A Novel Varactor Tuned Dielectric Resonator Filter

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Abstract — This paper presents a novel structure for tunable dielectric resonator (DR) filters using varactor tuning. The varactor is mounted outside the filter housing while interacting with the resonator through a PCB circuit board. The concept is analyzed both theoretically and experimentally. A prototype tunable DR filter employing this concept is designed, implemented and tested. The filter operates at 5 GHz with a bandwidth of 60 MHz demonstrating a tuning range of more than 300 MHz and a spurious free window larger than 1.0 GHz.

Index Terms — Dielectric resonator, tunable filter, varactor, electrical tuning.

I. Introduction

Tunable filters are very attractive in dynamical systems and multiband communication systems. In a dynamical system, a tunable filter can quickly react and adjust its operating frequency and band in accordance with the requirement of the dynamical system to suppress the unwanted signal and allow the required signal to pass through. In a multiband system, a tunable filter can be used to replace the parallel-path multiband filter banks, thereby achieving a more compact system size with less complexity and improved performance.

Dielectric resonator filters are widely deployed in base stations of wireless communication and satellite communication systems due to their advantages of high Q value, compact size, and less temperature drift. Tunable dielectric resonator filters have attracted much interest in the past years. The simplest method to realize tunable DR filters is to use mechanical tuning, in which the dielectric resonator loading is changed by physically moving the tuning element above the dielectric resonator.

MEMS tunable dielectric resonator filters were first developed in 2007 [1]. The mechanism incorporates MEMS technology to physically control placement of the tuning element on top of the dielectric resonator, thereby changing the loading of the dielectric resonators to realize tuning. However, this design is only applicable to high frequency applications, since the MEMS tuning element must be comparable with the size of the dielectric resonator to have an impact on its resonant frequency. A varactor-tuned dielectric resonator was presented in [2]. A slot is opened in the resonator for placing a diode varactor; However, this design is bulky in addition the varactor is not easily accessible for biasing. DR filters based on MEMS technologies and varactors are also reported in [3] , in which the tuning mechanism involves the use of the existing coupling between the dielectric resonator and the tunable circuits, to induce a frequency shift of the dielectric resonator. Nevertheless, these designs usually yield a low tuning range due to the weak coupling between the DR and the tuning circuits.

In this paper, a new structure for tunable dielectric resonator filters is proposed. A prototype 2-pole tunable filter is designed and implemented to verify the concept.

II. Design and Implementation

A. Tunable Resonator

Fig. 1 shows the 3D view of the proposed tunable dielectric resonator. The dielectric resonator is placed in the center of the metal cavity and is supported by a thin Teflon disk. The metal disk at the bottom of the cavity is used to align the dielectric resonator during the assembly process. The cavity is covered by a patch-printed Rogers 5880 PCB board. A disk patch is printed on the bottom surface of the PCB board, and linked to top patch of the PCB board through a via hole. A slot around the via hole isolates the via hole from the grounded top patch. A varactor is lumped over the slot, and a high value DC bias resistor is used to avoid RF leakage while applying DC voltage to the varactor. The schematic view of the tuning circuit board is illustrated in Fig.2, while the cross-sectional view of the tunable resonator and its circuit model are shown in Fig.3. The circuit model of the tunable resonator can be expressed as a varactor connected between the resonator and the ground (Fig.3 (b)). Upon tuning, the varactor capacitance will change with applied DC voltage, thereby changing the loading to the dielectric resonator and consequently shifting the frequency of the dielectric resonator. The advantage of this approach is that the varactor is located outside the DR cavity.

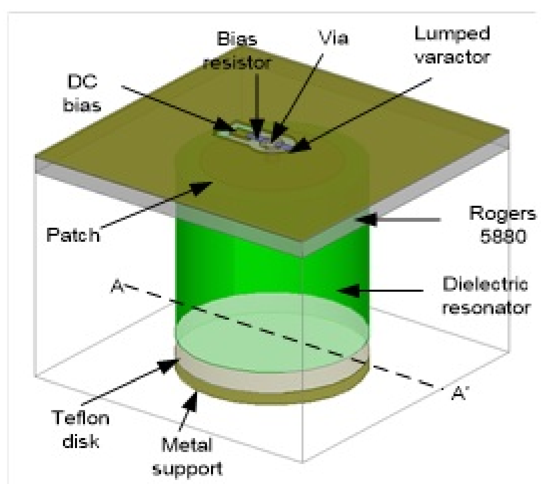

Fig.1 3 D view of designed tunable dielectric resonator

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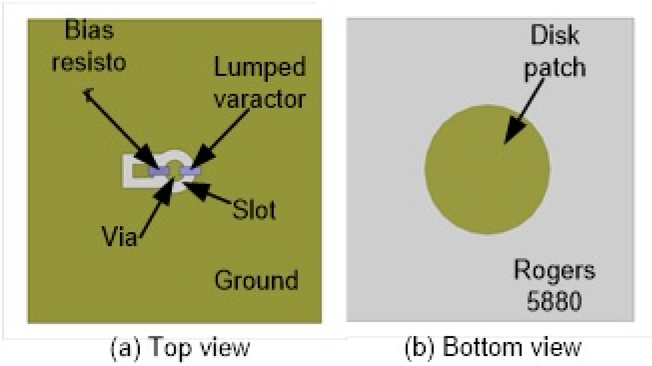

Fig.2 Schematic view of the designed circuits

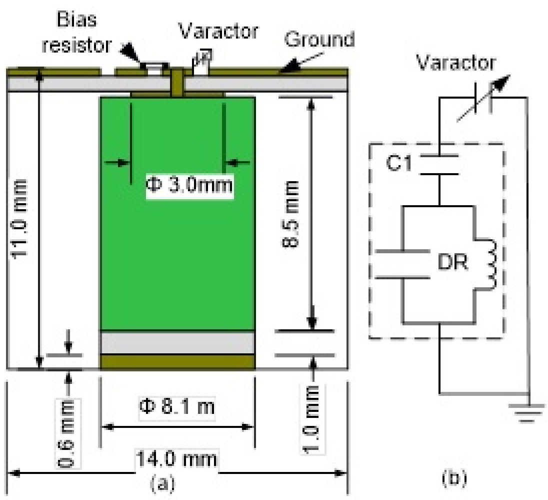

Fig. 3 (a) Cross-section view of the tunable resonator, and (b) Circuit model of the tunable resonator

A dielectric resonator with a dielectric constant of 24.4, a diameter of 8.1 mm and a length of 8.5 mm, is placed in the cavity as shown in Fig.3(a). The cavity dimensions are also displayed in Fig.3 (a). Based on this design, a single resonator is simulated with an HFSS EM model to investigate the tuning concept. The EM simulation results show that the lowest two modes of the designed resonator are the single mode (TME) and the Hybrid dual mode HEH. Fig.4 shows the variation of the resonant frequencies of those two modes as the varactor capacitance is varied. The results given in this figure illustrate that the frequency of the TME mode is tuned from 5.2 – 4.7 GHz with the lumped varactor changing from 0.2 to 1.8 pF. The spurious windows between the first two modes are larger than 900 MHz over the tuning range.

B. Tunable Filter

In order to demonstrate the proposed concept, a 2-pole filter design with a bandwidth of 60 MHz and an in-band ripple level of 0.1 dB at 5 GHz is considered. Based on the EM simulation, a horizontal iris of 11.6 mm x 3 mm positioned 6

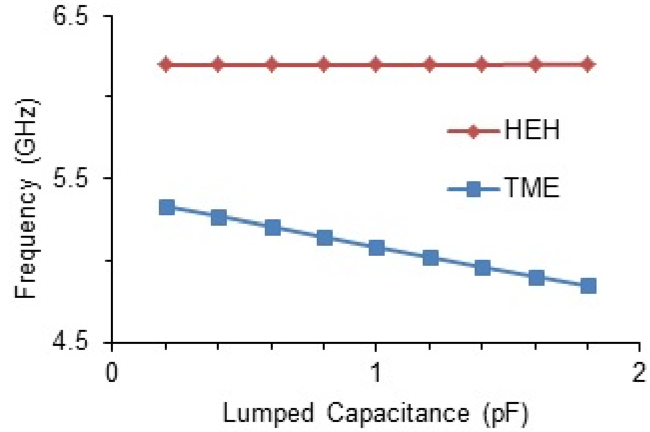

Fig. 4 Simulated results of the first two modes vs. the lumped varactor capacitance

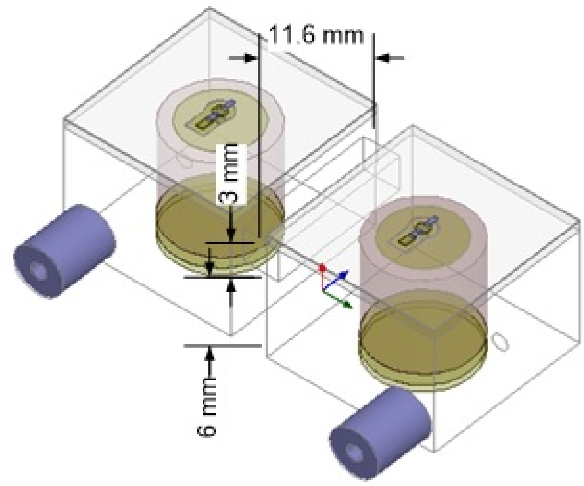

Fig. 5 EM model of the 2-pole filter for simulation

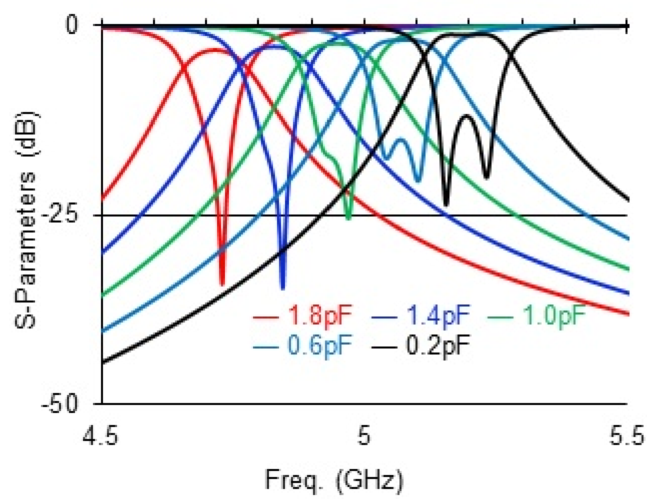

Fig. 6 Simulated tuning response of the 2-pole filter

mm above the cavity floor along the horizontal center line is opened, as shown in Fig.5. The input probe is placed right beside the resonator with a vertical position 2.5 mm from the cavity bottom, and an extension of 9 mm into the cavity. The EM full wave simulations of the 2-pole filter tuning responses are shown in Fig. 6, which illustrates that the filter is tuned from 5.2 to 4.72 GHz. A tuning range of 580 MHz is achieved with the lumped capacitance changing from 0.2 pF to 1.8 pF.

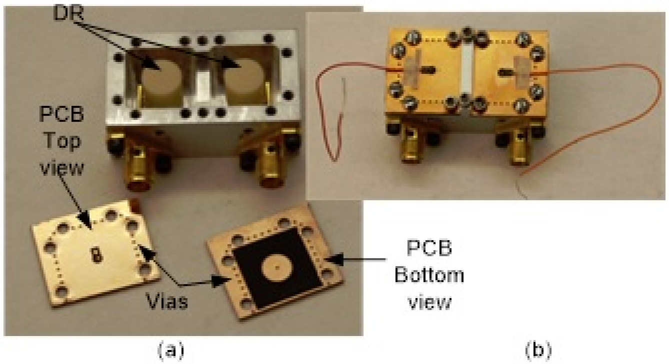

Fig. 7 Pictures of the designed filters, (a) cavity opened with PCB circuits, and (b) assembled filter

III. Measurement and Analysis

Based on the EM simulation, a two-pole tunable dielectric resonator filter was fabricated and measured. An aluminum housing is used for the filter body, and PCB tuning circuits are used as the cavity lid. The pictures of the housing and the tuning circuits are displayed in Fig.7 (a). The picture of the assembled filter is displayed in Fig.7 (b). GaAs vatactors (MGV100-20) from Aeloflex are used in the assembled filter, and DC voltages are applied between the DC bias and the cavity (ground). Fig. 8 shows the measured results of the filter at one tuning state. The spurious free window is larger than

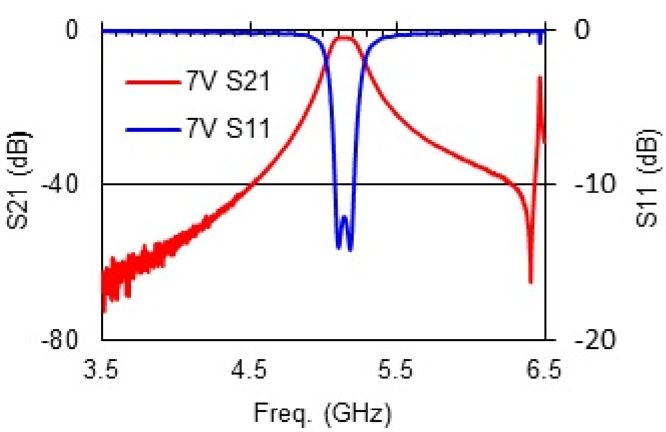

Fig.8 Measured results of the filter at one tuning state

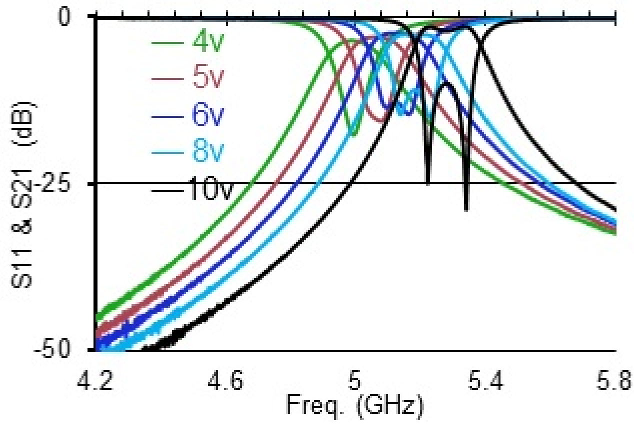

Fig. 9 Measured tuning response of the 2-pole filter with applied DC voltage from 4 – 10 volt

1.0 GHz. The filter demonstrates a spurious free windows larger than 1.0 GHz. Fig.9 shows the measured filter responses. The measured results show that the filter can be tuned from 4.98 to 5.28 GHz with the insertion loss changing from 3.4 dB to 1.47 dB as the applied DC voltage is varied from 4 to 10 volts.. The filter return loss degradation is mainly due to the inter-resonator and input/output couplings that do vary with the frequency tuning. Measurement results also show that the Q of the filter is better than 303 (303-576) over a tuning range of 300 MHz.

IV. Conclusion

In this paper, a novel structure for tunable DR filters is presented. The tuning mechanism is based on a PCB circuit with a varactor placed outside the DR cavity resonator. As the varactor capacitance changes, the loading to the dielectric resonator changes accordingly, thereby achieving the filter tuning. The performance of the proposed filter can be improved by using high-Q RF-MEMS switched capacitor.

References

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