



ISSN 2278 – 0211 (Online)

Design of Microwave Stepped Impedance Circuits

Shiwani Shekhar

B.Tech Final Year Student, Electronics & Communication Engineering Department
J.K. Institute of Applied Physics & Technology, University of Allahabad, Allahabad, India

Ripudaman Singh

B.Tech Final Year Student, Electronics & Communication Engineering Department
J.K. Institute of Applied Physics & Technology, University of Allahabad, Allahabad, India

Abstract:

This report explains the intuitive technique for designing the Microwave stepped impedance circuit. Microwave low pass filter suppresses the unwanted harmonics above the cut-off frequency. Two methods are discussed in detail namely image parameter method and insertion loss method. A low pass network can be represented by a quotient of finite degree rational polynomials, it is necessary to approximate it. The four classical solutions to the approximation problems are also elaborated, the Butterworth (maximally flat), Chebyshev (equal ripples in pass band), inverse Chebyshev (equal ripples in stop band) and elliptical (equal ripples in stop and pass band).

1. Introduction

Microwave low pass filter suppress unwanted harmonic components above cut off frequency. There are two methods of filter design. One is image parameter method and second is insertion loss method. The image parameter theory filter is based on the properties of transmission lines. A simple network with lumped components is described in terms of this continuous structure. In insertion loss method, a filter response is defined by a transfer function which is ratio of output voltage to the input voltage of the filter. The ideal low pass transfer function is characterized by a magnitude function that is constant in pass band and zero in stop band. Since such a low pass network can be represented by a quotient of finite degree rational polynomials, it is necessary to approximate it. The four classical solutions to the approximation problems are the Butterworth (maximally flat), Chebyshev (equal ripples in pass band), inverse Chebyshev (equal ripples in stop band) and elliptical (equal ripples in stop and pass band). Today most microwave filter designs are done with insertion loss method. The stepped impedance distribution element filter is one of the most popular microstrip filter configuration used in lower microwave frequencies because of easy design, manufacturing and open circuited stub ends. Because of the distributed circuit elemental nature of the lumped components at microwave frequency, distributed lines like microstrip, striplines etc. are used as microwave low pass filter components. For stepped impedance filter design high and low impedance lines are used. This topic describes designing of Butterworth and Chebyshev approximated stepped impedance low pass filter at 1.5 GHz, 3 GHz, 6 GHz and 10 GHz with microstrip line implementation. Designed filter is simulated using Advanced Design System (ADS) software. For this filter design microstrip line is a good transmission line due to advantages of low cost, compact size, light weight, planar structure and easy integration with other components on a single circuit board.

2. Filter Design Procedure

For Stepped Impedance LPF Design high and low impedance lines are used.

In practical Design procedure it is necessary to determine the order of the filter. The filter is designed to have a particular attenuation at a particular frequency; the order is selected from the Attenuation versus Normalised Frequency graph. The filter element coefficients are determined from the below prototype table.

N	g ₁	g ₂	g ₃	g ₄	g ₅	g ₆
1	2.0000	1.0000				
2	1.4142	1.4142	1.0000			
3	1.0000	2.0000	1.0000	1.0000		
4	0.7654	1.8478	1.8478	0.7654	1.0000	
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000

Table 1

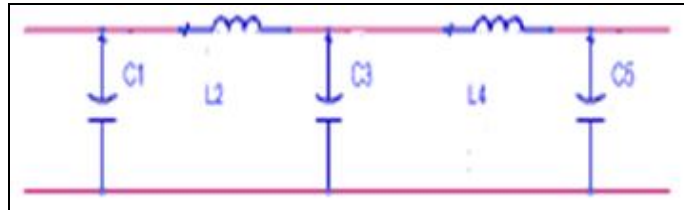


Figure 1

The final prototype section is shown in following figure:

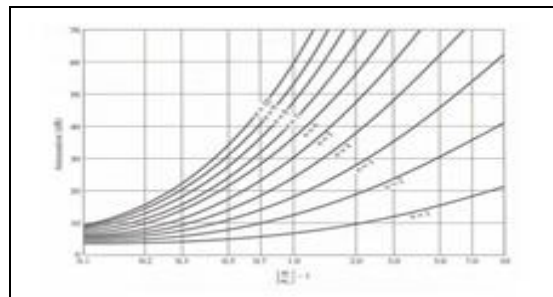


Figure 2

For proposed design work we assume the widths of low and high impedance lines to be 10 mm and 0.26 mm respectively. Then, using LineCalc tool the corresponding values of low and high impedance is determined. The electrical lengths of inductor and capacitor sections are calculated from following formula:

$$\beta l = L R_o / Z_h \text{ (for inductors),}$$

$$\beta l = C Z_l / R_o \text{ (for capacitors)}$$

Z_h : value of high impedance

Z_l : value of low impedance

C : value of prototype capacitance

L : value of prototype inductance

R_o : characteristic impedance, 60 Ohms

- Using this value of electrical length corresponding lengths of high and low impedance lines are calculated using Lincalctool .
- Inductor is replaced with high impedance line and capacitor with low impedance line.

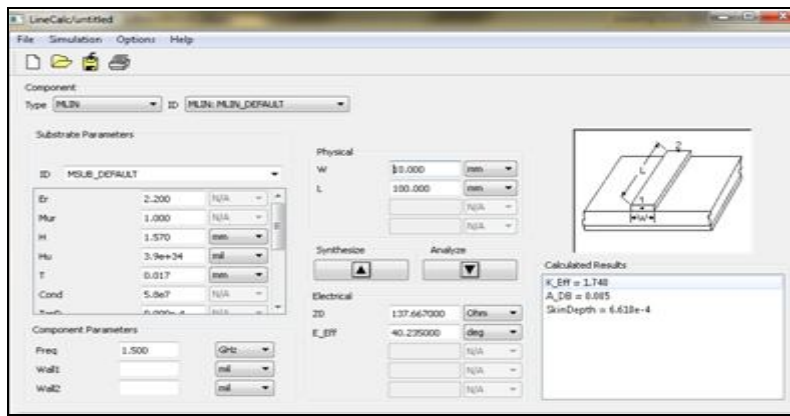


Figure 3

2.1. CHEBYSHEVLPF

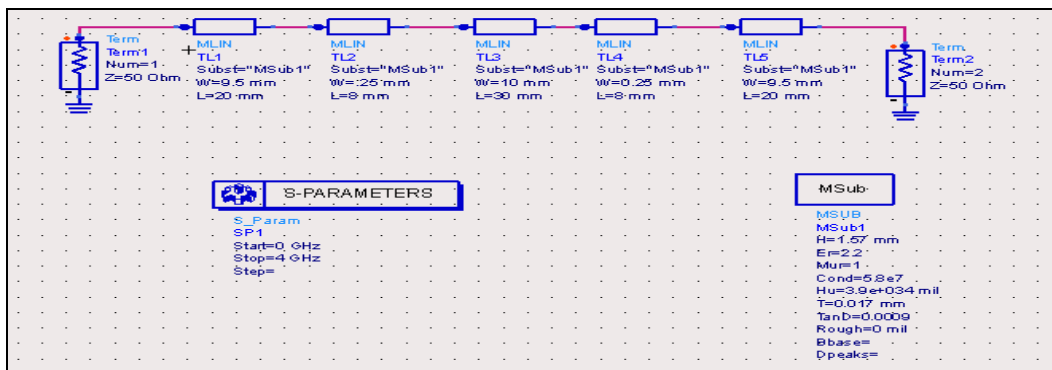


Figure 4: Schematic of LPF at 1.5 GHz (CHEBYSHEV)

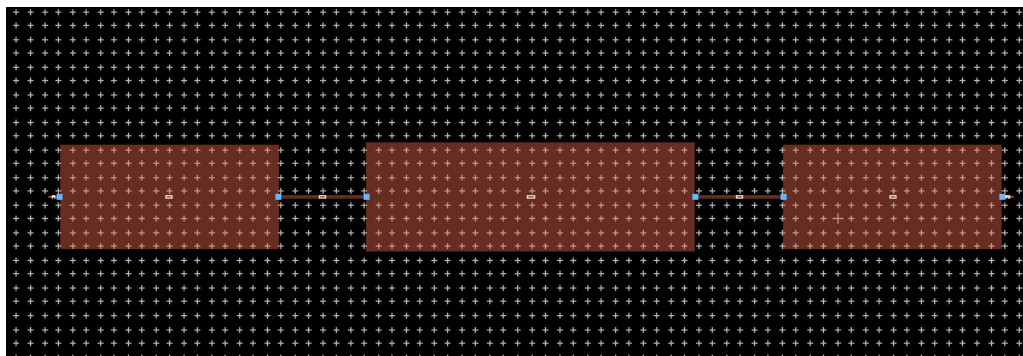


Figure 5: Layout of LPF at 1.5 GHz (CHEBYSHEV)

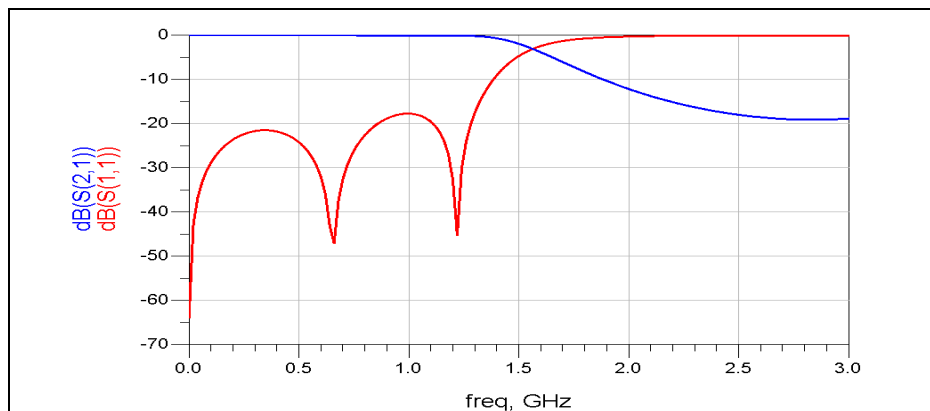


Figure 6: Output Graph of LPF at 1.5 GHz (CHEBYSHEV)

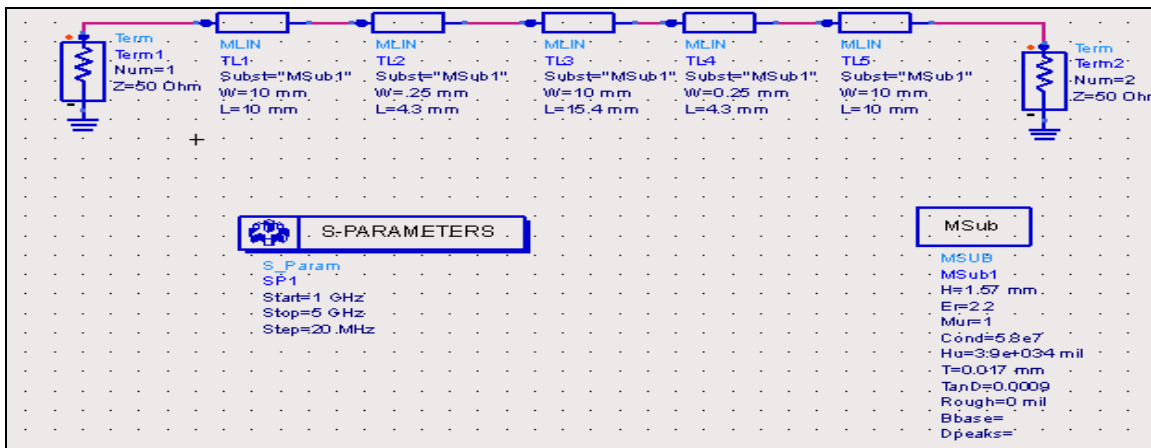


Figure 7: Schematic of LPF at 3 GHZ (CHEBYSHEV)

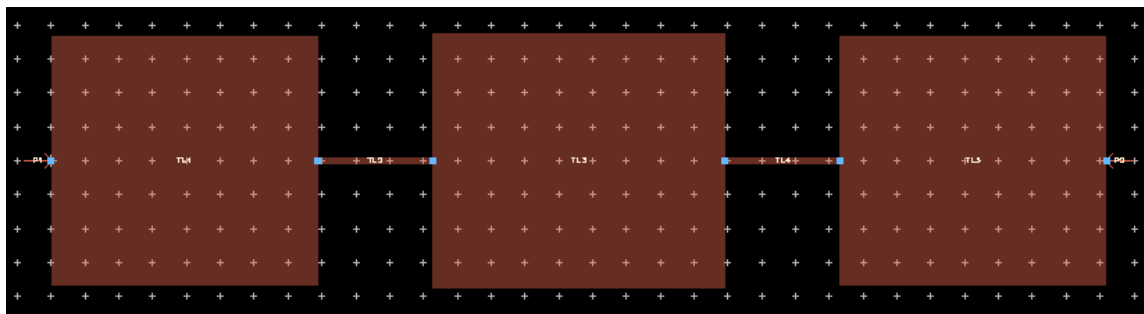


Figure 8: Layout of LPF at 3 GHZ (CHEBYSHEV)

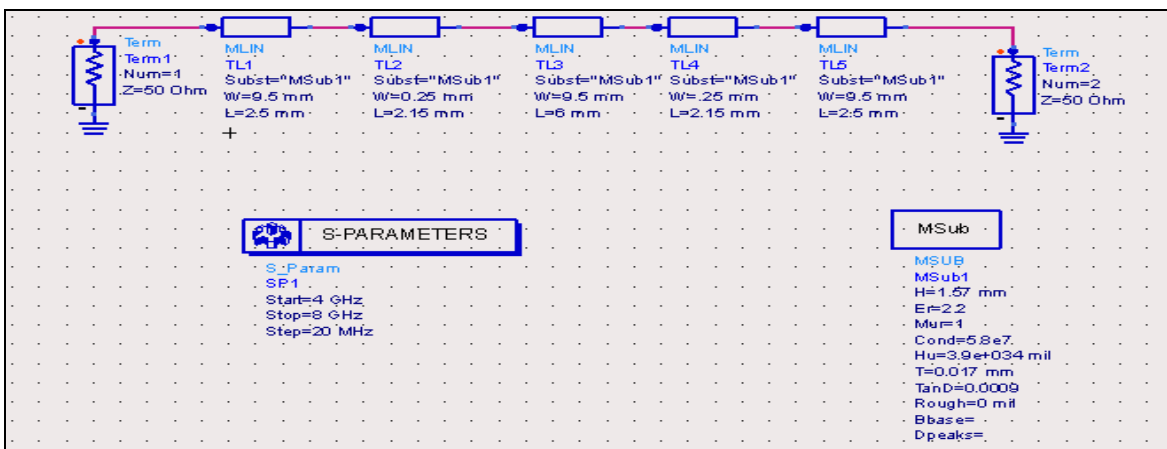


Figure 9: Schematic of LPF at 6 GHZ (CHEBYSHEV)

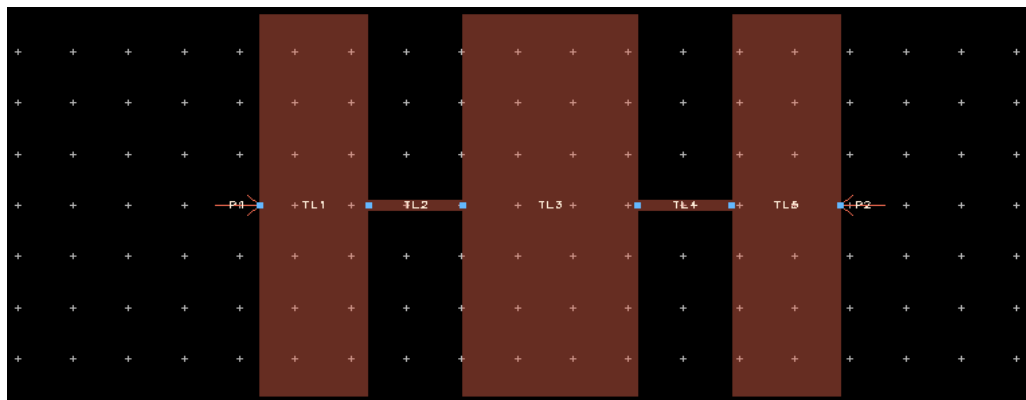


Figure 10: layout of LPF at 6 GHZ (CHEBYSHEV)

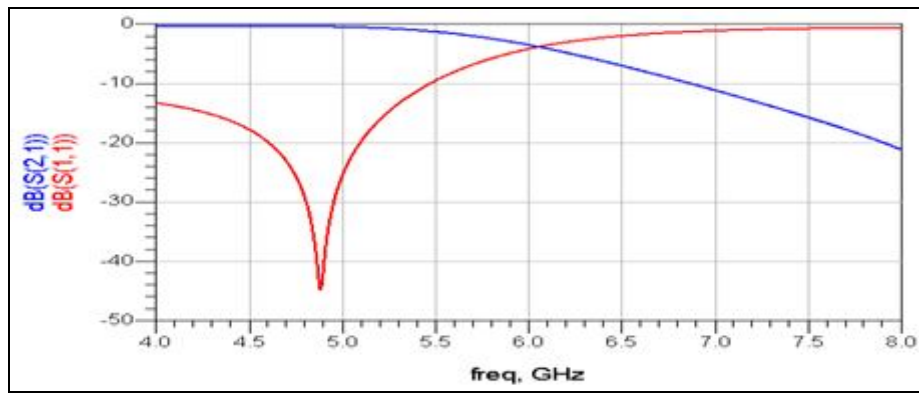


Figure 11: Output Graph of LPF at 6 GHZ (CHEBYSHEV)

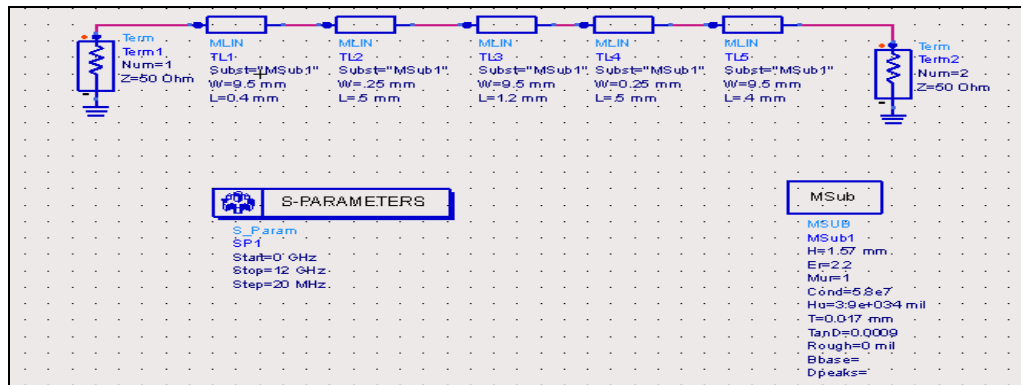


Figure 12: Schematic of LPF at 10 GHZ (CHEBYSHEV)

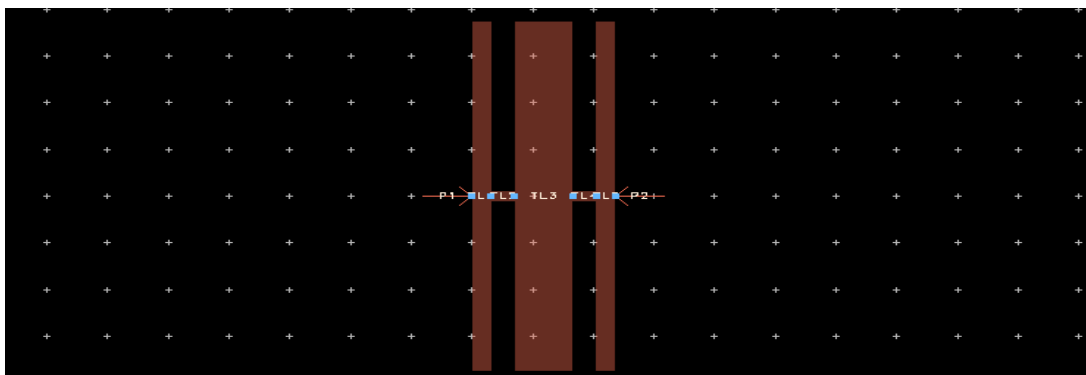


Figure 13: layout of LPF at 10 GHZ (CHEBYSHEV)

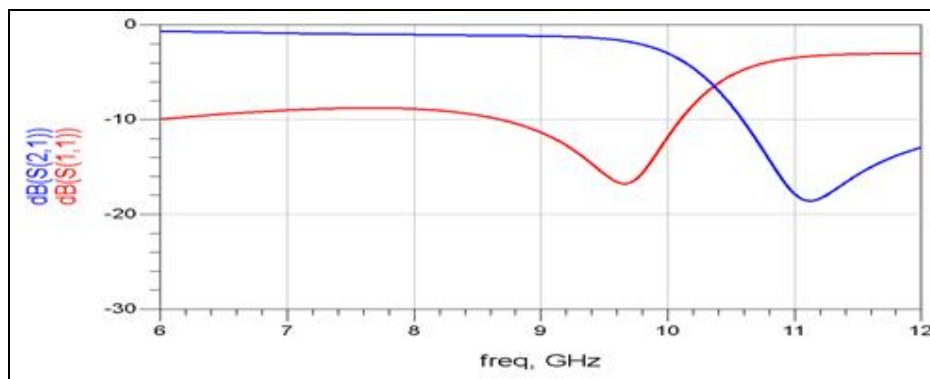


Figure 14: Output Graph of LPF at 10 GHZ (CHEBYSHEV)

2.2 Butterworth LPF

- At $F_c = 1.5$ GHz:

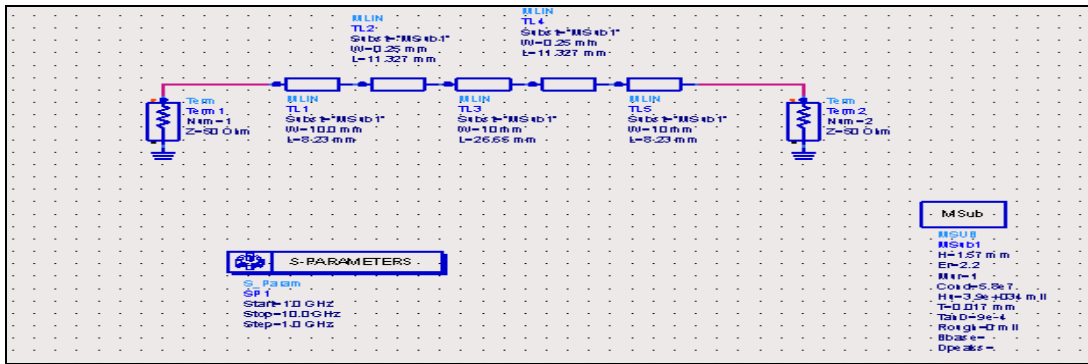


Figure 15: Schematic of LPF at 1.5 GHZ (BUTTERWORTH)

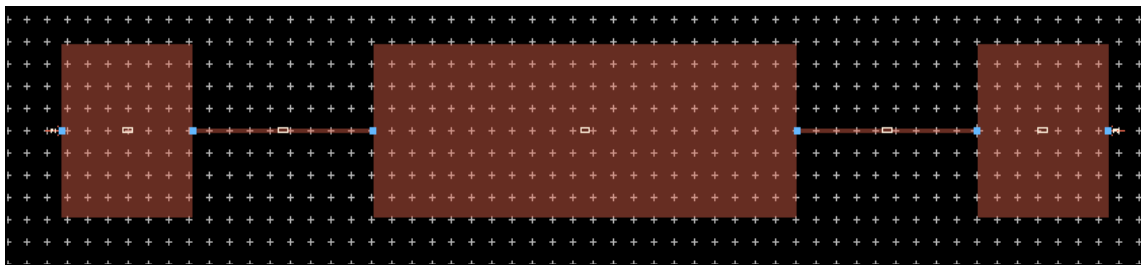


Figure 16: Layout of LPF at 1.5 GHZ (BUTTERWORTH)

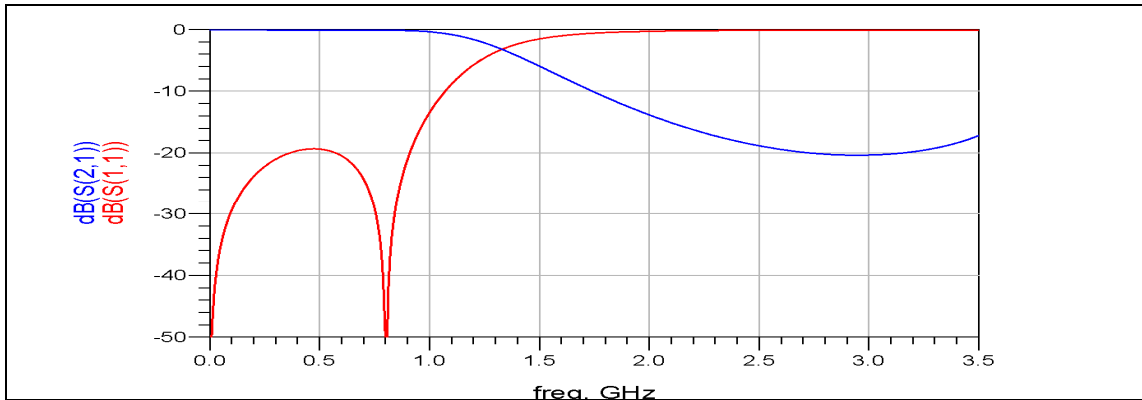


Figure 17: Output Graph of LPF at 1.5 GHZ (BUTTERWORTH)

- At $F_c = 3$ GHz:

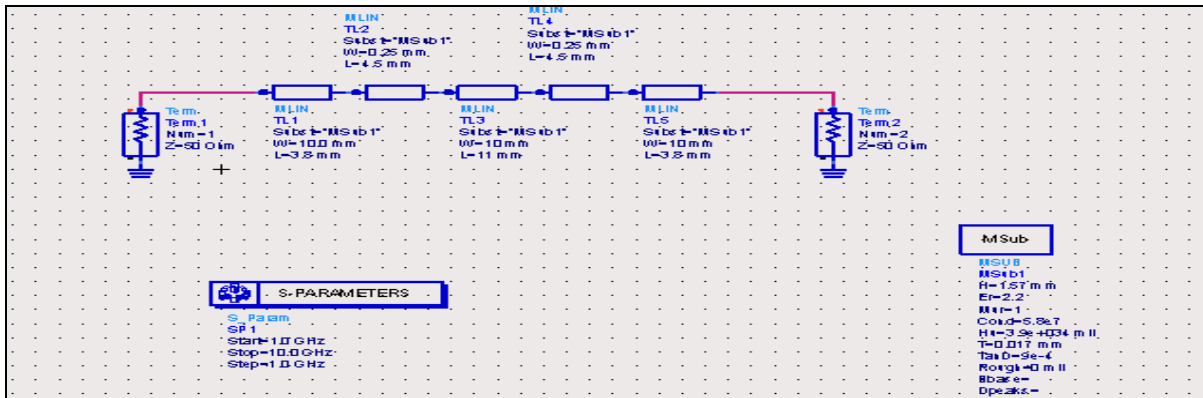


Figure 18: Schematic of LPF at 3 GHZ (BUTTERWORTH)

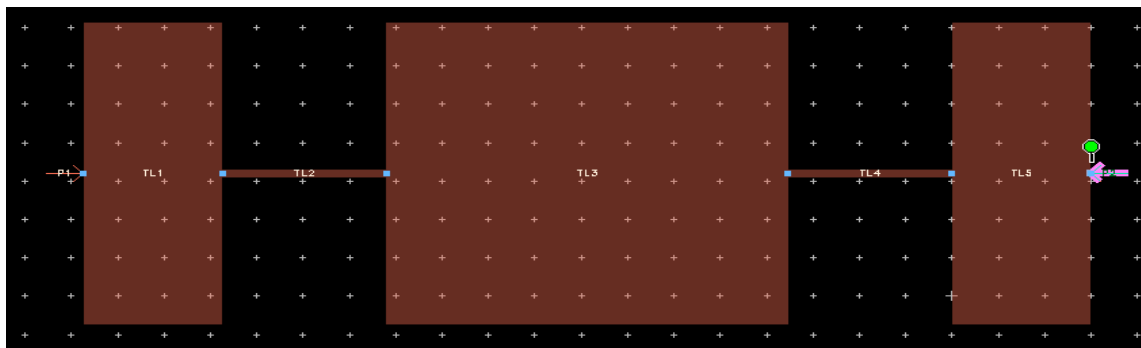


Figure 19: Layout of LPF at 3 GHZ (BUTTERWORTH)

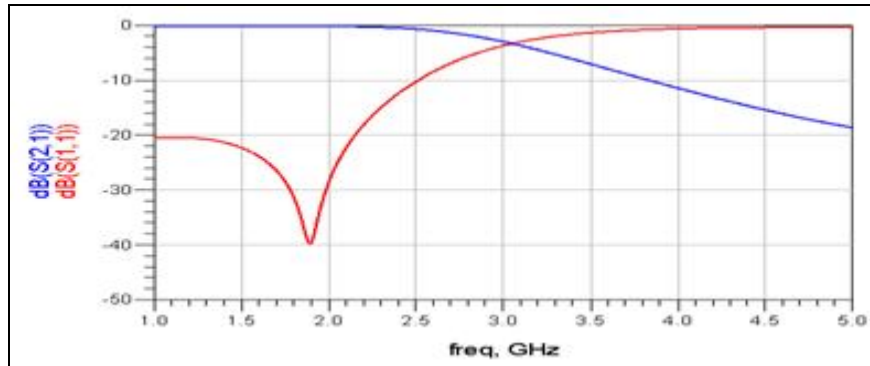


Figure 20: Output Graph of LPF at 3 GHZ (BUTTERWORTH)

- At $F_c = 6$ GHz:

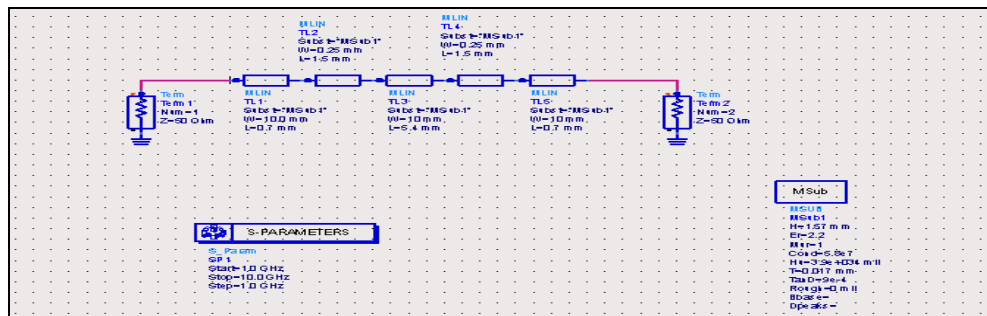


Figure 21: Schematic of LPF at 6 GHZ (BUTTERWORTH)

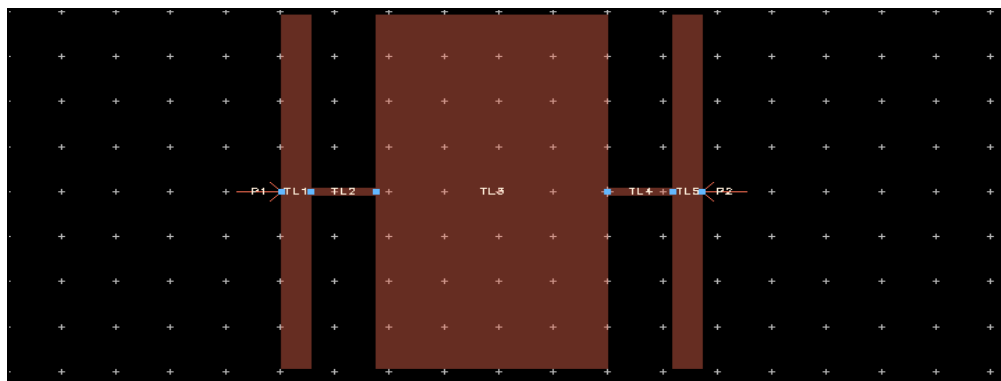


Figure 22: Layout of LPF at 6 GHZ (BUTTERWORTH)

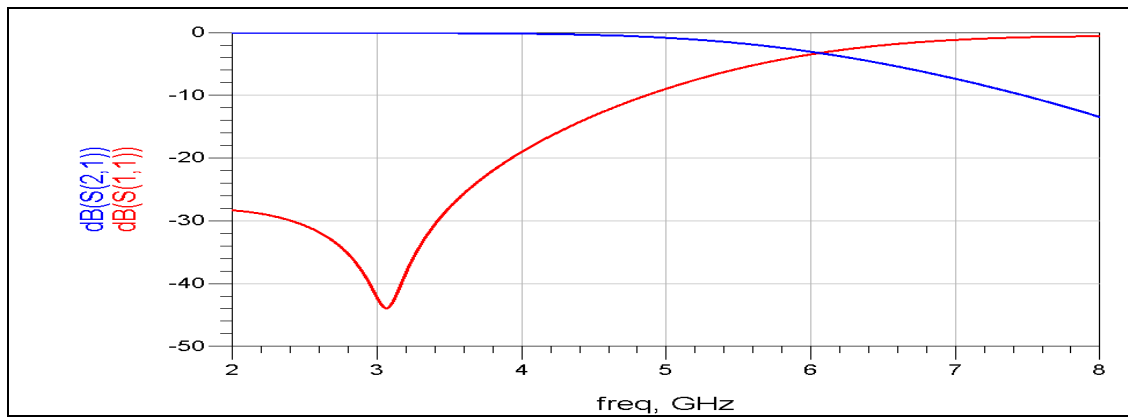


Figure 23: Output Graph of LPF at 6 GHz (BUTTERWORTH)

- At $F_c = 10$ GHz:

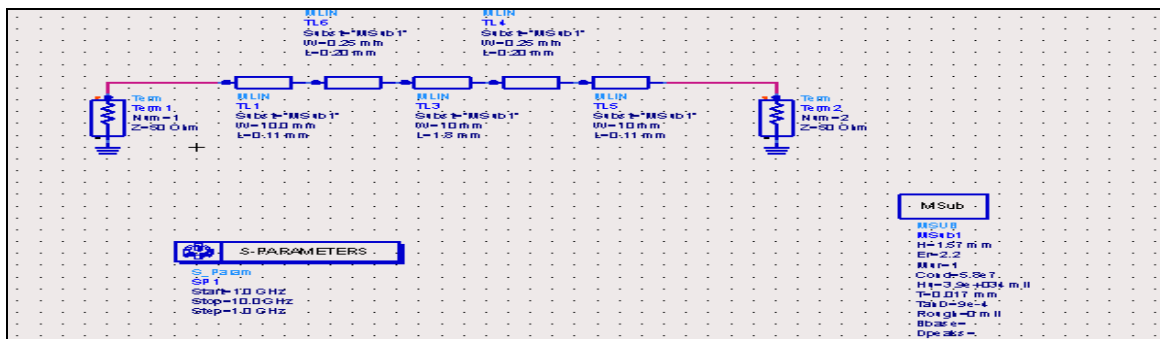


Figure 24: Schematic of LPF at 10 GHz (BUTTERWORTH)

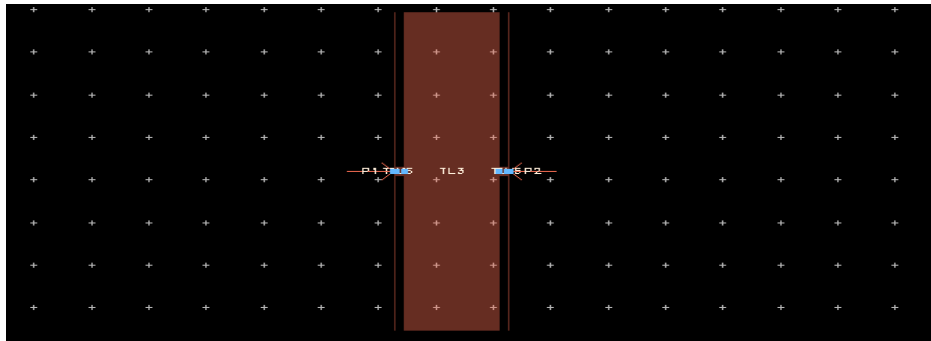


Figure 25: Layout of LPF at 10 GHz (BUTTERWORTH)

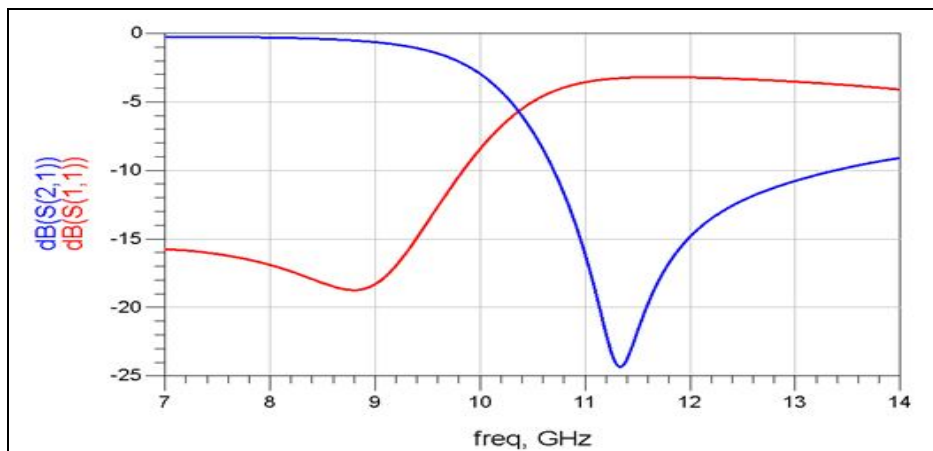


Figure 26: Output Graph of LPF at 10 GHz (BUTTERWORTH)

3. Comparison of Butterworth and Chebyshev LPFS

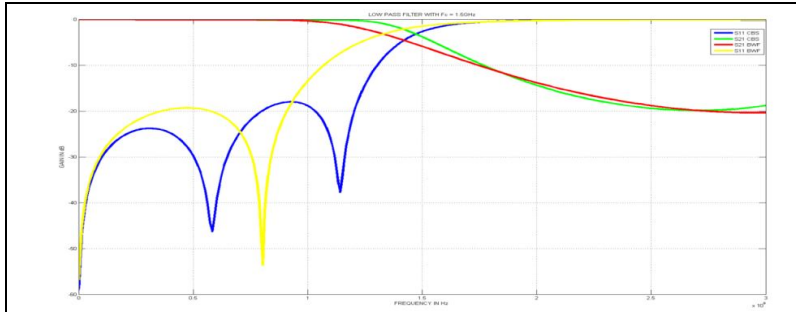


Figure 27: comparison of butterworth and chebyshev lpfs at $f_c = 1.5$ GHz.

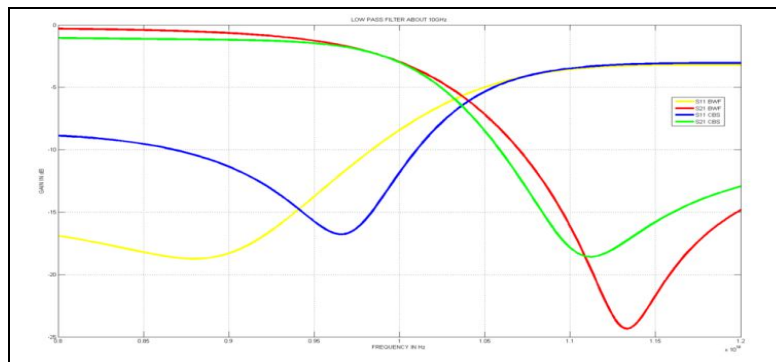


Figure 29: comparison of butterworth and chebyshev lpfs at $f_c = 6$ GHz.

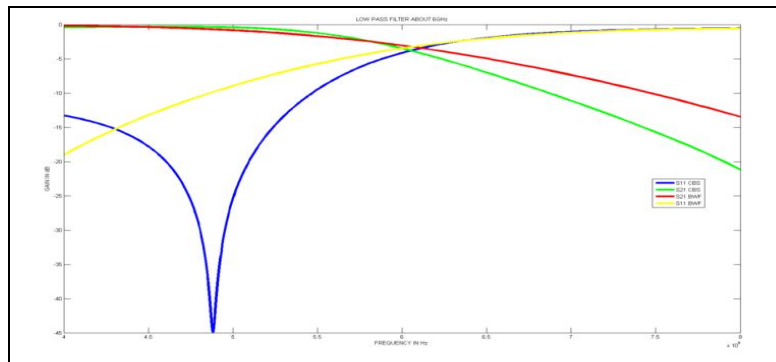


Figure 30: comparison of butterworth and chebyshev lpfs at $f_c = 10$ GHz.

4. Conclusion

In this report, we have discussed the techniques to design the Microwave stepped impedance circuits. Methods to design the circuits at different frequencies are discussed. Now, we have talked about the chebyshev Low pass filters and Butterworth low pass filters in detail to design the efficient microwave stepped impedance circuits. Comparisons have also been done to provide a complete and exhaustive knowledge about the methods.

5. References

1. D.M Pozar, "Microwave Engineering", John Wiley, 2000.
2. Agilent ADS 2002, Agilent Technologies, Palo Alto, CA, 2002.
3. G.L. Matthaei, L. Young, and E.M.T. Jones, Microwave Filters, Impedance-Matching Networks, and Coupling Structures, McGraw-Hill, New York, 1964.
4. D. M. Pozar, "Microwave Engineering", John Wiley & Sons Inc., 1998.
5. www.wikipedia.org
6. shodh.inflibnet.ac.in:8080/jspui/bitstream/123456789/1070/2/
7. vuir.vu.edu.au/600/1/03chapters4-6