# Design and Development of Bandpass Filter with High out of Band Rejection

**Kinjal Parekh[1] Prof A K Sisodia[2]**
[1,2]Department of Electronics and Communication Engineering
[1,2]LJIET, Gujarat Technological University, Ahmedabad, Gujarat, India

*Abstract*— The RF filter is one of most common component used in communication system. Band pass filter with high out of band rejection will improve the performance of the filter .This can be achieve by ap-plying new technique called DGS (defected ground structure).In this no stub is used but microstrip line is used. For the design of filter center frequency is 2.4 GHz that use for WLAN having band width of 80 MHz and creating defect in ground plan we can achieve rejection at various frequency. The results can be simulate on ADS platform, through which comparison of filter performance with and without DGS can be done.

***Key words:*** Chebyshev Prototype, Parallel Couple Line Microstrip Filter, DGS, ADS

## I. INTRODUCTION

Filter is one of the modules that help to pass certain frequencies and stop other frequencies as per the design. Each filter has its own characteristics that can be used as per our requirements. Microstrip BPF is widely used in recent years because it's characteristics that small in size, that easy to integrate and that can use different substrate to change frequency. Parallel coupled microstrip lines can realize narrow-band filters while stub lines can realize broad-band filters[1]. Now these days new methods are developed, one of the method called "prototype filter design" is usually adopted, which begins at the low-pass filter prototype and confirms the stage of the filter according to the attenuation required in a specified frequency after the type like Butterworth, Chebyshev, Ellipse etc is chosen, then we can get the unitary resistances in a experiential table and derive the length, width, gap of the coupled microstrip in different stage by calculation on a set of equations.

Owing to the round of the parameters when we calculate and the approximation of conventional formulas, the performance of the filter is usually dissatisfied. To get high band rejection a novel technique Defected Ground Structure DGS is used which can be done through providing defect in ground plane .for this design we choose chebyshev filter type response with design parameter shown s per table 1

### A. Chebyshev Filter Response

As the name suggests, chebyshev filter will allow ripples in the passband amplitude response. It is also known as equal ripple response filter. The amount of ripple is provided as one of the design parameter for this type of chebyshev filter. It provide sharp cutoff and steepest slop curve .

| Frequency | 2.4 GHz |
|---|---|
| Bandwidth | 80 MHz |
| Attenuating frequency | +/- 1 GHz |
| Substrate | FR_4 |
| Dielectric constant | 4.4 |
| Substrate thickness | 1.6 mm |
| Pass band ripple | 0.1 dB |

Table 1: Design goals for filter

## II. DESIGNING OF FILTER

This filter has cutoff frequency of 2.4 GHz which is use for WLAN. It has bandwidth of 80 MHz .filter is design with chebyshev prototype having ripple of 0.1 dB. and having -20 dB rejection at +/- 1GHz of frequency i.e.at frequency of 3.4 GHz.

### A. Calculate Fraction Bandwidth and Normalized frequency

The centre frequency can be calculated by, following equation.[2]

$$\mathrm{Wo} = \sqrt{\mathrm{w1} * \mathrm{w2}} = \sqrt{2.44 * 2.36} = 2.4\ \mathrm{GHz} \quad (1)$$

And fractional bandwidth is given by

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0} = \frac{2.44 - 2.36}{2.4} = 0.033 \quad (2)$$

### B. Calculation for Chebyshev type fiter's order

The filter order is the number of inductive and capacitive elements that should be included in the filter design. This can be done by following formulation. [3]

$$N = \frac{\cosh^{-1}\sqrt{(10^{L_r/10} - 1)/(k-1)}}{\cosh^{-1}(\frac{\omega}{\omega_0})}$$

$$N = \frac{\cosh^{-1}\sqrt{(10^{20/10} - 1)/(10^{0.1/10} - 1)}}{\cosh^{-1}(\frac{3.4}{2.4})}$$

$$N=5 \quad (3)$$

### C. Calculate Equal-Ripple Low-Pass Filter Prototypes

The following equations [4] are used to calculate the Element values for equal-ripple low-pass filter prototypes (0.1dB ripple).

$$a_k = \sin\left[\frac{(2k-1)\pi}{2N}\right] ; \quad k = 1,2,....N$$

$$b_k = \gamma^2 + \sin^2\left[\frac{k\pi}{N}\right] \quad ; \quad k = 1,2,..., N$$

$$\beta = \ln(\coth\frac{L_{ar}}{17.34})$$

$$\gamma = \sinh(\frac{\beta}{2n})$$

$$g_0 = 1 \ ; \ g_1 = \frac{2a_1}{\gamma}; \ g_k = \frac{4a_{k-1}a_k}{b_{k-1}g_{k-1}}; \ k = 2,3,..., n$$

$$g_{n+1} = \begin{cases} 1 & \text{for N odd} \\ \coth^2(\frac{\beta}{4}) & \text{for N even} \end{cases} \quad (4)$$

Now putting various value of k=1,2,3,..., we get the different values of coefficient. This coefficient can also be find same from the 0.1 dB ripple table which is provide same results as per above equations .

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From above table and through equation we get the same results and for n=5 the coefficient are as below.

g1=1.1467=L1'
g2=1.3712=C2'
g3=1.9750=L3'
g4=1.3712=C3'
g5=1.1467=L4'

### *D. Calculation of Lumped Values for the Bandpass Filter*

After finding this coefficient its require to convert Lumped Values of the Bandpass Filter calculate as following. Now we can calculate L and C component value as following parameter. The Lumped values of the Band pass filter after frequency and impedance scaling are given by [4]

*1) For series L&C:*

$$L_k = \frac{L_k' Z_0}{\omega_0 \Delta} \qquad C_k = \frac{\Delta}{\omega_0 C_k Z_0} \qquad (5)$$

*2) For shunt L & C:*

$$L_k = \frac{\Delta Z_0}{\omega_0 L_{k'}} \qquad C_k = \frac{C_{k'}}{\omega_0 \Delta Z_0} \qquad (6)$$

From these equations we get lumped element as below with consecutive connection of series and shunt element as per table 2.

| | |
|---|---|
| L1=115.270 nH | C1=0.03818 pF |
| L2=0.07983 nH | C2=55.1304 pF |
| L3=198.540 nH | C3=0.02488 pF |
| L4=0.07983 nH | C4=55.1301 pF |
| L5=115.270 nH | C5=0.03818 pF |

Table 2: Lumped elements values

This way we get the value of serial and shunt element that can be place to simulation platform in ADS. And necessary filter parameter can be simulated.

## III. FILTER DESIGN SIMULATION WITH LUMPED COMPONENT

Now we put all series and shunt lumped elements as calculated earlier and simulated in ads schematic window as below. [6]

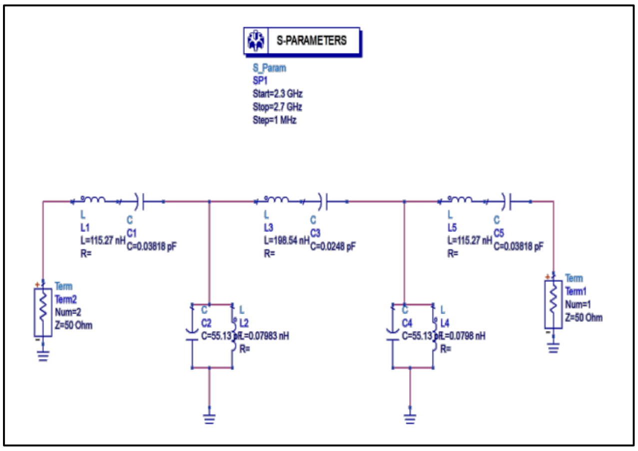


Fig. 1: Lumped element circuit diagram in schematic window

So we get simulated S parameter as per fig 3 that shows filter response at 2.4 GHz

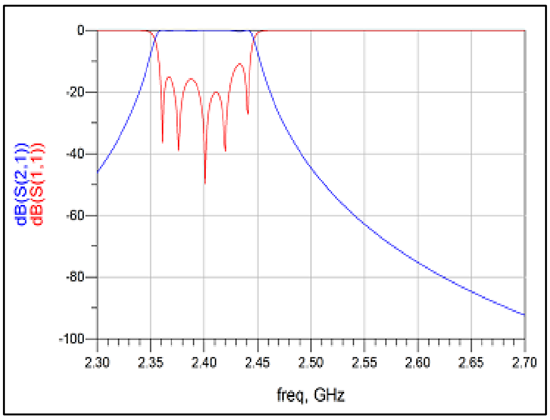


Fig. 3: S Parameter Response of Lumped Element Circuit

## IV. PARALLEL COUPLE FILTER DESIGN

To realize filter in microstrip transmission line we use parallel-coupled filter. The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. We use the following equations[5] for designing the parallel-coupled filter.

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2} \frac{FBW}{g_0 g_1}}$$

For j=1 to n-1

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi \times FBW}{2} \frac{1}{\sqrt{g_i \times g_{i+1}}}$$

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

g0, g1, .., gn can be taken from table, FBW is the relative bandwidth as explained before, Jj,j+1 is the characteristic admittance of J inverter and Yo is the characteristic admittance of the connecting transmission line. To realize the J-inverters [6] obtained above, the even- and odd-mode characteristic impedances of the coupled micro strip line resonator define by

$$(z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right]$$

$$(z_{0O})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right]$$

By putting values of coefficient we get even and odd mode impedance as below

| Couple line number(i) | JiZ0 | Zoe | Zoo |
|---|---|---|---|
| Line 1 & 6 | 0.2026 | 62.1823 | 41.9223 |
| Line 2 & 5 | 0.0375 | 51.9453 | 48.1953 |
| Line 3 & 4 | 0.0286 | 51.4708 | 48.6108 |

Table 3: Even and Odd Mode Impedance Value

Now using Line Calc tool in ADS, the dimension of the microstrip line viz. length (L), width(W) and gap(S) [7] between each other are calculated for the given odd and even resistances and to get accurate response we must do optimization in dimension . here the length and width get reduced by 2.5% to get good results in layout generation. The reduced parameter are as per table 4 and parallel couple design is shown in Fig 4 and their outcomes of S Parameters is as per fig 5.

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| Line description | W mm) | S(mm) | L (mm) |
|---|---|---|---|
| 50 ohm line | 3.0454 | - | 17.0118 |
| Couple line 1 &6 | 2.6479 | 0.8439 | 16.8690 |
| Couple line 2 &5 | 2.9495 | 4.3706 | 16.6381 |
| Couple line 3 &4 | 2.9561 | 5.3993 | 16.6415 |

Table 4: Dimensions of parallel couple line

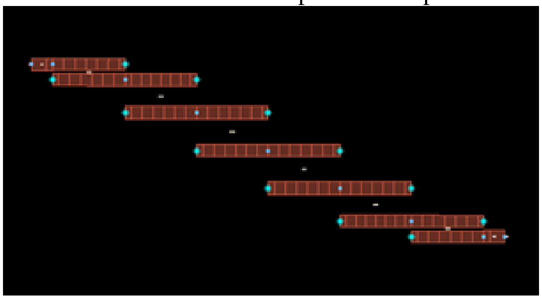

Fig. 4: parallel couple strip line in layout window

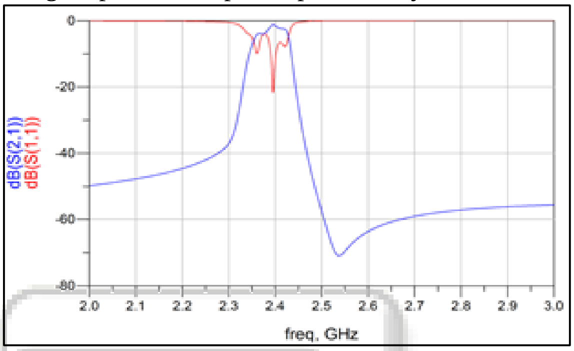


Fig. 5: Simulated S parameter of couple line filter

## V. DEFECTED GROUND STRUCTURE IN FILTER DESIGN

The defects in ground plane is proposed with vertical two slits as per Fig. 6 Changing the physical dimensions [8]of the DGS can easily control the effective inductance. It provides the rejection of some frequency band, which can be called bandgap or stopband effect. By employing an aperture on the ground plane, the parasitic capacitance in the single transmission line can be eliminated and attenuation poles are provided for wide-stopband performance[9]. This design is configured on FR_4 substrate having dielectric constant of 4.4 and thickness of substrate is 1.6 mm. the simulated S parameter is coming out as per fig 7.

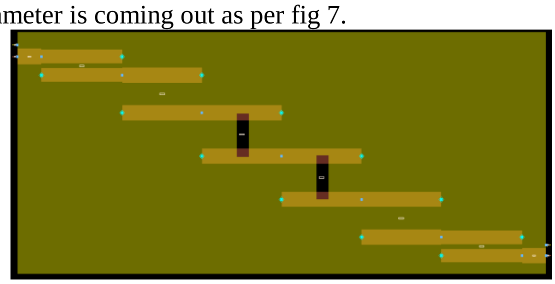

Fig. 6: Couple line filter with DGS of vertical slits

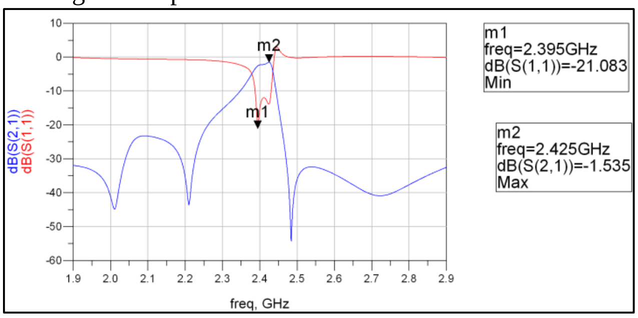


Fig. 7: Simulated results with defected ground structure

## VI. CONCLUSION

In this paper we design the parallel couple band pass filter .The new technique called defected ground structure is implemented .Comparing the results of with and without DGS it shows that using DGS we get sharp transition from the passbandto the stopband with high rejection in stop band region .The sharp notching effect can be possible with DGS. The filter can be fabricated with FR_4 substrate and proposed design parameter for WLAN application at 2.4 GHz with 0.1 dB passband ripple with more than -10dB return loss with band width of 80MHz which is desirable.

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