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A Bandpass-to-Bandstop Tunable Filter Using Shorted Stub Loaded Stepped Impedance Resonators (SSL-SIRs)

Tulika Sinha
Junior Engineer,Department of PCM,
Bharat Sanchar Nigam Limited, Ahmednagar,
Maharashtra(India)

Abstract—In this paper a bandpass-to-bandstop tunable filter is designed using shorted stub loaded stepped impedance resonators (SSL-SIRs)[1]-[3]. The substrate used in filter designing is FR4, a lossy material with relative permittivity of 4.4 and height 0.8mm. The bandpass-to-bandstop reconfiguration is done using pin diodes and varactor diodes are loaded to the four inward stubs to achieve tuning[4]. The passband has three transmission zeros lying in the range of 1.72GHz-2.6GHz with 20MHz tuning for the bandpass mode. On reconfiguration to bandstop mode the rejection band lie in the range of 1.9- 2.1GHz with return loss better than 15dB and has 20MHz tuning. This filter can be used in wireless communication where high interference occurs and increases the reception of desired signal.

Index Terms—Short stub loaded stepped impedance resonators (SSL-SIRs), bandpass filter, bandstop filter, tunable filter.

I. Introduction

The advances in modern wireless communication have pushed the area of research to multiband and multifunctional systems. Tunable filters add agility to the system. They reduce the component count, frequencies can be re-used in the radios, the noises entering the system are reduced and optimize the system performance. The apparent spectrum scarcity due to existing and new services has led to designing of tunable filters that can operate in this high interference environment and reconfigures itself as per the suitability [1].

In [2] a novel dual-band bandpass filter is presented that used stub loaded resonators(SLRs). The odd mode frequencies remained same but the even mode frequencies were tuned. Further shorted stub centrally loaded to stepped impedance resonators(SSL-SIRs) is proposed in [3] to create close dualbands. A novel bandpass-to-bandstop reconfigurable filter was proposed in [4] based on close ring resonators loaded with varactor diodes to switch from bandpass to bandstop and vice versa at 2.45GHz. A tunable bandpass-to-bandstop reconfigurable filter is discussed in [5]-[6] that used substrate integrated evanescent-mode cavity resonators. Two and four pole 0.7-1.1GHz bandpass-to-bandstop tunable filters are presented in [7] that used RF-MEMS for reconfiguration between the two modes of filter and asymmetrically loaded varactor diodes are used for making it tunable filter.

In this paper a bandpass-to-bandstop tunable filter is presented that uses shorted stubs centrally loaded to stepped impedance resonators with tapers at the corners. The reconfiguration from bandpass to bandstop mode is done by the use of two pin diodes in OFF-ON state and tuning is achieved by changing the bias voltage of the four varactor diodes that are loaded to the inward stubs. This filter can be used for various wireless applications in high interference environment. The filter operates in bandpass mode when a low power interferer is close to the desired signal allowing the desired signal to pass through it and reconfigures to bandstop mode when a high power interferer is close to the signal of interest stopping the high power interfering signal[5]-[6].

II. Filter Theory

A. Shorted Stub Loaded Stepped Impedance Resonators

A shorted stub centrally loaded to stepped impedance resonators is as shown in Fig.1.

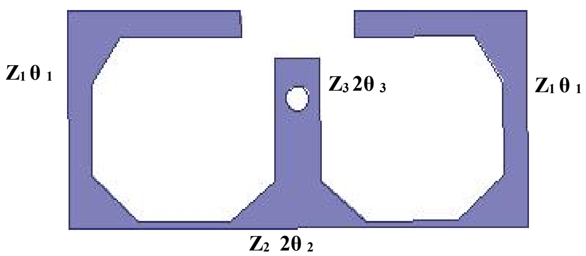

Fig.1. Layout of shorted stub loaded SIR

Since the resonator has symmetrical design; thus odd and even mode analysis is done. The equivalent odd and even mode configurations are as shown in Fig.2

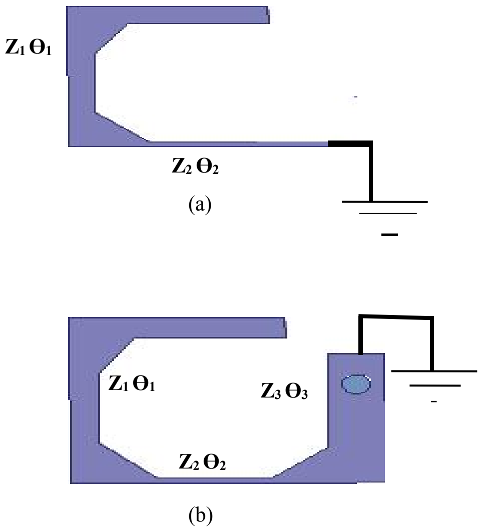

Fig.2. Equivalent circuits of (a) odd and (b) even mode analysis

At odd mode analysis, it shows a voltage null and has virtual ground in the plane of symmetry as shown in Fig.2(a). In even mode analysis it shows open-circuit in the plane of symmetry acting as a magnetic wall. The variation in electrical length of Θ_3 causes even mode of frequencies to vary but odd mode frequency remains at the same position. At resonance, the length of each stepped impedance resonator is $\lambda_g/4$ where λ_g is the guided wavelength.

B. Reconfiguration from Bandpass-to-Bandstop Filter

A single filter can set to operate in two modes. By the use of RF switch a bandpass filter can reconfigure itself to bandstop mode. When the switch is in OFF state then the source/load coupling has no direct connection thus coupling coefficient betweenthem is M=0 and acts in bandpass mode passing on the resonant frequencies.

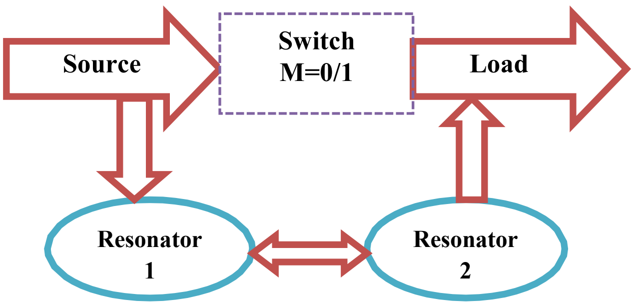

Fig.3. Concept of reconfiguration from bandpass-to-bandstop filter

As switch is turned ON the source/load has direct connection and coupling coefficient turns M=1 between them creating a bandstop filter. Thus stops the set of frequencies for which the resonators resonate.

C. Bandpass-to-Bandstop Tunable Filter

The bandpass-to-bandstop tunable filter is achieved by using variable inductors or capacitors. Varactor diodes show variable capacitance on changing the bias voltage. Thus, they are used to tune the filter over a frequency range by varying the bias voltage.

III. TUNABLE FILTER DESIGN & RESULTS

A. Filter Design

The filter is designed on Ansys HFSS with two shorted stub loaded stepped impedance resonators (SSL-SIRs) with tapers at the corners as shown in Fig.4.

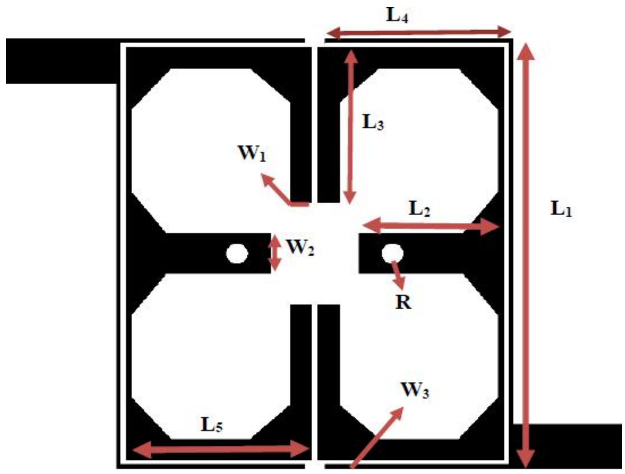

Fig.4. Layout of the bandpass filter

The substrate used is FR4 with relative permittivity ε_r= 4.4 and thickness t=0.8mm. The various lengths are denoted as L_i, widths as W_i and diameter of the vias are R with 50Ω transmission line. The dimensions of the filter are tabulated in TABLE I:

TABLE I.
DIMENSIONS OF THE FILTER

Dimensions	**Values(mm)**
L_1	14.5
L_2	4.6
L_3	5.2
L_4	6.0
L_5	6.0
W_1	0.7
W_2	1.3
W_3	0.15
R	0.7

The bandpass-to-bandstop reconfiguration is attained by the use of two pin diodes BAP65-02 with values of 0.9Ω resistance, 0.6nH inductance and 0.8pF capacitance. And tuning of the center frequency is done by loading four varactor diodes SMV1212 of Skyworks to inward stubs with typical values of 72.47pF to 0.7pF for varying bias voltage from 0V to 12V at the positions as shown in Fig.5.

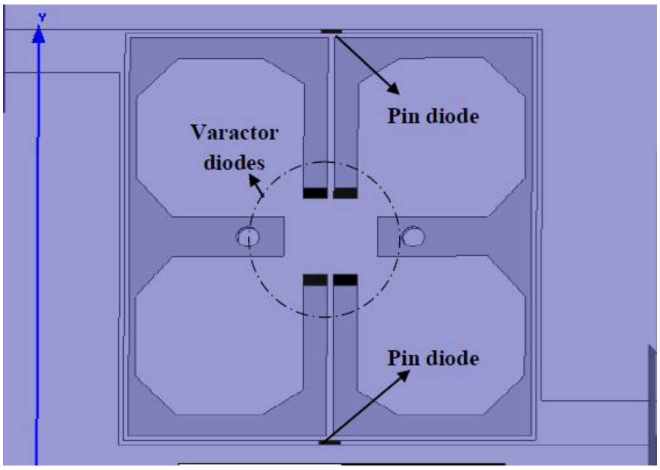

Fig.5. Tunable bandpass-to-bandstop filter

B. Simulated Results of the Tunable Filter

When the pin diodes are in OFF state and the bias voltage is of varactor diodes are varied from 0-12V, then the filter operates as tunable bandpass filter with bandwidth lying in the range 1.72-2.6GHz and has three poles. The insertion loss is of 1.4dB and tuning of center frequencies is for 20MHz as shown in Fig.6(a).

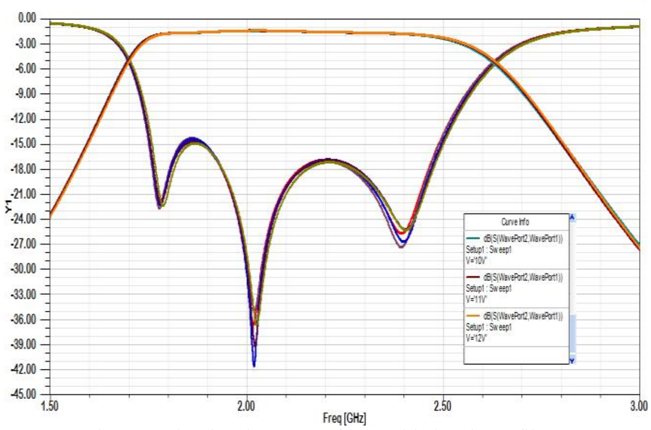

Fig.6(a). Simulated S_{11} & S_{21} for tunable bandpass filter

As the pin diodes are turned to ON state and the bias voltage of the four loaded varactor diodes are varied from 0-12V, the filter reconfigures to a tunable bandstop filter with three transmission zeros. Among them two are below 10dB thus are neglected and only one is considered. The band rejection lies in the range 1.9-2.1GHz with insertion loss of 1.5dB and tuning of center frequency for 20MHz as shown in Fig.6(b).

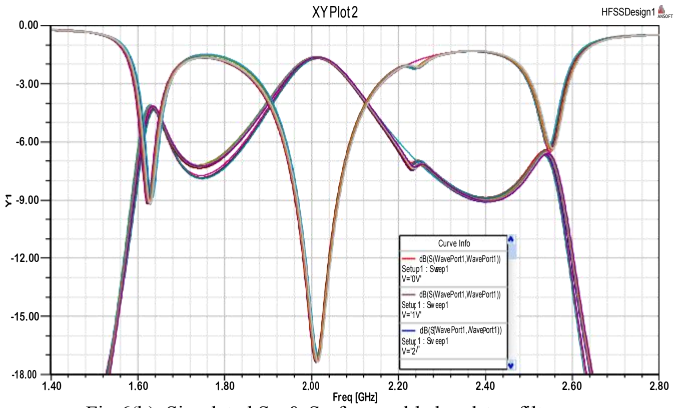

Fig.6(b). Simulated S_{11} & S_{21} for tunable bandstop filter

C. Measured Results of the Tunable Filter

The fabricated filter is as shown in Fig.7 that has filter size of 20mm×14.7mm.

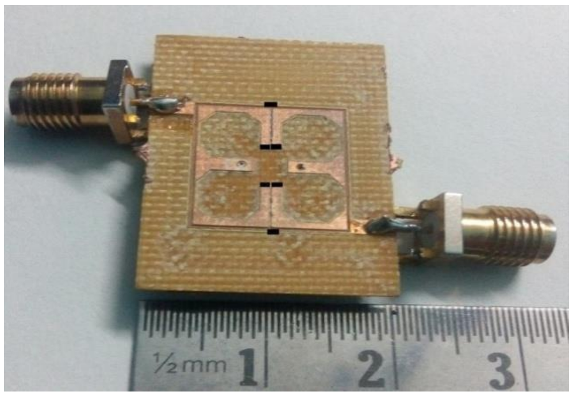

Fig.7. Fabricated filter

The measured results of the fabricated filter is as shown in Fig.8(a) and Fig.8(b) for tunable bandpass filter and tunable bandstop filter.

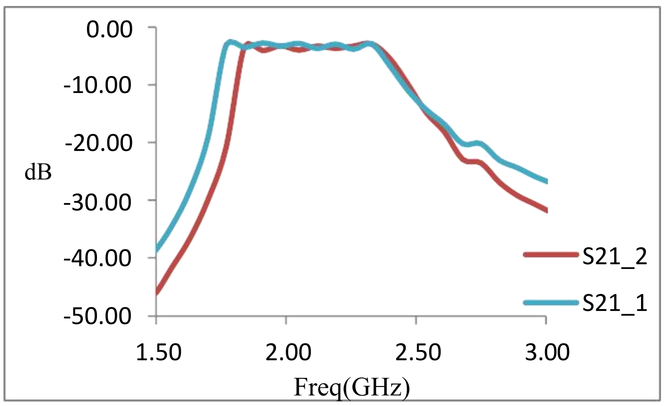

Fig.8(a). Measured S_{21} for tunable bandpass filter

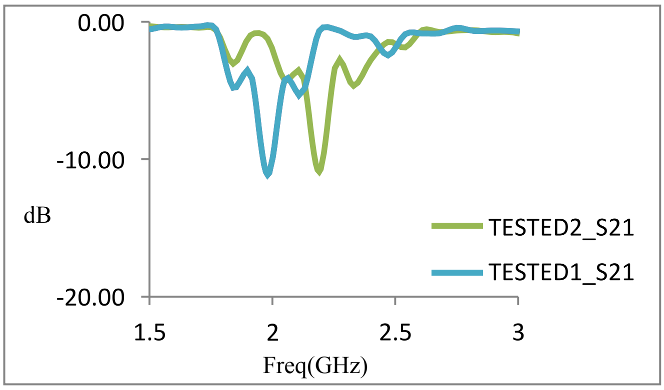

Fig.8(b). Measured S_{21} for tunable bandstop filter

The above two results show a good agreement with the simulated results and shows the characteristics of bandpass-to-bandstop tunable filter. The losses incurred are due to FR4 substrate which is a lossy material and the various other reasons. Thus, a single filter can easily be switched to two modes of operation.

III. Conclusions

In this paper a bandpass-to-bandstop tunable filter is presented based on shorted stub loaded stepped impedance resonators(SSL-SIRs) where pin diodes set the two modes of the filter either bandpass or bandstop; and varactor diodes are used to achieve the tunability of these filter modes[8]-[9]. The filter operates in band 1.72-2.6GHz for tunable bandpass filter and rejects band lying in the range of 1.9-2.1GHz for tunable bandstop filter with 20MHz tuning of center frequencies. Thus, this filter can be used for various wireless applications where high interference occurs. The incurred insertion losses are due to the use of lossy FR4 substrate, pin and varactor diodes and other fabrication limitations.

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