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A TE_{11} Dual-Mode Monoblock Dielectric Resonator Filter

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Abstract- A novel TE_{11} monoblock dual-mode dielectric resonator filter is presented in this paper. The proposed filter is made of a single piece of ceramic with silver plated external surfaces and metallic lids for hosting tuning elements. The dominant TE_{11} dual-mode is supported by H-shape dielectric resonator having ε_r =45. The resonator is ultra-compact in size and offers a maximized space utilization since no metallic housing is required. In addition, the proposed resonator offers a high unloaded quality factor, reasonably wide spurious window and lend itself to implement tunability. One prototype filter operating at 1.96 GHz with 50-MHz bandwidth is designed.

Index Terms- Dual mode dielectric filter, high Q, monoblock, tunability

I. Introduction

Dielectric resonator filters have been widely used in mobile communication and space applications due to their relatively small size, high unloaded Q-factor and stable thermal and mechanical performance. Further size reduction can be achieved by exploiting multi-mode degenerate resonances in a dielectric resonator. Since Cohn and Fiedziuszko [1] first introduced the possibility of realizing high Q-factor filters using the single mode, $TE_{01\delta}$ and $TM_{01\delta}$, and dual-mode, $HE_{11\delta}$ and $EH_{11\delta}$, dielectric resonators in 1968 and 1981 respectively, some practical applications have been employed in cellular base station and space applications. A number of dual-mode dielectric filter configuration for size and space utilization while maintaining high Q-factor can be found in [1]-[4]. Ordinarily, dielectric filters are made of a dielectric rod (puck) suspended in a metallic enclosure with necessary mounting fixtures and tuning screws. Therefore, additional weight, size and complexity are introduced. In addition, the current existing dual-mode dielectric resonator filters require tuning elements to introduce proper field perturbation for coupling the orthogonal polarized modes (inner-coupling) in which they might neither be present in the same plane as other tuning elements nor on the wall of the housing cavity. This introduces a challenge when a complex coupling or planar coupled filter or diplexer layout is required [3].

A novel H-shape TE_{11} dual-mode dielectric resonator filter is presented in this paper. The proposed resonator is ultra-compact in size compared to a traditional coaxial filter with similar unloaded Q-factor. The filter configuration based on the proposed resonator can further save size since no metallic housing is required as the external surface of H-shape resonator is silver plated. In addition, no screws or through holes at 45° [4][6] is required for inter-mode coupling and self-coupling of each degenerate modes.
Next, the bandwidth and center frequency of a 2nd-order bandpass filter (BPF) are tuned by using tuning screws. In addition, a 4th-order BPF with asymmetric response and wide tuning range of center frequency is realized displaying the validity of the proposed resonator.

II. H-Shape Dual-Mode Dielectric Resonator

A. Resonator Structure

Figure 1 shows the configuration of the novel TE_{11} dual mode monoblock dielectric resonator. The single monoblock H-shape resonator is build using a ceramic material with a loss tangent of $4 \cdot 10^{-5}$ and dielectric constant of 45, reported in [6]. The outer surface of the resonator is metallized by using silver paint with conductivity of $2 \cdot 10^{7}$ S/m. One obvious advantage of the proposed resonator is ensuring a nearly perfect contact between the resonator external surface and the metallic paint and overcome the problem stated in [6] maintaining a good electrical performance. In addition, the H-shape resonator offers a further size reduction, about 320%, compared to the ultra-compact new class of dual-mode dielectric resonator proposed in [6] since no metallic housing is required. The proposed resonator dimensions, shown in Fig.1, are chosen as follow: H_1=5mm; H_2=10mm and D=18mm.

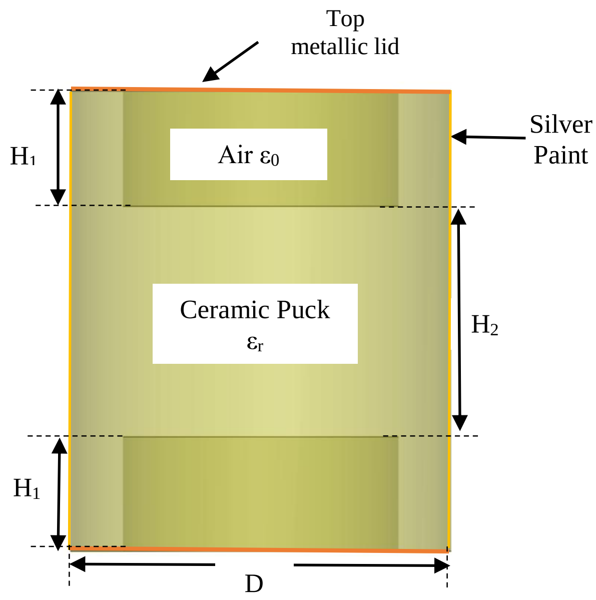


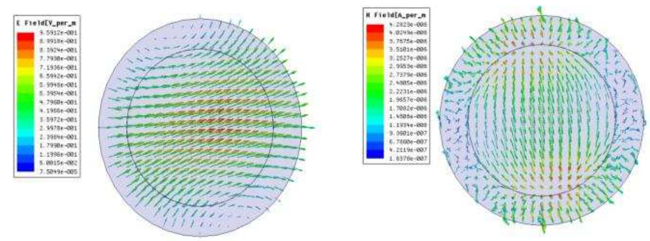
Fig. 1. Proposed monoblock H-shape dual-mode resonator

B. The Proposed Resonator Characteristic

Cross-section view of electric and magnetic field distributions of the first mode resonance are shown in Fig 2. A summary of the first five resonances and their unloaded quality factor (Q_u) is shown in Table 1. The results shown in this paper are obtained using HFSS 2015 and CST 2016 (EM) simulators. It can be seen from Table 1 that the unloaded resonator exhibits a fundamental resonant frequency of 1.96 GHz with unloaded quality factor (Q_u) of 3400 and a spurious window ratio (f_1/f_0) of 1.392 between the fundamental resonant mode and the first higher-order mode.

Table 1: First five resonant modes of the H-shape resonator

Mode No.	Name	Frequency (GHz)	Q_u
1	TE_{11}	1.96	3404
2	TE_{11}	1.96	3409
3	TM_{01}	2.73	3966
4	TE_{21}	2.78	2978
5	TE_{21}	2.78	2978



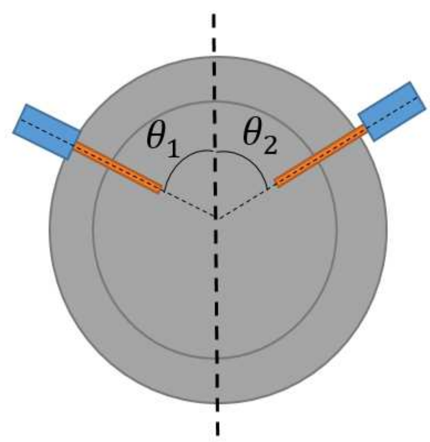
(a) (b)

Fig. 2. (a) Electric and (b) magnetic field distribution of TE_{11} in horizontal cross-section plane respectively

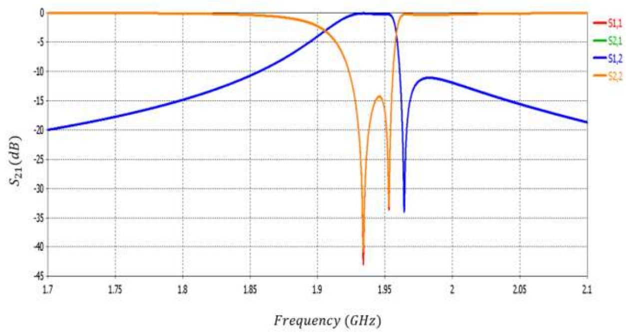
C. Resonator Coupling

Classically, coupling between two orthogonal modes can be achieved by presenting a proper field perturbation at 45° with respect to the direction of the orthogonal polarized fields. This can be achieved by introducing a hole\slot or a screw positioned vertically or horizontally at 45° in the DR surrounding as reported in [1][2][4].

In this paper, the coupling between the two orthogonal TE_{11} degenerate modes is achieved by introducing an angle, smaller or larger than 90° (θ_1 and θ_2), between the I\O coaxial probes as shown in Fig. 3a. The suitable choice of the angle creates proper field perturbation between the degenerate modes and provide enough coupling between the two orthogonal polarized fields without the need to use any means of inner-cavity couplings, e.g. screws or through holes\slots, and thus reduce the fabrication complexity. Figure 3 shows the coupling configuration used and the simulated results of a 2nd-order bandpass filter.



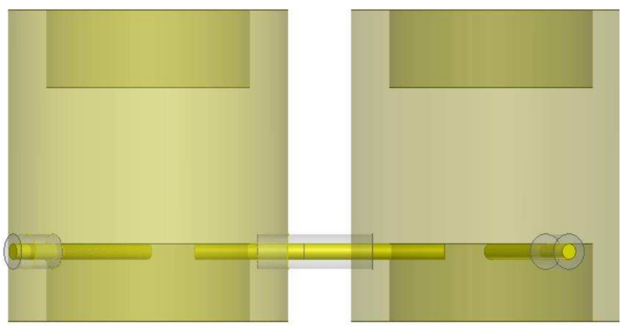
(a)



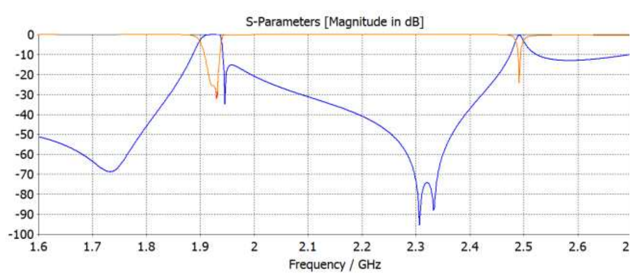
(b)

Fig. 3. (a) Coupling between two orthogonal polarized fields (b) Simulated response of the 2nd order monoblock prototype

A 4th-order dual-mode BPF based on the proposed resonator is designed and simulated as shown in Fig. 4. The coupling between the two cavities, intra-cavity coupling, is achieved by using a metallic wire in proximity of the H-shape puck since most of the EM field is confined within the resonator.



(a)



(b)

Fig. 4. (a) Coupling between two cavities in planar configuration (b) Simulated response of the 4th order monoblock prototype

The simulated filter exhibits a fractional bandwidth (FBW) of 2.5% at 3 dB and Insertion Loss of 0.3 dB.

III. Tunability

The tunability of the center frequency could be implemented by introducing a hole in the middle of the resonator where a tuning screw is mechanically moved changing the resonator loading capacitance and thus the center frequency as shown in Fig. 5.

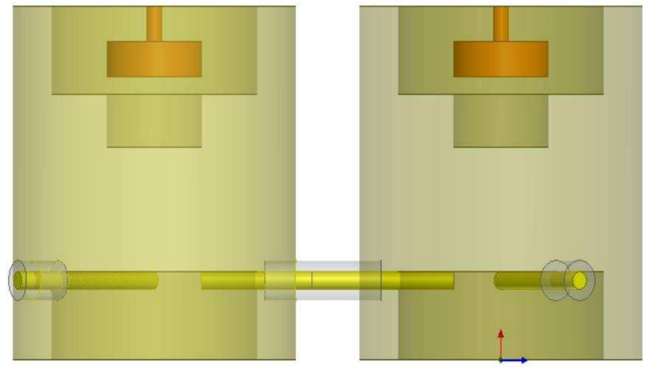
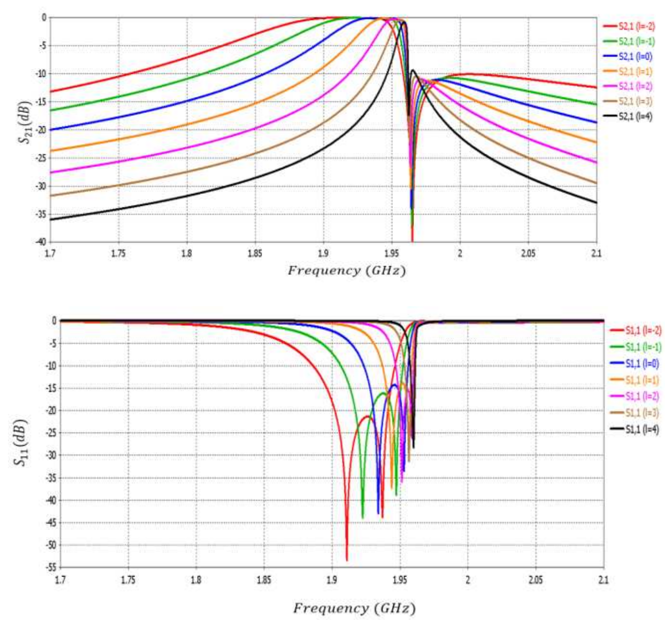
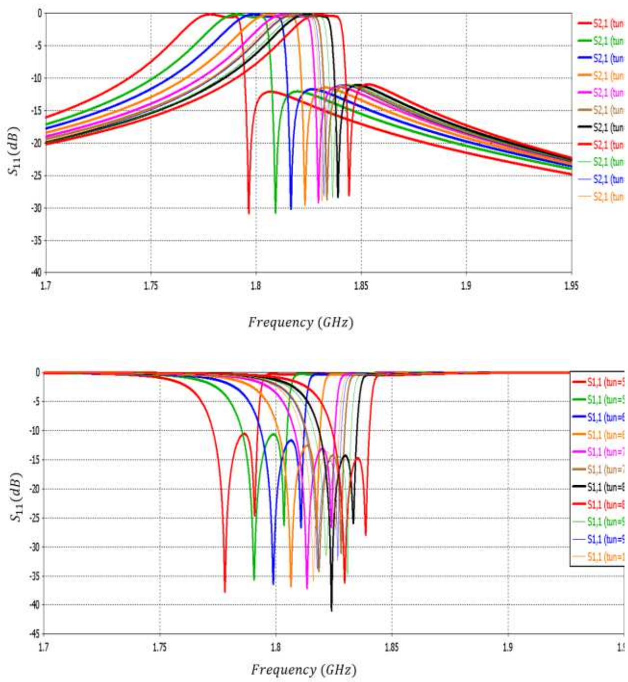


Fig. 5. Tuning configuration of the 4th-order monoblock prototype

The bandwidth and center frequency of the realized filter are tunable as shown in the simulated response of the 2nd order dual-mode bandpass filter presented in Fig. 6. The bandwidth can be tuned from 9 MHz to 100 MHz while the center frequency is tunable from 1.77 GHz to 1.83 GHz.



(a)



(b)

Fig. 6. (a) Simulated response of the 2nd order monoblock prototype with bandwidth tuning (b) Simulated response of the 2nd order monoblock prototype with tunable center frequency

In addition, the simulated response of the 4th-order bandpass filter with tunable center frequency is shown in Fig. 7. The filter offers a tuning range from 1.7 to 2 GHz with minimum variation in the in-band performance.

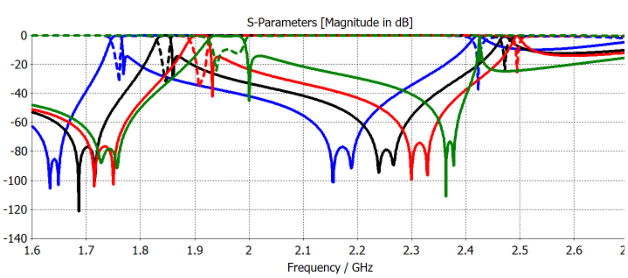


Fig. 7. Simulated response of the four pole monoblock prototype with tuning center frequency

IV. Conclusion

A new class of TE_{11} dual-mode dielectric resonator suitable for mobile communication applications is presented. The proposed resonator consists of H-shape ceramic puck with silver plated external surface. The ultra-compact size H-shape resonator exhibits high quality factor and reasonable spurious window. A 2nd- and 4th-order BPF with asymmetrical response was designed and simulated based on the proposed resonator. The filter offers a wide tuning range, center frequency and bandwidth, with acceptable in band performance.

V. Acknowledgment

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VI. References

[1] Fiedziuszko, S.J. "Dual-Mode Dielectric Resonator Loaded Cavity Filters". IEEE Transactions on Microwave Theory and Techniques 30.9 (1982): 1311-1316.

[2] Hoft, M. "Y-Shape Dielectric Dual-Mode Resonator". IEEE Transactions on Microwave Theory and Techniques 56.12 (2008): 3066-3071.

[3] Hu, Hai and Ke-Li Wu. "A TM11 Dual-Mode Dielectric Resonator Filter With Planar Coupling Configuration". IEEE Transactions on Microwave Theory and Techniques 61.1 (2013): 131-138.

[4] Hunter, I.C., J.D. Rhodes, and V. Dassonville. "Dual-Mode Filters With Conductor-Loaded Dielectric Resonators". IEEE Transactions on Microwave Theory and Techniques 47.12 (1999): 2304-2311.

[5] Wang, Xi and Ke-Li Wu. "A TM01 Mode Monoblock Dielectric Filter". IEEE Transactions on Microwave Theory and Techniques 62.2 (2014): 275-281.

[6] S.Bakr, Mustafa, Saad W.O. Luhaib, and Ian C. Hunter. "A Novel Dielectric Loaded Dual Mode Cavity for Cellular Base Station Applications". European Microwave Conference (2016).