

Band-Pass Filter Using Resonators

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Abstract: In this paper a Band-Pass filter is designed which is operating at Ultra High Frequency range between 1-2.5Ghz. The components that are used in the design of band-pass filter are 8 resonators and two coaxial feedings. PEC (Perfect Electric conductor) material is used to design the filter and the vacuum is used for designing the outer box. To solve the model, we have assigned Wave-port and taken the solution type as Driven-Terminal. We have taken the Terminal renormalizing impedance for both feeds as 50ohm and driven setup frequency as 1.5Ghz. Here we observed lower cut-off frequency(fL) as 1.2Ghz and higher cut-off frequency(fH) as 2Ghz with percentage bandwidth 50%. We have observed the VSWR, S-parameter, Z-parameter, Y-parameter followed by field report from the design of band-pass filter. These above results are obtained and verified by the simulation software HFSS (High frequency structure simulator).

KEYWORDS: Bandpass filters, resonators, HFSS, PEC, Wave-port, Driven-terminal, parameters-S,Y,Z.



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INTRODUCTION

Modern development in communication systems has created demand for band-pass filters. To meet the various application oriented requirements, here band-pass filter was proposed and designed using resonators completely without any active or passive elements involved and thus band-pass filter exploited mainly as a key circuit block in wireless communication systems [1]. In this paper, we are introducing simple structure design with compact size by using HFSS software version 15.0. The stimulated results shows a wide bandwidth along with high range of gain. In the design of any communication model, band pass filter plays a very prominent role. The band-pass filter blocks the unwanted frequencies and allows only a particular set of band of frequencies. Considering few general application like audio based example radio, it is required to allow only a particular range of frequency which may be wide range or narrow range. Thus this certain band of frequencies are known as Bandwidth ($f_H - f_L$). Without any variations in the input signal and with the help of resonators and feedings thus the design band pass filter (BPF) can allow only a particular frequency range and does not produce insertion loss or noise in the signal.

OBJECTIVES:

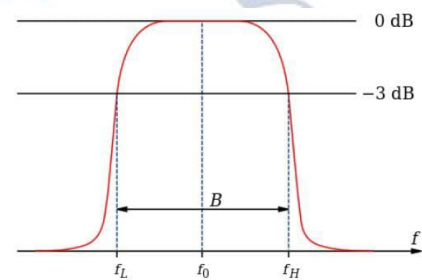
The main objective of this project is to achieve high bandwidth and low insertion loss with consistent performance and to reduce the system complexity of designing a band-pass filter. We reduced the number of components within the module, optimizing use of space/dimensions. This is economical or cost effective Band-pass filters are useful for 5G wi-fi applications. It is used in wireless communication medium at both transmitter circuits and receiver circuits. BPF also plays an important role in military and radar communication purposes. The band pass filter optimize the sensitivity of the receiver

RELATED WORK:

In this section, we analyze the related work regarding band-pass filters, such as how they are useful for modern wireless communication and upcoming theories to be proposed and also calculated the bandwidth, bandwidth percentage, quality factor [1][2]

1) Bandwidth and percentage bandwidth [1]:

A bandpass filter allows frequencies within a certain range and rejects frequencies outside that range. BPF passes through only certain components having specified band of frequencies which is said to be its pass band at the same time band-pass filter blocks all the components with frequencies below or above its pass band a band pass signal contains a band of frequencies not adjacent to 0 frequency. The band-pass filter cannot attenuate all frequencies outside the passband frequency range but in a particular region which is outside the intended passband frequencies are attenuated by BPF but they are not rejected. This process is said to be the filter roll-off and expressed in terms of dB of the attenuation. In practical bandpass filter is not ideal



Bandwidth measured at half-power points (gain -3 dB, $\sqrt{2}/2$, or about 0.707 relative to peak) on a diagram showing magnitude transfer function versus frequency for a band-pass filter.

Figure 1: Bandwidth representation of band pass filter

The above waveform can be obtained from the design of band-pass filter in HFSS simulation software with the rectangular plot of x and y axis taking frequency (Ghz) and gain(dB) respectively. From the graphical representation, bandwidth defined as a range of frequencies within a given band, used for transmitting a signal can be calculated. Here, bandwidth of band-pass filter is given as

$$BW = f_H - f_L$$

Where f_H is high cut-off frequency and f_L is low cut-off frequency

Percentage bandwidth is given as

$$BW\% = (BW / f_C)$$

Here, f_C is the Center frequency, also called as resonant frequency and given as $(f_H + f_L)/2$. Thus,

$$BW\% = 2 * (f_H - f_L) / (f_H + f_L)$$

Quality-factor [2]

In general, a band-pass filter can be characterized by its Quality factor also called as Q-factor. The Q-factor is the ratio of center frequency to the bandwidth(BW). Thus, for a bandpass filter, the Q-factor,

$$Q = f_C / (f_H - f_L)$$

The frequencies, f_H and f_L , are the two -3dB cutoff frequencies. f_L is the lower cutoff -3dB frequency and f_H is

higher cutoff -3dB frequency. The Resonant frequency which is also known as Center frequency is the frequency in the center point of the bandpass.

The center frequency,

$$f_C = \sqrt{f_1 f_2}$$

If the Q-factor is greater than 1 then it is said to be a narrow band-pass filter and at the same time if the Q-factor is less than 1 then it is known as wideband pass filter. For narrow band-pass filters, the ratio of f_H to f_L is less than 1. So, we can approximate the center frequency as,

$$f_C = (f_H + f_L) / 2$$

DESIGN USING HFSS

In this section, we come across the design of Band-pass filter using HFSS software [1][2][3]

B. Introduction to HFSS [1]

HFSS(High frequency structural simulation) is an industrial standard software developed by Ansys mostly used for simulating three-dimension (3-D) microwave passive circuits. Ansys HFSS, a 3D electromagnetic (EM) simulation software used for design and simulation of high-frequency electronic products such as antennas, RF components, antenna arrays, microwave components, filters, connectors, and printed circuit boards, IC packages. Worldwide, engineers use HFSS software by Ansys to design

high-speed, high-frequency electronic devices used in communications systems, satellites, advanced driver assistance systems (ADAS) and internet-of-things (IoT) products.

Design of Band-pass filter using HFSS [2]

Here we designed the band-pass filter using Ansys HFSS. The HFSS solution type we have considered is Driven terminal with excitation terminal renormalizing impedance for each feed as 50ohm for calculating terminal based S-Parameters, VSWR, Z- Parameters, Y-Parameters. All the Units are taken in 'inch'. Here the outer-box of the design is made by using the Vacuum material having co-ordinates in X,Y,Z as (-1.0in, -1.7in, -0.3125in) and the opposite corner having co-ordinates in X,Y,Z as (2in, 3.4in, 0.625in)

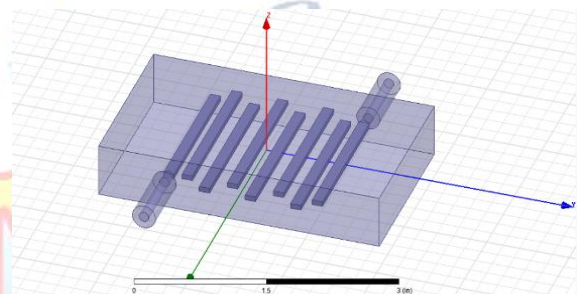


Figure 2: Design of Band-Pass Filter using HFSS

In the above fig.2, there are three cylinders naming each cylinder as Feed1, Feedpin1 and Feedprobe1. Here Feedpin1 and Feedprobe2 are made up of PEC (Perfect electric conductor) by fixing the grid plane to YZ-plane having center co-ordinates as (1in, - 0.9in, 0in). On the other hand Feed1 is made up of vacuum by fixing the grid plane to YZ-plane with center co-ordinates as (1in, - 0.9in, 0in). For each of these cylinders there exists a duplicate body around the axis. These three cylinders have assigned different height and radius which are shown in the below table-1.

Name	Height(in)	Radius(in)
FeedProbe1	-0.15	0.06
Feedpin1	0.75	0.06
Feed1	0.75	0.14

Table1.Height and Radius of each Feed

In this design we have arranged four Resonators which are capable of generating waves of ultra-high frequency in the frequency range between 1-2 GHz. For this Band-Pass Filter design four boxes made up of PEC (Perfect electric conductor) material was used and named each resonator as L1, L2, L3 and L4. For each of the resonators there exists a duplicate body around axis. The co-ordinate values of each Resonator are given in the below table-2

Resonator	(X,Y,Z)in	(dx,dy,dz)in
L1	0.85,-0.96,-0.03	-1.7,0.125,0.06
L2	-1,0.75,-0.03	1.81,0.125,0.06
L3	1,-0.48,-0.03	-1.81,0.125,0.06
L4	-1,0.2,0.03	1.81,0.125,0.06

Table2: Each Resonator co-ordinate values

Now assigning the port for HFSS band-pass filter design, there are three types of port available in HFSS namely Wave Port, Lumped Port, Floquet Port. For this BPF (Band-pass filter) design Wave port was assigned along

along with the outer face of cylinder and also given name as P1. As discussed above about the presence of duplicate body around axis of each feed cylinder and resonator, P1 selects all objects i.e. all the 3 cylinders and four resonators except air box and thus makes duplicate around Z-axis and assigns an angle of 180 degree to complete the band-pass filter design model. Further to analyze more about the band-pass filter design we have assigned count as 451, start and stop frequency as 0.6GHz and 2.4GHz respectively, and also assigned Solution frequency as 1.5 GHz, frequency setup type as linear count and sweep type as Fast.

METHODOLOGY – SIMULATION AND RESULTS

Thus designed band-pass filter was simulated through HFSS software. The impedance is matched with 50Ω. Here the simulation is done in four type of parameters i.e. S-Parameters, Z-Parameters, Y-Parameters and VSWR to correctly observe the

working of band-pass filter in various variables. The radiation pattern is also observed for electric E and magnetic H field ports. All the simulation results are represented in below figures.

Band-Pass filter simulation in s-parameters:

S parameters are the most used circuit analysis technique for linear multiport networks. There are four S-parameters with two ports system named as S11, S21, S12, and S22, here S12 and S21 are meant for transmission coefficients from port 2 to port 1 and port 1 to port 2 respectively, also S11 and S22 are meant for reflection coefficients in port 1 and 2 respectively. These parameters are also called as Scattering parameters

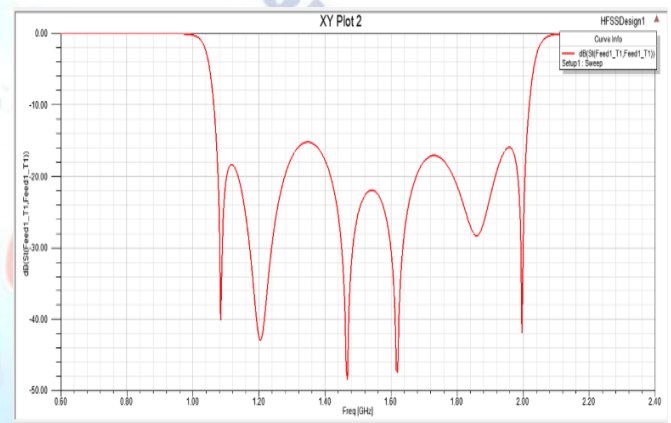


Figure3: BPF simulation result in S-parameters

Band-Pass filter simulation in y-parameters:

Y parameters are the properties which are used to explain the electrical behavior of linear electrical circuits or networks. Y-parameters are also used in Y-matrices to calculate the voltages, currents that are incoming and outgoing for a network. These are calculated under open-circuit conditions. Y11, Y12, Y21, and Y22 are Y parameters. The values can be determined of a particular 2-port network by making a short-circuited input port and output port alternatively. These are also known as admittance parameters and short-circuit impedance parameters

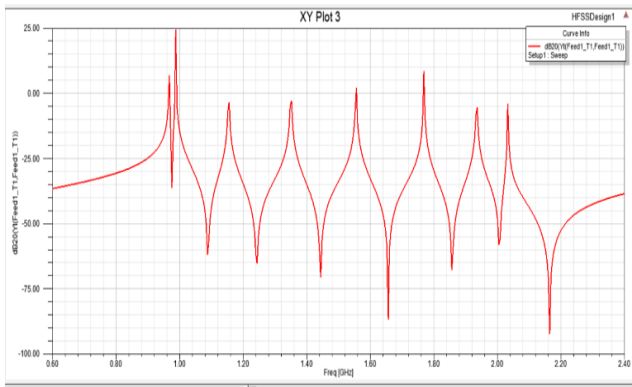


Figure 4: BPF simulation result in Y-parameters

Band-pass filter simulation in Z-parameters:

Z parameters are the properties which are used to understand the linear electrical circuits or networks electrical behavior approximately. Z-parameters are used in Z-matrixes for the calculation of incoming and outgoing currents and voltages of network. These parameters are calculated under open-circuit conditions. Z11, Z12, Z21, Z22 are Z parameters. These parameters are also known as impedance parameters and open-circuit impedance parameters

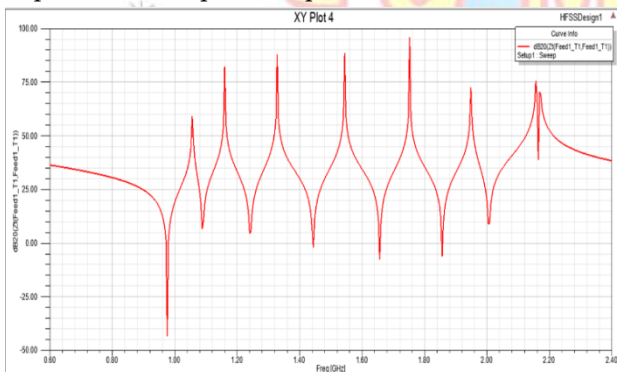


Figure 6: BPF simulation in Z-parameters

Band-pass filter simulation in VSWR:

VSWR- Voltage standing wave ratio provides the efficiency measurement of RF power transmitted from a source into the load and also in transmission line. Voltage Standing Wave Ration can be explained as the ratio of transmitted voltage standing waves to the reflected voltage standing waves in a radio frequency of electrical transmission system. It gives the relation between VSWR and the magnitude of voltage reflection coefficient Γ is given as

$$VSWR = (1 + |\Gamma|)/(1 - |\Gamma|)$$

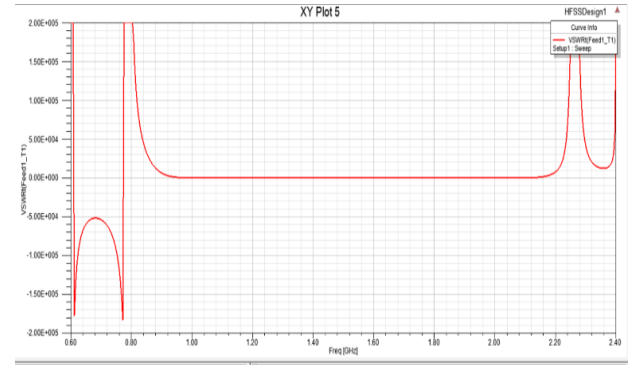


Figure 6: BPF simulation in VSWR

Field Report of BPF with feed:

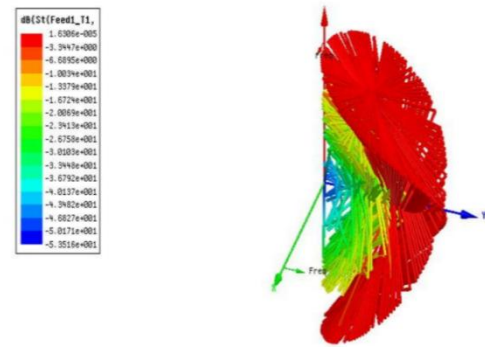


Figure 7: Field report of BPF

Thus all the simulations are done for the design of BPF and also calculated BW and percentage BW. The theoretical results can be obtained for BPF using mathematical calculations. It is clear that band-pass filter design passes only in frequency range 1-2.5GHz and rejects all the other frequency which may be below or above it.

FUTURE SCOPE AND CONCLUSION

Our work represents a modern design method for band-pass filter with high performance and wider bandwidth. The band-pass filter circuit which operates at ultra-high frequency range has been designed and simulated using Ansys HFSS software for wireless communication system purpose for passing band of frequency 1-2.5GHz and also calculated bandwidth, percentage bandwidth and Q-factor using various parameter. The design of BPF is simple in HFSS and can be easily fabricated in PCB. Bandpass filters have wide applications and more scope in wireless transmitters,

receivers i.e in wireless communication system and also in 5G wi-fi applications. BPF used in military communication, radar communication, civil fields and also used in medical field for the EEG device. It has more applications in optical communication example:LIDAR and can be applied in few color filtering techniques. The band pass filter can easily reduce and optimize the sensitivity and signal to noise ratio in the receiver section.

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