Indonesian Journal of Electrical Engineering and Computer Science
Vol. 11, No. 2, August 2018, pp. 797~804
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v11.i2.pp797-804

Microwave Bandpass Filter Integrated with Notch Response for Wide-band Applications

Mussa Mabrok, Zahriladha Zakaria, Nurhana Abu Hussin, M. A. Mutalib
Center for Telecommunication Research and Innovation (CeTRI), Faculty of Electronics and Computer Engineering,
Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

Article Info

Article history:

Received Apr 8, 2018
Revised May 1, 2018
Accepted May 27, 2018

Keywords:

Bnadpass Filter
Notched Filter
Stepped Impedance Resonator (SIR)

ABSTRACT

This paper presents the design of wide-band bandpass filter using microstrip structure at 3-6GHz with fractional bandwidth of 66.67% based upon short-circuited stubs structure of 5th degree. In order to avoid the interference from existing system that operates in the frequency band, the folded stepped impedance resonator (SIR) was introduced to generate a narrow notch band at 5.2GHz. Pin diode is employing as switching mechanism for the notch response. This design is simulated by Advance Design System (ADS) software and using Roger Duroid 4350B with a dielectric constant of 3.48, substrate thickness 0.508mm and loss tangent 0.0019. The achieved return loss is better than 15dB and insertion loss is less than 1dB. The designed filter can be used in microwave communication systems such as wireless communication devices and military applications (radar system).

Corresponding Author:

Zahriladha Zakaria,
Center for Telecommunication Research and Innovation (CeTRI),
Faculty of Electronics and Computer Engineering,
Universiti Teknikal Malaysia Melaka (UTeM),
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
Email: zahriladha@utem.edu.my

1. INTRODUCTION

In recent years, wireless communication system has evolved rapidly which make the microwave devices such as antenna, and filter have a huge demand when developing wireless communication technology. Basically, microwave filter is used in transmitter and receiver of microwave application to control the overall performance of the system. High performance filter with compact size is required when developing the wideband wireless communication system. Wideband can be defined as the wide range of operating frequencies used in microwave field. However, the existence of the other radio signal bands within the range of the wideband spectrum such as WLAN 802.11 at 5.2GHz limits the usage of the wideband technology for commercial communication application. The existing radio communication signal within the wideband spectrum will affect the accuracy of data reception for wideband system, thus decreasing its performance and introducing more losses in the system. Therefore, various studies have been conducted in order to design a microwave filter that is capable to eliminate the interference of other radio signals within the desired spectrum frequency (tunable filters) [1]-[4]. In [5], 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 [6], 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 [7]. 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 bandstop 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 in order 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.

2. DESIGN METHODOLOGY

The design process in this work starts with designing the bandpass filter, 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 the notch response.

2.1. 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 Figure 1, where the length of stubs and the connecting lines are equal to $\lambda g0/4$ respectively [8].

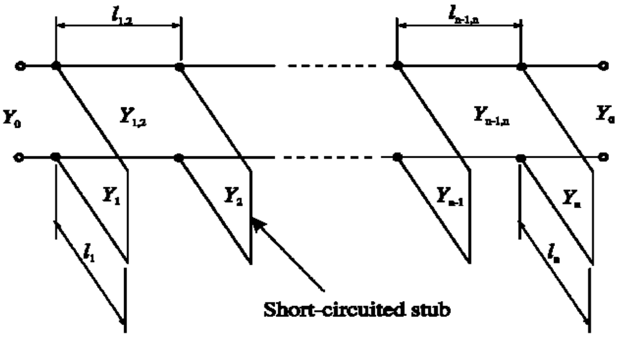


Figure 1. The Concept of Quarter-Wavelength Shunt Short-Circuited Stubs

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 thichness t of 0.035mm. The layout of microstrip bandpass filter and its dimension is shown in Figure 2. The simulation result of the microstrip layout structure is presented in Figure 3. From the graph, it can be seen that 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%.

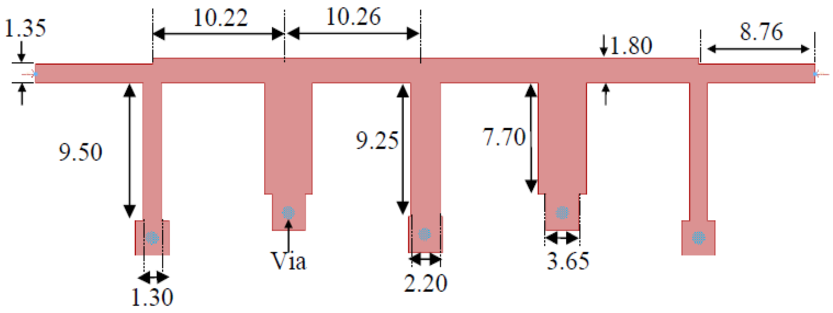


Figure 2. Physical Layout for 5th order short circuited stubs bandpass filter

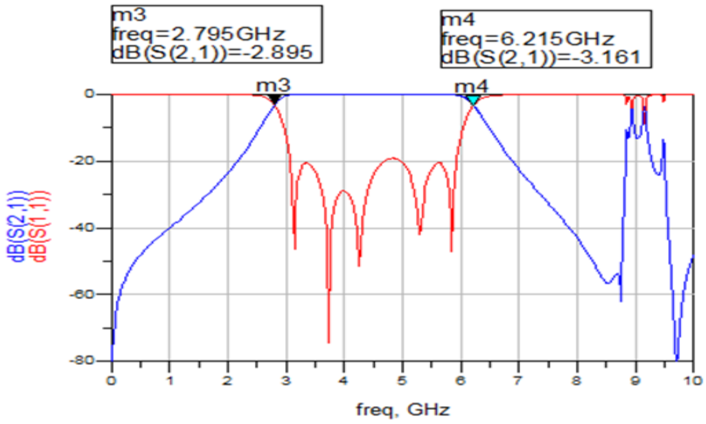


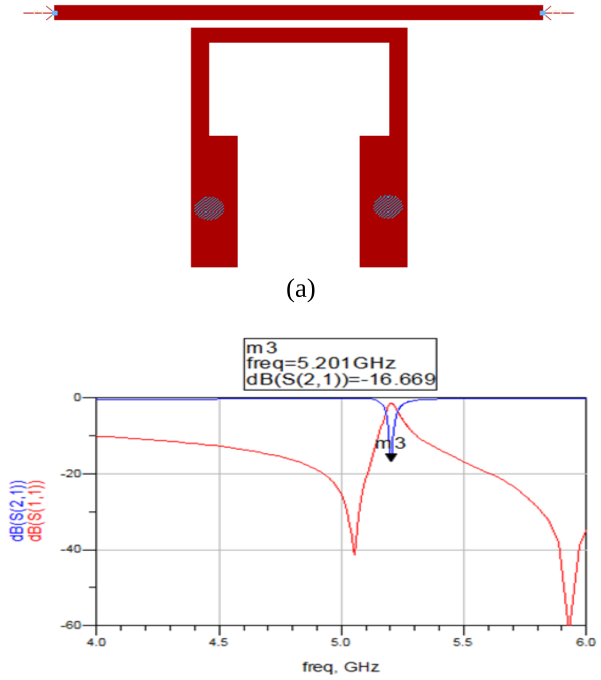
Figure 3. Simulated S-parameter for proposed microstrip bandpass filter

2.2. 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 designated to produce a notch response at 5.2GHz (WLAN application). The design process starts by developing a single folded SIR placed next to the microstrip transmission line as shown in Figure 4(a). The simulation result of single section SIR is shown in Figure 4(b), where the insertion loss S_{21} of the notch response is attenuated at -16.669dB for a frequency of 5.201GHz.

2.2.1. Single Folded SIR Integrated with BPF

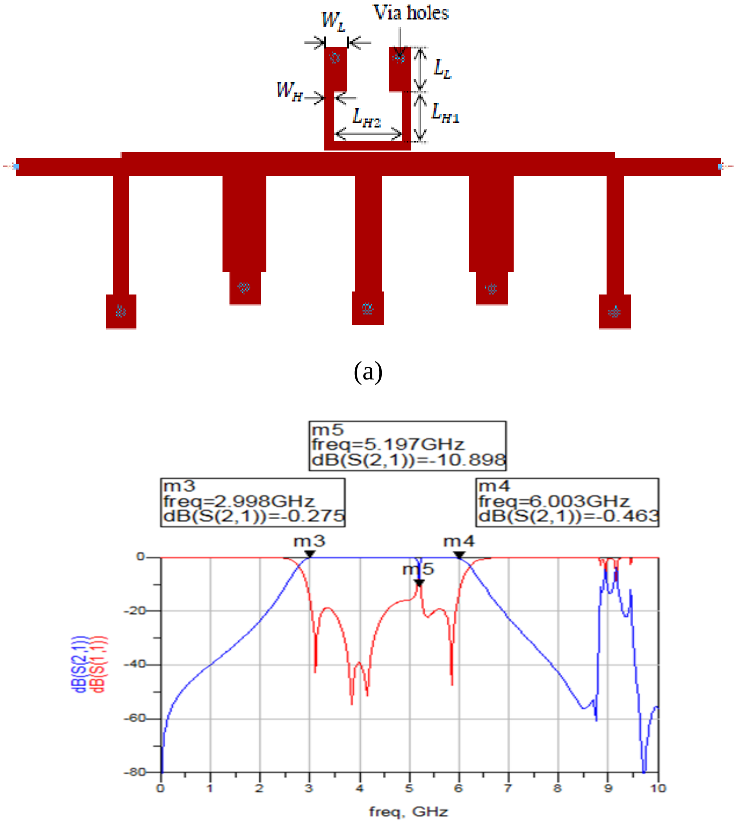
After obtaining the notch response under -15dB, the resonator structure is integrated into the layout of short-circuited stub structure as shown in Figure 5(a) in order to analyze their response. The simulation result of the single folded SIR structure integrated with bandpass filter is presented in Figure 5(b). From the observation based on the simulation response, the insertion loss S_{21} of the bandpass filter for frequency of 2.988GHz and 6.003GHz attenuated at -0.275dB and -0.463GHz respectively, while the insertion loss S_{21} of the single folded SIR structure for frequency of 5.197GHz is attenuated at -10.898dB.



(a)

(b)

Figure 4. (a) Proposed Folded Stepped-Impedance Resonator (SIR) Layout (b) Simulation Result of Single Folded SIR with Transmission Line



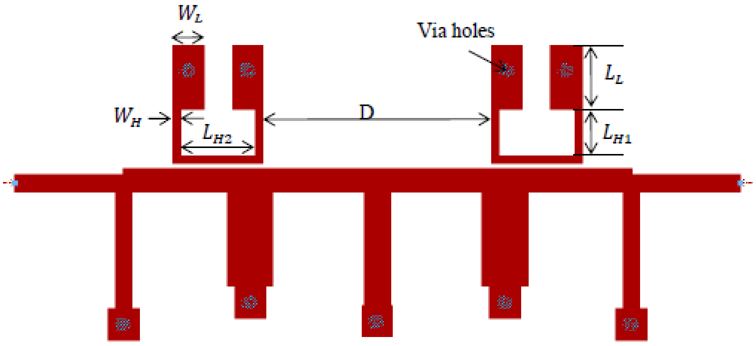
(a)

(b)

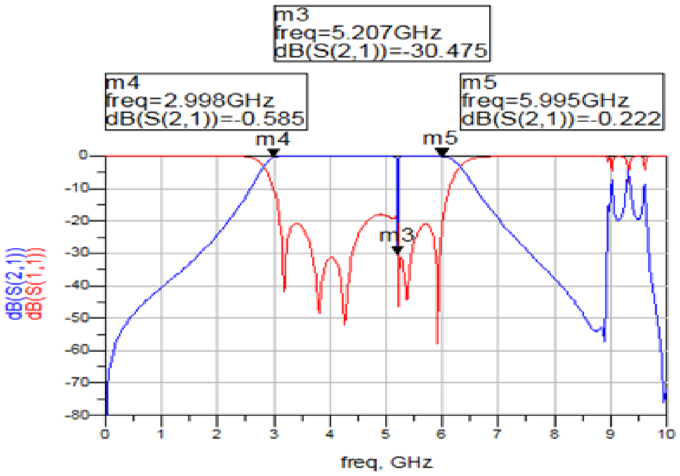
Figure 5. (a) Layout of Single Folded SIR Integrated with BPF (b) Simulation Result of Single Folded SIR with BPF

2.2.2. Two Folded SIR Integrated with BPF

Another 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. Thus, new design of filter structure is developed as shown in Figure 6(a). Where, the dimension of W_L and L_L is increased by 0.7mm and 1.55mm respectively compared to previous designs of single folded SIR structure in Figure 5(a), while the dimension of W_H and L_{H1} is decreased by 0.1mm and 0.24mm respectively but the L_{H2} is increased by 0.4mm. The simulation result as can be seen in Figure 6(b), where the notch response produced by the filter become very sharp and deeper, which is the insertion loss S_{21} at frequency 5.207GHz attenuate at -30.475dB comparing to the simulation result of single folded SIR shown in Figure 5(b).



(a)



(b)

Figure 6. (a) Layout of Two Folded SIR Integrated with BPF (b) Simulation Result of Two Folded SIR with BPF

3. 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 Figure 7.

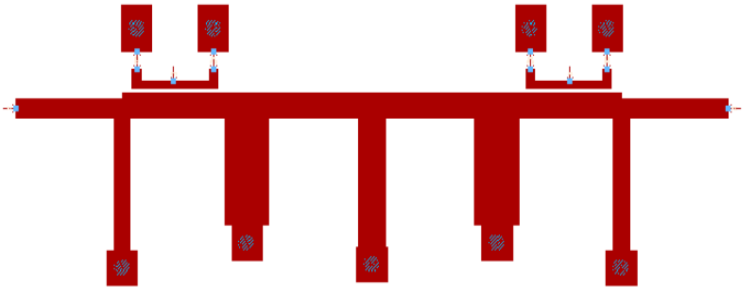
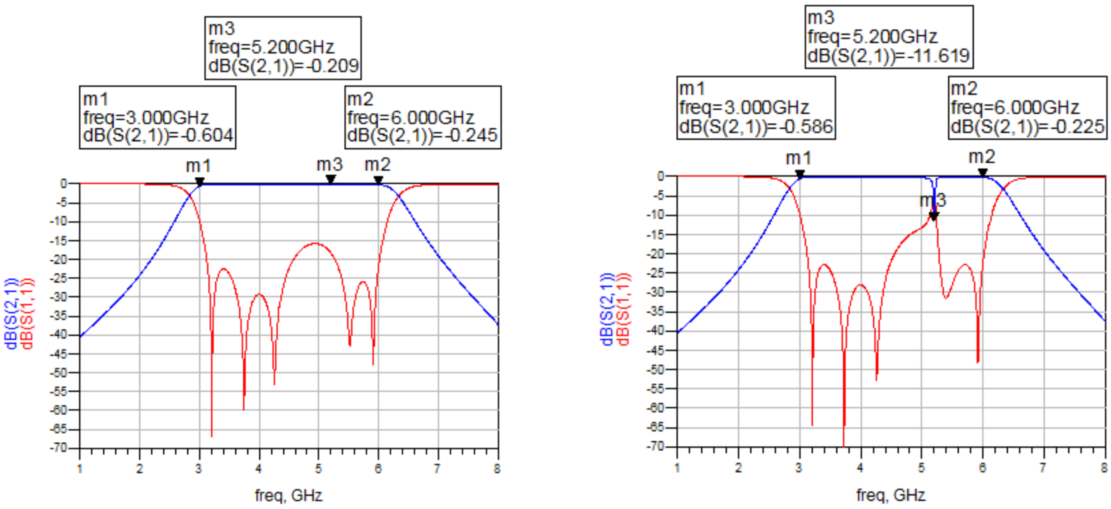


Figure 7. Layout of Active BPF with Tunable Response

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 Figure 8(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 Figure 8(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.



(a) (b)

Figure 8. (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

Table 1 shows the comparison between the performance of the previous designed notched filters and the proposed design. The proposed BPF design in this paper achieved low return loss which is lower than -20dB within the entire bandwidth 3 - 6GHz. Among the proposed BPF designs presented in Table 1, the same return loss is presented in [2] with insertion loss around o.7dB which is 0.2dB below that of the proposed BPF. The designed BPF shows good performance in terms of return loss, insertion loss, and fractional bandwidth.

Table 1. Comparison between the performance of proposed design and other recently designs

Reference	Return loss (dB)	Insertion loss (dB)	3-dB fractional Bandwidth (%)
2016 [1]	≥16	≤0.5	65.3
2017 [2]	19.37	0.7	111
2014 [9]	>18	0.5	-
2014 [10]	≥18	≤1.0	57.9
2016 [11]	>10	0.3	-
2015 [12]	>11	1.6	110
This work	≥ 20	< 0.58	66

4. CONCLUSION

In conclusion, wide-band bandpass filter integrated with two folded SIR and pin diode has been designed and simulated successfully using advanced design system (ADS). Two equal structures of folded SIR are utilized to introduce a narrow rejection band 5.2GHz (WLAN application). Four pin diodes are utilized into the folded SIR structure as tuning mechanism to electronically control the notch response within the wideband bandpass filter.The simulated results show good performance in terms of 3GHz bandwidth with 66% fractional bandwidth, return loss (S_{11}) better than -20dB, and insertion loss (S_{21}) around -0.5dB. The designed bandpass filter with tunable notch response can be used for filtering the existence 5.2GHz WLAN signal in wideband systems. PIN diode is used as tuning mechanism in this work. Other types of tuning elements may also be considered such as Microelectromechanical Systems (MEMS) which has been proven to be a great interest of tuning filters; because of its characteristics such as low loss, and excellent linearity. The size reduction criteria also play an important role when designing bandpass filter integrated with notch response. Hence, low temperature cofired ceramic (LTCC) technology may be considered to be implemented in the process design.

ACKNOWLEDGEMENTS

This work was supported by UTeM Zamalah Scheme. The authors would also like to thank Center for Research and Innovation Management (CRIM), Centre of Excellence, UTeM, UTeM's research grant JURNAL/2018/FKEKK/Q00001 and Universiti Teknikal Malaysia Melaka (UTeM) for their encouragement and help in sponsoring this study.

REFERENCES

[1] M. A. Mutalib, Z. Zakaria, N. A. Shairi, and M. S. M. Isa. Microstrip Bandpass Filter with Reconfigurable Notch Response at 5.2 GHz using Defected Microstrip Structure. *Journal of Telecommunication, Electronic and Computer Engineering*. 2016; 8(5): 75–79.

[2] Y. Gaurav and R. K. Chauhan. A Compact UWB BPF with a Notch Band using Rectangular Resonator Sandwiched between Interdigital Structure. *International Journal of Electrical and Computer Engineering (IJECE)*. 2017; 7(5): 2420–2425.

[3] Norfishah Ab. Wahab, A. Amiruddin, Roskhatijah Radzuan, Zuhaila Mat Yasin, N. A. Salim, N. A. Rahmat, and N. F. A. Aziz. Bandpass filter Based on Ring Resonator at RF Frequency above 20 GHz. *Indonesian Journal of Electrical Engineering and Computer Science*. 2018; 9.(3): 680–684.

[4] A. N. Obadiah, M. R. Hamid, M. Kamal, and A. Rahim. A Compact Bandpass Filter Using a T-shaped Loaded Open- Ended Stub Resonator. *Indonesian Journal of Electrical Engineering and Computer Science*. 2018; 10(3): 867–874.

[5] Y. Chun, and H. Shaman. Switchable Embedded Notch Structure for UWB Bandpass Filter. *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*. 2008; 18(9): 590–592.

[6] Q. Chu, and X. Tian. Design of UWB Bandpass Filter Using Stepped-Impedance Stub-Loaded Resonator. *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*. 2010; 20(9): 501–503.

[7] A. K. Keskin and H. P. Partal. *An UWB High-Q Bandpass Filter with Wide Rejection Band using Defected Ground Structures*. IEEE International Conference on Ultra-Wideband. Syracuse, NY, USA. 2012; 99–102.

[8] J. Hong and M. J. Lancaster. Microstrip Filters for RF/Microwave Applications. New York: JOHN WILEY & SONS, INC. 2001.

[9] Z. Zakaria et al. *Compact Structure of Band-pass Filter Integrated with Defected Microstrip Structure (DMS) for Wideband Applications*. The 8th European Conference on Antennas and Propagation (EuCAP 2014). The Hague, Netherlands. 2014; 2158–2162.

[10] J. Wang, J. Zhao, and J. Li. Compact UWB bandpass filter with triple notched bands using parallel U-shaped defected microstrip structure. *ELECTRONICS LETTERS*. 2014; 50.(2): 2–3.

[11] A. B. Jiim. Design of Compact Tunable Bandpass Filter for Wideband Application. *International Journal of Applied Engineering Research*. 2016; 11.(8): 6053–6057.

[12] D. Jhariya, A. R. Azad, A. Mohan, and M. Sinha. *Compact UWB Bandpass Filter with Notched Band Using Multiple-Mode Resonator*. Applied Electromagnetics Conference (AEMC). Guwahati, India. 2015; 10–11.