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High Stop Band Rejection for Ceramic Loaded Waveguide Filters

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ABSTRACT This Paper describes the design procedure of a compact narrowband ceramic loaded filters with wide out of band response. The idea of loading the waveguide filter resonators with ceramic TEM blocks and ceramic ridge blocks are presented. Resonator loading with silver plated transverse electromagnetic (TEM) hole and silver plated ridge ceramic blocks offers wide spurious free bandwidth 2.45 times of center frequency. Simulated and measured results of six pole chebyshev Ceramic ridge loaded filter and simulated results of Ceramic TEM loaded filter are presented in this paper showing excellent out-of-band performance.

INDEX TERMS Chebyshev, ceramic loaded, spurious, out-of-band, and TEM.

I. INTRODUCTION

The increasing flood of data traffic due to wireless devices initiate the intensive effort to develop more robust and compact cellular infrastructure. Microwave filters are important and widely used component of cellular base stations. They are used to isolate the required electromagnetic signals from undesired and unwanted signals. Coaxial filters are extensively used by mobile base stations due to their high spurious free stop band, high Q factor and low cost [1]. The dielectric resonator filters with low loss filters and good in-band and out-of-band performance also becomes the good candidate for cellular base stations [2], [3]. Cohn [4] in 1968 introduced a first ceramic resonator filter having a permittivity of 100 and loss tangent of 0.0001. The prime disadvantages of these ceramic filters are their crowded mode chart near the passband that creates a significant challenge for the commercial base stations filters stop band specifications [5].

Several filter design techniques have been suggested to increase the stop band rejection of waveguide filters. Riblet [6] in 1964 gives the idea of higher spurious suppression by using the varying width resonators. In [7], non-uniform width resonators were used to improve the stop band rejection of rectangular waveguide filters. The center frequency of resonator is kept same by only changing the length of the resonators. The same idea of different width resonators in ceramic loaded waveguide filters is also implemented in [8]. The introduction of capacitive post at the center of resonator is used to improve the stop band rejection of air-filled waveguide filter and ceramic loaded waveguide filters [9], [10]. The same stop band performance appeared to be improved by employing the stepped impedance resonators approach in waveguide and ceramic loaded waveguide filters [10], [11]. The mixed approach by employing different techniques together is also used to enhance the stop band rejection in different waveguide filters. However, these approaches are used to spread the higher order resonances to not allow them to contribute significantly near filter passband [12]–[14].

In this paper, two new design techniques to improve the stop band rejection of ceramic loaded waveguide filter are presented. These ceramic loaded filters offer high Q factor but suffer from the bad spurious performance. The cross-coupled approach of these ceramic loaded filter is presented in [15]. The use of low pass filter with bandpass filter has been a traditional way to suppress the unwanted spurious modes. But, the stringent requirement of size and cost allow us to integrate the bandpass and low pass filtering function in one device, which can lead us to a significant size reduction. We realized that the same idea in these two filter designs and improved spurious performance is achieved by the use of ceramic loaded TEM resonator with a blind hole at the

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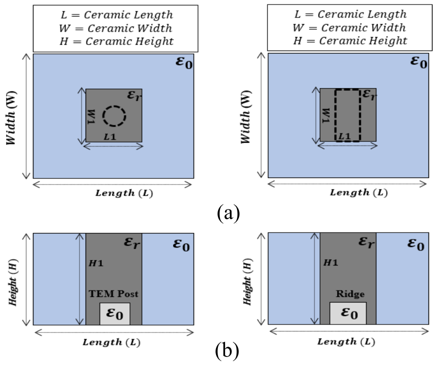

FIGURE 1. Ceramic loaded TEM and ridge resonator (a) Top view (b) Side view.

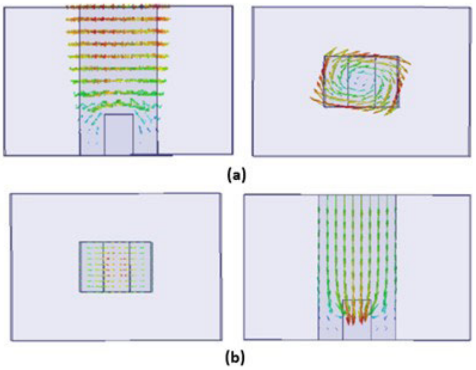

FIGURE 2. Top view and side view of field distributions in ceramic loaded ridge resonator (a) H-field (b) E-field.

center of a ceramic block and ceramic ridge resonator. These ceramic blocks with metal coated ridge and blind hole will enhance the spurious performance by pushing the higher order resonances upward but at the expense of lower Q factor. One of the ceramic loaded filter with ridge ceramic block is fabricated, measured and compared with simulation, showing very good agreement of filter design.

II. CERAMIC LOADED RESONATORS

The ceramic loaded resonators are composed of rectangular ceramic blocks with the metal coated blind hole and ridge at the center of ceramic block. The top and bottom surfaces of these ceramic blocks touch the metallic walls of the outer cavity. These ceramic blocks consisted of permittivity of 43 and their surfaces are metallized using the silver paint having the conductivity of 2e7. In the TEM ceramic loaded resonator, most of the current concentration is in the center conductor where the most of the energy loss is occurred. Therefore, the high Q factor and miniaturized size can be achieved with the minimum size ceramic at the center of the resonator [16]. The resonant mode is slightly distorted version of TE101 in this ceramic loaded resonator. The Q factor of these resonators can be improved by increasing the height but at the expense of higher volume. The ceramic blocks having similar height ridge and blind hole are used to design two different six order chebyshev ceramic waveguide filters. The ceramic loaded ridge resonator and ceramic TEM resonator are shown in the Figure 1. The electric and magnetic field distributions of the ceramic loaded ridge resonator and ceramic TEM resonator are illustrated in the figures 2 and 3.

III. CERAMIC LOADED RIDGE RESONATOR FILTER

The six order ceramic loaded ridge resonator filter is designed with rectangular ceramic block having a ridge at the center of the each ceramic block. The six order chebyshev filter is designed with the following specification.

- Center frequency: 1842 MHz
- Bandwidth: 75 MHz
- Ceramic permittivity: 43

All ceramic blocks in the filter resonators, having a same height ridge, touch the outer metal cavity from top and bottom. The physical layout of the filter is shown in the Figure 4. In ceramic loaded resonators, most of the electric field is concentrated in the ceramic placed at the center of the resonator while the H field is available around the ceramic in the resonant cavity. Therefore, the input/output coupling should be realized via magnetically coupled probes [16]. Metal inductive irises is used to realize the inter-resonator coupling among the resonators while coaxial cable is used to perturb the magnetic field around the ceramic block of external resonators for input/output coupling [15].

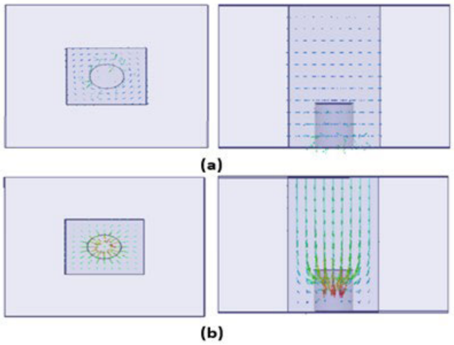

FIGURE 3. Top view and side view of field distributions in ceramic TEM resonator (a) H-field (b) E-field.

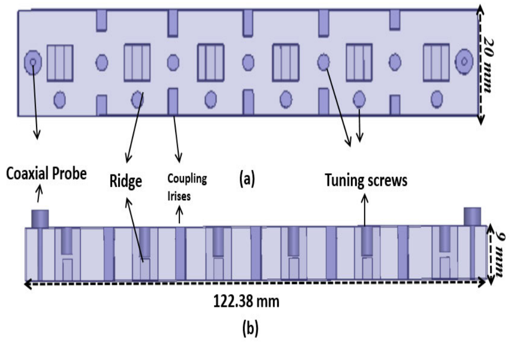

FIGURE 4. Ridge ceramic loaded resonator filter (a) top view (b) side view.

The passband response and insertion loss of the ceramic ridge filter is shown in the figures 5 and 6. The excellent

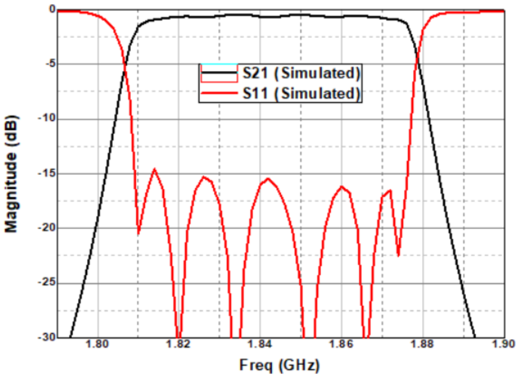

FIGURE 5. Passband response of ridge ceramic loaded resonator filter.

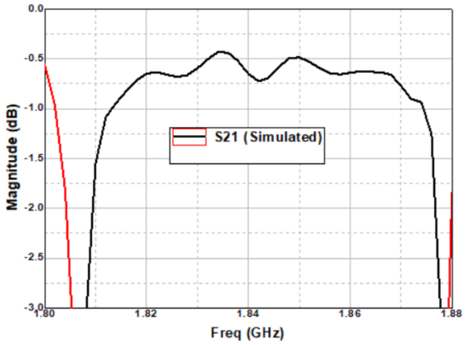

FIGURE 6. Insertion loss of ridge ceramic loaded resonator filter.

stop band performance of the filter is achieved by using the ridge type ceramic blocks which pushed the higher frequency upwards. Hence, offered excellent stop band rejection. The electromagnetic (EM) simulated broadband response of the filter is shown in the Figure 7. This filter shown 75 dB rejection upto 4.5 GHz of frequency which is around 2.45*fo. Tunning screws are also been included for mitigating the effect of mechanical discrepancies of hardware design. The ceramic ridge resonator filter is fabricated, measured and compared with the simulated result in next part.

A. FABRICATION AND MEASUREMENT

The ridge ceramic loaded resonator filter is fabricated with ridge ceramic blocks present at the center of each resonator as shown in the Figure 8. The ceramic ridge blocks were metallized from top and bottom that touch the outer cavity from the both ends. It is very difficult to remove the air gaps between the ceramic blocks and external metal cavity due to the surface roughness. Therefore, to generate the effective contact between the top and bottom surfaces of ceramic blocks with external cavity walls, the ceramic blocks were silver plated and then soldered to the external cavity lids as explained in the study [15]. The "LPKF Reflow oven" is used to solder the ceramic blocks with external cavity walls as shown in the Figure 9. Tuning screws were added to alleviate the effect of manufacturing discrepancies. Top and bottom surfaces of cavity were fabricated in copper to support the soldering of ceramic blocks while the sidewalls are fabricated in aluminium. Some unavoidable air gaps remains between the ceramic blocks and top lid that increases the insertion loss upto 1.45 dB. It also increases the desired bandwidth with the return loss of 12.5 dB at the center frequency. The unloaded Q factor of each resonator is same but the overall Q factor of the filter is calculated around 19.87. The Top and side views of the filter are presented in the Figure 10. The comparison of simulated and measured in-band and out-of-band responses are given in the figures 11 and 12. The excellent stop band rejection of 80 dB is achieved through

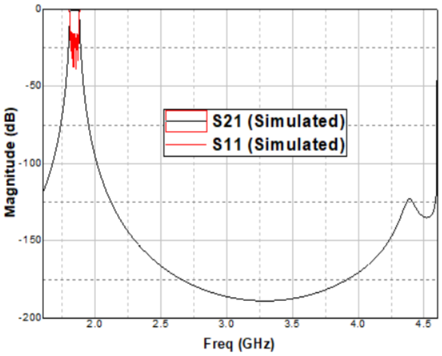

FIGURE 7. Broadband response of ridge ceramic loaded resonator filter.

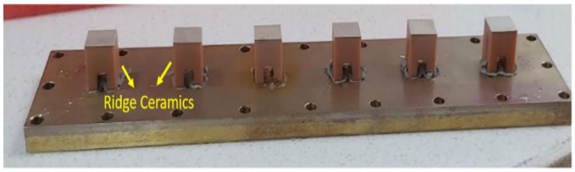

FIGURE 8. Ridge ceramic blocks placed at the center of the each resonator.

FIGURE 9. Ridge ceramic blocks soldered with bottom lid first using LPKF reflow oven.

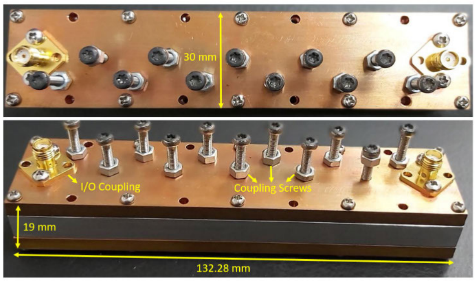

FIGURE 10. Top view and side view of six order ridge ceramic loaded resonator filter.

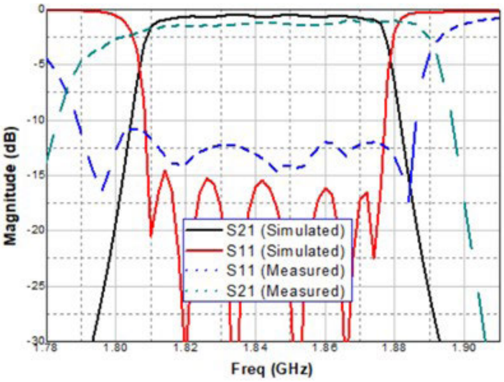

FIGURE 11. Comparison of simulated and measured passband response of ridge ceramic loaded filter.

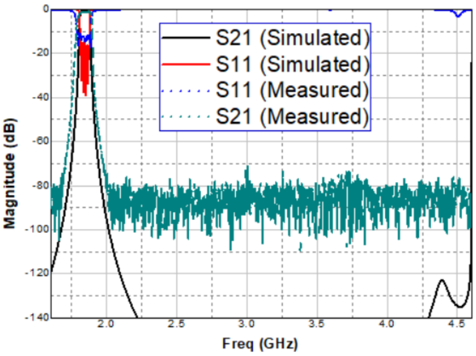

FIGURE 12. Simulated and measured broadband response of ridge ceramic loaded filter.

the use of metallized ridge ceramic blocks upto 4.5 GHz. In the future design fabrication, we would try to reduce the problem of air gaps between outer cavity and ceramic blocks by screwing them from top and bottom.

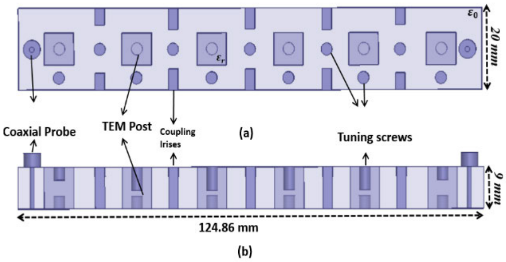

FIGURE 13. TEM ceramic loaded resonator filter (a) top view (b) side view.

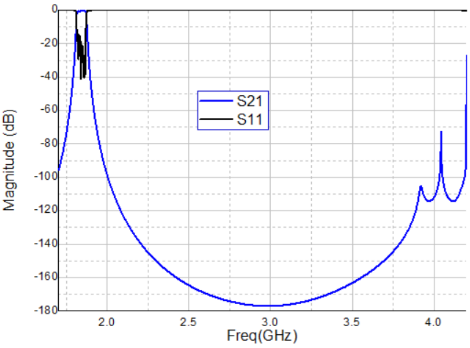

FIGURE 14. Broadband response of ceramic loaded TEM resonator filter.

TABLE 1. Summarises the details of both the resonators showing in figure 1. The outer cavity of both the resonators having the dimension of 20 × 20 × 9 mm3.

Parameter	Ceramic Ridge Resonator	Ceramic TEM Resonator
Q factor	2263	1879
F0 (MHz)	1842	1842
F1 (MHz)	4280	4311

IV. CERAMIC LOADED TEM RESONATOR FILTER

The six order ceramic loaded TEM resonator filter is designed with rectangular ceramic block having a TEM metallized blind hole at the center of each ceramic block. The six order chebyshev filter is also designed with the same filter specification given above. Each ceramic blocks in the filter touches the outer metal cavity from top and bottom. The physical layout of the filter is shown in the Figure 13 and ceramic TEM block is already shown in the Figure 1. As most of the H field is presented around the ceramic TEM block, therefore, the same input/output coupling and metal irises have been used in this filter [15]. The excellent stop band performance of a filter is achieved by using the TEM type ceramic blocks in each resonator. The EM simulated broadband response of the filter is shown in the Figure 14. The filter is observed with 75 dB rejection upto 4.5GHz of frequency. Tunning screws are included for mitigating the effect of mechanical discrepancies of hardware design as already presented in the Figure 13. The details of Q factor, resonant frequency and first spurious frequency of ridge ceramic resonator and TEM ceramic resonator are given in the Table 1.

V. CONCLUSION

In this paper, two new design techniques for ceramic loaded resonator filters are presented with improved stop band rejection. Ceramic blocks with metallized hole and metallized ridge at the center are used to spread the higher order resonances of ceramic loaded resonator filters. Ridge ceramic resonator filter is fabricated and measured that shows the better agreement with the simulated results. TEM ceramic resonator filter also exhibits the great out-of-band rejection. This work will be extended by employing new technique for reducing air gaps between ceramic blocks and outer cavity in fabrication of this filter.

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