Monolithic Dielectric Waveguide filters with Multi-width Cavities

Sharjeel Afridi[1], Shahnawaz Shah[2]

[1]Department of Electrical Engineering, Sukkur IBA University, Sukkur, Pakistan
[2]Department of Information and Communication Technology, University of Sindh, Jamshoro, Pakistan

Abstract
Two different configuration of monolithic ceramic waveguide filters with three different width resonators is described. To increase the gap between fundamental frequency and first spurious, the change of resonator geometry is required. Therefore, three different width resonators are used to spread out the spurious resonances without degrading the performance of a filter. The proposed designs offer 70% improvement in stop band rejection in comparison with uniform width ceramic waveguide filter. Improved out of band performance of two six order filters have been presented in comparison with ceramic waveguide filter.

Keywords:
Multi-width cavities, monolithic, dielectric, stop band rejection

1. Introduction

Microwave waveguide filters with good selectivity, high power and low loss used extensively in wireless and satellite communication systems. They are the essential part of cellular front end, used to introduce separation between receive and transmit channels.

The dielectric waveguide resonator filter are also ideal candidate for cellular base station due to their high quality factor and miniaturized size[1]. Cohn introduced the first ceramic resonator in 1968 with relative permittivity of 100 and loss tangent of 0.001. Dielectric materials are evaluated by their Q factor, permittivity, and temperature coefficient due to dielectric loss[2]. In [3], the ceramic waveguide filter with high permittivity achieved 50% volume reduction in comparison with the air-filled TEM filter, but the designed filter suffers from crowded spurious modes near the passband. This proximity of higher order modes creates a significant challenge to design a filter which meets commercial base station's out of band rejection specifications[4].

Many design techniques have been suggested to improve the out of band response of waveguide filters. In 1964, H.J. Riblet proposed the idea to suppress the parasitic passband by changing the width of the waveguide resonator[5]. In [6], multi width resonators were used to suppress the stop band spurious modes. The fundamental frequency of these resonators would keep same by changing the length of resonators. Introducing a metal post in a center of rectangular waveguide cavity improves the separation between fundamental and first spurious frequency[1, 7]. A multilayer dual band-dual mode filter and mixed lumped and distributed circuits for improved stop band performance is also discussed in [8, 9]. There have been other practical approaches to improve the stop band performance of air filled, ceramic loaded and monolithic ceramic waveguide filter by using stepped impedance resonators, mixed combline resonators or by mixing the metal post resonator with different width resonators[10-14].

In this paper, two different configurations of three different width resonators were used to enhance the stop band performance of monolithic ceramic filter. A filter is designed in different configurations to analyse the impact on spurious performance. In monolithic integrated ceramic waveguide filter configurations, a single ceramic block with metallized coating is used. Inter-resonator coupling is realized by introducing a through hole at regular intervals of each resonator size. Different width ceramic resonators offer better spurious performance without degradation in the Q factor. The simulated (HFSS) based results of monolithic ceramic waveguide filters in two different configurations were presented.

2. Design Methodology

Two different configurations of three different width ceramic waveguide filters are presented. Both the designs are six pole chebyshev filters with the following details.
Center frequency: 1842 MHz
Bandwidth: 75 MHz
Ceramic Permittivity: 43
The monolithic waveguide ceramic filter with three different widths is designed with following three resonators shown in figure 1. All three resonators using the same permittivity (ε_r) 43.

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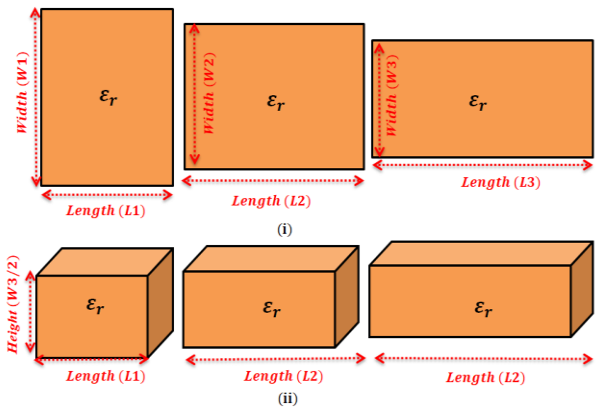

Fig. 1 Three different width resonators with same fundamental frequency

Waveguide resonator modes are the function of its physical dimensions. The physical geometry of a resonator can be changed in such a way that the gap between fundamental and spurious resonances is increased. This idea to spread the higher order modes by changing the width of resonators was first proposed by H.J Riblet[5]. This phenomenon spreads out the spurious modes in such a way, that they will not contribute as strongly as they did in waveguide filters. The details of three different width monolithic ceramic resonators were given in table 1. In [15], this approach is successfully applied in two different width ceramic waveguide filter. Here we optimized the resonator dimension by fixing their width and change their length to get three different width resonators with same fundamental frequency. In figure 2, the design of monolithic ceramic filter with three different width resonators is given. The same width filter gives you the only leverage to change the length of resonators, where as in different width you can optimize the width and lengths of a resonator at a same time. This strategy improve the overall stop band performance of a filter. The coaxial probe is used to excite the input/output coupling in first and last resonator of a six order filter. The inter-resonator coupling are realized via metal coated through holes as stated in [11].

3. Results

This six order filter improves the stop band performance upto 3.46 GHz, which gives the 33 dB rejection upto $f_o * 1.88$ without degrading the selectivity and overall performance of a ceramic waveguide filter. In figure 3, the insertion loss and pass band performance of three different width ceramic waveguide filter is shown. In the second configuration of three different width resonator filter, the first and last resonators have a minimum width, while center resonators have the maximum width. The external and inter-resonator coupling is achieved in a same way like first filter.

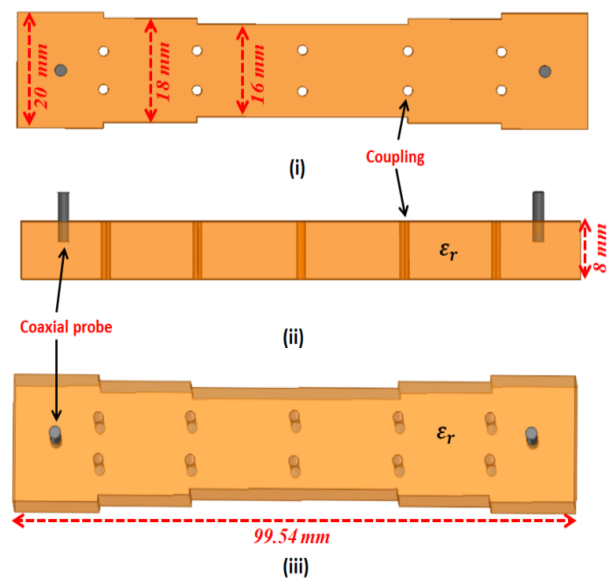

Fig. 2 physical layout of monolithic ceramic waveguide filters with three different width resonators in first configuration(i) Top view (ii) Side view (iii) 3D view

Table 1: Details of Resonators

Resonator Widths	Volume (Cm3)	First Spurious in (GHz)
Width = 20 mm	2.528	2.691
Width = 18 mm	2.453	2.87
Width = 16 mm	2.515	2.74

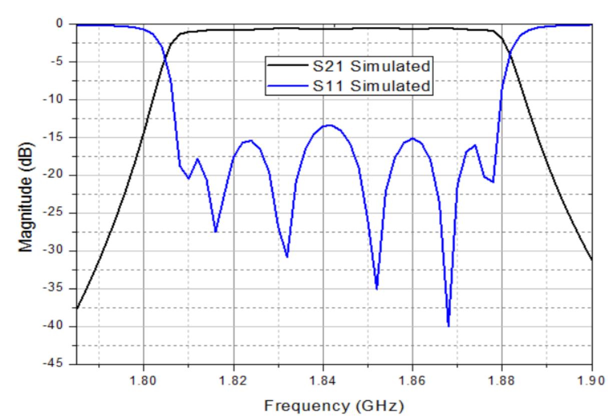

Fig. 3 simulated Passband response of a filter with first configuration.

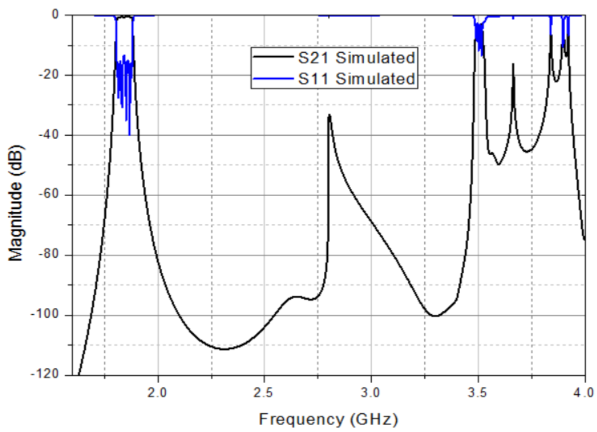

Fig. 4 Simulated broad band response of three different width ceramic waveguide filter in first configuration

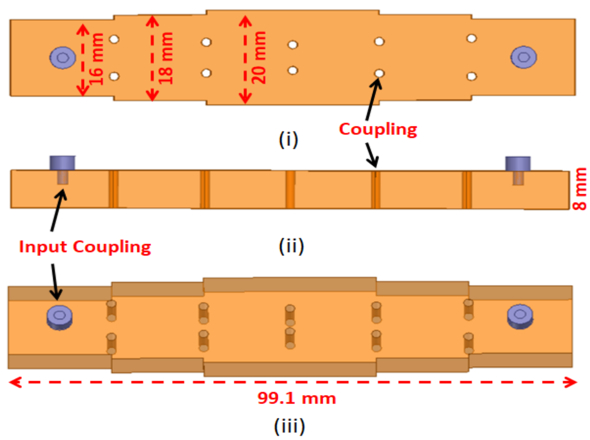

Fig. 5 physical layout of monolithic ceramic waveguide filters with three different width resonators in first configuration(i) Top view (ii) Side view (iii) 3D view

The simulated passband response of a filter with second configuration is shown in figure 6 with a 10 dB return loss. The simulated broadband response of a filter is shown in figure 7, where it achieved the stop band rejection of 49 dB upto 3.55 GHz. This approach improves the stop band performance of a three different width ceramic filter upto$f_o * 1.93$. In figure 8, the comparison of both these filter with uniform width ceramic filter[3] is shown.

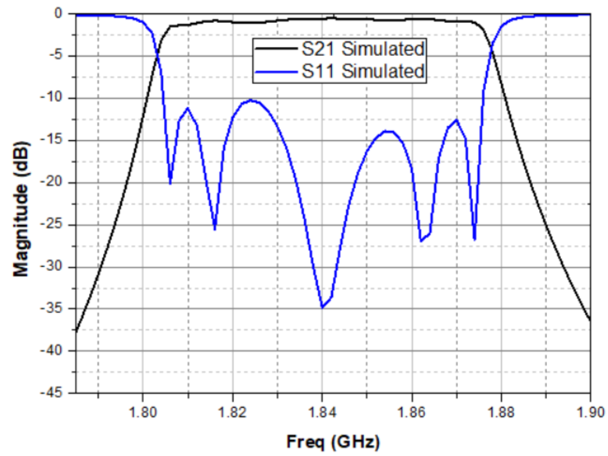

Fig. 6 Simulated Pass band response of three different width ceramic waveguide filter in second configuration

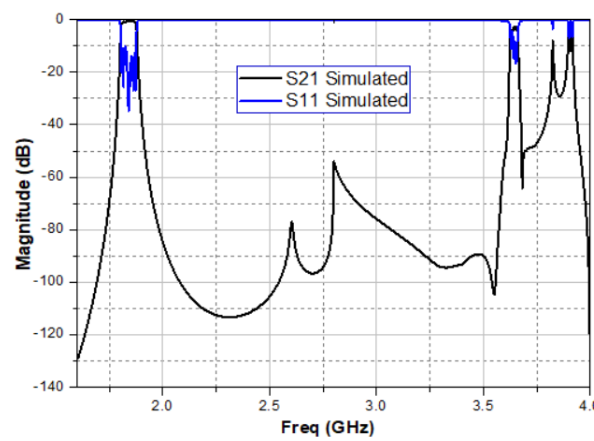

Fig. 7 Simulated broadband response of three different width ceramic waveguide filter in second configuration

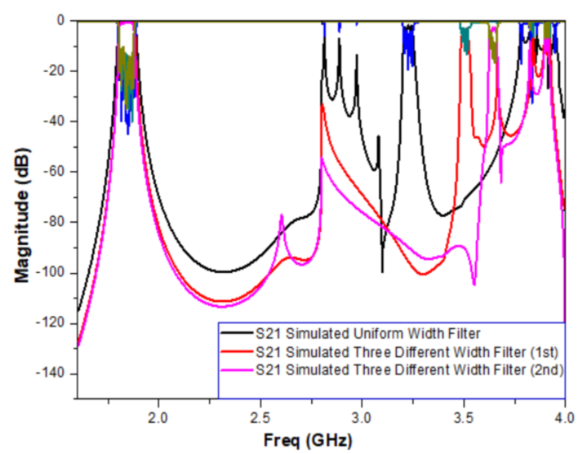

Fig. 8 Comparison of stop band performance of both three different width ceramic resonator filters with uniform width ceramic filter

4. Conclusion

The new design technique for monolithic ceramic waveguide filters to improve the stop band performance is presented. Integrated monolithic ceramic waveguide resonators with three different widths are used to spread the higher order resonances without degrading the Q factor of overall filter. Theoretical concepts are successfully demonstrated by EM results. As this work will also be extended to include the experimental results and address other design details including power handling, tuning interfaces, temperature performances and manufacture tolerances etc.

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