

A Wide Band Transition from Waveguide to Differential Microstrip Lines

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Abstract

A novel transition from rectangular waveguide to differential microstrip lines is illustrated in this paper. It transfers the dominant TE₁₀ mode signal in a rectangular waveguide to a differential mode signal in the coupled microstrip lines. The common mode signal in the coupled microstrip lines is highly rejected. The transition was designed at 75 GHz, which is the center frequency of E band and simulated by a 3D EM simulator. It has a wide bandwidth of 19 GHz for –15 dB return loss of the waveguide port. Several prototypes of the transitions were fabricated and measured. The measurement results agree very well with the simulation. The compact size and the simple fabrication enable the transition to be employed in a number of millimeter-wave applications.

Introduction

Rectangular waveguide structures are widely used in millimeter-wave technology because of their low-loss characteristics. On the other hand, most Monolithic Microwave Integrated Circuits (MMICs) are built in microstrip line structures due to their low profile attributes. Therefore, an optimized transition from rectangular waveguide to microstrip line structures is often required in millimeter wave applications, e. g. in automotive radars front-ends. In the last decade, many types of transitions have been published in the literature, for example rectangular patch type [1], Quasi-Yagi type [2] and U-shape ridge type [3]. All of these transitions convert signals from a rectangular waveguide to a single-ended microstrip line. In this paper, a novel transition from waveguide to differential microstrip lines is presented. It enables simple integration between differential active circuits and standard waveguide structures. It is also usable as a differential microstrip antenna feeder during far field antenna measurements.

Structures

The transition is composed of a metallized cap and a bottom mount with a dielectric structure in between. The cap mount is a short end WR12 waveguide with an open channel for the microstrip port. The cross section of the type-1 transition (looking from the microstrip port) is shown in Fig. 1. The inner

height of the cap mount equals $\lambda_0/4$ (λ_0 is the free space wavelength). The bottom mount is a sustainer which has a WR12 waveguide interface. The dielectric substrate between the mounts plays an important role in the transition. Fig. 2 shows the top layer of the substrate. Inside of the waveguide area (dashed line in the figure), there is a pair of triangular patches. One side of the triangular patch connects to the waveguide conductor, where as the other side of the patch connects to the microstrip port formed by a pair of coupled microstrip lines. The ground plane of the substrate within the waveguide area is removed. Vias are used around the waveguide to connect the cap and the bottom mount. The vias construct shielding walls around the waveguide area and prevent leakage of the plane waves. The shadowed parts in the Fig. 2 are metallized areas on the substrate. The top and bottom mounts are made of brass. The dielectric substrate in the structure is RO 3003 with 0.127 mm thickness.

The E-field distribution of the transition derived from EM simulation is shown in Fig. 3. It can be observed that the dominant TE₁₀ mode waveguide signal is guided by the triangular patches to the coupled microstrip lines. Therefore, it supports a large bandwidth and suppresses the common mode of the coupled microstrip lines. A section of un-grounded coupled microstrip lines (inside the waveguide area) works as $\lambda_0/4$ transformer for impedance matching. Simulation results are shown in Fig. 4. There is around 23 GHz bandwidth of -15 dB return loss for both the differential mode in the microstrip port and the waveguide port. The insertion loss of the waveguide port is less than 0.5 dB within the bandwidth. The return loss of the common mode in the microstrip port is below 0.5 dB.

Because of difficulties with via realization on the substrates, another structure type-2 transition is also tested within this paper. The cross section of this transition is shown in Fig. 5. In this structure, a U-shape slot is removed from the substrate inside via area (see Fig. 2) and a piece of metal sheet is put into the slot. This metal sheet substitutes the function of the vias and forms the shielding walls. Both sides of the substrate are 0.2 mm wider than the waveguide size to provide better contact with the top mount. Similar S-parameter results are reached by optimizing the triangular patches.

Fabrication and Measurements

Both types of the transitions were fabricated and measured. The vias in the substrate were realized by filling conductive epoxy glue into drilled holes. A pair of spiral structures is connected to the microstrip port of the transition. In combination with absorbing material on the top of the spiral structures, they work as a matched load for E band (the return loss is measured below -15 dB for the whole E band). Figure 6 shows a photograph of the transition with the spiral loads. The return loss of the waveguide port is measured using a network analyzer. The measurement and the simulation results are plotted in Fig. 7. The measurement results show good agreement with the simulation results.

There is a frequency extension module used within the measurement to generate signals from 67 GHz to 90 GHz. Noise in the measurement results above 67 GHz is due to the used equipment. There is a ripple in the return loss within the bandwidth of the measured results. The period of the ripple is approximately 4.5 GHz, which corresponds to 0.22 ns propagation delay in the time domain. The distance between the spiral load and the DMSLs port of the transition is 20 mm. Therefore the ripple is coming from the unintended mismatch of the spiral load.

The fabrication tolerances and the misalignment during the assembling influence the performance of the transition. These inaccuracies introduce some mismatch, resulting in a difference between the simulation and the measurement results. But the large bandwidth of the transition supports its wide usage in millimeter-wave applications

Conclusion

In this paper, a wide band transition from waveguide to differential microstrip lines in E band is demonstrated. The transition provides simple connection between differential active circuits and rectangular waveguide structures. Two types of transitions were fabricated and measured. Type-1 is suitable for mass production and type-2 is available for prototype in lab. The measurement results show a bandwidth of 19 GHz, which is 25% relative bandwidth. Low costs for fabrication and small dimensions enable the transition to be used in many applications.

Acknowledgement

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References

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Figures

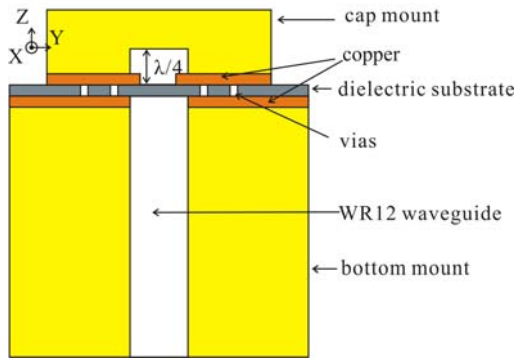


Fig. 1. Type-1 transition cross section.

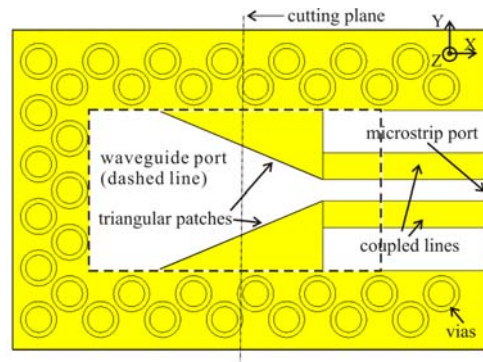


Fig. 2. Top layer of the substrate.

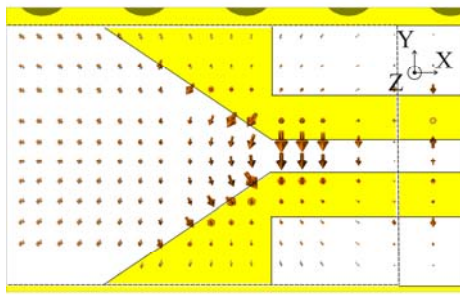


Fig. 3. E-field distribution inside the transition.

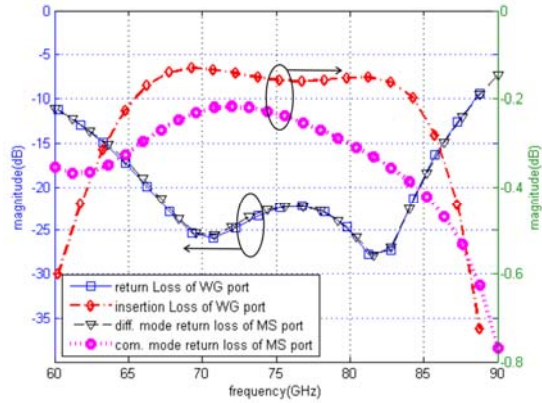


Fig. 4. Simulation results of the return loss and the insertion loss.

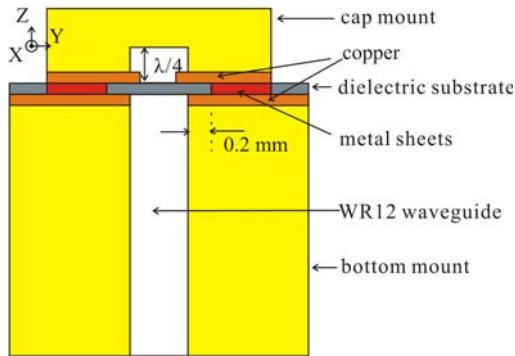


Fig. 5. Type-2 transition cross section.

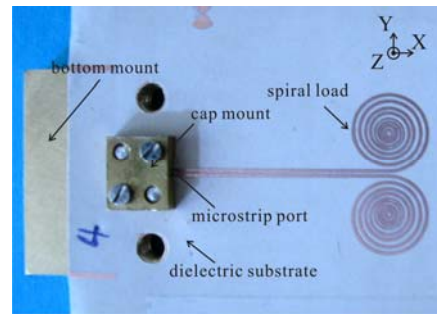
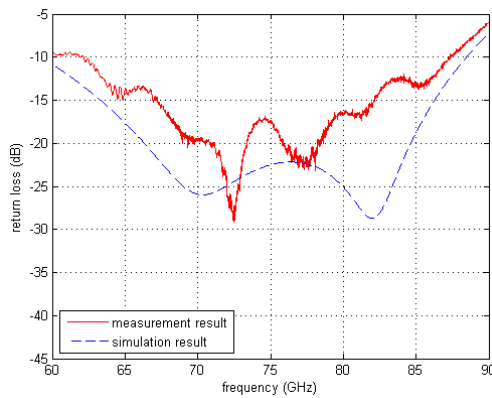
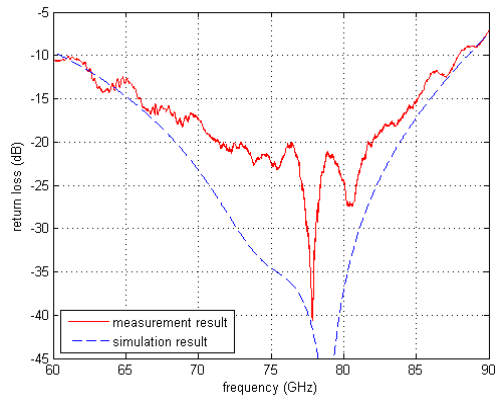


Fig. 6. Photograph of the transition with the spiral load.



(a)



(b)

Fig. 7. Simulation and measurement results of type-1 and type-2 transitions.