Proceedings Paper:

Bakr, MS, Hunter, IC and Bosch, W (2018) Broadband Dual-Mode Dielectric Resonator Filters. In: 2018 International Conference on Microwave and Millimeter Wave Technology (ICMMT). IEEE IWS'2018, 07-11 May 2018, Chengdu, China. IEEE. ISBN: 978-1-5386-2417-3.

https://doi.org/10.1109/ICMMT.2018.8563323

Broadband Dual-Mode Dielectric Resonator Filters

Mustafa S. Bakr[1,2,3], Ian C. Hunter[2] , Wolfgang Bosch[1]
[1]Institute of Microwave and Photonics, Graz University of Technology, Austria
[2]Pollard Institute, University of Leeds, UK
[3]Department of Electrical Engineering, University of Technology, Iraq

***Abstract*—This paper presents a broadband dual-mode microwave filter suitable for mobile communications. The Conductor loaded dielectric resonator filter reported in [5] is used as the basic building block for these devices. A simple input coupling configuration is introduced to improve the filter bandwidth significantly with less than half of the physical volume of TEM filters and good electrical performance. The basic properties of this resonator have been studied using a finite element method electromagnetic software (HFSS). Fundamental design rules for broadband bandpass filters have been presented. A two-pole bandpass filter was designed, fabricated and measured to verify the proposed approach.**

***Index Terms*—dual-mode filters, broadband filters, stepped impedance, transmission zeros.**

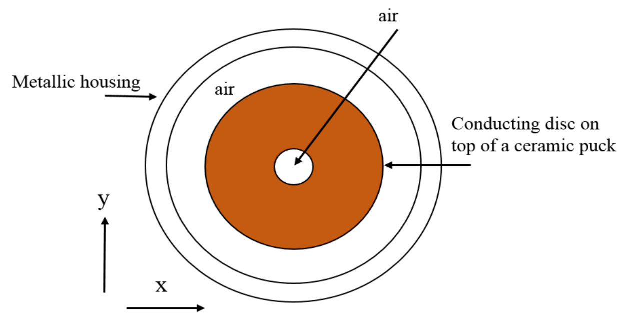
I. Introduction

Since the proposal of using multi-modes in microwave cavity filters in 1951 [1], several filter designs utilising dual, triple and quad mode resonators have been described. In order to meet the demanding requirements of filter designs for modern communication systems, in terms of size, Q-factor, and temperature stability, multi-mode dielectric resonator filters have been studied extensively [2]. However, most of the reported work is limited to narrow bandwidths. Recently, broadband multi-mode cavity filters were reported in [3]. In [4], a method for improving the bandwidth of single-mode dielectric resonator filter based on the TM_{01} mode is presented.

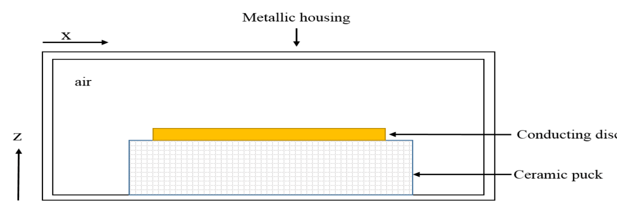
This paper presents a broadband dual-mode conductor loaded dielectric resonator filter. The basic resonator structure is based on the work presented by Hunter et al in [5]. A stepped impedance input coupling is introduced enabling high coupling values from input to resonators and thus wider bandwidth. The reported broadband dual-mode dielectric resonator filter is compact in size with good electrical performance.

II. Broadband Dual-mode Conductor-Loaded Dielectric Resonators

Fig. 1 shows the top and cross section view of the dual-mode conductor-loaded dielectric resonator filter. The resonator consists of a conductor-loaded ceramic puck where the bottom and top flat surfaces are short-circuited by the metallic housing base and metallic disc respectively. The fundamental mode is similar to the orthogonal degenerate TM_{110} mode found in circular microstrip resonators. Assuming that the height of the dielectric puck is much smaller than λ and the metallic housing walls and top surface are far away from the resonator, the resonant frequency is mainly determined by the diameter



(a)



(b)

Fig. 1. Schematic of conductor-loaded dielectric resonator (a) top view (b) cross section view.

of the metallic disc - similar to circular microstrip resonators. The dominant resonant frequency is given by:

$$f = \frac{1.841c}{2\pi a\epsilon_r} \tag{1}$$

The coupling between the orthogonal degenerate TM_{110} mode is achieved by introducing two notches in the metallic disc at 45° and 225° - position A- as shown in Fig.2. The coupling bandwidth k can be maximised by increasing the depth of the notches, as shown in Fig.3. The position of the notches, i.e. position B or A, controls the locations of the transmission zeros in the s-plane. In the first case, the roots of the transmission zeros are positioned on the imaginary axis while the latter case results in complex roots thus complex transmission zeros. The generation of the symmetric finite transmission zeros is due to phase cancellation in the two propagation paths between the input and the output.

The bandwidth of the dual-mode conductor-loaded dielectric resonator filter can be increased up to 7% by tapping the input\output probes to the metallic disc. Higher coupling values can be achieved by introducing stepped impedance

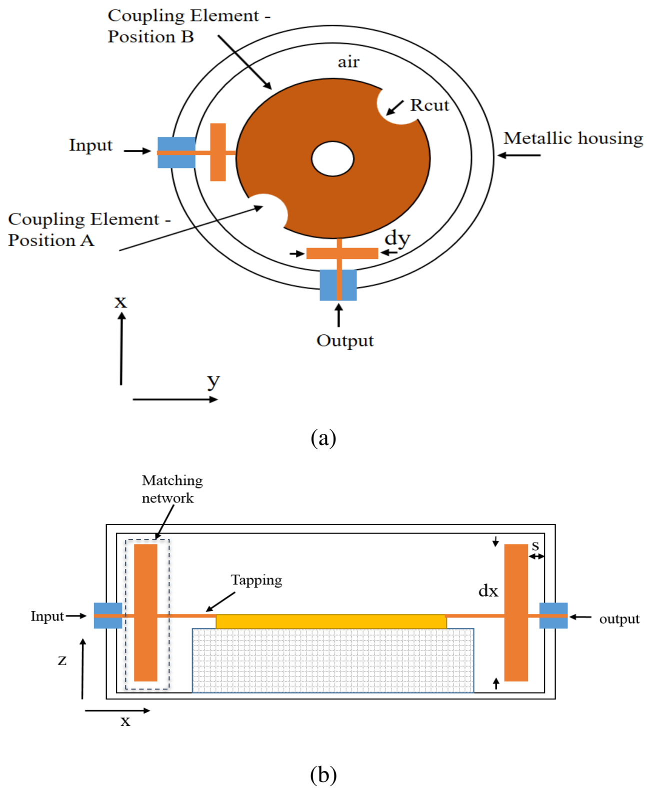


Fig. 2. Schematic of the proposed input coupling configuration of the conductor-loaded dielectric resonator (a) top view (b) cross section view.

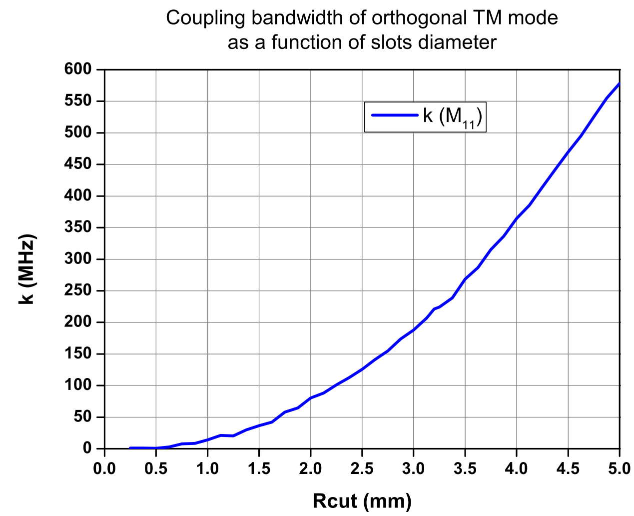


Fig. 3. Variation of the TM_{110} coupling bandwidth as a function of notches radius

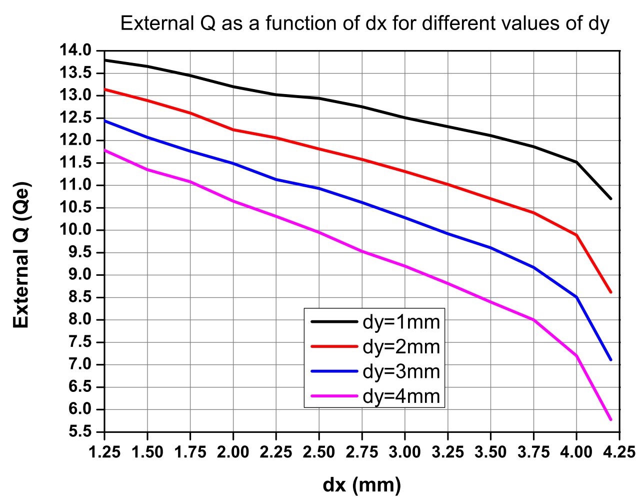


Fig. 4. Variation of external quality factor value as a function of the rectangular disc width (dx) for different values of lengths (dy)

coupling configuration as shown in Fig. 2. Changing the dimensions of the stepped impedance rectangular disc, i.e dx and dy, and adjust the distance between the rectangular disc and metallic housing, S, control the input to resonators coupling values. Fig. 4 and 5 show the external quality factor (Q_e) as a function of the rectangular disc dimensions and distance to the metallic housing. As can be seen, the bigger the rectangular disc the higher the coupling values. Simimalry the closer the rectangular disc to the metallic housing the higher the coupling values.

III. Filter Design

The proposed structure resonant frequency is mainly determined by the ceramic puck dielectric constant and the metallic disc radius while the Q-factor is mainly controlled by adjusting the height of the ceramic puck. A resonator was constructed with a 20mm diameter and 3.5mm height of ceramic puck with permittivity of 44 and tangent loss of $4 \times 10^{-}5$ in a copper cavity with internal dimensions of 24mm diameter and 9mm height with electrical conductivity of 4×10^7 S\m. The fundamental resonant frequency was 1.8 GHz with unloaded Q of 1700.

In this example, a 2-pole bandpass filter with ripple bandwidth of 10.5% is designed and fabricated to validate the proposed bandwidth improvement technique. The radius of the two notches are chosen to be 3.5mm with rectangular disc dimensions of 3.5×3.5mm to achieve the desired bandwidth. The simulated response of the designed broadband bandpass filter is shown in Fig. 6, where the notches are located at position A or B respectively. A photograph of the fabricated prototype is shown in Fig. 7. The measured vs simulated frequency response is shown in Fig. 8.

IV. Conclusion

In this paper, a broadband dual-mode conductor-loaded dielectric resonator filter has been presented. This enables the realisation of filters with less than half of the physical volume of TEM resonators, and good electrical performance. A stepped impedance input coupling configuration was introduced to maximise the coupling values from input to resonators. A prototype filter with ripple bandwidth of 10.5% was designed, fabricated and measured to validate the proposed approach. The bandwidth may be increased up to 50% by exciting higher order modes as will be shown in future publications.

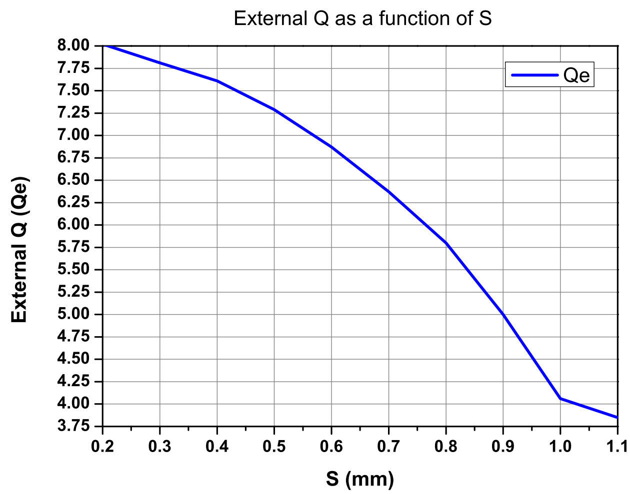


Fig. 5. Variation of external quality factor value as a function of distance between the rectangular disc and the metallic housing (S)

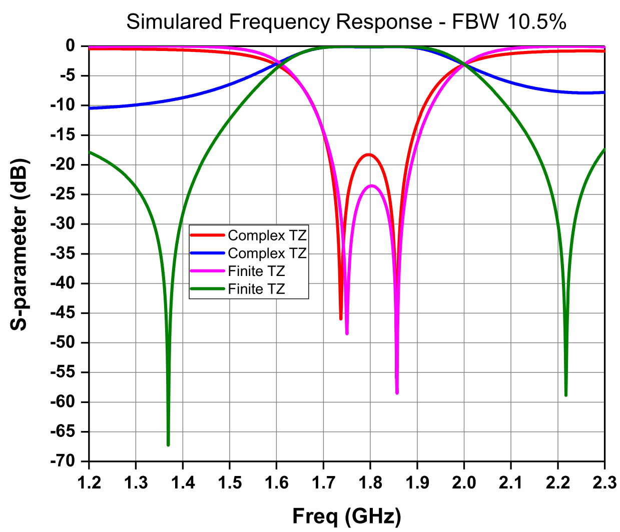


Fig. 6. Simulated response of the broadband filter with complex or finite transmission zeros

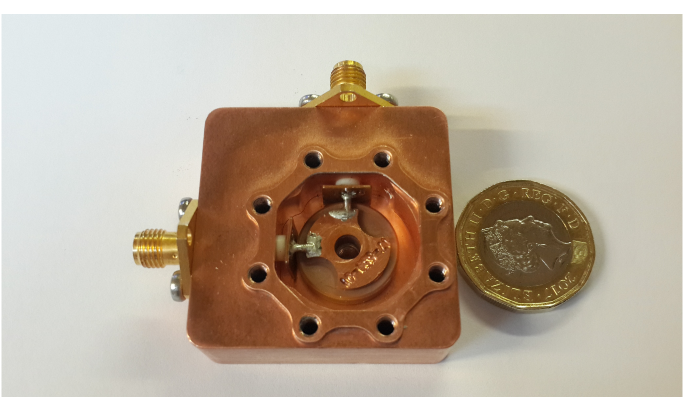


Fig. 7. Fabricated broadband 2-pole conductor-loaded dielectric filter

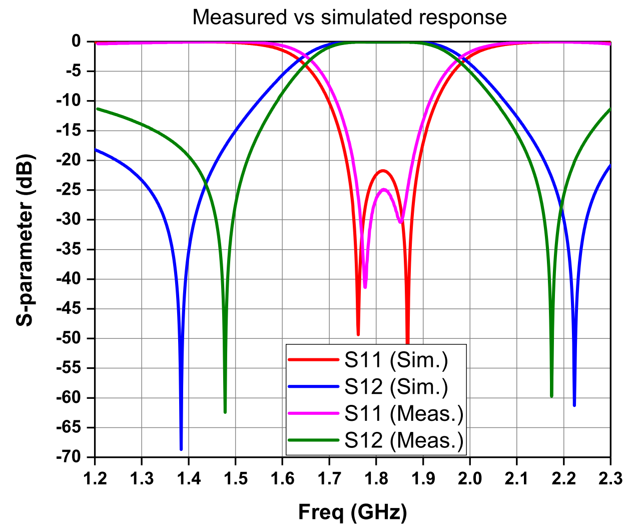


Fig. 8. Measured vs simulated response of the broadband filter with finite transmission zeros

V. Acknowledgement

This work was partially supported by the TU Graz LEAD project - Dependable Internet of Things in Adverse Environments, Radio Design LTD and IEEE Microwave Theory and Techniques Society.

References

[1] Wei-guan Lin. Microwave filters employing a single cavity excited in more than one mode. *Journal of Applied Physics*, 22(8):989–1001, 1951.

[2] V. Walker and I. C. Hunter. Design of triple mode te01spl delta// resonator transmission filters. *IEEE Microwave and Wireless Components Letters*, 12(6):215–217, June 2002.

[3] S. W. Wong, S. F. Feng, and L. Zhu. Multi-mode wideband bandpass filters using waveguide cavities (invited). In *2015 Asia-Pacific Microwave Conference (APMC)*, volume 2, pages 1–3, Dec 2015.

[4] Y. Marchives, N. Delhote, S. Verdeyme, and P. M. Iglesias. Wide-band dielectric filter at c-band manufactured by stereolithography. In *2014 44th European Microwave Conference*, pages 187–190, Oct 2014.

[5] I. C. Hunter, J. D. Rhodes, and V. Dassonville. Dual-mode filters with conductor-loaded dielectric resonators. *IEEE Transactions on Microwave Theory and Techniques*, 47(12):2304–2311, Dec 1999.