Capacitance Insertion for A Single Ring Tunable Dual-Band Bandpass Filter

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***Abstract*— A microstrip filter design for single dual-band bandpass filter (ring topology) is presented. Four lumped sum micro strip capacitors are added in the initial ring resonator topology to shift the center frequency (f_o) to about 6.2% of its nominal value, leading to usage with different frequency range. The estimation of capacitors is computed utilizing tuning combination after insertion in an existing topology. The passbands from the frequency response is enhanced by altering the microstrip size of capacitors which gives different value of the ring impedances. The recreation of tunable bandpass filters is to require the reference frequency (f_o) at 3.85GHz to be shifted to a new value. Rogers TMM10 with thickness 1.27mm and dielectric constant, ε_r of 9.2 is used as a core material of the circuit. The Ansoft High Frequency Electromagnetic Field Simulation (HFSS) is a full-wave electromagnetic (EM) software package is used in this simulation. The experiment results show the proposed filter can be tune within the desired frequency range with good passband performance.**

Index Term- Bandpass filter (BFP), single layer dual-band, microstrip capacitors, tunable filter, center frequency.

I. Introduction

WITH the rapid development of wireless communication technology, the requirement of tunable filters for dual band and multiband are growing rapidly due to their low cost and good stability [1]. Bandpass filter is a device that allows signal in certain frequency ranges to pass through. A filter removes the unnecessary data before sending to receiver. Communication technologies such as Worldwide Interoperability for Microwave Access (WiMAX) and Wireless LAN require high performances bandpass filters to ensure the quality of data received. Nowadays, microstrip bandpass filters have replaced the traditional bandpass filters in various applications because of their benefit such as minimal space utilization, low cost, high performance and multi frequency nature. Ring based topology is preferred in the filter design due its capability and advantages to produce single band, dual band and dual mode resonant [2].

Ring filter topology has demonstrated great change in its reaction as its offer transmission zeros that helps in enhancing the selectivity near the passband and also offer high degree of compactness [3]. A tunable of dual-band band pass filters are the most part utilized for multiband wireless communication and radar frameworks as it ready to abatement framework size and unpredictability and in addition high linearity in term of Radio Frequency Micro Electro Mechanical System (RF MEMS) technology [4]. However, electronically tunable bandpass filter have drawn much attention due to their capacity to deal with various operating system.

This paper presents the capacitance insertion in an existing filter topology in order to shift frequency response of the filter. Past review, capacitance inclusion and dispersed component were utilized to move frequency response on a perfect topology of dual-band bandpass filter[5]. Behavior of wavelength toward frequency is inversely proportional shorter to the distributed elements required, with increases of frequency. The best capacitance esteem that used to move center frequency response from 4.0GHz to 3.71GHz is around 0.17pF to1.37pF was proposed.

II. SINGLE RING DUAL-BAND BANDPASS FILTER

The initial filter is designed at 3.85GHz on the microstrip substrate of εr =9.2 and tan δ= 0.0022 and h=1.27mm. The computed estimations of the information/yield impedance (Z_o), odd mode impedance (Z_{oo}), even-mode impedance (Z_{oe}) and the ring impedance (Z_r) utilizing the union created in[6] are in table 1 as below:

TABLE 1
Characteristic Impedance

Impedance	Value (Ω)
Z_o	50
Z_{oo}	97
Z_{oe}	32
Z_r	55

Fig. 1 shows the existing filter topology for the single ring dual-band. This single ring dual-band bandpass filter is based on the ROGERS TMM10 substrate that is covered by copper with thickness of h =0.035mm on the top side. At the bottom layer of the substrate a copper foil with thickness of 0.035mm act as a ground to the circuit. The size of the filter is around 22mm x 23mm.

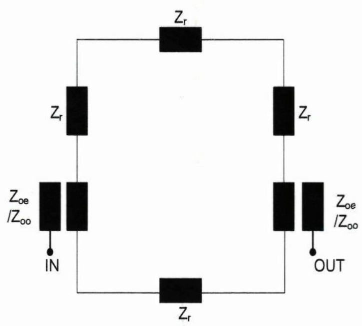


Fig. 1: Dual-band ring filter topology

The desired frequency single ring dual-band bandpass filter was attained by adjusting the impedance value, (Z_r) and even and odd mode impedance of couple line (Z_{oe} and Z_{oo}) as shown in table 2.

TABLE 2.

HFSS Design Parameter	
Design Parameters	**Size (mm)**
L_{io}	7.787
W_{io}	1.315
L_r	7.866
W_r	1.031
L_c	8.034
W_c	0.571
G	0.127

Fig. 2 shows the frequency response of single ring dual-band bandpass filter that contains two bands with independently having center frequency, f_o. Frequency of f_1 is the principal passband center frequency whiles f_2 is the second passband frequency. For better selectivity of frequency, there are four transmissions zero in the response.

Recreation for the existing filter topology was performed using HFSS full-wave electromagnetic software with 0.01GHz step precision. The center frequency, f_o was accomplished at 3.97 GHz with the two passbands of first frequency, f_1 = 2.64GHz and second frequency, f_2 = 5.30 GHz. Transmission zero for this response is shown at -68.15 dB and -26.11 dB for lower frequency and -37.39 dB and -39.12 dB for upper frequency. Besides, the band rejection for this dual-band bandpass filter are less than 1.38GHz for lower rejection band and more than 5.8GHz for upper rejection band as shown in fig. 2.

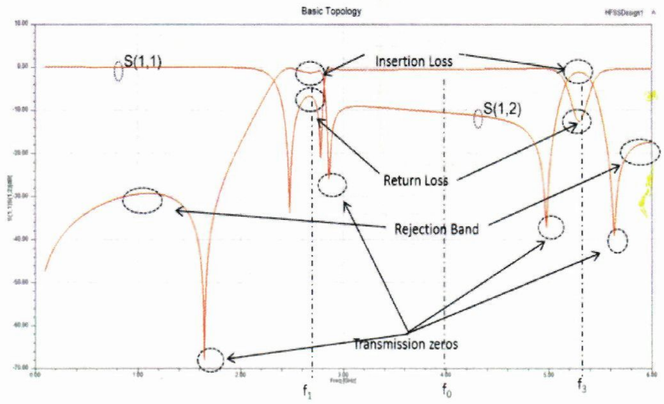


Fig. 2: Frequency response of single ring dual-band bandpass filter

The parametric studies on couple of parameters that have significant impact on single ring dual-band bandpass filter reactions were done. Seven parameter have been identified where the length of the resonator, L_r have real impact on the execution innately identified with the estimation of return loss, S_{11} and insertion loss, S_{12}. Both width and length of these parameters were varied to obtain the desired frequency and observed the optimized value.

Fig. 3(a), 3(b), 3(c), 3(d) and 3(e) shows the frequency responses of return loss, S_{11} and insertion loss, S_{12} when one of the parameter in Table 2 varies while others were remain constant. Refer to Fig. 3(a), transmission zero of first passband shifted to the left while second passband shifted to the left and right. As a result, the bandwidth is wider than the ideal response. Meanwhile, Fig, 3(b) shows all transmission zero of first passband shifted to the left while second passband shifted to the right when decreased W_c value. The return loss value for the second passband become smaller if the W_c value increased and as result filter not function. This is due to the available power is not totally delivered at port S_{11}. As result, the filter's reflection is become weak. The influence of length also has been analyzed and the result as shown in fig. 3(c) and 3(d). The transmission zero of both first and second band shifted to the left when increased the L_r and L_c value. This proved that when length microstrip is increase the electrical length will also increase due to increasing of inductance of the ring. This also proved the relationship between wavelength and frequency are inversely proportional where $\lambda = c/f$. The performance for return and insertion losses in lower passband is remain when L_r is increases while for upper passband performance is controlled by L_c value. By changing the value of gap, it is additionally coordinating the filter reaction execution. Fig. 3(e) demonstrates the frequency response (S-parameter) move descending to lower extent when the gap esteem expanded. All results have good agreement to design specifications. These result were important in order to predict the output of the design before applies the RF lumped capacitors as the tuning element.

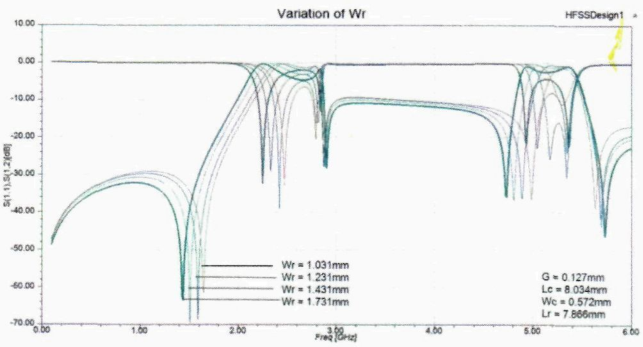


Fig. 3(a): S_{11} and S_{12} pattern with variations of W_r

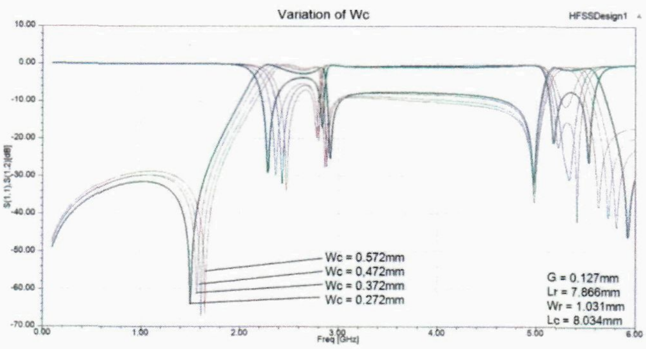


Fig. 3(b): S_{11} and S_{12} pattern with variations of W_c

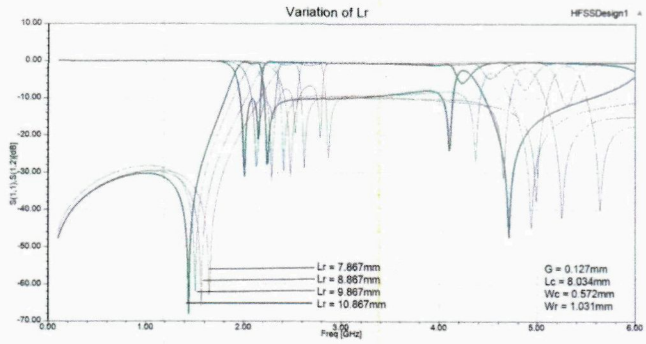


Fig. 3(c): S_{11} and S_{12} pattern with variations of L_r

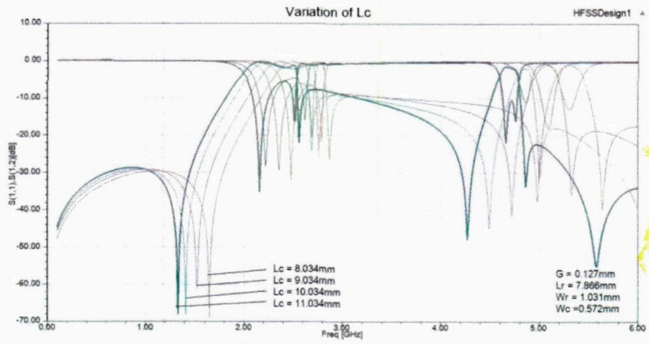


Fig. 3(d): S_{11} and S_{12} pattern with variations of L_c

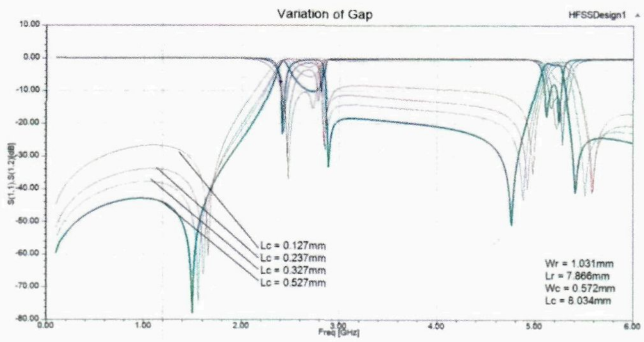


Fig. 3(e): S_{11} and S_{12} pattern with variations of gap

III. TUNABLE SINGLE RING DUAL-BAND BANDPASS FILTER

A single ring dual-band band filter is shunted with four capacitor elements, C_r at the edge of the ring lines to vary the nominal electrical length, L_r, of the ring as shown in Fig. 4 were proposed[1]. The variation of electrical length is dependents on variation of C_r to configure the nominal center frequency to a new position. The ring is mounted with capacitive elements and by varying the value of capacitive elements, the frequency response can be reconfigured [8]. The size of capacitance C_r was decided by utilizing equation (1)

$$X_C = \frac{1}{2\Pi f C_r} \quad (1)$$

Next, the width and length of microstrip is derived by using formula (2) and (3).

$$\frac{W}{d} = \begin{cases} \frac{8e^A}{e^{2A} - 2} & \text{For W/d <2} \\ \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right] & \text{For W/d >2} \end{cases} \quad (2)$$

$$l = \frac{\emptyset(\frac{\pi}{180})}{\sqrt{\varepsilon_r}k_o} \quad (3)$$

And introducing the term as below to simplified the above equation,

$$A = \frac{Z_c}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad (4)$$

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}} \quad (5)$$

The electrical length was varied to examine the best frequency response, band rejection and transmission zero. These capacitive elements were placed at two non-orthogonal position at the edge of the ring topology as shown in Fig. 5 after considering the filtering performance[9].

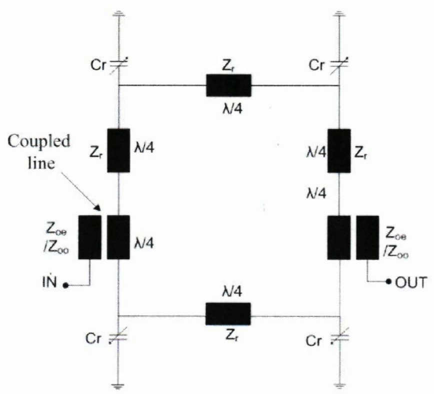


Fig. 4: Topology of Tunable Single Ring Dual-band Bandpass Filter

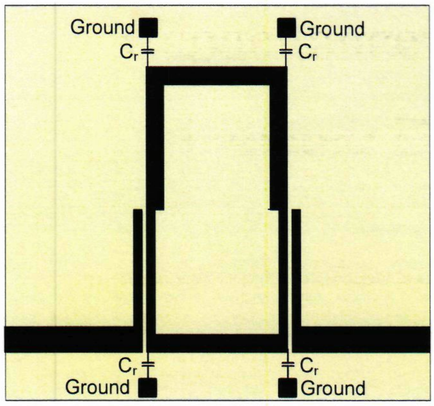


Fig. 5: Proposed location for Capacitor, Cr

Capacitive component can be changed over in circulated component by differing the width and length of microstrip line.

IV. RESULT AND DISCUSSION

By optimizing the capacitor, the response can be shifted from the original value. The final value of capacitor obtained as shown in Table 3. The final value of capacitor is selected according to the value available in market.

Fig. 6 shows the frequency differences between dual-band bandpass filter with and without capacitor. The frequency is shifted to lower frequency when the capacitor is added. It can be observed that insertion loss S_{11} for upper band with capacitor 1.07pF has improved with the insertion. In any case, the lower passband bandwidth is more extensive when the capacitor increments yet influencing the return loss and insertion loss quality.

TABLE 3.

OPTIMIZED VALUE OF CAPACITOR

Capacitor	Value (pF)	W(mm)	L(mm)
C_r	1.07	2.1039	0.9530

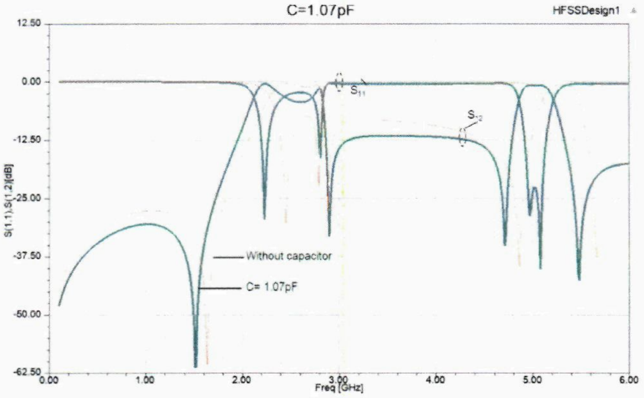


Fig. 6: Simulation result of dual-band bandpass filter with and without capacitor

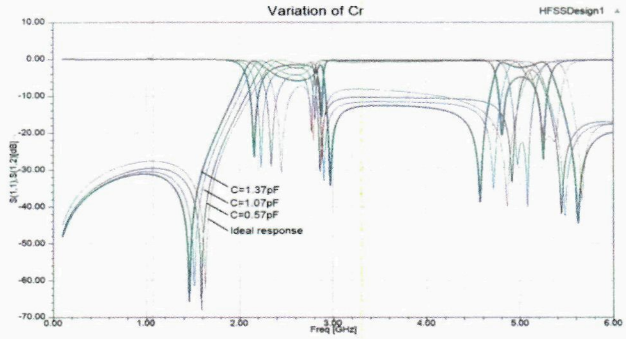


Fig. 7(a): Frequency response with variation of Capacitances

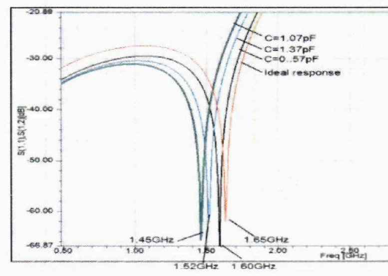


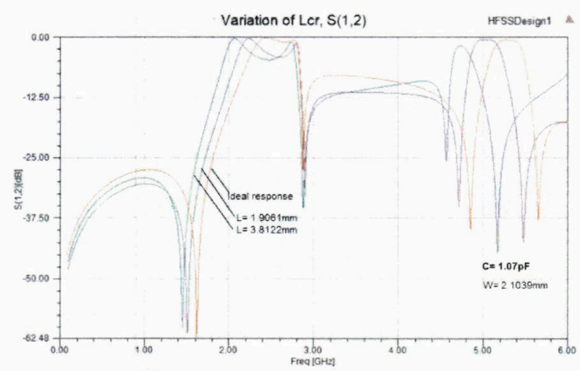
Fig. 7(b): Frequency response for position transmission zeros (S_{12})

Few investigations on capacitor size that contribute a major effect on the filter responses were conducted. Result in Table 4 shows frequency response succeeded shifted about 6.2% to lower frequency when increases the capacitor value. This result shows the first band and second band bandwidth become wider while increase capacitor size. The width and length indicated for C=0.17pF is 0.001mm and 1.0750mm, C=0.57pF (0.5470mm and 1.0060mm), C=1.07pF (2.1039mm and 0.9530mm) and C=1.37pF (3.1745mm and 0.9340mm). Therefore, capacitance increases by increasing the width and decreases the length of microstrip line[1]. Fig. 7(a) shows the simulation result by varying the capacitors size that will affect in shifting the frequency response. Transmission zeros for lower passband shifted to 12% from the original response as shows in fig. 7(b).

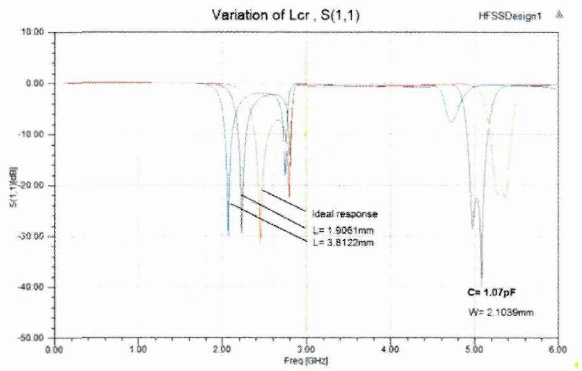
TABLE 4
PERCENTAGE OF RESPONSE WITH CAPACITANCE

Capacitance (pF)	f_1 (GHz)	f_0 (GHz)	f_2 (GHz)	Percentage (%)
-	2.65	4.00	5.33	0.00
0.17	2.60	3.89	5.18	2.81
0.57	2.57	3.85	5.13	3.75
1.07	2.48	3.74	5.00	6.2
1.37	2.42	3.71	5.00	6.2

To further explore the tuning aspect of the tunable filter, the electrical length of the ring can be manipulated to shift the nominal centre frequency to desired position. Fig. 8 (a) and 8(b) indicated lower frequency and upper frequency also shifted to left when the length is increased. Observed that the bandwidth for lower passband become larger while upper passband vice versa. The transmission zero for lower passband shifted from 1.65GHz to 1.45GHz which contributed 12% for frequency response. However, with increasing the electrical length or length size will shifted the frequency to desired value but filter performance also need to consider.



(a): S(1,2)



(b): S(1,1)

Fig. 8: Comparison of frequency response between initial and after electrical length increases

V. CONCLUSION

Using the idea and equations of single ring filter, a filter designed at certain frequency can operates at lower frequency by placing the capacitive elements. The influence of different geometry parameters on the filter performances has been analysed in detail. The filter design was observed and investigated to obtain the suitable value of capacitor in shifting the frequency response at desired value. The best capacitor size is 1.07pF to shift the center frequency, f_0 from 4.00GHz to 3.71GHz. Placing with the different electrical length (phase shift in degree) by adjusted the length of capacitor will also allow maximum capability to obtain the optimized frequency response.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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