# A Fully Micromachined W-band Waveguide-to-Grounded Coplanar Waveguide Transition for 91–113 GHz applications

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*Abstract*— **This paper presents a novel coplanar waveguide (CPW) to a fundamental rectangular waveguide transition for W-band applications. The designed waveguide-to-CPW transition is optimized to achieve low loss by using two software packages, CST Microwave Studio and the EM field solver of HFSS. The maximum insertion loss of the waveguide-to-CPW back-to-back transition is -1.8 dB in a frequency range of 91.2 – 113.2 GHz, corresponding to a 22% bandwidth. In addition to this wide bandwidth, the structure benefits from a simple structure.**

## I. INTRODUCTION

New frequency resources have been strongly required because of recent rapid developments in various wireless communication service areas and the resulting exhaustion of the microwave frequency band for commercial uses. For this reason, many researchers have made great efforts on highly integrated millimeter-wave monolithic integrated circuit (MIMIC) for the purpose of W-band wireless communication systems. A significant amount of research has been performed on coplanar waveguides (CPW), as one of the key MIMIC circuit features, due to several advantages over other competing transmission lines [1,2]. The grounds and the signal are on the same side of the substrate, eliminating the need for via-holes or wraparound process [3, 4]. Also, the characteristic impedance is determined by the ratio of the width of the center strip conductor to the distance between the two semi-infinite ground planes [5], enabling compact designs, which is demonstrated by the numerous CPW-based microwave probes commonly used for the characterization of microwave integrated circuits.

On the other hand, rectangular waveguides are widely used at higher frequencies for their low-loss characteristics in applications such as high-Q filters, resonators and antenna feed networks. Therefore at millimeter- and submillimeter-wave applications in which active and passive components are integrated, often waveguide structures are to be combined with CPW lines. For those applications, low-loss transitions are required.

The traditional rectangular waveguides at low frequencies, however, are bulky, making almost impossible their integration into system-on-chip geometries. Nevertheless, the size of rectangular waveguides shrinks dramatically at or above the mm-wave frequency range. At the same time, the losses of other transmission lines, such as microstrips, keep increasing when the frequency goes up. Various transitions from CPW to rectangular waveguide have been proposed in the past, in order to combine their respective advantages.

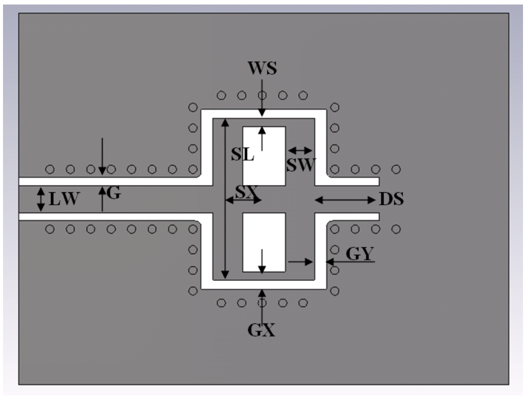
In this work, we propose a very simple and easy-to-fabricate transition from a low-loss ground coplanar waveguide (GCPW) to rectangular waveguide operational from 91.2 to 113.2 GHz frequency band, corresponding to a 22%. It consists of two step transitions, one from the rectangular waveguide to the slots in the ground of the CPW, and the other one from there to the CPW itself. Fig. 1 demonstrates the structure from different perspectives.

For an optimal design of a transition, the requirements are a minimum return loss at the input of the waveguide and a minimum radiation from the coupling slots. We have started with a simple structure which is the end-wall connection between a metal waveguide and a CPW line with a single slot in the ground. Many waveguide transitions with one slot in the ground have already been presented [6-7], but they suffer from a narrow bandwidth as a result of the high impedance difference between waveguide and strip, proportional to the difference between the dielectric constant of the substrate and the material in the waveguide [8].

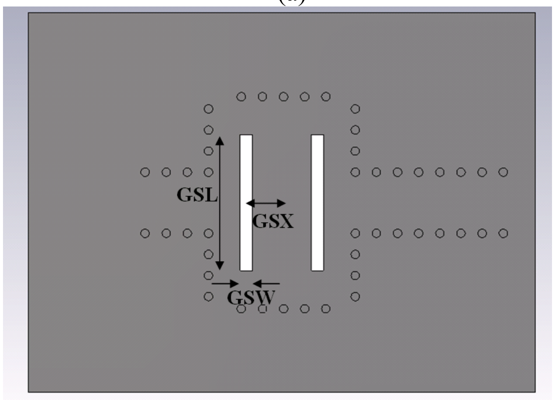
## II. DESIGN OF THE WAVEGUIDE-TO-GCPW TRANSITION

The structure shown in Fig. 1 is a new double slot transition from rectangular hollow waveguide to a grounded CPW. Double slot coupling highly increases the performance especially with respect to bandwidth [6-7], and eliminates the need for matching inside the metallic waveguide part [8] [9].

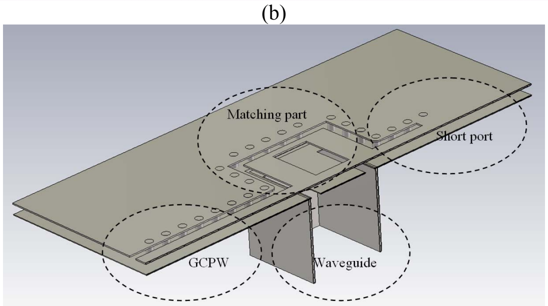
In this work slots have also been used for improving the coupling to the CPW line. In [6] and [7] the design of the microstrip line to waveguide transition includes two matching stubs on top of the slots, which also block the radiation from the resonant slots. In our case this is not enough for the CPW while the problem of radiation and surface waves are even more severe. Simulations show that the newly presented transition configuration, shown in Fig. 1, can increase the performance to a satisfactory level. The structure above the ground is a CPW line with a square cut on top of the coupling part. Two matching stubs, which are shortened to each other at their ends, are located on top of the slots. Then, to reduce the effect of surface waves, one set of metalized vias shorten the bottom ground to the CPW's top ground. The waveguide used for this frequency is WR8 which starts working from 90 to 140 GHz.




(a)




(b)




(c)

Fig. 1 The proposed structure for the GCPW to waveguide transition: (a) top view, (b) bottom view, (c) cross-section

The final design using the structure optimized with CST secures coupling better than -1.5 dB over 8.6 GHz (i.e 9% of the band) and better than -1.8 dB over 22 GHz (i.e 22% of the band) on Rogers 5880 substrate, as illustrated in Fig.2. The return loss of better than -10 dB over 89.9 and 118 GHz of the band is also achieved for the waveguide port and GCPW port respectively, as shown in Fig. 3 and Fig. 4. The rest of the power which is not coupled to the GCPW, is either reflected, radiated or coupled to other modes of the PCB board. The even mode coupling level, as shown in the Fig. 5 is ignorable, but the coupling to the parallel plate mode is quite significant (-12 dB). CST 2009 simulations are also validated using Ansoft HFSS 11. The important dimensions of the transition structure are shown in table I. The value for the slot length is 1.61 mm which is half of the wavelength of the start operating frequency. Also, the slots are positioned at the edge of the waveguide, 0.88 mm away from each other.

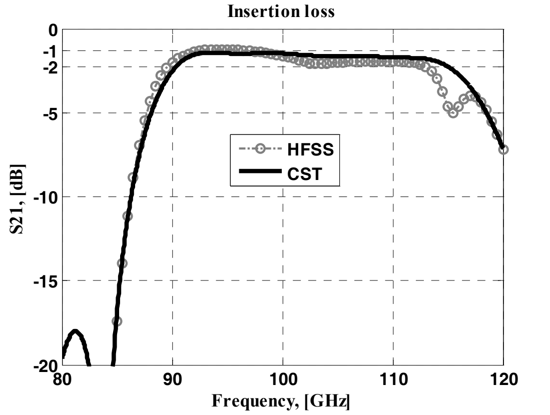



Fig. 2 Coupling between the waveguide and GCPW port

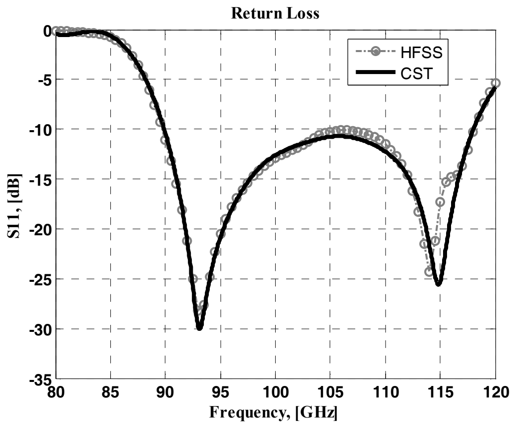



Fig. 3 Return loss at the waveguide port

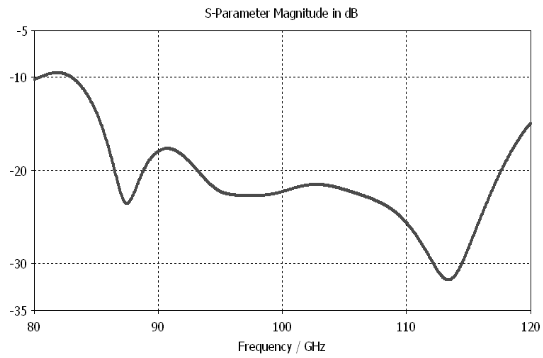



Fig.4 Return loss at the GCPW port

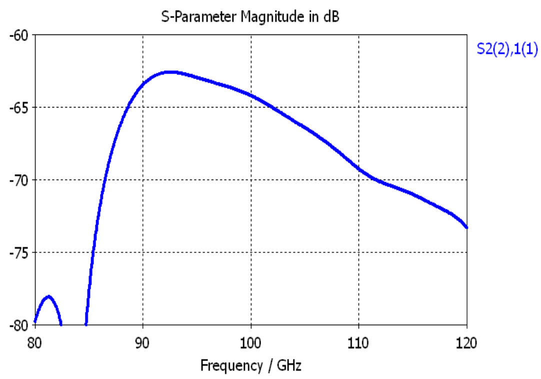



Fig.5 Coupling from the waveguide port to the CPW's even mode

The -1.2 dB coupling is equal to approximately 75 percent of power. Reducing the reflection, absorption and coupling to other modes, the remaining 7 to 8 percent will be radiated. This power can be radiation from the CPW slot or from the two slots in the center of the structure. Thus, the idea of reducing the slot size is raised to block the radiation from the transition. As illustrated in Fig. 6, the bandwidth of the coupling highly depends on the size of the slot. Therefore, the slot size cannot be changed without reducing the bandwidth.

TABLE I
IMPORTANT PARAMETERS OF THE TRANSITION STRUCTURE

| Parameter | name | Value (mm) |
|---|---|---|
| Ground slot's length | GSL | 1.61 |
| Ground slot's width | GSW | 0.14 |
| Ground slot X position | GSX | 0.42 |
| Line width | LW | 0.32 |
| CPW gap | G | 0.1 |
| Stub's length | SL | 1.96 |
| Stubs's width | SW | 0.36 |
| Stub's X position | SX | 0.44 |
| Width of stub short line | WS | 0.1 |
| Gap size between ground and transition(in x direction) | GX | 0.1 |
| Gap size between ground and transition(in y direction) | GY | 0.15 |
| Distance of the short from the transition | DS | 0.77 |

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As the implementation of vias at these frequencies is quite difficult, the effect of vias on the performance is also investigated. Fig. 7 shows that eliminating the vias will reduce the coupling with at least 1 dB and the bandwidth will also be decreased.

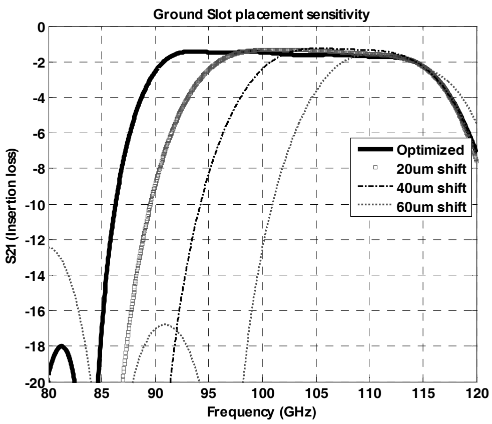


Fig. 6 Effect of reducing the ground slot size on the coupling

## III. CONCLUSION

A new transition from coplanar waveguide (CPW) to rectangular hollow waveguide for W-band applications has been presented. The transition has been designed to operate in the frequency range of 91 - 113 GHz. The return loss and radiation loss have been minimized to reduce the coupling insertion loss of the transition within the required band. The maximum insertion loss of the waveguide-to-CPW back-to-back transition is -1.8 dB in the frequency range of 91.2 – 113.2 GHz, corresponding to a 22% bandwidth, which is a huge improvement comparing to previously reported works.

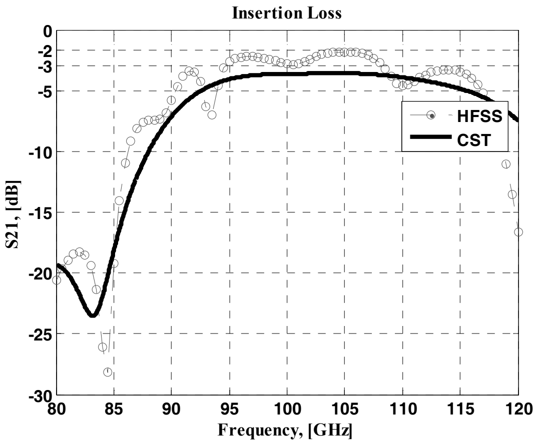


Fig. 7 Effect of removal of the vias on the coupling

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