E-plane Waveguide Band-pass Filter with High Selectivity and Compact Size

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***Abstract*—In this report, we investigate and design a type of waveguide band-pass filter. A novel E-plane substrate inserted waveguide band-pass filter with high selectivity and compact size is studied in Ka-band. By integrating a resonator between two metal septa, the E-plane waveguide filter is achieved with two transmission zeros at both sides of the pass-band which contribute to the high-skirt selectivity. One sample are designed and fabricated in detail, whose total length is just 5 mm, namely, less than 0.5 λg and the minimum insertion loss is only about 0.3 dB. Good agreements between simulated and measured results are obtained.**

***Index Terms*—E-plane filter, high selectivity, compact size, waveguide filter**

I. Introduction

In millimeter-wave band, the waveguide filters are widely used for their high cavity quality (Q) value, low insertion loss, large rejection and high power capacity. There are many kinds of method to accomplish waveguide filter. Firstly the simple implementation of a direct-coupled cavity filter in rectangular waveguide technology is composed of waveguide cavities coupled through thick inductive irises [1] ~ [3]. Generally in order to overcome the drawback of low-cost manufacturing techniques this waveguide topology always consists on the use of tuning screws. But recently some novel structures [4] have been researched to improve the performance. Secondly, the dual-mode or multi-mode waveguide filters can implement nonadjacent couplings between resonators, resulting in more complex filtering functions [5] [6]. Although this kind waveguide filter can provide improved selectivity and insertion loss performance, but high cost and hard integration is inevitable. Finally waveguide E-plane metal insert filters is another classical implementation of direct-coupled cavity waveguide filters. Since the waveguide E-plane septum filter was introduced by Konishi [7], it has been an important filter structure used in [8] [9]. In this filter configuration, the impedance inverter constants of the half-wave prototype are synthesized through the thin metal septa inserted in the mid-plane of waveguide resonators. One advantage of this kind waveguide filter is related to its easy manufacturing process, which is very suitable for low-cost and mass production.

In our project, we would like to focus on the only waveguide bandpass filter. But based on our survey, the conventional E-plane waveguide septum band-pass filter must cascade resonant cavities using more than two septa to obtain high skirt selectivity which will inevitably lead to lager size. Here, we propose a novel compact band-pass E-plane insert waveguide filter by adding an extra dual-mode resonant cell between the two thin metal septa circuit structure. The novel compact band-pass E-plane insert waveguide filter has the advantage of dual-mode resonance which contributes to achieve the sharp attenuation beside the both side of the pass-band. Two transmission zeros are obtained.

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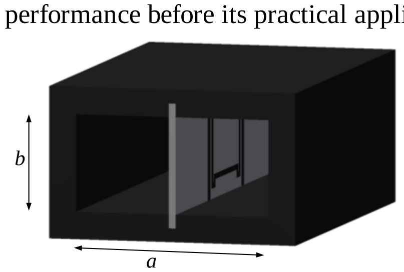
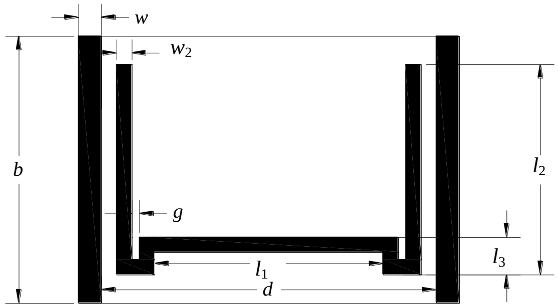
II. Design and Analysis

Fig.1 shows the layout of the proposed E-plane waveguide filter. Two metal septa and a resonant structure are fabricated on the Rogers 5880 substrate (with thickness of 0.254 mm and relative permittivity $\varepsilon r= 2.2$), which is inserted in E-plane of a standard Ka-band waveguide (WR 28 with a=7.112mm and b=3.556mm). Before the analysis on our proposed filter, we first pay attention to the characteristics of E-plane waveguide filters with only two metal septa inserted. As shown in Fig. 2, its band-pass properties are controlled by the distance between two metal septa d. When d = 4 mm and 4.4 mm, the center frequency of pass-band are 30.7 GHz (λg = 13.45 mm) and 31.8 GHz (λg = 12.38 mm), respectively. Affected by a negative length brought by the K-impedance inverters, the distance between the two metal septa is slightly less than 0.5λg [10]. Normalized K-impedance inverter value and negative electrical length are given by [11]. However, the resonator structured by two metal septa has slow attenuation in the stop-band. In [10] good performance was achieved by cascading five half-wavelength resonators. But in our study we would like to take some other novel techniques to improve the attenuation performance before its practical application.



(a)



(b)

Fig. 1 The layout of the proposed band-pass filter: (a) perspective view, (b) circuit structure on substrate

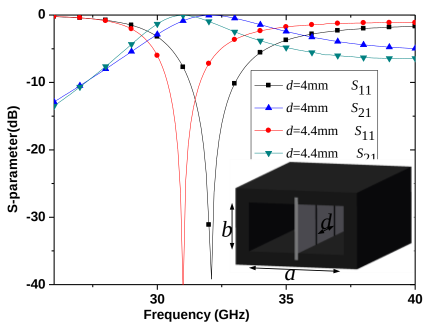


Fig. 2 Simulation of E-plane waveguide filters with two metal septa (w=0.3mm)

In this letter, we add an extra resonator in the metal-septa-based cavity instead of cascading several resonant cavities. The basic idea is to bring resonances into the stop-band of original waveguide filter. Thus, new pass-band will be created with different performances. No additional size is required because our extra resonator is in between of these two metal septa. The extra resonator with both electronic and magnetic resonances will create corresponding transmission zeros beside both sides of the pass-band.

III. SIMULATED AND MEASURED RESULTS OF THE PROPOSED E-PLANE SUBSTRATE INSERTED BANDPASS FILTER

The novel waveguide band-pass filter is designed and fabricated to testify the above analysis. Photograph of one sample is presented in Fig. 3. In our experiment, we make use of the standard waveguide WR 28 in our laboratory with a waveguide length of 20mm.

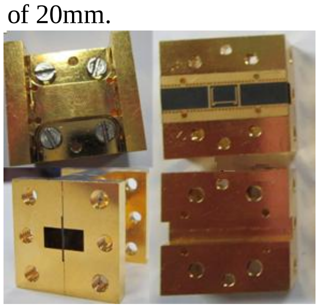


Fig. 3 Two novel E-plane filters

The simulated and measured results are shown in Fig.4. Two transmission zeros occur at both sides of the pass-band, which significantly contribute to the sharp attenuation in the stop-band.

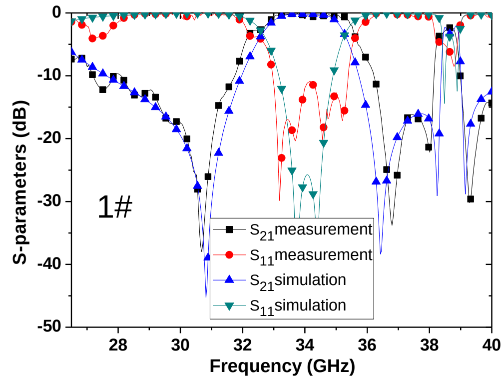


Fig.4 Simulated and Measured results

IV. CONCLUSION

In this study, we propose a kind of novel E-plane waveguide band-pass filter with high selectivity and compact size whose total length is less than 0.5 λg. By adjusting the size of the extra resonator rather than changing the length of the filter, we can receive different operating frequency bands.

V. NEXT CAREER PLANS

I am very honoured to receive the Undergraduate-Pregraduate Scholarship from you. In the future, I would like to finish my master degree well, and seek the opportunity to study abroad. I will try every possible chance to make impacts on my area.

I feel very sorry that I did not attend the MTT-S sponsored conference.

REFERENCES

[1] Levy R., Snyder R.V., and G. Matthaei.: 'Design of microwave filters', IEEE Trans. Microwave Theory Tech., Mar. 2002, vol. 50, no. 3, pp.783–793.

[2] Levy R.: 'Theory of direct-coupled-cavity filters', IEEE Trans. Microwave Theory Tech., Jun. 1967, vol. 15, no. 6, pp. 340–348.

[3] Yanfen Z., Qingyuan W., Zheyu W., and Xiu Xiao G.: 'The Design of an Iris Waveguide Filter at 35.75 GHz, in Millimeter Waves', Global Symposium on, 2008, pp. 348-350.

[4] Oloumi D.,Kordzadeh A., Neyestanak A.A.L.: 'Size Reduction and Bandwidth Enhancement of a Waveguide Bandpass Filter Using Fractal-Shaped Irises', Antennas and Wireless Propagation Letters, 2009, Vol.8 , Page(s): 1214 - 1217

[5] Williams A.E.: 'A four-cavity elliptic waveguide filter', IEEE Trans. Microwave Theory Tech., Dec.1970, Vol. 18, no. 12, pp. 1109–1114.

[6] Atia A.E. and Williams A.E.: 'Narrow-bandpass waveguide filters', IEEE Trans. Microwave Theory Tech., Apr. 1972, Vol. 20, no. 4, pp.258–265.

[7] Konishi Y., Venakada K.: 'The design of a bandpass filter with inductive strip-planar circuit mounted in waveguide'. [J].IEEE Trans. MTT,1974, Vol. 22, pp.869–873

[8] Vahldieck R., Bornemann J., Arndt F., and Grauerholz D.: 'Optimized waveguide E-plane metal insert filters for millimeter-wave applications', IEEE Trans. Microwave Theory Tech., Jan. 1983, Vol. 31, no. 1, pp. 65–69.

[9] Shih Y.-C. and Itoh T.: 'E-plane filters with finite-thickness septa', IEEE Trans. Microwave Theory Tech., Dec. 1983, Vol. 31, no. 12, pp.1009–1013

[10] Z. Wang, R. Xu, Y. Guo, Y. Zhang and B. Yan, A highly integrated ka-band transceiver module with two channels, Microwave and Optical Technology Letters 52 (2010), no. 3, 615-618.

[11] G. Matthaei, L. Yong, and E.M.T. Jones, Microwave Filter, Imped-ance-Matching Networks, and Coupling Structures, Artech House,Boston, MA, 1980.W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.