

# Broadband stripline to rectangular waveguide transition

Jun Dong<sup>1a)</sup>, Tao Yang<sup>1</sup>, Yu Liu<sup>1</sup>, Yihong Zhou<sup>2</sup>, and Haiyan Jin<sup>3</sup>

<sup>1</sup> School of Electronic Engineering, University of Electronic Science and Technology of China, No.2006, Xiyuan Ave, West Hi-Tech Zone, Chengdu, 611731, China

<sup>2</sup> School of Physics and Electronic, University of Electronic Science and Technology of China, Jianshe Road, Chengdu, 610054, China

<sup>3</sup> School of Communication and Information Engineering,  
University of Electronic Science and Technology of China,  
No. 4, Section 2, North Jianshe Road, Chengdu, 610054, China  
[a\)jundong.ee@gmail.com](mailto:a)jundong.ee@gmail.com)

**Abstract:** In this work, a broadband stripline-to-rectangular waveguide transition is presented. It uses a rectangular-shaped probe to couple the energy from rectangular waveguide to stripline. The two ground planes of the stripline are extended for field matching of the transition. A back-to-back transition prototype at Ka-band is designed, fabricated and measured. The measured results show that the transition has less than 1.2 dB insertion loss and better than 15 dB return loss over the frequency range from 26.5 to 40 GHz. The 15 dB fractional bandwidth is increased from 11.6 to 41% compared with conventional stripline-to-waveguide transition. The measured results agree well with simulated ones.

**Keywords:** Broadband transition, Ka-band, stripline, rectangular waveguide

**Classification:** Microwave and millimeter wave devices, circuits, and systems

## References

- [1] W. E. Fromm: IRE Trans. Microwave Theor. Tech. **3** (1955) 13. DOI:10.1109/TMTT.1955.1124912
- [2] B. Nauwelaers and A. Van de Capelle: Electron. Lett. **23** (1987) 930. DOI:10.1049/el:19870655
- [3] M. J. Havrilla: Proc. 13th Int. Sym. on Antenna Technology and Applied Electromagnetics and the Canadian Radio Science Meeting (2009) 15. DOI:10.1109/ANTEMURSI.2009.4805072
- [4] R. Rimolo-Donadio, J. Supper, T.-M. Winkel, H. Harrer and C. Schuster: IEEE Trans. Electromagn. Compat. **54** (2012) 495. DOI:10.1109/TEM.2011.2182054
- [5] R. Ruf and W. Menzel: Proc. Asia-Pacific Microwave Conference (2011) 411.
- [6] C. Chen, W. E. McKinzie and N. G. Alexopoulos: IEEE Trans. Antennas Propag. **45** (1997) 1186. DOI:10.1109/8.596914
- [7] W. Yang and J. Zhou: IEEE Antennas Wireless Propag. Lett. **12** (2013) 143.

- DOI:10.1109/LAWP.2013.2241011
- [8] T.-K. Chen and G. H. Huff: IEEE Antennas Wireless Propag. Lett. **10** (2011) 346. DOI:10.1109/LAWP.2011.2141971
  - [9] K. Thurn, S. Methfessel and L. Schmidt: Proc. 6th European Conf. on Antennas and Propagation (2012) 3529. DOI:10.1109/EuCAP.2012.6205854
  - [10] G. Amendola, E. Arnieri, L. Boccia, A. Borgia and I. Russo: Electron. Lett. **45** (2009) 1173. DOI:10.1049/el.2009.2250
  - [11] G. Amendola, E. Arnieri, L. Boccia, A. Borgia, P. Focardi and I. Russo: IET Microw. Antennas Propag. **5** (2011) 1568. DOI:10.1049/iet-map.2011.0018
  - [12] W. Jin, Z. Wang and B. Yan: Proc. Cross Strait Quad-Regional Radio Science and Wireless Technology (2011) 615. DOI:10.1109/CSQRWC.2011.6037025
  - [13] Y.-C. Shih, T.-N. Ton and L. Q. Bui: 1988 IEEE Int. Conf. Microwave Symp. Dig. (MTT-S) (1988) 473. DOI:10.1109/MWSYM.1988.22077
  - [14] Y.-C. Leong and S. Weinreb: 1999 IEEE Int. Conf. Microwave Symp. Dig. (MTT-S) (1999) 1435. DOI:10.1109/MWSYM.1999.780219

## 1 Introduction

The stripline is an important transmission line for microwave and millimeter-wave applications due to the characteristics of shielding property and quasi-TEM transmission mode, which has been widely used in microwave and millimeter-wave circuits [1, 2, 3, 4, 5]. The stripline is often employed as the feeding circuit network of various kinds of antennas [6, 7, 8]. The feeding circuit of antennas based on planar transmission line can provide compact size and ease of integration, but the performance is degraded as the operating frequency increases. The non-planar structure of waveguide-to-stripline transition is adopted as the feeding circuit at millimeter-wave band in some application [9]. In fact, in the design of antennas, losses due to the feeding lines can be very high at millimeter-wave band. The feeding network based on low-loss metallic waveguides can provide improved efficiency at higher frequencies [10, 11]. Therefore, the development of a broadband and low loss transition between metal waveguide and stripline is required in some applications. Several stripline-to-waveguide transitions have been presented in the open literatures [10, 11, 12]. In [12], a stripline-to-waveguide transition based

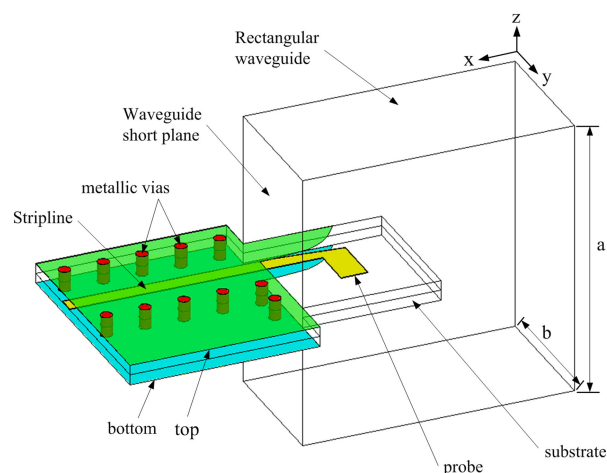
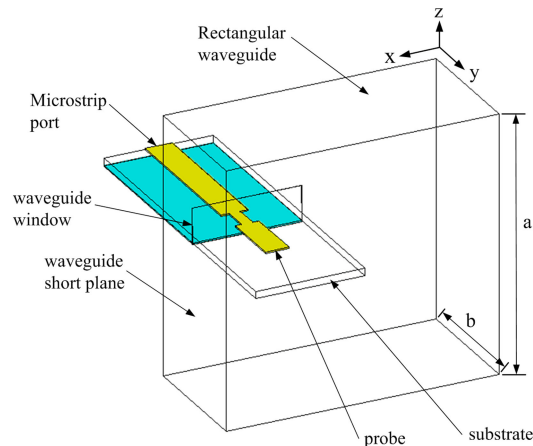


Fig. 1. Overview of the proposed stripline-to-waveguide transition.

on LTCC (Low Temperature Co-fired Ceramic) technology is designed, but suffers from narrow band.



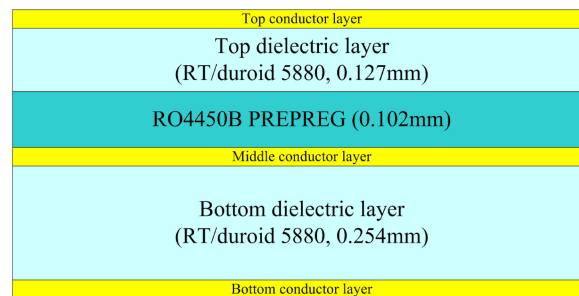
**Fig. 2.** Conventional microstrip-to-waveguide transition.

To obtain a wide bandwidth of operation, a novel stripline-to-waveguide transition is proposed in this work. As shown in Fig. 1, a rectangular-shaped probe placed a quarter-wavelength away from short-back of the rectangular waveguide is used to couple the energy from waveguide to the stripline. The stripline is placed close by one of the broad walls of waveguide and the two ground planes of the stripline are extended into the waveguide for field matching so that a broadband transition between stripline and waveguide can be achieved. Compared with the conventional microstrip-to-waveguide transition [13, 14] (see Fig. 2), this in-line transition structure does not require waveguide bends or cutting slots/holes on waveguide walls. Additionally, the proposed transition has a broader bandwidth compared to the currently reported stripline-to-waveguide transition [11, 12]. A back-to-back transition prototype has been fabricated and the scattering parameters are measured to verify the proposed design. The measured results show that the proposed transition provides a bandwidth of 26.5–40 GHz with return loss better than 15 dB. To my knowledge, this work provides a broadband in-line transition between stripline and rectangular waveguide, which are currently lacking in the open literature.

## 2 Transition structure and design

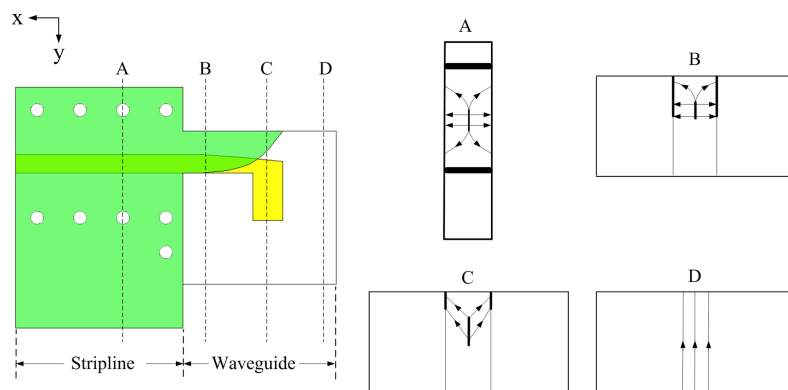
The overall structure of the proposed transition is depicted in Fig. 1, while the planar circuit of the transition is shown in Fig. 5. The whole transition structure consists of the stripline, the rectangular-shaped probe and the standard rectangular waveguide. The rectangular waveguide is WR-28 standard rectangular waveguide with dimensions of  $7.112 \times 3.556$  mm. It's known that the stripline is made of a center conductor and two sandwiched ground planes [1, 2]. In this design, the standard multilayer PCB process can be employed for the fabrication. The thicknesses of each layer of the multilayer structure are shown in Fig. 3. The bottom layer is used to place the center conductor of the stripline and the coupling probe, which is made of a 0.254 mm RT/duroid 5880 substrate (with relative dielectric

constant of 2.22, loss tangent of 0.0009). The top layer is 0.127 mm RT/duroid 5880 substrate. Such two substrates are bonded by RO4450B PREPREGS. The thickness of copper layer is 16  $\mu\text{m}$ . In the fabrication of stripline, firstly, the center conductor of stripline is manufactured in the bottom substrate using normal PCB process. After that, the top substrate is adhered using the bonding film (RO4450B PREPREGS with relative dielectric constant of 3.54). In this way, the two substrates are combined together and can be considered as a new single substrate.



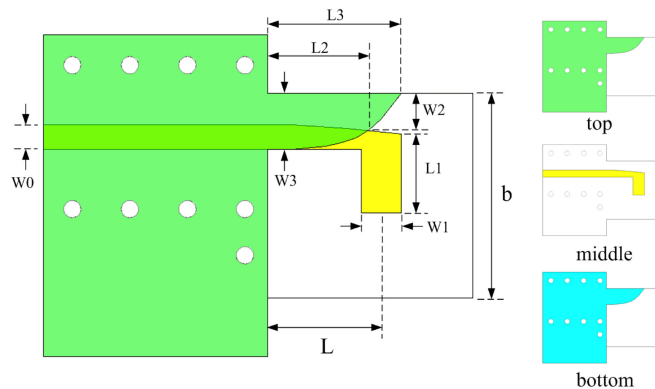
**Fig. 3.** Multilayer structure of layer thicknesses and metallization layers.

As shown in Fig. 1, a stripline dielectric substrate with a rectangular-shaped probe is centered in the E-plane of a full-height metallic waveguide in line with the propagation direction (x-direction) of waveguide. The short-back of rectangular waveguide forms a short plane into the waveguide to prevent the  $\text{TE}_{10}$  mode propagation toward the x-axis. The  $\text{TE}_{10}$  waveguide mode coming through the waveguide port on the right-hand side is coupled to the stripline with a rectangular-shaped probe. The probe is extended from the center conductor of stripline, which is approximately quarter-wavelength away from the short-back of waveguide. Unlike the conventional microstrip-to-waveguide transition [13, 14], the energy is coupled to the stripline in line with the propagation direction of waveguide and does not require cutting slot on waveguide wall (see Fig. 2). In realization, the stripline is placed close by one of the broad walls in order to maintain the field distribution in the substrate-containing waveguide section as uniform as possible. Meanwhile, the two tapered ground planes extended from the top and the bottom of



**Fig. 4.** E-field distribution of the cross-section.

stripline is made to alleviate the effects of the discontinuity between the stripline and the probe, which function as an impedance matching element. By this way, the  $TE_{10}$  mode of the waveguide is transformed to the quasi-TEM mode of the stripline, the progressive E-field distribution of the cross-section is shown in Fig. 4. It's noted that the metallic vias which penetrate all substrate layers are used. The function of these metallic vias is to suppress the unwanted parallel-mode [4] and provide a vertical connection between the top and the bottom ground planes of the stripline.

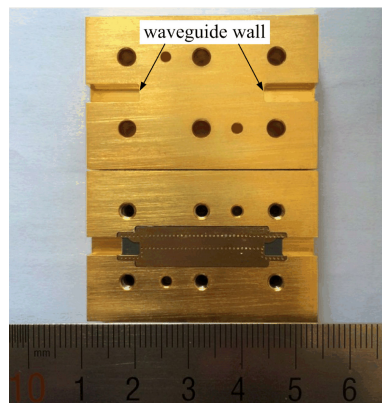


**Fig. 5.** Planar circuit of the proposed transition.

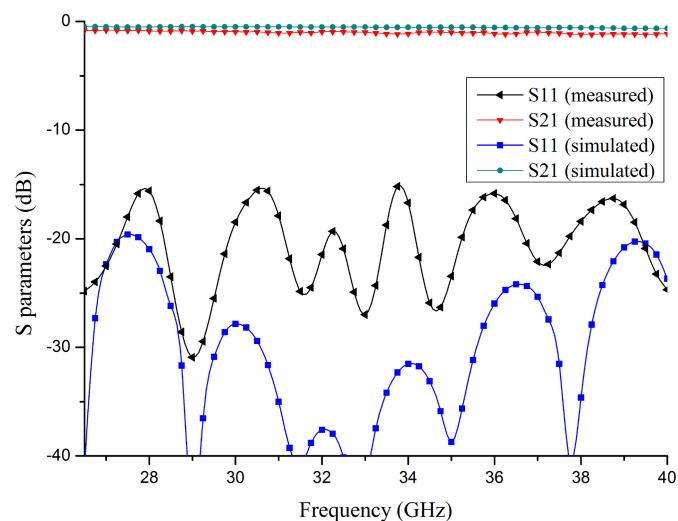
As discussed above, the rectangular-shaped probe extended from the center conductor of stripline and inserted into the center of a waveguide, which is approximately quarter-wavelength (around the center frequency of the desired frequency range) away from the short-back of waveguide. The extended ground plane is terminated at the end of the probe. An arc curvature is employed in the design of extended ground plane and the two extended ground plane are formed in same outline. Notice that to optimize the performance, the strip connecting the probe and the stripline is also tapered. The curvature of it is nearly a linear one and is found not to be a very sensitive design parameter. By properly choosing the dimension of the probe and the tapered ground planes, the  $TE_{10}$  mode in the waveguide can be transformed into the quasi-TEM mode in the stripline within a wide frequency band. The proposed transition is simulated and optimized using Ansoft high-frequency structure simulator (Ansoft HFSS). After optimization with Ansoft HFSS, the optimal parameters of the transition circuit are obtained. The design parameters are shown in Fig. 5. The final parameters of the fabricated transition (as shown in Fig. 5) are  $W2 = 0.66$  mm,  $W3 = 0.98$  mm,  $L2 = 1.74$  mm,  $L3 = 2.32$  mm,  $b = 3.556$  mm. The characteristic impedance of the stripline is set to  $50\ \Omega$  with  $W0 = 0.43$  mm for the fixed multilayer substrate structure. The distance between the short-back of waveguide and the center of probe in the x-axis direction is  $L = 1.97$  mm. The dimensions of the rectangular-shaped probe are  $W1 = 0.7$  mm and  $L1 = 1.37$  mm. The whole length of the transition circuit (contain substrate dimension) is approximately 4 mm.

### 3 Experimental results and discussion

To experimentally test the performance of the proposed transition, a Ka-band stripline-to-waveguide transition prototype was built by placing two identical transition back-to-back (see Fig. 6). In fabrication, the rectangular waveguide was fabricated through machining of the waveguide cavity in the copper block and split into two waveguide cavities. And then the stripline substrate sandwiched by the two metal waveguide cavities during the assembly process. Fig. 6 shows the photograph of the fabricated back-to-back transition. Measurements were carried out with a vector network analyzer. The simulated and measured results of the back-to-back transition are shown in Fig. 7, which show good agreement. The measured results show that the insertion loss of back-to-back transition is less than 1.2 dB (including the loss of a 24.6 mm stripline transmission line) with better than 15 dB return loss from 26.5 to 40 GHz. Therefore, the insertion loss of a single transition is less than 0.6 dB. As compared with previous reported stripline-to-waveguide transition [12], the 15 dB fractional bandwidth is increased from 12 to 41%. The tiny difference between the simulated and measured results is most probably attributed to the fabrication and assembly errors at such a high frequency band.



**Fig. 6.** Photograph of the fabricated back-to-back transition.



**Fig. 7.** The simulated and measured results of the back-to-back transition

Table I summarizes the performances of the proposed stripline-to-waveguide transitions along with previously published transitions for comparison. These transitions are either along the propagation direction of the waveguide or perpendicular to the propagation direction [10, 11, 12]. This work is designed for the application of in-line input/output systems. Compared with these ones [11, 12], the bandwidth is enhanced largely. It can be widely adopted in hybrid integrated models at millimeter-wave band.

**Table I.** Comparisons with previous stripline-to-waveguide transitions

	Freq	BW (GHz)	Relative BW (%)	RL (simulated) (dB)	IL (simulated) (dB)	RL (measured) (dB)	IL (measured) (dB)
[11]	K	19–21	10	>18	<0.1		
[12]	Ka	33.3–37.4	11.6	>15	<0.3		
This work	Ka	26.5–40	41	>19.5	<0.3	>15	<0.6

#### 4 Conclusion

In this work, a novel millimeter-wave stripline-to-waveguide transition has been proposed and demonstrated. The measured results show reasonable agreements with the simulated ones. With its advantages of broad bandwidth and low loss, such transition can be used for the feeding network of antennas and other specified applications at millimeter-wave band.

#### Acknowledgments

This work was supported by the Fundamental Research Funds for the Central Universities of China (Grant No. ZYGX2013J059).