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Switchable dual-band bandpass filter based on stepped impedance resonator with U-shaped defected microstrip structure for wireless applications

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Abstract

This paper presents a new technique in designing the switchable dual-band bandpass filter at 2.4 GHz and 3.5 GHz for WLAN and WiMAX applications. Wideband bandpass filter designed based on stepped impedance resonator at frequency of 3 GHz. To eliminate the interference from existing system that operates in the same frequency band, a defected microstrip structure applied and implemented to produce the notch response. In order to generate the switchable characteristic, the PIN diode was introduced at the dual-band filter. It exhibits that the measured results for switchable attributes when the diode is at OFF state, the wide passband is produced with the fractional bandwidth of 62.1 % centered at 2.9 GHz. Meanwhile, for the diode in ON state, the dual-passband has produced which centered at 2.5 GHz and 3.45 GHz. The experimental results showed good agreement with the simulation results. This structure is very useful for wireless communication systems and its applications.

Keywords: *bandpass filter, DMS, dual-band, SIR resonator, switchable filter*

1. Introduction

Due to the progression growth of multiservice wireless communication systems in a single device, multiband bandpass filter has attracted a great attention to the end user. Previously, single-band filter can only operate in single frequency band is used. To fulfil user end needed, dual band or multi band microwave filter which can be implemented in a single device are needed. A single device has capability to operate in multiple frequencies and support various wireless communications such as GSM, WLAN, WiMAX is one of the necessity for global devices [1-3]. As the wireless communications benchmark are continuously transforming to boost the new features and technologies. Hence, both of base station and end-user terminal have to implement dynamic communication chains capable of supporting multi-frequency that implied by Software defined radio (SDR). This SDR system will makes it easy to contain new standards with less hardware modification and reduce the time cost consuming. Due to the latest impositions towards the development and technology of multi-purpose RF front-ends [4], which can support multiple services at the same time such as global system for mobility (GSM) and code division multiple access (CDMA) mobile cell phone services at 0.9/1.8 GHz, or IEEE 802.11a/b/g wireless local area network (WLAN) specifications at the 2.4/5.2-GHz bands. So, a single microwave filter which can support multiple wireless applications is strongly demanded. Based on [5], multi-band microwave has been designed and comprised of antenna, amplifier and filter. Therefore, it has been a great interest in designing the multi-band bandpass filters with less complexity, minimal cost and high performance.

The challenges to circuit designers designing a multi-band bandpass filter are to achieve compact size, high stability and loss insertion simultaneously. Several designs of switchable bandpass filter have been proposed in [5-12]. In [13-14] had proposed the combination of two types of topologies in order to produce multiband filter. However, the size of circuit was large (91.8 & 483 mm^2) respectively. This paper presents a design of switchable

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dual-band band pass filter for WiMAX and WLAN applications. The design implemented with PIN Diode at the Defected Microstrip Structure (DMS) for the function of switchable of the filter. The designed circuit simulated using Advanced Designed Software (ADS). The topology of the band pass filter is structure of asymmetric Stepped Impedance Resonator (SIR) with U-shaped DMS. The proposed design achieves passband bandwidth is 2.3-2.7GHz and 3.1-3.75 GHz at -3dB. The passband return loss is better than -15dB while the insertion loss is between 0dB and -1dB.

2. Research Method

The process of the design in this work starting with designing wide-band bandpass filter, followed by designing DMS to introduce a notch response, then integration of DMS with wide-band filter in order to produce the dual-band bandpass filter. Finally, implementing PIN diode into design to be function as a switch to produce wideband passband when OFF state, while dual-band passband when ON state. Figure 1 shows the design stepts in the form of flowchart.

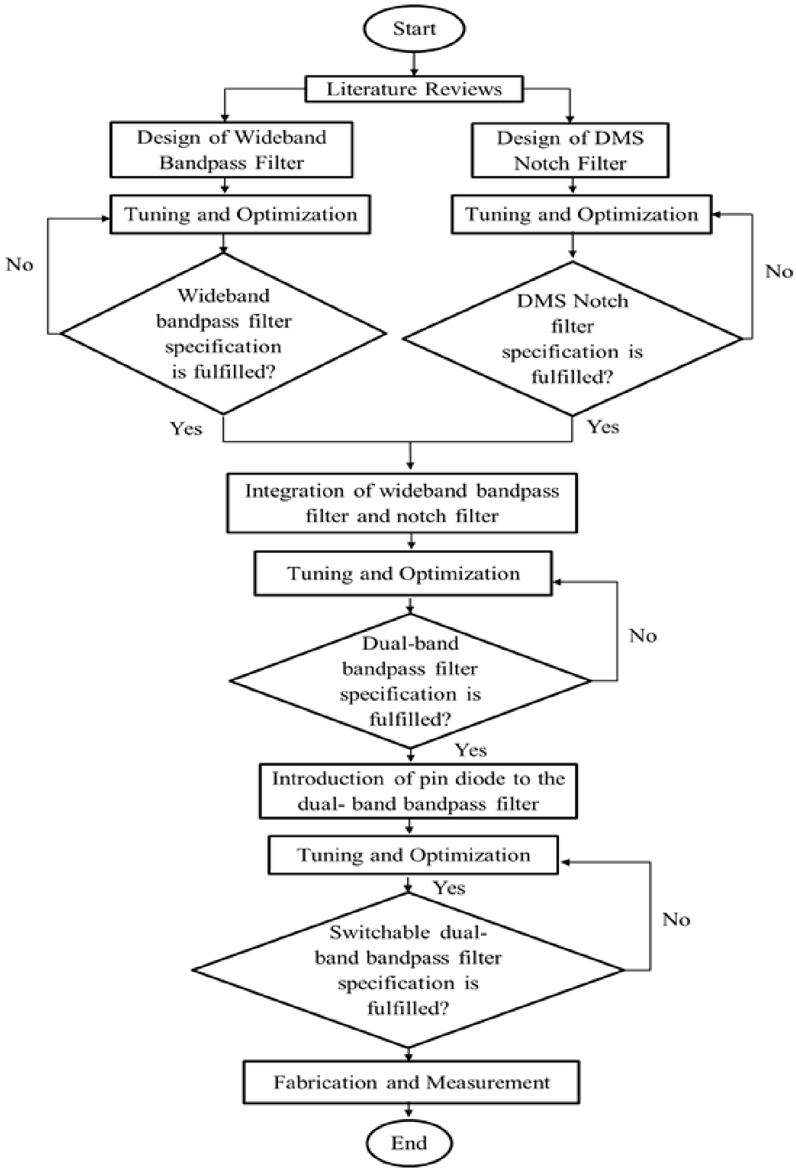


Figure 1. Flowchart of the design process

2.1. Wideband Bandpass Filter Based on SIR

The idea of a multimode resonator with a stepped-impedance configuration is an alternative way to develop the wideband bandpass filter 2.3–3.75GHz to fulfill the two types of wireless communication applications WLAN and WiMAX. In this design, the substrate of Roger Duroid 4350 with dielectric constant of 3.48 and the thickness of 0.508mm was chosen in designing and simulating the wideband bandpass filter. The optimized physical structure and parameters of SIR: W_1=4.9 mm, L_1=25.1mm, W_2=0.6mm, L_2=14.6mm, W_3=2.8mm, L_3=9.9mm, g=0.4mm and t=23.2mm is displayed in Figure 2 as the notch filter can be fitted in. The simulated results of the designed filter showed that a return loss and insertion loss are better than 16 dB and 2 dB respectively as shown in Figure 3.

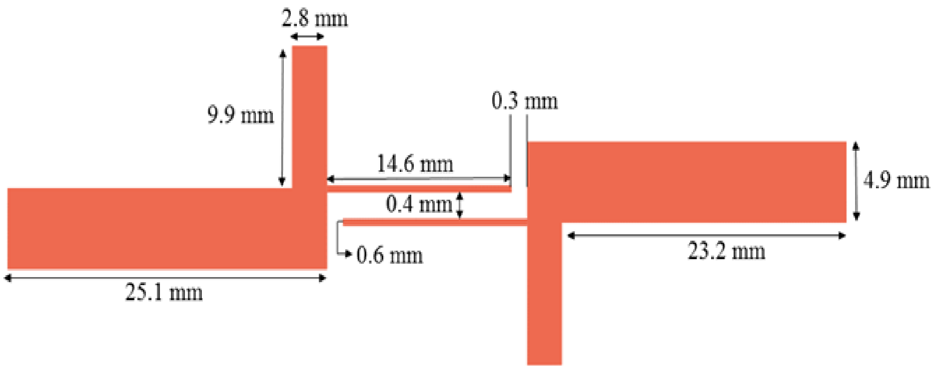


Figure 2. Optimized physical layout of SIR

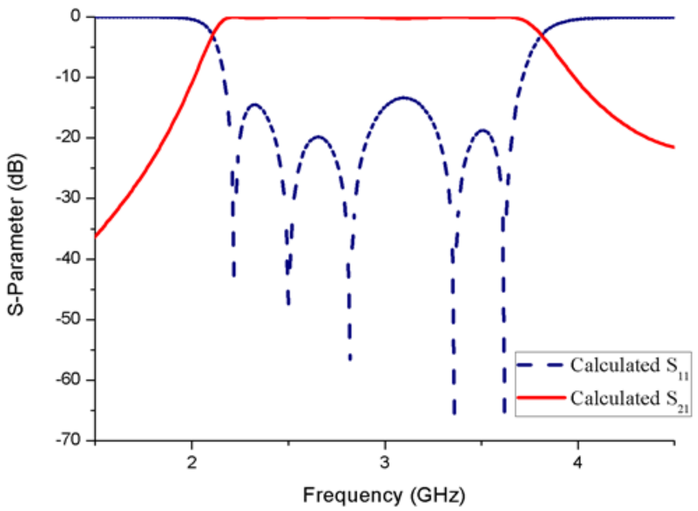
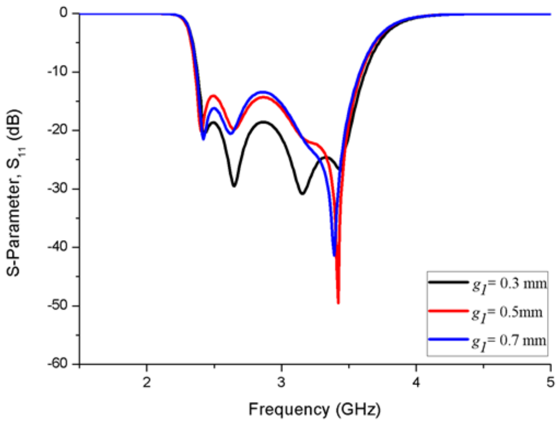


Figure 3. S-parameter for the physical layout of SIR

Based on [15], there are two parameters that might affect the performance of passband response which are gap coupling of g_1 and g_2. Figure 4(a) shows the effect of gap coupling, g_1 is varied. It is justifiably spotted that when decreasing the spacing g_1 from 0.7 mm and fixing g_2, the results of passband is roughly the same, but the level of return loss is enhanced. Noted that the bandwidth of response also be wider as the spacing of g_1 is decreased. Furthermore, as tuning the spacing of g_2 but fixing g_1, the behavior of the wideband response is ascertained as displayed in Figure 4(b). When the spacing of g_2 is smaller, the strong coupling strength causes the mode splitting. In contrast, larger the spacing of g_2 created the coupling between the symmetric SIRs are weak.



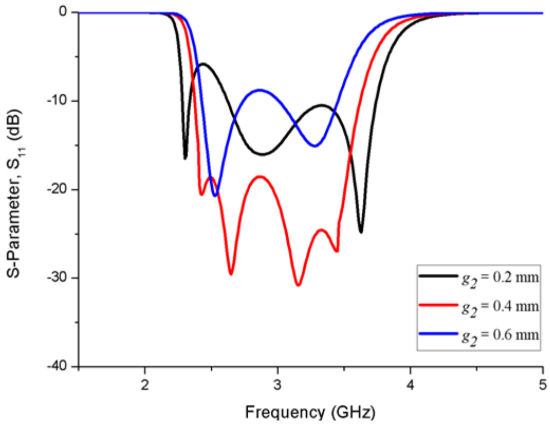


Figure 4. (a) Effect of gap coupling, g_1 is varied and g_2 is fixed
(b) effect of gap coupling, g_2 is varied and g_1 is fixed

2.2. DMS with Conventional U-Shaped

This sort of DMS was built as a way to eliminate undesired signals for example WLAN radio frequency that yield enhanced selectivity and high Q-factor. The recommended structure of the U-shaped DMS that comprises of horizontal and vertical slot in the middle of conductor line as in Figure 5. The DMS construction gives resonant frequency centered at 3GHz with the wider bandwidth and high selectivity. The substrate of Roger Duroid 4350 with permittivity of 3.28 and the thickness of 0.508mm is used to simulate and analyze the performance of the U-shaped DMS.

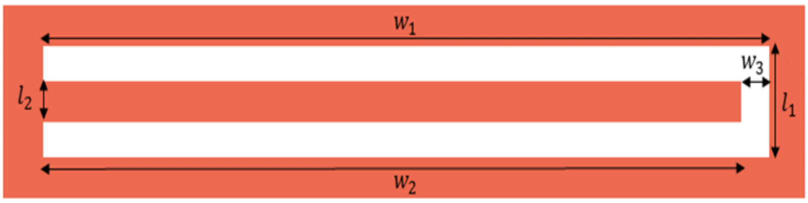


Figure 5. DMS of conventional u-inverse shaped

The simulated notch response in Figure 6 gives the attenuation level more than -30 dB, return loss is -0.2 dB and the bandwidth of 400MHz at frequency of 3GHz. The U-shaped DMS is constructed to attenuate the notch response at the preferred frequency with dimensions of w_1= 16.3mm, w_2= 16mm, w_3= 0.35mm, l_1= 1.1mm and l_2= 0.4mm. The parameter of w_1 and l_2 is selected to analyze the parametric study and observe the changes on the notch response. From the observation in Figure 7(a) and 7(b), it can be concluded that the increasing the length of w_1 and l_2 will cause the decreasing in resonant frequency. However, Figure 7(b) exhibited that the insertion loss of notch response is poor, and the bandwidth become wider as the dimension of l_2 increasing.

3. Switchable Dual-Band Bandpass Filter

The PIN diode is semiconductor-based tuning tools that commonly accustomed to generating discrete states reconfigurable/switchable filter. In this section, a brief analysis of reconfigurable/switchable based on PIN diode is conducted and demonstrated. To construct the proposed structure which have switchable feature, an RF front-end switching circuit will be introduced into the dual-band bandpass filter. By doing this, mismatch of losses during the implementation and circuit dimension are regarded beforehand and further minimized. Figure 8 shows the schematic of the proposed switchable dual-band bandpass filter with wide notch response by using RF PIN diode BAP 64-02. In addition to the diodes mounted on the both of U-shaped DMSs, the circuit involves the bias network consisting of resistors and capacitors. The external DC voltage is 1V to activate the diodes and the DC blocking capacitance is 10pF and a resistor of 1kΩ has been used for biasing.

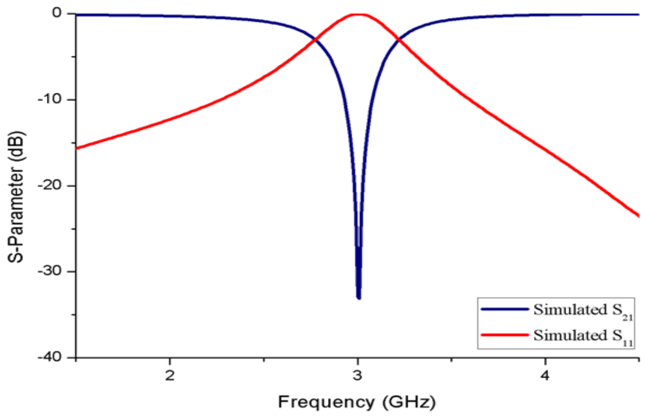
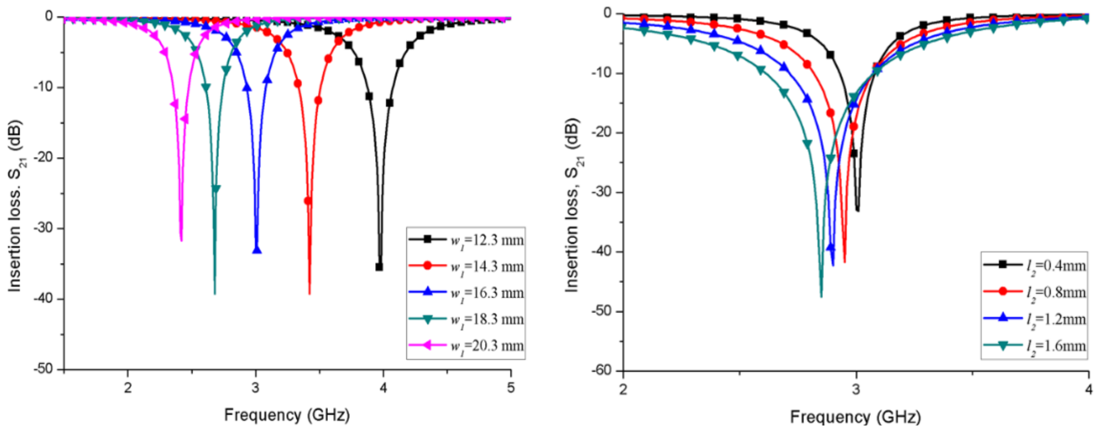


Figure 6. Simulated notch response of U-shaped DMS



(a) (b)

Figure 7. (a) Effect of notch response when w_1 is varied
(b) Effect of notch response when l_2 is varied

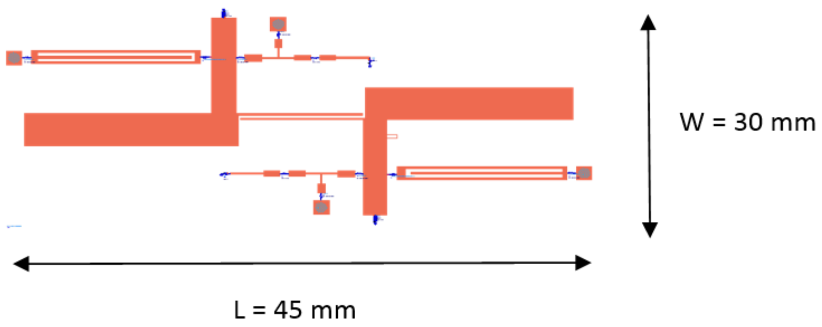


Figure 8. Schematic diagram of the proposed switchable dual-band bandpass filter

Figure 9 presented the simulated response for integrated dual-band bandpass filter with PIN diode. From the observation, as the both of pin diode is ON state, two passbands are produced with the notch attenuated at frequency of 2.97 GHz with the attenuation level of 60 dB. The fractional bandwidth for both passband are 21.4% and 13.8% centered at 2.48 GHz and 3.40 GHz respectively. The return loss for the dual band is greater than 15 dB while the insertion loss is better than 0.1 dB. Conversely, wideband passband is produced when the pin diode is OFF state with the fractional bandwidth of 48.2% at center frequency of 2.95 GHz. The proposed design of switchable dual-band bandpass filter is fabricated using Roger Duroid 4350 substrate. Figure 10 shows the fabricated circuit of switchable dual-band bandpass filter, where the overall size of the circuit as the length is 65.4 mm and width is 27.2 mm. Figure 11 signifies the simulated and measured results for switchable dual-band bandpass filter.

As presented in Figure 11 (a), it exhibits that the measured results for switchable characteristic when the diode is at OFF state, the wide passband is produced with the fractional bandwidth of 62.1% centered at 2.9 GHz. The bandwidth has increased and wider 10.6% compared to the simulated ones. The S_{11} and S_{21} for the wideband is greater than 10 dB and better than 1.0 dB which still fulfill the requirement. For the diode is forward-biased in ON condition such in Figure 11 (b), the dual-passband has produced which centered at 2.5 GHz and 3.45 GHz. The first passband possess the fractional bandwidth of 24% while the second passband is 20.3%. The simulated return and insertion losses of this design are greater than 10 dB and better than 1.0 dB. Then, the fractional bandwidth of the measured notch has decreased about 3.3% and the attenuation level of the notch is 45 dB which slightly decreased compared to the simulated response. In Figure 12 (a) & (b), it determined that the group delay for both outcomes is satisfied well with each other as illustrates a notable flatness in the passband. A slight shift is experienced because of the fabrication and component tolerance during the implementation.

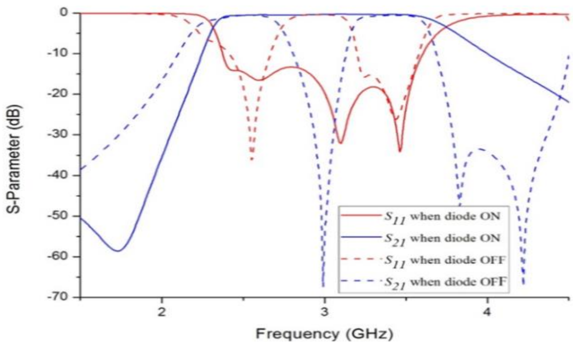


Figure 9. S-parameter for switchable dual-band bandpass filter

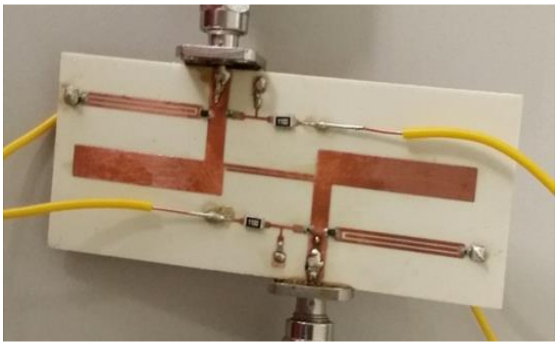
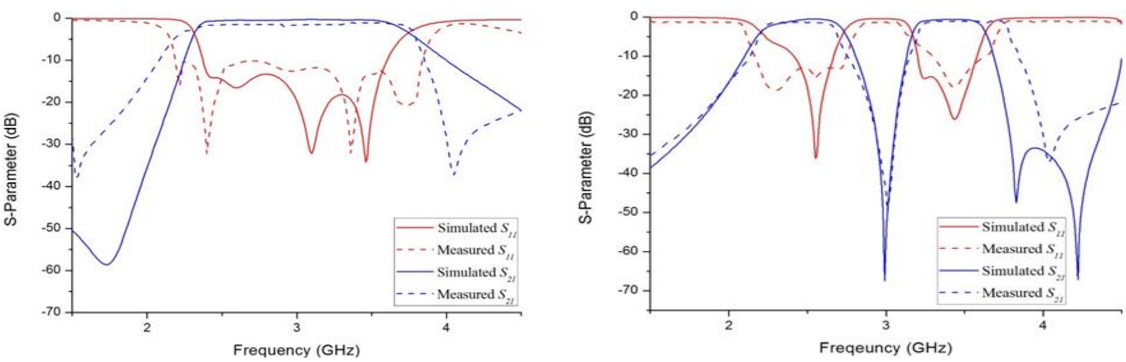


Figure 10. Fabrication of switchable dual-band BPF



(a) (b)

Figure 11. Comparison between simulated and measured response of switchable dual-band bandpass filter when (a) pin diode is OFF state (b) pin diode is ON state

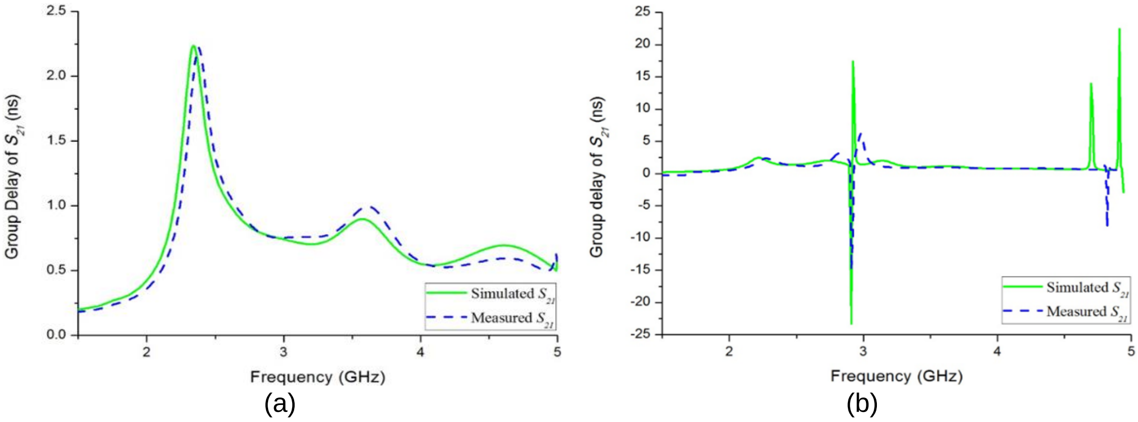


Figure 12. Comparison of group delay between simulated and measured response of switchable dual-band bandpass filter when (a) pin diode at OFF state (b) pin diode at ON state

4. Conclusion

In conclusion, the design and develop novel structures of switchable dual-band bandpass filter for wireless communication system at frequency 2.3-2.7GHz for WLAN and 3.1-3.75GHz for WiMAX for wireless communication applications has been successfully investigated and obtained. The performance of dual-band bandpass filter based on EM simulations to determine S-parameter, group delay and bandwidth has been discussed in this paper. The simulation results with experimental results of switchable dual-band bandpass filter has well-fabricated and validated in laboratory. This switchable filter had exhibited the fractional bandwidth of 46% centered at 3.05GHz when the diode was reversed biased in OFF state. When the pin diode was ON state, the results gave the return and insertion losses were greater than 10dB and better than 0.5dB respectively. This dual-passband attained the 3-dB fractional bandwidth of 18.9% and 20.3% with resonant frequency 2.64GHz and 3.45GHz. The overall dimensions were 45mm(L)x30mm(W), which consider as a large when compare with [13], and [14]. However, our design shows a good performance in terms of fractional bandwidth (FBW), and notch response. Where, it achieves FBW of 19.6%/ 18.7% and notch of 10%. Whereas, those designs are poor in fractional bandwidth of dual-band passband as well as the notch response (FBW of 2.89%/2.73% & 14%/15.28%, notch response of 4.1% and 4.3% respectively). The performance has shown good agreement between the simulation and measurement results. Further research can be undertaken to obtain triple-band bandpass filter with wide bandwidth.

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