Analysis and Design of 6th order High Pass Microstrip Filter using Optimum Distributed Technique

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***Abstract*— for various emerging applications like wireless communications and others, it is very challenging to design a RF/microwave filters to satisfy the more stringent requirements like higher performance, smaller size, lighter weight, and lower cost. Hence to fulfill these requirements, in this paper we propose a 6th order High Pass Filter using optimum distributed technique for Wi-Fi application. This microstrip high pass filter is designed at 2.4 GHz and implement on FR4 substrate of relative permittivity 4.3, loss tangent 0.02 with a thickness of 1.6mm. Results are simulated using computer simulation technology software (CST). All the dimensions of Microstrip HPF is calculated with the help of optimum distributed approach at the resonant frequency of 2.4 GHz. Results are also compared and validate with other proposed design using computer simulation technology software (CST).**

***Keywords*--** High Pass Filter, Microstrip Filter, Optimum Distributed Filter, Chebyshev Filter, Quasilumped Elements Filter.

I. INTRODUCTION

Filters play dominant role in communication as a frequency selective elements. Filter is designed to attenuate certain frequencies but pass other frequencies without any loss. Two-port microstrip filter which is used to control the frequency response at certain point in a microwave system by providing transmission at frequencies within the passband of the filter and attenuation in the stopband of the filter. Microwave filter designs have been at the forefront of research in both industry and academia due to increasing specification levels and demand for advanced communication systems. Planar microstrip filters used to possess compact size, low cost, flexible layout and easy fabrication, are preferably integrated in low power transceiver systems [1-2].

A defected ground structure (DGS) is a very popular methodology for reducing the size of microwave components in recent years. Still, a continuous research is going on this methodology for improving the properties of microwave/millimeter wave components. The concept of DGS is originated from photonic band gap structures (PBG) in the optical field .The DGS is realized by etching simple shape in the ground plane of microstrip line. The etched pattern disturbs the current path in the ground plane which changes the performance of microstrip line. The DGS has two main characteristics: one is slow-wave effect and another one is band stop characteristics. These characteristics can be modified by changing the dimensions and shapes of DGS. .The most important function of this structure is also help to filtering of frequency band, and harmonics of the filter in microwave circuit. It also reject the electromagnetic wave in certain frequency and direction. The parameter of filter also improved by using DGS like - transmission coefficient, return loss etc.

Microstrip could be a variety of electrical cable, which may be made-up victimization computer circuit board [PCB] technology and is employed to convey microwave-frequency signal. Stepped impedance consists of high and low impedance transmission lines in cascaded structure. The high-impedance lines act as series inductors and the low-impedance lines act as shunt capacitors. It consists of a conducting strip separated from a ground plane by dielectric layer known as the substrate [5-8].

High pass filters constructed from quasilumped elements may be used in many applications, provided that these elements can achieve good approximation of desired lumped elements over the entire operating frequency band. Care should be taken when design this type of filter because as the size of any quasilumped element becomes comparable with the wavelength of an operating frequency, it no longer behaves as a lumped element. In this paper we proposed a 6th order High Pass Filter using optimum distributed technique for Wi-Fi application using rectangular shape of DGS to improve the parameters of the filters like return loss, transmission coefficient etc.

II. PROPOSED FITER DESIGN PROCEDURE

High pass filters can be constructed from distributed elements such as commensurate (equal electrical length) transmission-line elements. This type of filter to be discussed is shown in Figure 1, which consists of a cascade of shunt short-circuited stubs of electrical length at some specified frequency fc (usually the cutoff frequency of high pass), separated by connecting lines (unit elements) of electrical length . Although the filter consists of only n stubs, it has an insertion function of degree 2n – 1 in frequency so that it's high pass response has 2n – 1 ripples. The typical transmission characteristic of this type of filter, where f is the frequency variable and θ is the electrical length, which is proportional to f. [11-12]

$$\theta = \theta_c \frac{f}{f_c} \quad (1)$$

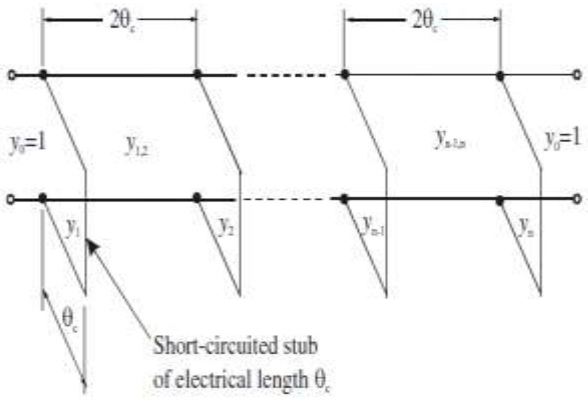


Figure 1: Optimum distributed high pass filter

To design high pass filter, the cut off frequency fc=2.4 GHz is selected and 0.1dB Ripple in pass band up to 10.4 GHz. As in figure the electrical length Ɵc can be determined by equation (2): [4-5]

$$\left(\frac{\pi}{\theta_c} - 1\right) f_c = 10.4 \quad (2)$$

By this, Ɵc =33.75^{oo} and for proposed 6th order high pass filter have element values given in table 1. For given terminating impedance Zo the associated impedance values can be determined by equation (3) and (4)

$$Z_i = Z_0 / Y_i \quad (3)$$

$$Z_{i,i+1} = Z_0 / Y_{i,i+1} \quad (4)$$

For i=1, 2......6

HPF was design at the cut off frequency of fc=2.4 GHz and formula which is used for the design of HPF is

Synthesis of W/h

$$\frac{W}{h} = \frac{8\,e^{A}}{e^{2A} - 2} \quad (5)$$

With

$$A = \frac{Z_c}{60}\left[\frac{\varepsilon_r + 1}{2}\right]^{0.5} + \frac{\varepsilon_r + 1}{\varepsilon_r + 1}\left[0.23 + \frac{0.11}{\varepsilon_r}\right] \quad (6)$$

Where Zc=Zo = 50Ω and εr (dielectric constent) = 4.4, W= width, h= height of dielectric which is taken as 1.6mm.

Effective dielectric constant of dielectric material given by equation (7) and (8)

For W/h ≤ 1:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\,\frac{h}{w}\right)^{-0.5} \quad (7)$$

For W/h>1

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\,\frac{h}{w}\right)^{-0.5} + 0.04\left(1 - \frac{w}{h}\right)^2\right] \quad (8)$$

Whereas guided wavelength is given by equation (9)

$$\lambda_g = \frac{300}{f(\mathrm{GHz})\sqrt{\varepsilon_{re}}} \quad (9)$$

εre = Effective dielectric constant , f= 2.4 GHz.

Lengths of the elements (l) were determined by equation (10)

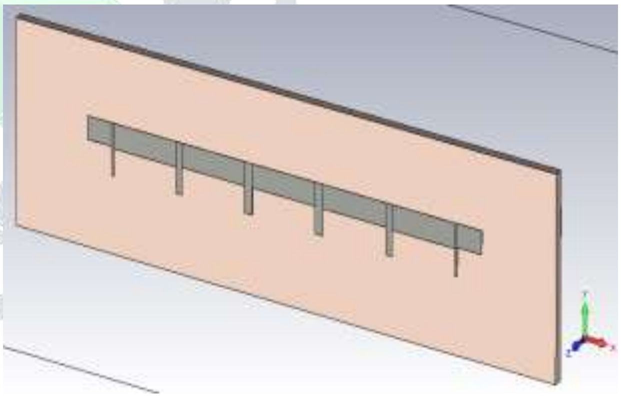
$$\Theta c = \beta * l \quad (10)$$

Where, β is the phase constant.

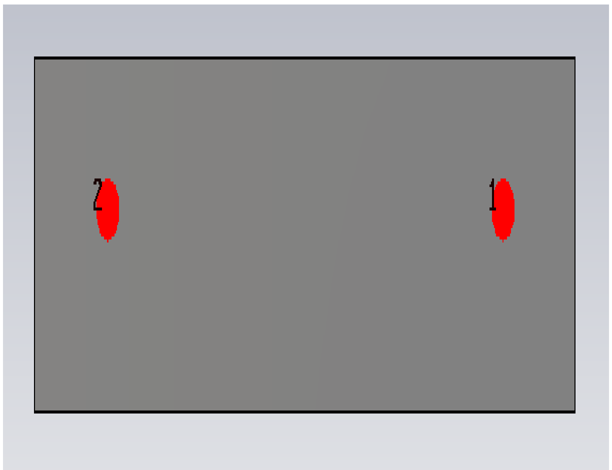
Table 1: Element values of the proposed configuration

Parameters	Unit Element (UE)	Short Circuit Stub (SC)
Admittance values (mho)	Y1,2= 1.03472 Y2,3=1.00483 Y3,4=0.99746 Y4,5=1.00483 Y5,6= 1.03472	Y1=0.44936 Y2=0.63258 Y3=0.71545 Y4=0.71545 Y5=0.63258 Y6=0.44936
Impedance values (ohm)	Z1,2= 48.336 Z2,3= 49.856 Z3,4= 50.147 Z4,5= 49.856 Z5,6= 48.336	Z1= 111.325 Z2= 79.128 Z3= 70.159 Z4= 70.159 Z5= 79.128 Z6= 111.325
Length of the element (mm)	l1,2= 12.937 l2,3= 12.964 l3,4= 12.970 l4,5= 12.964 l5,6= 12.937	l1= 6.822 l2= 6.690 l3= 6.636 l4= 6.636 l5= 6.690 l6= 6.822
Width of the element (mm)	w1,2= 3.296 w2,3= 3.133 w3,4= 3.103 w4,5= 3.133 w5,6= 3.296	w1= 0.535 w2= 1.302 w3= 1.684 w4= 1.684 w5= 1.302 w6= 0.535

The proposed design of 6th order microstrip high pass filter shown in figure 2(a) and 2(b).



a) Front View



b) Back View

Figure 2 (a) Front view of the designed Microstrip Optimum Distributed HPF (b) Back view of the designed microstrip HPF.

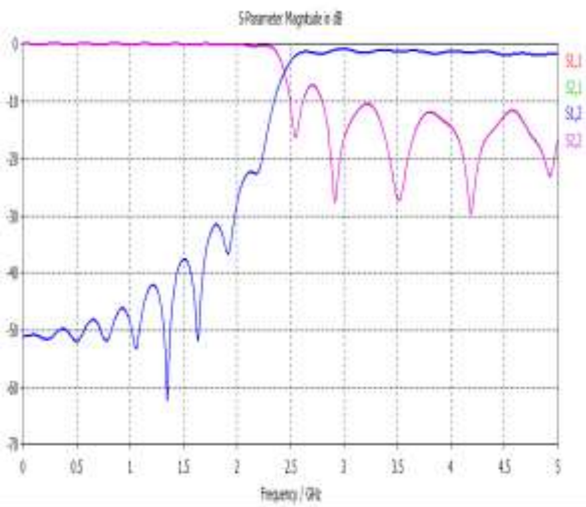


Figure 3: Simulated result of 6th order high pass filter.

III. Results Analysis and Discussion

The response of proposed 6th order HPF is obtained using CST Software [11] as shown in figure 3. From the figure it is clear that the cut-off frequency is found to be 2.4 GHz at -5dB. Hence proposed high pass filter using optimum distributed approach is capable of passing the frequency greater than 2.4 GHz & reject the frequency below 2.4 GHz. The geometry of proposed 6th order high pass filter is symmetric like unit element 1-2 and 5-6, 2-3 and 4-5 are of same size. Also short circuit stubs like 1 and 6, and 2 and 5, and 3 and 4 are of same size.

IV. Comparison of proposed work with Makrariya's et.al (ref 12)

In this section we compare our proposed design with Makrariya's et.al (ref 12) design which shown in given below table 2.

S. No	parameters	Makrariya's et.al (ref 12)	Proposed work
1	cut off frequency	fc=2.4 GHz	fc=2.4 GHz
2	Permittivity	4.4	4.3
3	Order	5th order	6th order
4	Reflection	-50db	-64db

Table 2: Comparison of results of proposed work with Reference paper [12]

From the table.2 we can conclude the following point.

1. The reflection below the cut-off frequency is -64dB which indicates more impedance matching as compare to base paper which is up to -50dB.
2. Harmonic distortion is less as compare to Makrariya's et.al (ref 12).
3. Order of proposed design is one more than the Makrariya's et.al (ref 12).

On the basis of above point, we can say that suggested design is good for filters design purpose.

V. CONCLUSION

The proposed Sixth order Optimum Distributed High Pass Filter design has been implemented and analyzed at the Centre frequency fc=2.4GHz for Wi-Fi Applications. It has been found that measured results are in good agreement with the simulated value. After adjusting the parameters of short stubs of high pass filter, the performance of high pass filter at 2.4GHz was enhanced. Proposed designed range of filter is used for applications of GSM band and Wi-Fi application.

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