Design of C-band Microstrip Lowpass Filter using Stepped Impedance Resonator

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***Abstract* - This article presents the C-band microstrip low pass filter using half wavelength stepped impedance resonator(HW-SIR). Two half wavelength stepped impedance resonators are used to realize the mirostrip low pass filter structure. The filter has the cut off frequency of 6GHz with lower insertion loss and rejection greater than 30dB at 10GHz.The filter is developed on the Duroid substrate with dielectric constant of 2.2 and substrate thickness of 1.6mm the proposed filter layout is designed and analyzed using Advanced Design System(ADS) software.**

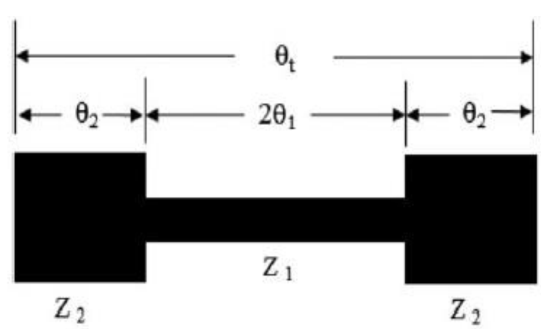
***Index Terms* - Microstrip, Low pass filter, Stepped impedance resonator(SIR), Lumped elements, Advanced Design System(ADS) software.**

I.INTRODUCTION

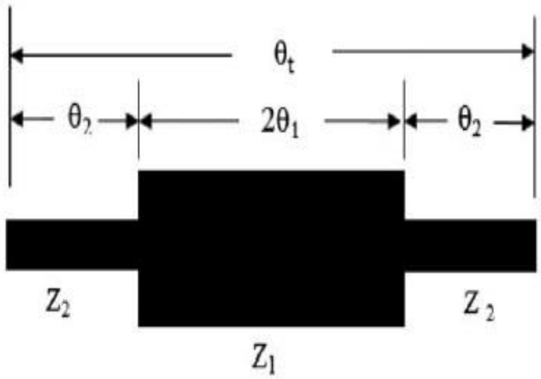
In the recent communication systems, filters play a vital role in adjusting the transmission response by removing the undesired band of frequencies. Different methods have been utilized to develop the filter characteristics using high frequency electromagnetic simulators (EM) like ADS, CST and HFSS etc. The main intension of this simulator is to achieve desired filter response by optimizing filter circuit. Among the different kinds of filter, low pass filter will allow only low frequency signals to pass and attenuate all other high frequency signals above the cut off frequency. Microstrip filter design constructed on dielectric substrate with conducting metal strips on the top/bottom plane. For low frequency applications, microstrip planar resonators are substantial for circuit design. Due to narrow bandwidth, high Q resonators are well known for oscillator and filter circuits. For designing planar filter circuits, stepped impedance resonator(SIR) is used in place of uniform impedance resonator(UIR). Different types of SIR employed for microwave circuits is given in [1]. Further the miniaturization can be obtained by using stepped impedance spiral resonator(SI-SR) metamaterial unit cell [2]. Moreover, the filter response has to be improved. In [3], dual band microstrip bandpass filter using quad mode stub loaded resonator is proposed. However, the even and odd mode can be adapted only to define the resonance. In [4] multiband resonators are used to design the multiband bandpass filter. But with larger circuit size. Bandpass filter with size miniaturization can be achieved using stepped impedance resonator(SIR) is proposed in [5]. However, the insertion loss of the filter is large. Further the low insertion loss of the filter can be achieved by designing microstrip lowpass filter using stepped impedance resonator (SIR) [6]. In [7] difference in magnitude of S-parameter in filter dimensions can be determined by utilizing artificial neural network(ANN) method in microstrip lowpass filter circuits . Moreover, the stopband performance of the filter is improved by employing defected ground structure is proposed in [8].

This article is arranged as follows. Section II explains the concept of stepped impedance resonator. Section III specifies the design of microstrip lowpass filter using stepped impedance resonator(SIR). The filter simulated results are presented and discussed in section IV. At last Section V summarize conclusion.

II.STEPPED IMPEDANCE RESONATOR



(a)



(b)

Figure.1 Basic structure of HW-SIR

(a) $K<1$, $\theta_t < \pi$ (b) $K>1$, $\theta_t > \pi$

Stepped impedance resonator(SIR) can be studied as two transmission lines of varying length and characteristic impedance. The parameters are regulated by length and impedance ratio. Because of its compact size and high quality factor, SIR can be used for filter, oscillator and mixer applications. Figure.1(a) and 1(b) shows the basic structure of half wavelength stepped impedance resonator(SIR) for K<1 and K>1. The advantage of half wavelength SIR is its lower insertion loss and operates in millimeter wave frequency. Basically the stepped impedance resonator(SIR) is not only to restrict the spurious response but also to lower the resonator volume. The impedance ratio K is given by

$$K = \frac{Z_2}{Z_1} \dots \dots (1)$$

The equation for length ratio α of the stepped impedance resonator is

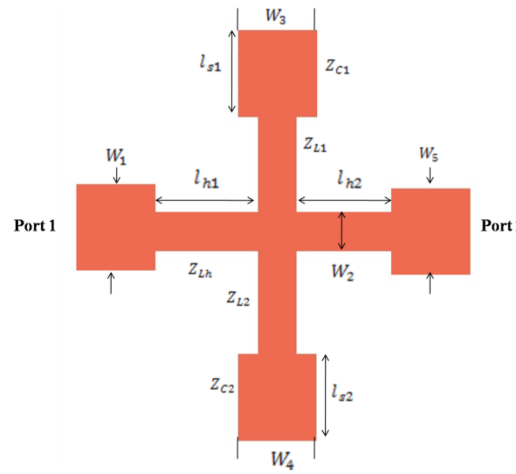
$$\alpha = \frac{\theta_2}{\theta_1 + \theta_2} \dots \dots . (2)$$

By substituting eq.(1) and (2) in the condition for resonance of the stepped impedance resonator produces odd and even mode resonances are defined by the following equations (3) and (4) are as follows

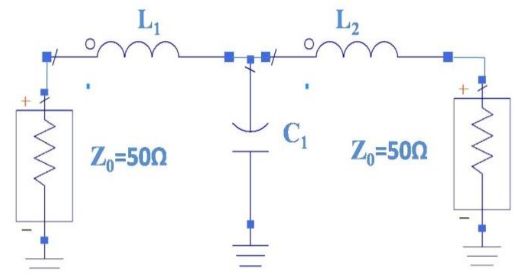
$$K = \cot\left(\frac{1}{2}\alpha.\theta_t\right) = \tan[\frac{1}{2}(1-\alpha).\theta_t] \dots \dots (3)$$

$$K = \cot\left(\frac{1}{2}\alpha.\theta_t\right) = -Cot[\frac{1}{2}(1-\alpha).\theta_t] \dots (4)$$

III.DESIGN OF MICROSTRIP LOWPASS FILTER USING HALF WAVELENGTH SIR



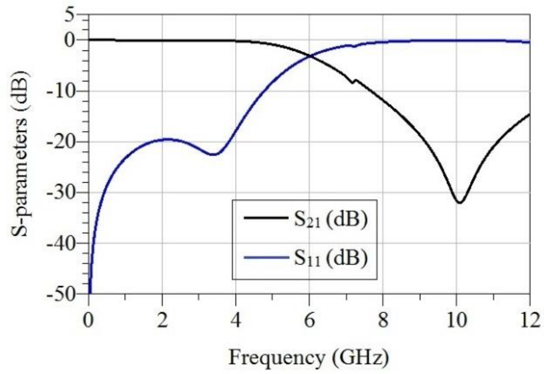
(a)



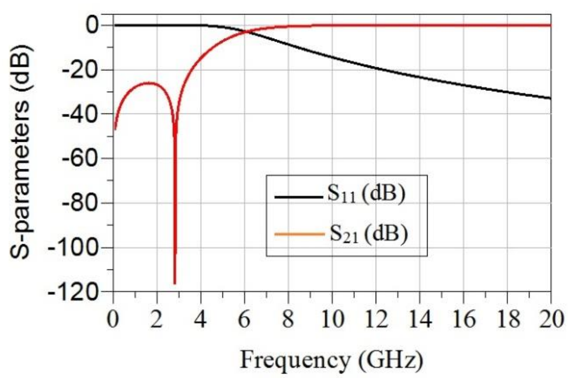
(b)

Figure. 2 (a) Layout of the microstrip LPF using HW-SIR (b) Equivalent Circuit model

Figure. 2(a) shows the layout of the microstrip lowpass filter using two half wavelength stepped impedance resonators ($\frac{\lambda_g}{2}$ SIR). Two series resonator branch consist of low impedance patch and high impedance stub are designed as capacitor and inductor, which is connected in parallel with high impedance transmission line. The dimensions of the filter are $W_1 = 1.9mm$, $l_{h1} = 2.5mm, l_{h2} = 2.3mm, W_2 = 1mm$,$l_{s1} = 2.1mm$, $l_{h2} = 2.3mm, W_3 = 2mm$, $l_{s2} = 2.2mm$ $W_4 = 2mm$, $W_5 = 2mm$. Z_{Lh} represents high impedance of the transmission line with length l_h. Impedance of the two series resonant branches are Z_{L1}, Z_{C1} and Z_{L2}, Z_{C2} respectively. The microstrip line width W_1, which corresponding to the 50Ω characteristic impedance line. The equivalent circuit model of lowpass filter is shown in figure 2(b). The value of L and C can be calculated using [8]. The value of inductor and capacitor are L_1= L_2 = 1.55nH and C_1=0.95pF.



(a)



(b)

Figure. 3Frequency response (a) EM simulation (b) Circuit simulation

IV.RESULTS AND DISCUSSION

The proposed filter is designed on the Duroid substrate with dielectric constant of 2.2 and substrate thickness of 1.6mm. The filter layout is simulated using EM simulator called Advanced Design System(ADS) software. The scattering parameters of the microstrip lowpass filter using EM simulation and circuit simulation is displayed in figure. 3(a) and 3(b). It can be seen that in filter layout simulation it has very low insertion loss, return loss of 20dB with cut off frequency of 6GHz with the attenuation of >30dB at 10.1GHz. The simulated S-parameters of the lumped lowpass circuit model is illustrated in figure. 3(b). It shows lower insertion loss, return loss of >60dB at 6GHz cut off frequency.

V.CONCLUSION

By utilizing half wavelength stepped impedance resonator ($\frac{\lambda_g}{2}$ SIR or HW-SIR), C-band microstrip low pass filter is designed and analyzed. The proposed filter structure provides compactness, very low insertion loss, good return loss at 6GHz and make it suitable for radar and satellite communications.

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