Tuning circuit using varactor diode for tunable bandstop resonator

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Tuning Circuit Using Varactor Diode for Tunable Bandstop Resonator

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***Abstract*—A tuning circuit based on the use of varactor is presented to tune the electrical length of an open-circuited stub. The complete circuit with the choice of components is given in the paper, along with its simulation results. The proposed circuit is realized using microstrip technology on FR4 substrate. The experimental results are found to be of good agreement with the ones obtained from simulation. The proposed circuit is expected to be advantageous for future tuning applications of bandpass filter. The experimental result shows the center frequency of tunable filter can be tuned up to 84%.**

Keywords-Microwave; varactor diode; stub resonator; microstrip bandstop filter.

I. INTRODUCTION

In view of the rapid growth and new demand of communication systems having multi-applications, tunable filters have emerged as an ideal solution. This recent trend has led to development of filters based on tunability working at different frequency bands and to meet various standards and functions [1]-[5]. Therefore, various types of tunable bandpass filters have been developed as to respond to the demand of numerous applications such as multi-band systems, radiometers and wideband radar systems [6].

Tunable filters have received a tremendous attention and various designs and techniques that may satisfy stringent requirements in terms of tunability and selectivity have been proposed. The tuning mechanisms are proposed to be either tuned-electrically or mechanically; achieved by using solid state devices or MEMS technologies. Therefore, numerous tunable filters have been extensively demonstrated and achieved greater performance and cost effective [7]-[10].

In this paper, an electrically tuning using varactor diode is presented. Based on varactor-tuned approach, DC bias voltage is adjusted to give certain capacitance values, hence results in tune of frequency response. To meet the wide tuning range, varactor diode SMV1232 is chosen such that the center frequency can be tuned up to wide tuning range.

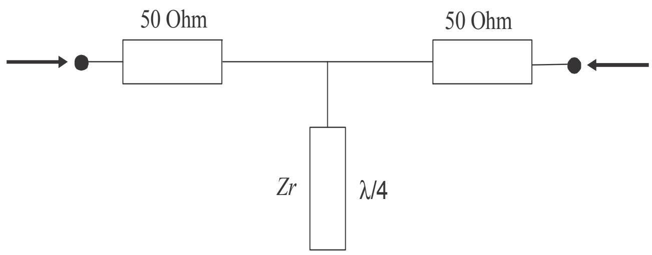

Fig. 1. Open-circuited stub resonator.

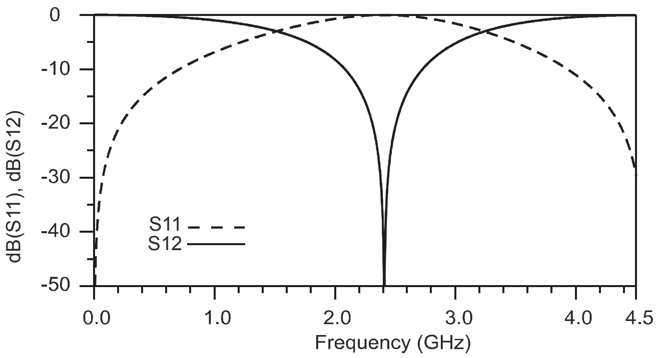

Fig. 2. Simulated response of the open-circuited stub resonator centred at 2.4 GHz.

The complete circuit is simulated using EM circuit simulator in order to investigate the design concept and performance of the electrical tunable bandstop filter. The experimental result shows 84% of tuning range from 0.907 to 1.666 GHz.

II. BANDSTOP FILTER USING OPEN-CIRCUITED STUB

To validate the tuning concept of the varactor electrically tuned, a simple structure of the bandstop filter with an open-circuited stub resonator is proposed. Fig. 1 shows the proposed topology of the open-circuited stub with the stub length is equal to one quarter wavelength at center frequency of 2.4 GHz.

In this design, the characteristic impedance, Z_r of 30 Ω is chosen for better quality factor and thus leads to an efficient tuning capability. The nominal filter response of the open-circuited stub resonator centered at 2.4 GHz is illustrated in Fig. 2.

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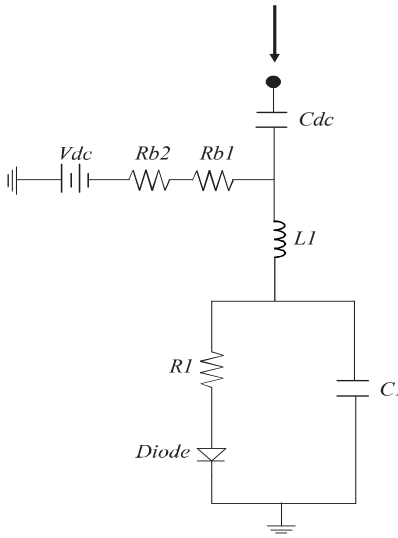


Fig.3. Varactor model with biasing circuit.

III. TUNABLE BANDSTOP FILTER USING OPEN-CIRCUITED STUB AND SHUNT VARACTOR

Fig. 3 shows the equivalent circuit of the varactor diode with biasing circuit that makes the filter becomes tunable. It consists of DC block capacitor, *Cdc* which is loaded in order to control the DC effect from flowing to the resonator and DC-feed resistors, *Rb1* and *Rb2* used in reducing the RF-signal leakage to the bias circuitry. For the varactor equivalent circuit, it basically consists of *R1*, the series resistance of the varactor diode, *C1* represents the package capacitance and *L1* is package inductance. A smallest value of *C1* and *R1* and a large value of *L1* are chosen for widest tuning range and higher quality factor [11].

TABLE I: VALUES OF VARACTOR'S CAPACITANCE WITH BIAS VOLTAGES

Reverse Voltage (V)	Capacitance (pF)
0	4.15
1	2.67
2	1.97
3	1.51
4	1.22
5	1.05
6	0.94

Table I shows the typical capacitance values provided by Skyworks SMV1232 varactor diode [12]. It is clearly can be seen that the bias DC voltage of 0 to 6 V caters the capacitance range of 0.94 to 4.15 pF and hence produces the proper tuning response of the filter.

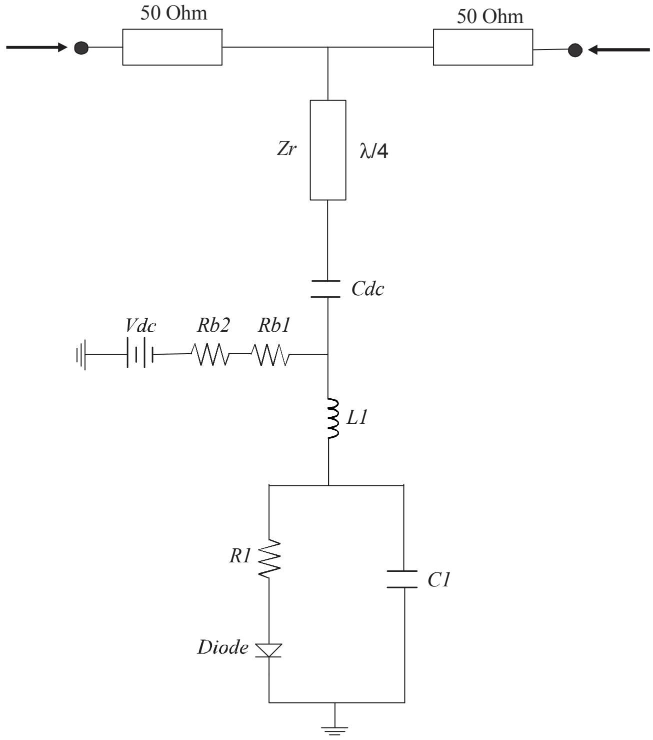


Fig. 4. Tunable open-circuited stub resonator with varactor-tune biasing circuit.

The varactor-based tuning circuit is then loaded at the end of the open stub in order to tune the filter resonator. The proposed structure is shown in Fig. 4 which comprising of λ/4 open-circuited stub connected by 50 Ω feeder lines and loaded with the varactor tuning circuit.

The relationship between the center frequency and the circuit element's parameters is as follows [1]:

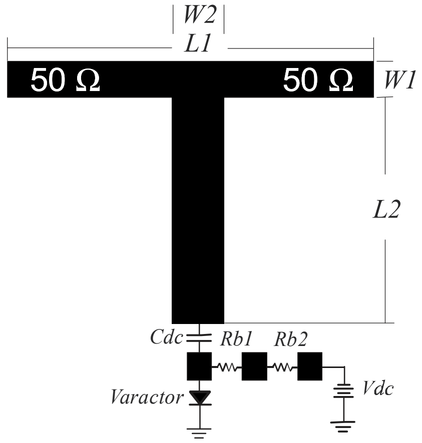
$$f_0 = \frac{1}{2\pi Z_0 C_v tan\theta_0} \quad (1)$$

Where $\omega_o = 2\pi f_0$ and θ_0 is the electrical length of the stub at operating frequency, f_0.

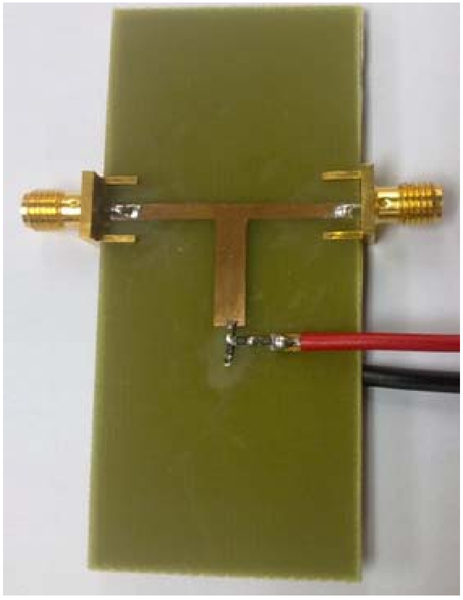
From (1), it has been proven that as the capacitance, C_v of the stub resonator increases, the central frequency will shift to the left. This basic fundamental is then validated by the measurement results on the next section.

IV. FABRICATION AND MEASUREMENT

Fig. 5(a) shows the layout of the tunable open-circuited stub resonator with its physical dimensions of L_1 = 31.32 mm, L_2 = 15.3 mm, W_1 = 2.58 mm and W_2 = 4.2 mm. The filter is designed on FR4 substrate with εr = 4.1, *tan* = 0.02 and *h* = 1.5 mm. The fabricated filter as shown in Fig. 5(b) also consists of DC blocking capacitor, *Cdc* of 1 µF and two 10 kΩ resistors (*Rb1* and *Rb2*) connected in series as DC-feed resistors.

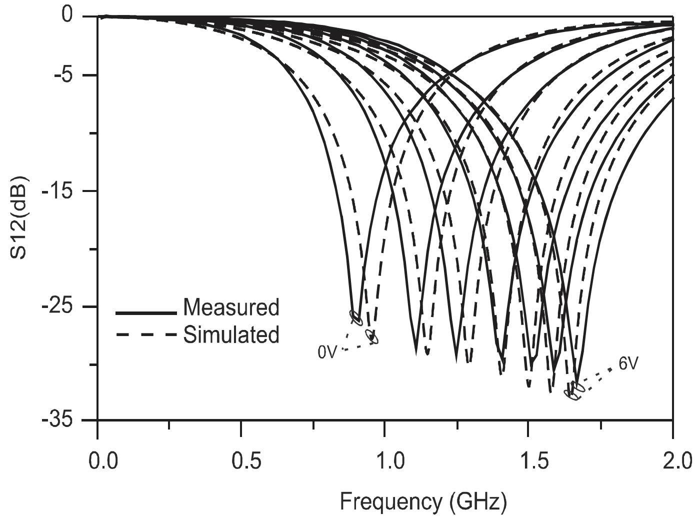


(a)

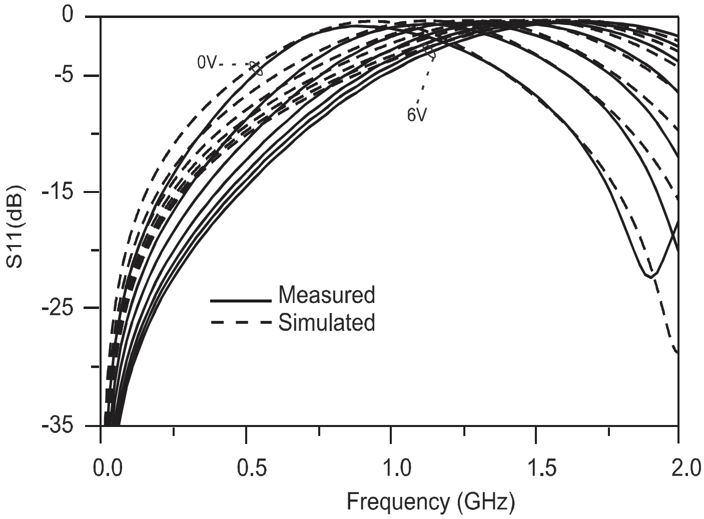


(b)

Fig. 5. Tunable open-circuited stub resonator. (a) Layout. (b) Fabricated filter.



(a)



(b)

Fig. 6. Measured results of the tunable open-circuited stub resonator under bias voltage from 0 V - 6 V. (a) Insertion loss. (b) Return loss.

The measured results are shown in Fig. 6. It is clearly can be seen the tuning effects for both return loss and insertion loss. Fig. 6(a) shows the measured frequency tuning of 0.907 to 1.666 GHz and achieved 84% tuning range by applying DC voltage from 0 V to 6 V. Fig. 6(b) shows measured return loss and the responses are below 5 dB for all states within the passband. The discrepancies between the measured and simulated results are due to several reasons such as introducing the large values of DC-feed resistors and large loss tangent (0.02) used from FR4 substrate would exhibit higher losses to the filter. However, the measured results have verified the design and tuning concept which are the main focus in this project. The scattering parameter measurements of the fabricated tunable filter are performed using Rohde & Schwarz ZVB20 Vector Network Analyzer over the frequency range from 20 MHz to 2 GHz.

V. Conclusion

A varactor-based tuning circuit is proposed by considering the tunability of the bandstop filter. The proposed tunable filter has yielded 84% of tuning range by varying bias DC voltage which results in the capacitance variation of the varactors. The proposed concept was successfully designed, built and measured subject to multi-application systems at different frequency bands.

Acknowledgment

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