HIGH-FREQUENCY FILTER DESIGN

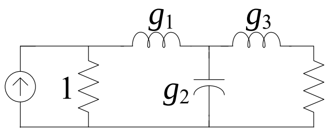
Dr. J. E. Rayas-Sánchez
May 14, 2020

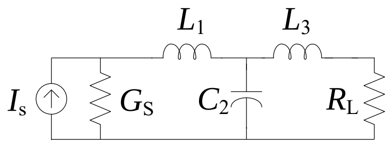
PROBLEMS

1. Using the Insertion-Loss method, design a low-pass filter, in current source configuration, with the following specifications: a) Cut-off frequency at 1 GHz; b) Reference impedance of 50 Ω; c) Minimum attenuation of 40 dB at 5 GHz; d) Chebyshev filtering profile with a 3-dB ripple level. Verify your design using Keysight ADS.
2. Using the Insertion-Loss method, design a low-pass filter prototype, in voltage source configuration, with the following specifications: a) Cut-off frequency at 5 GHz; b) Reference impedance of 50 Ω; c) Minimum attenuation of 40 dB at 10 GHz; d) Chebyshev filtering profile with a 3-dB ripple level. Verify your design using Keysight ADS.
3. Using the Insertion-Loss method, design a high-pass filter prototype with the following specifications: a) Cut-off frequency at 4 GHz; b) Reference impedance of 50 Ω; c) Minimum insertion loss of 70 dB at 1 GHz; d) Chebyshev response with a 3-dB ripple level. Verify your design using Keysight ADS.
4. Using the Insertion-Loss method, design a fourth-order band-pass filter prototype with the following specifications: a) Center frequency at 3 GHz; b) Relative bandwidth of 25%; c) Reference impedance of 50 Ω; d) Butterworth filtering profile. Check your design using Keysight ADS.
5. Using the Insertion-Loss method, design a sixth-order stop-band filter prototype with the following specifications: a) Center frequency at 10 GHz; b) Fractional bandwidth of 34%; c) Reference impedance of 50 Ω; d) Chebyshev filtering profile with a 0.5-dB ripple level. Check your design using Keysight ADS.
6. Implement the filter in the above problem 1 using ideal transmission lines on air ($\varepsilon_r = 1$). Do not use series stubs, only parallel stubs are allowed. Verify your design using Keysight ADS.
7. Implement the filter in the above problem 6 using microstrip lines on a dielectric substrate with relative dielectric constant $\varepsilon_r = 4$ and substrate height $H = 16$ mil. Check the final structure responses using Keysight ADS.

Solutions

1.





$g_1 = 3.3487$ $\quad g_0 = 1$

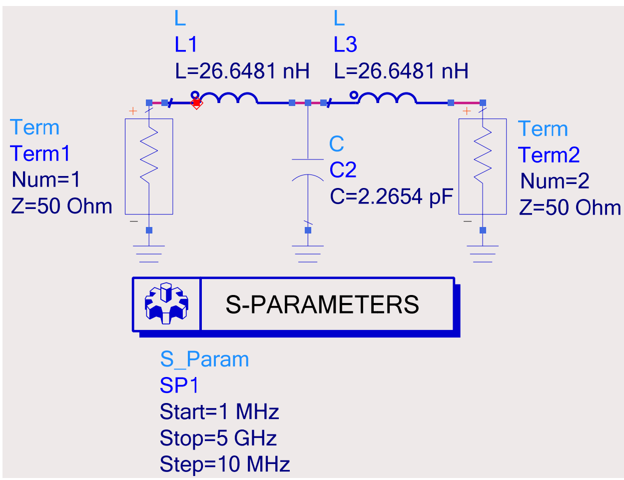
$g_2 = 0.7117$ $\quad g_4 = 1$

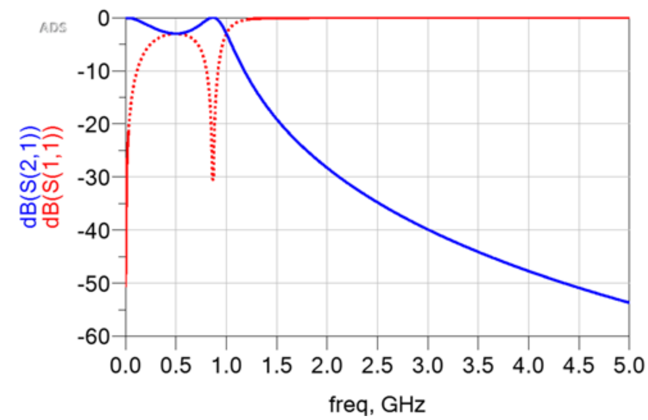
$g_3 = 3.3487$

$L_1 = 26.6481$ nH $\quad G_S = 1/50$ S

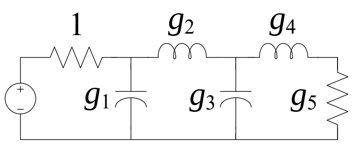
$C_2 = 2.2654$ pF $\quad R_L = 50\ \Omega$

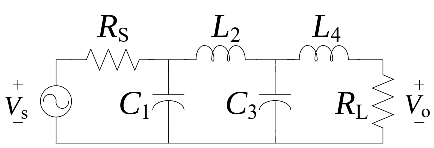
$L_3 = 26.6481$ nH





2.





$g_1 = 3.4389$ $\quad g_0 = 1$

$g_2 = 0.7483$ $\quad g_5 = 5.8095$

$g_3 = 4.3471$

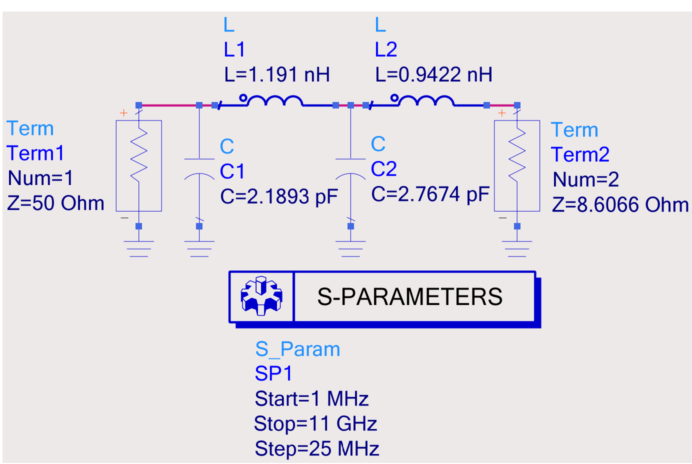
$g_4 = 0.5920$

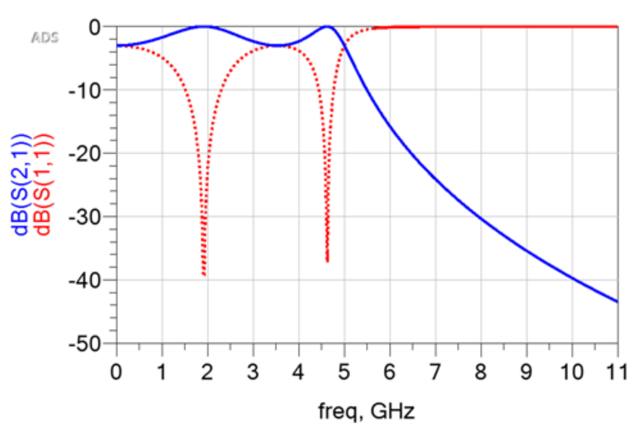
$C_1 = 2.1893$ pF $\quad R_S = 50\ \Omega$

$L_2 = 1.191$ nH $\quad R_L = 8.6066\ \Omega$

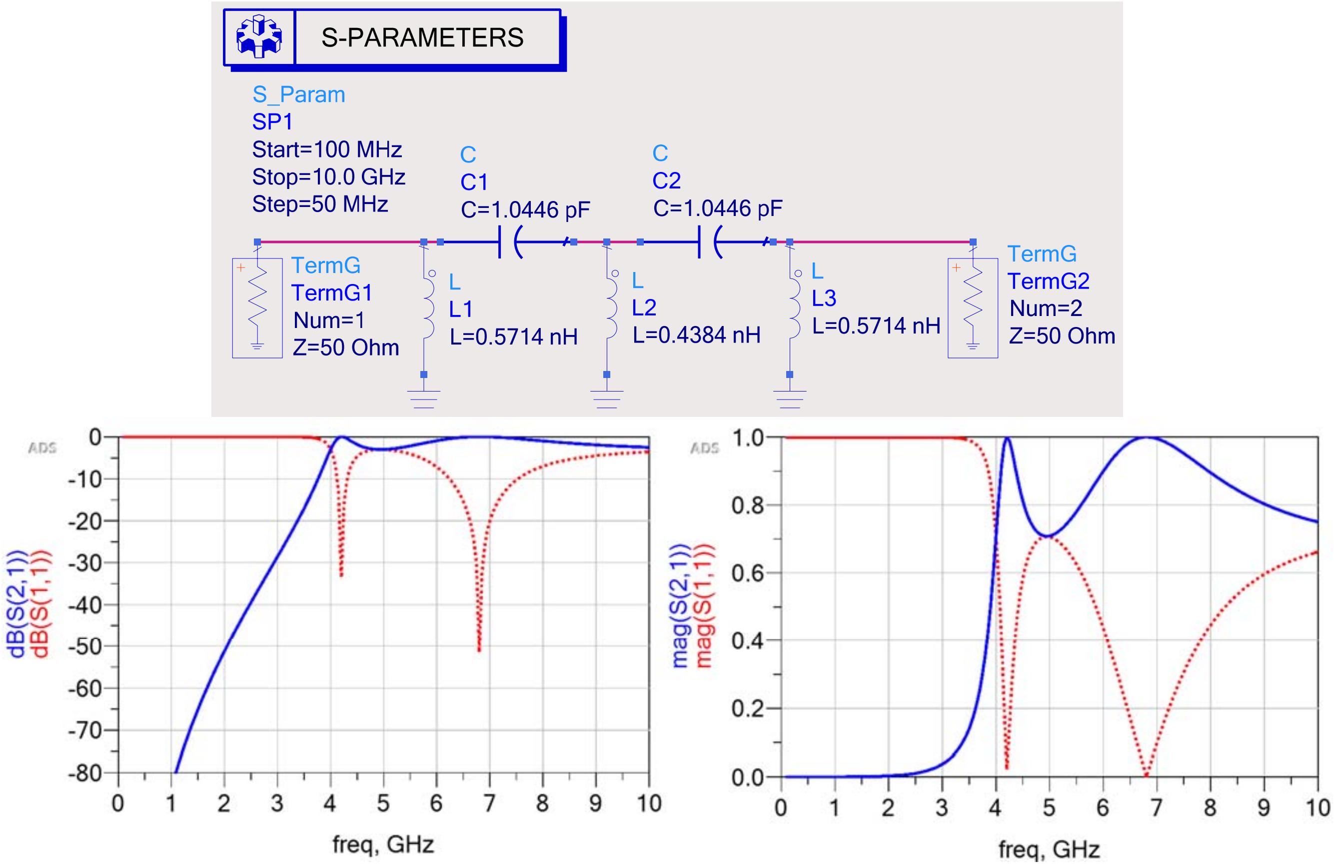
$C_3 = 2.7674$ pF

$L_4 = 0.9422$ nH

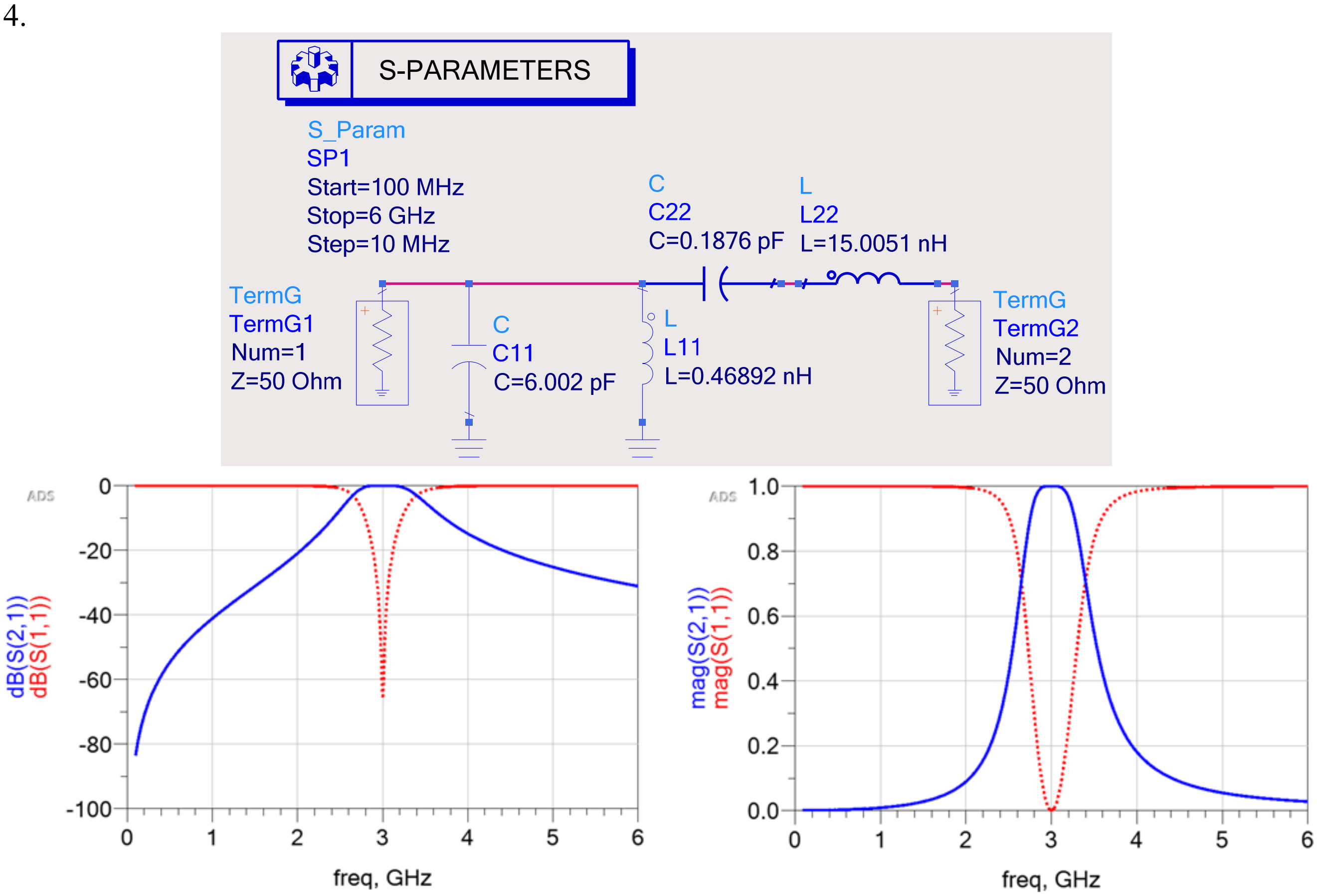


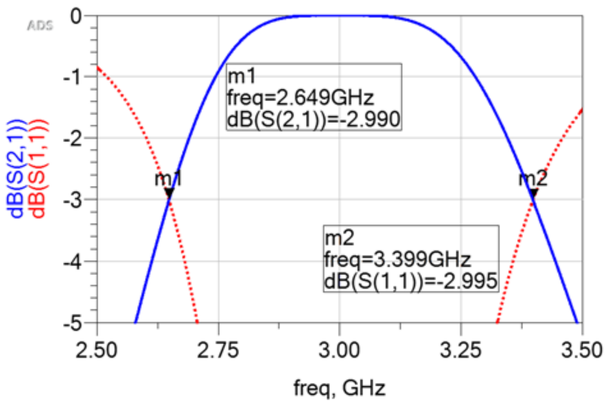


3.


S-PARAMETERS
S_Param
SP1
Start=100 MHz
Stop=10.0 GHz
Step=50 MHz
C
C1
C=1.0446 pF
C
C2
C=1.0446 pF
TermG
TermG1
Num=1
Z=50 Ohm
L
L1
L=0.5714 nH
L
L2
L=0.4384 nH
L
L3
L=0.5714 nH
TermG
TermG2
Num=2
Z=50 Ohm
dB(S(2,1))
dB(S(1,1))
freq, GHz
mag(S(2,1))
mag(S(1,1))
freq, GHz

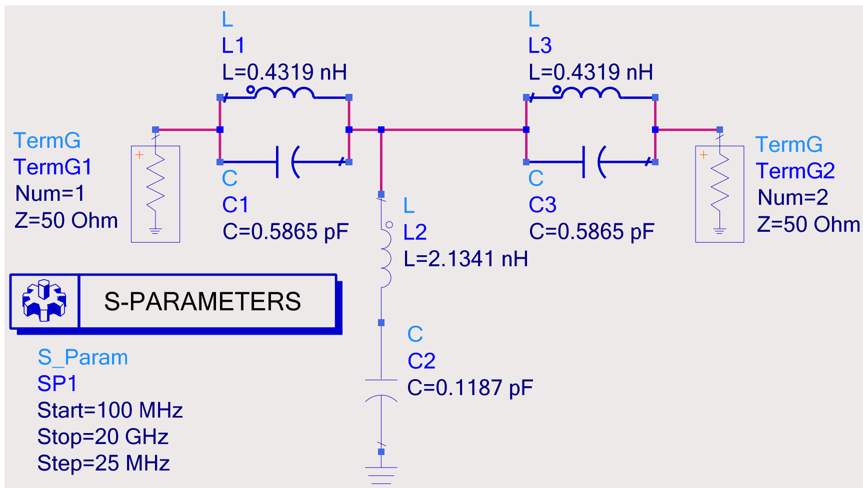
4.

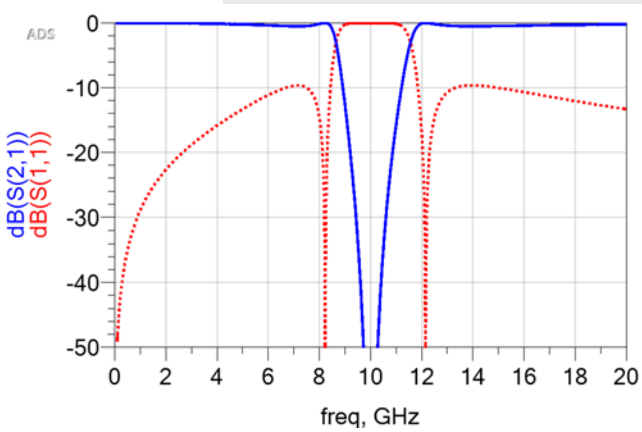

S-PARAMETERS
S_Param
SP1
Start=100 MHz
Stop=6 GHz
Step=10 MHz
C
C22
C=0.1876 pF
L
L22
L=15.0051 nH
TermG
TermG1
Num=1
Z=50 Ohm
C
C11
C=6.002 pF
L
L11
L=0.46892 nH
TermG
TermG2
Num=2
Z=50 Ohm
dB(S(2,1))
dB(S(1,1))
freq, GHz
mag(S(2,1))
mag(S(1,1))
freq, GHz

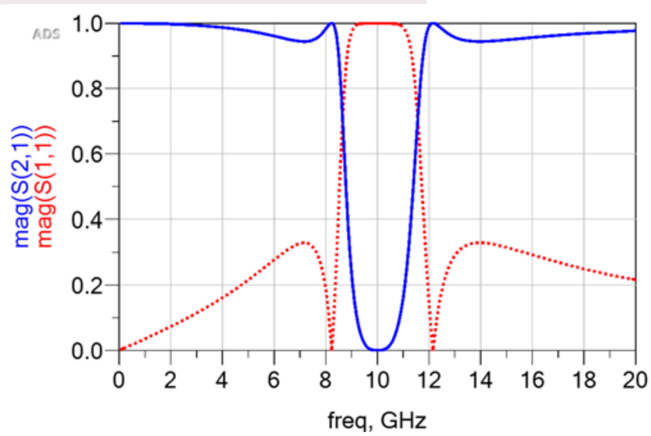


Zooming-in at the passband region, it is seen that the relative bandwidth is approximately (3.399GHz–2.649GHz)/3GHz = 25%, as expected.

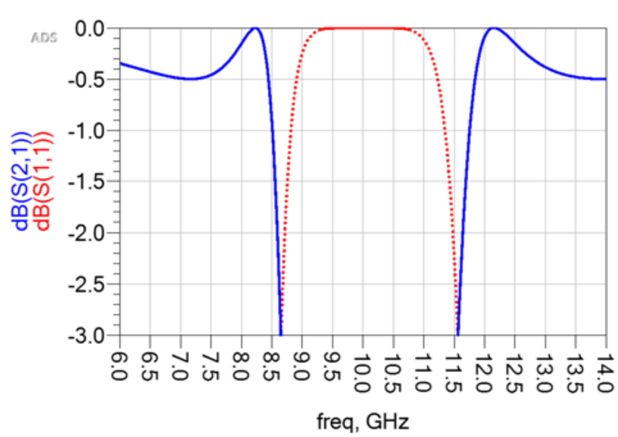
5.





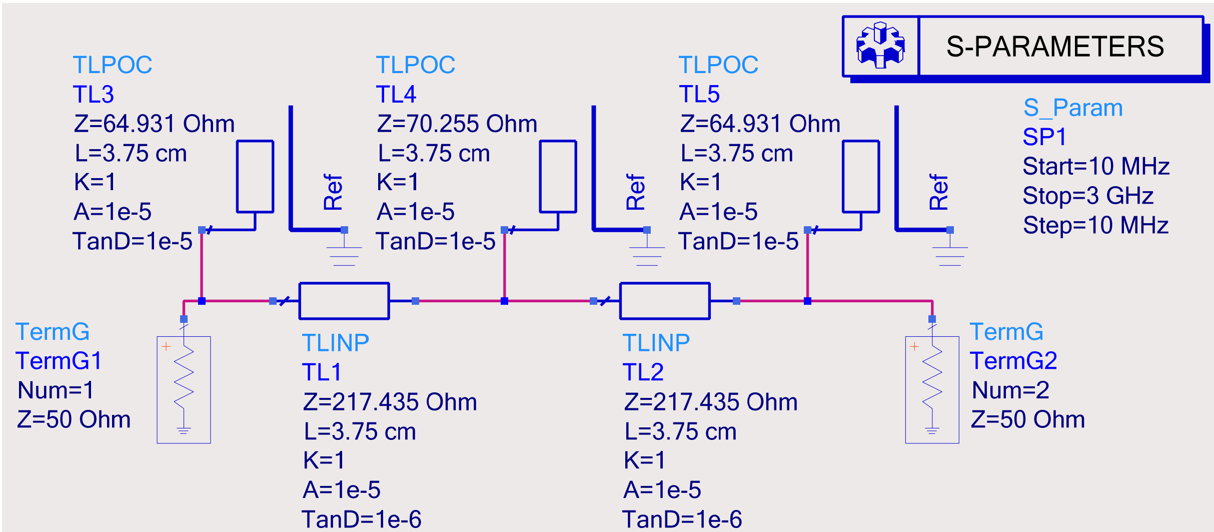


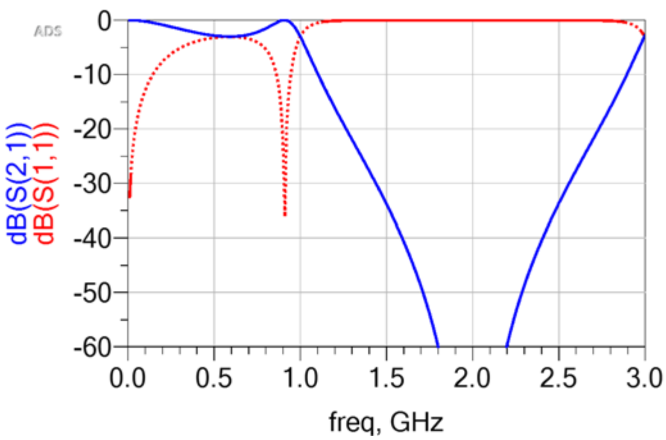
Zooming-in at the stopband region:

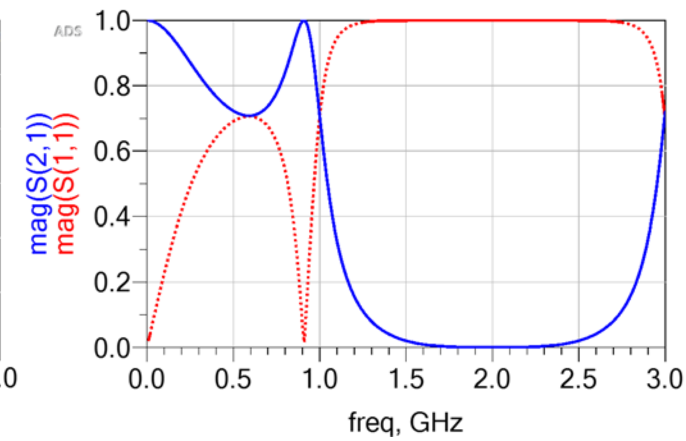


6.

Solution implemented in ADS using ideal transmission lines on air:

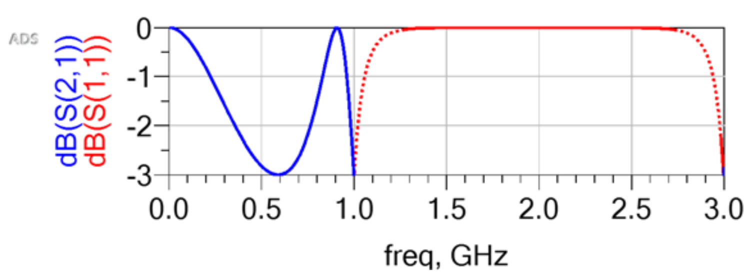






Notice the periodicity of the filter responses.

Zooming-in to measure the ripple amplitude:



7.

Using Gupta's formulas:

$W_0/H = 2.0438$ for $Z_0 = 50\ \Omega$ and $\varepsilon_r = 4$ (input/output microstrip lines)
$W_1/H = 1.2858$ for $Z_0 = 64.931\ \Omega$ and $\varepsilon_r = 4$
$W_2/H = 1.0976$ for $Z_0 = 70.255\ \Omega$ and $\varepsilon_r = 4$
$W_3/H = 0.0239$ for $Z_0 = 217.435\ \Omega$ and $\varepsilon_r = 4$

Since $H = 16$ mil, then

$W_0 = 32.70$ mil
$W_1 = 20.57$ mil
$W_2 = 17.56$ mil
$W_3 = 0.3824$ mil

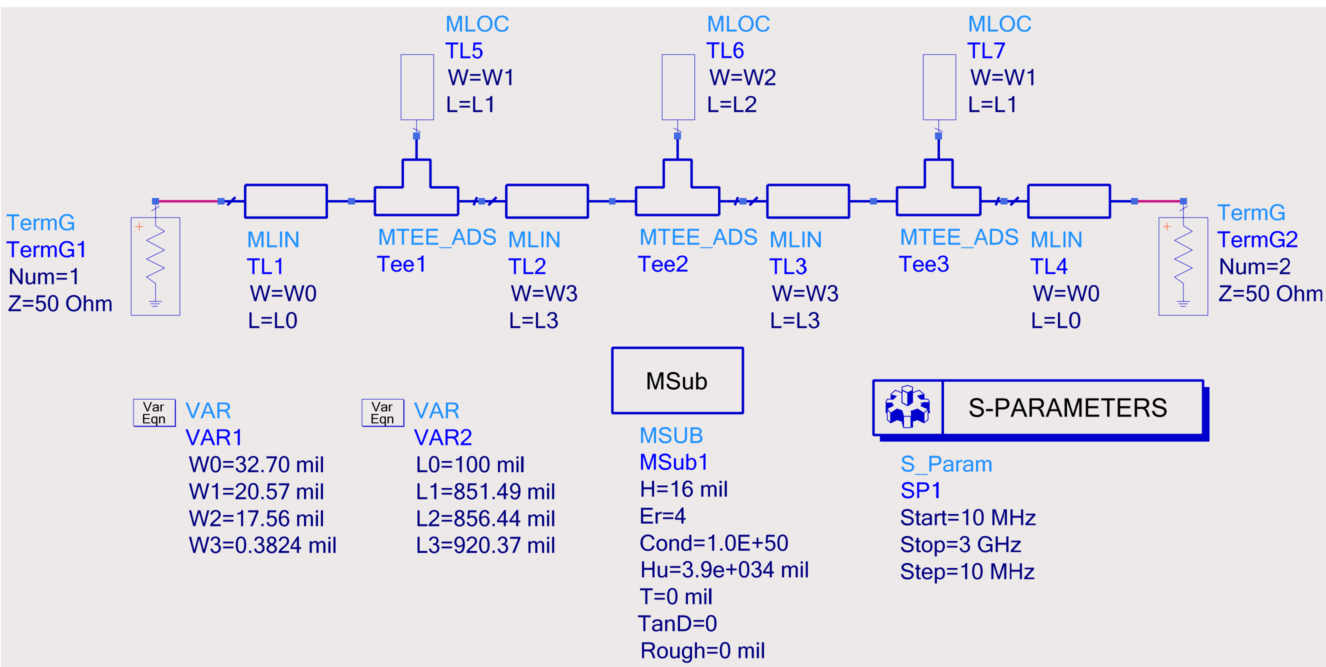
The effective relative permittivity for each segment of microstrip line is:

$\varepsilon_{e0} = 3.1179$ for $W_0/H = 2.0438$ and $\varepsilon_r = 4$
$\varepsilon_{e1} = 3.0063$ for $W_1/H = 1.2858$ and $\varepsilon_r = 4$
$\varepsilon_{e2} = 2.9717$ for $W_2/H = 1.0976$ and $\varepsilon_r = 4$
$\varepsilon_{e3} = 2.5732$ for $W_3/H = 0.0239$ and $\varepsilon_r = 4$

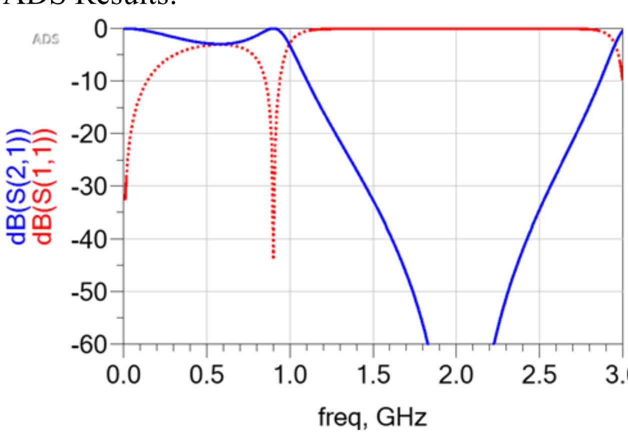
Calculating the corresponding physical lengths:

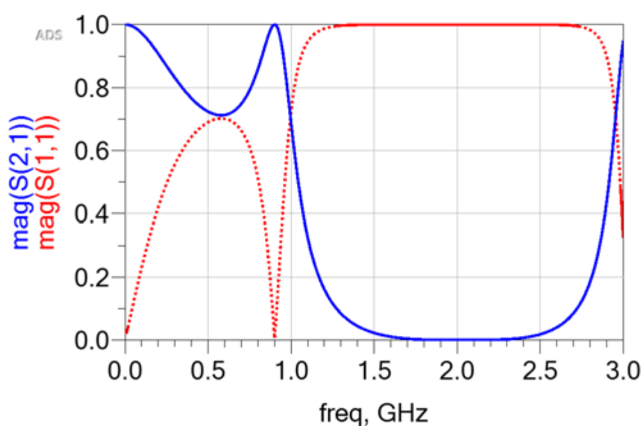
$l_0 = 100$ mil (arbitrarily selected)
$l_1 = \lambda_1/8 = 851.49$ mil
$l_2 = \lambda_2/8 = 856.44$ mil
$l_3 = \lambda_3/8 = 920.37$ mil

Implementing the microstrip circuit in ADS:

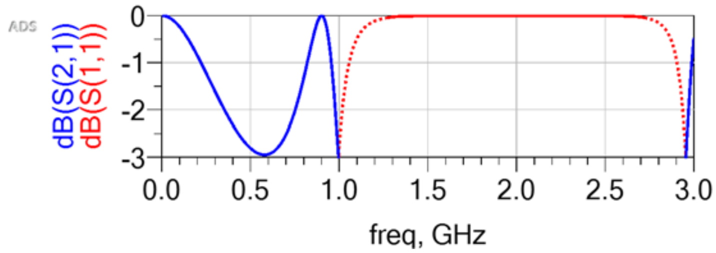


ADS Results:





Zooming-in to measure the ripple amplitude:



Notice that the response of this microstrip filter is almost identical (up to 2.5 GHz) to that one using ideal transmission lines (see problem 6).