International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Modelling of Butter worth low pass Stepped Impedance Microstrip line Filter

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Abstract: *This paper presents the design of a class of highly selective micro strip low pass filters. The proposed structure is considered for Stepped Impedance Low Pass Butterworth filter of order n=3 and n=5 with cut-off frequency 1.2 GHz and passband ripple of 3.01db [1]. The substrate FR4 having a dielectric constant 4.4 is considered for calculating the physical length of the micro strip low pass filter. The designing equation are solved using MATLAB Software and the results are analysed and compared using IE3D Simulator. The microwave filter is a building block that provides frequency selectivity in various microwave application like mobile, radar, satellite communication systems. The simulated results show the insertion loss and return loss of about -6.65 dB & - 55.49dB for N=3 and -7.23dB &-16.01 dB for N=5.Simulation has also been done for VSWR.*

Keywords *: Return loss, Substrate,Impedance Matching, MATLAB.*

I. INTRODUCTION

A filter is defined as a two port system which passes certain range of frequencies and reject the others and on that basis we classify different filters. Microwave Filters operates in GHz range. This frequency range is the range used by most broadcast radio, television, wireless communication. Microstrip line is one of the classification of transmission line, can be modelled by making use of printed circuit board [PCB] method, and it is used to allow the particular microwave-frequency signal. Stepped Impedance Micro-strip line is a better candidate to model the filter due to its advantages of very small size, economically cheap, light in heaviness. Micro strip transmission line low pass filters show a vital role in numerous radio frequency wireless Communication Systems. In the paper modelling of 3rd order and 5thorder Butterworth approximated stepped impedance Microstrip-line filter and the simulated results are compared on the basis of S-Parameter i.e. insertion loss and Return loss. For proposed design work, Butterworth Approximation is assumed which exhibits the monotonically decrease behavior in the passband and stopband. The designing equation are solved using MATLAB code and the results are simulated using ie3d software.

Manuscript published on January 30, 2020.
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II. MICROSTRIP FILTER DESIGN

Microstrip Geometry: The general structure of a microstrip is shown in Figure 1.1. A conducting-strip (microstrip line) having a width W and a thickness t is on the top of a dielectric material and relative dielectric material and height h, and the bottom of the substrate is a ground (conducting) plane [1][2].

The fields in the microstrip extend within two media—air above and dielectric below—so that the structure is inhomogeneous. The microstrip line does not hold on pure TEM wave because of its inhomogeneous nature. In Quasi-TEM Approximation the dominant mode then behaves like a TEM mode, and the TEM transmission line theory is applicable for the microstrip line as well. This is called the Quasi-TEM approximation and is valid almost all frequency ranges of microstrip line

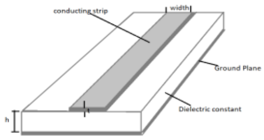

Fig 1.1 Geometry of Microstrip line

III. DESIGN PROCEDURE FOR LOW PASS FILTER

First of all, considering the specifications required in the designing of microstrip low pass filter

Cut-off frequency f_c = 1.2 GHz
Source/load impedance Z_0 = 50 ohms
Normalized frequency Ω_c = 1 GHz
Loss tangent tan δ = 0.02
Butterworth Low Pass Prototype Filters for Butterworth or maximally flat low pass prototype filters with an insertion loss L_{Ar} = 3.01 dB at the cut-off Ω_c = 1, the element values may be computed byg_0 = 1.0

$$g_i = 2\sin\left(\frac{(2i-1)\pi}{2n}\right) = 1 \text{ to } n$$

g_{n+1} = 1.0

For convenience, we have designed a Matlab code to calculate for generalized value of n as

```
clc
clear all
close all
%START OF PROGRAM
n=input('Enter order of filter: ');
%getting values for all g parameters
g=zeros(1,n+2);
g(1) = 1;
for i=1:n
   g(i+1)=2*sin((2*i-1)*pi/(2*n));
end
g(n+2)=1;
```

The normalized elements are then changed to L-C components for the given cut off frequency fc and normally 50Ω source impedance is use for micro strip filter [4][5].

The general structure and LC ladder type stepped impedance low pass micro strip line filter is displayed in figure 1.2

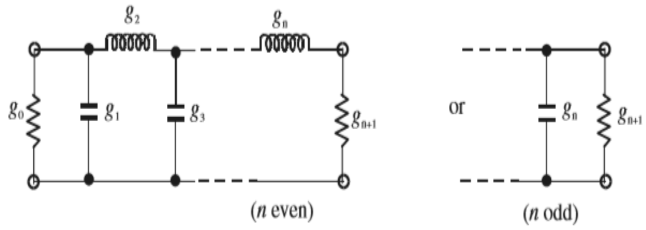

Fig 1.2: Ladder network structure for low pass prototype

Using Element Transformation for normalized cut-off frequency, we can have

$$L_1 = L_3 = \left(\frac{Z_0}{g_0}\right)\left(\frac{\Omega_c}{2\Pi f_c}\right)g_1$$

$$C_2 = \left(\frac{g_0}{Z_0}\right)\left(\frac{\Omega_c}{2\Pi f_c}\right)g_2$$

The fabrication of a filter is done on a substrate having relative dielectric constant of 4.4 and height of about 1.6mm. The characteristic impedance of high impedance line is chosen as Z_{0L} = 93 Ω and of low impedance line is chosen as Z_{0C} = 17 Ω. Now we calculate the relevant design parameters of microstrip line by using the designing formulas [6][7].
First of all, calculating the microstrip line width and guided wavelength for the given impedance by using, [3].

$$\frac{W}{h} = \frac{8\exp(A)}{\exp(2A)-2}$$

where

$$A = \frac{Z_c}{60}\left\{\frac{\varepsilon_r+1}{2}\right\}^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{0.23 + \frac{0.11}{\varepsilon_r}\right\}$$

Now calculating the effective dielectric constant by using following expression [3], since $W_0/h \geq 1$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-0.5}$$

Guided wavelength is calculated at the cut-off frequency f_c = 2.2 GHz as follows,

$$\lambda_{g0} = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}} \text{ mm}$$

As W/h ≤ 1, we use

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left\{\left(1+12\frac{h}{W}\right)^{-0.5} + 0.04\left(1-\frac{W}{h}\right)^2\right\}$$

$$\varepsilon_{re} = \frac{4.4+1}{2} + \frac{4.4-1}{2}\left\{\left(1+12\frac{1.2}{0.4}\right)^{-0.5} + 0.04\left(1-\frac{0.4}{1.2}\right)^2\right\}$$

Also, the calculation of physical length for high impedance and low impedance line is done by using following expression.
Physical length of the high impedance line is calculated by using,

$$l_L = \frac{\lambda_{gL}}{2\Pi}\sin^{-1}\left(\frac{\omega_c L}{Z_{0L}}\right)$$

low impedance line physical length is calculated as,

$$l_C = \frac{\lambda_{gC}}{2\Pi}\sin^{-1}(\omega_c C Z_{0C})$$

The modified length of high impedance line and low impedance line is calculated by using following expressions. We have to select their length in such a way that the following expressions must be satisfied.

$$\omega_c L = Z_{0L}\sin\left(\frac{2\Pi l_L}{\lambda_{gL}}\right) + Z_{0C}\tan\left(\frac{\Pi l_C}{\lambda_{gC}}\right)$$

$$\omega_c C = \frac{1}{Z_{0C}}\sin\left(\frac{2\Pi l_C}{\lambda_{gC}}\right) + 2\times\frac{1}{Z_{0L}}\tan\left(\frac{\Pi l_L}{\lambda_{gL}}\right)$$

In Matlab:

```
%n=3 butterworth.
clc
clear all
close all

zo1=input('zo1');
zo2=input('zo2');
zo3=input('zo3');
ER=input('ER');
H=input('H');
fc=input('fc');
L=7.96*10^(-9);
C=6.36*10^(-12);
%IF w/h is less than 2
A1=(zo1/60)*((ER+1)/2)^0.5+((ER-1)/(ER+1))*(0.23+(.11/ER));
WBYH1=((8*exp(A1))/((exp(2*A1)-2)));
W1=WBYH1*H
ERE1=((ER+1)/2)+((ER-1)/2)*((1+12*(H/W1))^(-0.5) +
0.04*(1-(W1/H))^2);
LAMBDA1=(300)/(ERE1)^0.5
Ll=(LAMBDA2/(2*3.14))*asin((2*3.14*fc*L)/zo2);
Lc=(LAMBDA3/(2*3.14))*asin((2*3.14*fc*C)*zo3);

%for adjustment

Llnew=((LAMBDA2)/(2*3.14))*asin((1/zo2)*((2*3.14*fc*L)-zo3*tan((3.1
4*Lc)/(LAMBDA3))))
Lcnew=(LAMBDA3/(2*3.14))*asin(zo3*((2*3.14*fc*C)-(2/zo2)*tan(3.14
*Ll/LAMBDA2)))
```

Retrieval Number: E5810018520/2020©BEIESP
DOI:10.35940/ijrte.E5810.018520
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
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IV. CALCULATED RESULTS AND LAYOUT

N=3

s.no	Source Impedance/low Impedance /High Impedance	Guided Wavelength	Width	Physical Length
01	50(source)	163.01 mm	3.05mm	6mm
02	93(high)	171.30 mm	.865mm	10.67mm
03	17(low)	98.17mm	15.97mm	7.87mm

N=5

s.no	Source Impedance/low Impedance /High Impedance	Guided Wavelength	Width	Physical Length
01	50(source)	163.01 mm	3.05mm	6mm
02	93(high)	17.30 mm	.865mm	6.27(l1 and l5) and 29.53mm(l 3
03	15(low)	83.61mm	15.97mm	6.36mm(c2 and c4)

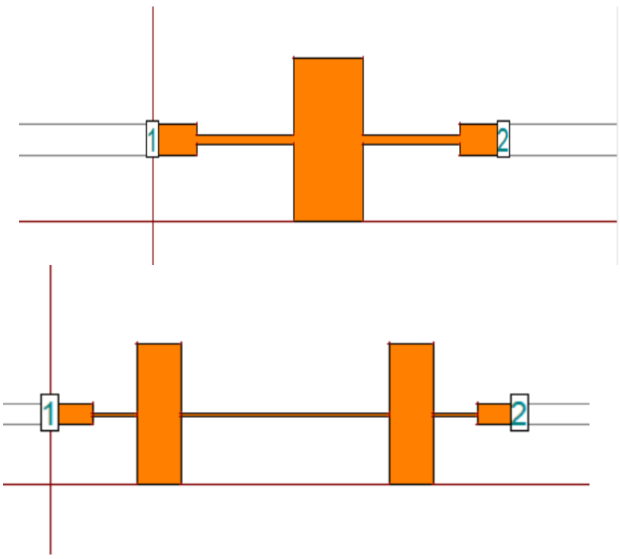

Fig 1.3 Microstrip line filter layout for N=3 and N=5

V. SIMULATED RESULTS

N=3

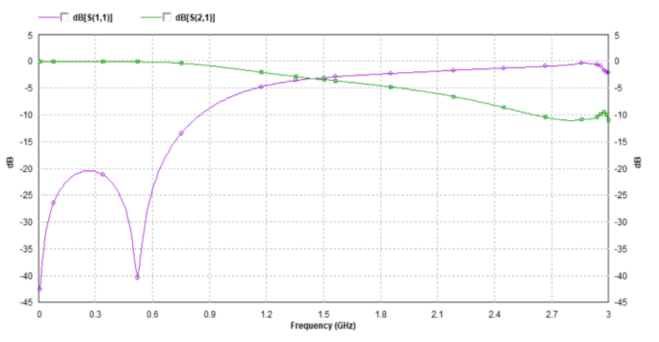

Fig 1.4: S(1,1)-Return Loss and S(2,1)-Insertion loss Parameters

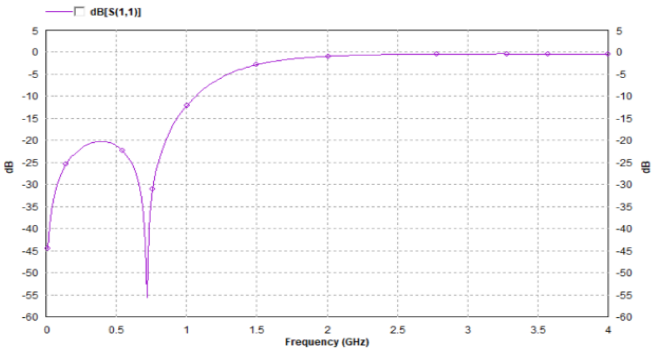

Fig 1.5: S(1,1)-Return Loss

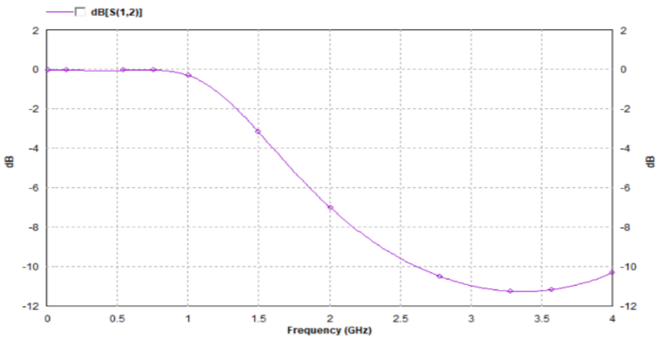

Fig 1.6: S(2,1)-Insertion loss

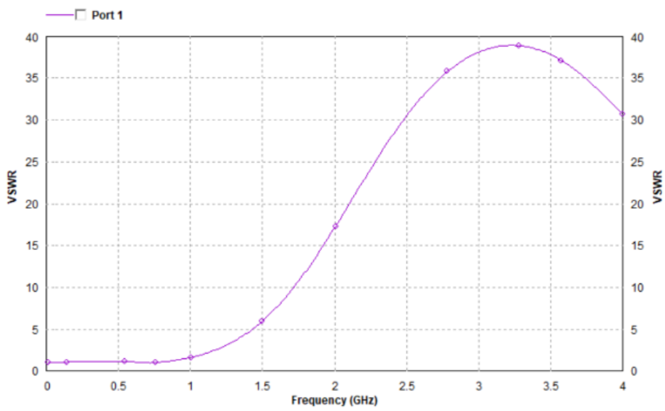

Fig 1.7: VSWR-input port

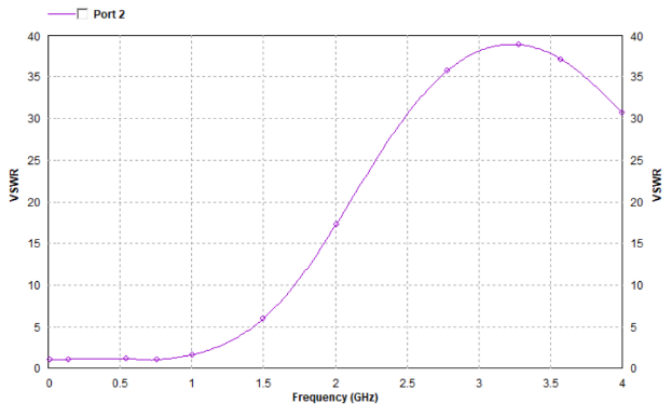

Fig 1.8: VSWR-output port

N=5

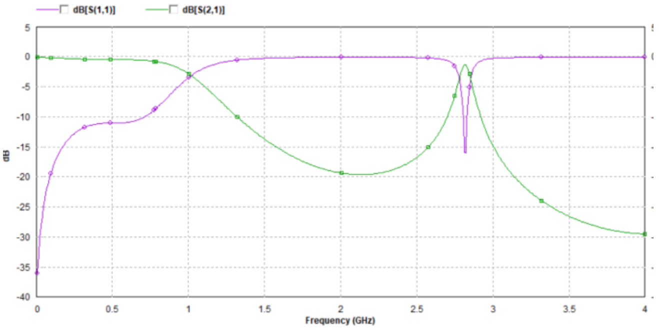

Fig 1.9: S(1,1)-Return Loss and S(2,1)-Insertion loss Parameters

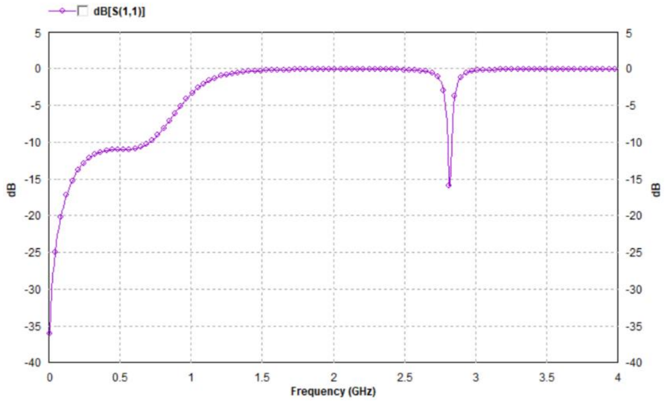

Fig 1.10: S(1,1)-Return Loss

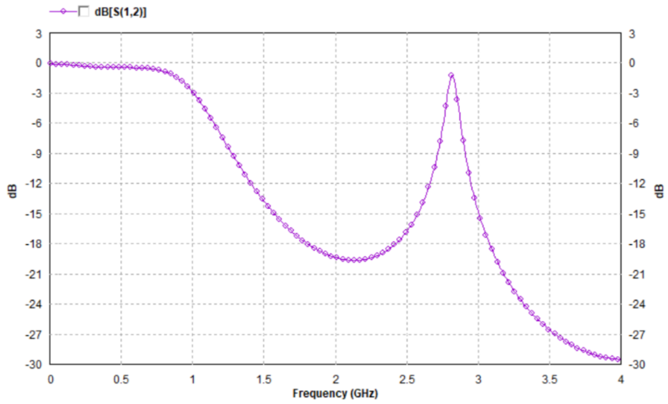

Fig 1.11: S(2,1)-Insertion loss Parameters

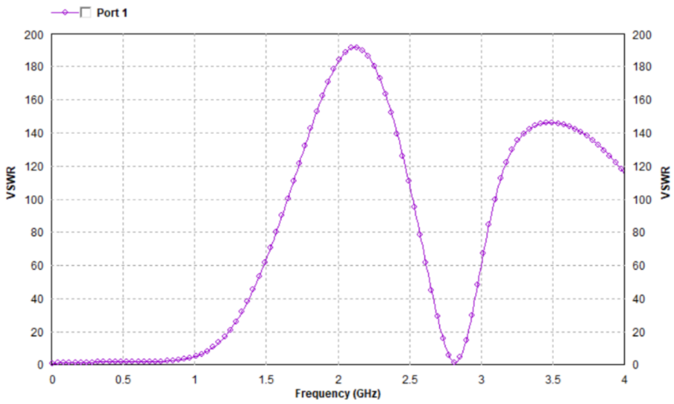

Fig 1.12: VSWR-output port

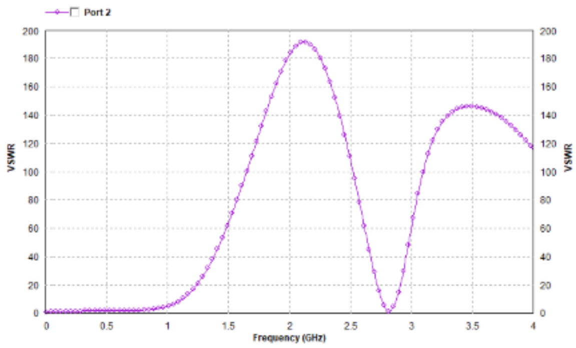

Fig 1.13: VSWR-output port

VI CONCLUSION AND DISCUSSION

In this paper, Modelling of Stepped Impedance low pass Butterworth filter for the order N=3 and N=5 having 1.2 GHz Cut-off frequency has been proposed and the simulated values of Insertion Loss and Return Loss for N=3 is -6.65 dB & -55.49dB and for N=5 is -7.23dB &-16.01 dB respectively. Various simulated results for VSWR has also been shown. Simulation of proposed filter has been done using IE3D Mentor Graphics. Designing equation are solved using MATLAB software. The results also show that by increasing the order of the filter Return Loss and Insertion Loss reflecting the changes.

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