Simulation and Analysis of Edge-Coupled Band Pass Filter for Ku Band Application

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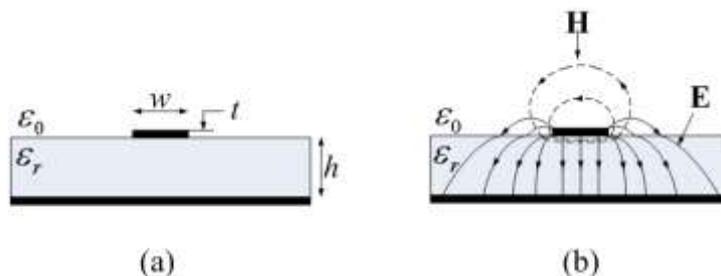[*]*Corresponding author's email: oranta68 [AT] yahoo.com*

ABSTRACT— *In this paper, an edge-coupled microstrip band pass filter using Ansoft designer is proposed. The filter is operated at Satellite downlink frequency for 12.2-12.7 GHz & the filter is designed on Roger RO6006 substrate with dielectric constant of 6.45, with dimension conductor thickness 0.035 mm and substrate height 0.787 mm. The proposed filter is designed at a center frequency of 12.45 GHz. In this paper, third order band pass filter development with the assistance of the Richards-Kuroda Transformation method is used. A comparison with filter designed on stripline technology is also presented.*

Keywords— microstrip, edge coupled, chebyshev band pass filter, ku band spectrum.

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1. INTRODUCTION

The Microstrip line it has become the best known and most widely used planar transmission line for RF and Microwave circuits [6]. 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 [1].

In this paper, design and simulation of an edge-coupled bandpass filter realized in microstrip technology is presented. Different filter parameters are estimated using analytical formulas, the simulation of a microstrip transmission line models in a circuit simulator is presented [3]-[6].

Fig. 1: (a) Model used for edge-coupled microstrip line band pass filter (b) Electric field and magnetic field lines.

In simple terms, Microstrip is the printed circuit version of a wire over a ground plane, and thus it tends to radiate as the spacing between the ground plane and the strip increases [1]. A substrate thickness of a few percent of a wavelength (or less) minimizes radiation without forcing the strip width to be too narrow. Two microstrip lines placed in close proximity and parallel to each other form coupled microstrip lines [5]. Coupled lines support two modes of propagations [2]-[5]. Even mode exists when charges on both lines are of the same sign, odd mode when the sign is opposite. Each of these modes of propagation has different characteristics of transmission line, namely even and odd mode characteristic impedances z_{0e} and z_{0o} , and even and odd mode phase velocities v_{pe} and v_{po} . Even and odd mode characteristic impedances of microstrip coupled lines depends on the dielectric constant ε_r and normalized dimension *s, h* and *w, h* , where *s* is a width of slot of coupled microstrip lines, *w* is a width of lines and *h* is a thickness of substrate.

In this paper, Ansoft Designer was used for the purpose of designing and simulating different types of filters. Ansoft Designer is a very powerful microwave simulator. It is the first suite of design tools to fully integrate high-frequency, physics-based electromagnetic simulation, modeling, and automation into a seamless environment for circuit and system analysis.

2. RESEARCH METHODOLOGY

The design specification of the filter is shown in Table 1. 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 bandpass configuration.

Fourth step: Scaling the bandpass configuration in both impedance and frequency.

Fifth step: Transforming the lumped circuit element into distributed realization [7]-[8].

Table 1: Specifications of edge-coupled band pass filter and dielectric material

Parameter	Value
Input and output impedance	50 ohm
Pass band ripple	0.5dB
Filter order	3
Pass band centre frequency	12.45GHz
Ripple bandwidth	0.5GHz
Substrate	Rogers R06006
Conductor thickness	0.035mm
Dielectric constant	6.45
Substrate height	0.787mm

2.1 Choice of Filter Type and Order:

A good band pass filter has minimal signal loss in its pass band, as well as a narrow pass band with as much out of band attenuation as possible. Chebychev filters have narrower pass band response in trade for more ripples in the pass band section. Higher order filters can have a narrower shape factor but will be physically larger in shape. The filter specification goals for return loss (scatter parameter S11) are >40 dB and for insertion loss (scatter parameter S21) <10dB. Simulations showed a filter order of n=3 will achieve this goal. The required order for a filter meeting the given specifications is calculated as below [8]:
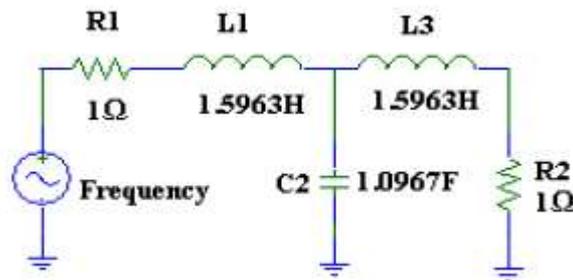
$$n = \frac{Cosh^{-1}\sqrt{\dfrac{10^{\frac{K_T}{10}} - 1}{K - 1}}}{Cosh^{-1}(\dfrac{f}{f_c})}$$

Where K_T is the minimum attenuation at frequency f_c, and $K = 10^{\wedge}(Lar/10)$, with Lar being the maximum ripple in dB allowed in the pass band. The order of the filter is a measure of the minimum number of elements to be included in the filter to realize the required amount of ripple in the pass band and attenuation at a frequency outside of the pass band. Additional elements may be included in the filter which will further improve the filter response at the cost of size and increased design time [8].

2.2 Finding the low pass prototype

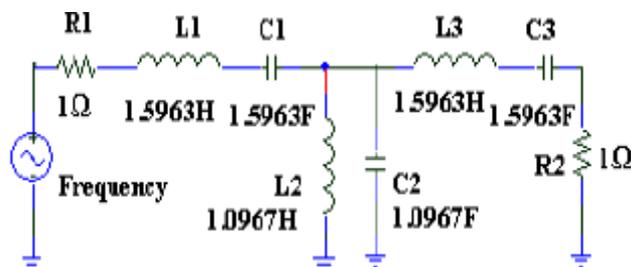**Table 2:** Chebyshev filter co-efficients; 0.5dB filter design (N=1 to 4)

N	g_1	g_2	g_3	g_4	g_5
1	0.6986	1.0000	0	0	0
2	1.4029	0.7071	1.9841	0	0
3	1.5963	1.0967	1.5963	1.0000	0
4	1.6703	1.1926	2.3661	0.8419	1.9841

Fig. 3: Third order low pass prototype [9]

After finalizing the order, the low pass filter prototype is developed using the component values from Table 2. The low pas filter protorype is shown in Fig 3. After getting the low pass filter prototype values, it's transformed into band pass filter design. The transformation from low pass to band pass all shunt element of the low pass prototype circuit becomes parallel-resonant circuit, and all series elements become series-resonant circuit in Fig 4.

2.3 Transforming the Low Pass Filter into Band Pass Filter Configuration

Fig. 4: Transformation of the third order low pass prototype to band pass prototype [9]

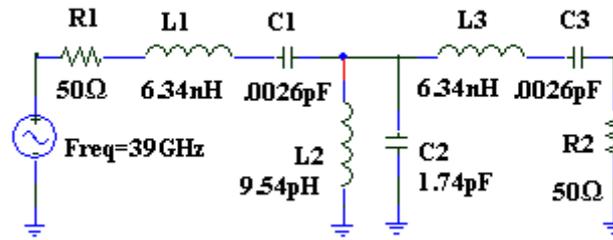## 2.4 Scaling the Band Pass Filter Configuration in both Impedance and Frequency

The transformed the filter is then frequency-scaled and impedance-scaled using the following formulas [8].

$$L_s = \left(\frac{1}{FBW \times \omega_0}\right) Z_0 \times g$$

$$C_s = \left(\frac{FBW}{\omega_0}\right) \frac{1}{Z_0 \times g}$$

$$C_p = \left(\frac{1}{FBW \times \omega_0}\right) \frac{g}{Z_0}$$

$$L_p = \left(\frac{FBW}{\omega_0}\right) \frac{Z_0}{g}$$

Fig. 5: Frequency and Impedance scaled band pass filter designed at center frequency

2.5 Even and Odd Modes in a Coupled Transmission Line

Calculation of Odd and Even Resistances to design the strip line filter, an approximate calculation is made based on the design equations. The no of stages n = 3. The characteristic impedance Z_0 is typically 50 Ohms [2]-[8]. The unitary bandwidth FBW is given by FBW = $((\omega 2-\omega 1))/\omega 0$ and it is .04016GHz for the design. The design equations are as follows:

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

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

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

Where $g_o, g_1 \ldots g_n$ are the elements 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_o is the characteristic admittance of the terminating lines [7]. The above equations will be used in edge-coupled line filter because the both types of filter can have the same low-pass network representation. To realize the J-inverters obtained above, the even- and odd-mode characteristic impedances of the coupled micro strip band pass filter are determined by:

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

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad \text{for j=0 to n}$$
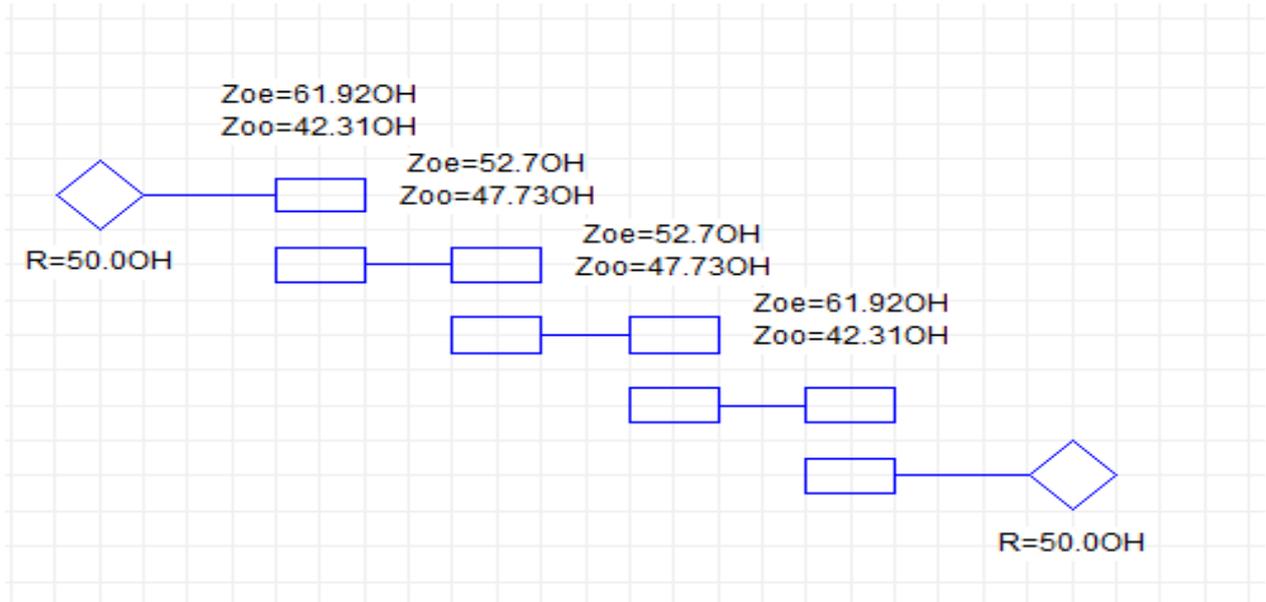
The sections are numbered from left to right. The source is connected at the left and the load is connected to the right. The filter could be reversed without affecting the response [2]. The results of Z0o and Z0e, are shown in table 3, are almost identical to that of the n=3 order approach, except an additional coupling section is used to represent the increased order.

Table 3. Circuit design parameters of 3rd order strip line edge-coupled band pass filter
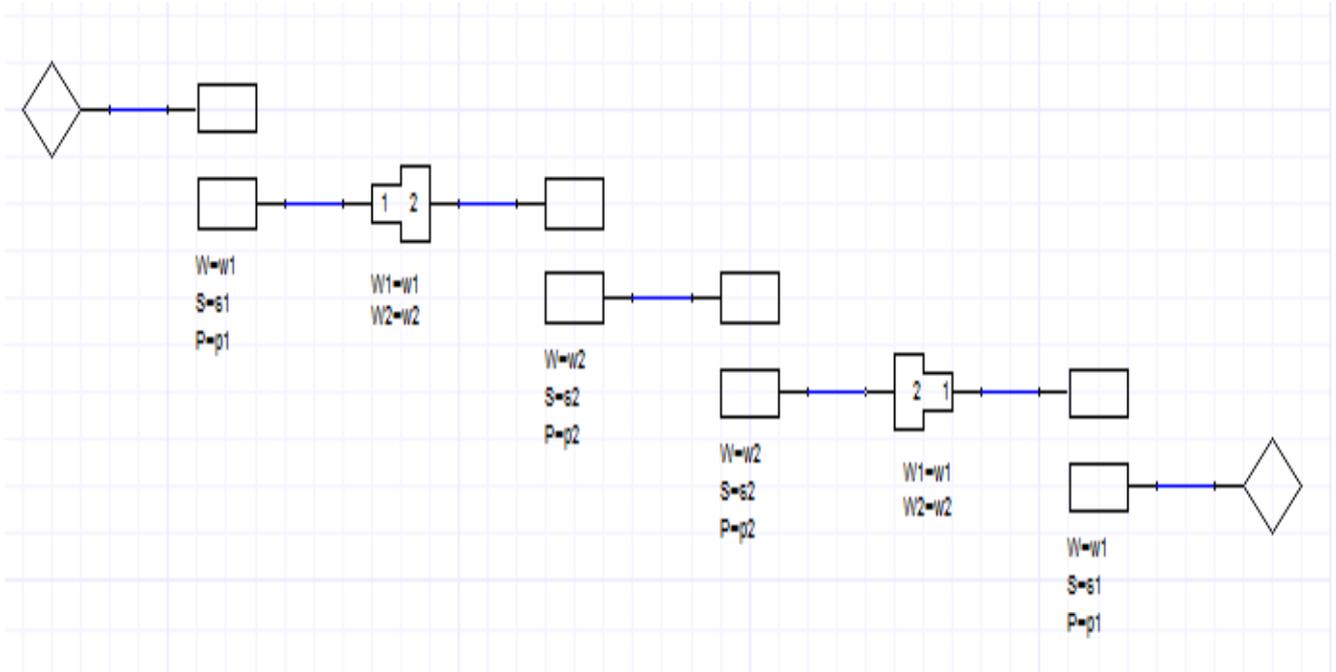
j	$J_{j,j+1}/ Y_0$	$(Z_{oe})_{j,j+1}$ (Ω) (Calculated Results)	$(Z_{oo})_{j,j+1}$ (Ω) (Calculated Results)	$(Z_{oe})_{j,j+1}$ (Ω) (Simulated results	$(Z_{oo})_{j,j+1}$ (Ω) (Simulated results
0	0.19879	61.921	41.97	61.972	42.31
1	0.04767	52.497	47.78	52.531	47.73
2	0.04767	52.497	47.97	52.531	47.73
3	0.19879	61.921	41.97	61.927	42.31

3. SIMULATED RESULTS AND DISCUSSION

The frequency sweep for the linear simulation of the advanced numerical models was performed from 12.2 to 12.7GHz in 12.45 GHz steps.
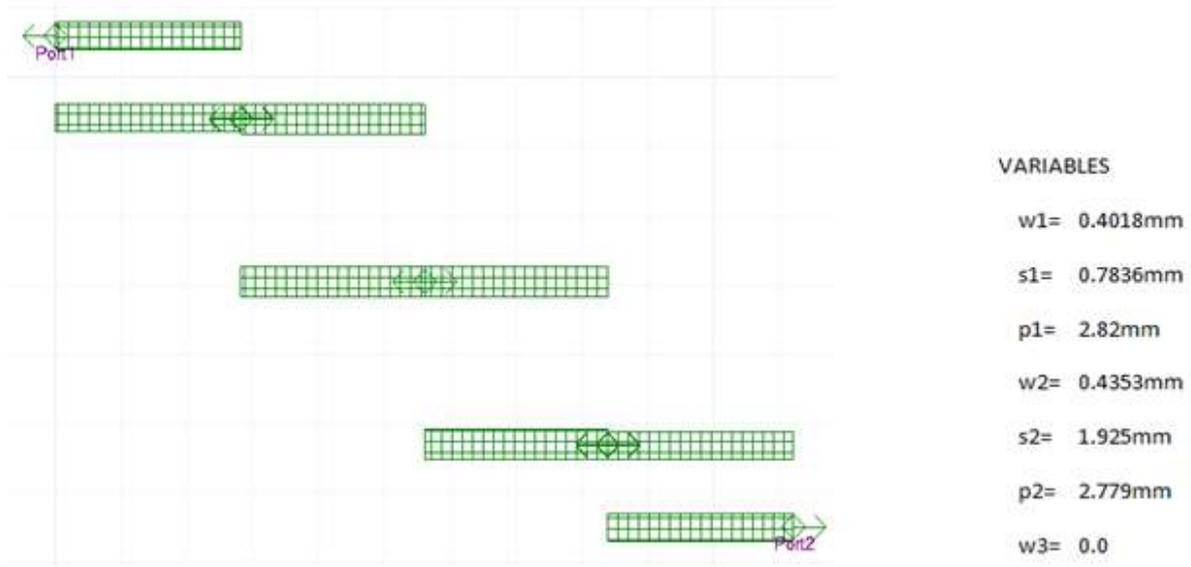
Fig.6: Software design of ddd and even Impedances of 3rd order edge-coupled microstrip band pass filter.
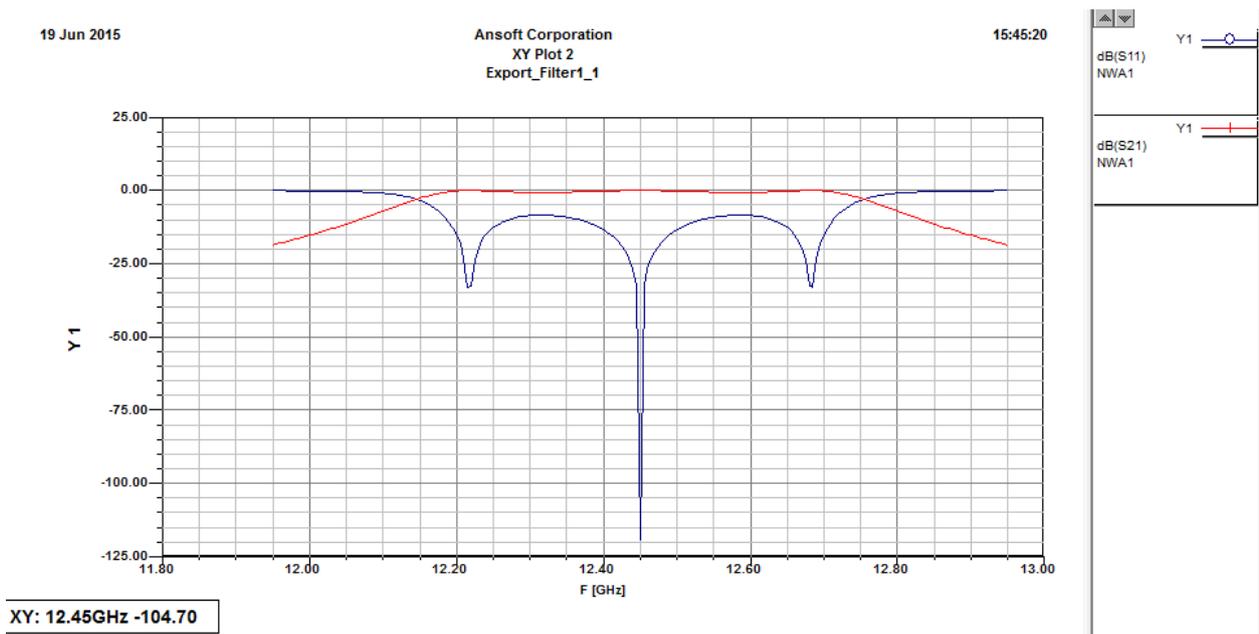

Fig. 7: Tuned chebyshev bandpass filter made from physical model of 3rd order edge-coupled microstrip Band pass Filter.
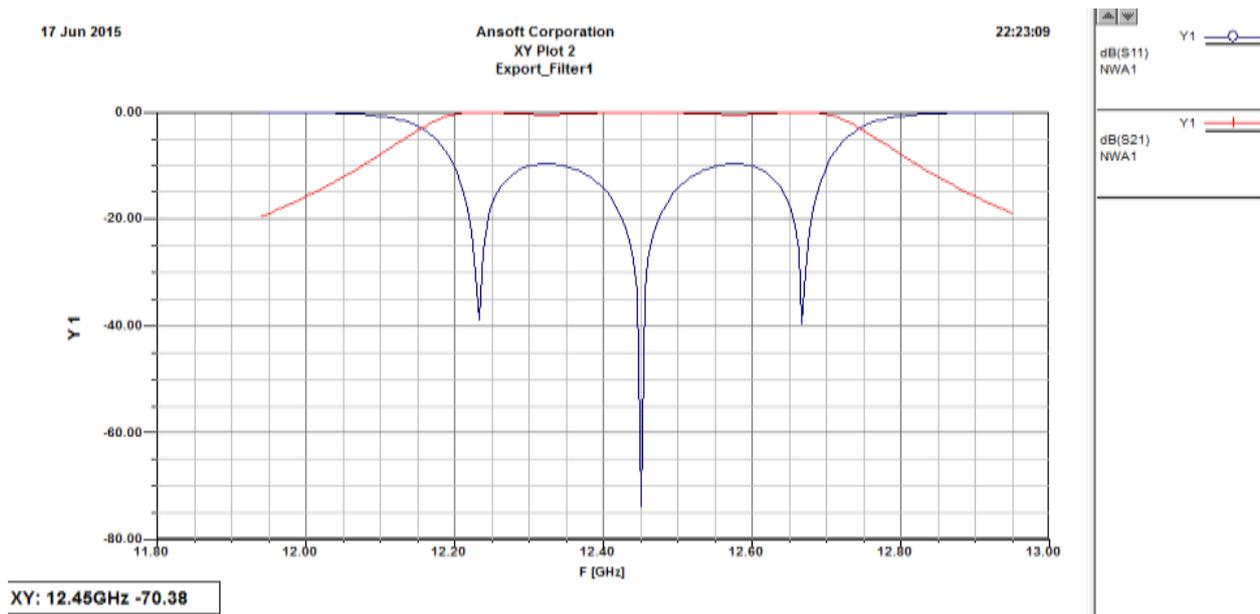
Fig.8: Electrical model of 3rd order edge-coupled microstrip band pass filter

Fig.9: Simulated smith chart impedance result of 3rd order edge-coupled microstrip band pass Filter.

VARIABLES

w1= 0.4018mm

s1= 0.7836mm

p1= 2.82mm

w2= 0.4353mm

s2= 1.925mm

p2= 2.779mm

w3= 0.0

Fig.10: Detailed dimensions of the simulated layout model of 3rd order edge-coupled microstrip band pass filter.

XY: 12.45GHz -104.70

Fig.11: Simulated s21 and s11 results for electrical model of 3rd order edge-coupled microstrip band pass filter

Fig.12: Simulated s21 and s11 results for electrical model of 3rd order edge-coupled stripline band pass filter.

Fig. 7 and Fig. 8 show the physical and electrical model configuration for microstrip line band pass filter. Fig. 9 show the smith chart for microstrip band pass filter by which we can evaluate the voltage standing wave ratio(VSWR).We know that for a perfect filter matching, the VSWR should be between 2 to 1for the pass band frequency. In the Fig. 9, the VSWR always varies from 1 to 1.2 at the desired range of frequencies.

.Fig 11 showed the electrical model configuration output for the 3rd order edge coupled microstrip band pass filter. The simulated Return loss parameter (S_{11}) is -110db at centre frequency. the Insertion(S_{21}) loss parameter is less then –0.5db in the pass band and the filter response is flat and uniform at the entire pass band. We also measure the reflection co efficient by the return loss parameter. The value of the reflection co efficient is almost zero(0.00000000001) and almost a perfect match exists.

4. CONCLUSION

This paper describes a procedure for designing edge coupled microstrip band pass filter. Third-order edge-coupled microstrip filter is used in order to realize this objective. Since the practical inductors and capacitors loses their intrinsic characteristics at high frequencies, lumped element filter is converted into distributed microstrip filter by using Richard's transformation and Kuroda's identities.

A comparison between the stripline and microstrip band pass filter is also presented. It is observed that the simulated return loss is less then -110db at centre frequency for the microstrip BPF. We have observed that the Return loss parameter for the "Stripline" band pass filter is -74db. So from the above discussion it is clear that a stripline filter will not give a good response for this frequency.

5. REFERENCES

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