Abu Sayed
UB-ID 50172775
EE-401 Filter Design
December 14, 2017

Purpose:

The primary purpose of these filter design is to learn how to design a filter using different parameter such as cut-off frequency, ripple, attenuation etc. It is also recommended that, how to calculate all the parameter that used to do the simulation. As an Engineer, one has to know the procedure to do the calculation procedure to find the raw data that usually software do it for us. Microstrip filters send and receive microwave signal.

Primary equation to be used:

Generator resistor

$g_k = \frac{4a_{k-1}a_k}{b_{k-1}g_{k-1}}$ $g_1 = \frac{2a_1}{sinh(\frac{\beta}{2N})}$ $a_k = sin[(\frac{2k-1}{2N})\pi]$ $\beta = ln[coth(\frac{L_{AR}}{17.37})]$ $b_k = sinh^2(\frac{\beta}{2N}) + sin^2(\frac{K\pi}{N})$

Find β Value:

In order to find g_k value, one must calculate the other parameters such as $\beta, a_k b_k$, and also in determination of these values number of elements (N) has to be chosen first. $\beta = ln[coth(\frac{L_{AR}}{17.37})]$ where L_{AR} is given as $0.2dBripple$ $\beta = ln[coth(\frac{0.2}{17.37})]$ $\beta = 4.4642$

Find a_k Value:

$N = 5$, Have Been Chosen For This Low-pass and Band-pass Filter Design
$k = 1,$ $a_1 = sin[\frac{\pi}{10}] = 0.3090$
$k = 2,$ $a_2 = sin[\frac{3*\pi}{10}] = 0.8090$
$k = 3,$ $a_3 = sin[\frac{5*\pi}{10}] = 1$
$k = 4,$ $a_4 = sin[\frac{7*\pi}{10}] = 0.8090$
$k = 5,$ $a_5 = sin[\frac{9*\pi}{10}] = 0.3090$
Now from the equation (2) we get,

$g_1 = \frac{2a_1}{sinh(\frac{\beta}{2N})} = \frac{2*0.3090}{sinh(\frac{4.4642}{2*5})} = 1.3394$ Since g_1 is not equal to other values of g so, we need to calculate them separately....

Find b_k Value:

Following the equation (3) we get,
$b_k = sinh^2(\frac{\beta}{2N}) + sin^2(\frac{K\pi}{N})$
$k = 1,$ $b_1 = sinh^2(\frac{4.4642}{2*5}) + sin^2(\frac{1*\pi}{5}) = 0.5584$
$k = 2,$ $b_2 = sinh^2(\frac{4.4642}{2*5}) + sin^2(\frac{2*\pi}{5}) = 1.1174$
$k = 3,$ $b_3 = sinh^2(\frac{4.4642}{2*5}) + sin^2(\frac{3*\pi}{5}) = 1.1174$
$k = 4,$ $b_4 = sinh^2(\frac{4.4642}{2*5}) + sin^2(\frac{4*\pi}{5}) = 0.5584$
$k = 5,$ $b_5 = sinh^2(\frac{4.4642}{2*5}) + sin^2(\frac{5*\pi}{5}) = 0.2129$

Find rest of g_k Values:

$g_k = \frac{4a_{k-1}a_k}{b_{k-1}g_{k-1}}$
$k = 2, 3, 4, ...n$
$k = 2,$ $g_2 = \frac{4*a_1*a_2}{b_1*g_1} = \frac{4*(0.3090)*(0.8090)}{(0.5584)(1.3394)} = 1.3370$
$k = 3,$ $g_3 = \frac{4*a_2*a_3}{b_2*g_2} = \frac{4*(0.8090)*(1)}{(1.1174)(1.3370)} = 2.1660$
$k = 4,$ $g_4 = \frac{4*a_3*a_4}{b_3*g_4} = \frac{4*(1)*(0.8090)}{(1.1174)(2.1660)} = 1.3370$
$k = 5,$ $g_5 = \frac{4*a_4*a_5}{b_4*g_4} = \frac{4*(0.8090)*(0.3090)}{(0.2129)(1.3370)} = 1.3399$
So, the generator resistor values are–
$g_1 = 1.3394$ $g_2 = 1.3370$
$g_3 = 2.1660$ $g_4 = 1.3370$
$g_5 = 1.3394$

1 Frequency Transformation:

Since N has been chosen as odd elements ($N = 5$), then the normalized impedance ($Z = 1$).
Cutoff Frequency, $f_c = 4GHz$
Using the given formulas, we get
$\frac{\omega_c'}{2\pi} = 4GHz$
$\frac{2\pi f_c}{2\pi} = 4$
$f_c = f_0 = 4GHz$

Shunt Capacitor:

$C_k' = \frac{g_k}{\omega_0}$
$C_2' = \frac{g_2}{2\pi f_c Z_0} = \frac{1.3370}{2*\pi*50*4*10^9} = 1.0659\,pF$

$C_4' = \frac{g_4}{2\pi f_c Z_0} = \frac{1.3370}{2*\pi*50*4*10^9} = 1.0639\, pF$

Shunt Inductor:

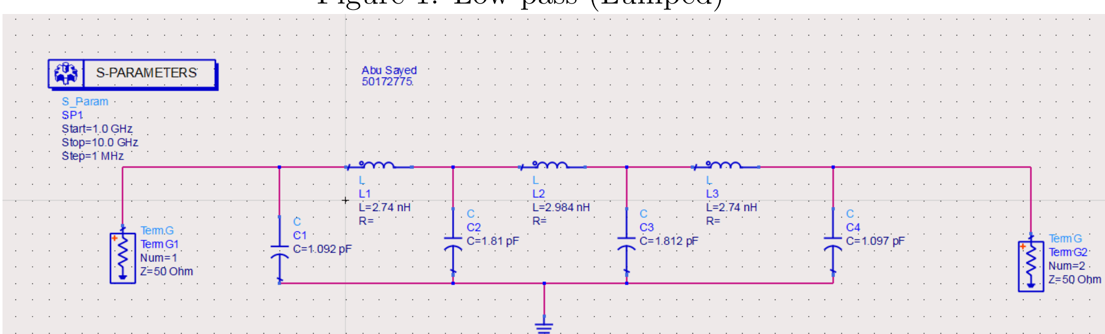
$L_1' = \frac{g_1*50}{2\pi f_c} = \frac{1.3394}{2*\pi*4*10^9} = 2.6647\, nH$
$L_3' = \frac{g_3*50}{2\pi f_c} = \frac{2.1660}{2*\pi*4*10^9} = 4.3091\, nH$
$L_5' = \frac{g_5*50}{2\pi f_c} = \frac{1.3394}{2*\pi*4*10^9} = 2.6647\, nH$

Series Capacitor:

Problem with calculation, Need to fix them first.

Low-pass Filter Design Schematic and Simulation:

Figure 1: Low-pass (Lumped)



Band-pass Filter:

$\omega = 8GHz$
$\omega_0 = \sqrt{\omega_1 * \omega_2} = \sqrt{35.75} = 5.9791GHz$ $|\frac{\omega}{\omega_0} - 1| = \frac{\omega'}{\omega_0'} = \frac{\omega_0}{\omega_2 - \omega_1}(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}) = \frac{5.9791}{(6.5-5.5)}(\frac{8}{5.9791} - \frac{5.9791}{8}) = 3.5313GHz$
$|\frac{\omega}{\omega_0} - 1| = \frac{5.9791}{(6.5-5.5)}(\frac{8}{5.9791} - \frac{5.9791}{8}) = 3.5313GHz$

Figure 2: Low-pass(Micro-strip)

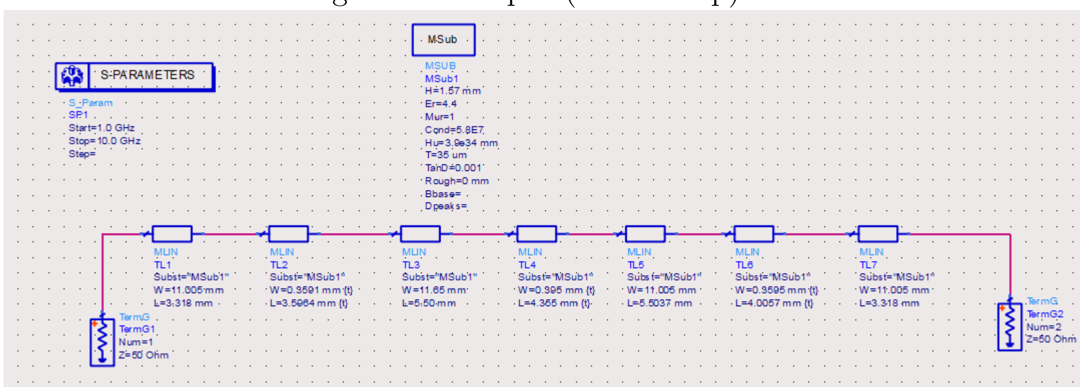
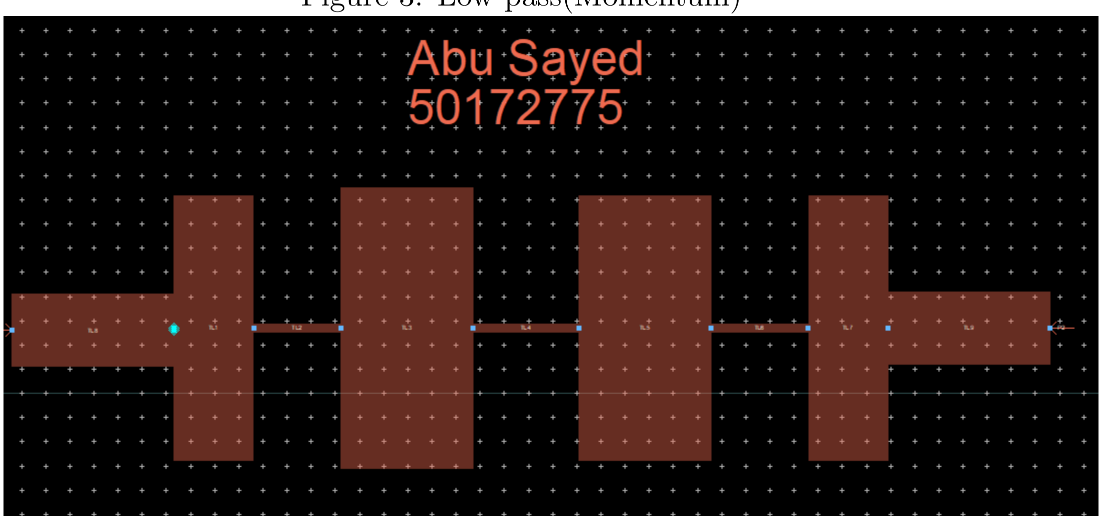


Figure 3: Low-pass(Momentum)



$|\frac{\omega}{\omega_0} - 1| = 3.5313 - 1 = 2.5313GHz$ Need to find the g_k Values for band-pass filter since $N = 5$ have found by using $2.5313GHz$ with compare with the figure 8.26, now need to figure only g_1, g_2, g_3 For Band-pass filter the following equation——
$L_1 = g_1, Z_0 = R_0 = 50\Omega$
So then the Ripple, $\Delta = \% = \frac{\omega_2 - \omega_1}{\omega_0} = \frac{6.5-5.5}{5.9791} = 0.1672 = 16.72\%$
also g_1, g_2, g_3, g_4, g_5 have found using Matlab formula, the found values are
$g_1 = 1.339447$
$g_2 = 1.337008$
$g_3 = 2.16608$
$g_4 = 1.337008$
$g_5 = 1.339447$

Coupled Inductance and capacitor values are:

$C'_1 = \frac{g_1}{\omega_0 * \Delta * Z_0} = \frac{1.339447}{5.9791E9*0.167*50} = 4.265nF$
$L'_1 = \frac{L_1 * Z_0}{\omega * \Delta} = \frac{1.337008*50}{5.9791E9*2\pi*0.167} = 0.1671nH$
$C'_2 = 0.0665pF$
$L'_2 = 10.752nH$
$C'_3 = 0.865pF$
$L'_3 = 0.1031nH$
$C'_4 = 0.0065pF$
$L'_4 = 10.752nH$
$C'_5 = 4.2534pF$
$L'_5 = 0.1671nH$

Determining a parallel coupled Band-pass filter parameter of $\frac{j}{Y_0}$ is

$\frac{J_0}{Y_0} = [\frac{\pi W}{2g_1g_1}]^2$
$\frac{J_0}{Y_0} = [\frac{\pi W}{2g_1g_2}]^{1/2}$
$W = 0.167$
$\frac{J_{0,1}}{Y_0} = [\frac{\pi W}{2g_og_1}]^{1/2} = [\frac{\pi*0.167}{2*1.33947*1}]^{1/2} = 0.4423$
$\frac{J_{1,2}}{Y_0} = \frac{\pi W}{2*(g_1g_2)^{1/2}} = \frac{\pi*0.167}{\sqrt{(1.339447*1.337008)}} = 0.1961$
$\frac{J_{2,3}}{Y_0} = 0.14407$
$\frac{J_{3,4}}{Y_0} = 0.1541$

$\frac{J_{4,5}}{Y_0} = 0.381$

Finding the Values for Z_{oo} and Z_{oe}:

This Values were found using LineCalc

Figure 4: Values of Ze

		for Z_e Values	-----------------------	-----------------------
Z_{oe}		W	S	L
Z_{01}	81.943	71.470	11.595	277.396
Z_{12}	61.73	108.496	42.339	268.222
Z_{23}	58.90	112.229	57.812	266.811
Z_{34}	58.90	112.809	55.708	266.836
Z_{45}	61.73	101.112	69.079	267.852

Figure 5: Values of Zo

		for Z_0 Values	-----------------------	-----------------------
Z_{00}		W	S	L
Z_{01}	37.66	1.968	0.294	7.045
Z_{12}	42.114	2.755	1.075	6.812
Z_{23}	43.47	2.850	1.418	6.777
Z_{34}	43.114	2.858	1.416	6.777
Z_{45}	47.115	1.967	1.754	6.803

Band-pass Filter Design(Lumped, Micro-strip, and Momentum):

Figure 6: Band-pass(Lumped)

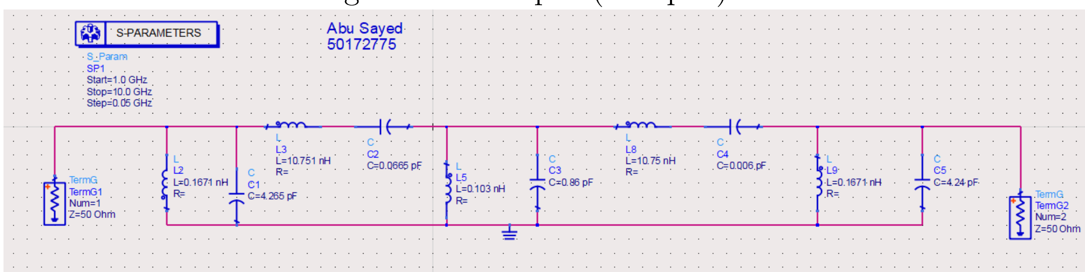


Figure 7: Band-pass(Micro-strip)

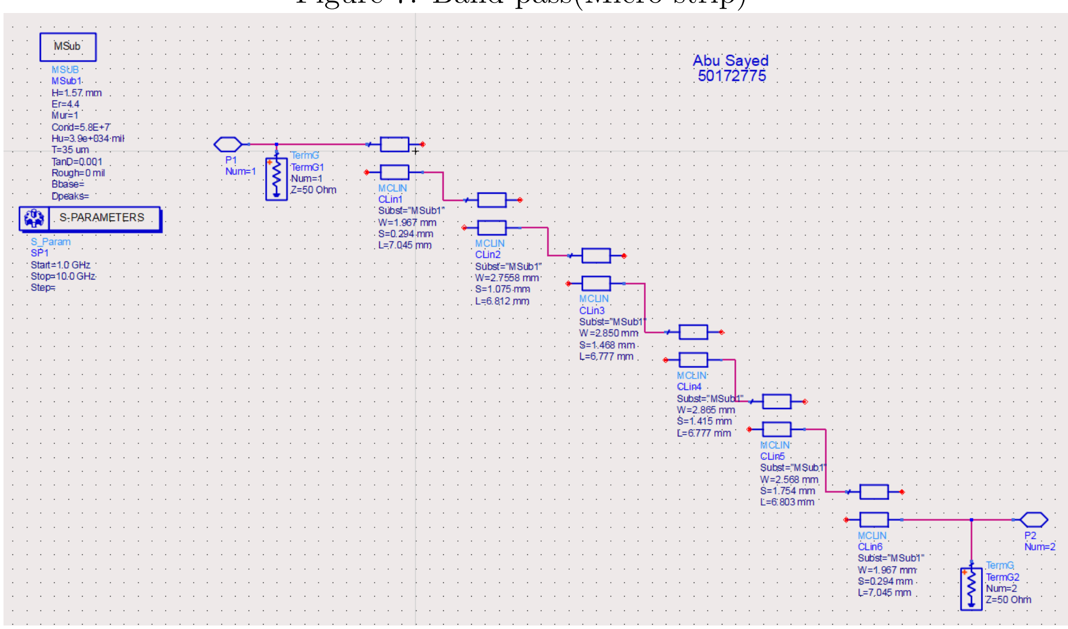


Figure 8: Band-pass(Micro-strip-Momentum)