A Novel Miniaturized Microstrip Low-pass Filter with Wide stopband using a Modified Hairpin Resonator

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Abstract: In this paper, a novel miniaturized low-pass filter (LPF) with wide stopband and low insertion loss using a modified hairpin resonator is presented. By optimizing the dimensions of the modified hairpin resonator and addition of a symmetric semi-circular open-end unit as a suppressing cell, the undesirable response and unwanted harmonics are suppressed; hence, a wide stopband from 5.94 GHz to 32.27 GHz is achieved. The transition band is 0.4 GHz from 5.54 GHz to 5.94 GHz with the attenuation level of -3 dB and -20 dB, respectively. The proposed LPF with -3 dB cut-off frequency of 5.54 GHz is designed, fabricated and measured. The size of the fabricated low-pass filter is only 73.84 mm2. The simulated results are compared with the measured results and good agreement between them is obtained.
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Keywords: Hairpin resonator, Low-pass filter, Wide stopband

1. Introduction

Microstrip low-pass filters have been widely used to suppress harmonics and spurious signals in communication systems. Compact size, low insertion loss, sharp roll off, and wide stopband are highly desirable factors to design the LPFs.

One of the main microstrip structures to design a LPF is the hairpin structures, which has benefits such as easy fabrication [1].

A LPF with wide stopband using coupled line hairpin unit has been presented in [2]. In this filter, the insertion loss and the return loss in the passband and the attenuation level in the stopband are not adequate. In [3], a LPF with the shunt open stubs at the feed points of a center feed coupled line hairpin resonator has been proposed with very wide stopband and sharp response, but the rejection level and the S_{11} parameters in the stopband are not satisfactory.

The conventional stepped-impedance filter, with hairpin resonator, in [4] has a simple structure, but it provides a gradual response in the transition band. In [5] a low-pass filter using stepped impedance hairpin units has been proposed, which has a low insertion loss, but it is not compact and has a gradual transition band, also it does not have a wide stopband. In [6], a LPF based on microstrip coupled-line hairpin unit, spiral slot and open stubs has been presented.

It has a compact size with an approximate wide stopband, but its frequency response is gradual in the transition band.

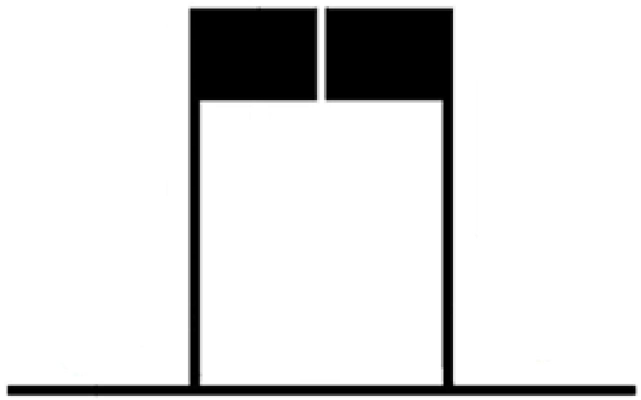
In this paper, a hairpin resonator is modified by open-end step impedance stubs to have a sharp response with -3 dB cut-off frequency of 5.54 GHz. To suppress the harmonics in higher frequencies a symmetric semi-circular unit is added to the proposed resonator. The result is a compact wide stopband LPF with optimum specifications such as low insertion loss less than 0.13 dB and good return loss better than 15.8dB, in the passband.

2. Filter design

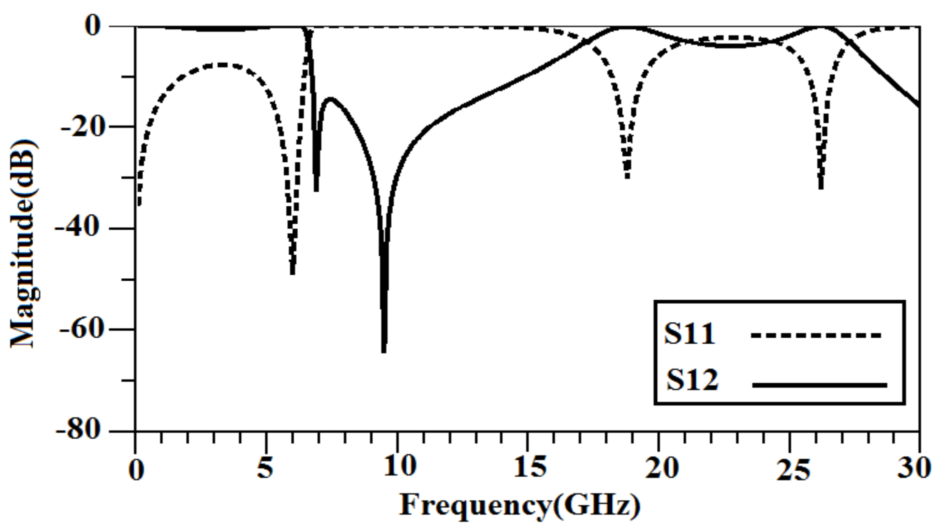
In the first step, an appropriate prototype elliptic function hairpin low-pass resonator is selected as shown in Figure 1(a).The simulated S-parameters of the proposed hairpin resonator, which is designed to have a -3 cut-off frequency of 5.54 GHz, is shown in Figure 1(b).

The resonator creates two transmission zeros at 6.9 GHz and 9.5 GHz with the attenuation level of -32.81 dB and -64.65 dB, respectively.

As seen from Figure 1(b), the most important problem in this structure is the insertion loss in the passband, which has a large value about 0.82 dB.



(a)



(b)

Figure 1. (a) The proposed hairpin resonator; (b) The simulated S-parameters of the proposed hairpin resonator

To solve this problem, a step impedance open-end unit is symmetrically added to the proposed hairpin resonator as shown in Figure 2. By adding these arms, the order of the circuit (filter) is increased; hence the return loss in the passband is improved and a good insertion loss nearby 0 dB can be obtained in the passband.

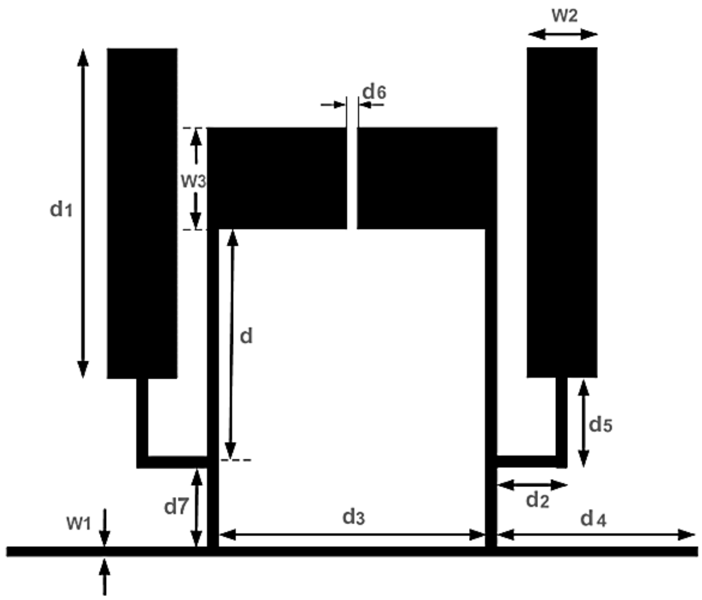
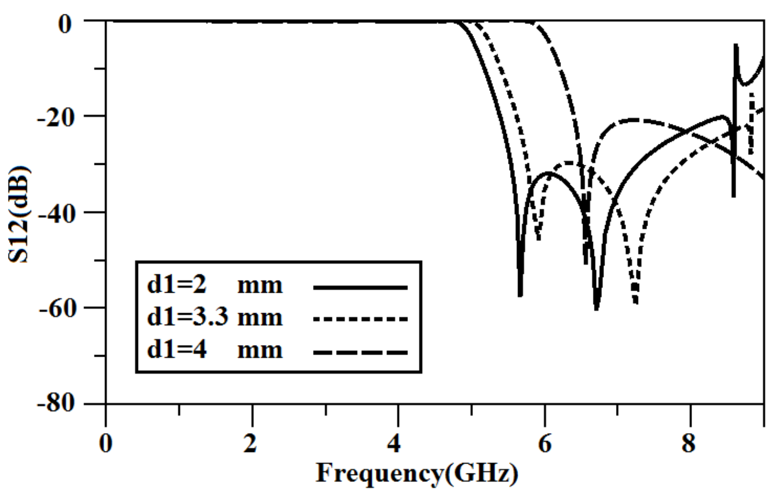
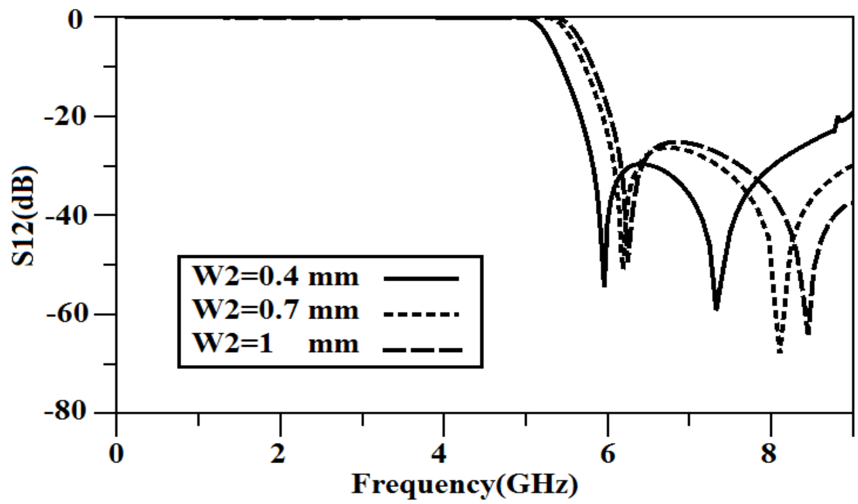


Figure 2. The improved proposed hairpin resonator resulted with the addition of symmetric open-end stubs

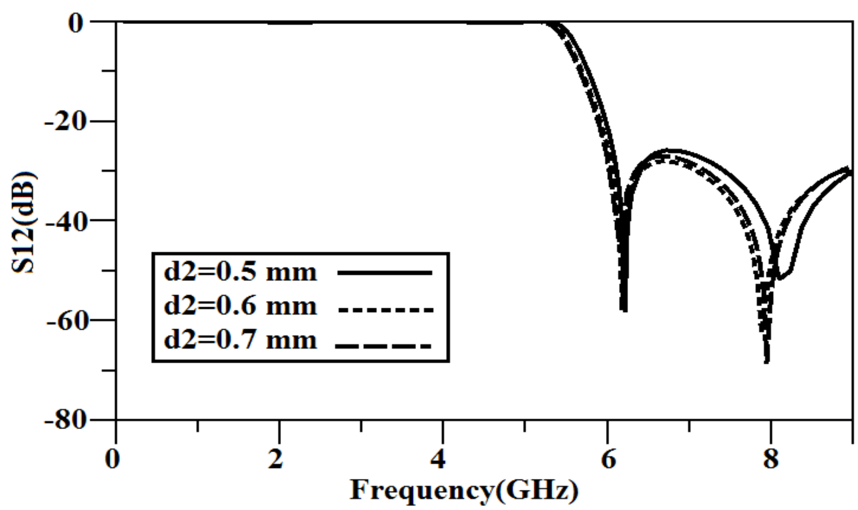
Figure 3(a) and Figure 3(b) shows the S12 parameter of the proposed resonator as a function of d1 and W2, respectively. Clearly, by increasing d1 from 2 mm to 4 mm and W2 from 0.4 mm to 1 mm, the capacitance of the added open-end stub with length of d1 and width of W2 increases, hence the transmission zeros get smaller to have a sharper transition band. The S12 Parameter of the proposed resonator as a function of d2 is shown in Figure 3(c). As seen from the Figure, by changing the distance between the open-end step impedance stubs and the hairpin resonator, the transmission zeros don't move significantly, it means that the coupling capacitance between these units can be negligible.



(a)



(b)



(c)

Figure 3. (a) The S12 parameter of the proposed resonator as a function of d1; (b) The S12 parameter of the proposed resonator as a function of W2; (c) The S12 parameter of the proposed resonator as a function of d2

With respect to the optimization with an EM simulator (ADS), the dimensions of the improved proposed hairpin resonator are obtained as follows: d= 2.3, d1 =3.3, d2 =0.7, d3 =2.7, d4 =2, d5 =0.9, d6 =0.1, d7=0.8, W1 =0.1, W2 =0.7, W3 =1, all in mm.

The simulated S-parameters of the proposed improved hairpin resonator is shown in Figure. 4. As seen, the resonator has a sharp transition band and low insertion loss less than 0.15 dB in the passband with -3 cut-off frequency at 5.5 GHz.

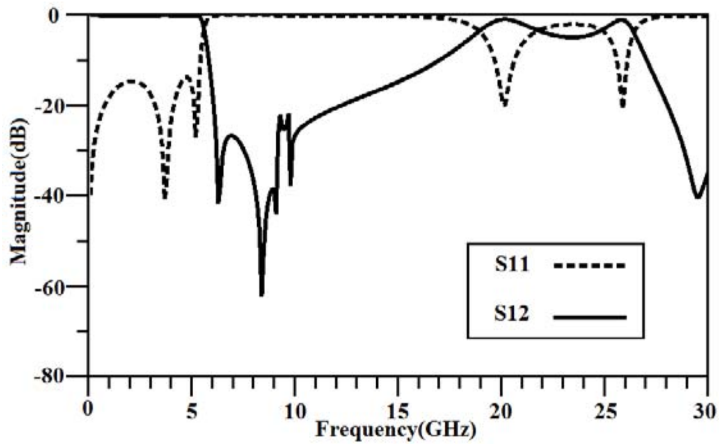


Figure 4. The simulated S-parameters of the proposed improved hairpin resonator

To extend the stopband, a symmetric semi-circular open-end cell as shown in Figure 5 is used.

This microstrip cell is used to perform the -20 dB suppression in the frequency range of 13 GHz to 32 GHz. The S12 parameter of the proposed suppression cell is shown in Figure 6.

As seen, the suppression cell creates a transmission zero at 22.5 GHz with the high attenuation level of -61.5 dB, which provide a wide stopband for the proposed LPF.

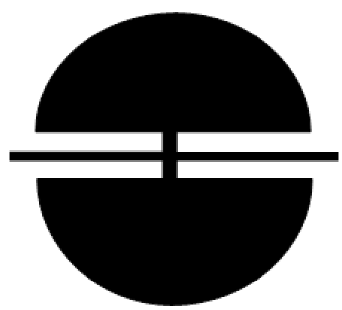


Figure 5. The symmetric semi-circular open-end unit as suppression cell

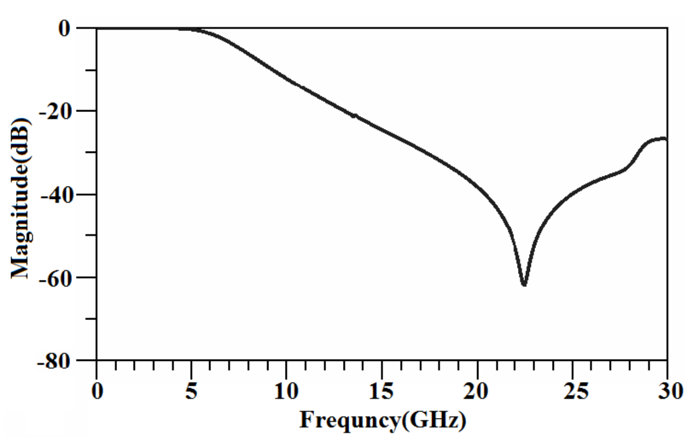


Figure 6. The S_{12} parameter of the proposed suppression cell

3. Simulation and measurement results

The layout of the fabricated low-pass filter is shown in Figure 7. The source and the load of the structure have characteristic impedance of Z0 equal to 50 Ω. The remaining dimensions of the LPF are as follows: a=2, b=1.7, d8=0.6, d9=0.8, W4=0.2, W5=1.5, all in mm. The proposed low-pass filter is implemented on (RT/Duriod 5880) substrate with relative permittivity, height and a loss tangent equal to 2.2, 15mil and 0.0009, respectively. The photograph of the fabricated filter is shown in Figure 8.

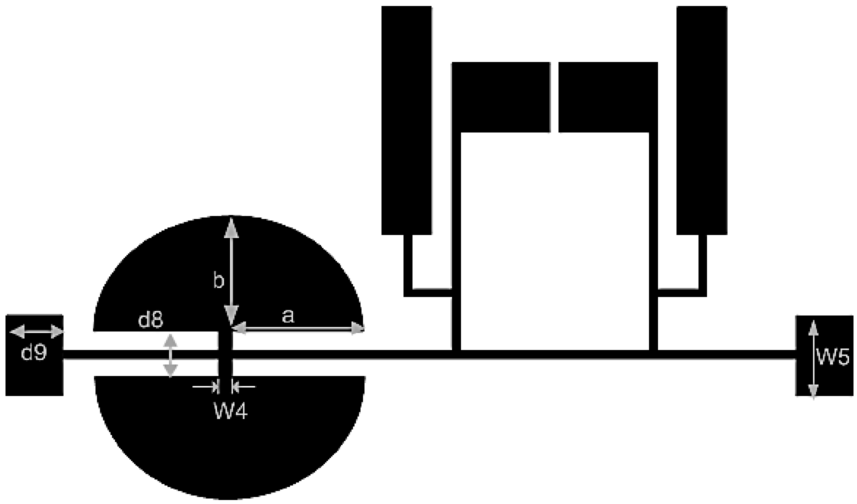


Figure 7. The layout of the fabricated low-pass filter

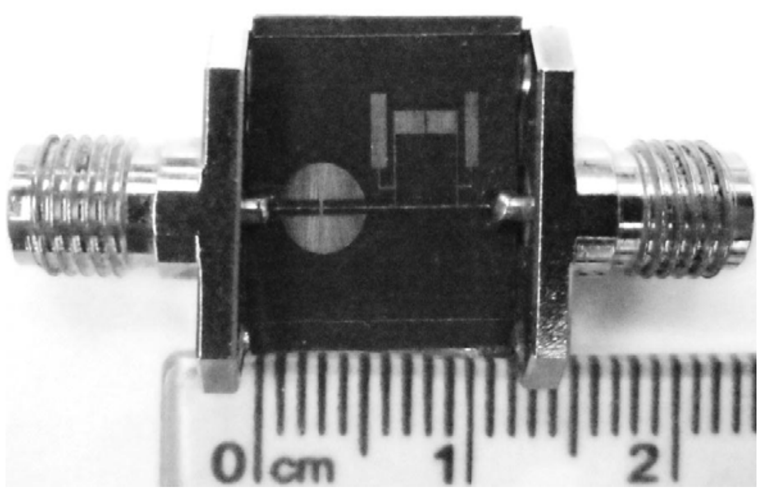


Figure 8. The photograph of the fabricated filter

The simulated and measured results of the proposed filter are illustrated in Figure 9. The measurements of the proposed LPF are carried out using an HP8757A network analyzer. As seen, the attenuation level in the stopband is higher than -20 dB. The stopband width (SBW) is achieved from 5.94 GHz to 32.27 GHz, which shows a wide stopband. The proposed filter has low insertion loss (IL) of less than 0.13 dB and return loss (RL) of more than 15.8 dB in the passband. The frequency response of the filter is adequate sharp with the transition band equal to 0.4 GHz from 5.54 GHz to 5.94 GHz with corresponding attenuation levels of -3 and -20 dB.

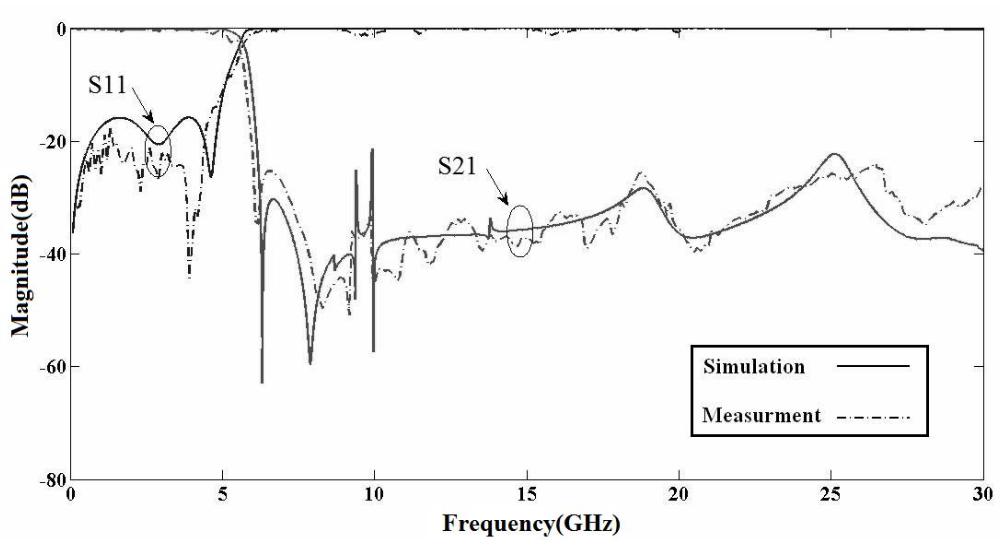


Figure 9. The simulated and measured results of the proposed filter

Table 1. Performance comparison of the proposed LPF with other works.

Ref.	ε_r	f_c(GHz)#	SBW	Size(mm2)	RL (dB)	IL(dB)
[2]	2.2	2.4	12.6	20×23	10	1.2
[3]	4.3	0.5	3.7	34.62×70.95	16.3	0.5
[4]	10.8	1.5	5.4	23.1×7.5	16.42	0.7
[5]	2.65	1	4.5	22.4×24.25	20	0.4
[6]	2.2	2	20	10.2×15.15	10	1
[7]	2.2	5.45	31.3	50×4.42	15	0.15
This work	**2.2**	**5.54**	**26.33**	**10.4×7.1**	**15.8**	**0.13**

As seen from Figure 10, the group delay in the passband for the proposed LPF has a maximum variation about 0.6 ns.

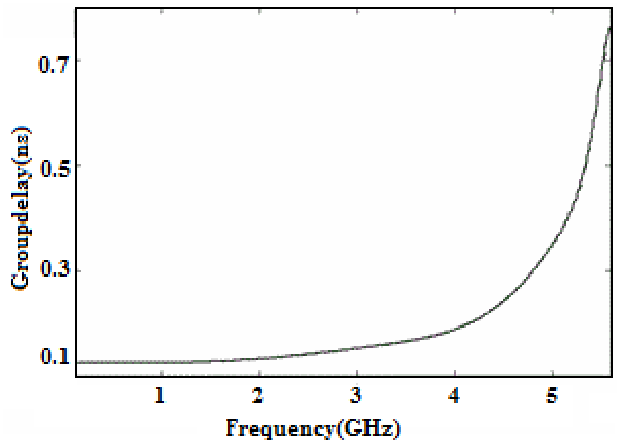


Figure 10. The group delay through the passband

The comparison between the performances of the proposed filter with the other works is shown in Table.1. As seen from the table, the proposed LPF has the best insertion loss in the passband, among the other works. The size of the filter is only 73.84 mm^2, the smallest size among [1-7], and also a wide stopband among the quoted hairpin filters [2-6]. The sharpness of cutoff frequency from -3 dB to -20 dB is about 0.4 GHz that is just 7.2% of the bandwidth and is sharper than [2-8].

4. Conclusion

A novel compact low-pass filter using a new modified hairpin resonator loaded by open-end stepped impedance stubs is designed, fabricated and measured. The measurement results show that the fabricated filter has many benefits such as compact size, low insertion loss in the passband, wide stopband and sharp transition band. The proposed LPF with these features is a good candidate for the modern microwave applications.

References

1. Lung-Hwa Hsieh and Kai Chang. (2001): Compact low-pass filter using stepped impedance hairpin resonator. Electron.Lett Vol. 37, No. 14.
2. Wei, F.; Chen, L.; Shi, X.-W.; Huang, Q.-L.; and Wang, X.-H. (2010): Compact low-pass filter with wide stopband using coupled line hairpin units. Electron.Lett. vol.46, no.1, 88-90.
3. Velidi, V. K.; and Sanyal, S. (2011): sharp roll-off low-pass filter with wide stopband using stub-loaded coupled-line hairpin unit.
4. IEEE Microw. Wireless compon.Lett., vol .21, no. 6, 301-303.
5. Tu, W.H and Chang, K. (2005): Compact microstrip low-pass filter with sharp rejection, Microwave Optical Tech. Lett., vol. 15, no. 6: 404-406.
6. L. Li, Li, and Mao, J.-F (2010):.Compact low-pass filters with sharp and expanded stopband using stepped impedance hairpin units", IEEE Microwave and Wireless components letters, vol. 20, pp. 310-312,
7. Wei, F.; Chen, L.; Shi, X.-W (2012): Compact low-pass filter based on coupled-line hairpin unit", Electronics Letters, vol. 48, no. 7, pp. 379 - 381.
8. Hayati, M and Shama, F (2012): Compact microstrip low-pass filter with wide stopband using symmetrical U-shaped resonator", IEICE Electronic Express, vol.9, pp. 127-132.
9. O. R. Seryasat, M. Aliyari shoorehdeli, F. Honarvar, Abolfazl Rahmani "Multi-fault diagnosis of ball bearing based on features extracted from time-domain and multi-class support vector machine (MSVM)" 2010 IEEE International Conference on Systems, Man, and Cybernetics.