Proceedings Paper:

Afridi, S orcid.org/0000-0002-7317-1615, Sandhu, M orcid.org/0000-0003-3081-8834, Somjit, N orcid.org/0000-0003-1981-2618 et al. (1 more author) (2017) Monolithic Ceramic Waveguide Filter with Wide Spurious Free Bandwidth. In: Proceedings of the 46th European Microwave Conference (EuMC 2016). European Microwave Conference 2016, 03-07 Oct 2016, London, United Kingdom. IEEE , pp. 241-244. ISBN 978-2-87487-043-9

https://doi.org/10.1109/EuMC.2016.7824323

Monolithic Ceramic Waveguide Filter with Wide Spurious Free Bandwidth

Sharjeel Afridi, Muhammad Sandhu, Nutapong Somjit, Ian Hunter
Institute of Microwave & Photonics, School of Electronic and Electrical Engineering
University of Leeds
LS2 9JT Leeds, United Kingdom
Email: el11s2a@leeds.ac.uk

Abstract— This paper presents two new design techniques for improving the spurious performance of an integrated ceramic waveguide filter without compromising its figure-of-merit e.g. Q-factor. Non-uniform width ceramic waveguide resonators are used to spread the undesired higher order mode frequencies along with ceramic TEM resonators reducing the overall cutoff frequency of the resonators. The proposed designs offer 60-65% better spurious performance in comparison with uniform width integrated ceramic waveguide filter. Simulated results for a six pole Chebyshev integrated non-uniform width ceramic waveguide filter and an integrated evanescent mode non-uniform width ceramic waveguide filter are presented in this paper showing improved spurious performance.

Keywords— ceramic, Waveguide Filter, TEM, Spurious performance, different width resonator

I. INTRODUCTION

Microwave filters are the integral and inevitable part of the satellite and terrestrial communication system. Coaxial TEM filters have been favoured candidate for cellular base stations offering excellent spurious performance while maintaining high Q-factors with only limitation of large volumes[1, 2]. Ceramic waveguide filters offer miniaturization by using high Permittivity materials [3, 4], but their crowded higher order resonances limit spurious free out of band spectrum. A ceramic filled waveguide filter achieves 50% size reduction as compared to coaxial TEM filter but their spurious free out of band rejection is limited to higher order waveguide modes[5]. Different design techniques have been proposed for the improvement of spurious performance of waveguide filters. Non-uniform width and step impedance waveguide resonators were used to improve the out of band response [6, 7]. Asymmetrical irises with different widths for enhancing spurious free range are proposed in [8]. Combline and mixed combline approach used to enhance the out of band performance is reported in [9, 10]. In a recent paper published by the authors [11] the spurious performance of a uniform width ceramic waveguide filter was improved by introducing the concept of ceramic TEM resonator and ceramic step impedance resonator. Both of these techniques increase the spurious free bandwidth of ceramic waveguide filters but degrade the Q-factor of uniform width ceramic waveguide filter significantly.

This paper presents two new design approaches to significantly improve the spurious performance of uniform width ceramic waveguide filter without degrading the Q-factor of ceramic waveguide resonators significantly. A non-uniform width ceramic waveguide (NWCW) filter and a combined non-uniform width and ceramic TEM resonator filter are designed. Fig 1. Shows the diagram of two ceramic different widths resonators.

II. NON-UNIFORM WIDTH CERAMIC WAVEGUIDE (NWCW) RESONATOR

Waveguide resonator mode frequencies are a function of its physical dimensions i.e. length, width and height. The common approach to increase the gap between fundamental frequency (f_o) and spurious resonances is to alter the geometry of resonator. In [12], the idea to improve the stop band response by using the different width resonators was proposed. The fundamental frequency (f_o) is kept the same by changing the length of resonators. This phenomenon spreads out the higher order resonant modes, so that it will not contribute as strongly as they did in normal waveguide filter.

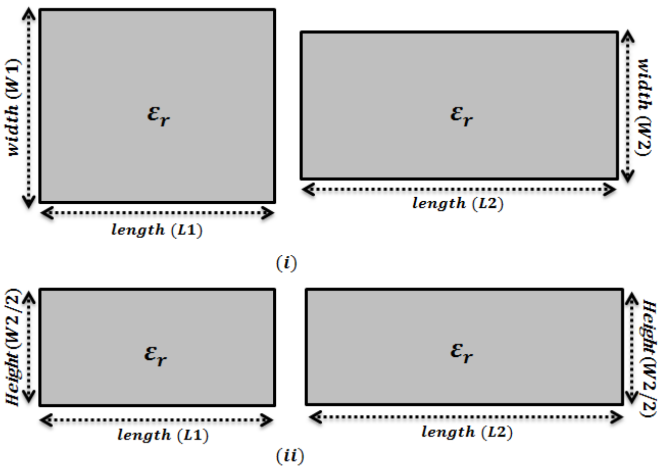

Fig 1. Different width Ceramic Waveguide Resonator (i) Top View (ii) Side View

In [6] the same idea in rectangular waveguide filters to achieve a very good stop band performance was employed. This approach is used in ceramic waveguide filter to eliminate or push the re-resonances or higher order modes higher in frequency. The NWCW filter consists of a mono-block ceramic ($\varepsilon_r = 43$) with its exterior silver plated. The Quality factor and resonant frequencies of resonators are determine by [13]. As both resonator have different dimensions, their widths and lengths can be computed by the following equations[6].

$$w_n = \frac{c}{2}\sqrt{\frac{3}{4(f_o)^2 - (f_1)^2}} \qquad (1)$$

$$l_n = \frac{w_n}{\sqrt{({}^{f_0}/_{f_c})^2 - 1}} \qquad (2)$$

Where w_n, l_n are widths and lengths of resonators respectively and f_c,f_1 are the cut-off and first spurious mode frequency respectively. In uniform width waveguide filter design, there is only a leverage to change the length of the resonator. Whereas, the difference in widths and length provides more freedom to spread out the second mode frequency resulting in better stop band performance of ceramic waveguide filter.

III. CHEBYSHEV INTEGRATED CERAMIC WAVEGUIDE FILTER WITH NON-UNIFORM WIDTH RESONATORS

A six pole integrated ceramic waveguide filter is designed with non-uniform width resonators having following specification;

Fundamental frequency (f_o)	:	1842 MHz
Bandwidth	:	75 MHz

The inter-resonator and external couplings are achieved via metal plated through holes and coaxial probes, respectively as described in [11]. The non-uniform width ceramic resonators improves the overall stop band performance up to 1.85*f_o without degrading the overall response and selectivity of filter. The integrated ceramic waveguide filter offers an out of band attenuation of 40 dB up to 2.75 GHz, while with the different width ceramic waveguide filter 40 dB stop band attenuation is achieved up to 3.37 GHz, shows 60% improvement in spurious. Fig 2 shows a physical layout of NWCW filter.
A comparison of simulated results of a NWCW filter with that of integrated ceramic waveguide filter[5] is shown in fig 3. EM simulated results show that a NWCW filter offers significantly improvement (up to 60%) in the stop band performance of a ceramic waveguide filter.

IV. CHEBYSHEV INTEGRATED CERAMIC WAVEGUIDE FILTER WITH TEM DIFFERENT WIDTH RESONATORS

To further enhance the stop band performance of the ceramic waveguide filter a mixed resonator with non-uniform width and ceramic TEM loading is designed. This mixed approach integrated resonator further reduces its size while slightly degrade the Q-factor.

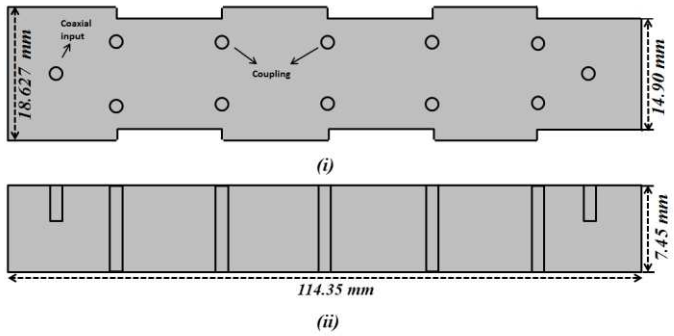

Fig 2. Non-uniform width Ceramic Waveguide (NWCW) Filter (i) Top view (ii) Side view

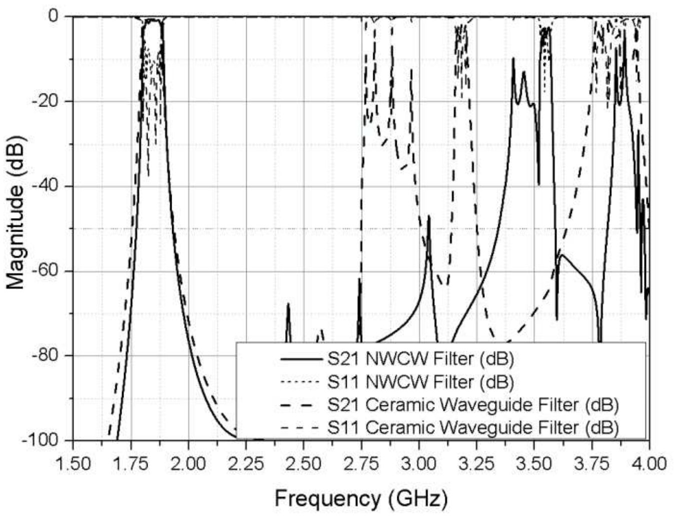

Fig 3. Spurious Performance Comparison of Ceramic Waveguide Filter and Non-Uniform Width Ceramic Waveguide (NWCW) Filter.

A six pole TEM NWCW filter is designed with subsequent specifications;

Fundamental frequency (f_o)	:	1842 MHz
Bandwidth	:	75 MHz

The six pole Chebyshev non-uniform width TEM resonator filter shown in Fig.5 further pushes away the higher order harmonics of fundamental frequency (f_o). This mix resonator approach gives further volume reduction at the cost of increased pass band insertion loss (of 1.3 dB). The input/output and inter resonator coupling follow the same procedure as defined in [11]. This filter combines the effect of TEM and non-uniform width resonators to offer stop band attenuation window of 72dB up to 3.45 GHz, which makes it 1.87 times of f_o. Fig 6 shows the comparison of spurious performance of an integrated ceramic waveguide filter, NWCW filter and TEM NWCW filter. It is evident that the TEM NWCW filter offers highest stop band attenuation performance in comparison with other two filters.

Table 1. Shows the comparison of quality factor and volume of ceramic waveguide resonator, NWCW filter and TEM NWCW filter at a fundamental frequency of 1842 MHz

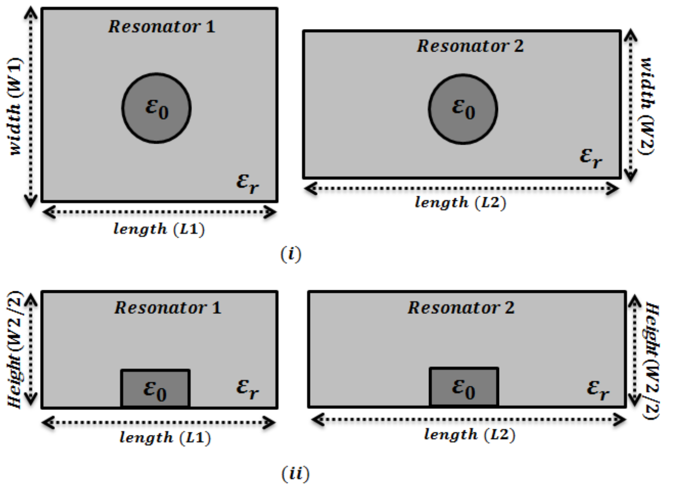

Fig 4. Different Width Ceramic Resonator with TEM approach

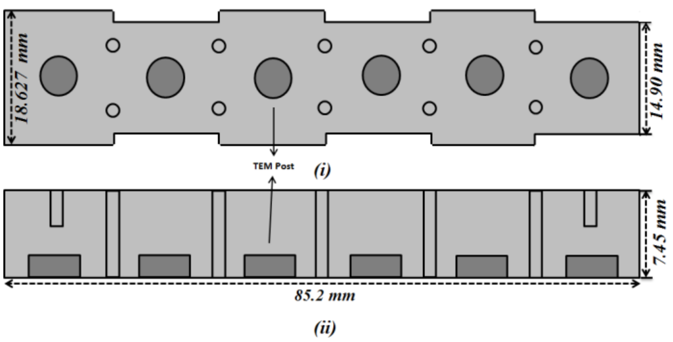

Fig 5. TEM Non-Uniform Width Ceramic Waveguide (NWCW) Filter (i) Top View (ii) Side View

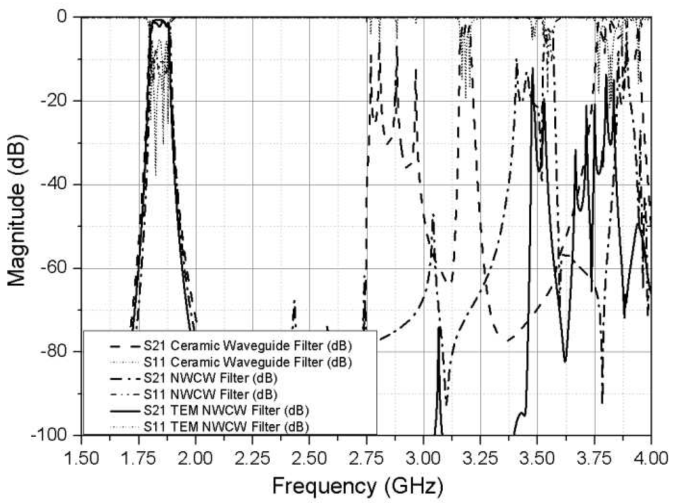

Fig 6. Spurious Performance comparison of ceramic waveguide filter, NWCW filter and TEM NWCW filter

The data shows that the ceramic TEM NWCW resonator offers much miniaturisation at the expense of slightly lower unloaded quality factor.

TABLE 1. Q factor and Volume of Resonators

Resonator Type	Volume (Cm^3)	Unloaded Q Factor
Ceramic Waveguide Resonator	2.529	2268
NWCW resonator (W1)	2.31	2298
NWCW resonator (W2)	2.48	2039
TEM non-uniform Ceramic Waveguide resonator (W1)	1.81	1699
TEM non-uniform Ceramic Waveguide resonator (W2)	1.67	1716

V. Conclusion

In this paper, two different design techniques are introduced to improve the spurious performance of the uniform width ceramic waveguide filter. A monolithic integrated non-uniform width ceramic waveguide (NWCW) filter and a TEM non-uniform width ceramic waveguide (NWCW) filters are designed. EM simulated results are in good agreement with theoretical concepts. This work will be extended to include the experimental results and address other design details including manufacture tolerances, power handling, temperature performance, tuning interfaces etc.

Acknowledgment

The authors would like to thank Royal academy of Engineering and Radio Design Ltd. for sponsorship of Prof. Ian Hunter and Sukkur Institute of Business Administration for Sponsoring Sharjeel Afridi and Muhammad Sandhu.

Refrences

[1] W. Chi, K. A. Zaki, A. E. Atia, and T. G. Dolan, "Dielectric combline resonators and filters," Microwave Theory and Techniques, IEEE Transactions on, vol. 46, pp. 2501-2506, 1998.

[2] N. E. A. Rashid, M. T. Ali, and N. Hamzah, "Properties of dielectric combline resonator for base station filters," in RF and Microwave Conference, 2004. RFM 2004. Proceedings, 2004, pp. 76-79.

[3] S. Kobayashi and K. Saito, "A miniaturized ceramic bandpass filter for cordless phone systems," in Microwave Symposium Digest, 1995., IEEE MTT-S International, 1995, pp. 391-394 vol.2.

[4] Y. Konishi, "Novel dielectric waveguide components-microwave applications of new ceramic materials," Proceedings of the IEEE, vol. 79, pp. 726-740, 1991.

[5] I. C. Hunter and M. Y. Sandhu, "Monolithic integrated ceramic waveguide filters," in Microwave Symposium (IMS), 2014 IEEE MTT-S International, 2014, pp. 1-3.

[6] M. Morelli, I. Hunter, R. Parry, and V. Postoyalko, "Stop-band improvement of rectangular waveguide filters using different width resonators: selection of resonator widths," in Microwave Symposium Digest, 2001 IEEE MTT-S International, 2001, pp. 1623-1626 vol.3.

[7] M. Morelli, I. Hunter, R. Parry, and V. Postoyalko, "Stopband performance improvement of rectangular waveguide filters using stepped-impedance resonators," Microwave Theory and Techniques, IEEE Transactions on, vol. 50, pp. 1657-1664, 2002.

[8] J. M. Perez Escudero, D. Martinez Martinez, A. Pons Abenza, J. A. Lorente Acosta, A. Alvarez-Melcon, and M. Guglielmi, "Enhancing the spurious free range in inductive rectangular waveguide filters," in Microwave Conference (EuMC), 2015 European, 2015, pp. 678-681.

[9] H. Hee-Yong, p. Nam-Sin, C. Yong-Ho, Y. Sang-Won, and C. Ik-Soo, "The design of band-pass filters made of both dielectric and coaxial resonators," in Microwave Symposium Digest, 1997., IEEE MTT-S International, 1997, pp. 805-808 vol.2.

[10] A. R. Weily and A. S. Mohan, "Mixed combline and He₁₁ mode dielectric resonator filter with improved spurious performance," in Microwave Conference Proceedings, 1997. APMC '97, 1997 Asia-Pacific, 1997, pp. 805-808 vol.2.

[11] I. Hunter, S. Afridi, and M. Sandhu, "Integrated ceramic waveguide filters with improved spurious performance," in Microwave Conference (EuMC), 2015 European, 2015, pp. 674-677.

[12] H. J. Riblet, "waveguide filter having non identical section resonant at same fundamental frequency and different harmonic frequency," U.S Patent, Oct 1964.

[13] G. L. Matthaei, Microwave Filters, Impedance Matching networks and coupling structure: Mc Graw Hill, 1964.