# A Broadband CPW-to-Waveguide Transition Using Quasi-Yagi Antenna

Noriaki Kaneda, Yongxi Qian and Tatsuo Itoh

Electrical Engineering Department
University of California, Los Angeles
405 Hilgard Ave., Los Angeles, CA 90095, USA
Email: kaneda@ee.ucla.edu

## ABSTRACT

**A novel CPW-to-waveguide transition utilizing a uniplanar quasi-Yagi antenna is presented. The X-band back-to-back transition demonstrates 33% bandwidth with return loss better than -10dB. This transition should find a wide variety of applications due to its high MIC/MMIC compatibility and low cost.**

## I. INTRODUCTION

A number of MMICs (monolithic microwave integrated circuits) for microwave and millimeter-wave communication systems require compact and low-cost integration of planar circuits and metallic waveguides. Coplanar waveguide (CPW) is widely used in MMIC designs due to its uniplanar nature, low dispersion and high compatibility with active and passive devices. A limited number of studies have been previously reported on CPW-to-waveguide transitions. Broadband CPW-to-waveguide transitions based on ridge or ridge-trough waveguide were reported and wafer probes based on this technique have been manufactured over 50GHz frequency range [1]-[3]. The antipodal finline transition is another approach achieving broadband characteristics for CPW on low permittivity substrate [4]. An aperture-coupled CPW antenna approach has also been attempted for MMIC based transitions [5]. Those approaches, however, require either a high degree of mechanical complexity or electrically large substrate size, making the integration of MMIC designs with waveguide systems very difficult.

To address these issues, we recently developed a broadband MMIC compatible microstrip-to-waveguide transition [6]. This transition utilized a broadband quasi-Yagi antenna fed by a uniplanar microstrip-to-CPS balun [7] [8]. In this work, we implement the quasi-Yagi antenna on CPW structure to develop a CPW-to-waveguide transition. The antenna is built on the high permittivity substrate (Duroid $\varepsilon_r = 10.2$) keeping the total transition size very compact. An X-band prototype of back-to-back transition demonstrates 33% bandwidth with return loss better than -10dB and about –1.0dB insertion loss at the center frequency. Extensive machining or via holes are not required in this novel transition. These features should greatly simplify and lower the cost of integrating CPW-based MMICs and waveguide systems.

## II. TRANSITION DESIGN

A schematic view of the proposed transition is shown in Fig. 1 and the printed circuit of the CPW quasi-Yagi antenna is shown in Fig. 2 (a). The balanced signal on the coplanar strips is excited by a CPW-to-CPS transition based on [9]. The field distribution of the CPS fed dipole antenna is in good alignment with the dominant mode of the rectangular waveguide when the antenna is inserted along the E-plane of the waveguide. The parasitic director element of the antenna guides the direction of wave propagation into the rectangular waveguide. As is illustrated in the side-view of the transition in Fig. 2 (b), the printed CPW circuit is placed face down on the trenched metal block. The ground planes of the CPW are placed in contact with the metal blocks to provide support for the circuit. The supporting metal block also acts as a back short to prevent the waveguide’s dominant mode from propagating backward, as well as serving as the antenna’s reflector element.

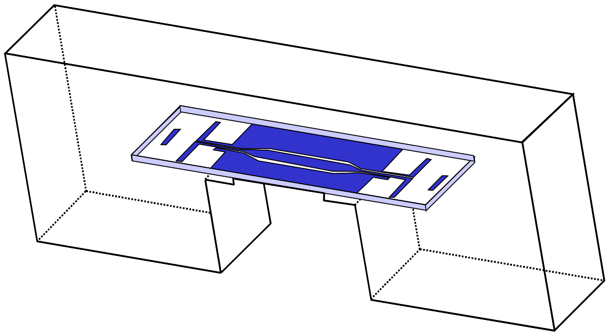

Fig. 1 Proposed CPW-to-Waveguide transition using quasi-Yagi antenna. (back-to-back)

Since the CPW can support two dominant modes, namely the CPW mode and the CSL (coupled slotline) mode, any discontinuity on the circuit can potentially excite the undesired CSL mode. Moreover, while the conductor-backed CPW provides mechanical strength and convenient packaging, the strongly excited parallel plate mode becomes an inherent problem. Thus, additional methods such as via holes, air-bridges and multi-layer substrates are required to suppress those undesired modes of CPW. The novel approach we propose in this work is the usage of the trenched metal block to suppress the CSL mode as well as the parallel plate mode. This ensures single mode operation of the CPW structure for broad bandwidth, in addition to providing support for the CPW-based circuit.

The antenna’s dimensions have to be carefully optimized like in the conventional Yagi-Uda antenna design. Since the metal block works as a reflector element for the quasi-Yagi antenna, the trench depth and position have to be carefully designed and optimized together with the other antenna parameters.

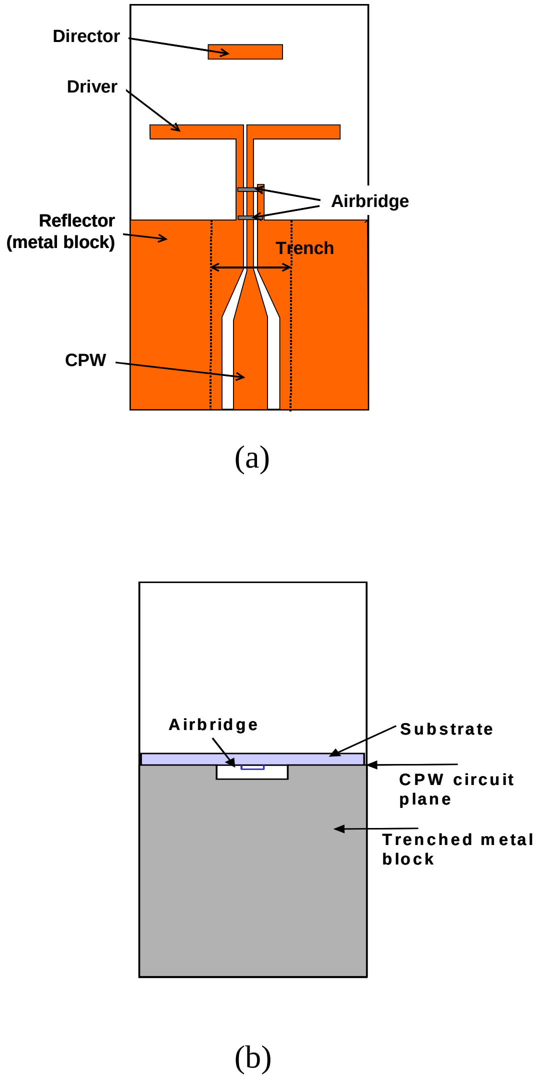

Fig. 2 Cross-section views of the transition (a) bottom view (b) side view.

## III. SIMULATION AND MEASUREMENT RESULTS

The transition for the X-band prototype is simulated and optimized using both Ansoft and HP HFSS. Fig. 3 shows the simulation results of the back-to-back X-band transition. The simulation results do not include metal and dielectric loss. The result shows that return loss is below -10dB across all of X-band with maximum insertion loss of -0.2dB.

The CPW circuit is fabricated on the 25mil thick RT Duroid substrate ($\varepsilon_r$=10.2) and thin copper film is used to construct the air-bridges. As mentioned earlier, a trenched copper block is utilized to support the CPW circuit in the E-plane of the standard waveguide. After the air-bridges were mounted, the CPW circuit was flipped over and soldered onto the trenched copper block. Finally the block with the CPW antenna is slid into a standard X-band waveguide, and waveguide adapters are used to measure the 2-port S-parameters.

The measured results of the back-to-back transition are shown in Fig.4. The results show 33% bandwidth with return loss better than -10dB. Insertion loss ranges from -1.0dB to -2.2dB in the pass-band. The waveguide adapter loss is measured to be about -0.3dB for the entire pass band and this loss is subtracted from the measured insertion loss to evaluate the transition loss. The antenna parameters can alternatively be optimized so that smaller insertion loss is achieved for narrower bandwidth. The simulation and measurement results show that the transition is very broadband and reasonably low-loss. These characteristics are comparable with the ridge waveguide transition and much better than the aperture-coupled antenna type transition in [5] both in bandwidth and insertion loss.

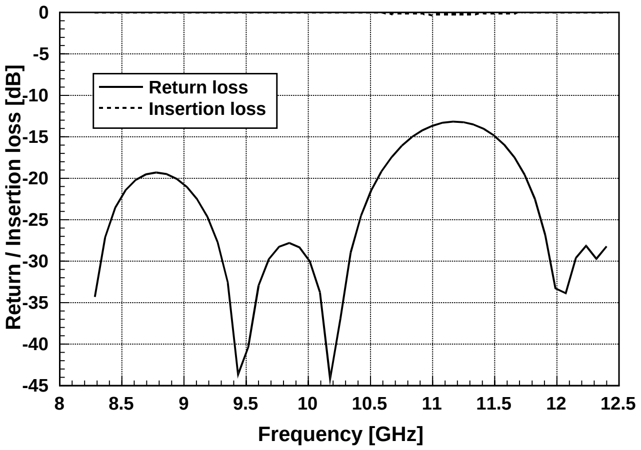

Fig. 3 Simulation results of the back-to-back X-band transition excluding conductor and dielectric loss.

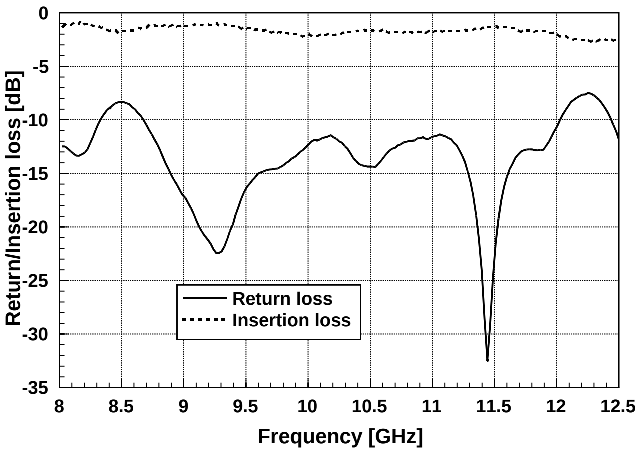

Fig. 4 Measurement results of the back-to-back transition.

## IV. CONCLUSION

A novel CPW-to-waveguide transition using a uniplanar quasi-Yagi antenna has been proposed and demonstrated. The transition uses high permittivity substrate suitable for the future monolithic integration with solid-state devices. The new structure requires much less fabrication effort than any existing techniques. An X-band prototype measures broad bandwidth of 33% and reasonably low insertion loss in a back-to-back configuration. We believe that this promising transition should find a wide range of uses for CPW-based MMIC applications.

## ACKKNOWLEDGEMENT

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