Miniaturization Of Multiband Filter using SIR

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ABSTRACT
Filter is very essential component in wireless communication system. Since need of compact devices is increasing day by day, Filter plays very important role in developments of such devices. In this paper, multiband micro strip stepped impedance resonator band pass filters operating in range of 1 to 10 GHz are designed. A series capacitively coupled series micro strip line resonator is modified by first widening the central section and then engraving multiple rectangular slots on it. Due to this size of the filter is reduced and filter can be operated in multiband. Filter operated in tri-band and quad band are designed. This paper consists of mathematical analysis & partial implementation of capacitively coupled multiband filters. The simulation is done by using IE3D software for wireless applications.

General Terms
Miniaturization, S-parameters, return loss, dielectric constant, and band pass filters

Keywords
Micro strip, multiband filters, stepped impedance resonators, tri-band, quad-band.

1. INTRODUCTION
Now days, micro strip filters play a very important role in modern wireless and communication systems. Due to the advantages such as low cost, compact size and light weight planner filters using printed circuit technology are becoming more popular. In telecommunication, Filtering of signals is essential so as to choose the particular signal from the range of signals transmitted and also to diminish the consequence of noise and hindrance of the unnecessary signals. Many of the applications in telecommunications have requirement of filters with very harshly defined frequency characteristics. In recent years, Miniaturization of printed planar microwave filters has been a popular research topic owing to the increasing enlargement of wireless and mobile communication systems operating at the lower end of the microwave spectrum. Conventionally, predictable distributed resonators are utilized but they are very bulky in size to be utilized at low frequency hence, it is necessary to reduce the size of filter. Therefore, to reduce the filter dimension and to operate in a multiple band multiband filters are designed. “Multiband filters are the filters which using more than one band for their operation”. In recent years, multiservice wireless systems have been gaining much more attention hence, Multi-band filters become quite popular. Therefore, they had been widely studied in several papers [6, 7, 8, 9, 10, 11, 12, and 13].

More recently, the multiband filters have been developed using the stepped impedance resonator concept [6, 7, 8, 9, 10, 11, 12, and 13]. By using Double Split End Stepped-Impedance Resonators Band-pass Filter is designed. The double split-end quarter-wave-length resonator is utilized to miniaturize the resonator as well as to provide additional transmission zeros which can also produce low in-band loss and wide stop band bandwidth [6]. Dual band filter is designed by using stub loaded folded stepped impedance resonators customized by integrating an inner quasi-lumped SIR stub [7]. A Rectangular Meandered- Line Stepped Impedance Resonator is used to design a compact band stop filter giving Triple-Band Band stop Response. Miniaturization of the filter was achieved by utilizing an easy structural design based on a meandered line SIR. Due to good frequency selectivity, the filter is useful for WiMAX applications [8]. A micro strip band-pass filter giving quad band response based on step-impedance ring resonators designed to generate quad band response. Due to its simple structure, compact size and good performance, the designed BPF is suitable for GPS, WiMAX and IEEE 802.11a applications [9]. Compact micro strip multiband band pass filter is designed by using symmetric U- shape triangular stepped impedance resonator for wireless application. A multiband filter response can be achieved, by appropriately tuning the length ratios of stepped impedance resonators [10].

In this paper design of micro strip filter is implemented for multiservice wireless applications, which consists of ground plane which is etched one & simple rectangular micro strip feed line is used. All the simulations & results are obtained by using IE3D software.

2. GEOMETRY OF THE FILTER
A micro strip line filter is a planner structure. It consists of a rectangular patch having length ‘P_l’ and width as ‘P_w’ and T shape micro strip feed line both are printed on dielectric substrate. A small capacitive gap is kept between the feed line and middle resonator section. T shape feed line is used for providing coupling of the electromagnetic energy from ports to the central micro strip section.

The parameters of micro strip line filters are,

ε_r = dielectric constant of substrate material. = 10.5

h =height of substrate = 1.25 mm.

P_w = width of micro strip patch.

P_l = length of micro strip patch.

ε_{reff} = Effective dielectric constant

λ = resonant wavelength.

f = Resonant frequency of operation.

Z_0= characteristics impedance.

3. MATHMATICAL ANALYSIS OF NARROW AND WIDEBAND FILTER
3.1 Dielectric constant
The design starts with the cull of large relative dielectric constant (ε_r) material. For miniaturization of filter and fields are closely bound in high ε_r material and so the filter does not radiate, large dielectric constant is chosen that is 10.5.

3.2 Substrate selection

Taking in account these factors, Rogers RT/Duroid 6010.5 substrate having ε_r = 10.5 and thickness 1.25 mm (h=1.25 mm) is utilized to design and manufacture the filters.

3.3 Effective dielectric constant calculations

Frequency dependant term for effective dielectric constant is first given by Getsinger in ref no. [5], reproduced in Equation below.

$$\varepsilon reff\,(f) \;=\; \varepsilon r - \left[\frac{\varepsilon_r - \varepsilon_{reff}\,(0)}{1+P(f)}\right]$$

$$\varepsilon reff\,(0) \;= \left\{\frac{\varepsilon_{r+1}}{2}\left[1-\frac{1}{2H}\,(\frac{\varepsilon_r - 1}{\varepsilon_r + 1})\left((\ln\frac{\pi}{2}+\frac{1}{\varepsilon_r}\ln\frac{4}{\pi})\right)\right]-2\right\}$$

$, \frac{w}{h} < 1.3$

$$\mathrm{H} = \ln\left(\frac{4h}{w}+\sqrt{16(\frac{h}{w})^2+2}\;\right)$$

$$\mathrm{P(f)} = \mathrm{P1P2[(0.1844+P3P4)10f\,h]^{1.5763}}$$

$$\mathrm{P1} = 0.27488+\left[\;0.6315+\frac{0.525}{(1+0.157\,fh)^{20}}\right]\frac{w}{h}$$

$$-\,0.065683\exp\left(-8.7513\frac{w}{h}\right)$$

$$\mathrm{P2} = 0.33622[1-\exp(-0.0344\,\varepsilon_r)]$$

$$\mathrm{P3} = 0.0363\exp\left(-4.6\frac{w}{h}\right)\left\{1-exp\left[-\left(\frac{fh}{3.87}\right)^{4.97}\right]\right\}$$

$$\mathrm{P4} = 1+2.751\left\{1-exp\left[-\left(\frac{\varepsilon_r}{15.916}\right)^{8}\right]\right\}$$

3.4 Length and width calculations

Rogers RT/Duroid 6010.5 substrate is used having ε_r= 10.5 and thickness 1.25 mm (h=1.25 mm) to design and manufacture the filters and f_r = 2.41GHz.

Width of the micro strip patch can be given by,

$$\mathrm{W} \;= \frac{1}{2f_{r\sqrt{\mu_0\epsilon_0}}}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$= \frac{v_0}{f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} = 26\;mm.$$

Extended incremental length of patch,

$$\frac{\Delta L}{h} = \frac{\left(\varepsilon_{reff}\; + 0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}\; - 0.258\right)\left(\frac{W}{h}+0.3\right)} = 0.5295\,mm.$$

Actual length of the patch,

L= λ/2 -2ΔL

$$\mathrm{L} = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L = 19.2\;mm.$$

3.5 Analysis of variation of width of micro strip patch

Using above terms, it is found that for 1mm width of the micro strip line, as we change the frequency from 1 GHz to 10 GHz, the value of ε_{reff} varies from 8 to 10.2. Calculated values are given in following table 1,

Table 11. Analysis of variation of width of micro strip patch

W=1 mm, f=1 GHz	**W=1mm, f=10GHz**
ε_{reff}= 10.17 ≈ 10.2	ε_{reff}= 10.17 ≈ 10.2
W=9 mm, f=1 GHz	**W=9mm, f=10GHz**
ε_{reff}= 9.895 ≈ 10	ε_{reff}= 10.47 ≈ 10.5

3.6 Resonant Frequency calculations

There are two modes for resonant frequencies depending upon the current distribution of the micro strip filter. When the current flowing indicating in the current distribution of the filter is along the length of the filter then it is referred as longitudinal mode and when the current flowing is along the width of the filter is referred as transverse mode of filter. Transverse mode is also called as orthogonal mode of filter. From the current distribution clearly indicates that the first three resonances are due to the longitudinal modes whereas the fourth resonance is due to the orthogonal/transverse mode.

3.6.1 *Longitudinal mode:*

The widespread equation for the jth resonant wavelength of longitudinal mode can be given by,

$$\lambda_j \;= \frac{2P_l}{j}$$

Where, ‘Pl’ is the length of the patch.

Resonant frequency can be calculated by using following Equation,

$$f \;= \frac{c}{\sqrt{\varepsilon_{reff}}\,\lambda}$$

For first resonant wavelength can be obtained by,

$$\lambda_1 = \frac{2P_l}{1} = 38.4mm$$

Hence the First resonant frequency can be given by,

$$f_1 = \frac{c}{\sqrt{\varepsilon_{reff}}\,\lambda_1} = 2.41GHz$$

For second resonant wavelength can be obtained by,

$$\lambda_2 = \frac{2P_l}{2} = 19.2\;mm.$$

Hence the Second resonant frequency can be given by,

$$f_2 = \frac{c}{\sqrt{\varepsilon_{reff}}\,\lambda_2} = 4.82GHz.$$

For third resonant wavelength can be obtained by,

$$\lambda_3 = \frac{2P_l}{3} = 12.8mm$$

Hence the Third resonant frequency can be given by,

$$f_3 = \frac{c}{\sqrt{\varepsilon_{reff}}\,\lambda_3} = 7.23\;GHz.$$

3.6.2 *Transverse mode*

The fourth resonant frequency can be given by,

$$f_4 = \frac{c}{\sqrt{\varepsilon_{reff}}\,\lambda_4} = 8.41\ GHz.$$

The values of parameters required to design the actual filter are summarized in the following table 2 and figure 1 shows the geometry of narrow band and wide band filters.

Table 2. Dimensions (in mm) of the designed narrow and wide band pass filter.

parameter	Narrow micro strip filter	Wide micro strip filter
Resonator Length(P_l)	19.2	19.2
Resonator Width(P_w)	1.0	1.0
Capacitive Gap(C_g)	0.1	0.1
Feed line / T section width(W_f =W_T)	1.0	1.0

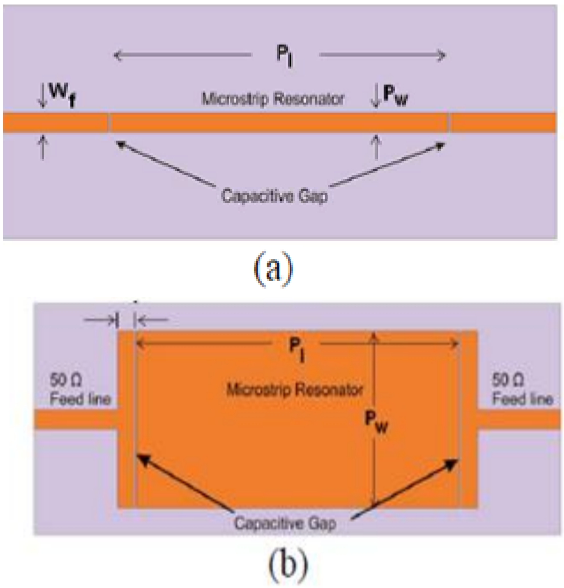

Fig 1: (a) Configuration of capacitively coupled narrow band filter (b) Configuration of capacitively coupled wide band filter.

4. SIMULATED RESULTS FOR NARROW AND WIDE BAND FILTER

By using IE3D simulator all designs are made & simulated. The following graphs in figure 2 and 3 shows the simulated results for s-parameters of narrow and wide band filter design.

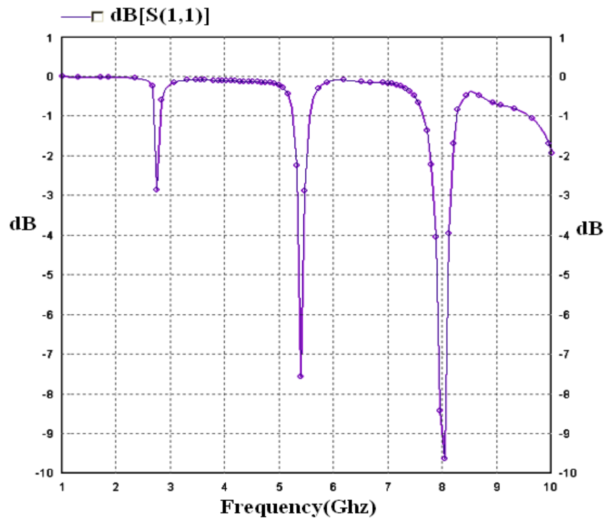

Fig 2: S11 parameter graph for capacitively coupled narrow band filter

S-parameters express the input-output relationship between ports in an electrical system. In practice, the most commonly cited parameter in concern to filter is S11. S11 is identified as reflection coefficient, as it tells how much power is reflected from the filter, and hence it is also called as return loss.

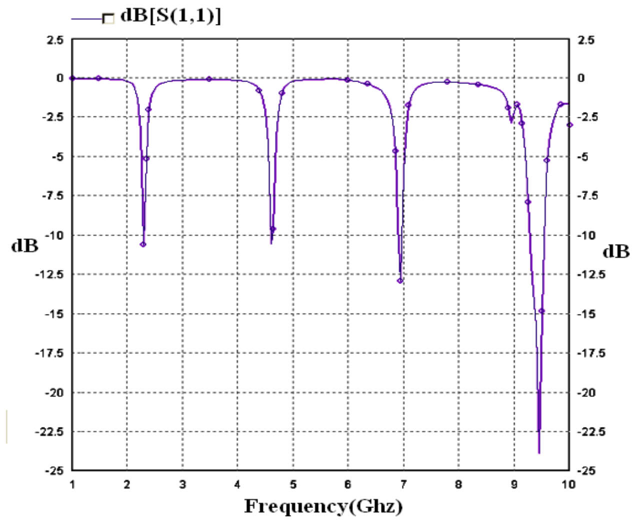

Fig 3: S11 parameter graph for capacitively coupled wide band filter.

From graphs, it can be seen that narrow band filter is giving a triband response at a resonant frequencies 2.71 GHz, 5.4 GHz and 8.00 GHz respectively. Similarly, from figure 3, it can be seen that there are four mode of resonance. Hence, wide band filter is giving a quad band response. The return loss for wide band filter for all resonant frequencies less than -10 dB. The resonant frequencies are 2.38 GHz, 4.75 GHz, 7.00 GHz and 9.34 GHz respectively.

All the calculated and simulated results of resonant frequencies are summarized in following table 3,

Table 3. Comparison of the calculated and simulated resonant frequencies of narrow and wide multiband band pass filter.

Parameter	f_1(GH)	f_2(GHz)	f_3(GHz)	f_4(GHz)
Narrow band filter(calculated)	2.41	4.82	7.23	-
Narrow band filter(simulated)	2.71	5.4	8.00	-
Wide band filter(calculated)	2.50	4.87	7.12	8.51
Wide band filter(simulated))	2.38	4.75	7.00	9.34

From table 3., it can be deduced that, the calculated and simulated results are in good agreement.

4.1 Current Distribution Of Wide Resonator Filter

From the current distribution diagram shown in figure 4, it can be seen that the current density is minimum in the center while it is maximum along the length of the micro strip resonator patch.

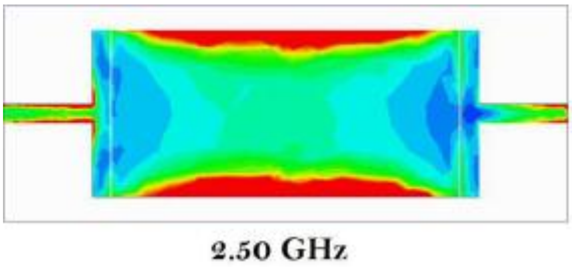

Fig 4: Current distribution of wide resonator filter at resonant frequency 2.50 GHz.

Accordingly, it can be said that engraving the slot in the center of the patch will not have an effect on resonant frequencies much while if the dimensions of slot are increased to disturb the current distribution alongside the edges of the patch, the resonant frequencies will change.

5. WIDE RESONATOR FILTER WITH RECTANGULAR SLOTS

5.1 Necessity of slots

In order to have be in command of on the resonant frequencies and for further miniaturization, rectangular slots are engraved on the micro strip resonator patch. First one slot is etched at the center of the rectangular patch and results are observed. Then for further reduction in size of filter, 3 and 4 slot configuration is made.

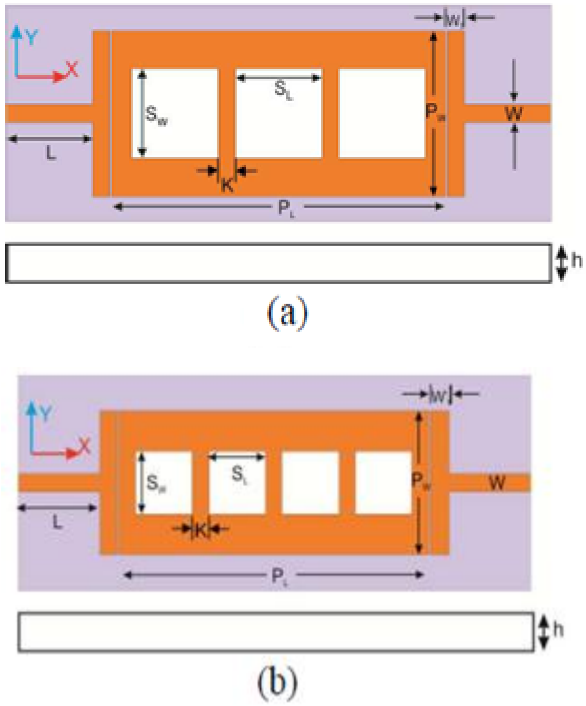

Fig 5: (a) Configuration of designed 3 slot filter (b) Configuration of designed 4 slot filters

In first design, a single slot is divided into 3 identical symmetrically placed slots as shown in Figure 5(a). In the second design, Figure 5 (b), a single large slot is divided into four identical and symmetrically placed slots. The dimensions of the slots are as shown in the table 4 given below.

Table 4. Dimensions (in mm) of the designed three andFour slot band pass filter.

Parameter	P_l	P_w	L	W	K	S_l, S_w
3 Slot filter	19.2	9.2	5	1	1	5.0,5.0
4 Slot filter	19.2	7.0	5	1	1	3.5,3.5

6. SIMULATION AND RESULTS OF WIDE RESONATOR FILTER WITH RECTANGULAT SLOTS

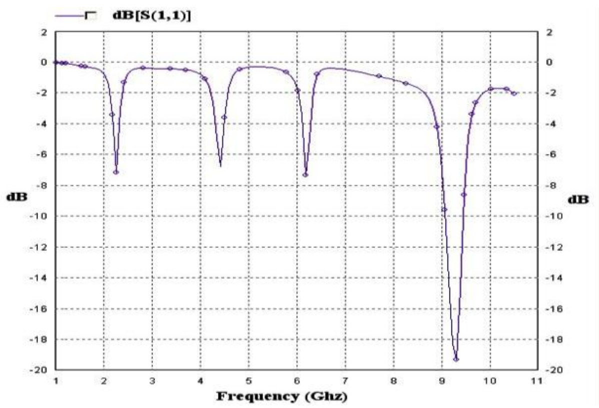

Fig 6: S11 parameter graph for 3 slot filter

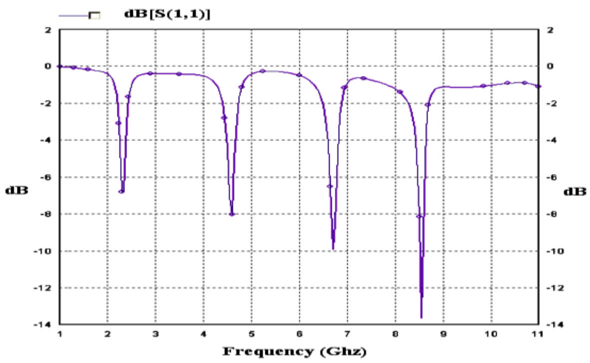

Fig 7: S11 parameter graph for 4 slot filter

From graphs, it can be seen that 3 slot band paas filter is giving a quad band response at a resonant frequencies 2.3 GHz, 3.56 GHz, 6.2 GHz and 9.25 GHz respectively. Similarly, from figure 7, it can be seen that there are four mode of resonance. Hence, 4 slot band pass filter is giving a quad band response. The resonant frequencies are 2.32 GHz, 4.65 GHz, 6.82 GHz and 8.59 GHz respectively.

All the calculated and simulated results of resonant frequencies are summarized in following table 5,

Table 5. Comparison of the calculated and simulated resonant frequencies of 3-slot and 4-slot multiband band pass filter.

Parameter	f_1(GHz)	f_2(GHz)	f_3(GHz)	f_4(GHz)
3 slot filter (calculated)	2.34	3.84	6.9	8.94
3 slot filter (simulated)	2.3	3.56	6.2	9.25
4 slot filter (calculated)	2.384	4.78	7.4	8.68
4 slot filter (simulated))	2.32	4.65	6.82	8.59

From table 5, it can be deduced that, the calculated and simulated results are in good agreement.

7. CONCLUSION

A multiband band pass filter design has been presented in this paper. For miniaturization of the filter, slots are added. 3 slot and 4 slot filters are designed to give quad band response. It can be seen that calculated results and simulated results are in close concurrence with each other. As this paper is on partial implementation, all the designs having results return losses are not much good. Due to the compact size and multiband operation, these filters are predictable to be useful in a horde of wireless applications where multiband operation is necessary.

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