

A rectangular waveguide filter with integrated E-plane probe transition

Ziqiang Yang^{1a)}, Weikui Chen¹, Haodong Lin¹, Tao Yang¹,
and Haiyan Jin²

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

² 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) yangziqiang@uestc.edu.cn

Abstract: A novel Rectangular waveguide (RWG) filter with integrated transitions is proposed in this letter. The E-plane probe transition, which is employed to couple the energy from the RWG resonator to the microstrip line (MSL), is used as the external coupling mechanism. The integrated design of the filter and transition can reduce the design complexity and size of the circuit. In order to verify the design, a prototype of the filter is fabricated and measured. It provides an in-band return loss and insertion loss of better than 14.6 and 1.5 dB, respectively, in the frequency range of 8.39 to 8.85 GHz.

Keywords: rectangular waveguide, filter, transition

Classification: Microwave and millimeter-wave devices, circuits, and modules

References

- [1] M. Politi and A. Fossati: "Direct coupled waveguide filters with generalized chebyshev response by resonating coupling structures," *Microwave Conference* (2010) 28.
- [2] J. A. Lorente, *et al.*: "Rigorous derivation of lossy equivalent circuit for narrowband waveguide direct-coupled-cavity filters," *IET Microw. Antennas Propag.* **7** (2013) 251 (DOI: [10.1049/iet-map.2012.0283](https://doi.org/10.1049/iet-map.2012.0283)).
- [3] K. W. Leung and K. K. So: "Simple and efficient microstrip-to-waveguide transition," *Electron. Lett.* **38** (2002) 280 (DOI: [10.1049/el:20020187](https://doi.org/10.1049/el:20020187)).
- [4] C. Risacher, *et al.*: "Waveguide-to-microstrip transition with integrated bias-T," *IEEE Microw. Wireless Compon. Lett.* **13** (2003) 262 (DOI: [10.1109/LMWC.2003.815182](https://doi.org/10.1109/LMWC.2003.815182)).
- [5] B. Jekanovic and D. Markovic: "Wideband microstrip-to-waveguide transition using double-Y balun," *Electron. Lett.* **42** (2006) 1043 (DOI: [10.1049/el:20061769](https://doi.org/10.1049/el:20061769)).
- [6] Y. Lou, *et al.*: "An in-line waveguide-to-microstrip transition using radial-shaped probe," *IEEE Microw. Wireless Compon. Lett.* **18** (2008) 311 (DOI: [10.1109/LMWC.2008.922114](https://doi.org/10.1109/LMWC.2008.922114)).
- [7] O. Donadio, *et al.*: "Waveguide-to-microstrip transition at G-band using

- elevated E-plane probe,” *Electron. Lett.* **47** (2011) 115 (DOI: [10.1049/el.2010.2926](https://doi.org/10.1049/el.2010.2926)).
- [8] R.-Y. Fang and C.-L. Wang: “Miniaturized microstrip-to-waveguide transition using capacitance-compensated broadside-coupled microstrip line,” *IEEE Trans. Compon. Packag. Manuf. Technol.* **3** (2013) 1588 (DOI: [10.1109/TCPMT.2013.2244644](https://doi.org/10.1109/TCPMT.2013.2244644)).
- [9] X. Dai: “An integrated millimeter-wave broadband microstrip-to-waveguide vertical transition suitable for multilayer planar circuits,” *IEEE Microw. Wireless Compon. Lett.* **26** (2016) 897 (DOI: [10.1109/LMWC.2016.2614973](https://doi.org/10.1109/LMWC.2016.2614973)).
- [10] X. Huang and K.-L. Wu: “A broadband u-slot coupled microstrip-to-waveguide transition,” *IEEE Trans. Microw. Theory Techn.* **60** (2012) 1210 (DOI: [10.1109/TMTT.2012.2187677](https://doi.org/10.1109/TMTT.2012.2187677)).
- [11] J. S. Hong and M. J. Lancaster: *Microstrip Filters for RF/Microwave Applications* (Wiley, New York, 2001).
- [12] J. Uher, *et al.*: *Waveguide Components for Antenna Feed Systems: Theory and CAD* (Artech House, Boston, 1993).

1 Introduction

Rectangular waveguide (RWG) filters are widely used in RF front-ends for communication and radar systems at microwave and millimeter-wave frequencies for their high-quality filtering properties [1, 2]. On the other hand, most RF front-ends are designed on the printed planar circuits for compact size. Since the input and output ports of the RWG filter are typically waveguides, especially at millimeter-wave frequencies, the transitions from waveguides to planar circuits are required in the RF front-ends. So far, various transitions between RWG and microstrip line (MSL), which is the most popular planar transmission line, have been studied and developed [3, 4, 5, 6, 7, 8, 9, 10]. These transitions can be utilized before and after the RWG filter with waveguide interface in the RF front-end design. However, the RWG filter and transition need to be designed separately first, and then be integrated together, which increase the design complexity.

In this letter, a novel third-order RWG filter with integrated transitions is developed. The E-plane probe transition is utilized to realize the external coupling of the filter. According to the bandwidth of the filter, the transition is optimized for an appropriate coupling between the RWG and MSL, rather than for the maximum coupling required by the conventional transition circuit. The design complexity is significantly reduced by using this integrated design technology. Moreover, since the transitions are used as parts of the filter, the size of the circuit is decreased.

2 Configuration and design

The proposed third-order filter with integrated transitions is shown in Fig. 1a, 1b and 1c, which was composed of three RWG resonators with a half-wavelength, four metal irises and two E-plane probe transitions between MSL and RWG. The transition, which is designed based on the Roger’s RT/Duroid 5880 substrate with relative permittivity of 2.2, loss tangent of 0.0009 and thickness of 0.254 mm, is inserted into the waveguide from the sidewall. The external and internal couplings

are achieved by using the E-plane probe transitions and irises between the RWG resonators, respectively.

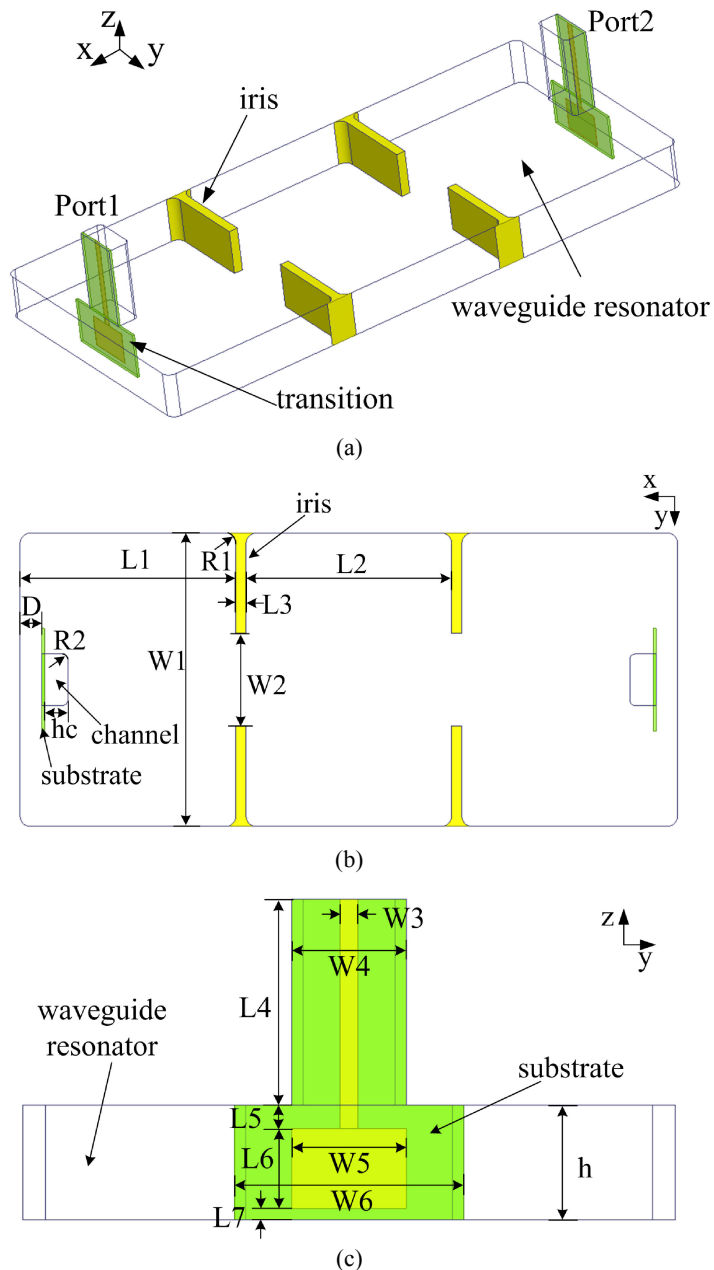


Fig. 1. Configuration of the proposed rectangular waveguide filter: (a) 3-D view (b) top view (c) side view

The equivalent circuit of the proposed filter is shown in Fig. 2. The external quality factors at port 1 and 2 (Q_{ext1} and Q_{ext4}) and internal coupling coefficients between successive RWG resonators, which are $k_{1,2}$ and $k_{2,3}$, can be calculated by the element values of the Chebyshev lowpass prototype [11], i.e.,

$$Q_{\text{ext1}} = \frac{g_0 g_1}{\text{FBW}} \quad Q_{\text{ext4}} = \frac{g_3 g_4}{\text{FBW}} \quad (1)$$

$$k_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \quad \text{for } i = 1 \text{ to } 2 \quad (2)$$

Where FBW is the fractional bandwidth of the filter. A 0.1 dB-ripple three-pole Chebyshev cavity filter is designed at center frequency of 8.55 GHz with 5.85% fractional bandwidth. According to (1) and (2), the required Q_{ext} is found to be 17.8, and $k_{1,2}$ and $k_{2,3}$ are both 0.053.

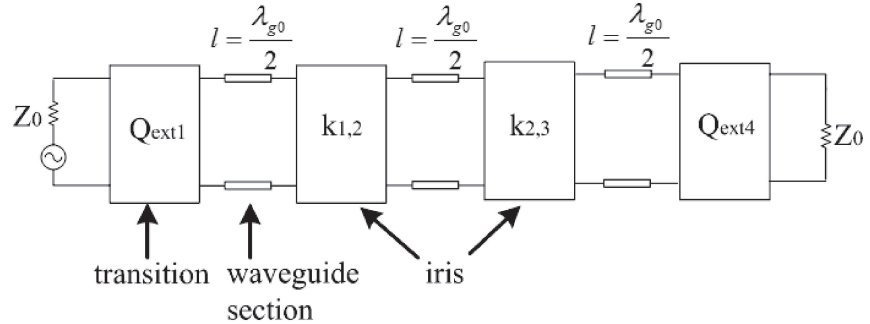


Fig. 2. Equivalent circuit of the proposed filter

Like the traditional RWG iris filter, the internal coupling is implemented through the irises between the RWG resonator, which can be designed by using the method proposed in [12]. The E-plane probe transition is utilized here as the external coupling mechanism. And the Q_{ext} is determined by D (see Fig. 1(b)), which is the distance between the planar circuit of the transition and end wall of the waveguide. Fig. 3 illustrates the design chart for Q_{ext} . As the distance D reduced from 3 to 1 mm, the achievable Q_{ext} range of the E-plane probe transition is found to be between 11.9 and 35.4, which approximately corresponds to a filter bandwidth range of 2.91–8.67%. From the design chart, the initial D is selected to be 1.9 mm to realize a Q_{ext} of 17.8. The parameters of the filter, which are shown in Fig. 2a and 2b, are analyzed and optimized using Ansoft HFSS after the initial design. Table I shows final dimensions of the proposed filter.

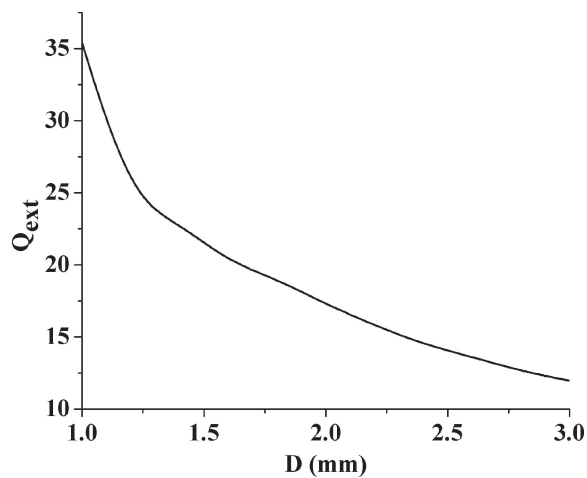


Fig. 3. Extracted Q_{ext} versus distance D

Table I. Dimensions of the filter (units: millimeters)

W1	W2	W3	W4	W5	W6	L1	L2	L3
28.5	9	0.75	5	5	10	21	19.9	1
L4	L5	L6	L7	R1	R2	D	h	hc
9	1	3.5	0.5	1	0.5	2.1	5	2.3

3 Experimental results

To verify our design, the filter with integrated E-plane probe transitions between the MSLs and RWGs is fabricated and measured. The developed filter, which is shown in Fig. 4, was measured by an Agilent vector network analyzer E8363B. The corresponding measured data compared with simulated results are shown in Fig. 5. The measured in-band return loss and insertion loss are better than 14.6 and 1.5 dB, respectively, in the frequency range from 8.39 to 8.85 GHz. The measured and simulated results are in good agreement except for a small difference in insertion loss level and a tiny frequency shift, which are mainly caused by the fabrication and assembly errors, and coaxial connectors mounted on the cavity.

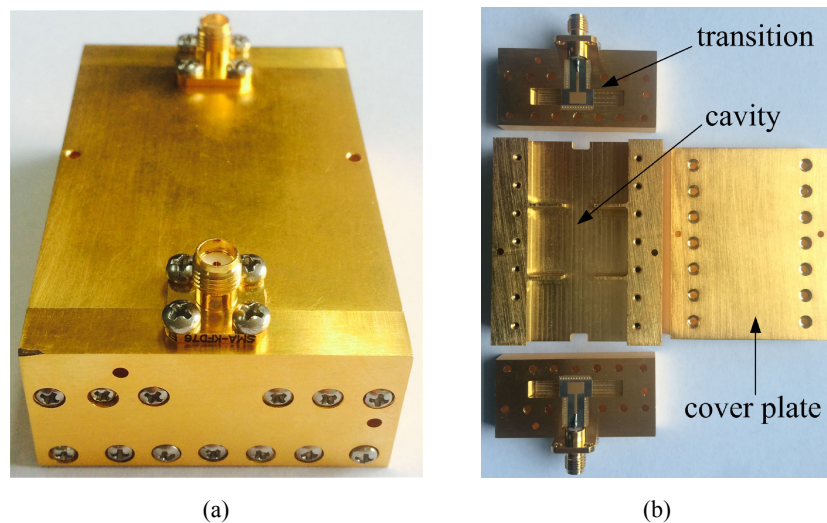


Fig. 4. Photograph of the fabricated filter. (a) Fully assembled filter. (b) Four parts of the block with the substrate

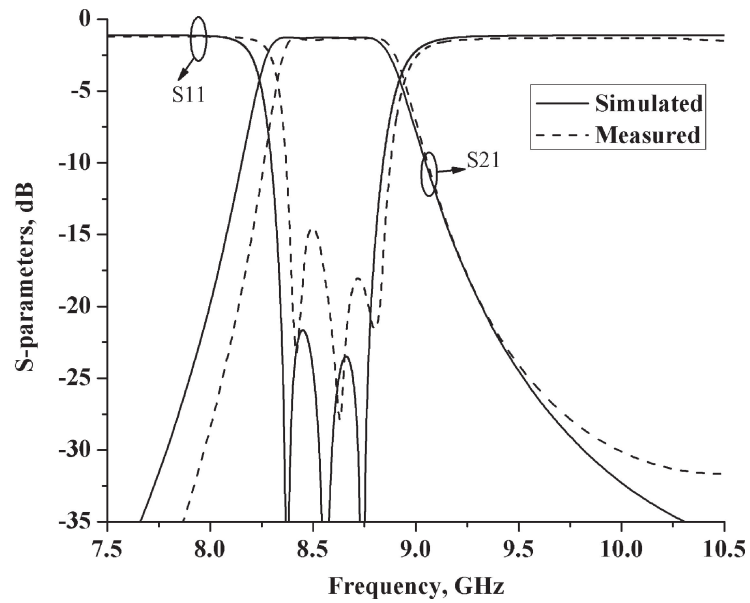


Fig. 5. Comparison of simulated and measured results of the filter

4 Conclusion

A novel three-order RWG filter with integrated E-plane probe transitions has been proposed in this letter. A prototype of the proposed filter is fabricated and measured at X band. Reasonable agreements between the simulated and measured results are observed.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Grant No. 61471093).