# Design of Microstrip Low Pass Filter for L-Band Application

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***Abstract*—Wireless communication is need of world. In this era life cannot imagine without it. In this paper it has been designed a microstrip low pass filter for L-band Application. Microstrip Filter is designed from the methods of Step impedance low pass prototype filter, basic property of microstrip filter like simulated design, return loss, amplitude frequency graph and smith chart discussed. Finally it is shown that -3dB return loss is shown at the frequency of 1.584GHz and this frequency come in the L-band so this filters showing a very sharp cutoff and used for different application of L-band (1-2GHz).**

***Index Terms*—microstrip low pass filter (LPF), return loss, smith chart**

## I. Introduction

Microstrip filters are always famous due to their easy fabrication, small size, and low cost, light weight in cellular mobile phone industry and in many integrated circuits. Many communication system need a small size filter which can easily be fit inside the body of cellular phone, although attempt is always continuing to achieve Sharp cutoff, by making defect in its ground called the defect ground structure. It has been designed a smple microstrip filter for L-band application. [1]

In this paper, a novel G-shaped defect microstrip structure is presented. Compared with the conventional DMS, the proposed G-Shaped DMS exhibit lower resonant frequency and wider stopband a low pass filter with 3dB cutoff frequency at 3.17GHz using four pair of parallel Cascade G-Shaped DMS unit is designed and fabricated [2].

An equivalent lumped L-C network is proposed to model the introduced DGS unit and corresponding L-C parameters are extracted. A 3rd order quasi-elliptic low pass filter with 1.4GHz cutoff frequency, 1.7GHz attenuation pole frequency, negligible passband insertion loss, almost 100dB/GHz sharpness factor and 1.56GHz pass band bandwidth (at -15dB) is designed by cascading three investigated DGS units of different dimensions under capacitively loaded microstrip line [3]

Most communication system contains an RF front end which performs signal processing with RF filters. Micro strip filters are a low cost means of doing this. This paper describes the design of low cost and low insertion loss microstrip stepped impedance fractal low pass filter (LPF) by using microstrip layout which works at 0.4GHz for permittivity 4.7 value with a substrate thickness 1.6mm with pass band ripple 0.1dB. Microstrip technology is used for simplicity and ease of fabrication. The design and simulation are performed using 3D full wave electromagnetic simulator IE3D [4].

The filter is required in all RF-communication techniques**.** Low pass filters play an important role in wireless power transmission systems. Transmitted and received signals have to be filtered at a certain frequency with a specific bandwidth. In this paper the design of filter is done in the ISM (Industrial, Scientific and Medical) band whose frequency lies between 1.55GHz-3.99GHz. After getting the specifications required, we realized the filter structure with the help of CST-MW software [5].

## II. Filter Design

In this section filter has been designed using a CST-Microwave studio simulation software and display the parameter by the figures.

### Design and Optimization of Low Pass Filter Using Micro Strip Lines

Filter designs beyond 500MHz are difficult to realize with discrete components because the wavelength becomes comparable with the physical filter element dimensions, resulting in various losses severely degrading the circuit performance. Thus to arrive at practical filters, the lumped component filters must be converted into distribution element realizations.

### Richards Transformation

To accomplish the conversion from lumped and distributed circuit designs, Richards proposed a special transformation that allows open and short circuit transmission line segments to emulate the inductive and

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capacitive behavior of the discrete components. The input impedance of a short circuit transmission line of characteristic impedance Zo is purely reactive.

$$Zin = j\, Zo \tan(\beta l) = j\, Zo \tan \Theta$$

where the electric length Θ can be rewritten in such a way as to make the frequency behavior explicit. If we pick the line length to be λo/8 at a particular reference frequency fo = Vp/λo the electric length becomes

$$\Theta = (\Pi/4)\Omega$$

On substituting we get

$$j\omega L = j\, Zo \tan((\Pi/4)\,\Omega) = SZo$$

Similarly

$$j\omega C = j\, Yo \tan((\Pi/4)\,\Omega) = SYo$$

where $S= j \tan((\Pi/4)\,\Omega)$ is Richards transform Richards transformation allows us to replace lumped inductors with short circuit stubs and capacitors with open circuit stubs of characteristic impedance $Zo=1/C$.

First of all there is a need to choose a dielectric constant and substrate height to design a filter as these are basic to design a filter, these are choose according to the design frequency our designed frequency is 1.5Ghz and the chooses material is FR4 lossy.

- Substrate Height=1.6mm
- Dielectric Constant=4.3
- Loss Tangent=0027

The design of microstrip low pass filters involves two main steps. The first one is to select an appropriate low pass prototype, The choice of the type of response, including pass band ripple and the number of reactive elements, will depend on the required specifications. The element values of the low pass prototype filter, which are usually normalized to make a source impedance $g0=1$ and a cutoff frequency $\Omega c=1.0$, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. The next main step in the design of microstrip low pass filters is to find an appropriate microstrip realization that approximates the lumped element filter [6]-[10].

In order to illustrate the design procedure for this type of filter, the design of a four-pole LPF is described in follows.

The filter design steps are as follows:

Order of filter N=4
Relative Dielectric Constant εr=4.3
Height of substrate, h=1.6mm
The loss tangent tan δ=0.02
The highest line impedance ZH=ZOL=110Ω
The lowest line impedance ZL=ZOC=15Ω
Normalized cutoff $\Omega c=1.0$
Cutoff frequency $fc$=1.5GHz
Passband riple 0.1dB (or return loss≤–16.42dB)

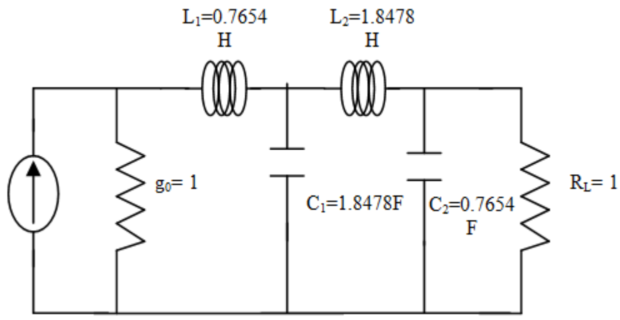


Figure 1. Fourth order low pass prototype filter

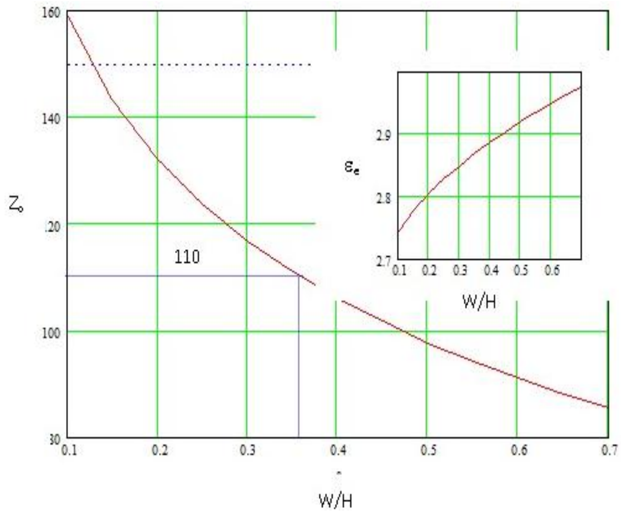


Figure 2. Characteristic impedance Vs W/H ration of the Low pass filter

## III. Calculation of Parameter of Filter

$$L_1 = g_1 = 0.7654H$$
$$L_2 = g_3 = 1.8478H$$
$$C_1 = g_2 = 1.8478F$$
$$C_2 = g_4 = 0.7654F$$

Fig. 1 shows the different value of capacitor and inductor according to the order of the filter. Now these value of inductance and impedance are change accordingly frequency scale conversion and we can find out the following value of inductance and capacitance

$$L_1=4.061nH$$
$$L_2=9.083nH$$
$$C_1=3.921pF$$
$$C_2=1.624pF$$

A typical FR4 fiberglass PCB with $\varepsilon_r=4.2$ and H=1.6mm is used. From Fig. 2 the following trace parameters are obtained:

TABLE I. Dimension of Various Microstrip Line Characteristic Impedance

| | W/H | H/mm | W/mm | $\varepsilon_e$ |
|---|---|---|---|---|
| $Z_o = 15\Omega$ | 10.0 | 1.6 | 15.0 | 3.68 |
| $Z_o = 50\Omega$ | 2.0 | 1.6 | 3.0 | 3.21 |
| $Z_o = 110\Omega$ | 0.36 | 1.6 | 0.6 | 2.83 |

According to the Table I we choose width and height of microstrip line. Now we calculate the electrical length of corresponding inductor and capacitors. Implement the low-pass filter using microstrip line – Hi Z-Low Z transmission line filter [10]. A relatively easy way to implement low-pass filters in microstrip or stripline is to use alternating sections of high and low characteristic impedance ($Z_o$) transmission lines. Such filters are usually referred to as stepped-impedance filter and are popular because they are easy to design and take up less space than similar low-pass filters using stubs. However due to the approximation involved, the performance is not as good and is limited to application where a sharp cutoff is not required (for instance in rejecting out-of-band mixer products). A short length of transmission line of characteristic impedance $Z_o$ can be represented by the equivalent symmetrical T network shown below.

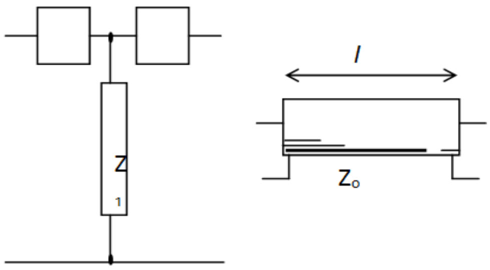


Figure 3. Equivalent T network for a transmission line with length *l*

$$Z_{11} = Z_{22} = -jZ_o \cot(\beta l) \quad (1)$$

$$Z_{12} = Z_{21} = -jZ_o \mathrm{cosec}(\beta l) \quad (2)$$

where $Z_{11}$ and $Z_{12}$ are the $Z$ parameters of the two port network. And $\beta$ is the propagation constant of the transmission line. For EM wave propagation that is of TEM mode or quasi-TEM mode, the propagation constant can be approximated as:

$$\beta \cong \omega\sqrt{\mu_o \varepsilon_e \varepsilon_o} = \sqrt{\varepsilon_e} k_o \quad (3)$$

where $\varepsilon_e$ is the effective dielectric constant of the transmission line structure. When $\beta l<\pi/2$, the series element of Fig. 3 can be thought of as inductor and the shunt element can be considered a capacitor. This is illustrated in Fig. 4(a) with:

$$|Z_{11} - Z_{12}| = \frac{X}{2} = Z_o \tan\left(\frac{\beta l}{2}\right) \quad (4)$$

$$\frac{1}{|Z_{12}|} = B = \frac{1}{Z_o}\sin(\beta l)$$

Assuming a short length of transmission line ($\beta l<\pi/4$) and $Z_o=Z_H>1$:

$$X \cong Z_H \beta l \quad (5)$$

$$B \cong 0$$

Assuming a short length of transmission line ($\beta l<\pi/4$) and $Z_o=Z_L \rightarrow 1$

$$X \cong 0$$

$$B \cong \frac{1}{Z_L}\beta l \quad (6)$$

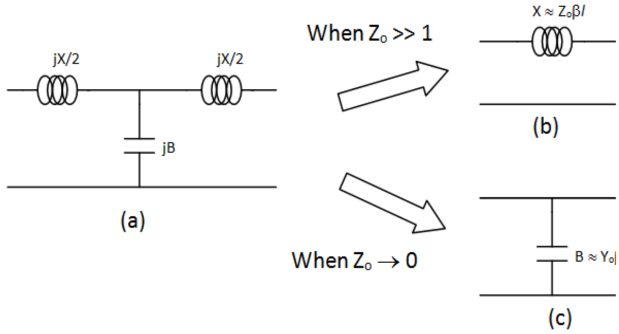


Figure 4. Approximate equivalent circuits for short section of transmission lines.

The ratio $Z_H/Z_L$ should be as high as possible, limited by the practical values that can be fabricated on a printed circuit board. Typical values are $Z_H$=100 to 150Ω and $Z_L$=10Ω to 15Ω. Since a typical low-pass filter consists of alternating series inductors and shunt capacitors in a ladder configuration, we could implement the filter on a printed circuit board by using alternating high and low characteristic impedance section transmission lines. The relationship between inductance and capacitance to the transmission line length at the cutoff frequency $\omega_c$ are:

$$l_L = \frac{\omega_c L}{Z_H \beta} \quad (7)$$

$$l_C = \frac{\omega_c C Z_L}{\beta} \quad (8)$$

$$\beta_L = \sqrt{\varepsilon_{eL}} k_o = \sqrt{\varepsilon_{eL}} \times 2\pi f_c \times 3.3356\times10^{-9} = 60.307 s^{-1}$$

$$\beta_H = \sqrt{\varepsilon_{eH}} k_o = \sqrt{\varepsilon_{eH}} \times 2\pi f_c \times 3.3356\times10^{-9} = 53.258 s^{-1}$$

$$l_1 = \frac{\omega_c L_1}{Z_H \beta_H} = 6.5mm$$

$$l_2 = \frac{\omega_c C_1 Z_L}{\beta_L} = 9.2mm$$

$$l_3 = 15.0mm$$

$$l_4 = 3.8mm$$

## IV. Simulation Results of Filter

Now we will design all filter components in CST-MWS Software now all results of CST-MWS Software [11] shown by different figures.

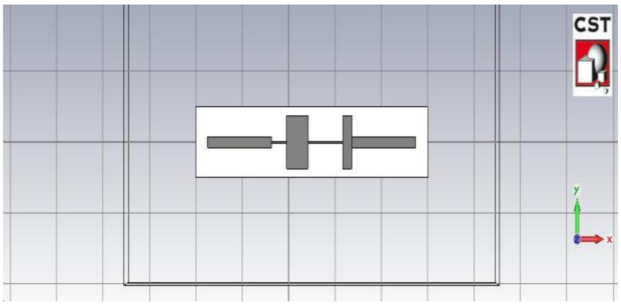

Figure 5. Designed microstrip low pass filter for L-band

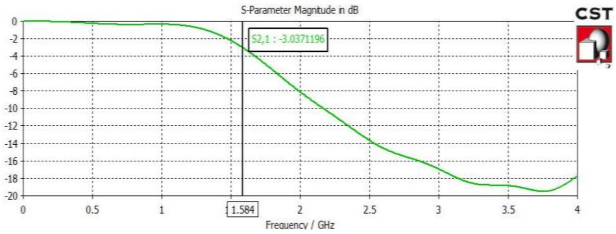


Figure 6. $S_{21}$ Parameter of Low pass filter -3db response is showing at 1.584GHz

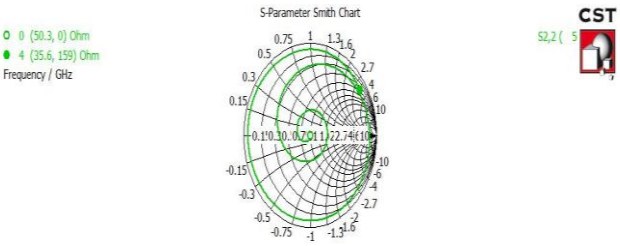


Figure 7. Smith chart at port 2 of designed filter

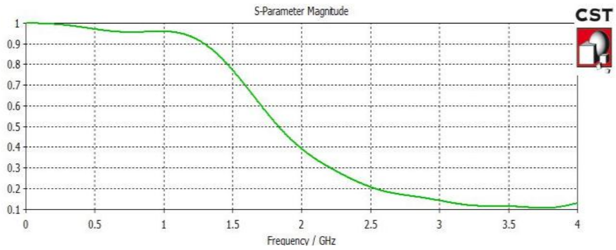


Figure 8. S-Parameter Magnitude vs. frequency

## V. RESULT

As it easily can be concluded from above figures that Fig. 5 shows the designed filter to CST-MWS Software filter showing very sharp response in the given band. Filter is showing very sharp cutoff -3db return loss at 1.584Ghz and this frequency lies in the L-band (1-2GHz). Fig. 6 shows the return loss parameter of the designed filter. Fig. 7 shows the Smith chart value at port 2. And Fig. 8 shows the S-parameter magnitude versus frequency graph which is also shown very sharp response at given frequency.

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