A Constant Absolute Bandwidth Tunable Bandpass Filter Based on Mixed Coupled Varactor Loaded Open Ring Resonators

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Abstract— In this paper, a novel analogue tunable bandpass filter with constant absolute bandwidth is presented. The filter is designed based on full wavelength microstrip open ring resonators loaded with varactors. Magnetic dominated mixed coupling is designed to make the coupling coefficient meet the requirement of constant absolute bandwidth response. The filter is designed, fabricated and measured. The measurement shows that the −3 dB bandwidth is from 105 MHz to 109 MHz while the central frequency of the passband varying from 2.39 GHz to 2.82 GHz. The return loss is better than 15 dB.

1. INTRODUCTION

Frequency-agile bandpass filters are essential for multiband telecommunication systems and wideband reconfigurable systems [1, 2]. Semiconductor varactors are widely used in tunable filters design due to its high tuning speed, reliability and the high cost performance [3–12]. In [10], a semiconductor varactor diode loaded microstrip LC resonator is adopted to design the second- and third-order tunable filters. In [11], four varactors embedded in the resonators separately to design a bandpass filter based on microstrip-to-CPW structure. At the same time, in [12], varactors loaded microstrip open ring resonators is also used to design the tunable bandpass filers. Compared with CPW or SIW, the microstrip technology is widely used because of its higher design freedom. Recently, microstrip resonator with mixed coupling structure is extensively utilized to design constant bandwidth tunable filter. In [6], tunable $\lambda/4$ resonators are used to design low-loss tunable filters with predefined bandwidth. In [12], a tunable filter with mixed electrical and magnetic coupling is designed based on tunable $\lambda/2$ resonator. A two-pole dual-band tunable bandpass filter (BPF) with independently controllable dual passbands is also designed based on tunable $\lambda/2$ resonator [13].

In this paper, tunable full wavelength open ring resonator is utilized to design tunable bandpass filter. Magnetic dominated mixed coupling structure is designed to obtain constant absolute bandwidth. The filter is designed, fabricated and measured. The measurement shows that the −3 dB bandwidth is from 105 MHz to 109 MHz while the central frequency of the passband varying from 2.39 GHz to 2.82 GHz. The return loss is better than 15 dB.

2. DESIGN OF THE TUNABLE FILTER

The configuration of the filter is shown in Figure 1. The varactor diode is loaded at one of the two splits on the open ring resonator to achieve full wavelength tunable resonator. The relationship between the coupling coefficient and bandwidth can be given as [15]:

$$k = \frac{ABW}{f_0\sqrt{g_1 g_2}} \tag{1}$$

where, g_1 and g_2 are constant, f_0 is the central frequency, ABW is the absolute bandwidth. Therefore, constant absolute bandwidth can be achieved when the coupling coefficient decreases as the center frequency increases. Figure 2 shows the normalized surface current and voltage distribution. ΔL_1 and ΔL_2 are equivalent electric length of the varactor capacitance under different bias voltages. The current and voltage distribution can indicate the magnetic field intensity and the electric field intensity [1, 14]. It can be seen from Figure 2 that, the magnetic coupling coefficient decreases and electric coupling coefficient increases when the central frequency is tuned up. Therefore, the overall coupling coefficient decreases when the resonating frequency is tuned up.

In the proposed filter as shown in Figure 1, the tunable resonators are coupled with strong magnetic coupling and weak electric coupling, and small rectangle stubs between the tunable resonators are used to enhance the electric coupling, thus the slop of the overall coupling coefficient to the central frequency can be controlled to achieve constant absolute bandwidth response.

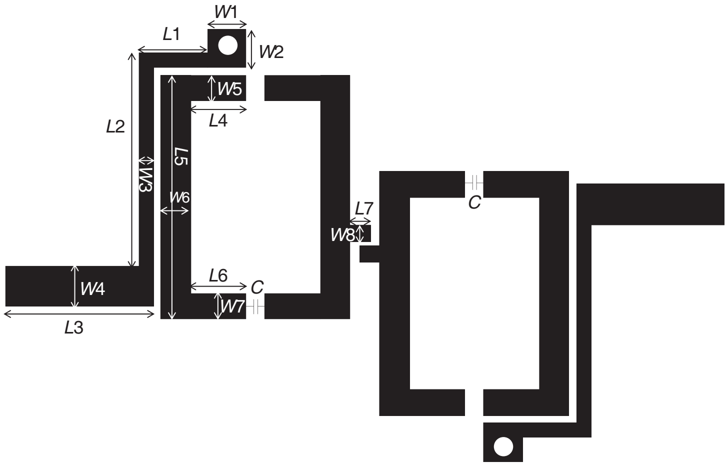

Figure 1: Configuration of the filter.

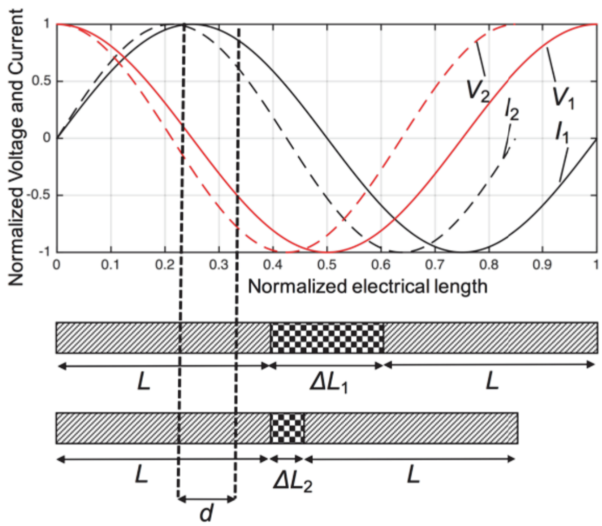

Figure 2: The voltage and current distributions on the resonator at different frequency.

Simulation is carried out based on the above structure. The geometry parameters of the proposed filter shown in Figure 1 are: $W1 = 2.0$, $W2 = 2.0$, $W3 = 0.8$, $W4 = 2.2$, $W5 = 1.4$, $W6 = 1.6$, $W7 = 1.4$, $W8 = 0.9$, $L1 = 4.3$, $L2 = 12.4$, $L3 = 12.0$, $L4 = 3.7$, $L5 = 14.6$, $L6 = 3.7$, $L7 = 1.1$ (Unit: mm). The substrate of the filter is F4B-2 ($h = 0.8$ mm, $\varepsilon_r = 2.65$, $\tan\theta = 0.001$). Two parallel connected SMV1405 diodes are chosen as the tunable capacitor for each resonator, and the varactors diodes are biased through two 51 kΩ resistors. The simulated transmission characteristics of the filter is shown in Figure 3(a), and it shows that the passband of the filter can be tuned. Figure 3(b) shows the fractional bandwidth and absolute bandwidth of the filter. The fractional bandwidth decreases as the central frequency increases, and the absolute bandwidth is in the range of 98 MHz to 99.4 MHz when the central frequency is tuned from 2.36 GHz to 2.80 GHz.

3. FABRICATION AND MEASUREMENT

The filter designed in Section 2 is fabricated as shown in Figure 4, and it is measured by using Agilent E5071C vector network analyzer. Figure 5(a) shows the measured and simulated scatter parameters under 0 V, 2 V, 10 V, and 25 V biasing voltages. Figure 5(b) shows the measured absolute bandwidth and fractional bandwidth versus central frequency. The measurement shows that the -3 dB bandwidth ranges from 105 MHz to 109 MHz, while the central frequency varying from 2.39 GHz to 2.82 GHz. The return loss is better than 15 dB.

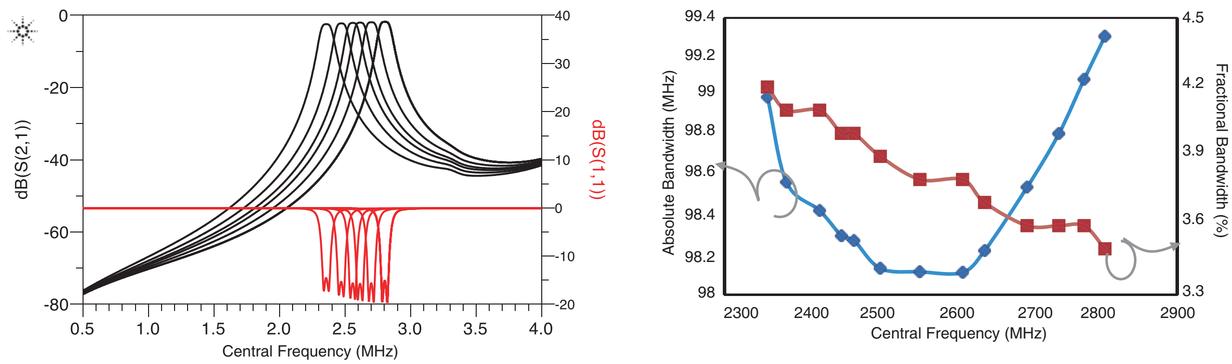

Figure 3: (a) The scatter parameters. (b) The bandwidth versus center frequency.

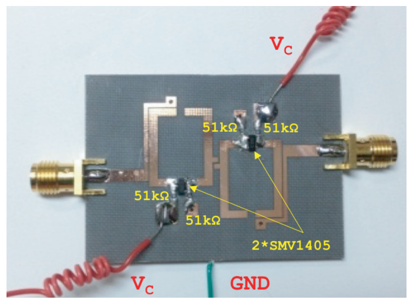

Figure 4: The photo of the fabricated tunable bandpass filter.

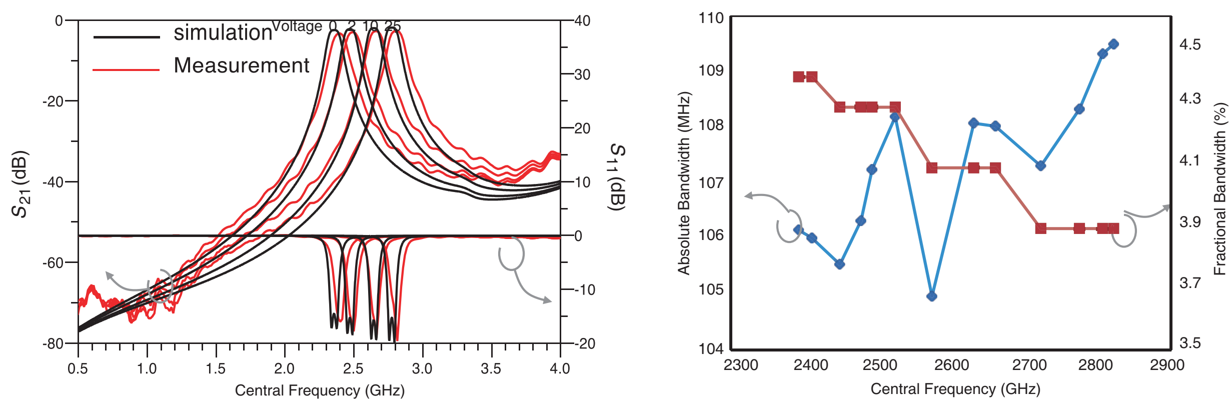

Figure 5: (a) The measured scatter parameters. (b) The measured bandwidth versus the center frequency.

4. CONCLUSION

A novel absolute-bandwidth tunable bandpass filter based on varactor loaded full wavelength microstrip open ring resonators with magnetic dominated mixed coupling is presented, and the filter is fabricated and measured. The measurement shows that the -3 dB bandwidth is from 105 MHz to 109 MHz while the central frequency of the passband varying from 2.39 GHz to 2.82 GHz. The return loss is better than 15 dB.

ACKNOWLEDGMENT

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