CPW to Waveguide Transition with Tapered Slotline Probe

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***Abstract*—A new CPW to waveguide transition is developed based on the concept of tapered slot antenna and E-plane probe coupling. The transition consists of a tapered slotline probe and a slotline to CPW matching section. The current design has the advantages of broad bandwidth, compact size, low fabrication cost, and high reliability. The characteristics of a prototype transition are investigated by numerical simulation on Duroid substrate and WR-90 waveguide. The back-to-back combination is measured to verify the agreement with the simulated results and realization of this design.**

***Index Terms*—CPW, tapered slotline, waveguide transition.**

I. INTRODUCTION

CPW has become more and more popular for microwave monolithic and hybrid integrated circuits due to its advantages of compact size, lower dispersion, and easy integration of series and shunt devices. In spite of the wide use of printed planar circuits in microwave and millimeter wave systems, metallic waveguides still play an essential role in various components like antenna feeds, high-Q filters, diplexers, and so on. Therefore, the increased use of CPW circuits in both commercial and military systems will drive the search for high performance, easy integration, and low cost transitions to rectangular waveguides.

In the past, a limited number of designs for the transition between CPW and rectangular waveguide have been reported. Transitions based on ridge waveguide have been studied [1]–[3]. These transitions provide broadband performance with low insertion loss, but the majority of them involve a high degree of mechanical complexity. The antipodal finline transition is another one capable of achieving broadband design [4], but suffers from electrically large substrate size. An aperture-coupled approach [5] and L-shaped loop coupling [6] on the end of waveguide have also been proposed for easy integration between waveguide and planar circuit, but generally only 10–20% bandwidth can be achieved. Recently, transition using uniplanar quasi-Yagi antenna is reported for wide bandwidth and easy integration [7]. However, this structure requires high permittivity substrate so that the antenna can fit into the E-plane of the rectangular waveguide.

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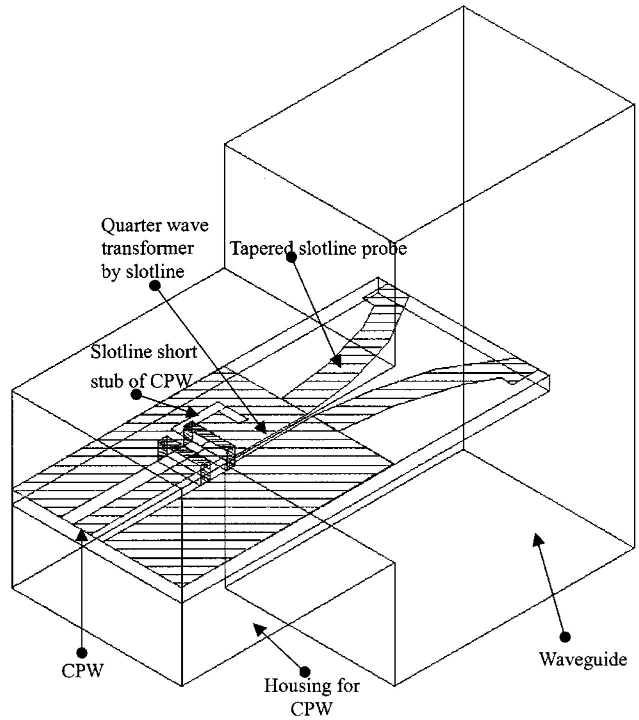

Fig. 1. CPW-to-waveguide transition based on tapered slotline probe.

This paper presents a new type of CPW-to-waveguide transition based on the concept of tapered slot antenna and E-plane probe coupling. It is realized on a single layer printed circuit and is inserted into the end launcher of waveguide. The characteristics of prototype transition are investigated by numerical simulation on Duroid substrate and WR-90 waveguide. A back-to-back prototype transition has been fabricated and the scattering parameters are measured to verify the present design. The transition is shown to operate well over almost the entire recommended waveguide band. It exhibits advantages of broad bandwidth, compact size, low fabrication cost, and high reliability.

II. TRANSITION DESIGN

A schematic view of the proposed transition is depicted in Fig. 1. The key features of the transition include two parts. One is a tapered slotline probe insertion into the E-plane of the end launcher of waveguide, and the other is slotline-to-CPW transition and matching circuit.

Consider the coupling region between tapered slotline probe and waveguide. As for tapered slotline, the structure is charac-

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teristic of broad bandwidth and with a symmetrical field pattern [8] in good match to the dominant TE_{10} mode of the rectangular waveguide. For easy integration and compact size, the tapered slotline is properly shaped for using in the proposed transition design. In order to ease the fabrication and improve the reliability, the outer metal parts of tapered slotline are reduced to be free of touch with the metallic walls of rectangular waveguide. Under this arrangement, the transition structure can be easily accomplished by directly inserting tapered slotline probe to the E-plane of the end of rectangular waveguide. Because the lateral dimension in the E-plane of rectangular waveguide is less than $\lambda/2$ of operation frequency and compact transition size is preferred, a tapered slotline probe of about a quarter wavelength for significant radiation through resonance mechanism is exploited. When the compact slotline probe is integrated into the E-plane of the end of the waveguide, the strong electrical fields of both the probe and waveguide match with each other and couple effectively to achieve good energy transfer.

In the transition region between CPW and tapered slotline probe, a quarter wavelength impedance transformer by slotline and CPW-to-slotline transition using CPW short with a slotline short stub [9] are used. The quarter wavelength impedance transformer is provided to match high input impedance of tapered slotline probe to relatively low impedance CPW. The length of the slotline short stub of CPW is about $\lambda/4$ and the shape is bending for limited space. At the junction of slotline and CPW, the ground planes of CPW are bonded with air bridge to suppress the excitation of slotline mode due to the structural nonsymmetry.

Both of the tapered slotline probe and the CPW-to-slotline transition have broadband performance. By properly selecting the electrical length and characteristic impedance of the interconnecting slotline to match the two parts and tuning the length of the slotline short stub of CPW to compensate part of the mismatch admittance, the integrated CPW-to-waveguide transition can achieve broadband matching.

III. Simulation and Measurement Results

Numerical simulation and testing was done on X band, although the present design can be applied for higher frequency band without much difficulty. Standard WR-90 waveguide with inside dimension 900×400 mil is used as the transition waveguide, while Rogers RT/Duroid 5880 substrate with 31-mil thickness and dielectric constant of 2.2 was chosen to implement the planar circuit. Note that the profile of the slotline probe using smoothly tapering and wider open width at the far end can achieve better performance. The profile of the coupling probe in the transition is designed to a three-section piecewise linear taper as shown in Fig. 1. The tapered slotline probe is located at the center of waveguide. In the simulation by commercial software HFSS, the length of tapered slotline probe for slotline to waveguide transition is chosen as a parameter to test the performance. Fig. 2 demonstrates that the compact tapered slotline probe can provide moderately good performance, which is insensitive to the probe length.

Fig. 3 shows the schematic and dimensions of the planar circuit of the CPW-to-waveguide transition. The planar circuit

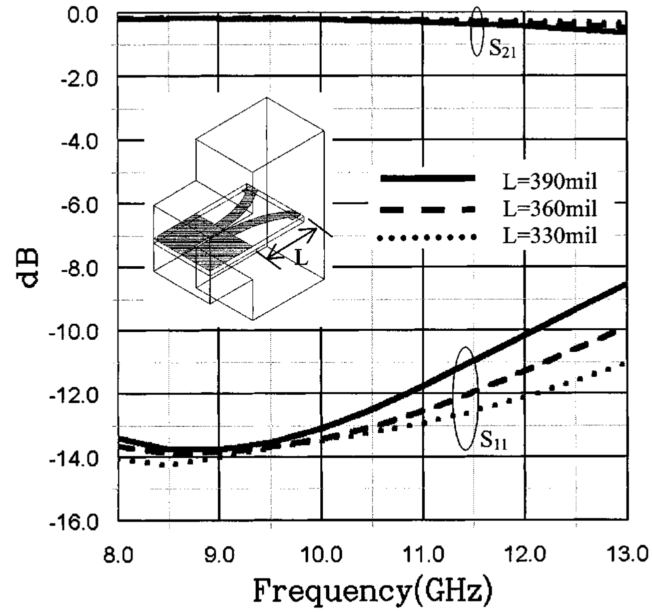

Fig. 2. Simulated results for slotline-to-waveguide transition with length of tapered slotline probe as a parameter.

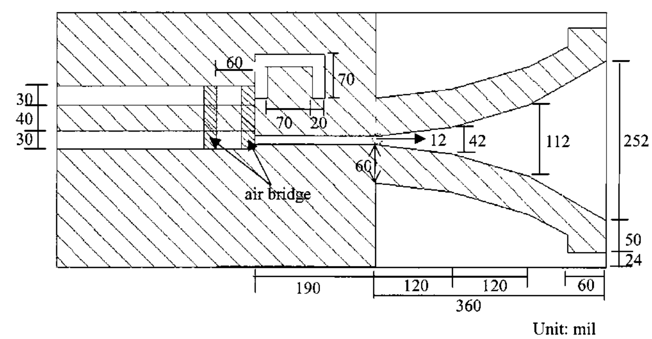

Fig. 3. Layout and dimensions of the planar circuit in the transition.

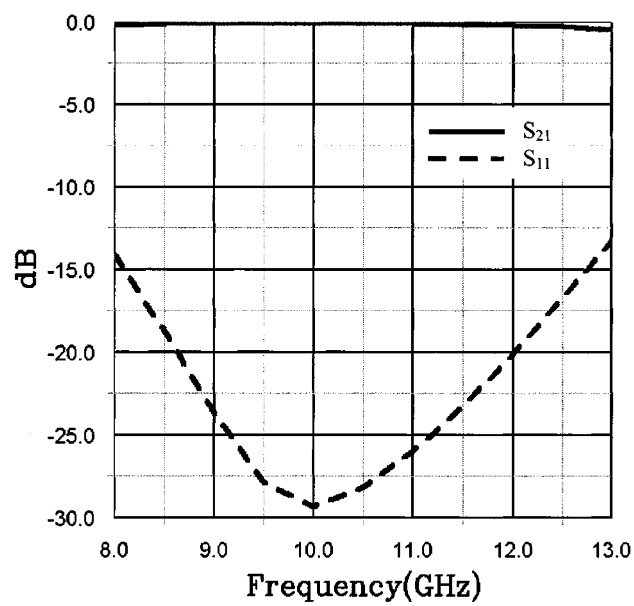

Fig. 4. Simulated results of insertion loss and return loss for the CPW-to-waveguide transition.

is realized by integrating CPW-to-slotline transition to tapered slotline probe. Impedance matching circuit is achieved by properly choosing the dimension of slotline and slotline short stub

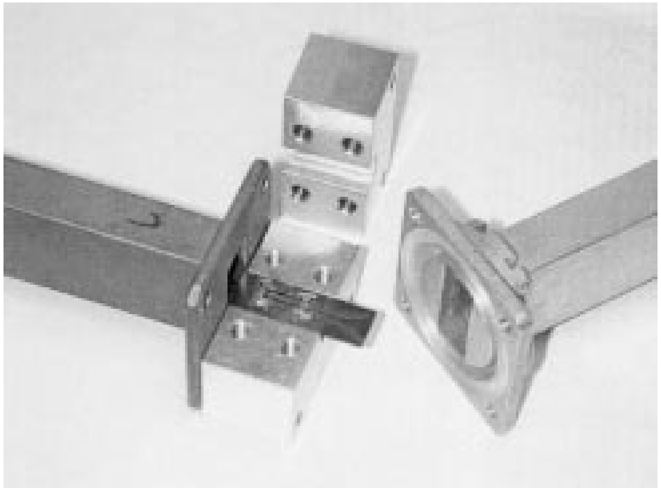

Fig. 5. Photography of the test structure for the back-to-back cascaded CPW-to-waveguide transitions.

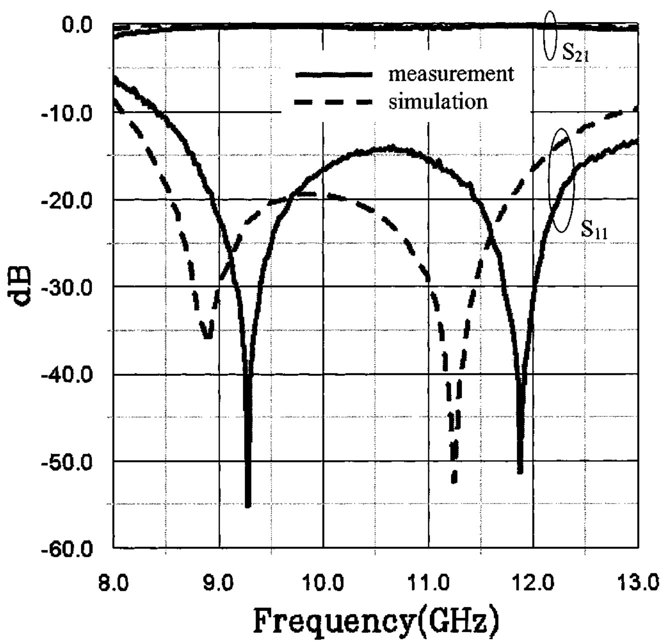

Fig. 6. Simulated and measured results for two back-to-back cascaded transitions.

of CPW. Note that the gaps between probe tips and waveguide walls are insensitive to their width, except very close to the metal walls. For performance stability and no touch of metal wall under mechanical tolerance, 24 mil gap width is chosen in the case. In the structure design, the housing for CPW, as shown in Fig. 1, is 400×400 mil. The conductor plane of the planar circuit is placed at the center of housing and contacts with the metal wall. Fig. 4 shows the simulated insertion and return loss for the transition, assuming that the metallic and material loss is negligible. It can be found that the return loss is below -20 dB over 30% bandwidth and below -15 dB over 40% bandwidth, which almost covers the whole recommended frequency range of the waveguide (8.2–12.4 GHz).

For ease of measurement, the two transitions considered in Fig. 3 are cascaded back-to-back. Fig. 5 shows the structure employed in the experimental setup, for which the total length of housing is 700 mil inclusive of two 190 mil probe-to-CPW matching circuits. The measured and simulated results for the back-to-back assembly are shown in Fig. 6. Reasonable agreement between the two results can be observed. From the measured results, the transition has better than -14 dB return loss over a bandwidth of 40%. The insertion loss is better than -0.75 dB over this bandwidth.

IV. Conclusion

A novel CPW-to-waveguide transition has been proposed and demonstrated. The transition is based on tapered slotline probe coupling and slotline-to-CPW matching circuit. The transition has compact size, and can be integrated easily with waveguide by directly inserting the coupling probe into the waveguide. Reasonable agreement between the simulated and measured results verifies that the design can successfully yield relatively broadband performance with low insertion loss. These features provide the transition a wide range of applications.

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