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Analysis of Stub Loaded Embedded With Open Loop Resonator for Multiband Band Pass Filter

J.Parimala,
Second Year M.E Communication System,
Sri Venkateswara College of Engg.,
Chennai

H.Umma Habiba,
Associate Professor of ECE,
Sri venkateswara college of Engg.,
Chennai

S.Pachiyappan,
Second Year M.E Communication System,
Sri Venkateswara College of Engg
Chennai

***Abstract*–This paper presents a high-selectivity planar multi-band band pass filter with high interference suppression between the bands. The proposed filter utilizes two different kinds of resonators, i.e., stub-loaded resonator and open loop resonator. To reduce the circuit size open loop resonator is embedded inside the stub-loaded resonator hence compact in size. A multi band BPF is designed for the applications of mobile communication at 1.0 GHz, the Global Positioning System at 1.5GHz, Bluetooth at 2.45GHz, WiMAX at 3.2GHz. Stub loaded resonator is designed to operate center frequency at 1.0GHz and 3.2GHz and the open loop resonator at 1.5GHz and 2.45GHz.The pass bands can be conveniently tuned to desired frequencies by controlling the corresponding resonator dimensions. Inter digital capacitor is used to realize inter-stage coupling between two resonators**

***Keywords*- Band pass filter (BPF), Stub-loaded resonator, Open-loop resonator, Coupling coefficient, Fractional bandwidth, Defected ground structure (DGS), Electronic band gap (EBG).**

I. INTRODUCTION

Band pass filter (BPF) is one of the essential building blocks for communication systems. It can reduce harmonic and spurious emission for transmitters as well as improve the interference rejection performance for receivers. Usually a BPF can be implemented with conventional micro strip parallel-coupled lines or transmission line stub. The wireless communication standard such as GSM, WCDMA, WiMAX, LTE, UWB and WPAN leads many narrow band communication systems. Therefore band pass filter with multiple frequency bands has been paid more attention. While the filtering function is critical in removing interference, spurious and other unwanted signals the physical size required by many filter design is often a limiting factor for many system architecture.

Now a days for reducing interference defected ground structure (DGS) and Electronic band gap(EBG) structure where introduced in filter circuit. The disadvantage of these structure is it radiates energy and in some cases it will introduce additional loss in the fabrication result. Therefore the reduction of fabrication complexity and interference suppression between the pass bands are achieved by interstage coupling using inter digital capacitor.

In this paper multiband band pass filter is designed by embedding open loop resonator inside the stub-loaded resonator. So that the filter size is the same as that of corresponding single-pass band filter. Two transmission lines with the characteristic impedance of 50 Ω are directly connected to the outer resonators, acting as input and output ports.

A. *Analysis of Open Loop Resonator*

Open-loop resonator also known in the literature as split ring resonator. This resonator resonates when the length of the resonator corresponds to λ/2[6]. The open end of resonator provides a capacitive coupling in parallel to the main path that provides a transmission zero at the higher stop band. Due to the fact that the electric field at the open sides of the open loop resonator is maximum at the resonance frequency of the resonator, and the magnetic field is maximum at the center of the resonator the coupling nature between two open loop depends on the neighboring side. Thus by having the resonators coupled from the open ends, capacitive coupling is generated, while having the resonators coupled from the opposite sides, an inductive coupling is generated [3].

Figure 1 Two possible shapes of open-loop resonator.

The two parameters that control the resonance frequencies are:

1. The width of the narrow strip line *w*, which affects only the quasi-lumped resonance without main change of the open-loop resonance, so by increasing *w*, the inductive value of the strip line is decreased, that will shift the quasi-lumped resonance to a higher frequency band, and vice versa[2].

2. The other parameters that mainly affect the open-loop resonance are the spacing between the open ends of the resonator *s*, and width of the open ends *x*, Decreasing *s* decreases the capacitive coupling between the open-ends of the resonator, which shifts the open-loop mode to a higher frequency and vice versa. On the other hand, increasing *x* increases the capacitive value between the open ends which shifts the open-loop mode to lower frequency band [2].

B. *Analysis of Stub Loaded Resonator*

It consists of a transmission line of length *L* and an L-shaped open stub loaded at the line center. The L-shaped stub can be utilized to tune the even-mode resonant frequencies of the resonator whereas, it has no impact on the odd-mode resonant frequencies [4]. As a result, it is easy to adjust the pass band frequencies.

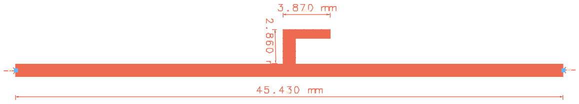

Figure 2. Stub loaded resonator

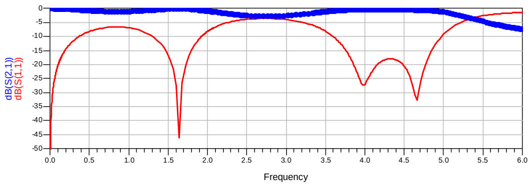

Figure 3.Simulated response of stub loaded resonator.

Each pass band of the filter is separated by transmission zeros generated by the stubs. For close spaced multiple pass bands, it is feasible to split single pass band into multiple pass bands by introducing transmission zeros between the adjacent pass bands [7]. The length *L* is the overall length of the line,

$$L=L_1+L_2+2L_3+2L_4+d+W+W_3 \qquad (1)$$

Two transmission lines with the characteristic impedance of 50Ω are connected to the outer resonators, acting as input and output ports.

C. *Inter digital capacitor and its equivalent circuit*

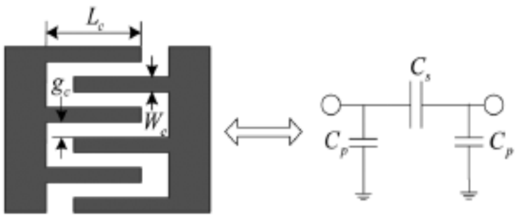

Figure 3.Interdigital capacitor and its equivalent circuit

Between the two resonators is an inter digital capacitor. It is utilized to realize inter-stage coupling. The finger number of an inter digital capacitor is 14. Each finger has the length of 2.25 mm and width of 0.5 mm. The distance between the adjacent fingers is 0.3 mm. The coupling coefficient is determined by the inter digital capacitor. Various coupling strength can be obtained by changing the physical dimensions of the inter digital capacitor.

II DESIGN PROCEDURE

This filter design procedure is as follows:

The first step is to obtain desired pass band frequencies. The resonators 1 and 4 operate at *f*1 and *f*4. The length *L* of the transmission line is half guided wavelength at the fundamental resonant frequency [6]. In this design, the inner resonators have the loading effect on the outer ones and hence the resonant frequency will shift downward. As a result, the length L is shorter than half guided wavelength at *f*1. The L shaped stub is loaded at the center of the transmission line, where the voltage is zero at *f*1. Hence, adding the stub will not affect the fundamental resonant frequency *f*1. On the other hand, the stub can be used to control the frequency of the second harmonic of this resonator .The dimensions of the L-shaped stub can be used to control *f*4. The second pass band frequency *f*2and*f*3, it is mainly determined by the length of the inner resonator. The length is around half guided wavelength at *f*2. It is noted that *f*2 and f3 are almost independent of *f*1 and *f*4 and thus it is easy to tune *f*2 and f3 to desired values.

The second step is to achieve required bandwidth for each pass band. For each pass band, the bandwidth depends on the external quality factor (*Q*e) and coupling coefficient $M_{i,j}$. For the first and last pass band, the *Q*e depends on the tap position or the length *d.* A large *d* results in a large *Q*e at *f*1 but small *Q*e at *f*4. The coupling coefficients at *f*1 and *f*4 depend on the coupling length *L*3. Since the responses at the first and last pass bands (*f*1 and *f*4) depend on the same dimension parameters, there is a compromise between the bandwidth of them. When it comes to the bandwidth of the second and third pass band, there are sufficient degrees of freedom to control it. The *Q*e at *f*2 and f3 is determined by the coupling between the inner and outer resonators. A smaller coupling gap and a narrower line result in a stronger coupling or a smaller external qualify factor. The coupling coefficient is determined by the inter digital capacitor. Various coupling strength can be obtained by changing the physical dimensions of the inter-digital capacitor. It is noted that the coupling between outer resonators also affects the response near *f*2 and f3. Fine tuning can be performed to meet the specifications at all the pass bands. The resonant modes of the stub-loaded resonator can be derived by setting $Y_{in}=0$. The resonant conditions can be expressed as[9]

$$(k_1 - \tan\theta_1 \tan\theta_2)=0 \tag{2}$$

and

$$[2k_2(k_1 \tan\theta_1 + \tan\theta_2)] + \tan\theta_s(k_1 - \tan\theta_1 \tan\theta_2)] = 0 \tag{3}$$

K_1 and K_2 are corresponded to the impedance ratio defined as

$$K_1=Z_1 /Z_2 \tag{4}$$

$$K_2=Z_s /Z_1 \tag{5}$$

To understand the resonant behavior of stub-loaded resonator the analysis of resonant modes is required. The impedance and electrical length of the stub-loaded section are expressed as Z_s and Θ_s

$$Y_{in} = \frac{1}{Z_2}\frac{Z_1(k_1 - \tan\theta_1 \tan\theta_2) + jZ_L(k_1 \tan\theta_1 + \tan\theta_2)}{Z_L(1 - k_1 \tan\theta_1 \tan\theta_2) + jZ_1(\tan\theta_1 + k_1 \tan\theta_2)} \tag{6}$$

where

$$Z_L = \frac{jZ_1K_2(\tan\theta_1 \tan\theta_2 - K_1)}{K_2(\tan\theta_2 + K_1 \tan\theta_1) + \tan\theta_s(\tan\theta_1 \tan\theta_2 - K_1)} \tag{7}$$

Two well-designed stub-loaded and open loop resonators are employed to form the Multi-band BPF. The 3 dB fractional bandwidths (FBW) of the pass bands center frequencies are 1.0, 1.575, 2.4, and 3.2 GHz. For satisfying filter specification for the bandwidths of the pass bands, the desired coupling coefficients $M_{i,j}$ and external quality factor Q_e methodology are performed. The theoretical $M_{i,j}$ and Q_e are calculated and defined as

$$M_{i.j} = \frac{FBW}{\sqrt{g_1 g_2}} \tag{8}$$

and

$$Q_e = \frac{g_0 g_1}{FBW} \tag{9}$$

Where FBW is fractional bandwidth, and gn and g_{n+1} are element values of the filter response function. From the filter specifications, the element values for the low-pass Chebyshev proto type with .2 dB ripple are found to be $g_0=g_3=1$ $g_1=1.5296$ $g_2=1.3633$

It is known that the coupling coefficients related with the desired fractional bandwidths are controlled by the coupling spacing (g) [11].The external quality Q_e at the corresponded frequencies f_0, f_1, f_2 andf_3 with respect to the length d defined by the tapped location to the symmetric plane is analyzed. The coupling coefficients Ki,j and external quality Q_e can be calculated by the equation (10) and (11)

$$K_{i.j} = \frac{f_H^2 - f_L^2}{f_H^2 + f_L^2} \tag{10}$$

And

$$Q_e = \frac{2\omega_0}{\Delta\omega_{3\,dB}} \tag{11}$$

Where f_H and f_L are defined to be the higher and lower of the two resonant modes, ω_0 is the resonant frequency, and the Δw_3 is the bandwidth. The analysis of center frequencies and external quality factors Q_e are calculated by full-wave EM simulation, Q_e at f_1 andf_2 are dominated by the tapped location. The desired multi-band response can be obtained simultaneously by shifting the 'd' to induce a suitable Q_e for the bandwidths of f_0, f_1,f_2 andf_3. A multi-band band pass filter is implemented operating at center frequencies of 1.0,1.5, 2.4 and 3.2 GHz. The experimental filter used a substrate with a relative dielectric constant of 4.6, loss tangent of 0.0012 and thickness of 1.6 mm

III FILTER CONFIGURATION AND SIMULATED RESPONSE

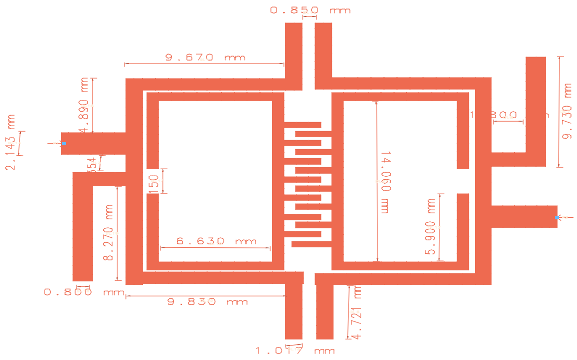

Figure 4. Layout of multi-band BPF for g=1.50mm

When the coupling gap is 1.5mm four bands are achieved with high selectivity of -45dB for first and -50dB for second and third bands. Return loss for second and third band is -16dB and -18dB

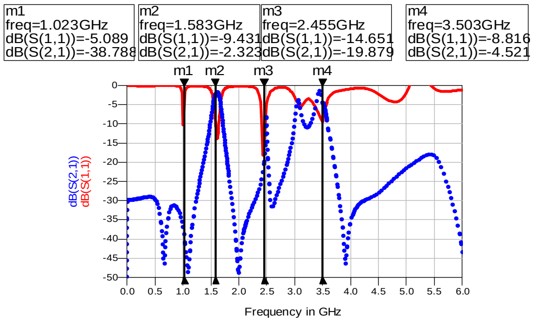

Figure 5. Simulated response of multi-band BPF for g=1.50mm

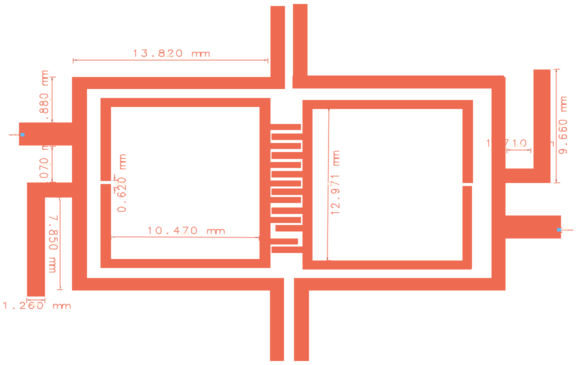

Figure 6.Layout of multi band BPF for g=0.625mm

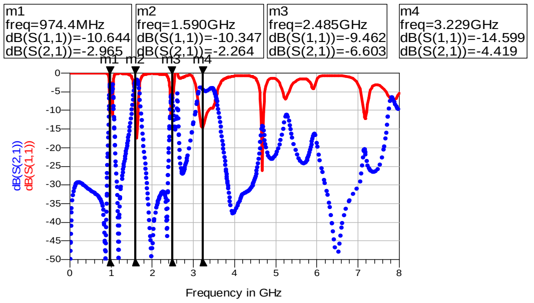

Fig 7. Simulated response of multi band BPF for g=0.625mm

Hence multi-bands achieved here with center frequencies are 974MHz, 1.590GHz, 2.485GHz and 3.229GHz for mobile phones, GPS, Blue tooth and Wi-max applications respectively. Selectivity for first two bands are nearly -50dB, third band -28dB and fourth band -38dB

IV SUMMARY AND CONCLUSION

This project presents a planar multi-band band pass filter with compact size and high selectivity with the following bandwidths and center frequencies

First band- Bandwidth of 974MHz with center frequency 0.974GHz and selectivity -50dB

Second band- Bandwidth of 616MHz with center frequency 1.590GHz and selectivity -50dB

Third band- Bandwidth of 895MHz with center frequency 2.485GHz and selectivity -28dB

Fourth band- Bandwidth of 744MHz with center frequency 3.229GHz and selectivity -38dB

The insertion loss and return loss were greatly reduced. Each pass band has good selectivity with high interference suppression and stop band attenuation.

REFERENCES

[1] C.-H. Lee, C.-I. G. Hsu and H.-K. Jhuang, “Design of a new tri-band microstrip BPF using combined quarter-wavelength SIRs,” IEEE Microwave Wireless Components Letters, vol.16, no.11, pp.594-596, Nov. 2006.

[2] C.-I. G. Hsu, C.-H. Lee, and Y.-H. Hsieh, “Tri-band bandpass filter withsharp passband skirts designed using tri-section SIRs,” IEEE Microwave Wireless Components Letters, vol.18, no.1, pp.19-21, Jan. 2008.

[3] C. Quendo, E. Rius, A. Manchec, Y. Clavet, B. Potelon, J.-F. Favennec and C. Person, “Planar tri-band filter based on dual behavior resonator,”in Proc. Eur. Microwave Conference, Oct 2005, pp.269-272.

[4] F.-C. Chen, Q.-X. Chu and Z.-H. Tu, “Tri-band bandpass filter using stub loaded resonators,” Electronics Letter, vol.44, no.12, pp.747-749, Jun 2008.

[5] J.A. Curtis and S.J. Fiedziuszko, “Miniature Dual-mode microstrip filters”, IEEE MTT-S Digest, 1991. pp. 443-446.

[6] J. S. Hong, H. Shaman, and Y. H. Chun, “Dual-mode microstrip openloop resonators and filters,” IEEE Trans. Microwave Theory Tech., vol.55, no. 8, pp. 1764–1770, Aug. 2007.

[7] J. S. Hong and M. J. Lancaster, Microwave Filters for RF/Microwave Applications. New York: John Wiley& Sons, 2001.loop resonator," IEEE Microwave Guided Wave Letters, vol. 5, no. 11, pp.371, Nov. 1995.

[8] L.Athukorala and D.Budimir,"Compact Filter Configurations using Concentric Microstrip Open Loop Resonators", IEEE Microwave and Wireless Components Letters, Vol. 22, No.5, May 2012.

[9] M. J. Lancaster and J.S. Hong , "Couplings of microstrip square open-loop resonators for cross-coupled planar microwave filters," IEEE Transactions Microwave Theory Tech., vol. 44, no. 11, pp. 2099–2109,Nov. 1996.

[10] L.-H. Hsieh and K. Chang, "Compact, low insertion-loss, sharp-rejection and wide-band microstrip bandpass filters," IEEE Transactions Microwave Theory Tech., vol. 51, no. 4, pp. 1241–1246, Apr. 2003.

[11] M-H. Weng, H.-W. Wu, "A novel triple-band bandpass filter using multilayer-based substrates for WiMAX," in Proc. Eur. Microwave Conference, Oct.2007, pp.325-328.

[15] M. J. Lancaster and J.S. Hong, "Bandpass characteristics of new dual mode microstrip square loop resonators," Electronics Letters, vol. 31, no.11, pp. 91–892, Nov. 1995.

[16] Pozar, David M. (1998). "Microwave Engineering" 2nd Edition, USA: John Wiley & Sons, Inc.

[17] X.-P. Chen, K. Wu and Z.-L. Li, "Dual-band and triple-band substrate integrated waveguide filters with Chebyshev and quasi-Elliptic responses," IEEE Transactions Microwave Theory Tech., vol.55, no.12, pp.2569-2578, Dec. 2007.

[18] X. Y. Zhang, J.-X. Chen, Q. Xue and S.-M. Li, "Dual-band bandpass filter using stub-loaded resonators," IEEE Microwave Wireless Components Letters., vol.17, no.8, pp.583-585, Aug. 2007.

[19] X. Y. Zhang, J. Shi, J.-X. Chen and Q. Xue, "Dual-band bandpass filter design using a novel feed scheme," IEEE Microwave Wireless Components Letters, vol.19, no.6, pp.350-352, Jun. 2009.

[20] Y. Kim, A.Tripathi, R.K.Settaluri, A.Weisshaar and V.K.Tripathi, "Extraction of multiple coupled line parameters using FDTD simulation " IEEE Proc.-Microwave Antennas Propagation, Vol. 146, No.6, December 1999.

[21] Yao, Yonggang Zhou, Qunsheng Cao, and Yinchao Chen, "A Novel ultra-wideband (UWB) Bandpass filter with compact size and improved upper-stop band performance" Member, IEEE 2009.