

# Bandpass Filter with Interdigital Capacitor in Open Loop Resonator for Wimax, RF-MEMS, and PCS Applications

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**Abstract.** In this paper, the design of a bandpass filter (BPF) using open-loop resonator (OLR) with interdigital capacitor added in one set of a half-wavelength resonator is presented. The open-loop resonator filter is constructed by placing a half-wavelength microstrip lines to achieve enhanced filter performance. The interdigital capacitors are employed to control the center frequency easily. An open-loop resonator is derived from one and half-wavelength resonator, which is used to enhance bandwidth. It also introduces transmission zeros in the passband. The three coupling methods, such as electric, magnetic, and mixed-couplings, are used to design the filter with desired characteristics. The filter is operating at 1.93 GHz and 2.41 GHz with 3 dB bandwidth of 8.8% and 9.5%, insertion loss of 0.6 dB and 0.5dB, return loss of passbands >15 dB, and two transmission zeros at 1.71 GHz and 2.88 GHz with better sharpness. The simulation performance evaluations of the filter are carried out using Computer Simulation Technology (CST). The proposed filter makes it very desirable for WiMAX and high-performance RF microelectromechanical system (RF-MEMS) tunable filter and PCS applications.

**Keywords:** Bandpass Filter (BPF), OLR, WiMAX, RF-MEMS

## 1. Introduction

RF filter is the critical component of wireless communication systems. In fast-growing technologies, the multi-band filters are highly desirable. Different approaches to mitigate the challenges associated with the design of a multi-band or dual-band bandpass filters have been proposed [1-8]. A dual-band bandpass filter design using a novel feed scheme which provides enough degrees of freedom to control the center frequency and bandwidth of the two passbands [1]. A compact bandpass filter using a polygonal open-loop resonator provided compactness in the microstrip bandpass filter [2]. However, it does not cover large frequency bands [2]. Two novel dual-band bandpass filters with multiple transmission zeros were proposed  $\lambda/4$  stepped-impedance resonators (SIRs) [3].

The stepped impedance parallel lines have been proposed to design BPFs and its various configurations were also investigated [4-6]. Some other resonator depends on Euclidean figures [7- 9] and fractal shapes [10] have also been investigated. The inter-digital capacitor approach was used to control the bandwidth of the filter. A high-selectivity planar multi-band bandpass filter with high interference suppression between the bands was presented [15] The proposed filter utilizes two different kinds of resonators, i.e., stub-loaded resonator and open-loop resonator. An open-loop resonator was embedded inside the stub-loaded resonator to achieve compactness of the circuit. A novel microstrip balun bandpass filter (BPF) was designed by using open-loop resonators having interdigital capacitors [16]. The interdigital capacitors were employed to control the center frequency easily. The opposite phase difference between the balanced outputs can be provided according to the suitable coupling topologies based on parallel and anti-parallel coupled lines. By using this method, minimized magnitude imbalances between the balanced ports can also be obtained. In order to

achieve two poles inside the passband, two identical resonators were coupled to each other.

In this paper, a dual bandpass filter with the interdigital capacitors and open-loop resonator is presented. It is suitable for WiMAX, RF microelectromechanical system (RF-MEMS) based tunable filters, and personal communication services (PCS) applications. The open-loop resonator filter is constructed by placing the half-wavelength microstrip lines implemented by an open-loop shape with a specific coupling structure to achieve desired filter performance. An open-loop resonator utilizes the odd and even mode field configurations which enhances the bandwidth and introduces transmission zeros in the passband. The electric, magnetic, and mixed-coupling methods are used to design the filter with desired characteristics. Two dual-band open-loop resonators with 7.3% and 12% bandwidth are utilized, respectively. Further, the interdigital capacitor is also used to increase the bandwidth by changing the length, gap, and width. The coupling coefficient can conveniently be tuned up to the desired value within a wide range of bandwidth. Based on this idea, the filter is implemented operating at 1.93GHz for RF-MEMS, PCS, and WiMAX applications.

## 2. Proposed filter design

The configuration of the proposed filter is shown in Figure 1. It is consisting of using two open-loop resonators and two interdigital capacitors. There are seven different length segments of open-loop resonator those are not connected to each other. The filter is designed on Rogers substrate (Rogers RT 5880) with relative permittivity of 2.2 and a thickness of 0.787mm. The overall dimension of the filter is 28.3 x 21.7mm<sup>2</sup>. This filter has 8.8% and 9.5% wider bandwidth with center frequencies 1.93 GHz and 2.41 GHz, respectively. The entire simulation is carried out using Computer Simulation Technology (CST).

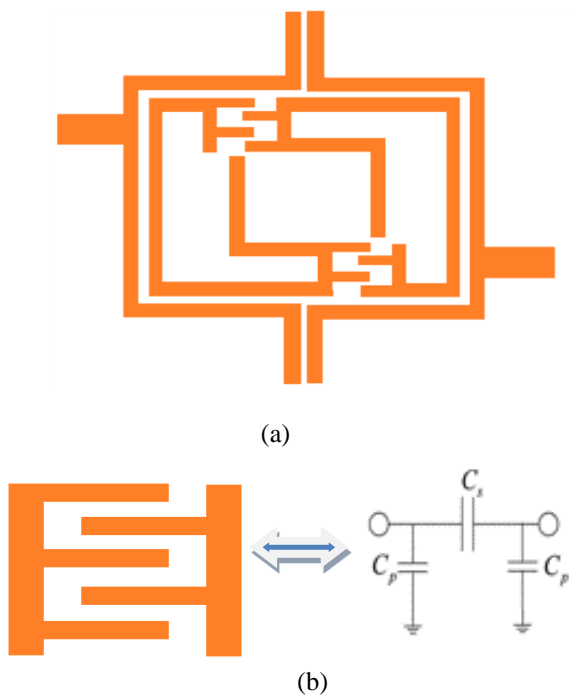


Fig. 1 (a). Configuration of the proposed bandpass filter, (b). Interdigital capacitor with its equivalent circuit.

**3. Structure development and frequency response**

Initially, open-loop single resonator is studied. Figure 2 shows the structure of open-loop single resonator with its frequency response in Figure 2. It consists of two transmission lines of 50Ω are connected to the outer open-loop resonators, acting as input and output ports. It provides single pass band. To achieve dual pass band, an open-loop resonator with interdigital capacitors are embedded inside the open-loop resonator of Figure 2 as shown in Figure 3 (a). The frequency response of the proposed filter is shown in Figure 3(b). The interdigital capacitors are utilized to realize inter-stage coupling, which provides increased bandwidth and compactness in microstrip bandpass filter. In order to provide enough degrees of freedom for achieving both wide and narrow upper passband, interdigital capacitors are employed to control the coupling strength within a wide range of frequencies. It can conveniently be tuned by changing the number of fingers, length of the fingers, and the gap between fingers. It is also noted that the coupled lines can be used instead of the interdigital capacitor in case of a narrow upper passband. The overall length (L) of the outer lines can be calculated as:

$$L=L_1+2L_2+2L_3+d+W$$

Open-circuited coupled lines with the length  $L_3$  and gap are employed to realize electrical coupling.

Due to brevity, the variations of a few shape parameters are shown here. The variation of parameters  $m_6$  and  $n_6$  are demonstrated in Figures 4 and 5, respectively. It is observed that the desired frequency bands can conveniently be tuned by varying the shape parameters  $m_6$  and  $n_6$ . The optimized shape parameters of the proposed filter are shown in Table 1.

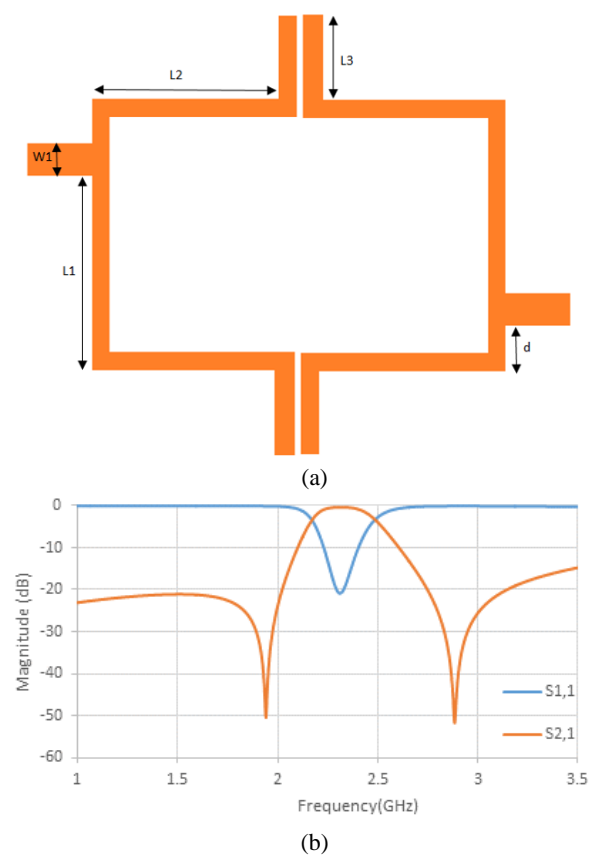


Fig. 2. Single resonator (a) geometry (b) frequency response

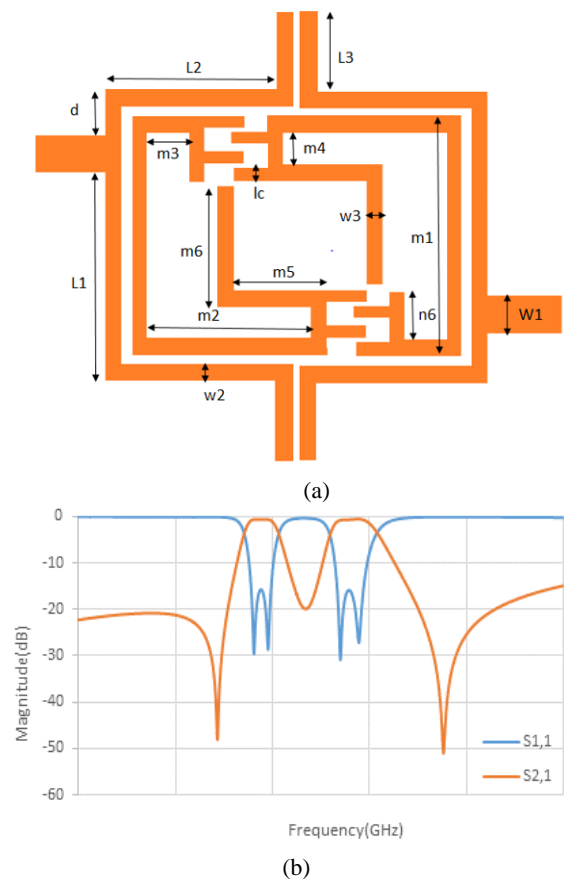


Fig. 3. Dual-band pass filter (a) geometry (b) frequency response

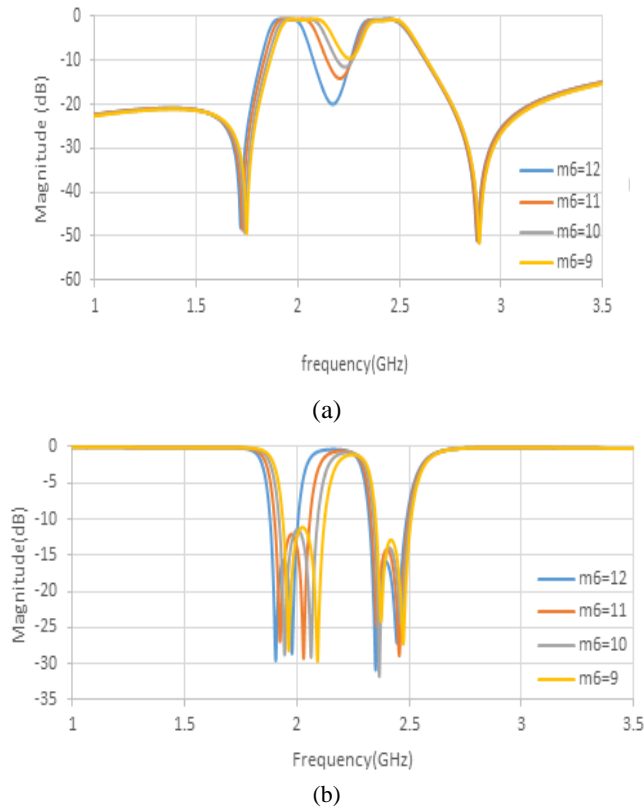


Fig. 4. Variation of different values of  $m_6$  (a) insertion loss (b) reflection coefficient

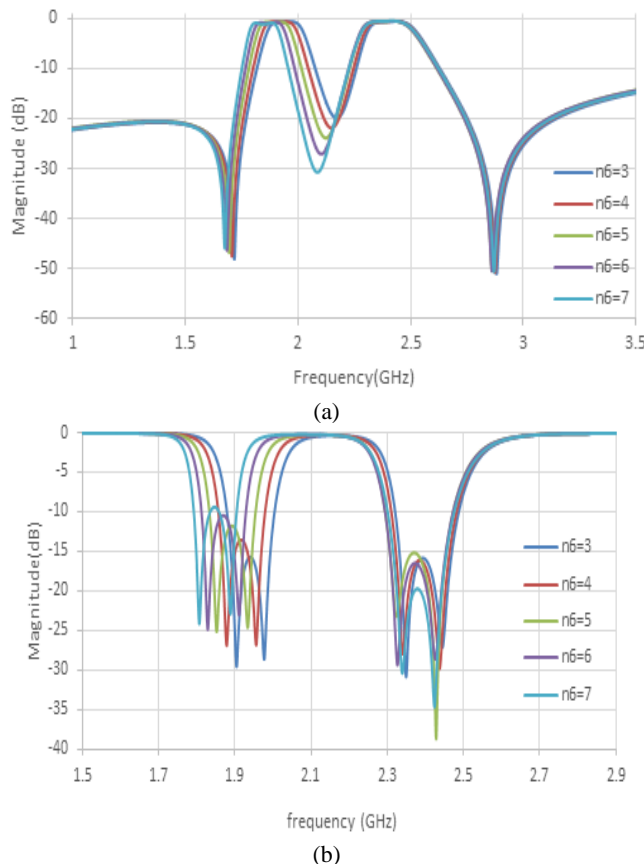


Fig. 5. Variation of different values of  $n_6$  (a) insertion loss (b) reflection coefficient.

Table 1. Optimized shape parameters of the proposed filter. All dimensions are in millimeter.

Parameter	L1	L2	L3
Value	12.55	10.65	4.9
Parameter	W1	W2	W3
Value	2.4	0.7	0.5
Parameter	m1	m2	m3
Value	16.3	10.15	1.8
Parameter	m4	m5	m6
Value	2	5.5	12
Parameter	n6	d	lc
Value	3	3.55	3.7

4. Results analysis

Dual-band bandpass filter is designed in this paper as a approaches with outer resonators and inner resonator (open loop resonators with polygonal form and interdigital capacitor). The overall filter dimensions are 28.3x21.7 mm<sup>2</sup> using Rogers substrate (RT 5880) with relative permittivity of 2.2 and thickness of 0.787mm. The simulated S-parameters results of the proposed optimized filter is shown in Figure 6. It is observed that the first and second frequency bands are observed between 1.85 GHz to 2.02 GHz and 2.30 GHz to 2.53 GHz with center frequencies 1.93 GHz and 2.41 GHz, respectively. The 3-dB bandwidth of 8.8% and 9.5% with insertion loss 0.6 dB and 0.5 dB, respectively observed for both passbands with better than 15 dB returnloss. There are two transmission zeros observed at 1.71 GHz and 2.88 GHz which means that there is a sharp cut before and after the passband.

The proposed filter is compared with the filters available in open literature, which is shown in Table 2.

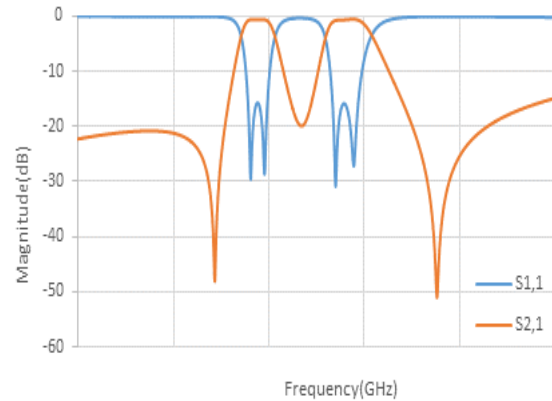


Fig. 6 Simulation results of proposed filter

Table 2 Comparison with available literatures

Reference	Passband (GHz)	No. of bands	-3dB FBW (%)	Insertion loss (dB)	Return loss (dB)	Transmission zeros	Filter size mmx mm
[1]	1.84/2.45	Dual	4.9/3.8	0.8/1.1	17/16	4	28.3 x 21.7
[2]	2.4	Single	19.2	0.8	26	2	4.3 x 5.8
[3]	1.57/3.70	Dual	4.5/4	< 2.5	> 12	4	44 x 50
[12]	1.57/2.41	Dual	3/2	< 2	> 15	4	21.1 x 14.1
[13]	1.58/2.40	Dual	5/2	1	> 16	2	26 x 26
[14]	9.3	Single	9.25	1.58	17.7	3	
This work	1.93/2.41	Dual	8.8/9.5	0.6/0.5	> 15	2	28.3 x 21.7

## 5. Conclusion

Bandpass filter designed using open-loop resonator with an interdigital capacitor added in one set of half-wavelength resonator. The bandwidth of the filter is increased by changing the length, width, and gap of the Interdigital capacitor. The coupling coefficient can conveniently be tuned up at the desired value within a wide range bandwidth. The dual bandpass filter with the interdigital capacitor in open-loop resonator for WiMAX, RF microelectromechanical system (RF-MEMS) tunable filter and personal communication services (PCS)

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