

AN ABSOLUTE DESIGN AND ADS SIMULATION OF 2.5GHz MICROSTRIP BANDPASS FILTER

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Abstract: This work shows a complete realization of the design and simulation of microstrip bandpass filter (M-BPF). The bandwidth of the filter was taken as 80 MHz with a center frequency of 2.5GHz. Further, the simulation was done with the help of Advance design System (ADS) Software. In addition to this, the microstrip filter at 2.5GHz can be used in the receivers of Indian Regional Navigation Satellite System (IRNSS). With the help of this analysis, insertion loss and return loss were investigated. The simulation also reveals the physical dimensions of this M-BPF. Finally, the outcomes from ADS are in great concurrence with the theoretical calculated values.

Index Terms - Bandpass Filter, Microstrip, Center Frequency, Advance Design System Software, Chebyshev filter.

1. INTRODUCTION

In Radio frequency (RF) applications, generally planar transmission lines are used which are known as microstrip transmission line. There are several methods to achieve the planar configuration, like the thin-film deposition techniques, lithography process and thick film techniques. The designing of certain components in RF communication system, like filter, power divider, transformer & coupler can also be possible with the help of transmission line. Figure 1.1 shows a microstrip transmission line, it is a transporter of waves with relative small frequencies. Quasi-TEM wave, generally propagate through a microstrip transmission line. This is the fundamental mode in the microstrip transmission line. The characteristic impedance Z_0 of the transmission line can be measured from the thickness of the strip.

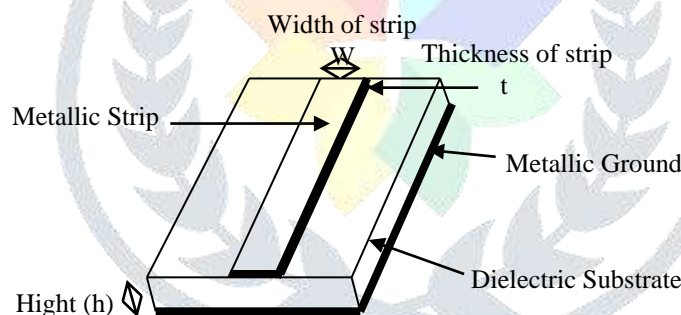


Figure 1.1: Microstrip Transmission Line

In RF communication system, bandpass filter plays an important role. Bandpass filters are one such filters which allows a certain band to pass through it and attenuates the other bands. There are many types of filters that can be used for bandpass. The choice of a filter depends on the filter parameters like roll-off rate in high & low frequency, variation with phase, etc. Here Chebyshev filter was used. As the roll-off rate of Chebyshev filter is very sharp in the passband, when compared to the other types of filter, which makes it suitable for such kind of applications.

M-BPF has been a subject of research from many years and the exploration in this field is still going on. Alaydrus *et al* [1] has designed a M-BPF at 3.5GHz centre frequency for wireless communication applications. A similar work in the M-BPF was reported by Vidhya *et al* [2], where they demonstrated a Dual-M-BPF with the help of hairpin resonator and microstrip tapped feed line. Further, Salima *et al* [4] presented a comparison between simulated and the measured results of a parallel coupled M-BPF. A interdigital microwave bandpass filter at 2.45GHz centre frequency was also designed by Azad *et al* [8]. In filter designing the application plays a vital role. As the filter parameter like attenuation in the stop band, ripples in the pass band, centre frequency, etc. will gradually change according to the application. This work demonstrates the step by step calculation of M-BPF. Based on the characteristics impedance of the transmission line the size of the filter was calculated. With the help of these calculations, parameters for the designing of M-BPF were considered. Finally, designing of the M-BPF will then lead to its ADS simulation.

2. CALCULATION

2.1 FILTER SPECIFICATION

The fractional bandwidth (Δ) in the passband, with $\omega_0 = 2.5\text{GHz}$, as the Centre frequency & 80MHz of bandwidth are the parameters for this M-BPF. Also, the maximum ripple in the pass band was taken as 0.1 dB, and in the attenuation band it was -20dB. Further, $f_1 = 2.46\text{ GHz}$ & $f_2 = 2.54\text{ GHz}$. The equation (2.1-2.2) shows the calculation of the filter design with all these specifications

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0} \quad (2.1)$$

$$\Delta = 0.032$$

The Normalized frequency $\frac{\omega}{\omega_c}$ was calculated from equation (2.2), that is,

$$\frac{\omega}{\omega_c} = \frac{1}{\Delta} \left(\frac{\omega}{\omega_c} - \frac{\omega_c}{\omega} \right), \text{ i.e. } \frac{\omega}{\omega_c} = 2.42 \quad (2.2)$$

The order for a Chebyshev filter the filter was calculated by equation (2.3).

$$n = \frac{\cosh^{-1} \left[\frac{1}{\varepsilon} \left(\frac{1}{\omega^2} - 1 \right)^{\frac{1}{2}} \right]}{\cosh^{-1} \left(\frac{\omega}{\omega_0} \right)} \quad (2.3)$$

Where, $\varepsilon = 0.1\text{ dB}$ ripple factor, and $n \cong 3$. So, the filter which was designed, is of order 3.

2.2 REALIZATION OF LUMPED COMPONENT OF BANDPASS FILTER

The impedance and capacitance components of the M-BPF are also known as the lumped value of M-BPF. Generally, lumped values are accompanied by parasitic as a parasitic capacitance & inductor has parasitic resistance. The filter's frequency response is affected when it is of high frequency (around 1 GHz). So, this results in the difficulty of modeling lumped values. Therefore, to model these lumped value, it was changed over to microstrip transmission line structure, with the help of Richard's transformation and Kuroda's identities. The lumped values for this bandpass filter were calculated as given below.

$$a_k = \sin \left(\frac{(2k-1)\pi}{2 * n} \right) \quad (2.4)$$

$$b_k = \gamma^2 + \sin^2 \left(\frac{k\pi}{n} \right) \quad (2.5)$$

$$\beta = \ln \left[\coth \left(\frac{\varepsilon}{17.37} \right) \right] \quad (2.6)$$

$$\gamma = \sinh \left(\frac{\beta}{2 * n} \right) \quad (2.7)$$

$$g_0 = 1 \quad (2.8)$$

$$g_1 = \frac{2 * a_1}{\gamma} \quad (2.9)$$

$$g_k = \frac{4 * a_{k-1} * a_k}{b_{k-1} * g_{k-1}} \quad (2.10)$$

$$g_{n+1} = 1 \quad (2.11)$$

The values substitute amongst series and shunt connections, and g_k has the accompanying definition:

$g_0 = \{ \text{generator resistance, generator conductance} \}$

$g_k (k=1 \text{ to } N) = \{ \text{inductance for series inductors, capacitance for shunt capacitors} \}$

$g_{N+1} = \{ \text{load resistance if } g_N \text{ is a shunt capacitor, load conductance if } g_N \text{ is a series inductor} \}$

Table 2.1: Lumped values for 0.1DB Ripple

| n | g_1 | g_2 | g_3 | g_4 | g_5 | g_6 |
|---|-------|-------|-------|-------|-------|-------|
| 1 | 0.305 | 1.0 | | | | |
| 2 | 0.843 | 0.622 | 1.411 | | | |
| 3 | 1.032 | 1.202 | 1.032 | 1.0 | | |
| 4 | 1.110 | 1.215 | 1.770 | 1.020 | 1.410 | |
| 5 | 1.150 | 1.234 | 2.010 | 1.401 | 1.257 | 1.0 |

As the order of the filter is 3, so the values at 3 were considered as the lumped value as, $g_1 = 1.032 = L_1$, $g_2 = 1.210 = C_2$, $g_3 = 1.032 = L_3$. These are the values for low pass prototype. So, to convert it into the bandpass filter, impedance scaling was done using equation (2.12-2.15) and are shown in table 2.2

L&C (For Series)

$$L_K = \frac{Z_0 * L'_K}{\omega_0 * \Delta} \tag{2.12}$$

$$C_K = \frac{\Delta}{Z_0 * L'_K * \omega_0} \tag{2.13}$$

L&C (For Shunt)

$$L_K = \frac{\Delta * L'_K}{\omega_0 * C'_K} \tag{2.14}$$

$$C_K = \frac{C'_K}{Z_0 * \omega_0 * \Delta} \tag{2.15}$$

Table 2.2: Elemental value of bandpass filter for order 3

| Parameter | Specification | |
|-----------|---------------|--------------------|
| | LPF | BPF |
| Order | 3 | 3 |
| $Z_0=Z_L$ | 1 | 50 |
| g_1 | $L_1 = 1.032$ | $L'_1 = 105.61945$ |
| | | $C'_1 = 0.0895268$ |
| g_2 | $C_2 = 1.202$ | $L'_2 = 105.61945$ |
| | | $C'_2 = 0.0895268$ |
| g_3 | $L_3 = 1.032$ | $L'_3 = 0.0395051$ |
| | | $C'_3 = 42.689853$ |

2.3 CALCULATION OF ODD & EVEN RESISTANCE

Admittance inverters were used to calculate the even & odd impedances of parallel-coupled M-BPF.

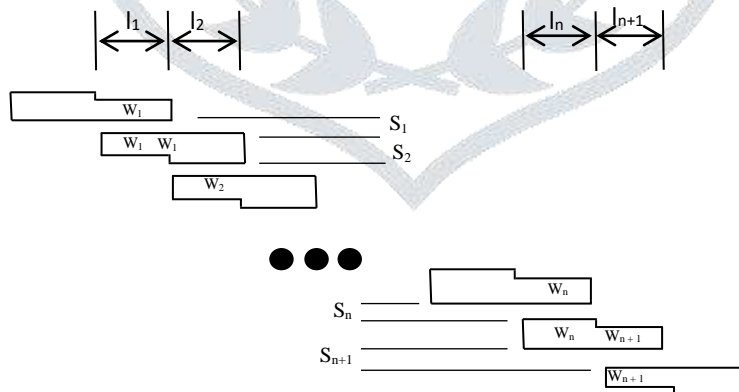


Figure 2.2: Microstrip Couples filter

Figure 2.2 shows a microstrip coupled filter. As it is clear from the figure that strips are arranged in such a way that they are in parallel and close to one another. So, they must have a certain coupling factor. With the help of equations (2.16-2.18), the parallel-coupled filter was designed. Further, it was calculated in 3 modes, given as:

Mode 1: Calculation of $Z_0 J_{0,1}$ (For the first value)

$$Z_0 J_1 = \sqrt{\frac{\pi \Delta}{2 g_1}} \tag{2.16}$$

Mode 2: Calculation of Z_0J_n (For $n=1,2,3\dots N$)

$$Z_0J_n = \left[\frac{\pi\Delta}{2\sqrt{g_n(g_{n-1})}} \right] \tag{2.17}$$

Mode 3: Calculation of Z_0J_{N+1} (For the last value)

$$Z_0J_{N+1} = \sqrt{\frac{\pi\Delta}{2g_n(g_{n+1})}} \tag{2.18}$$

The J-inverters were obtained from the above equations, the even & odd characteristic impedances of the coupled microstrip filter were determined by

$$\text{For Even: } - Z_{0e} = \frac{1}{y_0} \left[1 + Z_0J + (Z_0J)^2 \right] \tag{2.20}$$

$$\text{For Odd: } - Z_{0o} = \frac{1}{y_0} \left[1 - Z_0J + (Z_0J)^2 \right] \tag{2.21}$$

Where Y_0 is the admittance value, that is $Y_0=1/Z_0$. So, even and odd resistance was calculated by equation 2.20 & 2.21, which is given in the following table

Table 2.3: Calculated values of resistance (even and odd)

| Stage (i, i+1) | $Z_{0e}\Omega$ | $Z_{0o}\Omega$ |
|----------------|----------------|----------------|
| 1,4 | 62.25 | 42.88 |
| 2,3 | 59.74 | 43.03 |

Further, these even & odd impedances were then used to investigate the dimensions of the M-BPF.

3. ADS SIMULATION AND RESULTS

So, after all the above calculation the designing parameters were carried out for simulation. Advance digital system 2017 software was used to simulate the M-BPF. Figure 3.1 shows the simulation of the lumped values in ADS.

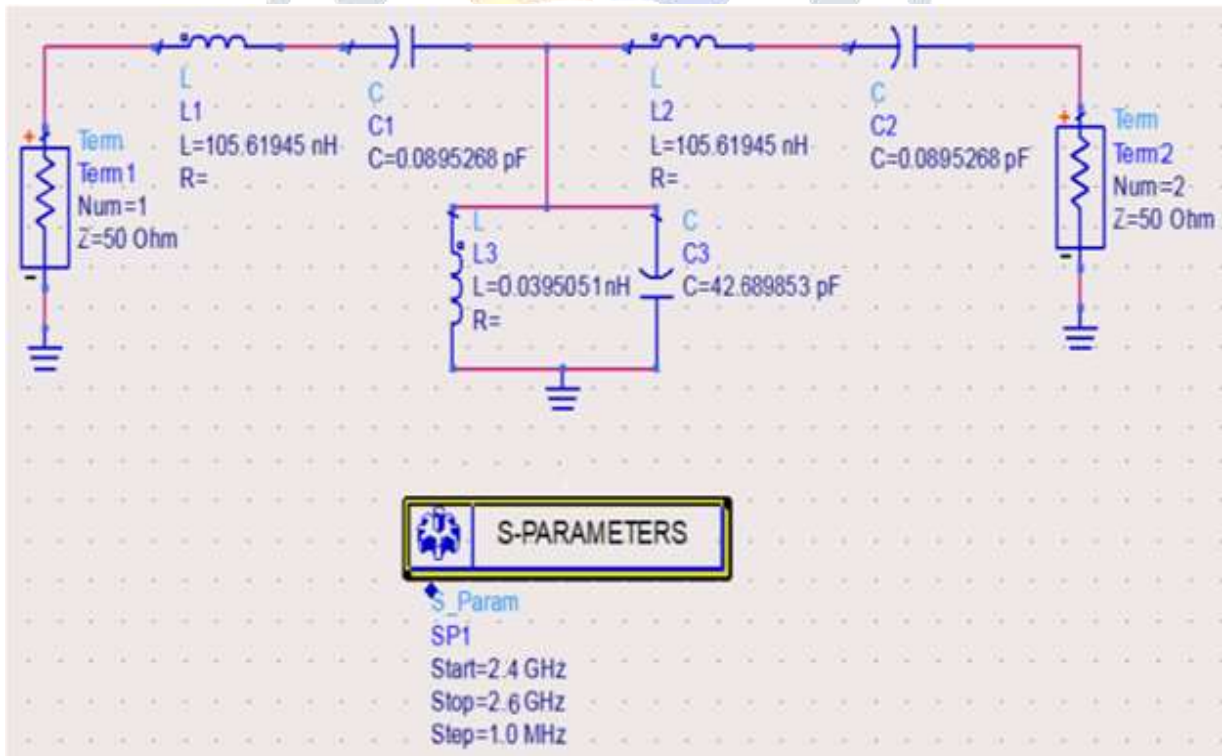
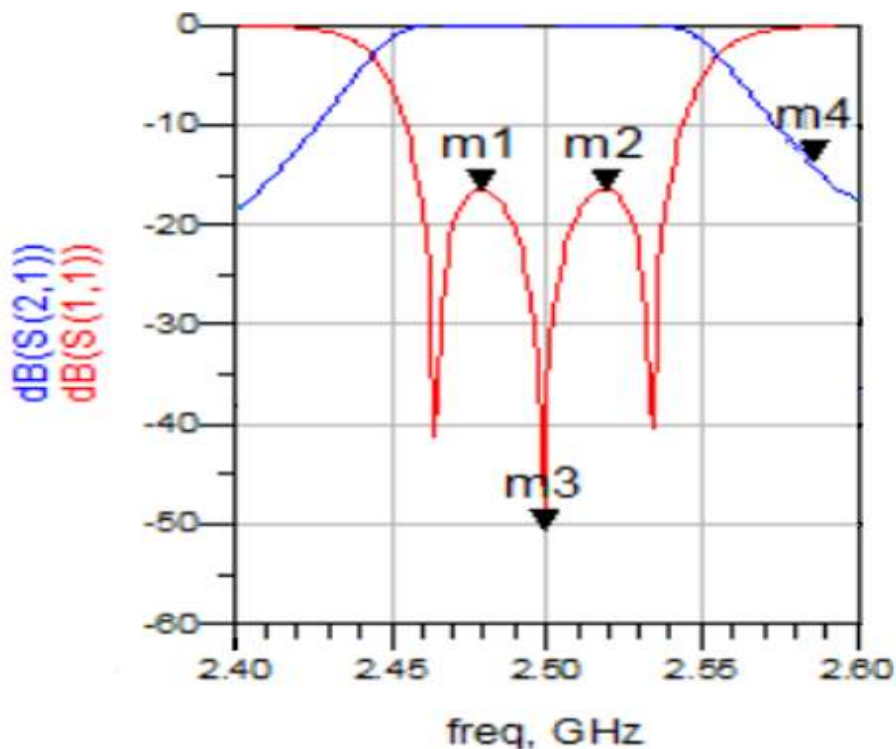


Figure 3.1: ADS simulation of M-BPF

Figure 3.2 shows the S-parameter of this M-BPF, which is the frequency response curve of the filter. From this the scattering parameters were determined, which helped in the calculations of losses. Further, it is also clear that there is a linear variation in the phase with respect to frequency.



| | |
|--|---|
| m1 freq=2.479GHz dB(S(1,1))=-16.445 | m2 freq=2.539GHz dB(S(1,1))=-16.442 |
| m4 freq=2.581 GHz dB(S(2,1))=-15.154 | m3 freq=2.499GHz dB(S(1,1))=-50.400 |

Figure 3.2: S-Parameter for M-BPF

Finally, the insertion loss was investigated around - 3.58dB and the return loss was -20.51 dB in passband with 80 MHz bandwidth. It is not possible to design a bandpass filter with such a high frequency theoretical. So, microstrips transmission lines could be used to fabricate such bandpass filter.

Table 3.1: Coupling line parameters

| Coupled line | Width W (mm) | Length l (mm) | S (mm) |
|--------------|--------------|---------------|--------|
| 50 Ω | 2.31 | 16.501 | -- |
| $C_1 = C_4$ | 42.03 | 17.102 | 0.610 |
| $C_2 = C_3$ | 3.31 | 16.342 | 3..205 |

With the help of ADS software, the dimensions for this filter were also investigated, which is given in table 3.1. LineCalc tool in ADS 2017 were used to determining the physical dimensions of M-BPF.

4. CONCLUSION

This work reveals the design of M-BPF at 2.5GHz, using ADS software. The theoretical calculations are in good agreement with the simulation results. Microstrip transmission line was used by calculating even & odd impedance, to design a bandpass filter; through which filter performance was improved. The result gives a clear idea of the losses. The return loss is high with 80MHz bandwidth, which makes it applicable in the receivers of Indian Regional Navigation Satellite System (IRNSS). The dimensions of this M-BPF were also investigated. The convenient designing with small size and low insertion loss is another big advantage of M-BPF, it can easily be combined with other RF systems. Further, the layout can also be designed using ADS, for the M-BPF fabrication.

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