Realization of Butterworth Low Pass Filter Design in Microstrip

Salai Thillai Thilagam.J, M.Vittal, T.Sarath Babu, B.Siva Reddy, K.Raju

Abstract--- ***A low pass butterworth π shaped filter design is realized in Microstrip patch using IE3D software. The filter design is arrived at the cut off frequency of 2650 MHz with attenuation of 20 dB by selecting the FR4 substrate material as dielectric, and loss tangent as 0.02. The maximum meshing frequency is taken as 5000 MHz. The Microstrip patch size is taken as 25X15 mm² board. The 4th order low pass filter is designed and simulated. The results are nearly matching close to the designed values. At -3dB, the cut off occurs on 2660 MHz and at -19.48 dB, the attenuation falls for the 4990 MHz. The filter design is made on the patch for 24.3x11.2 mm² area. This compact design is useful in the communication field of microwave band of frequencies.***

Keywords: LPF, filter design, butterworth, microstrip, pass band

INTRODUCTION

In wireless communication applications, the system requires compact size of passive circuits like filters to function at microwave bands. The design of filters consisted of many design parameters with different topologies, types and methods. More filter designs are available such as butterworth, Chebychef, Elliptic etc. Here, the proposed filter is low pass frequency type response of 4th order butterworth type with shunt first topology on Microstrip patch planes. The novelty in this design is realization of filters on the the microstrip patch to achieve the low pass frequency response. The filter design details are given and the simulated results are provided to study its performance.

LITERATURE SURVEY

Filter design by using Filtsoft computational tool is proposed by M.H.Elsayed et al (2018)[1]. Microstrip filters design and applications presented by Ieu.W et al (2017)[2]. Filter designed by using Agilent ADS proposed by Jayaseelan Marimuthu et al (2013)[3]. Filters with resonators are designed by Kuo et al (2012)[4]. D.Xi et al, proposed a Compact low pass filter with sharp cut off and low insertion loss characteristics using novel defected ground structure(2010)[5]. Ali Pirasteh et al, presented a Compact microstrip low pass filter with ultrasharp response using a square loaded modified T shaped resonator(2018)[6]. 2GHz Microstrip low pass filter design with open circuited stub published by Akinwande Jubril et al [7]. Compact filters for WLAN is given by Ma et al (2011)[8]. In this work, the proposed filter design circuit is displayed in figure 1.

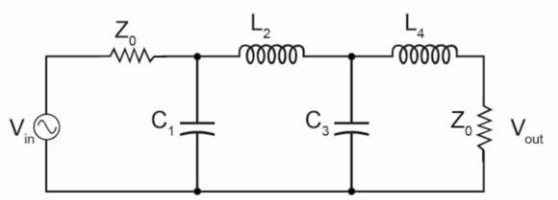

Figure 1: Fourth order Butterworth Low Pass Filter Circuit

SYSTEM DESIGN DESCRIPTION

A 4th order butterworth low pass filter circuit with shunt first topology is considered here to model in microstrip patch plane. The source resistance, load resistance, shunt capacitances, series inductances are designed for the cut off frequency of 2650 MHz[10]. The filter layout geometry is shown in figure 2.

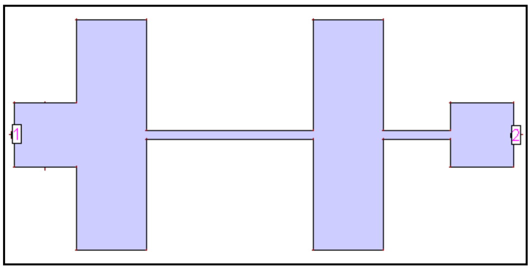

Figure 2. Geometry of Low Pass filter in Microstrip patch

Design flow

i. Selecting the filter's response
ii. Choosing the type of filter technology
iii. Calculating the number of elements
iv. Selecting the cut off frequency
v. Choosing the meshing frequency
vi. Declaring the attenuation value
vii. Displaying the LP Filters components values
viii. Transforming the components values in to planar dimensions
ix. Physical layout is prepared
x. Design of patch is executed.

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The filter's response is Butterworth low pass filter. The Butterworth technique of filter design is chosen, because of the no ripple profile at its pass band region and stop band region. The number of elements in terms of order is taken as four. The cut off frequency is selected as 2650 MHz. The meshing maximum frequency is chosen to 5000 MHz. The value of the minimum insertion loss attenuation is declared as 20 dB. For this design, the formulas were given by David M.Pozar[9]. The low pass filter components values are displayed in the table 1.

For the Frequency, f=2650 MHz

$$Wavelength, \lambda = \frac{3 \times 10^8}{2650 \times 10^6} = 0.113\, m = 11.3\, cm$$

$$order\ of\ the\ filter, n = \frac{\log_{10}\left(10^{\frac{A}{10}} - 1\right)}{2\log_{10}\left(\frac{\omega 1}{\omega c}\right)}$$

Where ω1 is angular frequency at attenuation and ωc is the angular frequency at cut off frequency. By substituting the values A=20 dB and ω1=2π5000 and ωc=2π 2650, we get n=3.56, by rounding of this number to maximum n=4. By taking g1=gc1=0.765, g2=gL2=1.847

g3=gc3=1.847, g4=gL4=0.765

These 'g' values are taken to calculate the values of C1, L2, C3 and L4.

$$C1 = \frac{g1}{z0\omega c} = 918.8\, fF$$

$$L2 = \frac{z0g2}{\omega c} = 5.56\, nH$$

$$C3 = \frac{g3}{z0\omega c} = 2.22\, pF$$

$$L4 = \frac{z0g4}{\omega c} = 2.30\, nH$$

Table 1: Low Pass filter designed values of lumped elements

Design	Rs	C1	L2	C3	L4	RL
LPF	50 ohms	918.8 fF	5.56 nH	2.22 pF	2.30 nH	50 ohms

Transforming the lumped elements components values in to Microstrip patch, the following length and width are obtained as dimensions in the Filtsoft tool[1] and presented as in table 2 and the layout with dimensions shown in figure 3.

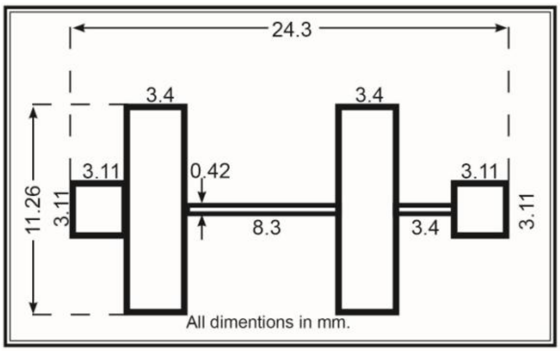

Figure 3: Microstrip Layout of LowPass Filter

Table 2: LPF filter layout dimensions

Microstrip LPF Design components	W (mm)	L (mm)
Rs	3.11	3.11
C1	3.4	11.26
L2	8.2	0.42
C3	3.4	11.26
L4	3.4	0.42
RL	3.11	3.11

The planar design is constructed on the Microstrip patch of the size 25x15 mm^2 , FR4 dieletric substrate material with 4.4 and loss tangent values of 0.02. The tool used to design the filter is IE3D[11]. The designed structure is shown in figure 3 and three dimensional geometry is shown in figure 4.

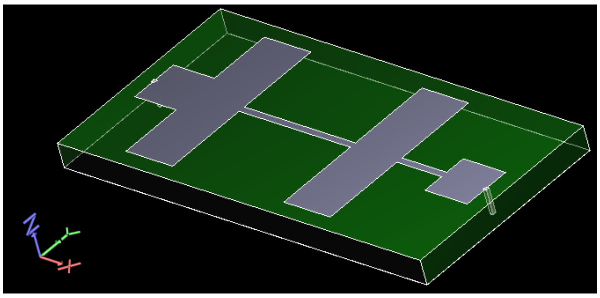

Figure 4: Three dimensional geometry of the filter

SIMULATION RESULTS AND DISCUSSIONS

The designed LPF realization is executed in the simulation tool. The height of the dielectric substrate is assumed as h=1.59 mm. The geometry is meshed to the frequency 5000 MHz and simulation is carried out. The following results were got from the simulation. From the filter design, S11 and S21 in dB with respect to the frequency are arrived. The -3 dB value at the cut off frequency 2660 MHz is achieved. The insertion loss attenuation is got -19.48 dB at 4990 MHz. The characteristic curves are displayed in the figure 5, 6-7.

Table 3: Results of Realized filter

Design	Microstrip LPF
[S11]dB at frequency (GHz)	-19.48 dB @ 4.99
[S21]dB at frequency(GHz)	-3 dB @ 2.66

CONCLUSION

A butterworth low pass filter design on Microstrip patch has been presented. It consists of shunt capacitance first as π type filter. The low pass filter response obtained -19.48 dB, attenuation at 4990 MHz. the cut off frequency occurred at -3dB at 2660 MHz and is shown in the S11, S21 characteristics. The computed and simulated results are close to the designed values. As a future work, this filter design can be fabricated as a prototype of microwave circuit. This filter design can be used in wireless communication applications.

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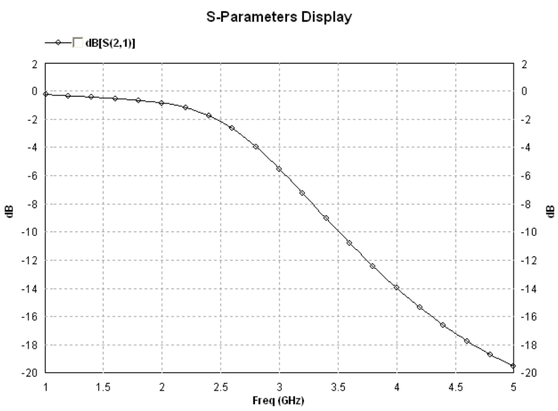

Figure 5: S21-S-parameters in dB with frequency characteristics of the filter

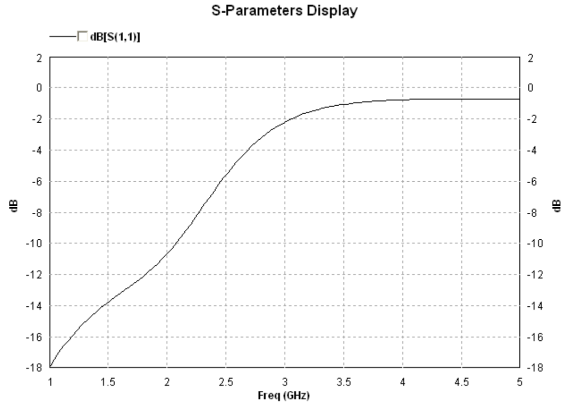

Figure 6: S11-S-parameters in dB with frequency characteristics of the filter

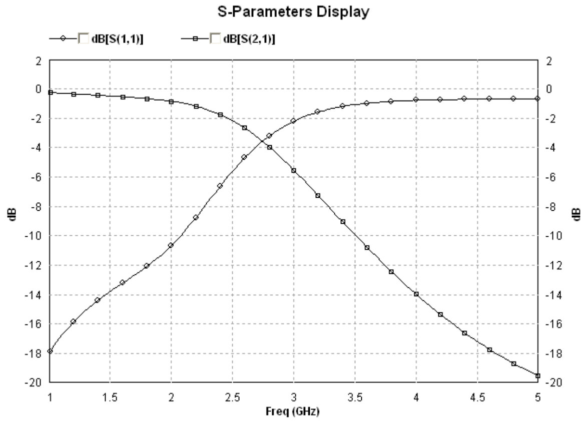

Figure 7: S11 and S21 parameters in dB with frequency characteristics of the filter