# Implementation of Stepped Impedance Microstrip Low Pass Filter

***Ms.Vandana M. Anerao***

**Abstract: Filters are significant RF and Microwave components. Lumped element filters are impractical for compact designs of wireless communications equipment, especially hand-held devices. Distributed element filter design offers a much smaller area and profile. With the advent of advanced substrate materials offering high dielectric constants with low loss, the size reduction with preserved efficiency is greatly enhanced.**

**Transmission line filters can be easy to implement, depending on the type of transmission line used. The aim of this paper is to develop a transmission line filters to do practical work.**

**This paper describes about the design, testing and fabrication of microwave low pass filter by using micro strip layout. The development of the micro strip filters are simulated by using Ansoft designer SV simulator software. The final testing was done by using the RF Network Analyzer. The Microstrip low pass filter has a return loss is -22.41 dB and insertion loss is -1.12 dB for frequency of 1.28GHz.**

***Index Terms- Lowpass, filter, stepped impedance, fr4 substrate, dielectric constant.***

## I. Introduction

In today's fast-growing wireless industry, time to market is critical. Smaller and less expensive units are becoming the norm and the use of CAD tools to quickly and accurately simulate the behavior of wireless components becomes more important as designs become more complex and prototyping cycles become shorter. Microwave filters can be divided into two main different types, lumped or distributed. Lumped elements consist of discrete elements, such as inductors and capacitors, while distributed elements use the lengths and widths of transmission lines to create their inductive or capacitive values [3].

Lumped elements are very small compared to the wavelength, while distributed elements usually are in the order of the wavelength. At high frequencies (10's of GHz or higher) the wavelength is so short that only distributed elements are possible to practically realize, while at low frequencies lumped elements are used due to the fact that distributed elements become too large.

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## II. Microstrip filter design Steps

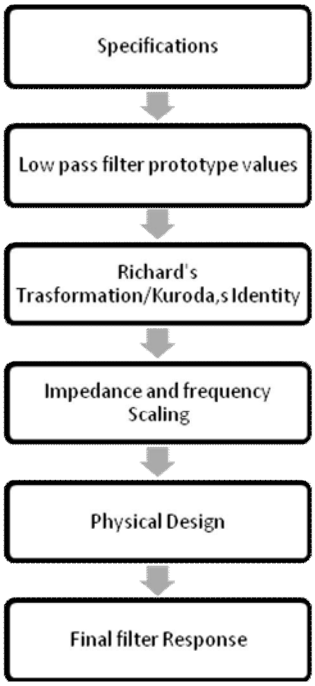


**Fig1. Microstrip filter design steps**

## II. Steps to design stepped impedance micro-strip low pass filter are as follow:

1. Determine the number of sections from the specification characteristics for Microstrip low pass filter.

Filter Specifications

Topology: Stepped Impedance
Passband: Lowpass
Order: 3
Passband ripple: 0.5 dB
Lower PB corner, fp1: 1.27 GHz
Upper PB corner, fp2: 1.29 GHz
Source resistance: 50.0 ohms
Load resistance: 50.0 ohms
Implementation = Stepped Impedance
Order = 3
Relative Permittivity of substrate = 4.4
Thickness of substrate = 1.59mm
tan δ = 0.023

2. To find Lowpass filter prototype values.

$g_1 = g_3 = L_1 = L_3 = 1.5963$
$g_2 = C_2 = 1.0967$
$g_4 = R_L = 1.0$

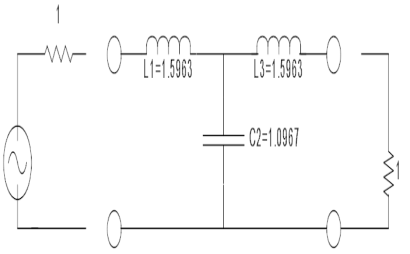


**Fig 2 .Lumped element low pass filter prototype**

3. Application of Richard's Transformation.
Using Richard's Transformation, series conductors were converted to their equivalent series stubs and shunt capacitors to their equivalent shunt stubs. The characteristic impedances of series stubs remains inductance L while characteristic impedances of shunt stubs becomes capacitance 1/C. Resultant circuit is displayed in fig. 3

$$Z_{OL} = L = 1.5963$$

$$Z_{OC} = \frac{1}{C} = \frac{1}{1.0967} = 0.9118$$

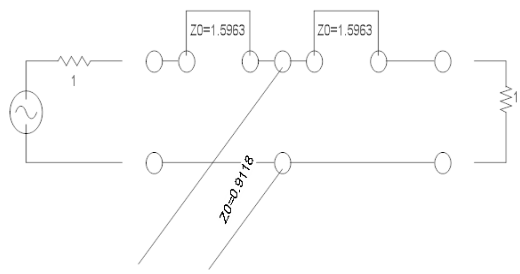


**Fig3. Converted stub impedances using Richards Transformation**

The length l of the stubs is λ/8 at cut off frequency.
The normalized stub lengths are l= λ/8 at ω =1
Series stubs are difficult to implement in microstrip form hence it is necessary to use Kuroda's identity to
convert these series stubs into shunt stubs. This is done by first adding unit elements at either end of filter as shown in fig 4.

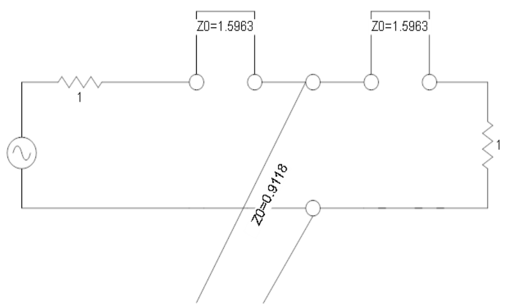


**Fig4. Unit element added to both sides of filter**

These elements will not affect overall performance of filter as long as they are matched to source and load.

$$\frac{Z_1}{n^2} = Z_{OL} = 1.5963$$

$$\frac{Z_2}{n^2} = Z_0 = 1$$

$$\frac{Z_2}{Z_1} = \frac{1}{1.5963}$$

Then Kuroda identity can be applied by using the formula

$$n^2 = 1 + \frac{Z_2}{Z_1}$$

Where $Z_2$ is the impedance of series stub and $Z_1$ is the impedance of unit element placed adjacent to it. This will result in the following value of $n^2$

$$n^2 = 1 + \frac{Z_2}{Z_1}$$

$$n^2 = 1 + \frac{1}{1.5963}$$

$$n^2 = 1.6264$$

The impedance of each stub excluding the centre shunt stub shall be multiplied with this value so that the impedances of stubs are equivalent to those as shown in fig 5.

$$Z_1 = n^2 Z_{OL} = 1.6264 * 1.5963$$

$$Z_1 = 2.5962$$

$$Z_2 = Z_0 n^2 = 1 * 1.6264$$

$$Z_2 = 1.6264$$

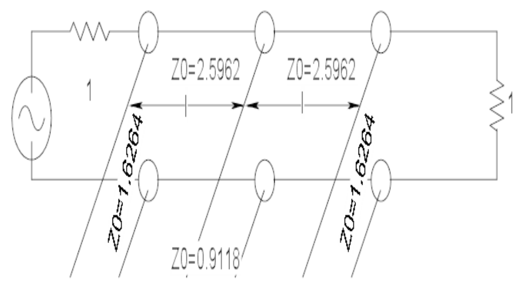


**Fig5. Filter Design after applying Kuroda's Identity**

4. Frequency Scaling
Lastly the impedances of the segments are scaled by 50Ω and the stub lengths are adjusted to λ/8 at the cut off frequency of 1.28GHz

$$Z_1 = 1.6264 * 50 = 81.32\Omega$$

$$Z_{OC} = 0.9118 * 50 = 45.59\Omega$$

$$Z_2 = 2.5962 * 50 = 129.81\Omega$$

Hence the resulting microstrip filter should thus be similar to fig.5.

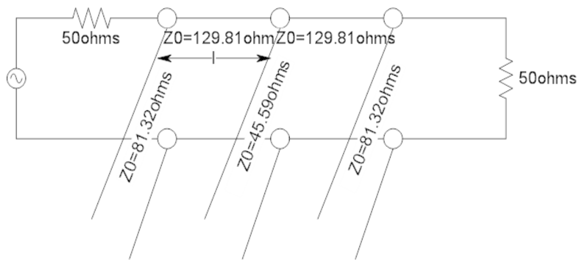


**Fig6. Filter design after applying frequency scaling**

The following calculations are performed to obtain lengths and widths of microstrip stubs.

$$Z = 81.32\Omega$$

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}(0.23 + \frac{0.11}{\varepsilon_r})$$

$$A = 2.3875$$

$$\frac{w}{d} = \frac{8 * e^A}{e^{2A} - 2} = 0.74748$$

$$let d = 2mm$$

$$w = 1.4949$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(\frac{1}{\sqrt{1 + \frac{12d}{w}}})$$

$$\varepsilon_{eff} = 3.1116$$

$$Z_0 = 50\ \Omega$$

$$B = \frac{377\ \pi}{2Z_0\sqrt{\varepsilon_r}}$$

$$B = 5.6463$$

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}} = 0.1328$$

$$l = \frac{\lambda}{8} = 16.6083\ mm$$

$$Z = 50\Omega$$

$$\frac{w}{d} = \frac{2}{\pi}[B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\{\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\}]$$

$$\frac{w}{d} = 1.9069$$

$$let d = 2mm$$

$$w = 3.8138$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(\frac{1}{\sqrt{1 + \frac{12d}{w}}})$$

$$\varepsilon_{eff} = 3.3295$$

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}} = 0.12844$$

$$l = \frac{\lambda}{8} = 16.055mm$$

Similarly all other values of lengths and widths of transmission lines are calculated.

**Table 1: Lengths and widths of transmission line**

| Impedance | Length(mm) | Width(mm) |
|---|---|---|
| 50Ω | 16.055 | 3.8138 |
| 45.95Ω | 15.953 | 4.448 |
| 81.32Ω | 16.6083 | 1.4949 |
| 129.81Ω | 17.159 | 0.38996 |

## III. Ansoft Simulation Results

Symbols are used for circuit representation of the filter. In this case the filter is composed of microstrip coupled lines (MSCL).Once the filter is specified we can generate the layout from the circuit representation. The data required by this utility to synthesize the microstrip dimensions are the substrate parameters, in this case fr4 with
dielectric constant = 4.4,
thickness = 1.59mm,
tan δ = 0.0023, 50mil thick,
impedance of the lines (50 ohms),
Electrical length (180 degrees) ,
Frequency (1.28GHz).
Using the starting dimensions we can draw schematic.We can then perform electromagnetic (EM) analysis over the layout and compare the results.

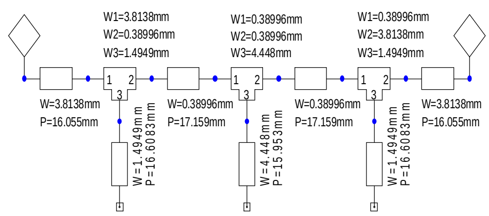


**Fig7. Schematic of stepped impedance micro strip low pass filter**

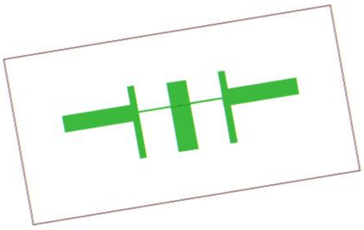

**Fig8. Layout of stepped impedance microstrip lowpass filter**

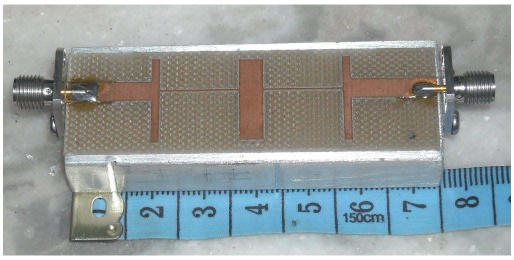


**Fig9. Designed hardware for microstrip LPF**

**III(a). Measurement Results**

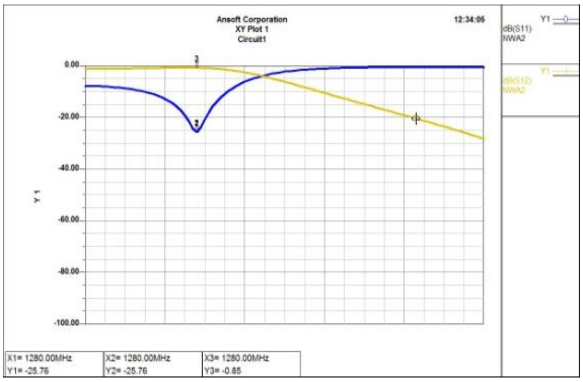


**Fig10. Simulated results for S11 and S12**

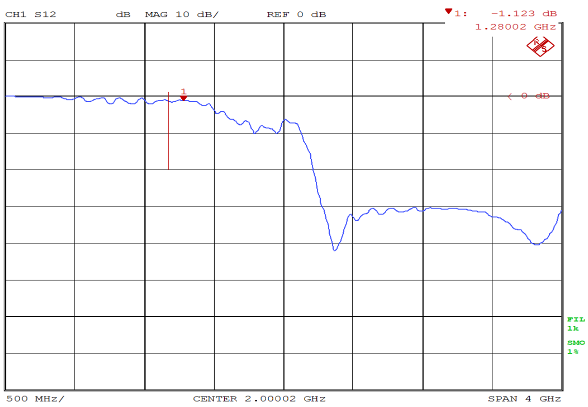


**Fig11. Practical result for S12**

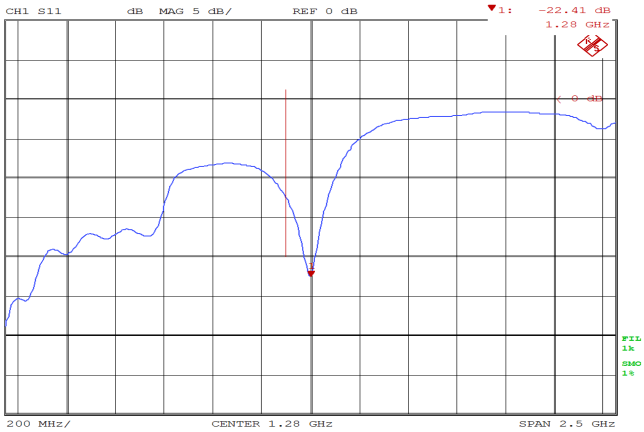


**Fig12. Practical result for S11**

**Table 2: Comparision of Simulated and hardware results**

| Parameter | Simulated Result | Hardware Result |
|---|---|---|
| Return Loss | -25.76 dB | -22.41 dB |
| Insertion Loss | -0.85 dB | -1.123 dB |

## IV. Conclusion

In this paper study of low pass filter based on stepped impedance topology is presented. Third order Stepped impedance Low Pass Filter is fabricated and tested on fr4 substrate. Overall performance of designed filter easily met proposed requirements.In future same design can be modified using fractal technology to get miniaturized dimensions.

## V. References

[1] Ludwig, Reinhold and Bretchko, Pavel (2000). “RF Circuit Design - Theory and Application” New Jersey, USA: Prentice-Hall, Inc.

[2] Hong, Jia-Sheng and Lanchester, M.J. (2001). “Microstrip Filters for RF / Microwave Applications” USA: John Wiley & Sons, Inc.

[3] Pozar, DavidM. (1998) “Microwave Engineering” 2nd Edition, USA: John Wiley &Sons, Inc.

Ms.Vandana Anerao working in K.J.Somaiya College of Engineering, Mumbai since 2004.She has completed M.E.in electronics and telecommunication. Her area of interest is RF, Microwaves and antenna. She has published 2 international and 3 national papers. she has completed research project on “Design and fabrication of Microstrip components”