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Research Article

Design of Microstrip Filter for Wide Band Applications

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Abstract:

In this paper, a novel integrated microstrip filter technology useful for wideband and narrow band applications is presented. This design integrates both Low Pass Filter (LPF) and High Pass Filter (HPF) design techniques to achieve the desired band pass characteristics. The optimized results achieved for the given structure by proper tuning of the attached stubs. The designed filters are working in the Ultra-Wide Band ranging from 3 GHz to 11 GHz and it is observed that the combinational filter can even work from 2 GHz to 17 GHz. The proposed structure is simulated using MATLAB-Tool Box and the corresponding results are discussed. These filters are more useful for the modern wireless devices for UWB applications.

***Keywords:*Combinational Filter, LPF, HPF, Wideband, FR4, MATLAB- Tool Box, UWB applications**

I. Introduction

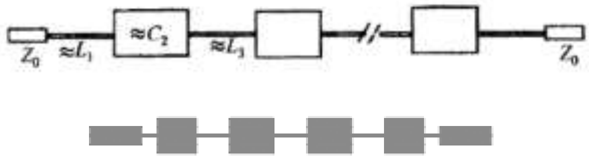
Conventional Radio Frequency communication systems are developed for fixed operations that have been pre-defined by its use cases. However, the emerging applications of wireless services over radio frequencies bring forth radically the requirement of new design paradigms for the effective usage of electromagnetic spectrum. The Ultra-Wideband technology is the most promising area which can provide the scope for implementing different wireless applications due to its wide band operation [1]. Therefore, the microstrip filter design must provide the wideband characteristics with low insertion loss and return loss while switching over different frequency bands. They also must provide the good pass band characteristics for speedy operation and reliable performance characteristics. The band pass filter allows the transmission of desired frequencies and rejects other bands. The major challenge in the design of combinational BPF is to achieve higher data rates, linearity, bandwidth, selectivity and the pass band characteristics. The simplest way to achieve the combinational filter is by integrating both the LPF and HPF operation within the structure to work with different frequency bands. There are several possibilities to realize the microstrip filter by attaching the transmission line sections in different ways and to tune them accordingly [2]. The filter can be designed for the UWB range requires good fractional bandwidth for their operation in modern wireless applications [3].

There are different types of filter technologies that are available in the literature and are discussed below. I-Tseng Tang et al. [4] have presented an UWB filter with defected ground structure. The filter could provide good pass band characteristics, but the insertion loss is found to be moderate. In [5], Zhewang Ma et.al have demonstrated dual mode resonator Filter with good performance, but exhibits sharp attenuation near its pass band. P.K.Singhal et.al [6], have presented the UWB filter using short circuited stubs. The structure could not provide the accurate harmonic suppression. Amin M.Abbosh et.al [7] have presented a filter design for UWB applications. This filter could not provide necessary coupling between the successive elements. In [8], A.K.Keskin et.al have presented the UWB filter with wide rejection band using defected ground structure. The design has good bandwidth performance, but the range of tuning frequency is found to be less. In [9], Hong-wei Deng et.al. has designed a UWB filter with stub loaded resonator. But the size of the design is large and exhibits poor frequency response. Lei Zhu et.al.[10] have designed a UWB filter with multi mode resonator. The structure could not give proper pass band characteristics. In [11], Binyan Yao has demonstrated a UWB filter with improved upper stop band performance, but have resulted moderate values of insertion loss. It is found from the above literature that there is a requirement for the microwave band pass filter for ultra wideband with good pass band characteristics and lesser values of insertion loss. The various combinations of LPF and HPF are to be analyzed to validate the design of BPF .

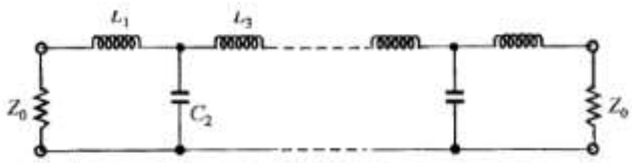
II. THEORETICAL ANALYSIS OF PROPOSED DESIGN

A microwave filter is a two port microwave network to allow the desired frequency response in the electromagnetic spectrum which makes the source power to be transferred to the load as a function of frequency. The filters can be classified as Low Pass Filters, High Pass Filters, Band Pass Filters, Band Rejection Filters based on the pass band characteristics. The important characteristics of any type of filter are the cut off frequencies, insertion loss, pass band and return loss. They find many applications at different frequencies and especially they are more useful at UWB, like GPS, Radar applications, Satellite Communications and many wireless applications. The microstrip filters has the advantages of low cost, compact in size and can be integrated into any circuit. There are many ways to construct the microwave filters with distributed elements. The simplest way to realize any type of filter is by inserting and tuning the transmission line sections. The realization of each individual lumped element with transmission line sections can be approximated with the proper position and length. The Low Pass Filter and High Pass Filters are designed with a single cut off frequency which allows to propagate lower frequency band or the Higher Frequency band respectively. The LPF and HPF can be constructed by using the series or short circuited stubs along with the transmission line sections. The Band Pass Filter requires two cut off frequencies namely, the lower cut off frequency and upper cut off frequency to transmit a band of frequencies. The Band Pass Filter can be designed by cascading the LPF and HPF that allows frequency bands from narrow to wide pass bands. At the same time, it is essential to match the impedance so as to allow these bands.

The LPF can be build with a series of microstrip patches with the given cut off frequency, whereas the HPF can be built with the insertion of stubs with the main transmission line to tune to the desired frequency. It is to be understood that the dimensions of the filters depend upon the wavelength of the signal. The higher values of selectivity, constant group delay with lower insertion loss over the desired band are the design requirements of any filter . The general structure of the LPF and HPF using the transmission line model is are shown in Fig.1, Fig.2 respectively.

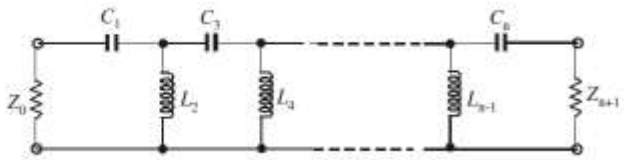


(a)

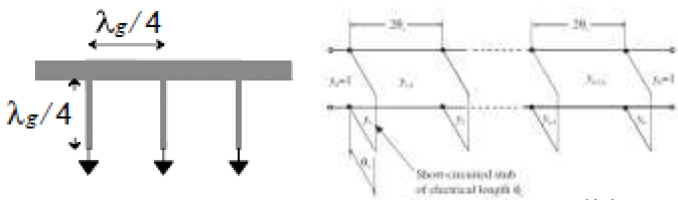


(b)

Fig.1. (a) Structure of Stepped impedance LPF
(b) Inductor-Capacitor Ladder type LPF



(a)



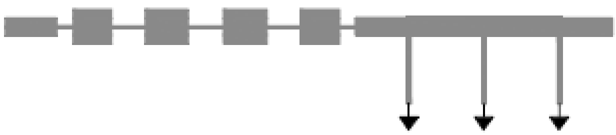
(b)

Fig.2. (a) Structure of High Pass Filter
(b) Optimum Distributed High Pass Filter

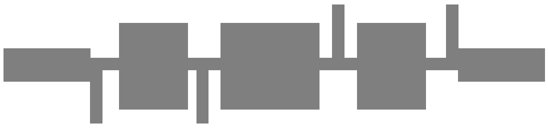
There are different transformations required to convert LPF to BPF and also HPF to BPF [12]. The following Fig.3 shows the general configuration of a BPF.

Fig.3.General Configuration of a Band Pass Filter

The directly cascaded Band Pass Filter is shown in the Fig.4 (a) and the integrated Band Pass Filter is shown in Fig.4(b)



(a)



(b)
Fig.4(a) Cascaded Band Pass Filter
(b) Integrated band Pass Filter

The Band Pass Filter under consideration operates like shunt resonator and the design equations are given by

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2}\frac{FBW}{g_0 g_1}} \quad (1)$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{Y_0}\frac{1}{\sqrt{g_j g_{j+1}}} \quad : \quad j = 1\ to\ n-1 \quad (2)$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_n g_{n+1}}} \quad (3)$$

where FBW= the fractional bandwidth , of band pass filter, g_o, g_1 . . . g_n are the elements with a normalized cutoff frequency = 1, The characteristic admittances of J-inverters are represented by $J_{j,j+1}$, Y_0 = characteristic admittance of the microstrip line and series-capacitance discontinuities with susceptance, $B_{j,j+1}$.

$$\frac{B_{j,j+1}}{Y_0} = \frac{\frac{J_{j,j+1}}{Y_0}}{1-\left(\frac{J_{j,j+1}}{Y_0}\right)^2} \quad (4)$$

and

$$\theta_j(rad) = \pi - \frac{1}{2}\left[tan^{-1}\left(\frac{2B_{j-1,j}}{Y_0}\right) + tan^{-1}\left(\frac{2B_{j,j+1}}{Y_0}\right)\right] \quad (5)$$

The term $tan^{-1}\left(\frac{2B_{j,j+1}}{Y_0}\right)$ represents the absorption of the electric length (negative) of the inverter and $B_{j,j+1}$ and θ_j is calculated at f_0. The capacitance can be calculated by using

$$C_g j, j+1 = \frac{B_{j,j+1}}{\omega_0} \quad (6)$$

Where $\omega_0 = 2\pi f_0$ is the mid band angular frequency. The length can be calculated by using the equation

$$l_j = \frac{\lambda_{g0}}{2\pi}\theta_j - \Delta l_{j^{e1}} - \Delta l_{j^{e2}} \quad (7)$$

where , $\Delta l_{j^{e1}}$, $\Delta l_{j^{e2}}$ are the effective length of the shunt capacitances of the resonator on both ends. The shunt capacitance, $C_p j, j+1$ and $C_g j, j+1$, the series capacitance are defined to form the equivalent circuit and coupling gaps of the BPF [13]. The effective lengths of the stubs can be found by using the following equations.

$$\Delta l_{j^{e1}} = \frac{\omega_0 C_{pj-1,j}}{Y_0}\frac{\lambda_{g_0}}{2\pi} \quad (8)$$

$$\Delta l_{j^{e1}} = \frac{\omega_0 C_{pj+1,j}}{Y_0}\frac{\lambda_{g_0}}{2\pi} \quad (9)$$

The design of the LPF and HPF can be designed using the above equations and the combination of these filters can be used to form the BPF to work with UWB and narrow band accordingly. The

dimensions of Low Pass Filter are given by L1=1mm, L2=2.5mm, L3=2mm, L4=3mm, L5=2mm, W1=0.5mm, W2=3mm and High Pass Filter dimensions are calculated as L_{stub}=6mm, L_i=6mm, Z_{stub}= 140Ω, Z_i=50Ω. These filters are combined to form a Band Pass Filter with symmetric with respective to their centers.
The another combination of LPF and HPF for BPF operation is shown in the following Fig.5.

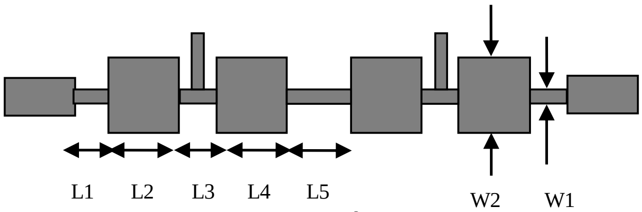
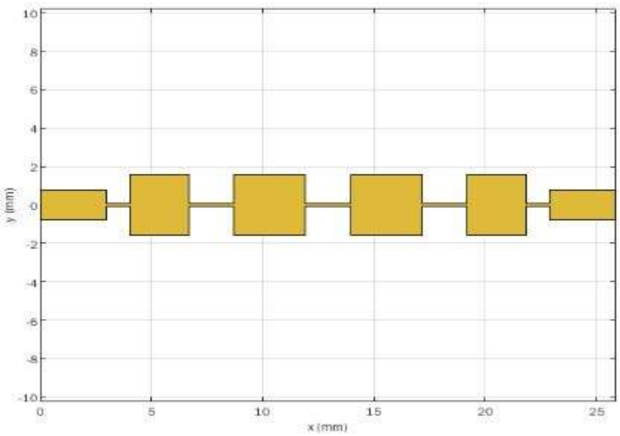


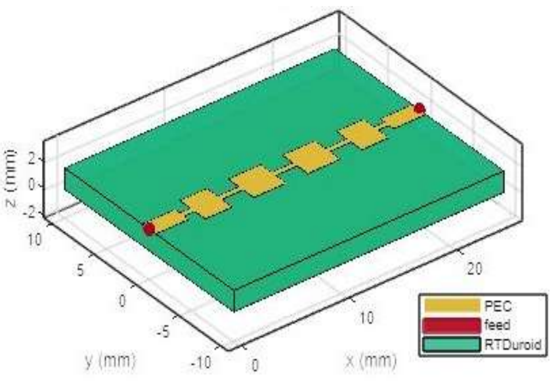
Fig.5. The Proposed designs of LPF and HPF to form combined Band Pass Filter

III. PROPOSED INTEGRATED BAND PASS FILTER DESIGN

In this section, the procedure followed to design the proposed ultra wideband microstrip filter using MATLAB [14] is presented. The design started with the design of Low Pass Filter and the geometrical structure of LPF using MATLAB is shown in Fig.6. The Low pass filter is designed on to the RT-Duroid substrate having the effective dielectric constant of 4.4with the thickness of 1.6mm and loss tangent of tanδ=0.02 for the estimated dimensions.



(a)



(b)

Fig.6. (a) Geometry of Low Pass Filter (b) LPF structure in MATLAB

The performance characteristics of the Low Pass Filter as a function of frequency are shown in Fig.7. The Pass Band characteristics are represented using the transmission coefficients S_{21} and S_{12} and the reflection coefficient S_{11} and S_{22} respectively.

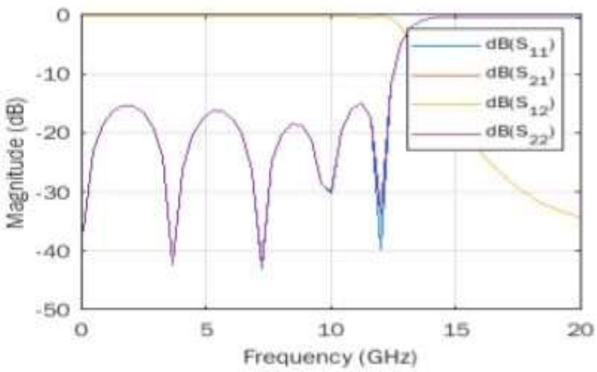
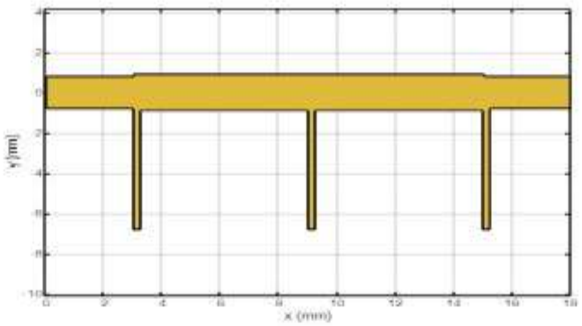
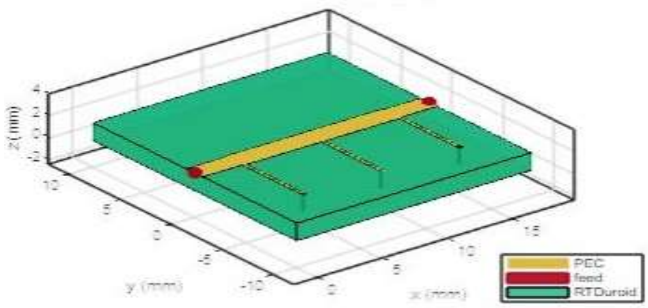


Fig.7. Simulated Pass band characteristics of LPF

It is clear from the results that the LPF is working below 12 GHz with the reflection coefficient values are in the range of -18dB to –42dB.
Similarly, the design of the High Pass Filter is carried out with the above dimensions calculated is shown in Fig.8.



(a)



(b)

Fig.8. (a) Geometry of High Pass Filter (b) HPF structure in MATLAB

The simulated operational characteristics of the High Pass Filter is shown in below Fig.9.

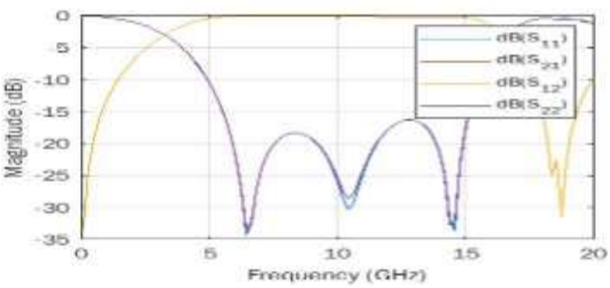
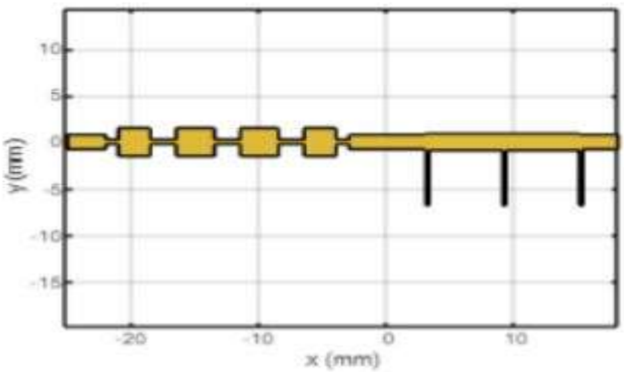


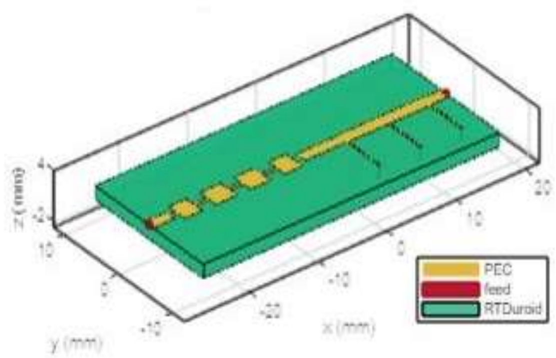
Fig.9. Simulated Pass band characteristics of HPF

It can be seen from the above results that the High Pass Filter is working in between 3 GHz to 16 GHz. The Pass Band characteristics are represented using the transmission coefficients S_{21} and S_{12} and the reflection coefficient S_{11} and S_{22} respectively.

The cascading of LPF and HPF filters is being done to get the hybrid response and the simulation is carried out accordingly and is shown in Fig.10.



(a)



(b)

Fig.10. (a) Geometry of Cascaded Filter (b) Cascaded LPF and HPF in MATLAB

The corresponding results are shown in Fig.11 along with pass band characteristics.

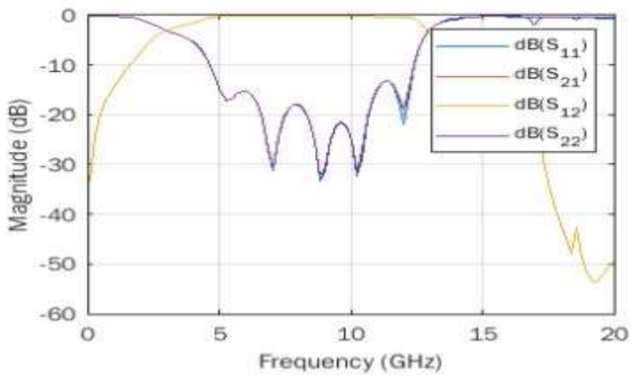
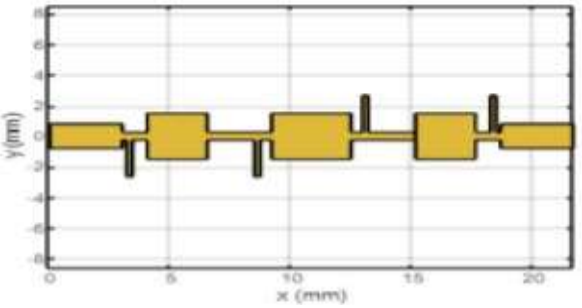
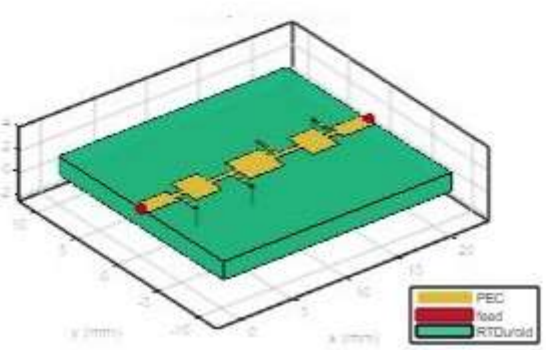


Fig.11. Simulated Cascaded Filter Characteristics

It can be seen from the above figure that the filter is showing the hybrid performance characteristics and is working like a High Pass Filter starting from 2 GHz to 17 GHz. The Pass Band characteristics of the cascaded filter are represented using the transmission coefficients S_{21} and S_{12} and the reflection coefficient S_{11} and S_{22} respectively.
Now, the Low Pass Filter and High Pass Filter are combined and simulated and shown in Fig.12.



(a)



(b)

Fig.12. (a) Geometry of Combinational Filter
(b) Combinational LPF and HPF structure in MATLAB.

The same structure is analyzed with the mesh analysis and is shown in Fig.13.

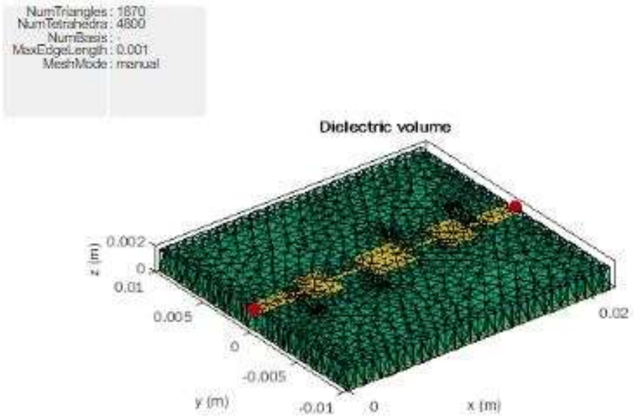


Fig.13.Mesh Analysis of the combinational filter

The corresponding results of the combinational filter are shown in Fig.14.

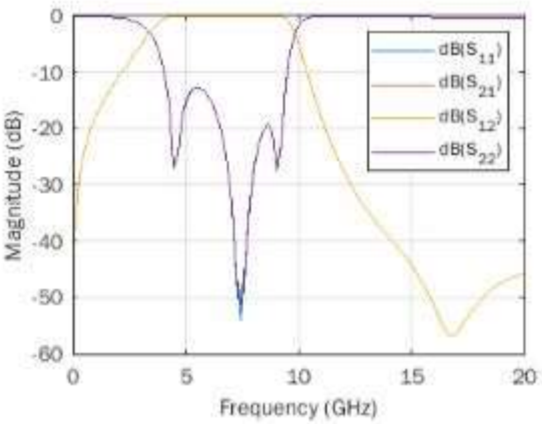
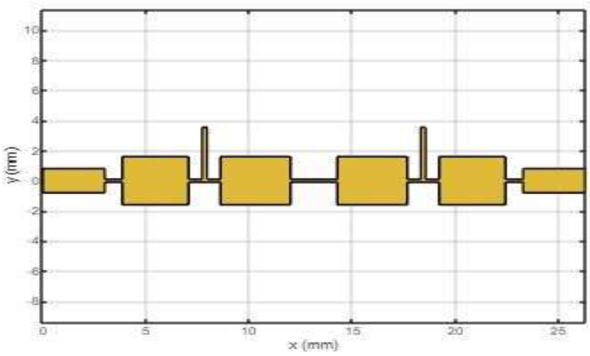


Fig.14. Simulated Combinational Filter Characteristics

The Pass Band characteristics are represented using the transmission coefficients S_{21} and S_{12} and the reflection coefficient S_{11} and S_{22} respectively. The filter is operating in between 3 GHz to 9 GHz.
In the similar manner, the design of BPF by the hybrid combination of LPF and HPF is carried out and the geometrical structure is shown in the Fig.15.



(a)

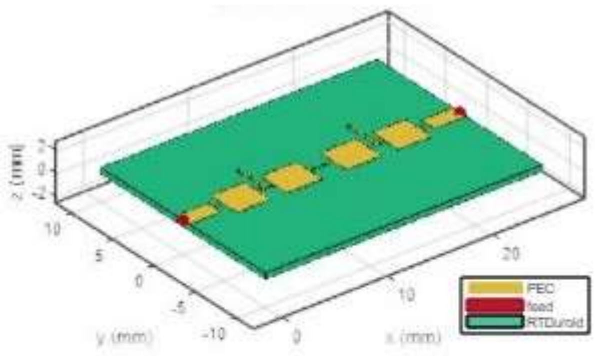


Fig.15. (a) Geometry Hybrid BPF Design (b) Hybrid LPF and HPF structure in MATLAB

The same structure is analyzed with the MATLAB mesh analysis as shown in below along with its performance characteristics in Fig.16.

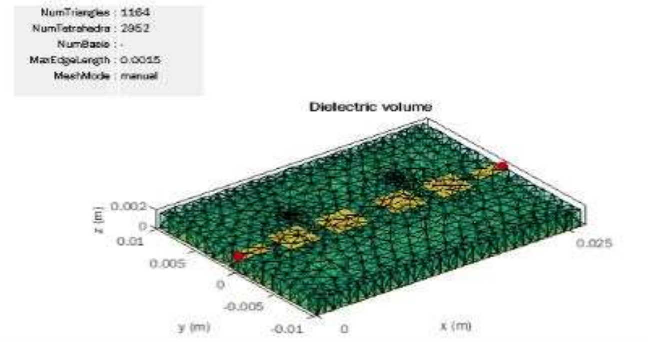
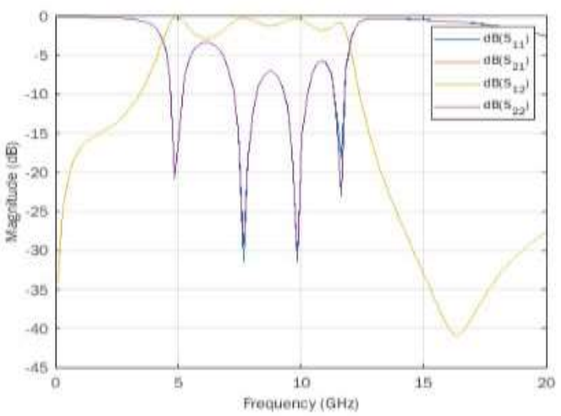


Fig.16.Mesh Analysis of the Hybrid Filter using MATLAB



The Pass Band characteristics are represented using the transmission coefficients S_{21} and S_{12} and the reflection coefficient S_{11} and S_{22} respectively. The filter is operating in between 3 GHz to 12 GHz.

IV. CONCLUSIONS

In this paper, the design of various microstrip filter for wide band applications is presented. A novel design technique of microstrip Band Pass Filter suitable for Ultra Wide Band applications are proposed by cascading the Low Pass Filter and High Pass Filter is demonstrated. Different combinations of the Low Pass Filter and High Pass Filter are verified through the MATLAB simulation. The Band Pass

Filter is designed by cascading the LPF and HPF and the High Pass Filter is realized using the short circuited stubs. The design of Low Pass Filter is carried out using the stepped impedance method. The filter is operating in the ultra wide band range starting from 3 GHz to 12 GHz and the combinational filter even working in between 2GHz to 17 GHz. These designs show the satisfactory performance of the Band Pass Filter response over wide bandwidth. These designs shows the good pass band characteristics with return loss characteristics and are suitable for Ultra Wide Band applications in modern wireless systems.

. ACKNOWLEDGEMENTS

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REFERENCES

[1] Dr. Abhishek Bhatt, Pooja Kotkar, Dr. Pradeep Chouksey, Prof. Pooja Rai, “Implementation of UWB Band Pass Filter Using Stub Resonator and drill out the best simulation outcome”, High Technology Letters, Volume 26, Issue 8, 2020.

[2] J. S. G. Hong and .M J. Lancaster, “Microstrip filters for RF/microwave applications”, Vol. 167. John Wiley & Sons, 2004.

[3] Hao, Zhang-Cheng, and Jia-Sheng Hong. “Ultrawideband filter technologies.” Microwave Magazine,IEEE 11.4 (2010): 56-68.

[4] I-Tseng Tang, Ding-Bing Lin, Chi-Min Li, and Min-Yuan Chiu, “Ultra-Wideband Band pass Filter Using Hybrid Micro-strip Defected-Ground Structure,”Microwave and Optical Technology Letters/Vol.50,No.12, December , 2008.

[5] Zhewang Ma, Wenqing He, Chun-Ping Chen, Yoshio Kobayashi, and Tetsuo Anada, “A Novel Compact Ultra-Wideband Band pass Filter Using Micro-strip Stub-Loaded Dual-Mode Resonator Doublets,”IEEE Magazine, 2008.

[6] P. K. Singhal, SumanMathur, and R. N. Baral, “Ultra-wide micro-strip band pass filter using short circuited stubs,” of Electrical and electronics Engineering Research Vol. 3(6), pp. 101-107, August 2011.

[7] Amin M. Abbosh, “Design Method for Ultra-Wideband Band pass Filter With Wide Stop band Using Parallel-Coupled Microstrip Lines,”IEEE Transactions on Microwave Theory and Techniques, Vol 60 No1, January 2012.

[8] A.K.Keskin, H.P.Partal, “An UWB High-Q Band pass Filter with Wide Rejection Band using Defected Ground Structures,”2012 IEEE International Conference on Ultra-Wideband Syracuse, NY, 17-20 September 2012.

[9] Deng, Hong-wei, “Compact quintuple-mode stub-loaded resonator and UWB filter.” Microwave and Wireless Components Letters, IEEE 20.8 (2010): 438-440.

[10] Zhu, Lei, H. Bu, and K. Wu. “Broadband and compact multi-pole microstrip bandpass filters using ground plane aperture technique.” IEEE Proceedings-Microwaves, Antennas and Propagation 149.1(2002): 71-77.

[11] Yao, Binyan, “Compact UWB bandpass filter with improved upper-stopband performance.” Microwave and Wireless Components Letters, IEEE19.1 (2009): 27-29.

[12] D.M.K.Chaitanya. “Reconfigurable Hairpin Bandpass Filter for wireless Applications”, International Journal of Engineering & Technology, Vol.7, pp.229-232, 2018.

[13] G. Matthaei, E. M. T. Jones and L. Young, “Microwave Filters, Impedance- atching Networks, and Coupling Structures” Artech House Publishing, 1980.
[14] From the Websites of https://in.mathworks.com/products/rf-pcb.html/support