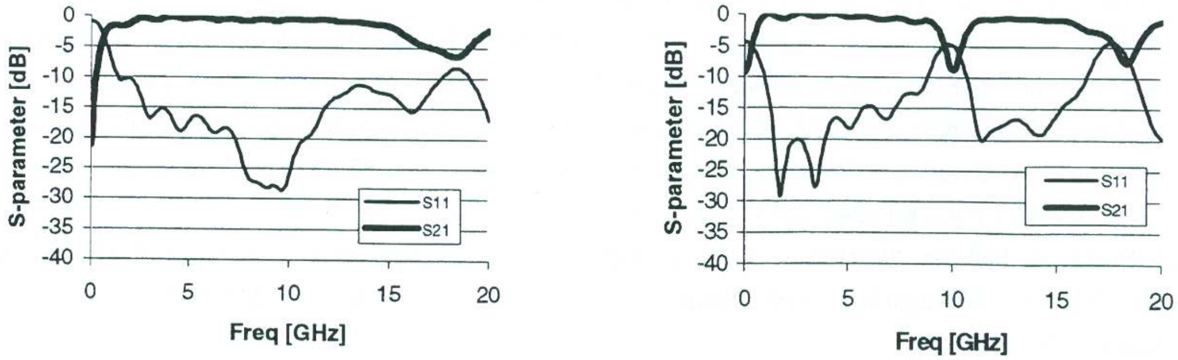
(a) (b)

Fig. 1. Configurations of the microstrip-to-CPW transitions: (a) tapering on the top ground planes, (b) tapering both on the top and the bottom ground planes



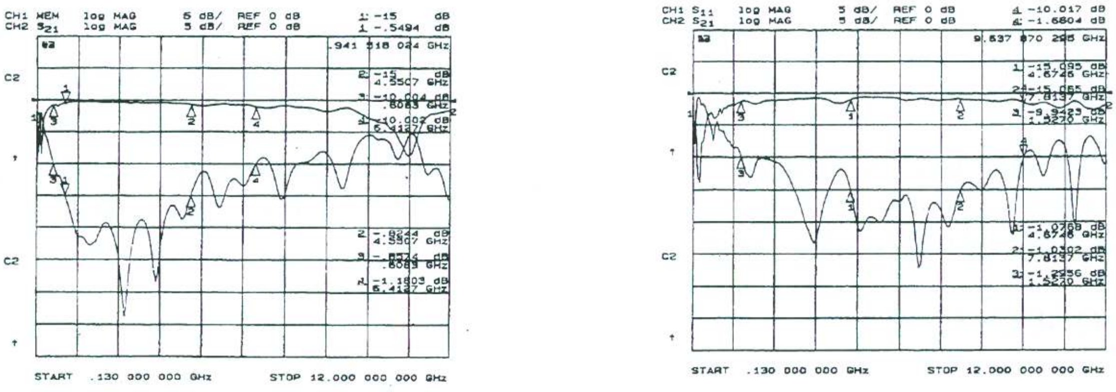
(a) (b)

Fig. 2. Simulated results: (a) the transition tapering only the top ground, (b) transition tapering the both grounds: $\varepsilon_{r,sub}$=10.2, H_{sub}=635um, W=600um, G=200um, L_{tr_top}= W_{gnd}=2.5mm, L_{tr_bottom}=2.6mm



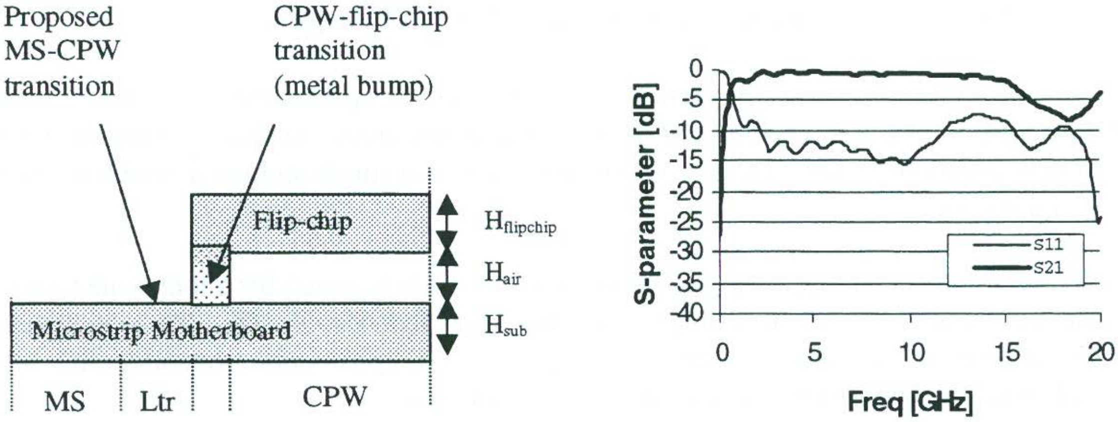
(a) (b)

Fig. 3. Simulated results of the transitions tapering the both ground planes: (a) L_{tr_top}= W_{gnd}=2.5mm, L_{tr_bottom}=2.6mm, (b) L_{tr_top}= W_{gnd}=5mm, L_{tr_bottom}=5.1mm: $\varepsilon_{r,sub}$=10.2, H_{sub}=635um, W=600um, G=200um



(a) (b)

Fig. 4. Measured results of the same transitions in Fig. 3; (a), (b) same with that in Fig3 (a), (b), respectively.



(a) (b)

Fig. 5. Microstrip motherboard to CPW flip-chip single transition: (a) half MS-flip-chip transition circuit, $L_{tr}= W_{gnd}=2.5$mm, $H_{sub}=H_{air}=H_{flipchip}=212$um, (b) FDTD simulation result.