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Designing of Tri-Band Band Pass Filter with MMR

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Abstract

Two efficient and practical design methods for tri-band band pass filter (BPF) are presented. The electrical specifications of the filter, such as the bandwidth, transmission zero location and center frequency are controllable and adjustable by proper designing methods. Once, the desired ratio of the resonant frequency of the three bands is given, the characteristic impedance of the line corresponding to the specific ratio can be accurately determined from the design curve. Compared with the conventional half and quarter-wavelength stepped-impedance resonators (SIRs), the proposed unequal-length shunted-line stepped- impedance resonator (shunted-line SIR) can provide an efficient way to realize the tri-band filter, especially when three pass bands are closely spaced. Furthermore, the multi-transmission zeros and one controllable transmission zero are generated near the pass bands to improve the out-of-band rejection. The design example of micro strip tri-band BPFs operating at 1.89/2.71/3.56GHz and with equal absolute bandwidths and high isolation are demonstrated to validate of the design method. Second filter is designed on FR4 substrate with permittivity of 4.4 and height of substrate is 0.8 mm. In second designed filter, three pass bands are achieved with operating frequencies 2.4GHz for Bluetooth application, 5.5GHz and 8.8GHz for satellite communication.

Keywords

Bandpass filter (BPF), tri-band, microstrip, unequal-length shunted-line stepped-impedance resonator (shunted-line SIR), open stub.

I. Introduction

In recent years, the rapid progress in mobile and wireless communication has increased the need of integrating more than one communication standard or mode into a single communication system, where different standards may use different frequency bands. Different wireless standards have been emerged into the communication industry for producing new consumer system such as GSM, Bluetooth, WLAN, Wi-Max. The tri-band transceiver is used for GPRS applications [1]. The tri band was designed using combined quarter wavelength step impedance resonators. Feed positions for the two quarter wavelength step impedance resonator are carefully located to have the same distance from the via-hole ground and meanwhile to give the required external quality factors [2]. In such a way, the micro-strip line sections between the via-hole and each of the feed positions can be combined into one to simplify the filter structure, and to reduce the band pass filter circuit size. The assembled resonator constructed by a step impedance resonator and a common half wavelength resonator is employed to obtain tri band response. The SIR is designed to operate at the 1st and 3rd pass-bands and other resonator is designed to operate at the 2nd pass-bands [3]. In [5] a pair of asymmetric SIR with parallel coupling arrangement was predicted to realize the tri-band responses. However the selectivity and symmetry of pass-bands still needed to be improved. In the recent days no. of tri-band filters have been realized with the help of SIR due to its multi-band behavior, well established design methodology and simple structure. For SIR to operate at three arbitrary frequency, the design of resonator must rely on a preplotted design graph, also the direct coupling structure results to large size of filter [6].

In [7], triple-mode resonator were discussed an designed using split-ring resonator to obtain three controllable resonant frequency. The tri-section SIR could also be used to design tri-band filters by properly determining the improved ratio, three pass bands at any desired frequency can be obtained, but it is hard to achieve coupling coefficient and different external quality factors to simultaneously satisfy the specification of all pass bands [8]. One discussed a specific tri-band filter based upon the dual behaviour resonator [9]. Coupling is needed to TZs into pass band to increase the selectivity of filter. By properly controlling the coupling strength at each path the desirable coupling coefficient at both pass bands can be obtained and thus the bandwidths can be controlled. The low impedance lines of SIRs provides the electric coupling, While the grounded via hole offers the magnetic coupling. TZs are critical frequencies where signal transmission between input and output is stopped. Filter uses the TZ frequencies together with the pass band edge frequencies and pass band ripple to form the transfer function between the input and output of the filter, and for shaping the response of the filter. This paper is organized as follows. In section II, designing method for tri-band BPF filter is given by introducing an open stub at the center of MMR. Then in section III, layout of designed filter has been described with its dimensions. In section IV, simulation procedure of designed filter and result which has been got by simulating the designed filter with the help of HFSS is discussed. At last in section V conclusion and future scope of this work is given.

II. Designing Method

With the help of open stub, dual band BPF will be converted in to tri band band pass filter. By properly adjusting the position of resonators, pass-bands will be achieved at desired frequency for different applications. By adjusting the position of transmission zeros with the help of magnetic and electric coupling, stop-band can be achieved upto the desired level. The open stub is added at the middle point of both multimode resonators, because at the middle point of multimode resonator the voltage is zero, so that no effect on the existing band and due to addition of open stub a new band has created.

Height (h) of substrate, which is used to design proposed tri-band BPF is 25mil (.635mm) and relative permittivity is 10.2. By putting the value of relative permittivity, height of substrate and width of feed required parameter for filter designing can be achieved. The value of effective permittivity is 6.5, the value of guided wavelength is 11.73, the value of characteristic impedance is 51.73.

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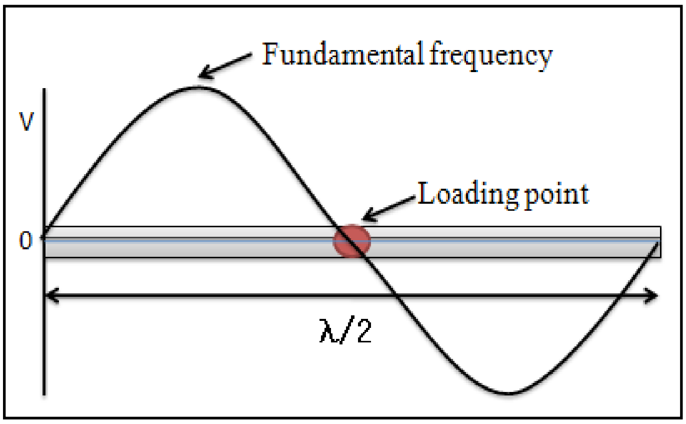

Fig. 1: Basic Logic on Centrally Loaded Open Stub.

Fig. 1 shows the basic logic on zero voltage at middle point of multimode resonator. In the above diagram half wavelength resonator has been shown. The middle point of resonator is called loading point at this point the voltage is zero. Designing of the filter with HFSS is very complex and more accurate as compare to other software like ADS, CST. For designing of filter in first step substrate is required. Roggers RT/duroid 6010/6010LM(tm) substrate with relative permittivity of 10.2 and thickness of 25mil has been selected as a substrate material. Ground plane has been created after choosing the substrate material and assign the boundary as finite conductivity.

Now patches are created on substrate material. After creating patches, boundary of all patches has been assigned as perfect E. After creating the patches, feed is needed to provide the EM waves as input to the filter. To the first port of filter input is given and from the second port of the filter output is taken. With the help of wave port feed is provided.

Calculation of wave port is done by the following formula. Where W_h the height of wave port and W_w denotes the width of wave port. Eqn.(4.1) and (4.2) shows the width and height calculation formula for wave port.

$$W_h = 5*h \qquad (1)$$

$$W_w = 3*w \qquad (2)$$

Where h denotes the height of the substrate and w denotes the width of the feed. W_h denotes the height of waveport and W_w represents the width of wave port. Characteristic impedance of the microstrip line is calculated by the formula given below in. Characteristic impedance is represented by z_0.

$$z_0 = \begin{cases} \frac{60}{\sqrt{\varepsilon eff}} \ln\left(\frac{8d}{W} + \frac{W}{4d}\right) & \text{for } \frac{W}{d} \ll 1 \\ \frac{120\pi}{\sqrt{\varepsilon eff\left[\frac{W}{d}\right] + 1.393 + 0.667 \ln\left(\frac{W}{d} + 1.444\right)}} & \text{for } \gg 1 \end{cases} \qquad (3)$$

Dielectric of the substrate is vary by the effect of the frequency and dimension of the copper plate. Calculation formula for the calculation is given below in Eqn.(4).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left\{\left(1 + 12\frac{d}{W}\right)^{-0.5}\right\} \qquad (4)$$

Where ε_r and ε_{eff} is dielectric and effective dielectric constant respectively. The fundamental resonance frequency (f_1) can be determined from Eqn.(5) and the second resonance frequency (f_2) can be determined from Eqn.(6).

$$z_{03} \tan\theta_4 + z_{04} \tan\theta_3 = \frac{z_{03}z_{04}}{z_{01}} \cot\theta_1 \qquad (5)$$

$$z_{03} \tan\theta_4 + z_{04} \tan\theta_3 = \frac{-z_{03}z_{04}}{z_{01}} \tan\theta_1 \qquad (6)$$

III. LAYOUT OF TRI-BAND BPF

(a) First Design on Rogger RT6010 Substrate

In Fig.2 layout of designed tri-band BPF is shown, where l_1=9mm, l_2=11.95mm, l_3=6.6mm, l_4=5.9mm, l_5=7.45mm, l_6=7.85mm, l_7=8.40mm, l_8=4.25mm, l_9=13mm, l_{10}=6.35mm, l_{11}=10.8, w_1=1mm, w_2=1mm, w_3=.5mm. The size of designed filter is 36mm*14mm.

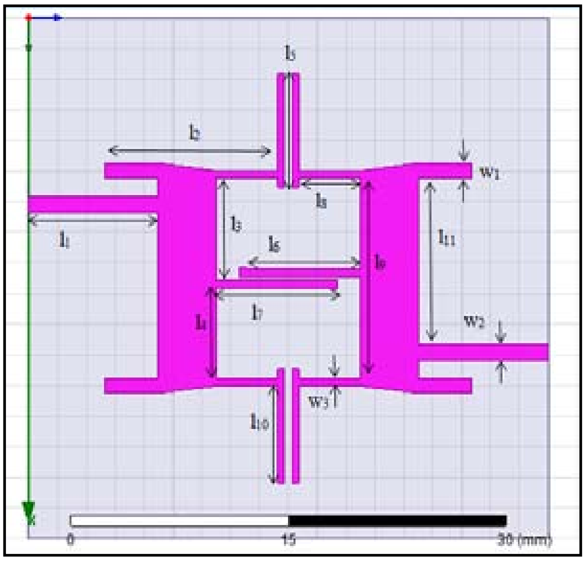

Fig. 2: Design of 1st tri-band BPF filter

In designing method of tri-band BPF, micro-strip line feeding method is used to give excitation to filter structure. It is simplest excitation technique, a conducting strip is directly connected to the filter but feed line width should be smaller to filter feed point width. Sometimes for proper impedance matching a insect cut is made inside to the feed line. After providing the feed, radiation box is created. After all the above process a result is shown after simulation of the structure and a graph is located as result.

Table1 : Specifications of the designed Tri-band BPF

	f_1	f_2	f_3
Center frequency	1.89GHz	2.71GHz	3.56GHz
Bandwidth	145.4MHz	193.9MHz	115MHz
Return Loss	27.01	19.76	26.53
Insertion Loss	0.80	1.27	1.03

Table 1 shows the specifications of designed tri-band BPF. S_{11} is 27.01/19.76/26.53 and S_{21} is .80/1.27/1.03 for three pass bands respectively. These three pass bands can be used for three different applications. Bandwidth of Ist pass band is 145.4MHz, bandwidth of 2nd pass band is 193.9MHz and bandwidth of 3rd pass band is 115MHz.

(b) Second Design with FR4 substrate

By adjusting the position of via in MMR tri band BPF is achieved. With the help of two open stubs in the middle of design and two short circuited stubs at the upper and lower ends of design three required bands are achieved at three different frequencies. The dimensions of filters are given as: l_1=4.45mm, l_2=1.32mm, l_3=2mm, l_4=2.47mm, l_5=4.5mm, l_6=2.1mm, l_7=1.06mm, l_8=8.845mm, l_9=3.92mm, l_{10}=3.03mm, w_1=0.5mm, w_2=0.805mm, w_3=0.3mm. Two vias are created with radius 0.3mm each.

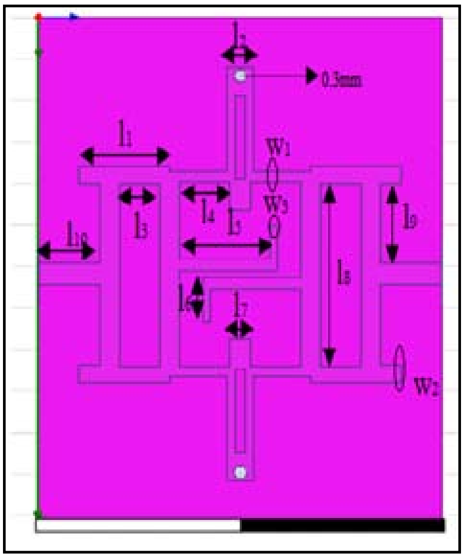

Fig. 3: Design of 2nd tri-band BPF filter

IV. Simulation and Results

(a) First design by using Rogger RT 6010

In tri-band BPF there are three pass bands can be seen, having the center frequency of first pass band is 1.89GHz, center frequency of the second pass band is 2.71GHz (for Wi-Fi application) and center frequency of third pass band is 3.56GHz. By adjusting the position of feed the insertion loss has been reduced. The occurrence of TZs between two pass bands has been helped to reduce in insertion loss. The value of insertion loss of first pass band is .80dB, insertion loss of second pass band is 1.27dB and insertion loss of third pass band is 1dB. By adjusting the position of feed the insertion loss has been reduced.

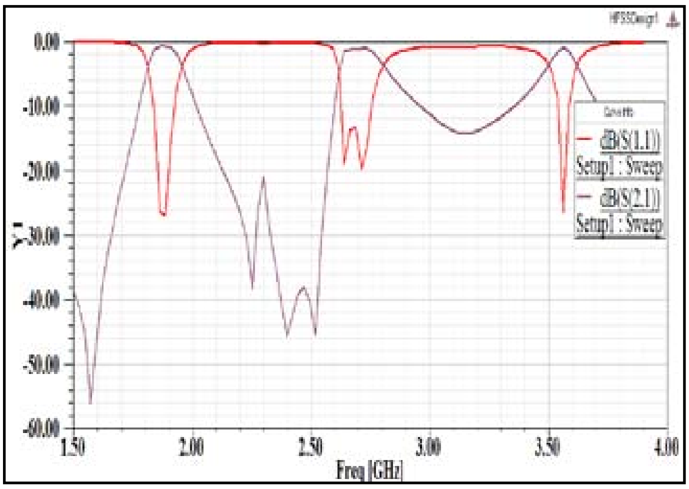

Fig. 4: Simulated result of 1st tri-band BPF

The occurrence of TPs in pass bands, are helped to reduce in insertion loss. The value of return loss of first pass band is 27dB, RL of second pass band is- 20dB and RL of third pass band is 26dB. Fig.3 shows the Return loss and insertion loss of designed tri-band BPF. This is simulated by the help of HFSS. Three pass bands which have been shown in Fig.3. It can be used for three different applications.

(b) Second design by using FR4 substrate

In second designed filter tri band BPF is achieved for different three applications. 1st pass band is 2.1GHz-3.2GHz, 2nd pass band is 4.95GHz-6.5GHz and 3rd pass band is 8.6GHz-9.5GHz.

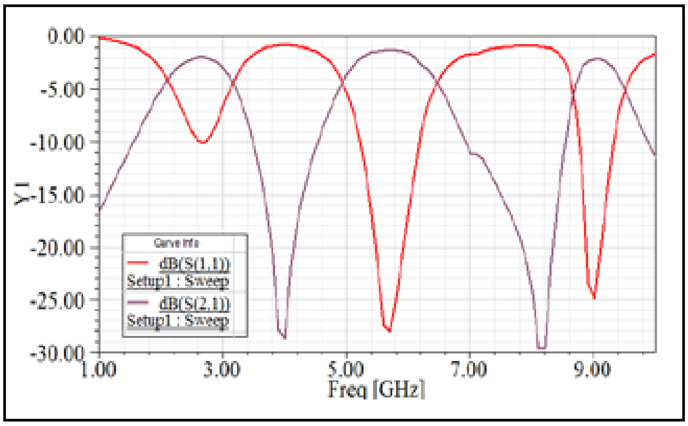

Fig. 5: Simulated result of 2nd tri band BPF

The insertion loss of first pass band is 2.03dB, for second pass band is 1.34dB and for third pass band is 2.20dB is achieved. The return loss of first pass band is 10.6dB, for second pass band is 27.40dB and for third pass band is 23.3dB is achieved.

V. Conclusion

The unequal-length shunted-line SIR that can be applied to effectively realize the tri-band BPF is demonstrated in this work. Without affecting the performance of the pass band, the sharp rejection between the two adjacent pass bands can be created by appropriately placing the transmission zeros. In addition, by appropriately selecting the coupled-line section, the upper band rejection can be further improved. In designing method, using the unequal-length shunted-line SIR is very useful for the tri-band BPF filter design, especially when the three pass bands are closely spaced. TZs are created close to each pass band edge, resulting in high skirt selectivity. Comparisons of the measured and simulated results are presented to verify the theoretical predications. The fundamental structure is based on a half-wavelength resonator with a centre-tapped open-stub. The constant absolute bandwidth is achieved at different center frequencies by maintaining the distance between the in-band transmission poles. Meanwhile, the coupling strength could be compensable by tuning varactors that are side and embedding loaded in the parallel coupled micro strip lines. Second filter is designed on FR4 substrate with very good return loss and low insertion loss. Designed filter is utilized for three applications as Bluetooth, Wi-Fi and satellite communication respectively.

VI. Future Scope

The bands of the proposed tri-band BPF may be used for GPS application, Wi-MAX application and WLAN applications. These applications may be performed through the proposed BPF. There are several techniques to enhance the selectivity in which one of the best techniques will be used in proposed work. Better coupling methods can be used to decrease the insertion loss. With the increasing demand for tri-band applications in modern wireless systems, such as the global systems for the Global Positioning System (GPS) at 1.57 GHz, Worldwide Interoperability for Microwave Access (Wi-MAX) at 3.5 GHz and wireless local area networks (WLANs) at 2.4/5.2 GHz, research on innovative designs of tri-band filters has become very popular. The advantage of this filter is the ability to produce three pass bands separated by TZ.

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