

# A Novel Wideband Antipodal Fin-line Waveguide-to-Microstrip Transition Structure for Ka-band Applications

Bo Fang\*, Youlei Pu, and Yong Luo

*School of Physical Electronics, University of Electronic Science and Technology of China, Chengdu, Sichuan610054, China,*

\* Contact: 18200516559@163.com, phone +18200516559

**Abstract**— In this paper, a wideband low loss antipodal fin-line waveguide-to-microstrip transition structure for operation in the Ka-Band (28 ~ 40 GHz) has been designed. The design uses a novel fin-line transition structure to eliminate the resonance caused by the traditional resonant cavity and thus broadens the bandwidth. The transition structure is realized by clamping the printed circuit board (PCB) between two halves of the metal body. The compact transition design could decrease the effect of manufacture and assembly error. All parameters of the designed structure are optimized by using a high-frequency structure simulator (HFSS). The design was verified by experimental results at Ka-band, which has a coincidence with the results of simulation. Test results show that insertion loss fluctuates between 0.09 dB and 1.0 dB covering 28 ~ 40 GHz. In the frequency range of 29.1 ~ 32.8 GHz and 36 ~ 39.4 GHz, the insertion loss fluctuates in the range of 0.09 dB to 0.6 dB. The return loss fluctuates between 10 dB and 30 dB covering 28 ~ 40 GHz.

## INTRODUCTION

With the millimeter-wave technology broadly used in short-distance wireless communications and radar systems, the use of low-cost and high reliable Monolithic Microwave Integrated Circuit (MMIC) is becoming increasingly widespread. In the millimeter-wave receiving system, microstrip line is used as the connection between MMICs. However, current millimeter-wave test system mostly use a rectangular waveguide interface which requires the system to find a low cost, low loss, easy to manufacture, wide bandwidth rectangular waveguide to microstrip ferry. Currently, the transition structure commonly used between waveguide and microstrip is: stepped ridge waveguide transition [1], antipodal fin-line waveguide-to-microstrip transition [2-4], microstrip probe coupling transition [5-6]. These transition structures have wide bandwidth, low insertion loss characteristic. Wherein, the stepped ridge waveguide transition has the characteristics of complex processing. Microstrip probe coupling transition due

to the outlet direction perpendicular the circuit, it does not meet many systems' requirements. With regard to antipodal fin-line waveguide-to-microstrip transition, it provides low insertion and reflection loss levels in comparison with the aperture coupled transitions and also are easier in realization comparing with the probe transitions. Those transitions were first demonstrated in [7] for the 18 ~ 26GHz frequency band. Later in [8-9] their modifications were presented for frequencies up to 48 GHz.

This paper presents a design of a wideband waveguide-to-microstrip transition operating in the Ka-Band (28 ~ 40 GHz) with a low insertion loss. The transition is formed on the PCB with realized antipodal fin-line inserted into a standard WR28 (26.5 ~ 40GHz) rectangular waveguide structure. The PCB is disposed along the E-plane of the waveguide. The PCB in the proposed transition is based on high frequency technology RO5880 (with dielectric permittivity  $\epsilon = 2.2$  and loss tangent  $\tan\delta = 0.0009$ ). The transition characteristics are optimized with 3D electromagnetic simulation (HFSS) and confirmed by experimental verification.

## WAVEGUIDE-TO-MICROSTRIP TRANSITION STRUCTURE

In this paper, all parameters of the designed structure are optimized by using a high-frequency structure simulator (HFSS). Fig. 1 shows the structure of antipodal fin-line waveguide-to-microstrip transition. As we can see, the transition structure is realized by clamping the printed circuit board (PCB) between two halves of the metal body. The tapered antipodal fin-line smoothly transforms the incident TE<sub>10</sub> waveguide mode to a quasi-microstrip mode [10] which is propagating in the area of overlapping antipodal fins of the transition. E field in the transition area concentrates and rotates by 90 degrees until waveguide mode transforms to the microstrip mode. Smooth transformation of the field

mode allows the transition to operate in a wide frequency band.

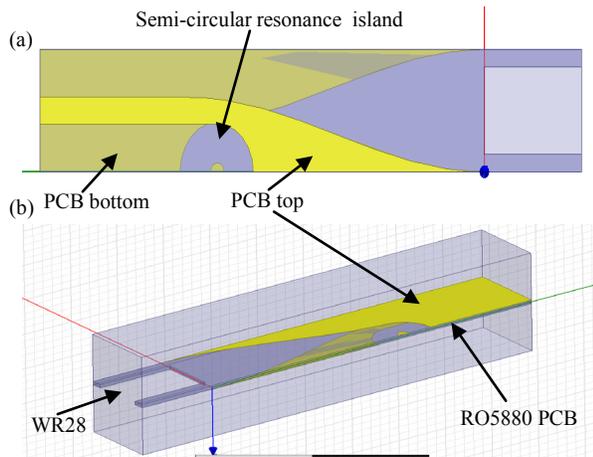


Fig. 1 A typical antipodal fin-line waveguide-to-microstrip transition structure

In order to obtain good impedance matching between waveguide and microstrip, smooth gradient segment between the top and bottom of PCB is necessary. Generally, parabolic curve, exponential curve and cosine squared curve are widely used in fin-line transition. In consideration of easy processing, this paper will use cosine squared curve.

In tradition, to prevent electromagnetic field resonate with the cavity wall, a semi-circular resonance island is introduced and it achieves the elimination of resonance. In this paper, a novel triangle resonance island will be used, this structure eliminates resonance more easily and is easier to be fabricated.

ELECTROMAGNETIC SIMULATION RESULTS

Fig. 2 shows the back to back model which achieves antipodal fin-line waveguide-to-microstrip transition. Extending to both sides of the portion of the substrate is to make the substrate assemble in the waveguide cavity more stably. The metal via holes extends the waveguide walls inside the PCB structure along the fin length. That allows increasing stability of the transition and improving its reflection characteristics by eliminating the slot mode excitation between two halves of the metal body.

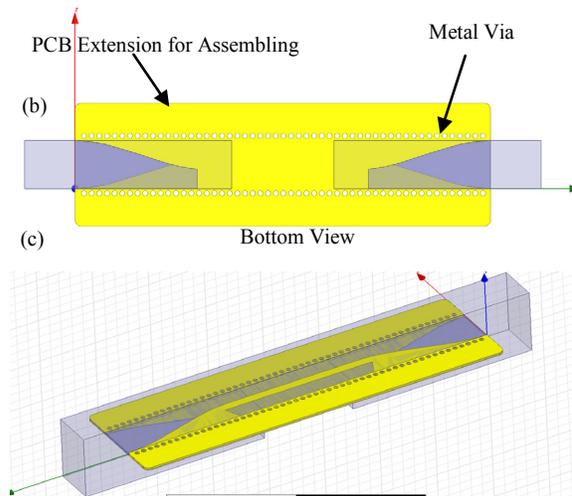
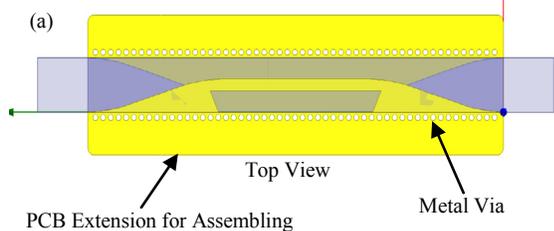


Fig. 2 Back to back model in HFSS simulation

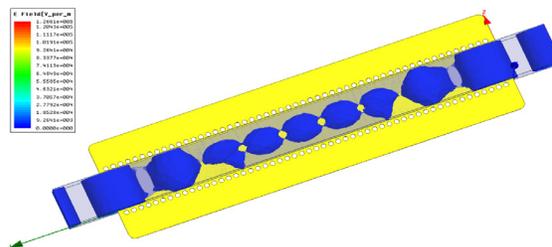
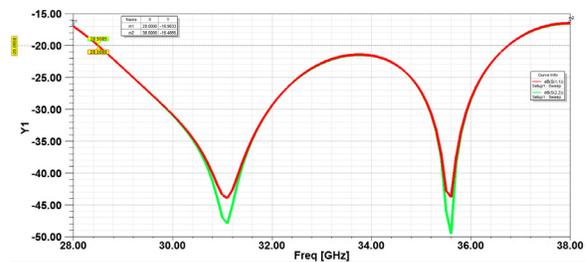
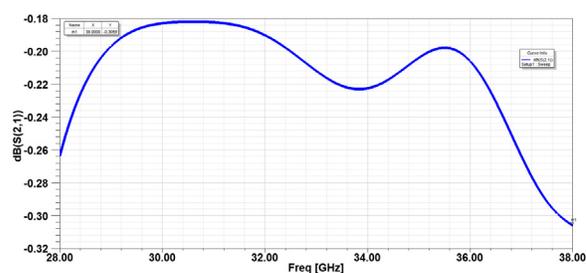


Fig. 3 E field simulation result

From Fig. 3, we can see that electromagnetic energy achieve good transition from waveguide to microstrip. The tapered antipodal fin-line smoothly transforms the incident TE<sub>10</sub> waveguide mode to a quasi-microstrip mode.



(a)



(b)

Fig. 4 Simulated S<sub>11</sub>, S<sub>22</sub> (a) and S<sub>21</sub> (b) of the designed waveguide to microstrip transition

By means of using HFSS software' optimization function, we achieved some good results which proved the rationality of this design. Finally, results are shown in Fig. 4. Simulation results show that insertion loss fluctuates between 0.18 dB and 0.3 dB covering 28 ~ 40 GHz. The return loss fluctuates between 16.98 dB and 45 dB covering 28 ~ 40 GHz.

#### EXPERIMENTAL RESULTS

In order to further verify the reasonableness of the design, we use SolidWorks software design the mechanical processing map about antipodal fin-line waveguide-to-microstrip transition structure as Fig. 5 shows. Physical process is shown in Fig. 6.

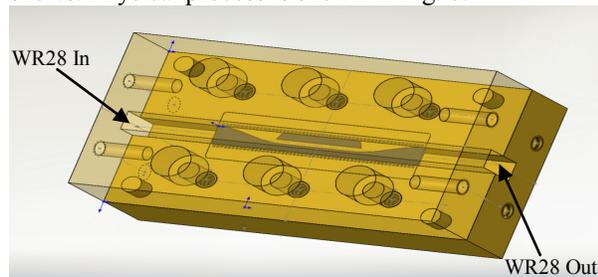


Fig. 5 3-D model of design diagram

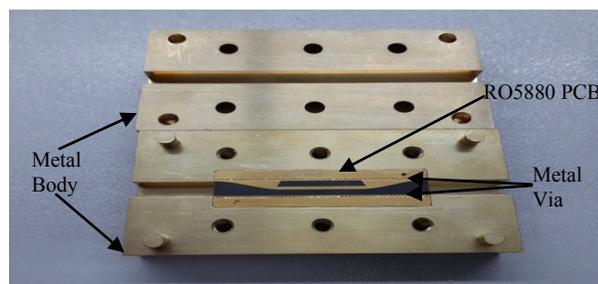


Fig. 6 Fabricated PCB and metal body of back-to-back antipodal fin-line waveguide-to-microstrip assembled transition

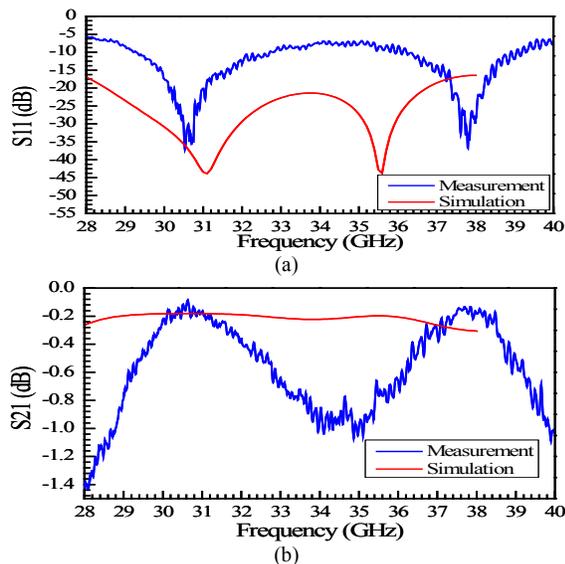


Fig. 7 Comparison of experimental results and simulation results

The insertion loss of single waveguide-to-fin-line-to-microstrip structure ( $S_{21}$ ) is about half of the test result. Physical test results are shown in Fig. 7. The test results show that the maximum value of insertion loss is 1.0 dB while at the minimum of 0.09dB covering 28 GHz ~ 40 GHz. In the frequency range of 29.1 ~ 32.8 GHz and 36 ~ 39.4 GHz, the insertion loss fluctuates in the range of 0.09 dB to 0.6 dB. The return loss ( $S_{11}$ ,  $S_{22}$ ) fluctuates between 10 dB and 30 dB covering 28 ~ 40 GHz.

By comparing the experimental and simulation results, the experimental results and simulation results exists some deviation, but the trends about experimental results are much the same as simulation results. The fabricating error, assembling error, physical dimensions and conductor loss are the main reason for this difference. Therefore, this design can be considered as a success.

#### CONCLUSION

A novel Ka-Band waveguide-to-microstrip antipodal fin-line transition was designed in this paper. The transition was fabricated to verify the design. The results of simulation and experimental show the transition has a broadband, low insertion loss and low return loss performance. It is helpful for millimeter band devices and circuits. Simultaneously, due to these characteristics, the transition structure also has a certain potential applications at higher frequencies.

#### REFERENCES

- Yao Hui-Wen, Abdelmonem Amr, Liang Ji-Fuh. A full wave analysis of microstrip-to-waveguide transition. *IEEE MTT-S*, 1994, 1: 213-216
- J H C van Heuven. A New Integrated Waveguide-Microstrip Transition. *IEEE Trans. MTT*, 1976, 24 (3): 144-147
- Dydyk M, Moore B D. Shielded microstrip aids V-band receiver designs. *Microwaves*, 1982, 21 (3): 77-82
- Ponchak George E, Downey Alan N. A new model for broad-band waveguide-to-microstrip Transition Design. *Microwave Journal*, 1988, 5:333 - 343
- Villegas Frank J, Stones D Ian, Hung H Alfred. A novel waveguide-to-microstrip transition for millimeter2wave module applications. *IEEE MTT*, 1999, 47(1): 48-55
- Yoke2Choy Leong, Sander Weinreb. Full band waveguide-to-microstrip probe transitions. *IEEE MTT-S*, 1999, 4: 1435 - 1438
- J. H. C. van Heuven, "A New Integrated Waveguide-Microstrip Transition," *IEEE Trans. on Microwave Theory Tech.*, vol. 24, is. 3, pp.144-147, March 1976.
- A. K. Sharma, "Tunable Waveguide-to-Microstrip Transition for Millimeter-Wave Applications," *Proc. IEEE MTT-S int. Microwave Symp. Dig.*, vol. 1, pp. 353-356, 1987.
- T. Djerafi, A. Ghiotto, and K. Wu, "Antipodal fin-line Waveguide to Substrate Integrated Waveguide Transition," *Proc. IEEE MTT-S int. Microwave Symp. Dig.*, pp. 1-3, 2012.
- J. B. Knorr and P.M. Shayda, "Millimeter-wave fin-line characteristics," *IEEE Transactions on Microwave Theory and Techniques*, vol. 28, no. 7, pp. 737-43, July 1980.