NOVEL DESIGN FOR COPLANAR WAVEGUIDE TO MICROSTRIP TRANSITION*

Amr M. E. Safwat**[a)], student member, IEEE, Kawthar A. Zaki* Fellow, IEEE, William Johnson** member IEEE, and Chi H. Lee*, Fellow, IEEE

*Department of Electrical and Computer Engineering, University of Maryland, College Park, Maryland 20742.
** Laboratory for Physical Sciences, College Park, Maryland 20740
[a)] Email: safwat@glue.umd.edu Fax:301 314 9281

***Abstract* -- A new design of a coplanar waveguide (CPW) to microstrip transition is presented. Simulation using the high frequency simulator software (HFSS) shows that a bandwidth of 13 GHz with less than -25 dB return loss can be achieved. The transition was fabricated and characterized. Experimentally, the S_{11} of two back to back conductor backed CPW to microstrip transitions on InP substrate is better than –12 dB up to 14 GHz. For Alumina substrate the S_{11} was less than –15 dB up to 25 GHz.**

I. INTRODUCTION

Coplanar waveguide (CPW) to microstrip transitions have been subject to rigorous study since 1979 [1-5]. Integrating CPW with microstrip on the same wafer, making on wafer measurements through CPW probes and packaging CPW monolithic microwave integrated circuits (MMIC) are the motives for this increasing interest.

The transition proposed by Houdart et al [4] consists of three coupled lines that couple the signal from the microstrip to the CPW at a specific frequency. Such transition has a narrow bandwidth. Williams et al. presented a coplanar probe to microstrip transition [5], which coupled the bottom ground of the microstrip and the top surface by a large reactance that has the form of a semicircular metal layer on the top surface. This transition suffers from two disadvantages. First, it can not work efficiently at low frequency since this reactance, acting as a capacitor, is considerably large. Second, it can not be used to interconnect CPW to microstrip. To provide connection between them, different modifications have been introduced to the last structure [1]. The measured return loss was more than –12 dB within the operating bandwidth and much larger in low frequency and up to 5 GHz.

In this paper, a structure that provides a gradual transformation of the electric and magnetic fields and constant impedance along the transition between a coplanar waveguide or conductor backed coplanar waveguide from one side and microstrip from the other side is studied numerically and experimentally

II. THEORY

The Conductor backed coplanar waveguide (CPWG) as shown in Fig. 1 has four conductors over a substrate. Three conductors are on one surface forming the center line and two ground lines and the fourth is a ground line at the bottom. 2w is the width of the center line, s is the separation between the center line and the ground lines on the surface, g is the ground line width on the surface, h is the substrate height and ε_r is the relative dielectric constant of the substrate.

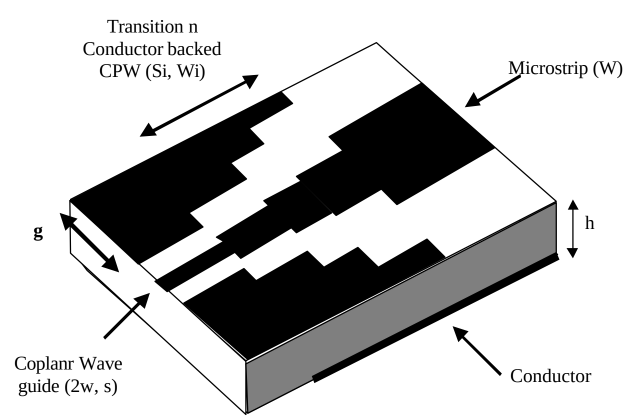

Fig. 1. The proposed transition. It consists of n sections of conductor backed CPW , in the figure n = 3 , one port is a CPW and the second port is a microstrip line

By using the mode matching technique, it has been shown that the characteristic impedance of CPWG can be

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considered as the parallel combination of two characteristic impedances [6]. One corresponds to the CPW mode (Z_{WG}) and the second corresponds to the microstrip mode (Z_{MS}). These impedances are functions of the structure dimension. For small s/h the wave is guided on the surface and Z_{WG} dominates. As this ratio increases, the structure turns to a simple microstrip line where the wave is guided between the metal on the surface and the metal at the bottom and Z_{MS} becomes more dominant. Splitting of the characteristic impedance into the CPW and the microstrip is the basic idea of the proposed structure. The new transition consists of a CPWG that connects the CPW at one side to the microstrip at the other side. The width of the center conductor of the CPWG changes linearly or according to any specific function between the width of the center conductor of the CPW and the width of the microstrip. For practical implementation, the transition is divided into n sections of CPWG as shown in Fig. 1. All sections are designed to have 50 Ω impedance. At the CPW side, the design parameters (2w, s) are very small with respect to the substrate height (h). Along the transition to the microstrip line, the width of the central line increases gradually. To keep the overall Z equals to 50 Ω the separation (s) is recalculated using the expressions in [7]. This process is repeated a number of times equal to the number of sections. The last section has the microstrip impedance of the CPWG.

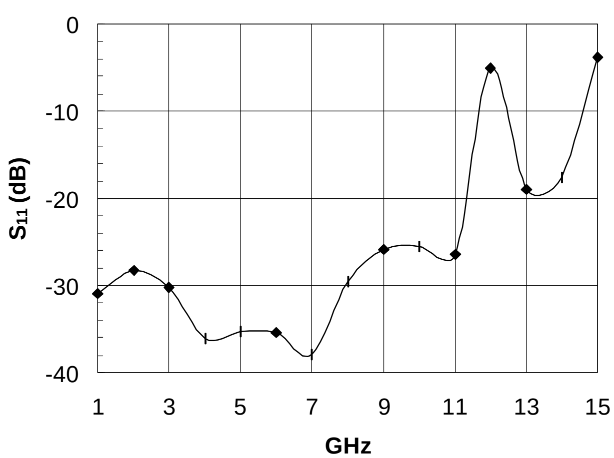

Fig. 2. S_{11} of the proposed transition, which consists of 5 sections each of length equals to 1 mm . S_{11} is less than –25 dB up to 11 GHz.

III. Results and discussion

The transition was studied using the high frequency structure simulator (HFSS), which is commercial software based on finite element method [8]. The substrate is InP that has ε_r = 12.4. Port 1 is a CPW that has 2w = 100 µm, s = 70 µm and 5 mm length. This is followed by a transition formed by 5 sections of equal length. The inner width increases with a step equals 30 µm and the total length of the transition equals 5 mm. Finally port 2 is a microstrip having 2w = 260 µm and 5 mm length. The S_{11} of this transition is less than -25 dB up to 11 GHz, as shown in Fig. 2. This is 10-20 dB better than [1]. Resonance occurs at f = 12 GHz and f =14 GHz because of the finite length of the device.

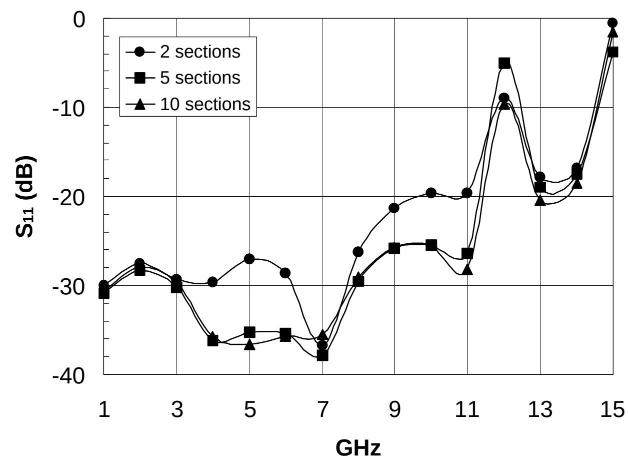

Fig. 3. The effect of the number of sections on S_{11}. The total length of the transition is kept 5 mm.

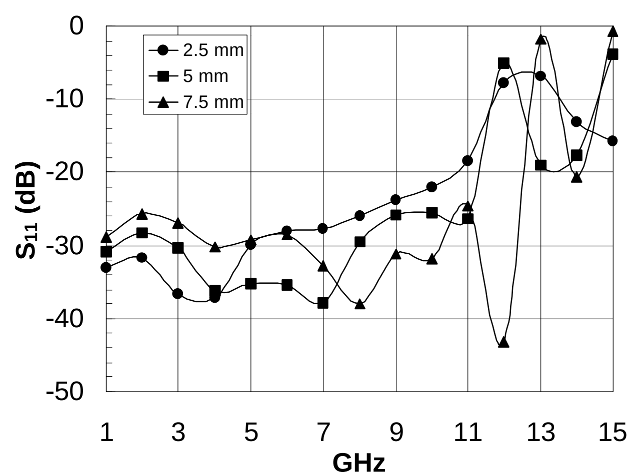

Fig. 4 S_{11} calculated for three different lengths of the transition: 2.5 mm, 5 mm and 7.5 mm. The number of sections equals to 5

The effect of the number of sections and the length of the transition were also studied. Fig. 3 shows S_{11} for three different cases, n = 2, 5 and 10 keeping the length equals 5 mm. When n = 5 or 10 S_{11} is less than -25 dB up to 11 GHz but as n decreases to 2, S_{11} increases such that it is 10 dB larger than the case when n = 5. Keeping the number of sections equals to 5, the S_{11} has been calculated for three different lengths of the transition: 2.5 mm, 5 mm and 7.5 mm. Fig. 4 shows that as the length of the transition increases the bandwidth increases as well, so when the length is 7.5 mm the bandwidth increases to 13 GHz. And when the length decreases to. 2.5 mm, S_{11} is less than -25 dB at f = 8 GHz.

To verify the idea, two back to back transitions formed by 5 mm 5 sections CPWG transition each of length 1 mm, 5 mm microstrip and 5 mm 5 sections CPWG transition each of length 1 mm was fabricated on InP using conventional photolithography. 2w and s are as mentioned above and w+s+g = 3 mm along the transition. The measured S_{11}, shown in Fig 5, is less than –12 dB between 1 GHz and 14 GHz. These results are better than those obtained in [1]. Simulation results for this structure, also shown in Fig. 5, show that S_{11} for the fundamental mode can be less than –15 dB up to 15 GHz. The discrepancy between experiment and simulation can be explained by two reasons. First, the mismatch in the pitch size between the coplanar probes used in measuring the S parameters and the pitch size of the input stage. Second, the device under test is an open structure while in the simulation it was enclosed in a conductor shield. The last reason can also explain the resonance that occurs around 9 GHz. For closed structures, the fields are exponentially decaying in the longitudinal direction while they are propagating in open structures. Consequently the structure resonates at the frequencies corresponding to this dimension.

For practical application, the transitional device was fabricated on an Alumina substrate that has 635 μm thickness. The fabricated device consists of 5 mm CPWG, 5 mm 10 sections transition each of length 0.5 mm, 5 mm microstrip, 5 mm 10 sections transition and 5 mm CPWG. The input and output CPWG have 2w = 100 μm s = 44 μm, the width of the microstrip is 642 μm, and the width of each section in the transition increases with a step equals 50 μm. w+s+g is kept equal to 3 mm. The measured return loss, shown in Fig. 6, is less than –15 dB up to 25 GHz. As in InP, resonance occurs at f = 4.8 GHz and its multiples. This increases the return loss to around –10 dB. Connecting the ground on the surface of the CPWG to its ground at the bottom using silver paint to form an ideal CPWG, resonance disappears and the return loss obtained is less than –15 dB from freq. = 45 MHz up to 25 GHz. The presence of the silver paint reduces the S_{12} from –2 dB to –4 dB as shown in Fig. 6. Reducing the width of the ground g can also solve the problem of resonance.

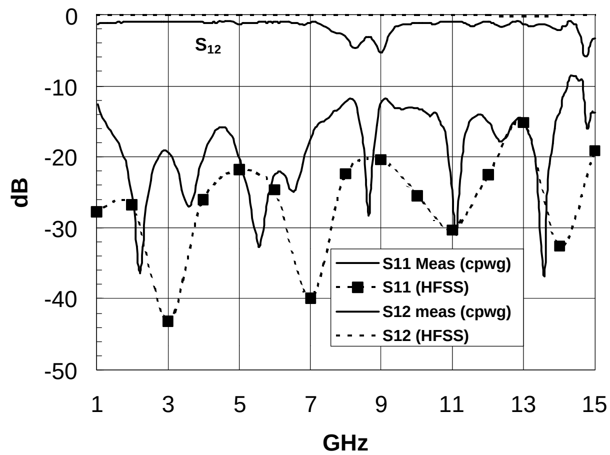

Fig. 5. Measured S_{11} for a back to back transition on InP substrate. It consists of 5 sections of CPWG, microstrip then 5 sections of CPWG

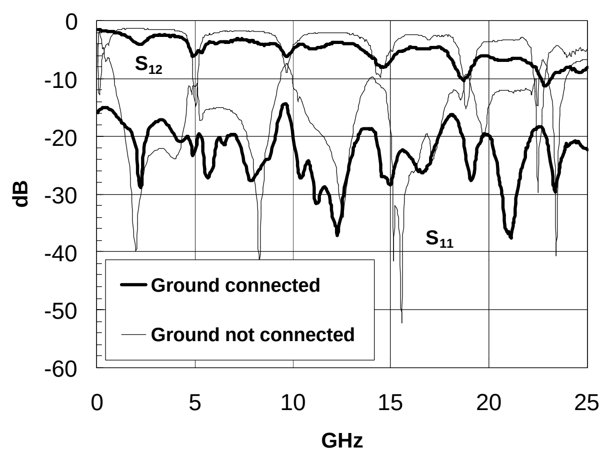

Fig. 6. Measured S_{11} for a back to back transition on Alumina Substrate. It consists of an input CPWG of length 5 mm, 10 sections of CPWG, microstrip, 10 sections of CPWG then an output CPWG of length 5 mm

IV. CONCLUSION

In this paper, a novel design of CPW to microstrip transition that provides a gradual transition for the electric and magnetic fields and constant impedance along the transition has been proposed. The simulation using HFSS shows that a bandwidth of 13 GHz with less than -25 dB return loss can be achieved. Experimentally, a back to

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back transition of a CPWG to microstrip on InP substrate has S_{11} less than –12 dB up to 14 GHz. In the case of Alumina substrate, S_{11} is less than –15 dB up to 25 GHz.

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