Design of Notch filter using Metamaterial Structure

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***Abstract*—This paper present the metamaterial features of Spiral Resonator on compact microwave devices. Any microwave device can have a rejection band by using the metamaterial factor of Spiral Resonator. Spiral resonator is known for their inductive property and easy fabrication due to their small size at electrical resonance. In this paper, rectangular shape of spiral resonator has been implemented in order to achieve band rejection for compact microwave devices such as Microstrip transmission line. Analysis is performed by shifting the location and changing the structure of resonator for which characteristic response is obtained. The stimulated result correlates with the notch filter whose frequency can be manipulate by change in length. The size of notch filter is 5.2mm x 3mm and 3mm I/O feed lines.**

Keywords—Microwave Devices, Spiral Resonators, Metamaterial, Notch, Microstrip Transmission Lines.

I. INTRODUCTION

The term ‘meta’ means ‘beyond’ and metamaterials are the artificial material which exhibits the properties that are not found in nature. The term come into play when scientist started exploring the less explored area in search of the impossible material with both permittivity and permeability being negative. The theoretical aspect was presented in 1960s by V.G. Veselago who proposed the physical feasibility of such less explored Metamaterials and discover the Left-Hand Media(LHM) a hypothetical medium that time which is compatible with Maxwell`s equation. Later on, come the stage when series inductance and shunt capacitance loaded on conventional transmission line possess the metamaterial properties which are responsible for electric permittivity and magnetic permeability of the overall media. This type of loaded capacitance. Inductance and transmission line later known as CRLH (Composite Right Left Handed) metamaterials. The main feature of such metamaterial is its compatibility with numerous microwave devices. Such materials can enhance the current established technology of communication with their manipulative behavior towards different types of wave. CRLH structure can simultaneously support forward, backward and standalone waves.

Split Ring Resonator (SRR) is the most popular metamaterial structure which is being used in numerous microwave and antenna application. There are different approaches towards the arrangement and shape of such structure but scope of this paper is limited to Spirals. Spirals are the classic resonators known for their inductive property. Such structure been experimented and proven to exhibit metamaterial property. The fabrication of such structure is also easy due to their small size at electrical resonance. Their small size is also handy when introducing it into microwave devices.

In this paper, rectangular spiral structure been implemented in an ordinary transmission line and the response of the same been obtained for different values of length and location of the structure on FR4 substrate with relative permittivity of 4.4, thickness of 1.6mm, width of 3mm and characteristic impedance of 50 Ω. The size of the structure is 5.2 mm x 3mm. The structure introduces a band rejection in the response of device.

II. DESIGN AND STIMULATION

A. Microstrip Transmission Line

We know that at low frequencies, transmission lines don't affect power transfer in practical applications we use every day. However, at high frequencies, even short lengths of transmission lines will affect the power transfer. It is not the length of the transmission line, or what frequency we operate at that determines if a transmission line will affect a circuit. What matters is how long the transmission line is, measured in wavelengths at the frequency of interest.

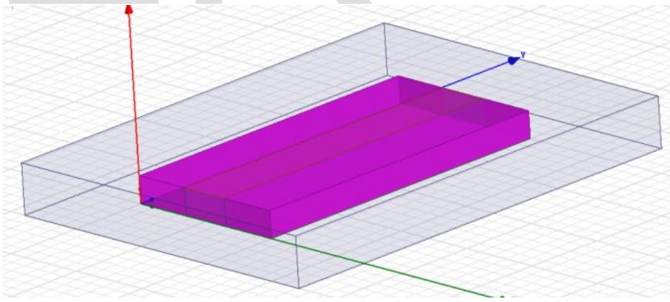

Figure 1. Microstrip Transmission Line

If a transmission line has a length greater than about 10% of a wavelength, then the line length will noticeably affect the circuit's impedance. Different length allows different resonant frequency depends upon the length of the transmission line which is equal to half of the wavelength passed. Microstrip transmission line is design for different length on FR4 Substrate with relative permittivity of 4.4 and thickness of 1.6mm.

B. Single Spiral Resonator

Rectangular shaped spiral resonator is used to check the notch property of metamaterial in microwave devices. No fabrication limit on the structure. Spiral Resonator is embedded on transmission line of fixed length of 16mm (including MMR) comprise of 9 arms of width 0.3 mm and spacing of 0.3mm attached to the feed line as shown in Figure 2.

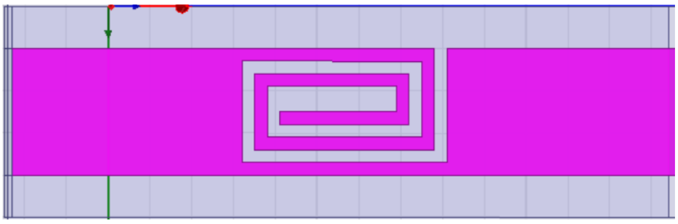

Figure 2. Spiral Resonator on Microstrip Transmission Line

Length of the spiral is sum of all the 9 arms that is 26.9mm Width of spiral resonator is 3 mm equal to the width of 50 Ω Microstrip transmission line.

C. Double Spiral Resonator

A Combination of Spiral Resonators can be used to in order to fulfill the needs of Bandstop filter. Resonator 1 and Resonator 2 is embedded with same dimension: width =0.3mm, spacing=0.3mm, length of structure=10.2mm and length of the spiral = 26.9mm on Microstrip transmission line with width of 3mm equal to the width of resonators as shown in Figure 3.

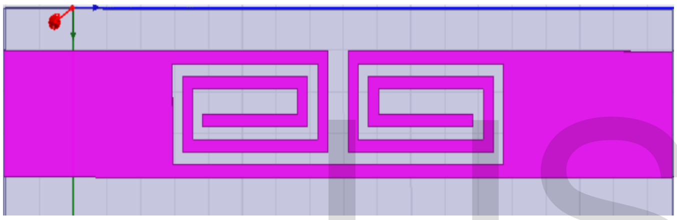

Figure 3. Double Resonator on Microstrip Transmission Line

III. Parametric Analysis and Results

A. Ordinary Transmission Line

Stimulated response of 20mm, 25mm and 30mm is shown in Figure 5.

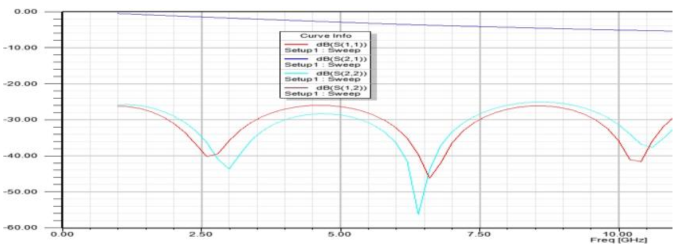

Figure 5. (a) 20mm of transmission line

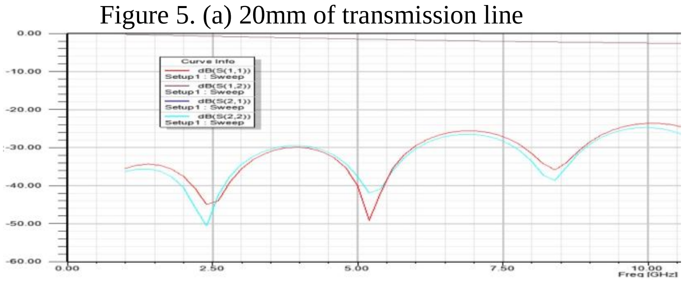

Figure 5. (b) 25mm of transmission line

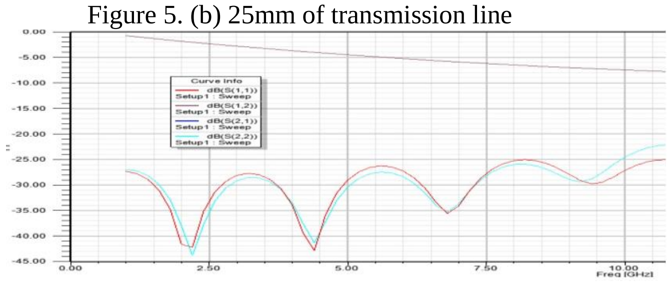

Figure 5. (c) 30mm of transmission line

Transmission Line response S11 coincides with S22 and similarly S12 coincides with S21. Band Rejection is absent in ordinary transmission line. All waves are allowed but waves of wavelength equal twice the length of transmission line suffers zero loss.

B. Single Spiral Resonator

Two analysis performed based on the location shift of Resonator and varying the length of the spiral resonator on fixed location on Microstrip transmission line of length 16mm. Different location of the resonator on Microstrip transmission line is shown in Figure 4.

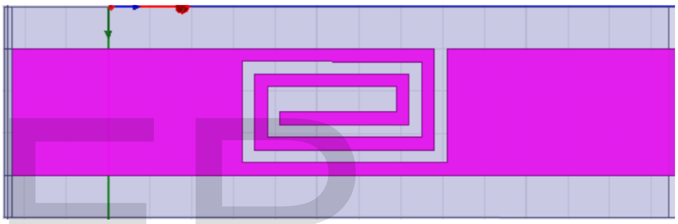

Figure 4. (a) Middle Location with 5.4 mm Feed lines

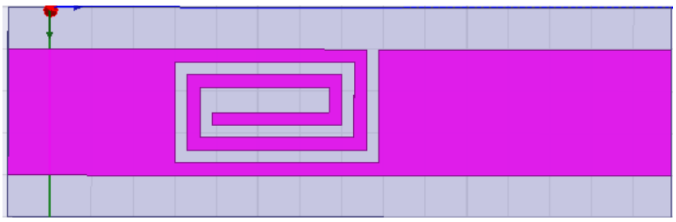

Figure 4. (b) 4mm left and 7mm right in feed lines

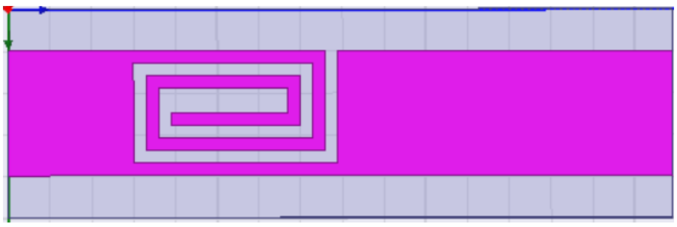

Figure 4. (c) 3 mm left and 8 mm right in feed lines

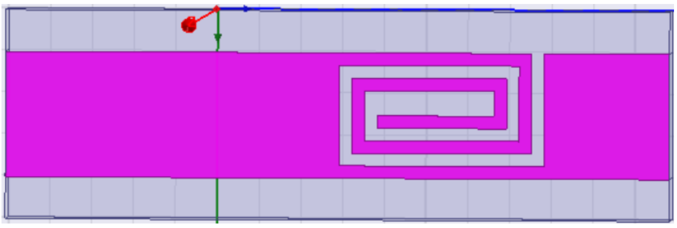

Figure 4. (d) 8 mm left and 3 mm right in feed lines

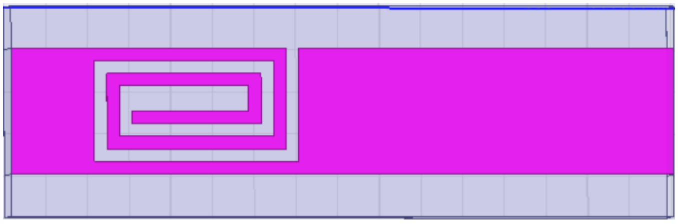

Figure 4. (e) 2 mm left and 9 mm right in feed lines

After embedding Spiral in transmission line of constant length of 16mm the response shows center frequency rejection at 2.4GHz with 300MHz band. Change in location yields the following transmission coefficient as shown in Figure 5.

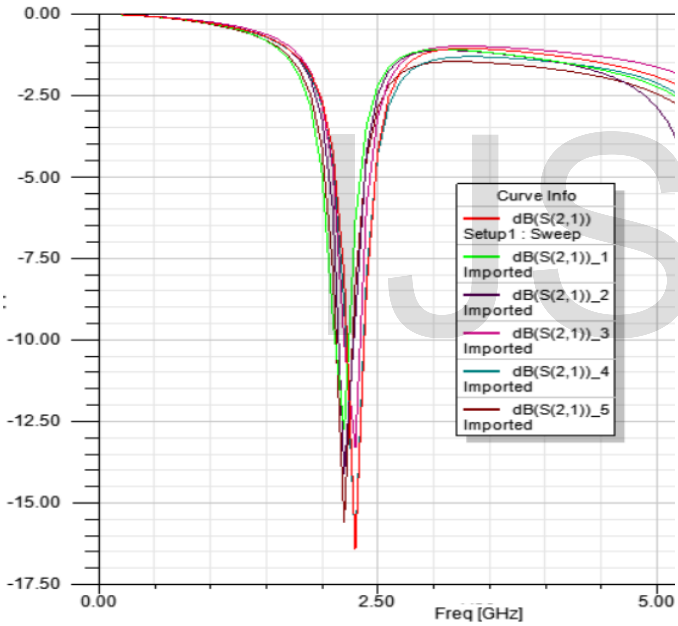

Figure 6. Insertion Loss of different location

The response show negligible change in the rejection frequency for change in location. It does not effect by the feed line distribution around it. So we can use it in either side of feed lines and achieve the same result with negligible change in rejection frequency.

The same structure has gone through variation in length of the spiral in order to analyze the effect on the response. Variation in the length from 26.9mm are as shown in Figure 7.

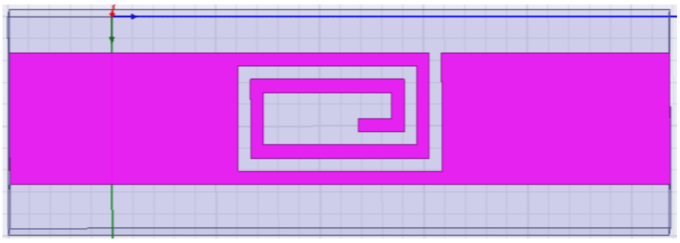

Figure 7. (a) Spiral Length = 25.5mm

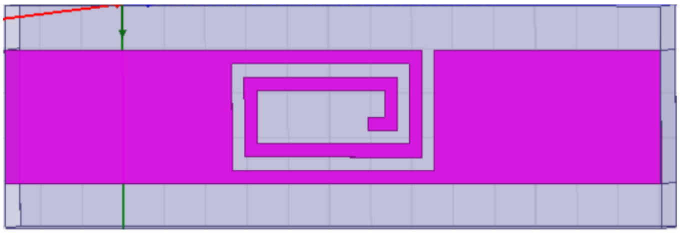

Figure 7. (b) Spiral Length = 24.9mm

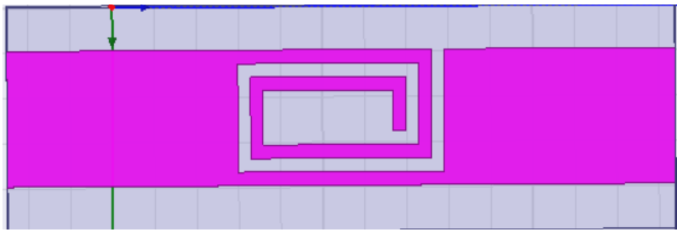

Figure 7. (c) Spiral Length = 24.4mm

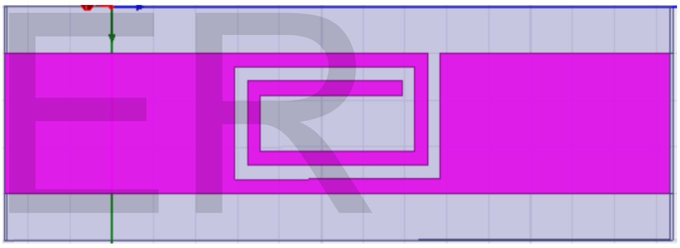

Figure 7. (d) Spiral Length = 23.5mm

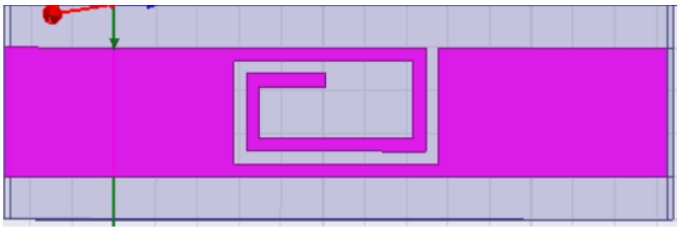

Figure 7. (e) Spiral Length = 21.7mm

The variation in the length yields the transmission coefficient as shown in figure 8. Change in the length is restrict to the point where structure loses its metamaterial factor.

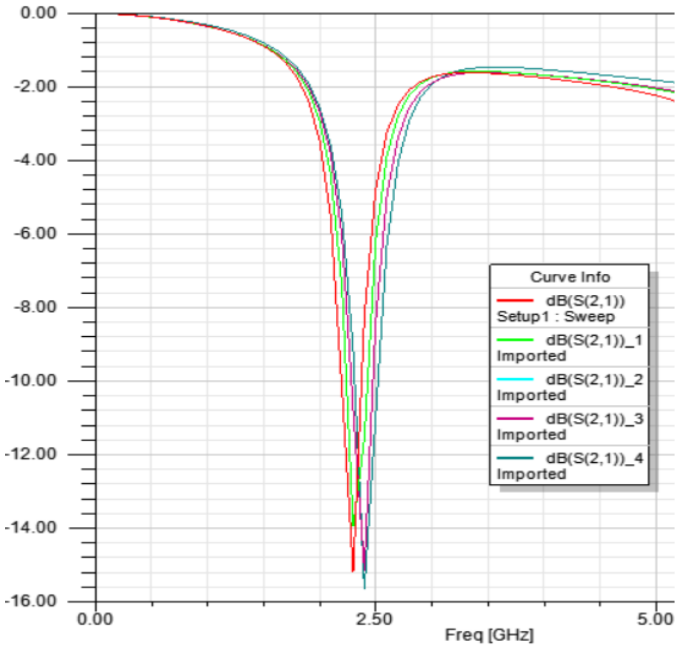

Figure 8. Insertion Loss for variation in spiral length

Figure 8 shows that we can tune the frequency by changing the length of spiral. Increasing the length of the spiral increases the inductance provide a significant reduction in resonating frequency. To observe more shift we need to vary other parameters.

C. Double Spiral Resonator

Two spiral resonators of same configuration been embedded on the same transmission line and to obtain a symmetric dual notch structure so as to accumulate in both feed lines. Response is obtained for combination and each of the individual spiral resonator as shown in Figure 9.

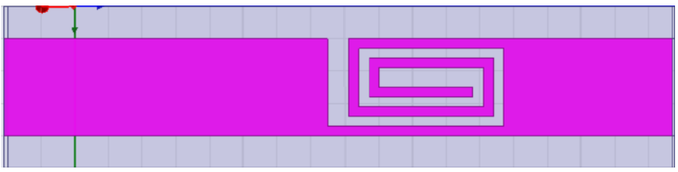

Figure 9. (a) Resonator 1 Structure

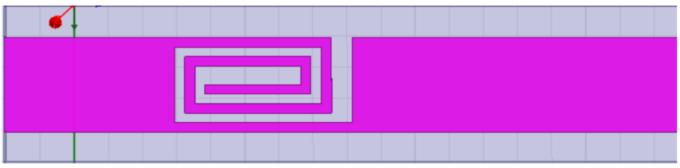

Figure 9. (b) Resonator 2 Structure

Dual Notch of such combination and its comparative analysis is shown in Figure 10.

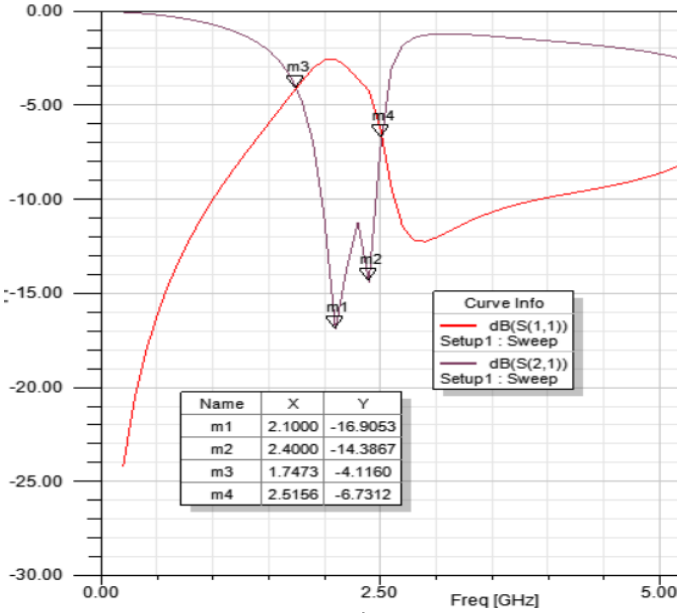

Figure 10. (a) Response of Dual Notch Structure

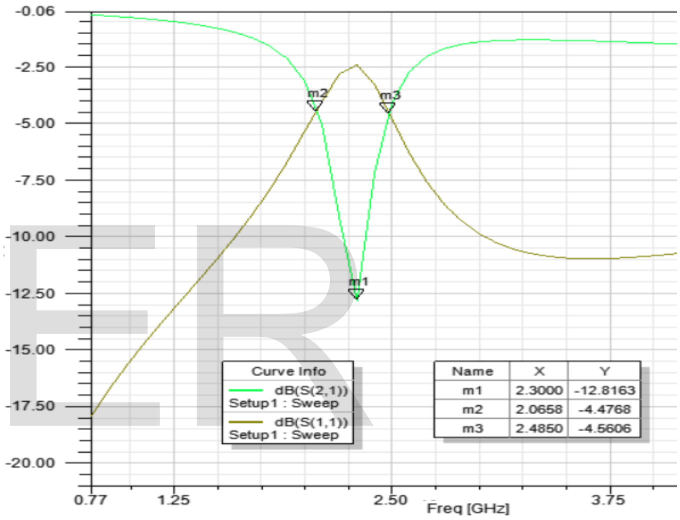

Figure 10. (b) Response of Resonator 1 Structure

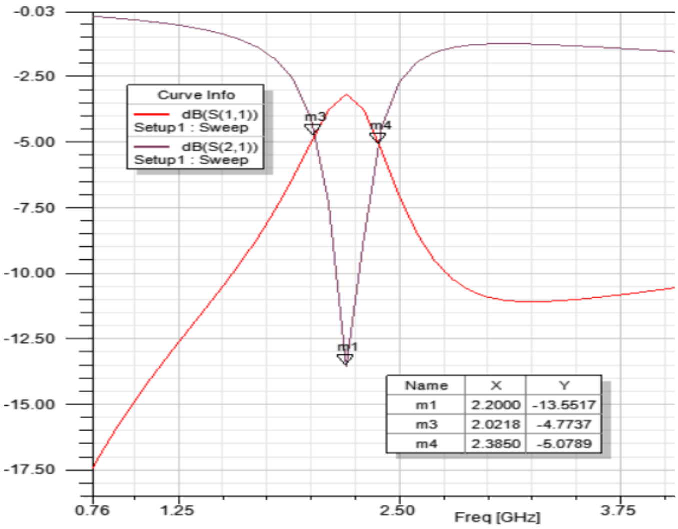

Figure 10. (c) Response of Resonator 2 Structure

In Fig.10a two resonators are providing response as that of the Notch filter with band rejection of 760MHz from 1.75GHz to 2.51GHz. In Fig. 10b Resonator 1 is only providing notch with center frequency of 2.3 GHz with 420MHz band. In Fig. 10c Resonator 2 is only providing notch with center frequency of 2.2 GHz and band of 360MHz. This shows that we can accommodate ‘n’ spiral to achieve ‘n’ band rejection.

IV. CONCLUSION

This paper concludes that a metamaterial structure like spiral resonator can be injected into microwave devices in order to provide a band rejection of specific bandwidth based on length, spacing and width of spiral arms. The position of such structure can be anywhere and notch frequency can be vary by changing the length, spacing and width of the spiral arms.

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