Compact Design of Strip line Edge-coupled Band Pass Filter for Q-Band

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Abstract— **Design and Simulation of a parallel-coupled Stripline band pass filter using Ansoft Designer Software is presented. In this paper, band pass filter (BPF) development with the assistance of the Richards-Kuroda Transformation method, is presented. Q-Band refers to spectrum allocated within the band 38-40 GHz. The spectrum is used for fixed point-to-point microwave operations that would provide communications infrastructure such as "backhaul" and "backbone" communications links for services including broadband personal communications services (broadband PCS), cellular radio, and other commercial and private mobile radio operations.The filter is operated at downlink frequency segment of 38 GHz for different microwave application. The proposed circuit is simulated using Roger R03035 substrate with dielectric constant of 3.6, substrate height of 14 mm and thickness of 32 mm. The simulation results are excellent and the filter is suitable for integration within various microwave subsystems. The filter is designed and optimized at a center frequency of 39 GHz. The filter is built on a relatively cheap substrate FR-4 with permittivity ε_r=3.6 and loss tangent tanδ= 0.0017 .Simulation results reveal that the filter operation is optimum over the frequency range 38 GHz to 40 GHz..**

Index Terms— **Edge-coupled, Strip line, Dielectric substrates, Chebyshev band pass filter.**

I. INTRODUCTION

A Stripline circuit uses a flat strip of metal which is sandwiched between two parallel ground planes. The insulating material of the substrate forms a dielectric. The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip which is a transmission line [1]. In the general case, the dielectric material may be different above and below the central conductor. The Strip line it has become the best known and most widely used planar transmission line for RF and Microwave circuits. This popularity and widespread use are due to its planar nature, ease of fabrication using various processes, easy integration with solid-state devices, good heat sinking, and good mechanical support. Therefore, a third order chebyshev stripline edge-coupled filter is designed in the research. The band pass filter is simulated by using Ansoft Designer software. Many works have been reported that use waveguides for transmission line filter. However, waveguides systems are bulky and expensive. Low-power and cheaper alternatives are stripline and microstrip. These transmission lines are compact. Edge-coupled stripline is used instead of microstrip line as stripline does not suffer from dispersion and its propagation mode is pure TEM mode. Hence it is the preferred structured for coupled-line filters. A microstrip is similar to stripline transmission line except that the microstrip is not sandwiched, it is on a surface layer, above a ground plane. Stripline is much harder (and more expensive) to fabricate than microstrip, and because of the second ground plane, the strip widths are much narrower for a given impedance and board thickness than for microstrip[1].

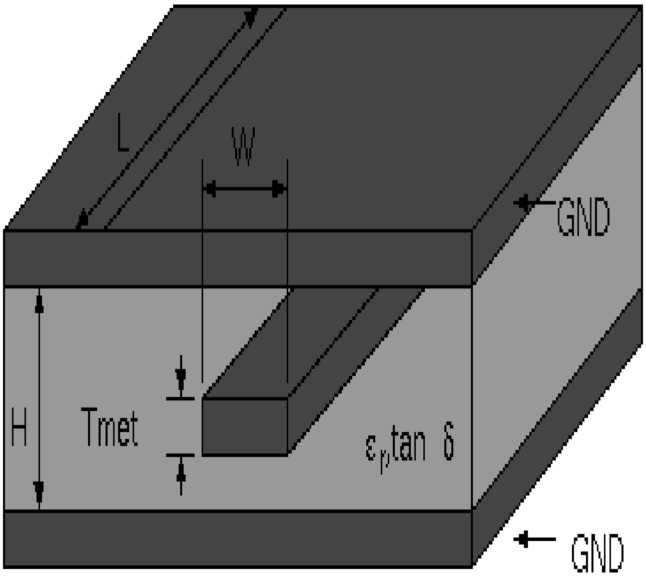

Figure 1: Model used by Designer for edge-coupled Stripline

II. METHODOLOGY

The design specification of the filter is shown in Table. The specification of dielectric material is obtained from Rogers Corporation. The proposed filter is designed by following the five steps. **First step:** Determining the order and type of approximation functions to be used. **Second step:** Finding the corresponding low-pass prototype. **Third step:** Transforming the low-pass network into a band pass configuration. **Fourth step:** Scaling the band pass configuration in both impedance and frequency. **Fifth step:** Transforming the lumped circuit element into distributed realization. This filter type is often used in the frequency range above 10 GHz because of it's reliable reproduction, cheap and simple production and high accuracy. An additional advantage: the mechanical dimensions decrease linearly with frequency [9].

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SPECIFICATIONS: TABLE

Specifications of Band Pass Filter, Specifications of Dielectric Material From ROGERS Corporation
Dielectric Material Used Rogers R03035 from Rogers High frequency Material.

1). Input and Output Impedance:	Z = 50 Ohms
2). Passband ripple of S21:	0.5 dB
3). Filter Order:	N = 3
4). Passband Centre Frequency:	39 GHz ((broadband PCS), cellular radio, and other commercial and private mobile radio operations)
5). Ripple Bandwidth:	2 GHz
6). Substrate:	Rogers R03035
7). Thickness:	32 mil (= 0.813 mm)
8). Dielectric Constant:	3.6
9). Loss Tangent:	0.0017
10). Copper cladding (up and down):	1 oz (thickness = 5.11 mil = 0.13 mm)
11). Cover Height:	14 mm

Transmission Line	Useful Frequency range (GHz)	Impedance Range(Ω)	Cross-Sectional Dimensions	Q-Factor	Power Rating	Active Device Mounting	Potential for Low-Cost Production
Rectangular Waveguide	<300	100-500	Moderate to large	High	High	Easy	Poor
Coaxial Line	<50	10-100	Moderate	Moderate	Moderate	Fair	Poor
Stripline	<10	10-100	Moderate	Low	Low	Fair	Good
Microstrip Line	≤100	10-100	Small	Low	Low	Easy	Good
Suspended Stripline	≤150	20-150	Small	Moderate	Low	Easy	Fair
Finline	≤100	20-400	Moderate	Moderate	Low	Easy	Fair
Slotline	≤60	60-200	Small	Low	Low	Fair	Good
Coplanar Waveguide	≤60	40-150	Small	Low	Low	Fair	Good
Image guide	<300	30-30	Moderate	High	Low	Poor	Good
Dielectric Line	<300	20-50	Moderate	High	Low	Poor	Fair

Table 1: Transmission Line and Waveguide Comparisons [6]

III. SIMULATION RESULT

The BPF circuit is simulated with Ansoft Designer Student Version 2.2 Software in order to predict the performance of the filter.Few parameters in the circuit are analyzed and have a good relation ship to microwave theory.An optimization process has been introduced along the simulation procedure focusing on the filter dimension in order to improve the response of the filter. Refer to the filter tables given in D.M Pozar and G. L. Matther [7] to find the following coefficients for a third order Chebyshev filter.
Normalized element values for 0.5 dB ripple low-pass Chebyshev filter given in was g0 = 1, g1 = 1.5963, g2 =1.0967, g3 = 1.5963, g4 = 1.0000. The bandpass filter is realized as a cascade of N+1 coupled line sections as shown in Fig. 1. The sections are numbered from left to right. The source is connected at the left and the load is connected to the right. The filter could be reversed without affecting the response[2].
Calculation of Odd and Even Resistances To design the stripline filter, an approximate calculation is made based on the design equations. The no of stages (N) = 3. The characteristic impedance Z0 is typically 50 Ohms. The unitary bandwidth BW is given by where $BW = \frac{(\omega_2 - \omega_1)}{\omega_0}$ is the fractional

$$FBW = \frac{(40\times10^9 - 38\times10^9)}{39\times10^9} \approx .051308$$

(1)

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

(2)

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_j g_{j+1}}} \quad \text{for } j=1 \text{ to } n-1$$

(3)

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

(4)

where g_0, g_1… g_n are the element of a ladder-type low-pass prototype with a Normalized cutoff $\Omega_c = 1$, and FBW is the fractional bandwidth of band-pass filter. $J_{j,\ j+1}$ are the characteristic admittances of J-inverters and Y_0 is the characteristic admittance of the terminating lines.

The equation above will be use in end-coupled line filter because the both types of filter can have the same low-pass network representation. However, the implementation will be different [6].

To realize the *J*-inverters obtained above, the even- and odd-mode characteristic impedances of the coupled microstrip line resonators are determined by

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad \text{for } j=0 \text{ to } n \qquad (5)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad \text{for } j=0 \text{ to } n \qquad (6)$$

j	$J_{j,j+1}/Y_0$	$(Z_{oe})_{j,j+1}$ (Ω) (Measured Results)	$(Z_{oo})_{j,j+1}$ (Ω) (Measured Results)	$(Z_{oe})_{j,j+1}$ (Ω) (Simulated results)	$(Z_{oo})_{j,j+1}$ (Ω) (Simulated results)
0	.24709	**65.40**	**40.69**	**63.86**	**41.25**
1	.06088	**53.22**	**47.14**	**53.27**	**47.11**
2	.06088	**53.22**	**47.14**	**53.27**	**47.11**
3	.24709	**65.40**	**40.69**	**63.86**	**41.25**

(1) Table 2 : Circuit design parameters of the three-pole, parallel-coupled Stripline Band Pass filter [6]

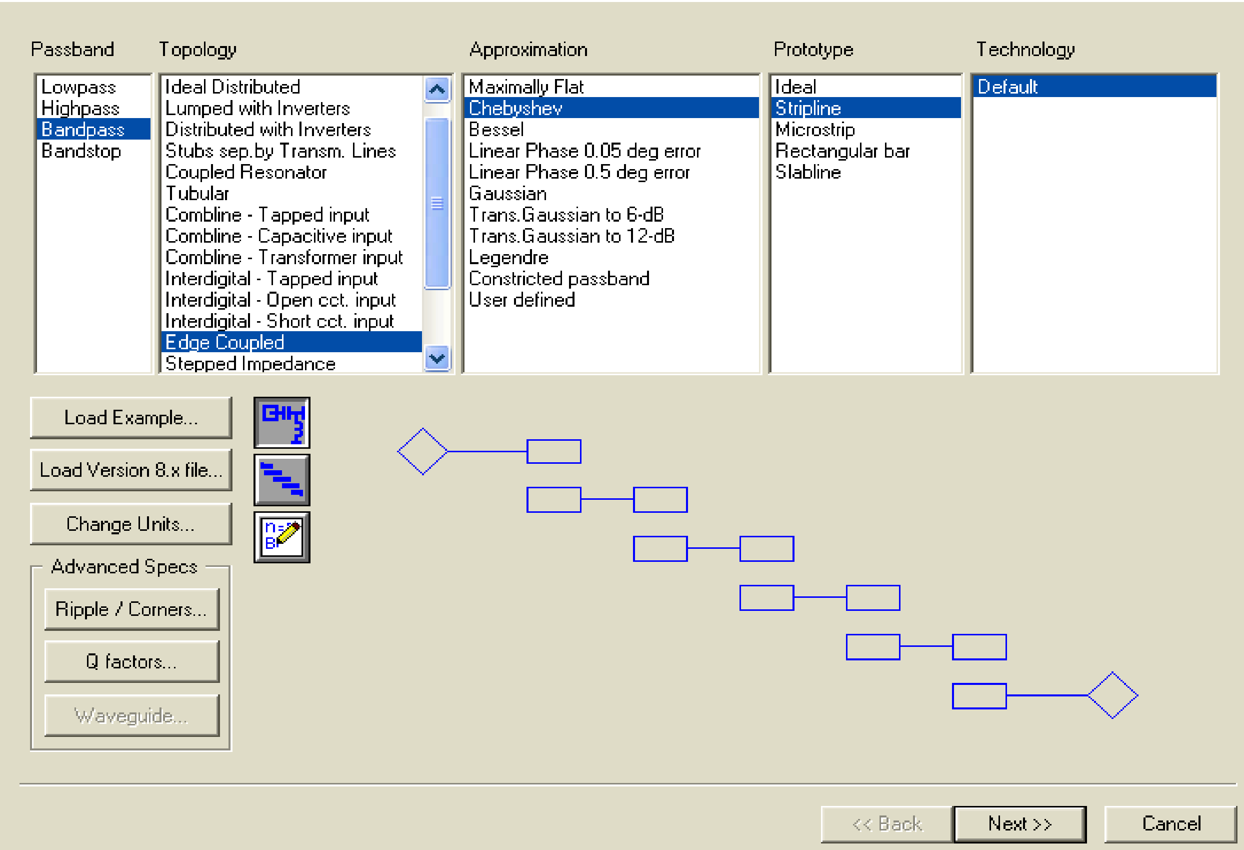

Figure 2 : Working with Filter Design Tool [3]

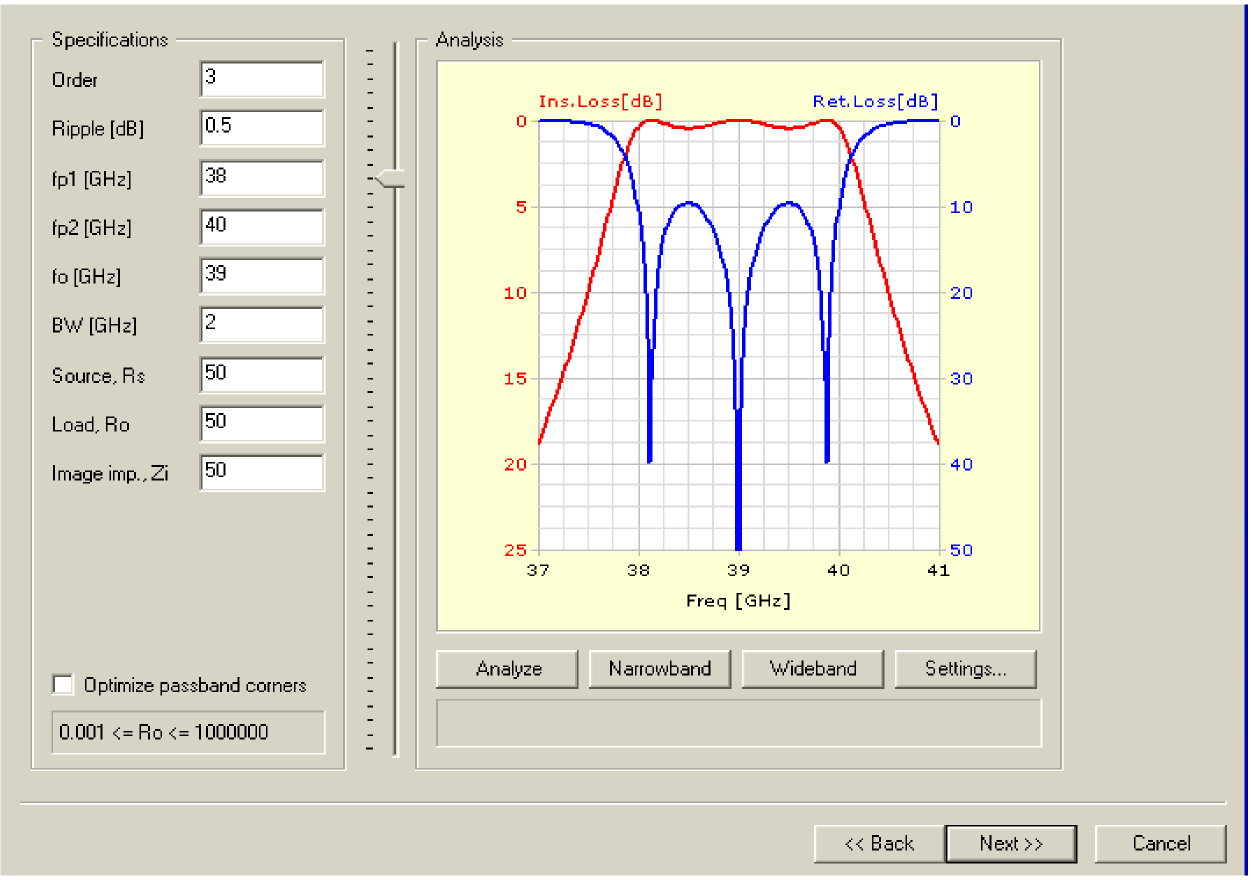

Figure 3 : "Analyse" and then "Narrow Band" to get the characteristic filter curves [3]

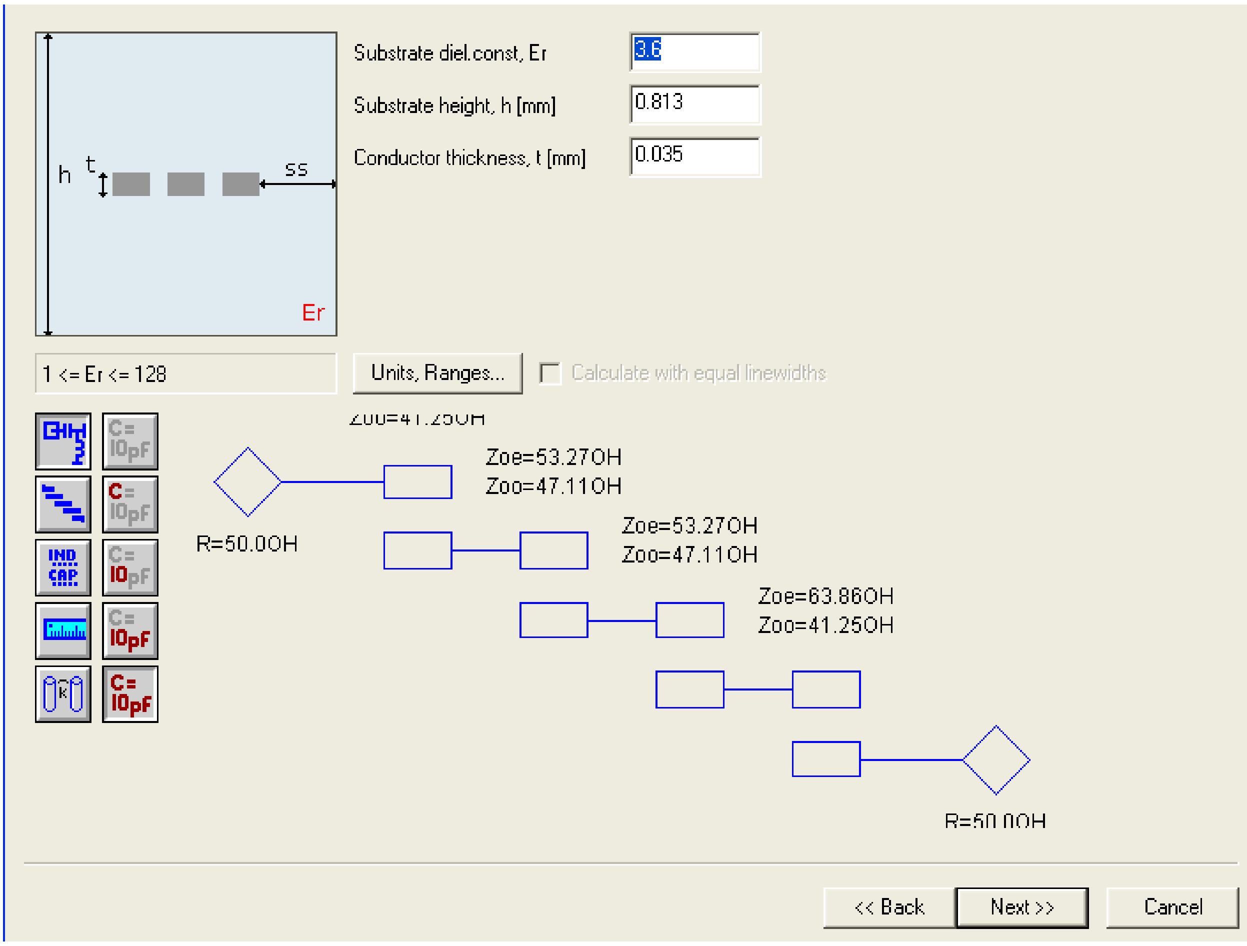

Figure 4: Configuration For filter Specifications [3]

IV. RESULT & DISCUSSION

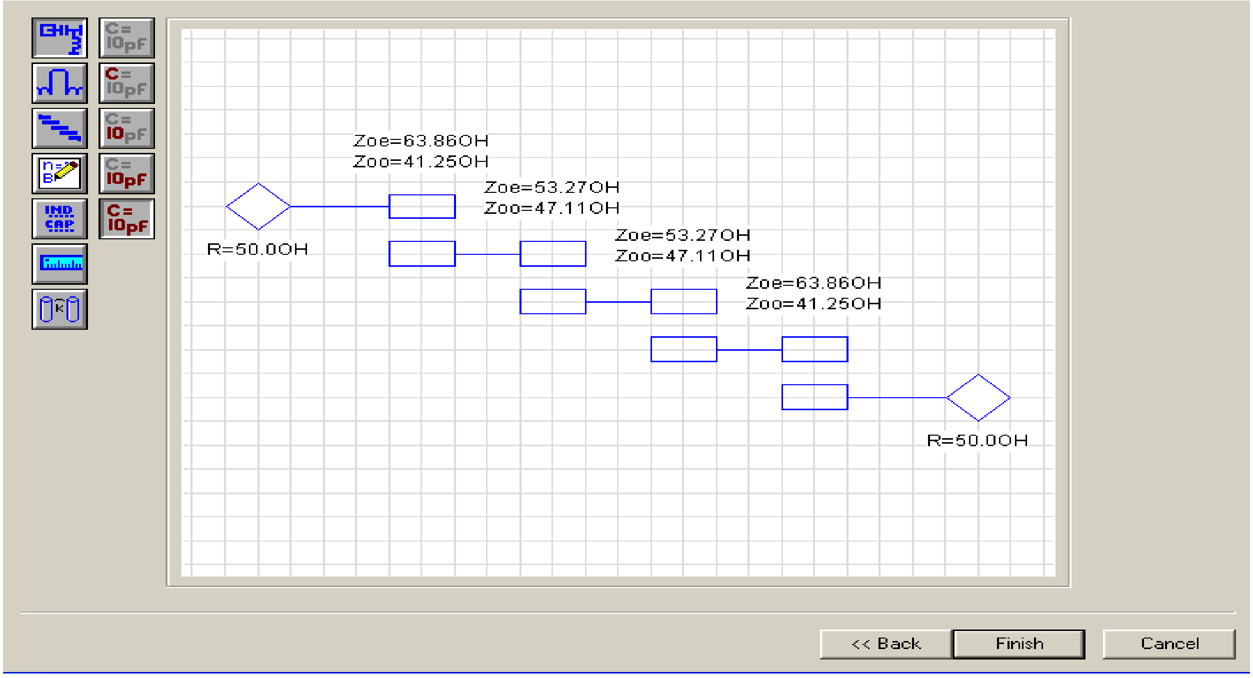

Figure 5: Software Result Of Odd and Even Impedances [3]

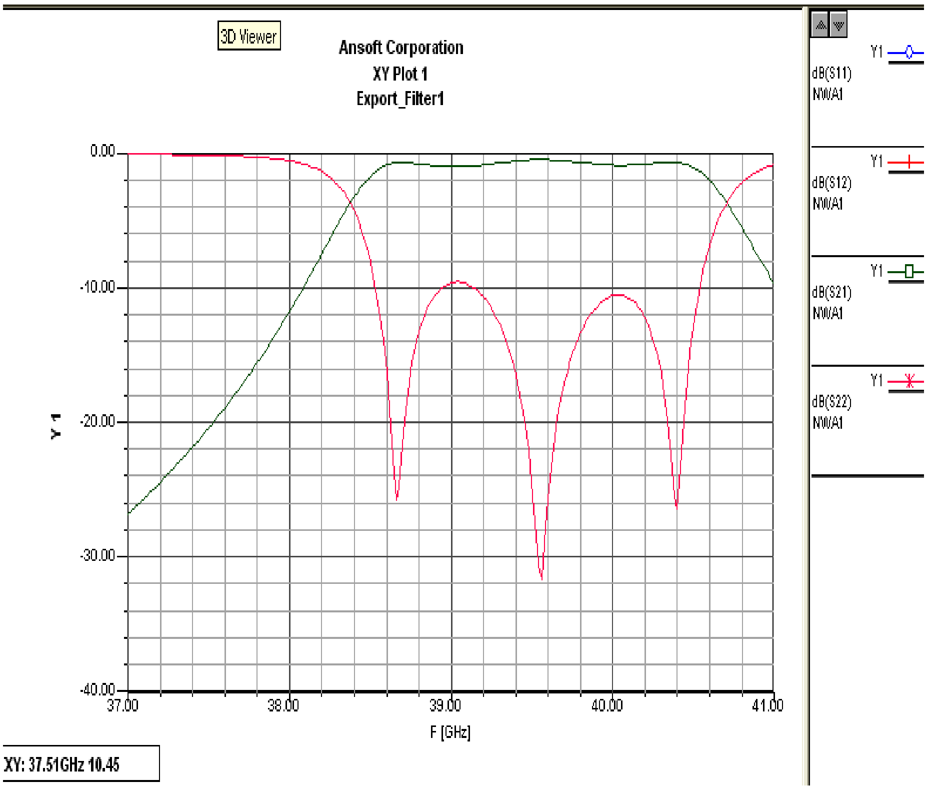

Figure 6 : Simulated Insertion Loss and Return Loss [3]

The simulated insertion loss is less than 0.5 dB in passband. Also the response is flat and uniform over the entire pass-band. In addition, the simulated response has the attenuation of more than 50 dB at 39 GHz. For S11 of 50 dB, reflection coefficient is 0.00001 which is nearly equal to 0 and a perfect match exists. Therefore, all simulated results are nearly identical to the design specifications.

The simulated group delay for the designed filter is depicted in Fig.7. It is clear from the result that the group delay reaches a peak value close to the cut-off point. Moreover, the simulated group delay has a very low peak-to-peak variation of less than 3ns across the passband of the filter. Therefore, the designed filter shows attractive characteristics for BPF applications.

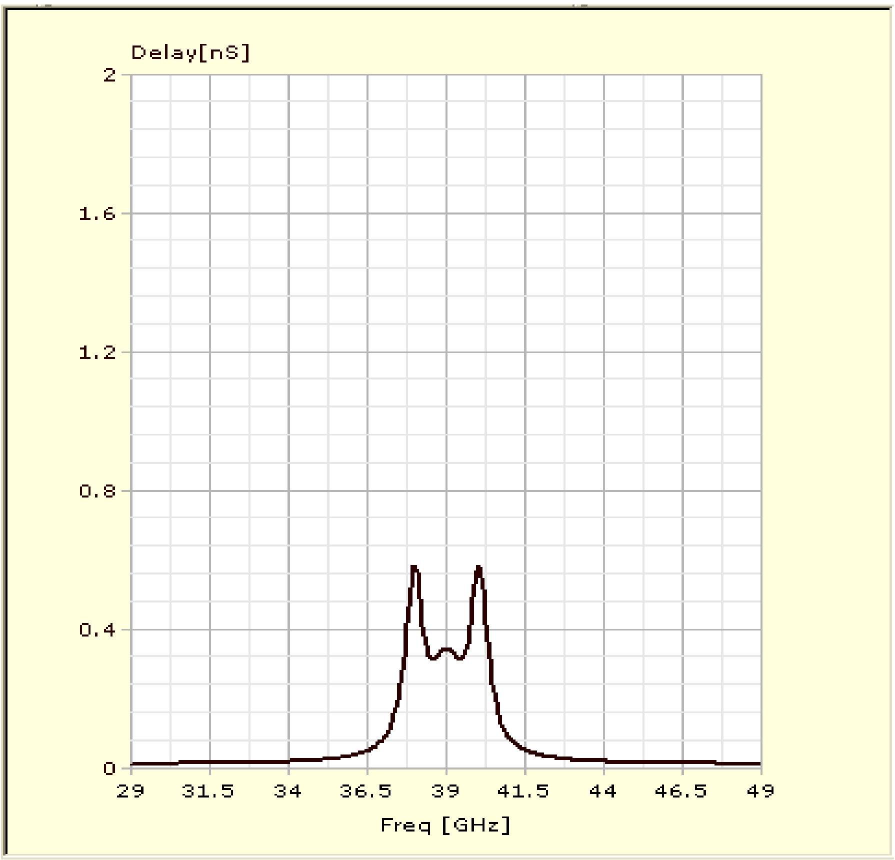

Figure 7 : Simulated group delay result [3]

Moreover, the simulated group delay has a very low peak-to-peak variation of less than 1ns across the passband of the filter. Therefore, the designed filter shows attractive characteristics for BPF applications.

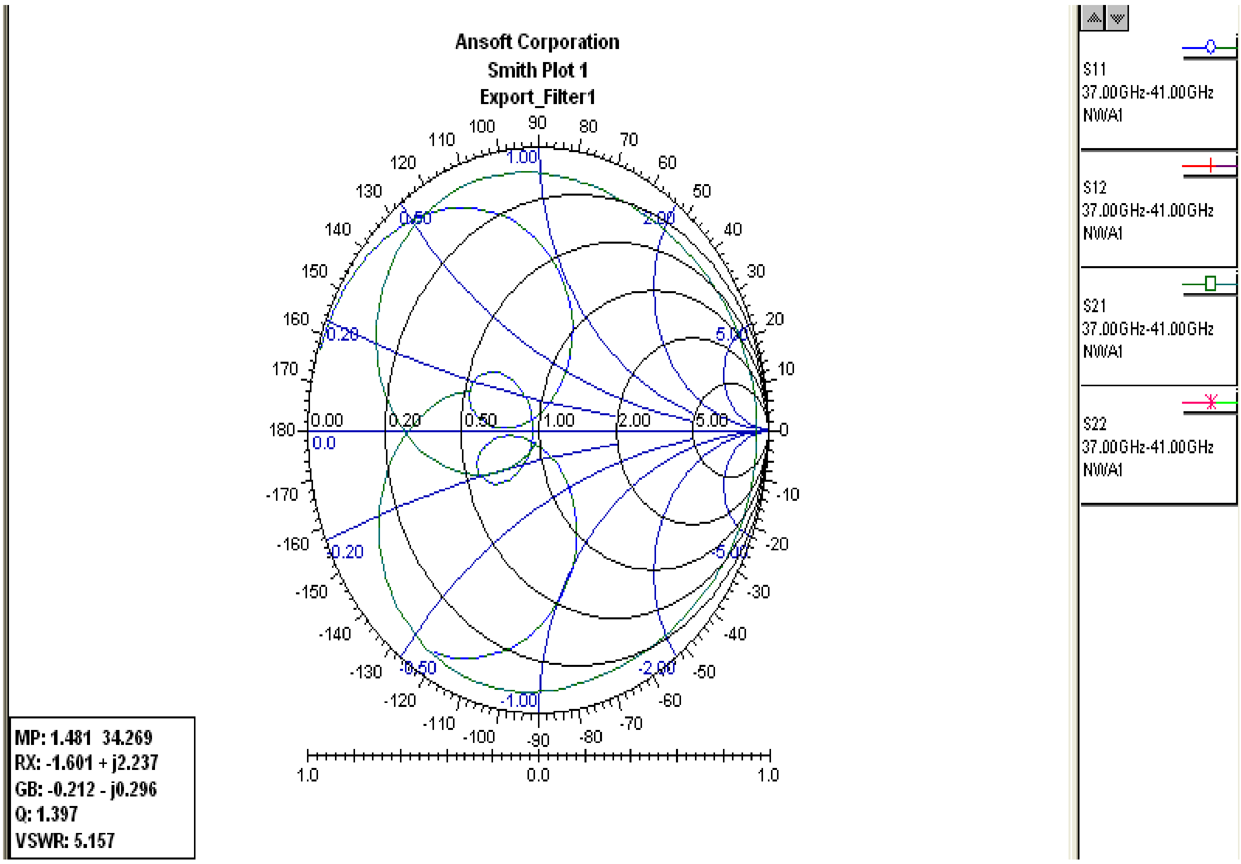

Figure 8 : Smith Chart of Simulated Insertion Loss and Return Loss [3]

V. CONCLUSION

This paper describes a procedure for designing edgecoupled stripline band pass filter. It also rejects image signal appearing at the frequency range between 38 GHz to 40GHz. Experimental implementation of this work involves the Roger R3035 substrate with dielectric constant of 3.6 dielectric characterization at microwave frequencies, which has been investigated. The measured parameters were also in good agreement with the simulated results.This paper describes a procedure for designing stripline edge-coupled band pass filter. Third-order stripline edge-coupled band pass filter is used in order to realize these objectives. The filter is simulated with Ansoft Designer 2.2 software to predict the performance of filter. The simulated insertion loss is less than 0.5 dB in the desired passband and the simulated return loss is greater than 50 dB at center frequency. All simulated results are nearly identical with the calculated results and also they are good agreement to the design specifications. An effective general procedure that may be applied to the design of many RF circuit designs has been reviewed. The authors utilized the proposed procedure in an effort to design an edge coupled band-pass filter centered at 39 GHz with a 2 GHz bandwidth based on Chebyshev approximation. Simulation results the authors agree that the errors are not overly extensive and the presented process may be considered a success.

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