Design and Simulation of a Microstrip Band Pass Filter for C Band

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***Abstract* - The objective of this work is to study and design a band pass filter based on microstrip technology for application in equipment of the fifth generation (5G) of cell phones in the C band. The presented process includes the estimation of filter parameters using analytical formulas, finding the corresponding low-pass prototype structure impedance and frequency scaling is performed to achieve a band pass filter. The pass-band filter is then implemented using end-coupled microstrip lines, the lengths of these lines and the gaps between them are obtained by using analytical formulas. The structure of this filter is simulated using Ansoft designer SV2.2 simulator. Good agreement between theoretical and simulated results is observed.**

Index Terms – Band pass filter, microstrip, end-coupled.

I. INTRODUCTION

Microwave filters are widely used in communication systems whose function is the frequency discrimination of the signal in order to select a frequency band containing the useful signal and to attenuate the frequencies around this band. Microwave filters can be classified into two categories localized element-based filters and distributed element-based filters. Localized elements are discrete elements which can be coils or capacitors while distributed elements are based on microstrip transmission lines and use lengths and widths to create their inductive or capacitive values [1].

The majority of communication systems operate on a frequency band therefore these systems incorporate a band pass filter usually just after the low noise amplifier as shown in the fig.1[2]. In this work the design of an end-coupled band-pass filter realized on microstrip technology is detailed and presented. The presented process begin by specifying the characteristics of the filter then the filter parameters estimation is done by using analytical formulas and finally the implementation of the filter is realized using end-coupled microstrip lines where the lengths and gaps are obtained from the filter parameters already estimated. The structure obtained of the filter on microstrip technology is simulated using Ansoft designer SV2 simulator [3], Scattering parameters of the filter are carried out.

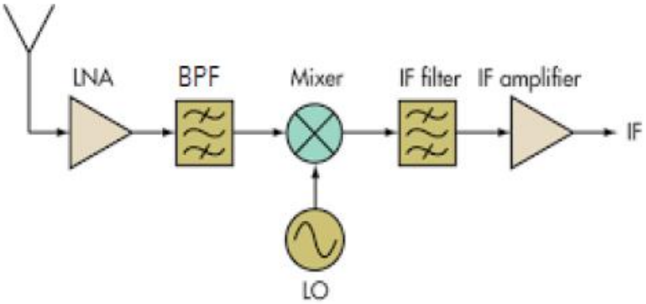

Fig. 1 Block Diagram of RF Receiver system

II. MICROSTRIP FILTER DESIGN STEPS

The design of microwave filters based on microstrip technology goes through various stages. The first is to specify the characteristics of the filter, then we establish the prototype of the low-pass filter then a translation to the desired frequencies and impedances is made and finally the lumped-element components replaced with distributed circuit elements for implementation at microwave frequencies.

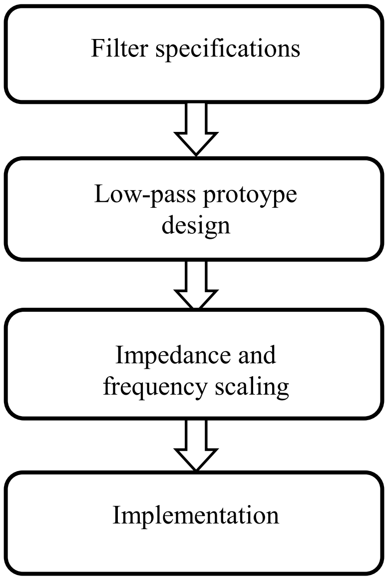

Fig. 2 Microstrip filter design steps.

A. Specifications

In this work we propose to study and simulate a band pass filter in microstrip technology for use in equipment of the fifth generation of cell phones, the specifications of which are as follows.

TABLE I
PARAMETERS OF THE FILTER

Parameter	**Value**
Order of the filter	3
Passband ripple	0.1 dB
Center Frequency	6 GHz
Operating Range	5.88-6.12 GHz
Source Impedance	50 Ω
Dielectric Constant	10.8
Thickness of substrate	1.27

B. Low pass filter prototype values

The first step is the design of a low-pass filter prototype with source impedance equal to 1 ohm and a cut off frequency equal to 1 rad/sec. the elements values are tabulated [4]

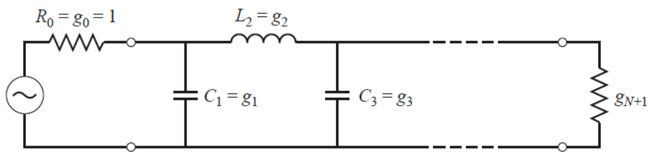

Fig. 3 Low-pass filter prototype

TABLE II
ELEMENT VALUES FOR EQUAL-RIPPLE LOW-PASS FILTER PROTOTYPES

n	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}
1	0.3052	1.0								
2	0.8431	0.6220	1.3554							
3	1.0316	1.1474	1.0316	1.0						
4	1.1088	1.3062	1.7704	0.8181	1.3554					
5	1.1468	1.3712	1.9750	1.3712	1.1468	1.0				
6	1.1681	1.4040	2.0562	1.5171	1.9029	0.8618	1.3554			
7	1.1812	1.4228	2.0967	1.5734	2.0967	1.4228	1.1812	1.0		
8	1.1898	1.4346	2.1199	1.6010	2.1700	1.5641	1.9445	0.8778	1.3554	
9	1.1957	1.4426	2.1346	1.6167	2.2054	1.6167	2.1346	1.4426	1.1957	1.0

Then the values of our prototype will be:

TABLE III
ELEMENT VALUES FOR 3 ORDER FILTER PROTOTYPE

Parameter	Value	Element
g_1	1.0316	C_1
g_2	1.1474	L_2
g_3	1.0316	C_3
g_4	1	Z_L

C. Scaling and conversion

Once the element values are defined the scaling of impedance and frequency is realized to obtain the lumped model of the filter. The new elements values are determined by applying the next formulas [1].

$$L_k^{'} = \frac{R_0 L_k}{w_c} \qquad (1)$$

$$C_k^{'} = \frac{C_k}{R_0 w_c} \qquad (2)$$

The element values obtained of the low-pass prototype filter are summarized in the table.

TABLE IV
ELEMENT VALUES OF LOW-PASS FILTER PROTOTYPE

Parameter	**Value**
C_1	0.5475 pF
L_2	1.5225 nH
C_3	0. 5475 pF
Z_L	50 Ω

Once the lumped elements of the low-pass filter prototype are obtained, then the transformation to band-pass filter is done easily, by replacing the inductive element by a series LC resonant circuit and the capacitive element by parallel LC resonant circuit [4].

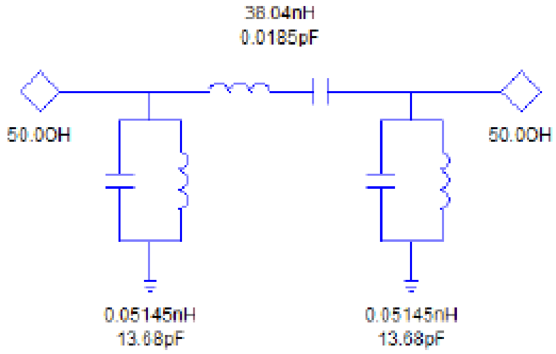

Fig. 4 Conversion of Low-Pass Filter to Band-Pass Filter

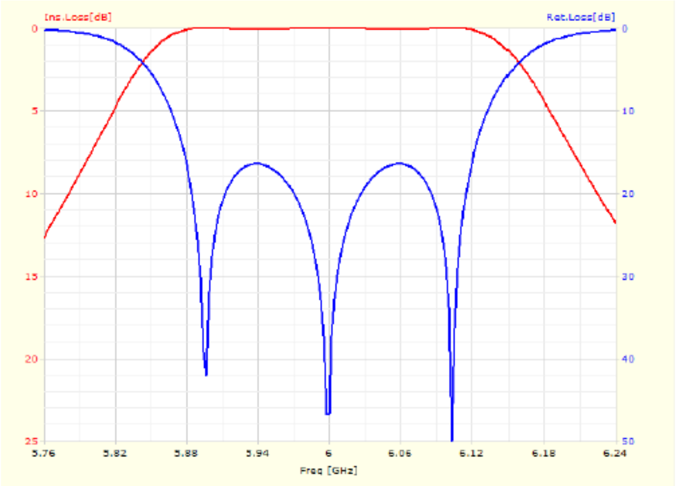

Fig. 5 Filter Design Wizard (FDW) Simulated result for insertion loss(S_{11}) and return loss(S_{21}) response

D. Implementation

The lumped-element filter generally work well at low frequencies, but two problems arise at higher RF and microwave frequencies. First, lumped-element inductors and capacitors are generally available only for a limited range of values, and can be difficult to implement at microwave frequencies. For these reasons the distributed element filter are suitable at high frequencies [1]. End-coupled microstrip lines are chosen to realize this filter fig.6

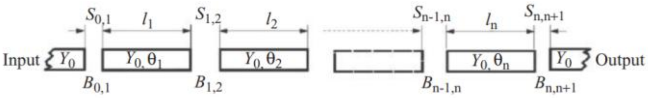

Fig. 6 General configuration of end-coupled microstrip band-pass filter.

For microstrip implementation, we use a substrate with a relative dielectric constant εr = 10.8 and a thickness h = 1.27 mm. The line width for microstrip half wavelength resonators is also chosen as W = 1.1 mm, which gives characteristic impedance $Z_0 = 50\ \Omega$ on the substrate.

The $J_{j,j+1}$ are the characteristic admittances of J inverters and Y_0 is the characteristic admittance of the microstrip line.

The filter under consideration operates like the shunt-resonator type of filter whose general design equations are given as follows [4].

$$\frac{J_{0.1}}{Y_0} = \sqrt{\frac{\pi FBW}{2g_0 g_1}} \tag{3}$$

Where g_o, g_1. . . g_n are the element of a ladder-type low-pass prototype with a normalized cutoff Ω_c=1, and FBW is the fractional bandwidth of band-pass filter.

For $j=1$ to n-1, we have

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2} \frac{1}{\sqrt{g_j g_{j+1}}} \tag{4}$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2g_n g_{n+1}}} \tag{5}$$

Assuming the capacitive gaps act as perfect, series-capacitance discontinuities of susceptance $B_{j,j+1}$ given by

$$\frac{B_{j,j+1}}{Y_0} = \frac{\frac{J_{j,j+1}}{Y_0}}{1-(\frac{J_{j,j+1}}{Y_0})^2} \tag{6}$$

And

$$\theta_j = \pi - \frac{1}{2}\left[\tan^{-1}(\frac{2B_{j-1,j}}{Y_0}) + \tan^{-1}(\frac{2B_{j,j+1}}{Y_0})\right] \tag{7}$$

Where the $B_{j,j+1}$ and θ_j are evaluated at f_0.

By referring to the equivalent circuit of microstrip gap [4], the coupling gaps $s_{j,j+1}$ of the microstrip end-coupled resonator filter can be determined as to obtain the series capacitances that satisfy

$$C_g^{j,j+1} = \frac{B_{j,j+1}}{\omega_0} \tag{8}$$

Because the shunt capacitances $C_p^{j,j+1}$ are associated with the series capacitances $C_g^{j,j+1}$, as defined in the equivalent circuit of microstrip gap, they are also determined once $C_g^{j,j+1}$ are solved for the required

The physical lengths of resonators are given by

$$l_j = \frac{\lambda g_0}{2\pi}\theta_j - \Delta_j^{e1} - \Delta_j^{e2} \tag{9}$$

Where $\Delta_j^{e1,e2}$ are the effective lengths of the shunt capacitances on the both ends of resonator j

$$\Delta_j^{e1} = \frac{\omega_0 C_P^{j-1,j}}{Y_0} \frac{\lambda g_0}{2\pi} \tag{10}$$

$$\Delta_j^{e2} = \frac{\omega_0 C_P^{j,j+1}}{Y_0} \frac{\lambda g_0}{2\pi} \qquad (11)$$

So the results are summarized in the next table.

TABLE V
MICROSTRIP LINE DIMENSIONS

Parameter	Value (mm)
h	1.27
W	1.1
l_1	8. 148
l_2	8.399
l_3	8.148
$S_{0,1}$	0.057
$S_{1,2}$	0.801
$S_{2,3}$	0.801
$S_{3,4}$	0.057

III. ANSOFT DESIGNER SIMULATION RESULTS

Ansoft designer SV2.2 is used to realize a physical band-pass filter using microstrip end-coupled lines where the dimensions are already calculated in last section.

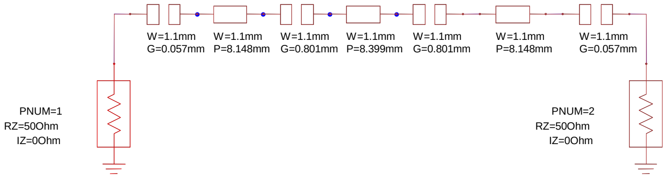

Fig. 7 Schematic of end-coupled micro strip band- pass filter

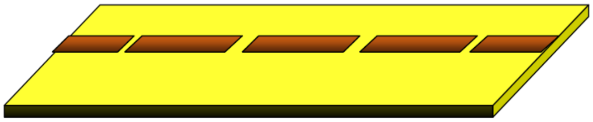

Fig. 8 Layout of end coupled microstrip band-pass filter.

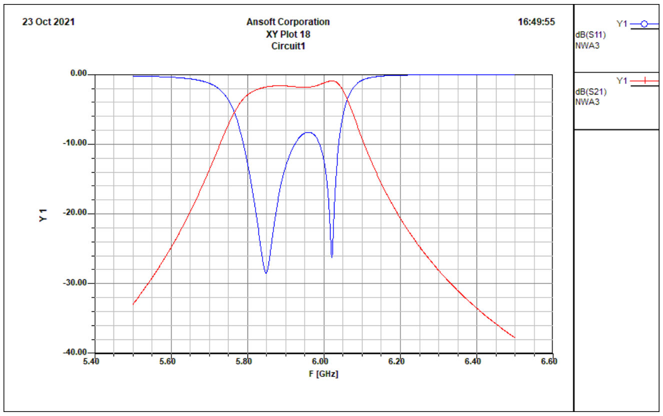

Fig. 9 Simulated Result for Insertion Loss(S_{11}) and Return Loss(S_{21}) Response of 3rd Order End-Coupled Microstrip Band Pass Filter

The simulated result for insertion loss and return loss response of 3rd order end-coupled microstrip band pass filter is shown in fig. 9. We observe that the insertion loss in the pass band is less than -2 dB and a return loss around -28 dB which are the characteristics of a good filter. However the filter design wizard simulated results as seen in fig.5 are -25 dB for return loss and -0.1dB for the insertion loss.

IV. CONCLUSION

A complete procedure to design a band-pass filter using Chebyshev low-pass filter approximation is reported. The procedure includes the filter specifications, finding the corresponding low-pass prototype filter, impedance and frequency scaling, transformation to get the structure of the band-pass filter and finally the implementation of the band-pass filter using end coupled microstrip lines. Then the structure of this filter is simulated using Ansoft designer V2.2. Obtained results seem good however a fabricated filter would be suitable to take some measure to validate the results.

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