IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 11, November 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

A Compact Tri-Band Bandpass Filter using Right and Left Handed Transmission Line

Ummer Rashid Dar[1], Dr.T. Shanmuganantham[2]
Department of Electronic Engineering , Pondicherry University
Kalapet , Puducherry, 605014(India)
[1]umar.rashid.1021@gmail.com,[2]shanmugapu2010@gmail.com

Abstract— A compact tri-band bandpass filter is designed using right and left handed transmission line concept. The proposed filter has three pass bands which are located at 3.39, 6.38 and 8.60 GHz. The proposed structure is composed of artificial right- and left-handed transmission lines, instead of traditional distributed transmission line sections. By this approach, it is helpful in frequency performance achievement. The designed filter has tolerable passband insertion losses of 0.0001, 0.0142 and 0.1034 dB respectively. The proposed tri-band bandpass filter has a passband covering 0.4-8.6 GHz and its measured 3-dB fractional bandwidth is about 66.7%, 21% and 12% respectively.

Keywords— Right and left handed transmission lines (RHTL), Band pass filter (BPF), SRR (Split Ring Resonators)
CSRR (Complementary Split Ring Resonators).

I .INTRODUCTION

Bandpass filters (BPFs) are necessary components of RF/microwave systems because of their high performance and compact size. More attentions have been focused on the wireless communication applications from the past years. Wireless local area network (WLAN) has become one of the most general methods for the internet access. The new field of wireless communication systems stimulates the demand for compact band-pass filter.

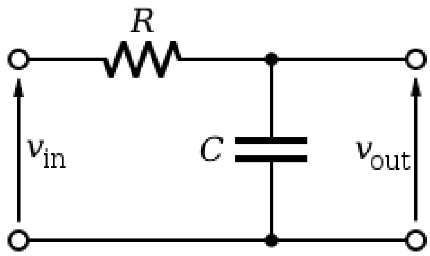
In order to design a band-pass filter (BPF), many different design methods have been proposed previously. In [1] re-entrant resonators has been used for the filter design, the transmission zeros are placed above the passband has been placed. However, the large area of those three dimensional filter is not suitable for design. The work has been done for the size reduction by using evanescent mode propagation technique but the suppression level of passbands is poor [2,5].

For the smooth and continuous communication in the multiband transceiver, it is important to have good and high performance multiband bandpass filters(BPF) to avoid any interference from other wireless bands which are operating on the same transceiver. In this regard, various research has been performed on, and several approaches have been developed for designing multiband bandpass filters (BPFs). On dual bandpass filters a lot of work has been done based on loaded stub techniques, frequency transformation techniques and coupling matrix techniques. The most of the studies considered filters with specific passband responses [4]. Bandpass filters are dual and tri-band band pass filters. There are different techniques to design of dual-band and tri-band band pass filters [8],[9]. Without a need to design two/three different single band circuits, the dual/tri-band filters can be operated at two/three bands respectively. Because of this property such filters are of interest to modern communication systems. The resonant-type approach is useful for the design of band-pass filters. Also, they are shown that the split ring resonators (SRRs) and complementary split ring resonator (CSRRs) are useful particles for the synthesis of resonant-type left-handed (LH) structures. SRRs provide the negative effective permeability . The CSRR, which is

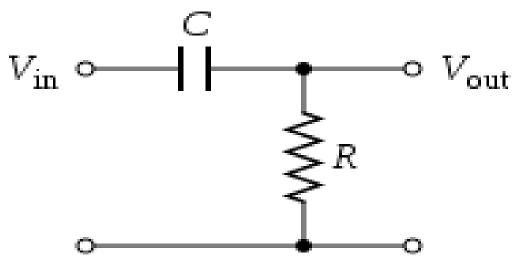
IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 11, November 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

the dual version of the SRR, is a resonant particle for the implementation of negative-permittivity media in the planar technology [13].
The RLH transmission line (TL) combines the LH and RH sections in one structure. The RLH TL consists of SRRs combined with gaps, or CSRRs combined with shunt-connected strips. The RLH TL exhibits a transmission zero above the passband. By overlapping the passbands of both stages, it is potentially possible to achieve roughly symmetric and highly frequency-selective devices. By using the LH structures, the typical frequency responses of these structures are very selective at the lower edge of the band which is due to the presence of a transmission zero while the transition band on the upper band edge is smooth [14]. The switch frequency is used to determine the upper band limit of the series impedance from capacitive to inductive behaviour (for SRR-based structures) or the shunt impedance from inductive to capacitive behaviour (for CSRR-based structures). This change is gradual rather than abrupt. This is the reason of the soft transition that may be occurred above the passband. To improve the frequency selectivity at the upper edge of the band, the alternate right–left handed (ARLH)structures with artificial right-handed (RH) sections is used instead of composite right–left handed (CRLH) Structures [8]. For good stopband performance, the filters usually need more than one filtering section.

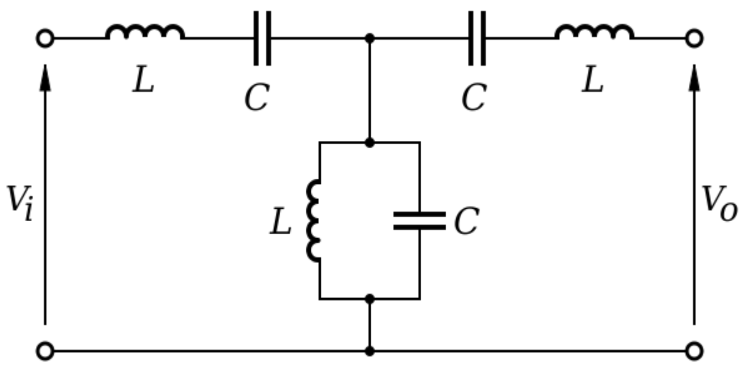
II. Theoretical Analysis



(a)



(b)



(c)

Fig. 1: Equivalent circuits: (a) pure RH TL, (b) pure LH TL, and (c) CRLH TL.

Figure 1(a) shows the equivalent circuit of RH TL ,figure and 1(b) shows the equivalent circuit of RH TL . Figure 1(a) shows the RH TL has series resistance R and shunt capacitance C which has a low-pass filtering response. Figure 1(b) shows the pure LH TL is composed of series capacitance C and shunt resistance R and shows a high-pass response.. The cut-off frequencies of these two filters can be expressed as

$$WcR = \frac{1}{\sqrt{RC}}$$

$$WcL = \frac{1}{\sqrt{RC}} \qquad (1)$$

R and L represent RH and LH, respectively.

The general model of CRLH TL is shown in figure 1(c),which consists of resistance R in series with capacitance C and shunt capacitance C in parallel with resistance R. when $wcL < wcR$, a bandpass characteristic can be constructed under. The center frequency of the passband W_O can be calculated by

$$Wo = \sqrt{WcR}x\sqrt{WcL} \qquad (2)$$

The passband is formed by two parts, the LH part and RH part, the wider the bandwidth, wider the band response. Other EM properties can also be calculated when $wcL \geq wcR$.

III. FILTER DESIGN

Unit Cell.

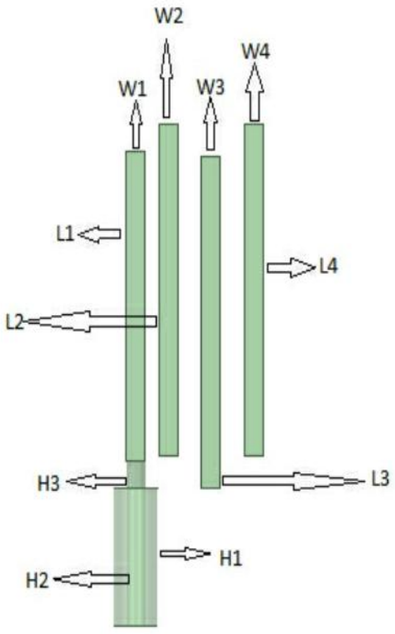


Fig.2 Unit Cell Design of Compact Tri-Band Bandpass Filter.

A tri-band bandpass filter is designed using alternative right and left handed transmission line. Figure 2 shows the unit cell of filter which is right handed transmission line. The pass bands is generated by controlling individual resonator lengths and resonator widths. The open resonators are connected together to reduce the size and to improve the frequency selectivity of the tri-band band pass filter. Copper is used as material for the design of filter which has relative permittivity of 1 and the loss tangent 0. The resonators used in the design are cavity resonators which are closed metal structures that confines electromagnetic fields in the microwave region. The ports have outer coax diameter(feed),the inner coax diameter(feed-pin) and the feed-probe. 3D full-wave software ANSYS HFSS v20. is used for the simulations of tri-band bandpass filter.

The geometrical dimensions of proposed tri-band bandpass filter for unit cell are L1 = -43.18mm, W1=3.175mm, L2 = 4646.17mm, W2 = 33.17mm, L3= -46.177mm, W3= 33.17mm, L4= 46.1772, W4= 3.175mm. Each resonator has same height which is 1.525 mm. For the feed (outer coax diameter) the dimensions are H1 = 19.05mm, Radius = 3.556mm, for feed-pin H2 =19.0mm, Radius = 19.05mm, for feed-probe H3 =1.524mm, Radius = -3.81mm. The other unit cell((LHTL) of design is created by duplicating the first half (RHTL) of design at 180 degree angle on the Z-axis.

IV. TRI-BAND BANDPASS FILTER DESIGN

.

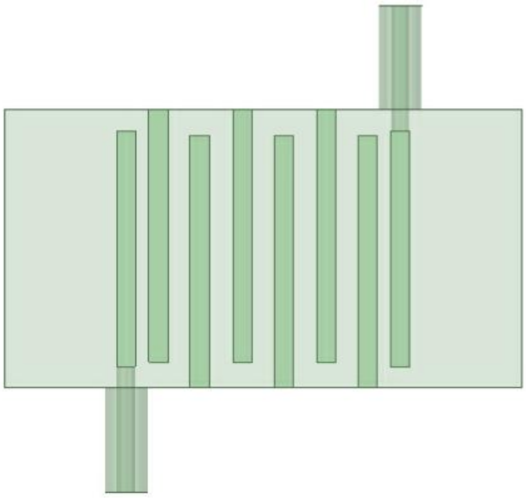


Fig.3 -Layout of proposed Tri-Band Bandpass Filter

A tri-band bandpass filter is designed, operating at the centre frequency $f_{0=}$ 4.5 GHz over the frequency range of 0.4 -8.6 GHz. The designed filter is optimized in ANSYS HFSS v20. Figure 3 shows the proposed design which is the combination of right and left handed transmission line. The RH and LH are united to decrease the over all size of filter. The 3-D layout of the proposed filter is shown in figure 4. The E-Field distribution is shown in figure 5 which is stimulated at the frequency of 4.5GHz using ANSYS HFSS v20 . The total size of the filter is 50×41 mm .

To improve the frequency selectivity at the upper edges of the band in tri-band bandpass filter the ARLH transmission line is used . For the improvement in the sharp transition at lower edges the open resonators are connected together. Proposed design gives symmetric and highly selective frequency responses .The LH stage and the RH stage are used for the realization of tri-band bandpass filter. For the RH stage four resonators and one port is used and for the LH stage four resonators and one port is used by duplicating the RH side. At different frequencies the RH and LH are used to exhibit the transmission zeros. RLH TL is used for the achievable frequency selectivity characteristics. The solution frequency has been set at f_0= 4.5 GHz. Because of the good selectivity the proposed tri-band bandpass is suitable for WiMAX applications. Total size of the proposed tri-band bandpass filter has been reduced. In the proposed work ,the reduction of dimension strategy is presented.

ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

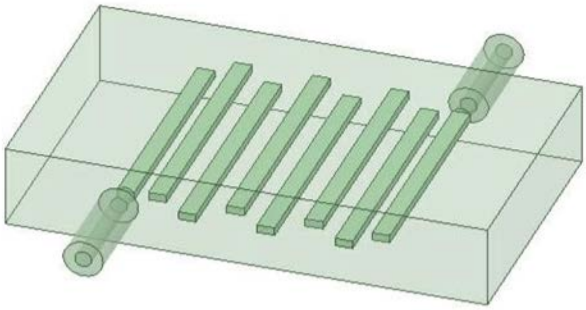


Fig.4. 3-D, Layout of Proposed Tri-Band Bandpass Filter.

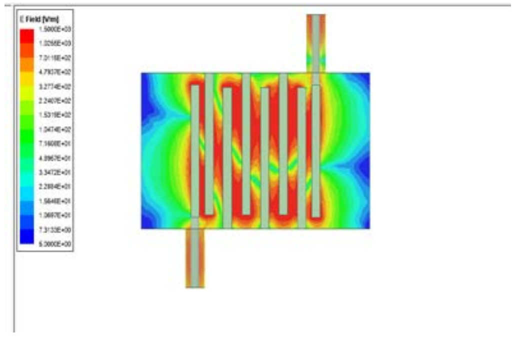


Fig.5. E Field layout of Tri-Band Bandpass filter.

V. RESULTS AND DISCUSSION.

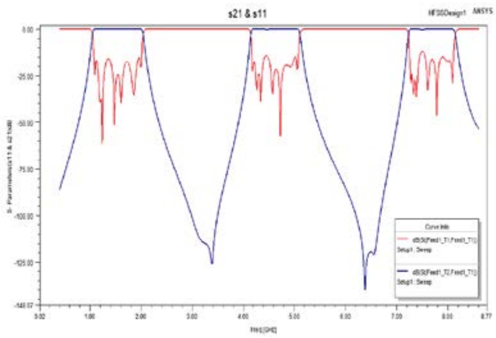


Fig.6.. Simulated frequency response (S_{11} & S_{21} plot) of tri-band bandpass filter.

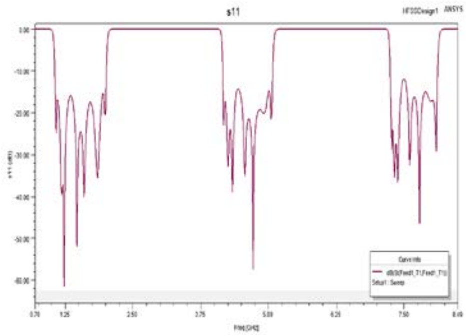


Fig.7. Simulated S_{11} frequency response of proposed tri-band bandpass filter.

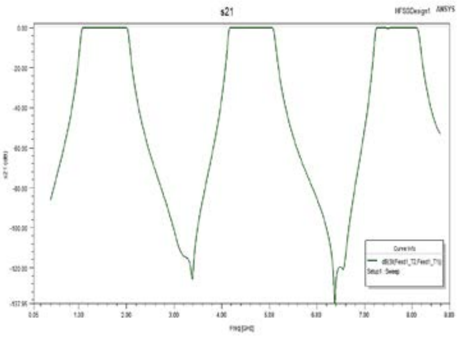


Fig.8. Simulated S_{21} frequency response of proposed tri-band bandpass filter

A tri-band bandpass filter is designed with a solution frequency of 4.5 GHz which starts at 0.4 GHz and stops at 8.6 GHz. The insertion losses of three pass bands of tri-band bandpass filter are 0.0007, 0.0144 and 0.1065 dB respectively. Three passbands are located at 3.38, 6.37, 8.69 GHz respectively. It is found that the fractional bandwidth of three passbands are 65% ,21% and 12% . The return losses of three passbands are 2.0179, 5.0802 and 8.1143 dB respectively. Each passband has six transmission zeros which are located at different frequencies. Six transmission zeros are generated on S_{21} plot which are located at 0.5022, 3.0987, 3.3849, 6.3698, 6.5538,

and 8.4142 GHz. The total size of the filter is 50×41 mm. Figure 6 gives us the simulated frequency response at the solution frequency of 4.5 GHz . Figure 7 is the simulated S_{11}, which has three pass bands at the frequency of 3.4, 6.4 and 8.6 respectively. Each passband has 6 transmission zeros and return loss of 2.17,5 and 8.2. Similarly figure 8 shows S_{21} response from which 3dB fractional bandwidth and insertion losses are calculated.

In Table 1, the characteristics of existing tri-band bandpass filters are compared with the proposed tri-band bandpass filter. The proposed filter exhibits high selectivity with low insertion losses and high fractional bandwidth .

TABLE I Comparisons Table of Proposed tri-band bandpass filter and Existing tri-band filters.

Ref.	3dB FBW(%)	$f_1/f_2/f_3$	RL(dB)	TZs	IL(dB)
[3]	N/A	1.4/3.5 /3.5	>15	5	1.7/1.8 /2.5
[4]	N/A	2.5/3.5 /6	17/13 /15	2	0.8/2.3 /2.4
[7]	10/7/9	2.4/3.5/ 5.2	N/A	6	1.5/2.5 /1.2
[10]	7/5/6	3.5/4/ 5.5	15/22/ 8	5	1.5/2 /2.6
[11]	N/A	1.5/2.4 /3.4	18/22 /17	5	0.7/1 /0.3
[12]	40/10/16	0.92/2 /3.6	28/12/ 16	6	0.41 /1.39/2
This Work	65/21/12	3.4/6.4 /8.6	2.17/5/ 8.2	6	0.0001/ 0.0142/ 0.1034

V. CONCLUSION.

In this work a tri-band bandpass filter is designed based on right and left handed transmission line concept. The designed filter is studied in HFSS v20. Th simulated results shows that the filter has good frequency selectivity due to the transmission zeros. The frequency at which it is operated is 4.5 GHz. The frequency response shows that filter has low insertion losses , high fractional bandwidth of three passbands. Hence filter is attractive for many different application in modern communication.

REFERENCES

[1] Musonda, E., & Hunter, I. C., “Microwave bandpass filters using re-entrant resonators” *IEEE Transactions on Microwave Theory and Techniques*, 63(3), 954–965,2015.
[2] Danaeian, M., & Ghayoumi-Zadeh, H. “Miniaturized substrate integrated waveguide filter using fractal open complementary split-ring resonators” *The International Journal of RF and Microwave Computer-Aided Engineering*, 28(5), e21249,2018.
[3] Lan, S. W., M. H. Weng, and S. J. Chang, “A tri-band bandpass filter with wide stopband using symmetric stub-loaded resonators,” *IEEE Microwave and Wireless Components*,2015.
[4] Wei, F., Y. J. Guo, P. Y. Qin, and X. W. Shi, “Compact balanced dual- and tri-band bandpass filters based on stub loaded resonators,” *IEEE Microwave and Wireless Components Letters*, Vol. 25, 76– 78, 2015..
[5] Danaeian, M., Afrooz, K., & Hakimi, A. “ Miniaturization of substrate integrated waveguide filters using novel compact metamaterial unit-cells based on SIR technique. AEU”: *International Journal of Electronics and Communications*, 84, 62–73,2018.
[6] Lan, S. W., M. H. Weng, and S. J. Chang, “A tri-band bandpass filter with wide stopband using symmetric stub-loaded resonators”, *IEEE Microwave and Wireless Components Letters*, Vol. 25, 19–21, 2015.
[7] N. Jankovic, R. Geschke, and V. C. Bengin, “Compact tri-band bandpass and bandstop filters based on Hilbert-fork resonators,” *IEEE Microwave. Wireless Components*. Lett., vol. 23, no. 6, pp. 282–284, Jun. 2013.
[8] Ma, M. M., Tang, Z. X., Cao, X., & Qian, T. “Tri-band cross-coupling bandpass filter with rectangular defected ground structure array”. *Journal of Electromagnetic Waves and Applications*, 17, 1–7,2018.
[9] Y. Mo, K. Song, and Y. Fan, “Miniaturized triple-band bandpass filter using coupled lines and grounded stepped impedance resonators,” *IEEE Microwave. Wireless Components*. Lett., vol. 24, no. 5, pp. 333–335, May 2014.
[10] Chu,Q. X. and X. M. Lin, “Advanced triple-band bandpass filter using tri-section SIR,” *Electronics Letters*, Vol. 44, 295–296, 2008.
[11] Rahan, M. U., Ko, D. S., & Park, J. D, “A compact tri-band bandpass filter utilizing double mode resonator with 6 transmission zeros”, *Microwave and Optical Technology Letters* 60(7), 1767–1771,2018.
[12] Lakhindar Murmu ,Sushrut Das ,Amit Bage , “A Compact Tri-Band Bandpass Filter using Multi-Mode Stub-Loaded Resonator”, *Proceedings of the Asia-Pacific Microwave Conference* ,2018.
[13] Marques, R., Martin, F., Falcone, F., & Sorolla, M. “Metamaterials with negative parameter”, *Theory, design, and microwave applications,NewYork: Wiley*,2011.
[14] Mostafa Danaeian, Ali-Raza Mozneb, Kambiz Afrooz, “Compact narrow band-pas filter based on alternate right-left handed transmission line concept”, *Springer science Business Media, LLC, part of Springer*,2020.