

Microstrip Bandpass Filter with Notch Response at 5.2 GHz using Stepped Impedance Resonator

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Abstract

The design of wideband bandpass filter 3 to 6 GHz integrated with notch response at 5.2GHz is presented. The filter designed based upon the short-circuited stub structure of 5th degree, and the folded stepped impedance resonator introduced to generate a notch band to avoid the interference from existence WLAN signal. PIN diode used as switching mechanism to generate a notch band. The device designed and simulated using Advanced Design System (ADS) based on Roger Duroid 4350B with a dielectric constant of 3.48, substrate constant of 0.508mm and loss tangent 0.0019. The simulation results demonstrated that the filter is useful in communication systems such as wireless communication devices and military application.

Keywords - Wideband; BPF; Switchable Filters; Stepped Impedance Resonator (SIR); Tunable Notch Response.

I. INTRODUCTION

Over the last few decades, the wideband application system was primarily used for military technology. Wideband can be defined as the wide range of operating frequencies used in a microwave field. However, the existence of the other radio signal bands within the range of the wideband spectrum limits the usage of the wideband technology for commercial communication application. One of the examples of the existence radio communication technology is WLAN 802.11 at 5.2GHz. The existing radio communication signal within the wideband spectrum will affect the accuracy of data reception for wideband system, thus decreasing its performance and introduced more losses to the system. Therefore, various studies have been conducted to design a microwave filter that is capable to eliminate the interference of other radio signals within the desired spectrum frequency (tunable filters) [1], [2], and [3]. In [4], two quarter-wavelength open-circuited stubs technique

is implemented to produce the proposed notch band in the UWB bandpass microstrip filter. The notch frequency can be reconfigurable by controlling the PIN diode state into forward (PIN diode is turned on) and reverse biased condition (PIN diode is turned off). However, the notch band produce by this filter is very narrow thus minimize the possibility to entirely block the existing radio signal in the passband. In [5], the notch frequency is generated by implementing the SIR structure coupled with multimode resonators (MMR) resonator through coupling gap. Unfortunately, this technique increased the circuit size of the filter, which is not applicable to be used for wireless communication devices. The bandpass filter that operates from 2GHz to 4.7GHz with wide rejection band is presented in [6]. This filter used the method of defected ground structure (DGS) to produce the notch response. The microstrip lines with shorted stubs is etched on top side of the substrate acted as a high pass filter while the dumbbell shaped DGS etched on bottom side acted as band stop filter. The optimization of seventh order high pass filter with three dumbbells shaped DGS are conducted by using the electromagnetic (EM) simulation tools to obtain the UWB bandpass filter with notch. This work presents design a bandpass filter integrated with band reject filter within a single device to minimize the size of the filter while maintaining its performance. The filter is designed to operate at wideband frequency from 3 to 6 GHz while in the meantime to reject the unwanted signal frequency at 5.2GHz within the desired frequency. The notch response designed using folded stepped impedance resonator (SIR). The diode is utilized in this filter to tune the notch response electronically, without decrease the performance of the filter. Simulation results of the designed filter are presented.

II. DESIGN METHODOLOGY

The design process in this work starts with designing the bandpass filter (BPF), followed by designing the folded SIR to produce the notch response, and finally combine the bandpass filter with the folded SIR to produce the desired frequency bandwidth along with notch response.

II.I Microstrip Bandpass Filter

The quarter-wavelength short-circuited stub method commonly being used when designing microstrip bandpass filter because of it's convenient to design this developed method with microstrip lines. The concept of quarter-wavelength shunt short-circuited stubs is shown in Fig 1, where the length of stubs and the connecting lines are equal to $\lambda g/4$ respectively [7].

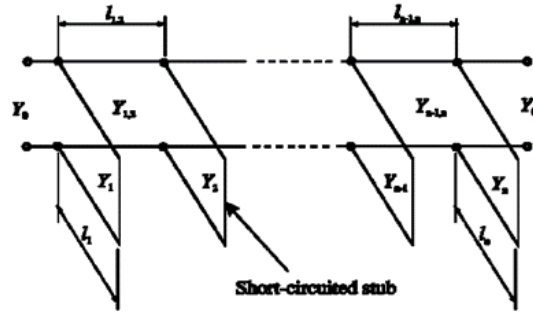


Figure 1: The concept of quarter-wavelength shunt short-circuited stubs

In the design process of BPF, the number of orders of the filter needed to determine first. Equations 1 and 2 can be used.

$$S = \frac{\text{Upper Frequency, } f_U}{\text{Lower frequency, } f_L} = \frac{6\text{GHz}}{3\text{GHz}} = 2 \quad (1)$$

$$N \geq \frac{L_A + L_R + 6}{20 \log_{10} \left[S + (S^2 - 1)^{\frac{1}{2}} \right]} \approx 5 \quad (2)$$

The characteristic impedance of 50Ω resultant in characteristic admittance, Y_0 equals to $\frac{1}{50}$ mhos. To determine the length and separation of the stub, the characteristics admittances, Y_i and transmission line admittance, $Y_{i,i+1}$ is calculated by using equation 3.

$$Y_{i,i+1} = Y_0 \left(\frac{J_{i,i+1}}{Y_0} \right) \text{ for } i = 1 \text{ to } n - 1 \quad (3)$$

where $J_{i,i+1}$ is the J-inverter given by equation 4:

$$\frac{J_{1,2}}{Y_0} = g_0 \sqrt{\frac{hg_1}{g_2}}, \quad \frac{J_{n-1,n}}{Y_0} = g_0 \sqrt{\frac{hg_1g_{n+1}}{g_0g_{n-1}}} \quad (4)$$

The constant h is a dimensionless constant which may be assigned to another value to give a convenient admittance level in the interior of the filter.

$$h = 2$$

Stub admittance Y_1 can be found from equation (5);

$$Y_1 = g_0 Y_0 \left(1 - \frac{h}{2}\right) g_1 \tan \theta + Y_0 \left(N_{1,2} - \frac{J_{1,2}}{Y_0}\right) \quad (5)$$

$$\text{Where, } \theta = \frac{\pi}{2} \left(1 - \frac{FBW}{2}\right) = 1.047$$

The other value of stub admittances can be obtained based from equation (6) and (7):

$$Y_i = Y_0 \left(N_{i-1,i} + N_{i,i+1} - \frac{J_{i-1,i}}{Y_0} - \frac{J_{i,i+1}}{Y_0}\right) \quad (6)$$

for $i = 2$ to $n - 1$

$$N_{i,i+1} = \sqrt{\left(\frac{J_{i,i+1}}{Y_0}\right)^2 + \left(\frac{hg_0 g_1 \tan \theta}{2}\right)^2} \quad (7)$$

for $i = 1$ to $n - 1$

The calculated admittances and impedances for five short-circuited stubs (Y_i and Z_i) and transmission lines ($Y_{i,i+1}$ and $Z_{i,i+1}$) are summarized in Table 1.

Table 1

Design Parameters for 5th Order Quarter-Wavelength Short-Circuited Stubs

i	Y_i(mhos)	Z_i(ohm)	$Y_{i,i+1}$(mhos)	$Z_{i,i+1}$(ohm)
1	0.0215	46.51	0.0259	38.61
2	0.0422	23.70	0.0279	35.84
3	0.0413	24.21	0.0279	35.84
4	0.0422	23.70	0.0259	38.61
5	0.0215	46.51		

The width of the microstrip line can be calculated using equations 8.

$$\frac{W}{h} = \frac{2}{\pi} \left\{ (B - 1) - \ln + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 + \frac{0.61}{\epsilon_r} \right] \right\} \quad (8)$$

$$\text{Where, } B = \frac{60\pi^2}{Z_c \sqrt{\epsilon_r}}$$

The guided wavelength, λ_g can be calculated using equation 9.

$$\lambda_g(\text{mm}) = \left(\frac{300}{f(\text{GHz}) \sqrt{\epsilon_{\text{eff}}}} \right) \quad (9)$$

where

$$\epsilon_{\text{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{W} \right)^{-0.5}$$

Table 2 shows the microstrip design parameters of 5th Order Quarter-Wavelength Short-Circuited Stubs.

Table 2

Microstrip Design Parameters for 5th Order Quarter-Wavelength Short-Circuited Stubs

i	W_i (mm)	λ_{g0i}/4 (mm)	W_{i,i+1} (mm)	λ_{g0i,i+1}/4 (mm)
1	1.2910	10.0351	1.7029	9.9259
2	3.2720	9.6664	1.8925	9.8837
3	3.1853	9.6768	1.8925	9.8837
4	3.2720	9.6664	1.7029	9.9259
5	1.2910	10.0351	-	-

The filter was designed based on Roger boards RO4350B with a dielectric constant (ϵ_r) of 3.48, substrate thickness (h) of 0.508mm, and copper thickness t of 0.035mm. The layout of microstrip bandpass filter and its dimension is shown in Fig 2. The simulation result of the microstrip layout structure is presented in Fig 3. From the graph, the insertion loss S_{21} for frequency of 2.795GHz and 6.215GHz attenuate at -2.895dB and -6.215GHz respectively. The return loss S_{11} of the passband response is rippled under -20dB. Furthermore, the designed filter achieves good performance with fractional bandwidth of 66.67%.

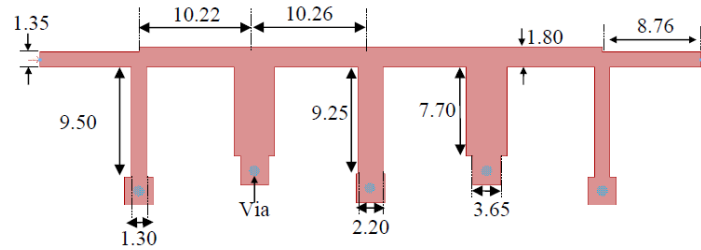


Figure 2: Physical layout for 5th order short circuited stubs bandpass filter

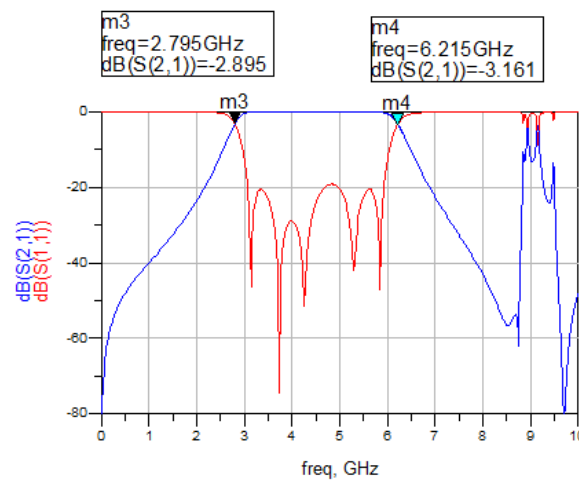


Figure 3: Simulated s-parameter for proposed microstrip bandpass filter

II.II Folded Stepped-Impedance Resonator (SIR)

The folded SIR structure is constructed directly into the EM momentum mode. The folded SIR structure also using the same substrate as a microstrip bandpass filter, which is Roger Duroid RO4350B. The folded SIR is designed to produce a notch response at 5.2GHz (WLAN application). Two folded SIR is implemented; cause of the notch response generated by using single folded SIR not capable to produce the insertion loss S_{21} below -15dB as shown in Fig 4. The simulated results in Fig 5 show that when the dimension of W_H and L_{H1} is decreased by 0.1mm and 0.24mm respectively and the L_{H2} is increased by 0.4mm, the notch response produces by the filter become very sharp and deeper, which is the insertion loss S_{21} at frequency 5.207GHz attenuate at -30.475dB.

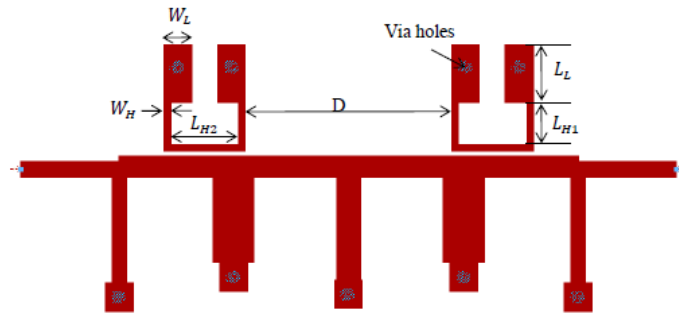


Figure 4: Layout of two folded SIR Integrated with BPF

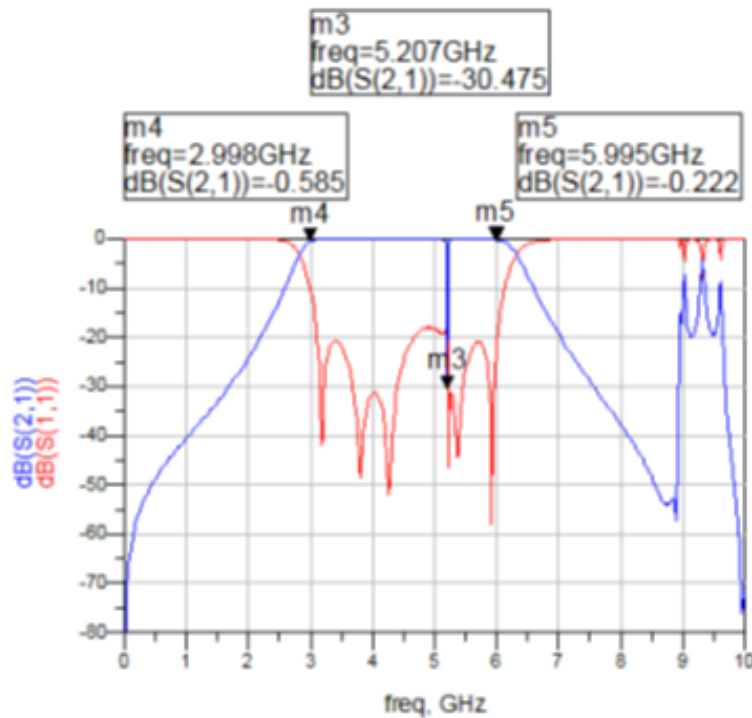


Figure 5: Simulation result of two folded SIR with BPF.

III. WIDEBAND BPF WITH TUNABLE NOTCH RESPONSE

To electronically tune the filter, four pin diodes are utilized into the folded SIR structure as a tuning mechanism. The function of tuning device is to electronically control the notch response within the wideband bandpass filter. However, the DC biasing circuit is designed using the schematic layout; because it is very complex to design the internal DC biasing circuit. The physical layout of short circuited stub with tunable folded SIR is presented in Fig 6.

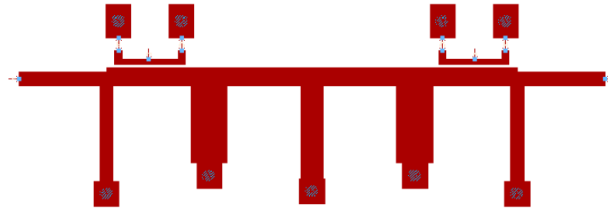


Figure 6: Layout of active BPF with tunable response

The pin diode is in reverse biased condition when no current is flowing to the diode (voltage supply is negative). The diode will act like an ideal open circuit configuration. The simulation result when pin diode is turned off is presented in Fig 7(a), where the insertion loss S_{21} of the notch response attenuated at -0.209dB for a frequency of 5.2GHz . Since the notch response not exceeded of minimum 1dB , the response can be neglected. Whereas the pin diode is in forward biased condition when the diode conducting the current. The diode will act like a short circuit configuration when the voltage is supplied to the filter. The simulation result when pin diode is turned on is shown in Fig 7(b), where the insertion loss S_{21} of the notch response attenuated at -11.619dB for a frequency of 5.2GHz . The passband bandwidth generated when the pin diode is either in on or off condition stimulates the same response from the frequency of 3GHz to 6.2GHz . The return loss S_{11} of the passband is over -20dB .

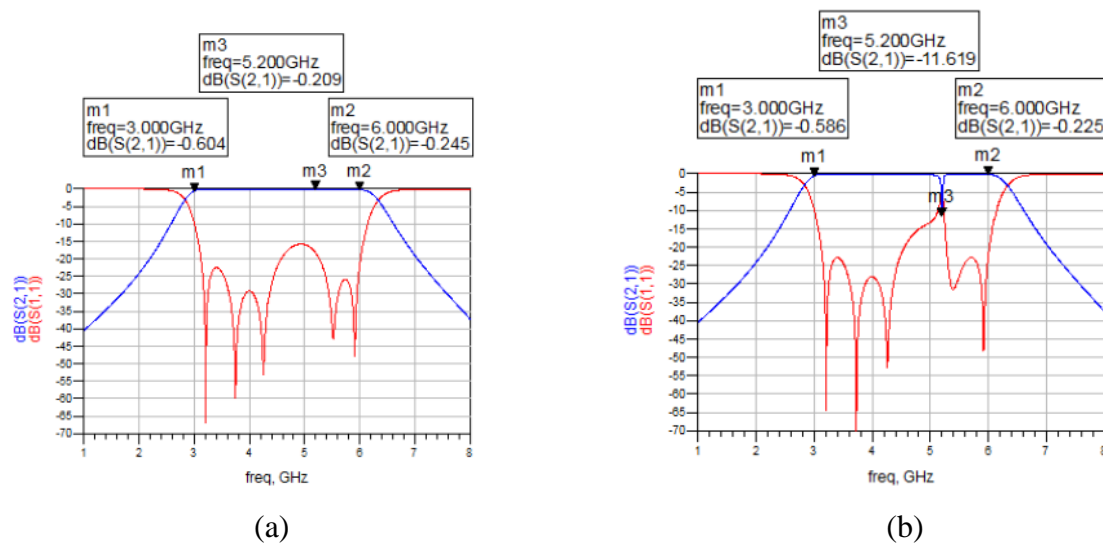


Figure 7:(a) Simulation result of wide-band bandpass filter when pin diode is tuned off (b) Simulation result of wide-band bandpass filter when pin diode is tuned on.

IV. CONCLUSION

Wide-band bandpass filter integrated with folded SIR and pin diode has been successfully designed. 5th order quarter wavelength short-circuited stubs, and two folded SIR have been designed to produce wide-band response 3 to 6 GHz with band reject response at 5.2GHz. Advanced Design System (ADS) has been used to simulate the designed circuit. Simulation results such as pass-band bandwidth, band reject response, return loss and insertion loss has been presented. The designed filter has been shown a good performance, and successfully meets the specifications of bandpass filter integrated with notch response. For fabrication process, it is recommended to design the biasing circuit internally connected to the PIN diode to minimize the probability error.

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