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Analysis of T Shaped Resonator

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Abstract

A detailed analysis of the multiband bandpass filter has been presented in this letter. A single structure has been used to investigate multiband behavior. Increasing only the length of the stub in a proper ratio enable us to achieve single, dual, tri, quad and penta band characteristics without changing the shape of the structure. The design concept is increasing the length of the resonator section in a single filter circuit in order to increase the degrees of freedom. To verify the presented concept, four structures were designed and simulated with microstrip technology. For demonstration purpose, three of these structures have been fabricated and their experimental results are found to be in correlation with simulated results.

***Index Terms*:**Multiband band pass filter, Meander technique, stub loaded resonator, cross coupling

1 Introduction

In modern era, wireless communication technology has a rapid growth in electronic devices. Databases are proving that there is an exponential increase in the number of users of wireless technology. The evolution of wireless technology comforts wireless communication devices to be accessed anytime irrespective of the geographical location. The role of filters in wireless communication is more predominant and vital. Among all the available filters, the usage of band pass filters is more recommended compared to other filters in wireless applications. The reason behind this is band pass filters ensures the trap of microwave signals into specified spectral limits without any interference. Various configurations of band pass filter structures have been implemented using lumped element, coaxial, micro striplines and coplanar waveguide models [1]. There are several techniques and materials available for designing band pass filters. However, band pass filter which are to be used in wireless applications have to be designed in such a way that it satisfies the criteria such as compact size, minimized loss in single as well as multiband operation. Among bandpass filter structures, microstrip bandpass filters are very famous because of its ease of design with minimum fabrication cost and also less weight of the device. Recently multiband filters are most popular due to the high demand of multiband response and multiservice in communication systems [2]. The multifunctional device has to face more challenges in reducing the factors such as insertion loss, cost, weight and size. Main element of the band pass filter is resonator. Stepped Impedance Resonators (SIRs) [3] are the first technique in the design of multiband band pass filter. Later the development of MultiMode Resonator (MMR) [4], interdigital capacitor, meander line and Stub Loaded Resonator (SLR) [5] techniques aid in designing the multiband band pass filter. Either interdigital or meander technique is used to reduce the size of the resonator and additionally it act as a controlling parameter of harmonic resonant frequency which is desired. In both the techniques cross coupling exist on a particular resonator. This helps in improving the performance of the filter. In this article multiband band pass filter has been investigated based on T shape resonator. This T shaped resonator comes under symmetrical structure category. And also symmetrical structure must exhibit even-odd mode behavior. This symmetrical structure is the conventional structure. The conventional structure of T shaped resonator is been capable of producing tri-band in nature along with wide passband. Detailed research has been carried out by adding stubs to T shaped resonator and meandering various parts of the T shaped resonator and the obtained results have been explored by comparing with the filter characteristics. Here two sets of design aspects are discussed. The first design follows stub loading technique while the second design is done by employing a meandered line on the first design. These two proposed designs are done using the simulation tool named High Frequency Structural Simulator (HFSS). The frequency response of the designs can be determined using this simulation tool. The transmission characteristics, S11 and the reflection characteristics, S21 of the filters are experimentally measured by means of a vector network analyser. In general scenarios, it is been observed that the insertion loss should be greater than -3 dB at all frequencies and the return loss should be lesser than -10 dB. The proposed multiband band pass filter finds its application in the frequency bands such as Global System for Mobile communication (GSM), Wireless Local Area Network (WLAN) and Worldwide interoperability for Microwave Access (WiMAX) systems. The two investigated filters of this letter are fabricated on FR 4 substrate with whose dielectric constant (r) is 4.4, thickness is 1.6 mm and loss tangent () is 0.02.

2 CONVENTIONAL FILTER DEISGN

The research work has been initiated by considering the conventional structure. Stub loaded resonators has been used for the conventional filter design. The combination of a common transmission line and a single open ended stub forms the conventional band pass filter design. Common transmission line in the conventional structure is also called as uniform impedance resonator. The main transmission line has been designed by clubbing two stubs together. Stub is a small portion of transmission line. No separate feed line is been used in this design. The main transmission line itself acts as feed line to the circuit. Layout of the conventional band pass filter is shown in figure 1. The filter which is designed is a two port device. Here the ports are named, P1 (input port) and P2 (output port). The resonator used in this design is quarter wavelength resonator.

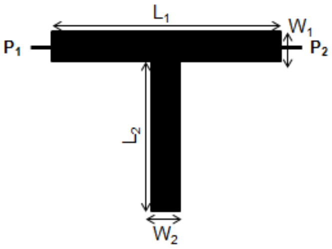


Figure 1. Layout of the conventional bandpass filter

The design specification of the quarter wavelength resonator has been indicated as L1, L2, W1, and W2. The exact dimensions of the filter are given as follows: L1 = L2 = 31.25mm, W1 = 2.58 mm, W2 = 4.2 mm. The designed filter is been analyzed using the simulation tool HFSS and the resultant graph is shown in figure 2.

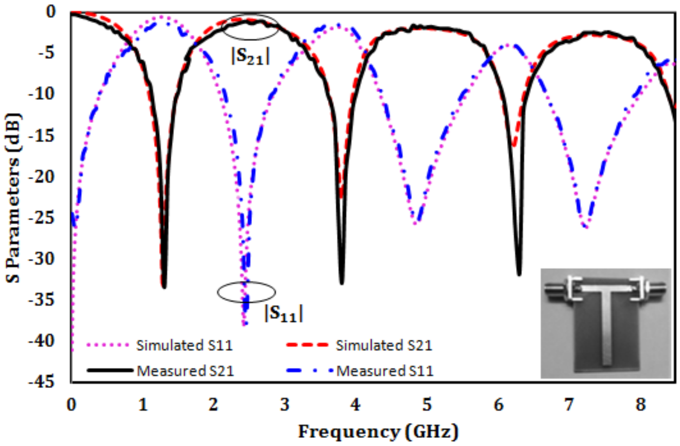


Figure 2. Simulated and measured result of conventional BPF

From this graph obtained it has been inferred that the design has produced a tri band (three pass bands) which is been achieved by means of using three sections of transmission line. The structure gives fundamental frequency of 2.4 GHz and higher order harmonic frequencies of 4.8 GHz and 7 GHz respectively. The fundamental as well as first higher order frequency is suitable for wireless local area network applications.

3 MODIFIED FILTERS

In this section, two cases of band pass filter analysis is been discussed. In Case I, the design work follows stub loading method whereas in case II, the filter is designed by meandering a resonator at several parts.

Case I:

As stated, the first design has been structured by means of implementing the stub loading technique. Stub loaded resonators are used to form the structure. In this case, the conventional band pass filter given above is been considered and a stub is connected at the end of the second resonator forming and L shape (i.e right angle bend). This addition of stub to the conventional structure makes the design asymetrical. The purpose of this addtion of stub to the uniform impedance resonator is to achieve more number of pass bands, improving the bandwidth. The proposed design 1 has been altered in order to achieve single, dual and quad bands band pass filters, only by increasing the electrical length of the resonators, has been achieved. Investigated filter structure is shown in figure 2.

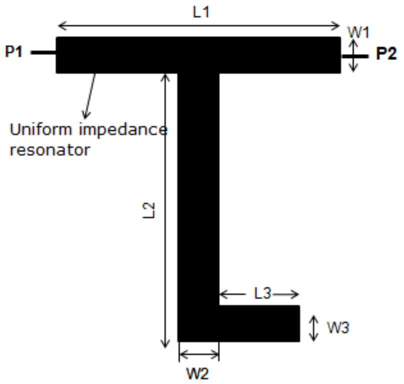
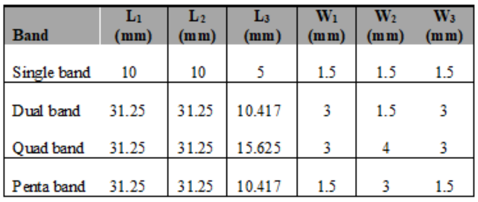


Figure 3. Layout of the modified T shape bandpass filter

TABLE I



Band	L_1 (mm)	L_2 (mm)	L_3 (mm)	W_1 (mm)	W_2 (mm)	W_3 (mm)
Single band	10	10	5	1.5	1.5	1.5
Dual band	31.25	31.25	10.417	3	1.5	3
Quad band	31.25	31.25	15.625	3	4	3
Penta band	31.25	31.25	10.417	1.5	3	1.5

Table I indicates the dimension of the proposed band pass filter. At L1=L2 scenario, the investigated filter has multiband nature. Based on L3 to L1 proportion of the filter, different bands have been achieved. Simulation and experimental results of band pass filter have been shown : dual band in figure 4 and quad band in figure 5. All these filter design results are consolidated and displayed in table II.

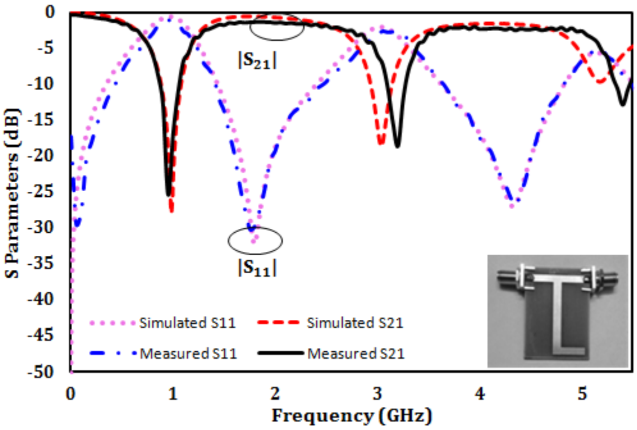


Figure 4. Simulation and experimental result of dual band BPF

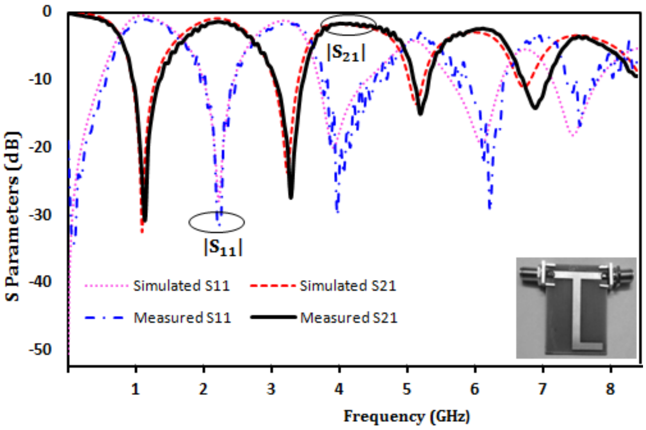


Figure 5. Simulation and experimental result of quad band BPF

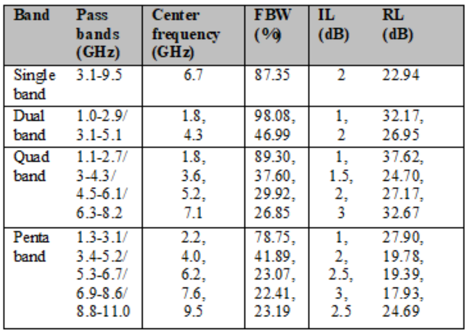
Case II:

This section describes three filter designs.

i. Filter A Replacing single open ended stub by meander line from T shape. ii. Filter B Replacing center section of stub by meander line from modified T shape resonator iii. Filter C Replacing open stub by meander line from modified T shaped resonator.

It presents the design of multiband band pass filter using uniform impedance resonator with meander technique. Filter A is formed by replacing single open ended stub by meander lines in conventional structure. It is capable of producing penta band response. The reason behind the respsponse is that the structure uses cross coupling mechanism at meandered stub. It helps the bandpass filter to achieve high selectivity. The dimensions of the filter are L1= 31.25mm, L2= 31.25 mm, W1= 3.5 mm, W2 = 5 mm. Meandered resonator of 0.5 mm width is been given for each slots.

TABLE II



Band	Pass bands (GHz)	Center frequency (GHz)	FBW (%)	IL (dB)	RL (dB)
Single band	3.1-9.5	6.7	87.35	2	22.94
Dual band	1.0-2.9/ 3.1-5.1	1.8, 4.3	98.08, 46.99	1, 2	32.17, 26.95
Quad band	1.1-2.7/ 3-4.3/ 4.5-6.1/ 6.3-8.2	1.8, 3.6, 5.2, 7.1	89.30, 37.60, 29.92, 26.85	1, 1.5, 2, 3	37.62, 24.70, 27.17, 32.67
Penta band	1.3-3.1/ 3.4-5.2/ 5.3-6.7/ 6.9-8.6/ 8.8-11.0	2.2, 4.0, 6.2, 7.6, 9.5	78.75, 41.89, 23.07, 22.41, 23.19	1, 2, 2.5, 3, 2.5	27.90, 19.78, 19.39, 17.93, 24.69

Comparing the results of conventional band pass filter with meandered band pass filter it is observed that the number of passbands has been increased, selectivity of the filter in each pass band has been improved and frequency responses are obtained at lower frequency ranges. Thus meandered band pass filter performance is been improved due to cross coupling. The proposed filter A structure is shown in figure 6. In this design, the meander section has fifteen number of turns. These turns are responsible for the filter to produce penta bands at lower frequency ranges. Simulation and experimental results are plotted in the graph shown in figure 7. Filter A has center frequency at 0.95 GHz and other harmonics frequencies are at 1.9, 3, 3.8 and 4.56 GHz respectively. Insertion loss falls below 2 dB and the return loss is greater than 27 dB. From the resonance frequencies obtained it is been observed that the fundamental frequency supports GSM applications very well and first higher order harmonics is also been suitable for GSM applications.

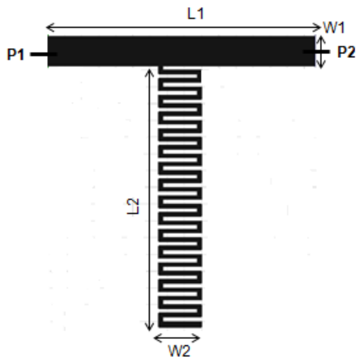


Figure 6. Layout of proposed filter A

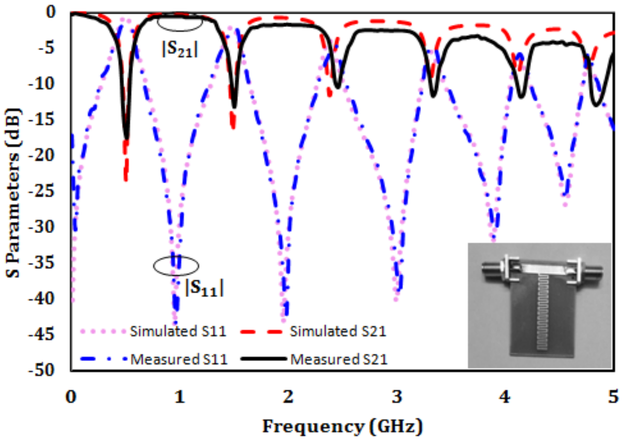


Figure 7. Filter A simulated and measured results

As discussed earlier filter B has been structured from modified T shaped reonator. Both stub and meander techniques are used in this design. The proposed filter structure is shown in figure 8. Compactness and better selectivity has been achieved in this design. The design configuration of filter B is L1 = L2 = 31.25 mm, L3 = 15.625 mm, W1= 2.5 mm, W2= 5 mm, W3= 2.8 mm, spacing = 0.5 mm. Filter B is asymmetrical in its structure and have discontinuity elements including right angle bend along with uniform impedance resonator. It makes the structure becomes tight cross coupling and multi mode resonance. From this detailed parametric study, optimum width parameters have been chosen to get the desired resonant frequencies. It has certain characteristics such as compact size, simple topology, closely spaced frequency responses, wide pass band, low insertion loss and high frequency selectivity. It is also been suitable for multiservice wireless communication. Filter B has measured centre frequencies at 0.9GHz (0.42-1.23 GHz), 1.8GHz (1.29-2.1 GHz), 2.6GHz (2.2-3.03 GHz) and 3.5GHz (3.1-3.84 GHz) with 10 dB bandwidths of 0.81, 0.81, 0.81 and 0.72 GHz respectively. The observed bandwidth response is shown in figure 9. The inference obtained from the response is filter B provides equally spaced bandwidths while providing closely spaced resonant frequencies. From the graph, it is been identified that fundamental and first harmonic frequencies are suitable for GSM applications. Remaining resonance frequencies support WLAN application.

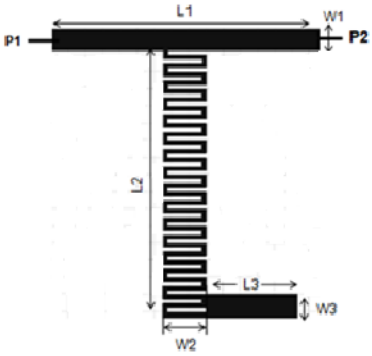


Figure 8. Layout of proposed filter B

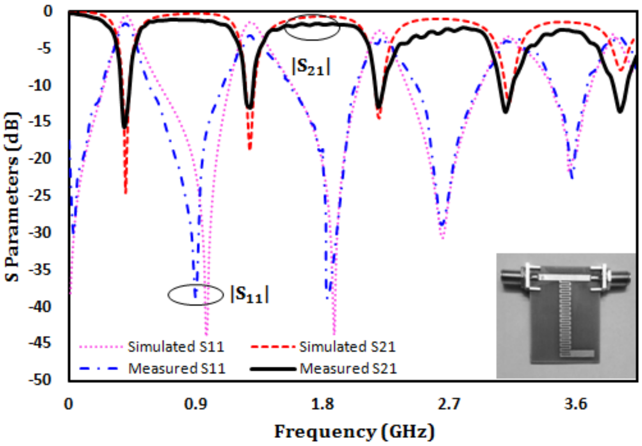


Figure 9. Filter B simulated and measured results

In filter C construction, changes were made at the open stub of the modified T shaped resonator. The design configuration of filter C is L1 = L2 = 31.25 mm, L3 = 15.625 mm, W1= 2.5 mm, W2= 5 mm, W3= 2.5 mm, spacing = 0.5 mm. Here the number of turns in the meandered portion should be less when compared to filter B. Due to less cross coupling, one band is reduced when compared with filter B. The structure of the filter is shown in figure 10.

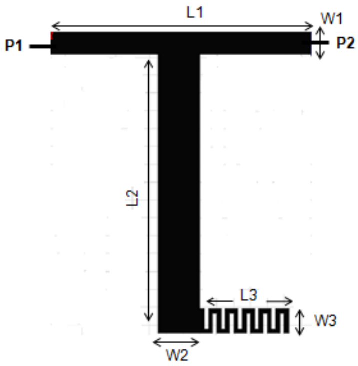


Figure 11. Filter C simulated and measured resultsF

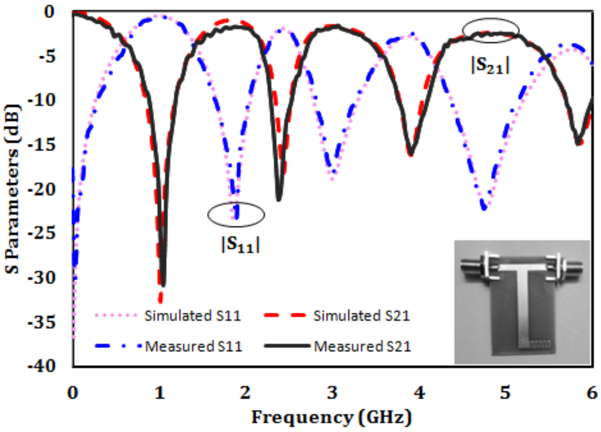


Figure 4. Simulation and experimental result of dual band BPF

The simulation and experimental results that are plotted for comparison is been shown in figure 11. It shows that above 18 dB, the selectivity of filter C is very high. Insertion loss was not more than 4 dB. This structure is suitable for both GSM and WLAN application in the frequencies of 1.8 GHz, 3 GHz and 4.7 GHz.

Throughout this investigation, all the filters that are designed are employed without separate feedline. Direct feed has been applied via uniform impedance resonator. These filters experience single transmission zero in each passband.

4 Conclusion:

Investigation of filters has been done by following stub loading and meandered techniques. Two cases of filter design have been discussed. These two cases satisfies the scenario of L1=L2 condition. The designed filters are relatively simple and they provide high selectivity, closely spaced resonant frequencies and wide pass bands.

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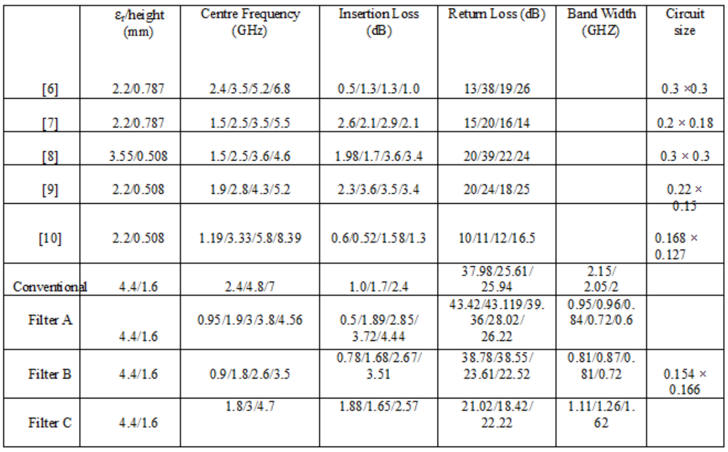
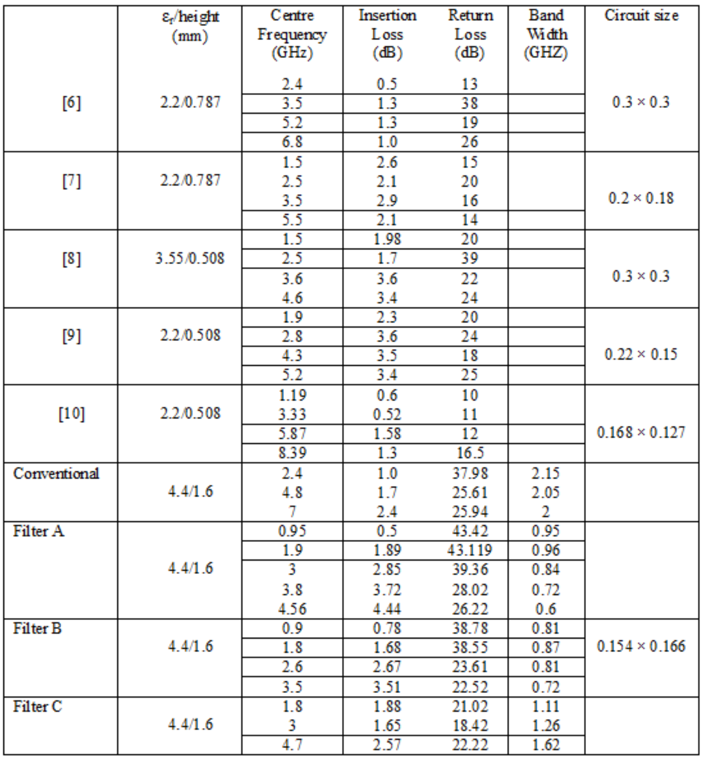
TABLE III



	ε_r/height (mm)	Centre Frequency (GHz)	Insertion Loss (dB)	Return Loss (dB)	Band Width (GHZ)	Circuit size
[6]	2.2/0.787	2.4/3.5/5.2/6.8	0.5/1.3/1.3/1.0	13/38/19/26		0.3 ×0.3
[7]	2.2/0.787	1.5/2.5/3.5/5.5	2.6/2.1/2.9/2.1	15/20/16/14		0.2 × 0.18
[8]	3.55/0.508	1.5/2.5/3.6/4.6	1.98/1.7/3.6/3.4	20/39/22/24		0.3 × 0.3
[9]	2.2/0.508	1.9/2.8/4.3/5.2	2.3/3.6/3.5/3.4	20/24/18/25		0.22 × 0.15
[10]	2.2/0.508	1.19/3.33/5.8/8.39	0.6/0.52/1.58/1.3	10/11/12/16.5		0.168 × 0.127
Conventional	4.4/1.6	2.4/4.8/7	1.0/1.7/2.4	37.98/25.61/25.94	2.15/2.05/2	
Filter A	4.4/1.6	0.95/1.9/3/3.8/4.56	0.5/1.89/2.85/3.72/4.44	43.42/43.119/39.36/28.02/26.22	0.95/0.96/0.84/0.72/0.6	
Filter B	4.4/1.6	0.9/1.8/2.6/3.5	0.78/1.68/2.67/3.51	38.78/38.55/23.61/22.52	0.81/0.87/0.81/0.72	0.154 × 0.166
Filter C	4.4/1.6	1.8/3/4.7	1.88/1.65/2.57	21.02/18.42/22.22	1.11/1.26/1.62	



	ε_r/height (mm)	Centre Frequency (GHz)	Insertion Loss (dB)	Return Loss (dB)	Band Width (GHZ)	Circuit size
[6]	2.2/0.787	2.4	0.5	13		0.3 × 0.3
		3.5	1.3	38		
		5.2	1.3	19		
		6.8	1.0	26		
[7]	2.2/0.787	1.5	2.6	15		0.2 × 0.18
		2.5	2.1	20		
		3.5	2.9	16		
		5.5	2.1	14		
[8]	3.55/0.508	1.5	1.98	20		0.3 × 0.3
		2.5	1.7	39		
		3.6	3.6	22		
		4.6	3.4	24		
[9]	2.2/0.508	1.9	2.3	20		0.22 × 0.15
		2.8	3.6	24		
		4.3	3.5	18		
		5.2	3.4	25		
[10]	2.2/0.508	1.19	0.6	10		0.168 × 0.127
		3.33	0.52	11		
		5.87	1.58	12		
		8.39	1.3	16.5		
Conventional	4.4/1.6	2.4	1.0	37.98	2.15	
		4.8	1.7	25.61	2.05	
		7	2.4	25.94	2	
Filter A	4.4/1.6	0.95	0.5	43.42	0.95	
		1.9	1.89	43.119	0.96	
		3	2.85	39.36	0.84	
		3.8	3.72	28.02	0.72	
		4.56	4.44	26.22	0.6	
Filter B	4.4/1.6	0.9	0.78	38.78	0.81	0.154 × 0.166
		1.8	1.68	38.55	0.87	
		2.6	2.67	23.61	0.81	
		3.5	3.51	22.52	0.72	
Filter C	4.4/1.6	1.8	1.88	21.02	1.11	
		3	1.65	18.42	1.26	
		4.7	2.57	22.22	1.62	

References

[1] D.Pozar, Microwave engineering, John Wiley & Sons, Inc 2012.

[2] M. Pal and R. Ghatak, A Distinctive Resonance: Multiband Bandpass Filter Design Techniques Using Multimode Resonators, IEEE Microwave Magazine ., vol.16, no.11, pp. 36-55, Dec. 2015.

[3] Jian-Xin Chen, Yang Zhan, and Quan Xue, Novel LTCC Distributed-Element Wideband Bandpass Filter Based on the Dual-Mode Stepped-Impedance Resonator, IEEE Trans. On Comp. Packaging And Manufacturing Technology, vol. 5, no. 3, March 2015.

[4] Wenjie Feng1, Wenquan Che1, Liming Gu1, Quan Xue2, High-selectivity wideband balanced bandpass filters using symmetrical multi-mode resonators, IET Microwaves, Antennas & Propagation, vol. 07, no. 12, pp. 10051015, Jan. 2013

[5] Feng Wei, Pei-Yuan Qin, Y. Jay Guo and Xiao-Wei Shi, Design of multi-band bandpass filters based on stub loaded stepped-impedance resonator with defected microstrip structure, IET Microwaves, Antennas & Propagation., vol.10, no. 2, pp. 230-236, 2016.

[6] Hung-Wei Wu, and Ru-Yuan Yang, A New Quad-Band Bandpass Filter Using Asymmetric Stepped Impedance Resonators, IEEE Microw. Wireless Compon. Lett., vol. 21, no. 4, pp. 203205, Apr. 2011

[7] Hsu, K.-W., Tu, W.-H.: Sharp-rejection quad-band bandpass filter using meandering structure, Eletron. Lett., 2012, 48, (15), pp. 935937.

[8] J.-Y. Wu and W.-H. Tu, Design of quad-band bandpass filter with multiple transmission zeros, Electron. Lett. , vol 47, no 8, April 2011.

[9] Xu, J., Miao, C., Cui, L., et al.: Compact high isolation quad-band bandpass filter using quad-mode resonator, Electron. Lett., 2012, 48, (1), pp. 2830.

[10] Xu, J., Wu, W., Miao, C.: Compact microstrip dual-/tri-/quad-band bandpass filter using open stubs loaded shorted stepped-impedance resonator, IEEE Trans. Microw. Theory Tech., 2013, 61, (9), pp. 31873199.

[11] J. Mo, X. Liu, H. Yang, S. Liu, High-selectivity microstrip bandpass filters using stub-loaded resonators, Optik- International Journal for Light and Electron Optics (2015).

[12] L. Ren and H. Huang, Dual-band bandpass filter based on dual-plane microstrip/interdigital DGS slot structure, Electron. Lett. , vol 45, no 21, oct. 2009.

[13] Haiwen Liu, Baoping Ren, Xuehui Guan, Pin Wen, and Yan Wang, Quad-Band High-Temperature Superconducting Bandpass Filter Using Quadruple-Mode Square Ring Loaded Resonator, IEEE Trans. On Microwave Theory And Techniques, Vol. 62, No. 12, Dc.2014.

[14] Hong-wei Deng, Yong-jiu Zhao, Ying He, Hao Liu, Hong-li Wang, High selectivity and common-mode suppression wideband balanced bandpass filter using slotline resonator, IET Microw. Antennas Propag.,2015, vol.9, no.6, pp. 508-516

[15] K.-W.Hsu,W.-H.Tu, Design of asymmetrical resonator for microstrip triple-band and broadband bandpass filters, Microelectron Journal 2015.

[16] Ko-Wen Hsu, Jui-Hsiang Lin, Wei-Chung Hung, and Wen-Hua Tu, Design of Compact Quad-Band Bandpass Filter Using Semi-Lumped Resonators, IEEE 2013, 978-1-4673-2141-9.

[17] Chenwei Cui and Yun Liu, quad-band bandpass filter design by embedding dual-band bandpass filter with dual-mode notch elements, Electron. Lett. , vol 50, no 23, April 2014.

[18] J.-C. Liu, J.-W. Wang, B.-H. Zeng, and D.-C. Chang, CPW-fed dual mode double-square-ring resonators for quad-band filters, IEEE Microw. Wireless Compon. Lett., vol. 20, no. 3, pp. 142144, Mar. 2010.

[19] Chen, F.C., Chu, Q.X., Tu, Z.H.: Tri-band bandpass filter using stub loaded resonator, Eletron. Lett., 2008, 44, (12), pp. 747749.

[20] Wei, F., Huang, Q.L., Li, W.-T., et al.: A compact quad-band bandpass filter using novel stub loaded SIR structure, Microw. Opt. Technol. Lett., 2014, 56, (3), pp. 538542