

Microstrip Bandpass Filter with Reconfigurable Notch Response at 5.2 GHz using Defected Microstrip Structure

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Abstract—An investigation of a new design of short circuit stub wideband bandpass filter integrated with reconfigurable notch characteristic is presented. The wideband bandpass filter was designed from a quarter-wavelength short circuit stub with folded topology in order to reduce overall physical dimension. The U-shaped DMS was designed on a microstrip line by defecting the bandpass filter. The reconfigurable characteristic was then realized by introducing PIN diode (BAP 64-02) as a switching element that is placed on top of the U-shaped DMS. When the diode was OFF, it produced a wideband bandpass response from 3.0 GHz to 6.0 GHz. On the other hand, when the PIN diode was ON, a sharp rejection of notch response at 5.2 GHz with a very low passband transmission coefficient was finally demonstrated. This type of filter is very useful in radar and wireless communication systems.

Index Terms—Bandpass Filter; Tunable Filter; Notch; Defected Microstrip Structure (DMS); PIN Diode.

I. INTRODUCTION

Mobile communication becomes more promising for wideband technology and receives incredible interests in the field of academic and industry. The development of this spectrum has been used for various devices, such as antenna [1], filter [2], power amplifier and etc. However, there are many unwanted signal sharing and interference on the radio frequency band for different purpose inside the wideband frequency allocation. By introducing the notch response, the interference inside the wideband response can be eliminated. The Wireless Local Area Network (WLAN) at 5.2 GHz overlaps with wide frequency range for wideband spectrum [3]. This interference causes distortion to transmit the signal and loss of sensitivity in bandpass filters. However, the future cognitive radio makes it more critical to develop tunable microwave filters. Therefore, the development of tunable notch response is preferred in wideband bandpass filter to eliminate the interference signals [4]. With the increasing development of tunable filter in wireless communications, several researchers are attempting to form it in a compact size while at the same time maintaining the performance of the microstrip filter.

Several methods of developing notch response have been proposed recently, such as the Electromagnetic Bandgap

(EBG) [5], Defected Microstrip Structure (DMS) [6][7] and Defected Ground Structure (DGS) [8]. The DMS is etched by defecting the stripline using some structures, making it to be easily embedded with other microwave devices. This structure is easier to design efficiently and reduces the circuit design in comparison with the DGS. The DMS has proven to have slow-wave properties, and it rejects (bandstop notch response) at desired frequencies by controlling the electrical length for the circuit design. The DMS will not affect the ground plane, when avoiding any leakage of the RF signal. Moreover, the DMS has been discovered and generally used for the development of a compact size microwave filter.

In this study, a new design of bandpass filter integrated with the reconfigurable notch response is presented. The bandpass filter was designed with FBW recorded at 66.6% with transmission and reflection coefficient at 0.3 dB and 18 dB respectively. The notch response was designed using U-shape DMS and PIN diode (BAP 64-02) as switching element.

II. WIDEBAND BANDPASS FILTER

The design of wideband bandpass filter is based on the previous works described in [9]. However, the improvement was made to miniaturize the structure in order to maintain the performance of the conventional short circuit stub bandpass filter. The proposed design is slightly modified to simplify the structure and reduce the fabrication cost. The synthesis of lumped element to the physical layout is obtained based on the characteristic impedance and the electrical length for each number of short circuit stubs and the connecting lines. The filter was designed by Roger Duroid 4350B with a dielectric constant of 3.48. The substrate thickness and $\tan \delta$ was set to 0.508 mm and 0.019 respectively. The layout of wideband bandpass filter and its physical dimensions is shown in Figure 1. The curve bending discontinuities junction has been taken into account for this proposed wideband bandpass filter.

The simulated results showed a reflection and the transmission coefficient of greater than 15 dB and 0.3 dB respectively for passband response. The filter in

Figure 2 shows a good performance and high selectivity with a fractional bandwidth of passband for about 66.67%. The group delay of the passband response varied between 0.6

to 0.78 ns and very flat in the passband with 0.76 ns. The results of quarter wavelength short circuit stubs are shown in Table 1.

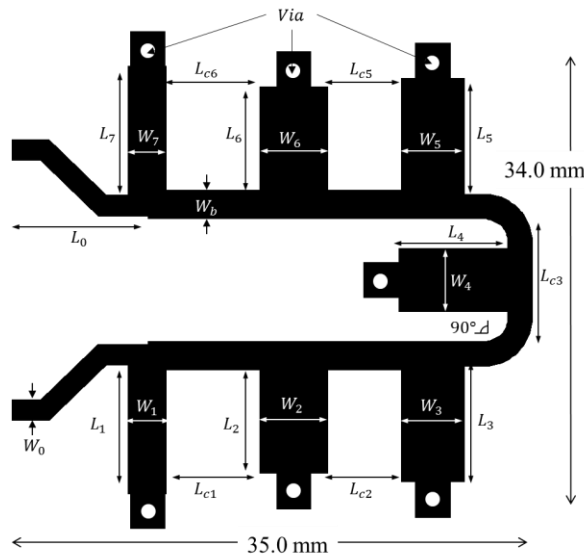


Figure 1: Proposed physical layout for 7th order short circuited stubs bandpass filter. $W_0=1.5$, $W_1=W_7=3.1$, $W_2=W_6=4.9$, $W_3=W_5=4.5$, $W_4=4.5$, $W_7=2.7$, $W_6=2.05$, $L_0=11.8$, $L_1=L_7=8.45$, $L_2=L_6=7.35$, $L_3=L_5=8.2$, $L_4=7.7$, $L_7=9.1$, $L_{c1}=L_{c6}=7.45$, $L_{c2}=L_{c5}=5.2$, $Via=1.0$. Unit in mm

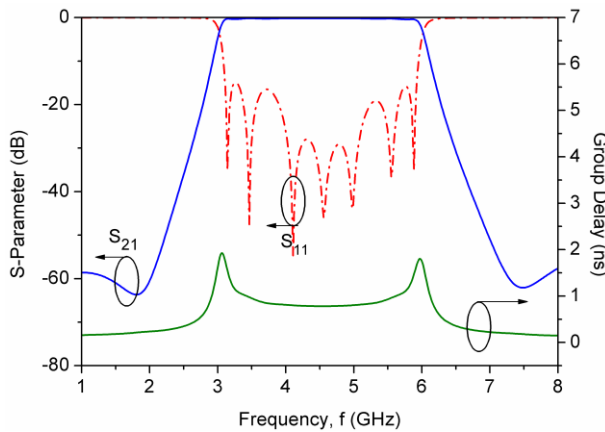


Figure 2: Simulation result of wideband bandpass filter

Table 1
Simulation Result for Wideband Bandpass Filter

Bandpass Filter	
Frequency Band (GHz)	3.0 – 6.0
Fractional Bandwidth, FBW (%)	66.67
Transmission Coefficient, S_{21} (dB)	-0.3
Reflection Coefficient, S_{11} (dB)	-15
Group Delay (ns)	0.74
Overall Dimension (λ_0)	0.663 x 0.685

A. Design of Defected Microstrip Structure (DMS)

This DMS structure unit was made by etching a slot on a microstrip line to produce a notch response at the desired frequency. The structure along with dimensions consisting of U-shape DMS can be realized, as shown in

Figure 3. The notch response was constructed with a resonant frequency of 5.2 GHz, which represents a WLAN

frequency spectrum. The U-shape DMS was designed by Roger Duroid RO4350B with a dielectric constant of 3.48, thickness of 0.508 mm and $\tan \delta$ of 0.019 for all simulations. Figure 4 shows the equivalent circuit that consists of parallel-connected LC resonant circuit. In equation (1), the equivalent circuit parameters of U-shape DMS were obtained as $L=0.261$ nH and $C=3.576$ pF.

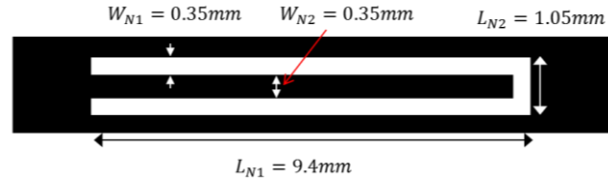


Figure 3: Proposed U-shape Defected Microstrip Structure

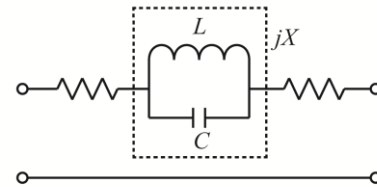


Figure 4: Equivalent circuit of U-shape DMS

$$C = \frac{1}{2\pi Z_0 (f_u - f_l)}, L = \frac{1}{4\pi^2 f_0^2 C} \quad (1)$$

where f_u is upper cut-off frequency, f_l is a lower frequency and f_0 is a resonant frequency.

To investigate the U-shape DMS, the structural effects by unit size L_{N2} , L_{N1} and W_{N1} were analyzed in detail. The parametric analysis of the U-shape DMS is shown in

Figure 5 (a). This is to determine the resonant frequency and the attenuation due to the increment on its length, L_{N2} . In

Figure 5 (b), the dimension of L_{N1} was investigated due to the resonant frequency of 4.8 GHz, 5.0 GHz, 5.2 GHz and 5.5 GHz. The effects of resonant frequency are shown in

Figure 5 (c) by varying the W_{N1} . The bandwidth increases by the increment of W_{N1} from 0.25 mm to 0.55 mm, hence decreases the selectivity of the response.

B. Tunable Notch Response

In this section, the general review of PIN diodes is discussed. The PIN diodes are normally used to provide discrete states of tunable filters and act as a tuning device for semiconductor. The concept of PIN diode for U-shape DMS with supply DC voltage on the island of the slot line is shown in Figure 6. PIN diode was employed as a switching device to turn ON / OFF the DC supply. Then, the external DC voltage supplies 10 V to turn ON the PIN diode with the incoming current of 1 mA. In this simulation, the tunable notch response was realized using PIN diode BAP 64-02. The biasing circuit consists of DC blocking capacitance with 47 pF, resistor of 100 Ω and DC feed of 22 nH. Figure 7(a) shows the response of zero bias (OFF state) and Figure 7(b) shows the response of forward bias (ON state). The simulation result shows that when PIN diode is ON, it produced a notch response at WLAN 5.2 GHz with FBW and attenuation for about 13.6%

and 25 dB respectively. In the passband, the group delay was below 0.12 ns. However, when the PIN diode is OFF, the notch response disappeared and became all pass with a reflection coefficient better than 15 dB and transmission coefficient at 0.3 dB. The group delay for the U-shape DMS was very flat in the passband lower than 0.62 ns.

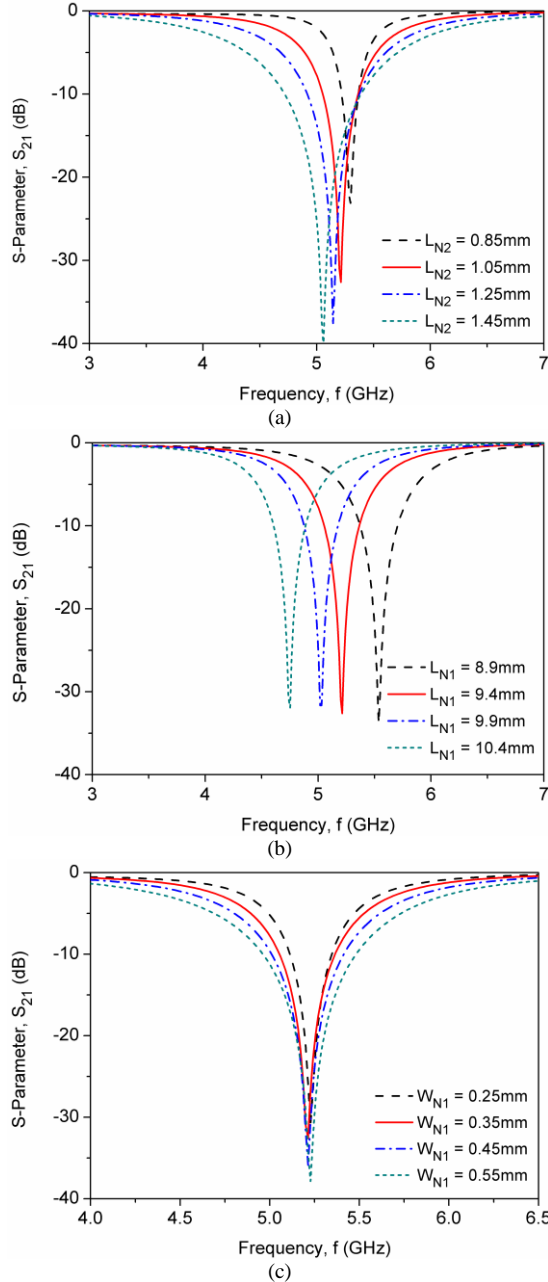


Figure 5: Simulated response of parametric analysis (a) L_{N2} =1.0 mm, 1.2 mm, 1.4 mm and 1.6 mm varying (b) L_{N1} =8.7 mm, 9.2 mm, 9.7 mm and 10.2 mm varying and (c) varying W_{N1} 0.25 mm, 0.35 mm, 0.45 mm, and 0.55 mm.



Figure 6: Proposed tunable U-shape DMS

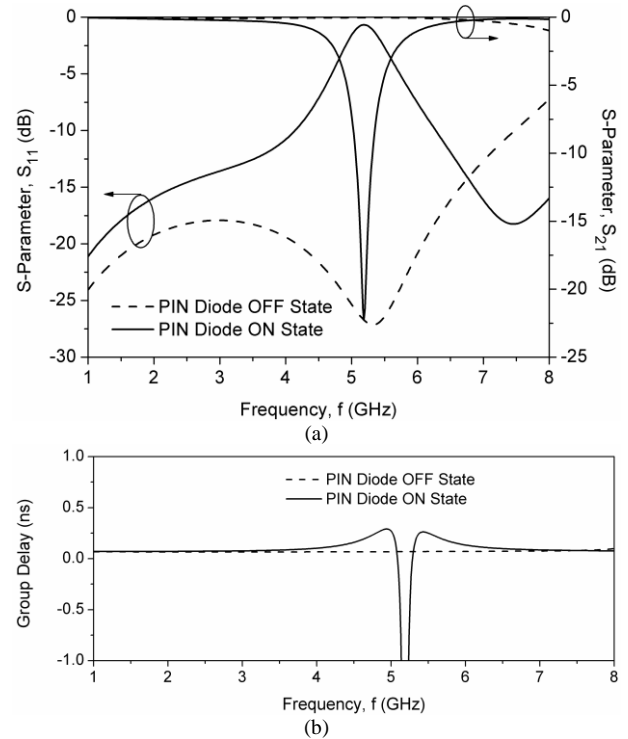


Figure 7: Simulation results of U-shape DMS with PIN diode (a) S-Parameter and (b) Group delay.

III. INTEGRATION OF SHORT CIRCUIT STUB BANDPASS FILTER WITH U-SHAPE DMS

The simulated result of short circuit stub bandpass filter with tunable notch response is described in this section.

Figure 8 shows the equivalent circuit of bandpass filter with notch response. The biasing circuit consists of DC supply, resistor 110 ohm, capacitor 47 pF and inductor 2.1 nH. The integration of wideband bandpass filter with U-shape of DMS is illustrated in

Figure 9. To produce the bandpass and notch response in a single device, the DMS can be placed at arbitrary microstrip line by integrating it inside the bandpass filter structure.

This integrated structure produces a wideband bandpass response from 3 GHz to 6 GHz and rejects the unwanted signal of 5.2 GHz WLAN frequency response. At the OFF state, the notch filter disappeared inside the wideband range and covered the 5.2 GHz WLAN frequency band. At the ON state, the external DC source of 10 V and 1 mA was supplied to turn on the PIN diode. The notch response was present at 5.2 GHz with attenuation of 14 dB and fractional bandwidth of 13.6%. The simulation result is shown in

Figure 10(a). The simulation group delay at both ON/OFF state is depicted in

Figure 10(b). The flat group delay was with 0.74 ns in the

passband for the OFF state. It shows that the filter has a good linearity for signal transfer. Evidence from the ON state shows that the wideband response for the passbands the group delay was lower than 0.83 ns. Figure 11 shows the current flow visualization of integrated bandpass filter with DMS. The current flow focuses at 5.2 GHz with high concentrated red color (15.24 A/m).

Table 2 shows the comparison of different topology of wideband bandpass filter.

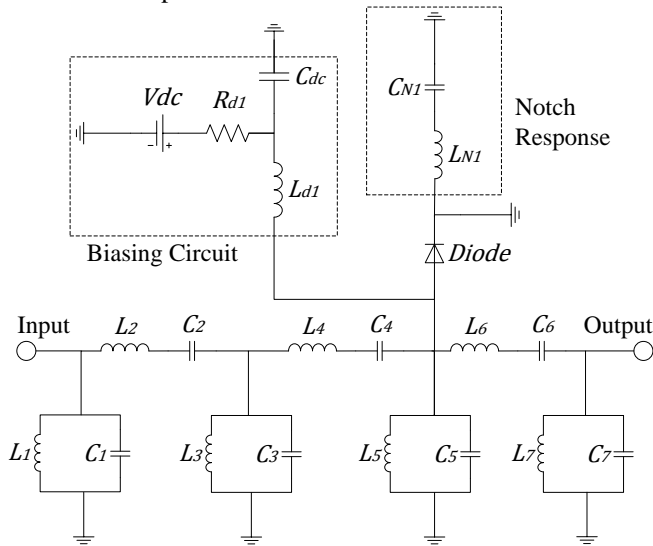


Figure 8: Equivalent circuit of integration bandpass filter with DMS (notch response)

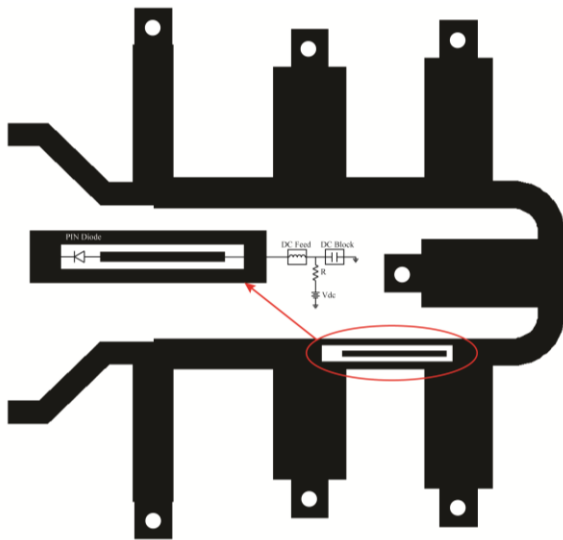


Figure 9: Physical layout of the proposed wideband bandpass filter with reconfigurable notch response.

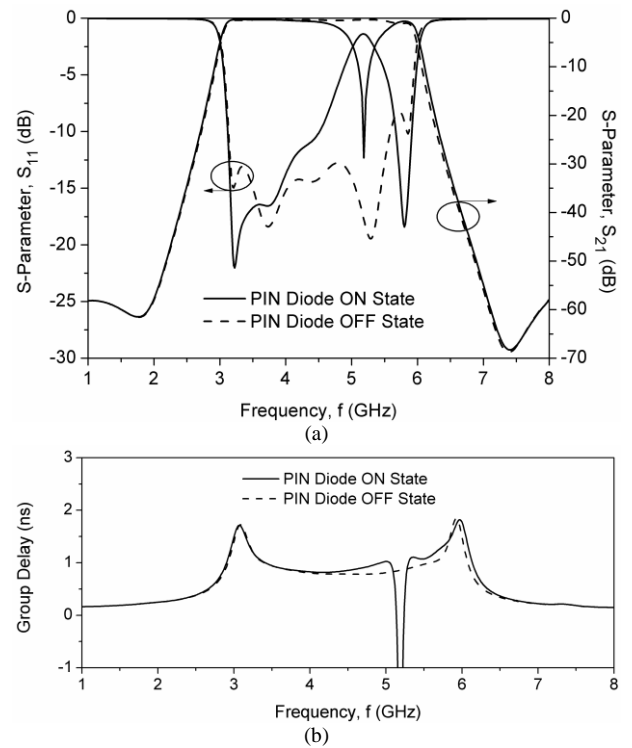


Figure 10: Simulation results of wideband bandpass filter with reconfigurable notch response (a) S-Parameter and (b) Group delay

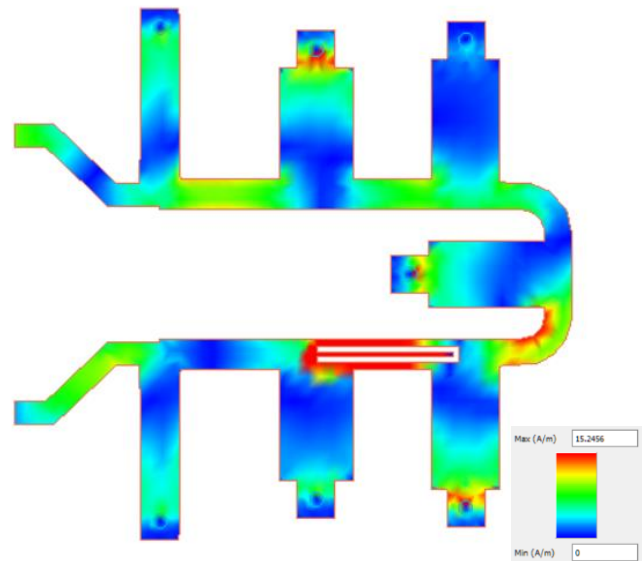


Figure 11: Current flow visualization of bandpass filter integrated with DMS

Table 2
Comparison between Different Topologies

Ref	S11 (dB)	S21 (dB)	3-dB FBW (%)	f_o (GHz)	Dielectric Constant, ϵ_r	Size ($\lambda_g \times \lambda_g$)
[2]	≥ 12	≤ 1.5	88.0	3.80	2.45	0.700 x 0.380
[3]	≥ 11	≤ 1.0	66.0	3.00	10.8	0.236 x 0.073
[4]	≥ 15	≤ 1.0	70.0	6.85	2.65	1.266 x 0.870
[5]	≥ 15	≤ 6.0	66.0	3.50	2.55	0.600 x 0.330
[6]	≥ 18	≤ 1.0	57.9	1.45	11.2	0.238 x 0.716
This Work	≥ 16	≤ 0.5	65.3	4.50	3.48	0.663 x 0.686

IV. CONCLUSION

A novel wideband bandpass filter and integrated with reconfigurable notch characteristic has been successfully designed and simulated. A reconfigurable notch response was realized using PIN diode BAP 64-02 as a switching element. This technique was achieved by connecting the diode with external DC supply to provide a forward-bias connection (ON-state) or zero-bias (OFF-state). The biasing connection was completed by introducing the resistor and DC blocking throughout the circuit. The overall results with excellent characteristics have been successfully demonstrated. This new type of wideband bandpass filter with tunable notch response is highly suitable and can be applied for filtering the existing interference signal in radio systems.

ACKNOWLEDGMENT

This work was supported by UTeM Zamalah Scheme and

funded by UTeM and the Malaysian Government (MOHE) via research grant RAGS/1/2015/TK0/ FKEKK/03/B00100.

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