Western New England University
College of Engineering
ECE Department
Microwave Engineering
EE 414
Spring 2024
Design Project #2
Due: March 15, 2024

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References: ______________________________________

Design Project #2

Task	Score	Max
1		100
2		100
3		100
4		100
5		100
6		100
7		100
8		100
9		200
Total		1000

1. Design a lumped element bandpass filter that meets the following performance specifications:
   - $RL \geq 22\,\text{dB}$ for $f_L \leq f \leq f_H$ where $f_L = 7.6\,\text{GHz}$ and $f_H = 8.4\,\text{GHz}$.
   - $IL \leq 0.5\,\text{dB}$ for $f_L \leq f \leq f_H$ where $f_L = 7.6\,\text{GHz}$ and $f_H = 8.4\,\text{GHz}$.
   - $IL \geq 40\,\text{dB}$ for $f \leq f_{Ls}$ where $f_{Ls} = 7.25\,\text{GHz}$.
   - $IL \geq 50\,\text{dB}$ for $f \geq f_{Hs}$ where $f \geq f_{Hs} = 9\,\text{GHz}$.
   - The source and load impedances of the filter are 50-Ω.

2. Using MATLAB and ideal lumped elements, simulate the BPF. Employ a frequency range of 7 GHz to 9 GHz.

3. Convert the BPF into a coupled line filter. Employ a feed transmission line with an electrical length of 90° at the input port and the output port. Determine a value for the impedance(s) and electrical length of each transmission line.

4. Using MATLAB and ideal transmission lines, simulate the coupled line BPF. Employ a frequency range of 7 GHz to 9 GHz. Compare the coupled-line BPF to the lumped element BPF filter.

5. Convert the coupled line BPF employing ideal transmission to microstrip transmission lines. Assume that the microstrip transmission lines are to be realized using a 0.635 mm thick Duroid 6010 substrate ($\varepsilon_r = 10.7$, $\tan\delta = 0.0023$, $\sigma_c = 5.8\times10^{+7}$ S/m , and $t = 18\,\mu\text{m}$). Determine a value for the width, spacing, and length of each transmission line.

6. Using ADS, microstrip transmission lines, and the MCFIL element (Microstrip Coupled-Line Filter Section), simulate the microstrip coupled-line BPF (V1). Employ a frequency range of 7 GHz to 9 GHz.

7. Tune the microstrip coupled-line BPF model in Task (6). Determine a value for the width, spacing, and length of each transmission line. Using ADS, simulate the tuned microstrip coupled-line BPF (V2). Employ a frequency range of 7 GHz to 9 GHz.

8. Summarize the results for the ideal transmission line coupled-line BPF and the microstrip coupled-line BPF (V2).
   - On the same graph, plot $|S_{21}|$ in dB, for the two cases. Employ a frequency range of 7 GHz to 9 GHz and a range of -40 dB to 0 dB for $|S_{21}|$.
   - On the same graph, plot $|S_{21}|$ in dB, for the two cases. Employ a of frequency range 7.5 GHz to 8.5 GHz and a range of -4 dB to 0 dB for $|S_{21}|$.
   - On the same graph, plot $|S_{11}|$ in dB, for the two cases. Employ a frequency range of 7 GHz to 9 GHz and a range of -40 dB to 0 dB for $|S_{11}|$.

9. Present the results from the design project into a well-organized presentation.

Design Project 2

Band Pass Filter

By : Nittala Satya Surya Lakshmi Vasuki Siva Srinivas

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    - $IL \geq 40\ \text{dB}$ for $f \leq f_{Ls}$ where $f_{Ls} = 7.25\ \text{GHz}$.
    - $IL \geq 50\ \text{dB}$ for $f \geq f_{Hs}$ where $f \geq f_{Hs} = 9\ \text{GHz}$.
    - The source and load impedances of the filter are 50-Ω.

Hand Calculations

Part-1

$f_L = 7.6\ GHz$

$f_L = 8.4\ GHz$

$f_0 = \sqrt{f_H \cdot f_L} = \sqrt{(8.4)(7.6)}$

$\boxed{f_0 = 7.9900\ GHz}$

$\Delta = (f_H - f_L)/f_0$

$\boxed{\Delta = 0.1001}$

$\boxed{Bw_f = 0.8000\ GHz}$

$\boxed{Bw_f = 800.0000\ MHz}$

Part-2

$f_L \le f \le f_H$

$IL \le 0.5$

$IL_{max} = 0.5$

$|S_{21}|_{dB} \ge -IL_{max}$

$|S_{21}|_{dB} \ge -0.5$

$|S_{21}|_{min} = 10^{(-0.5/20)}$

$\boxed{|S_{21}|_{min} = 0.9441}$

$|S_{11}|_{max} = \sqrt{1-(0.9441)^2}$

$= 0.3298$

$|S_{11}|_{dB} = -9.6357$

$\boxed{|S_{11}|_{dB} = -9.6357}$

Part-3

$f_L \le f \le f_H$

$RL \ge 22\ dB$

$RL_{min} = 22\ dB$

$|S_{11}|_{dB} = -RL_{min}$

$|S_{11}|_{dB} = -22\ dB$

$|S_{11}|_{max} = 0.0794$

$|S_{21}|_{min} = \sqrt{1-(0.0794)^2}$

$\boxed{|S_{21}|_{min} = 0.9968}$

$\boxed{|S_{21}|^{dB}_{min} = -0.0275}$

Part-4

$f_L = 7.6\ GHz$

$f_H = 8.4\ GHz$

$\boxed{|S_{21}|^{dB}_{min} = -0.0275}$

$A_P \le -|S_{21}|_{dB}$

$A_P \le 0.0275\ dB$

$\boxed{A_P = 0.0275\ dB}$

~~Round of to~~

Round down

$\boxed{A_P = 0.0200\ dB}$

$\boxed{A_P(\text{Ripple}) = 0.0200\ dB}$

Part-5

$f_{LS} = 7.25\ GHz$

$f_{HS} = 9\ GHz$

$f \le f_{LS}$ & $IL = 40\ dB$

$\boxed{A_{LS} = 40\ dB}$

$f_{LS} \Rightarrow 7.25\ GHz$

$f \ge f_{HS}$ & $IL \ge 50\ dB$

$\boxed{A_{HS} = \cancel{50}\ 50\ dB}$

Part-6

$f_L = 7.6\ GHz$

$f_H = 8.4\ GHz$

$A_P(w/w) = 10^{(A_P/10)}$

$\boxed{A_P(w/w) = 1.0064}$

$X_P = A_P - 1$

$\boxed{X_P = 0.0064}$

$\varepsilon = \sqrt{X_P}$

$\boxed{\varepsilon = 0.0797}$

(or)

$\boxed{\varepsilon = 0.08}$

Part-7

$f_{LS} = 7.25\ GHz$

$A_{LS} = 40\ dB$

$A_{LS}(w/w) = 10^{(A_{LS}/10)}$

$\boxed{A_{LS}(w/w) = 10{,}000\ w/w}$

$X_{LS} = A_{LS} - 1$

$\boxed{X_{LS} = 9999.0000\ w/w}$

Part-8

$f_0 = 7.9900\ GHz$

$f_{LS} = 7.25\ GHz$

$\varepsilon = 0.0797$

$X_{LS} = 9999$

$\Omega_{LS} = (1/\Delta)\left[(f_{LS}/f_0) - (f_0/f_{LS})\right]$

$\boxed{\Omega_{LS} = -1.9449}$

$\rightarrow \Omega_{LS} = \left(\frac{1}{0.1001}\right)\left[\left(\frac{7.25}{7.99}\right) - \left(\frac{7.99}{7.25}\right)\right]$

$\boxed{\Omega_{LS} = -1.9449}$

$\boxed{\text{Part- 9}}$

$f_{HS} = 9\,GHz$

$A_{HS} = 50\,dB$

$A_{HS}(w/w) = 10^{(A_{HS}/10)}$

$\boxed{A_{HS} = 100{,}000\ w/w}$

$x_{HS} = A_{HS} - 1$

$\boxed{x_{HS} = 99{,}999.0000\ w/w}$

$f_0 = 7.9900\,GHz$

$f_{HS} = 9\,GHz$

$\boxed{\varepsilon = 0.0797}$

(or)

$\boxed{\varepsilon = 0.08}$

$$N_{LS} = \frac{\cosh^{-1}\left[(1/\varepsilon)(\sqrt{x_{LS}})\right]}{\cosh^{-1}(|\Omega_{LS}|)}$$

$\boxed{N_{LS} = 6.219\cancel{4}9}$

$$\Omega_{HS} = (1/\Delta)\left[\left(\frac{f_{HS}}{f_0}\right) - \left(\frac{f_0}{f_{HS}}\right)\right]$$

$$= \left(\frac{1}{0.1001}\right)\left[\left(\frac{9}{7.99}\right) - \left(\frac{7.99}{9}\right)\right]$$

$\boxed{\Omega_{HS} = 2.3839}$

$$N_{HS} = \frac{\cosh^{-1}\left[(1/\varepsilon)\left[\sqrt{x_{HS}}\right]\right]}{\cosh^{-1}(|\Omega_{HS}|)}$$

$\boxed{N_{HS} = 6.03499}$

$\boxed{N_P = 7}$

∴ 7th order.

$g_0 = 1$
$g_1 = 0.8859$
$g_2 = 1.4217$
$g_3 = 1.8300$
$g_4 = 1.6372$
$g_5 = 1.8300$
$g_6 = 1.4217$
$g_7 = 0.8859$
$g_8 = 1.0000$

$\boxed{Z_0 = 50\Omega.}$

$Y_0 = 1/Z_0$

$\boxed{Y_0 = 0.02, \times 10^{2}}$

$\boxed{1/Y_0 = 20.0000}$

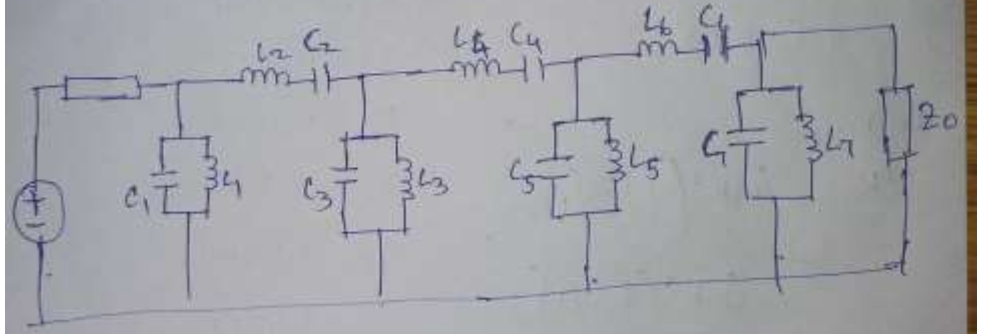
$f_0 = 7.9900$

$\omega_0 = 2\pi f_0$

$= 2\pi \times (7.9900)$

$\boxed{\omega_0 = 50.20259\ Grad/sec}$

$\Delta = 0.1001$



MATLAB Calculations

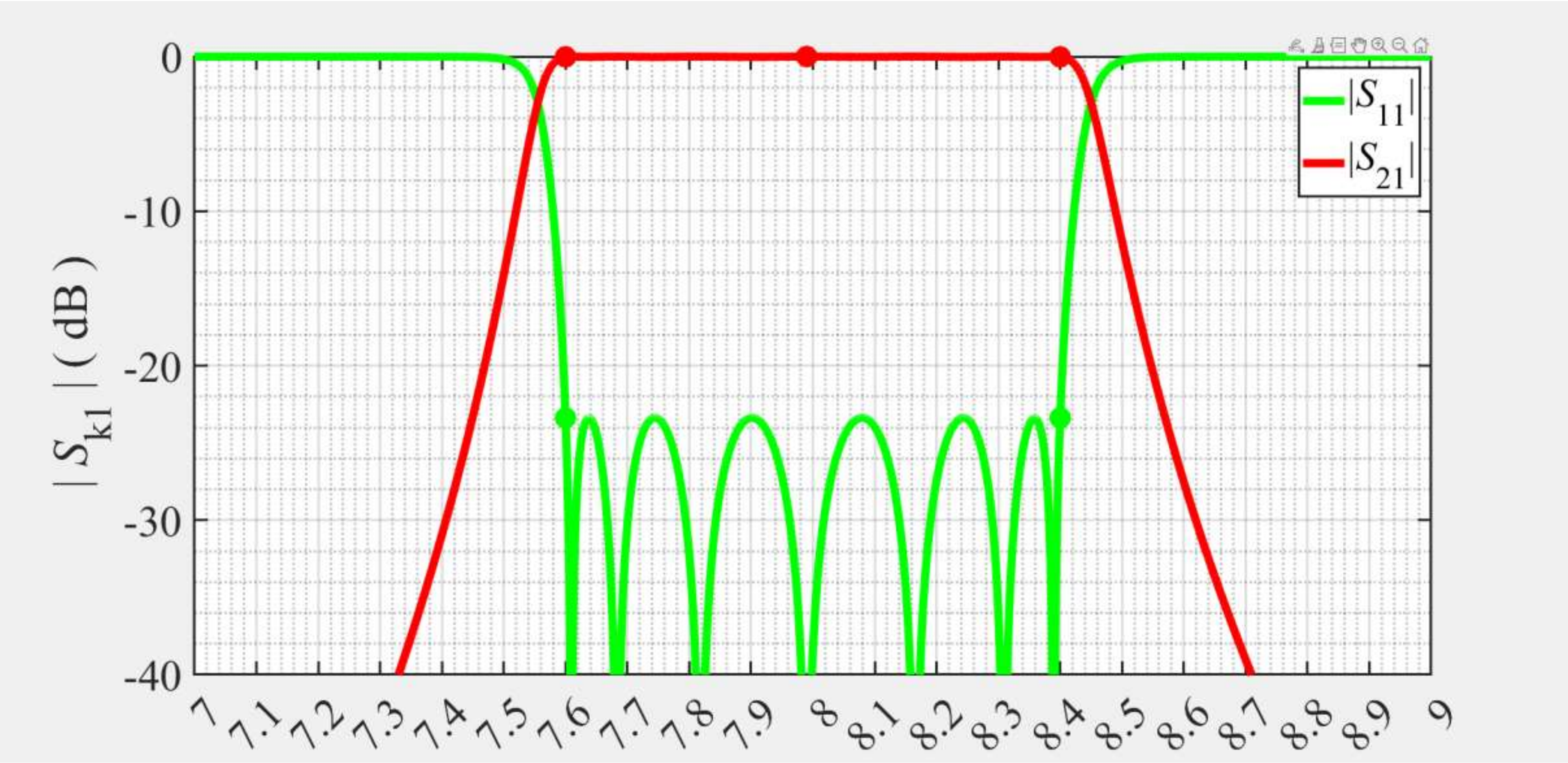
```
f0 = 7.9900 GHz

Bwf = 800.0000 MHz

delta = 0.1001

S21_Min(IL) = 0.9441 W/W

S11_max (IL) = 0.3298 W/W

S11_dB (IL) = -9.6357 W/W

S21_min (RL) = 0.9968 W/W

S21_min (RL) = -0.0275 dB

Ap (RIPPLE) = 0.0200 dB

NLS = 6.2195

NHS = 6.0345

w0 = 50.2026 GGrad/s
```

```
C1 = 3.5249 pF

L1 = 112.5648 pH

L2 = 14.1419 nH

C2 = 28.0569 fF

C3 = 7.2813 pF

L3 = 54.4924 pH

L4 = 16.2855 nH

C4 = 24.3638 fF

C5 = 7.2813 pF

L5 = 54.4924 pH

L6 = 14.1419 nH

C6 = 28.0569 fF

C7 = 3.5249 pF

L7 = 112.5648 pH
```

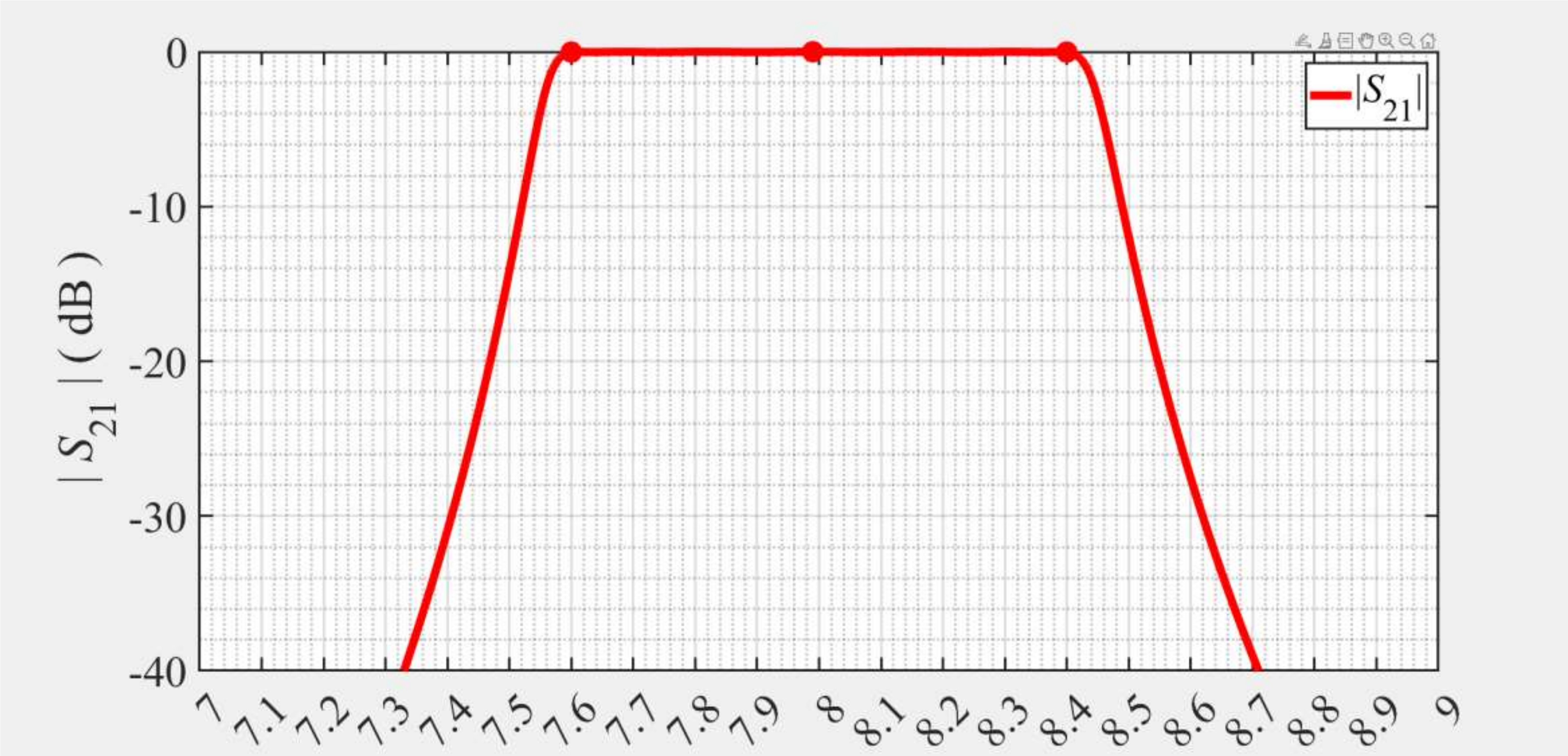
```
j01 = 421.3465 mS/S

z0e_01 = 79.9440  Ohms

z0o_01 = 37.8093  Ohms

j12 = 140.1416 mS/S

z0e_12 = 57.9891  Ohms

z0o_12 = 43.9749  Ohms

j23 = 97.5066 mS/S

z0e_23 = 55.3507  Ohms

z0o_23 = 45.6000  Ohms

j34 = 90.8630 mS/S

z0e_34 = 54.9560  Ohms

z0o_34 = 45.8697  Ohms

j45 = 90.8630 mS/S

z0e_45 = 54.9560  Ohms

z0o_45 = 45.8697  Ohms
```

```
j56 = 97.5066 mS/S

z0e_56 = 55.3507  Ohms

z0o_56 = 45.6000  Ohms

j67 = 140.1416 mS/S

z0e_67 = 57.9891  Ohms

z0o_67 = 43.9749  Ohms

j78 = 421.3465 mS/S

z0e_78 = 79.9440  Ohms

z0o_78 = 37.8093  Ohms

er_eff = 7.1127

delta_L = 192.2534 um
```

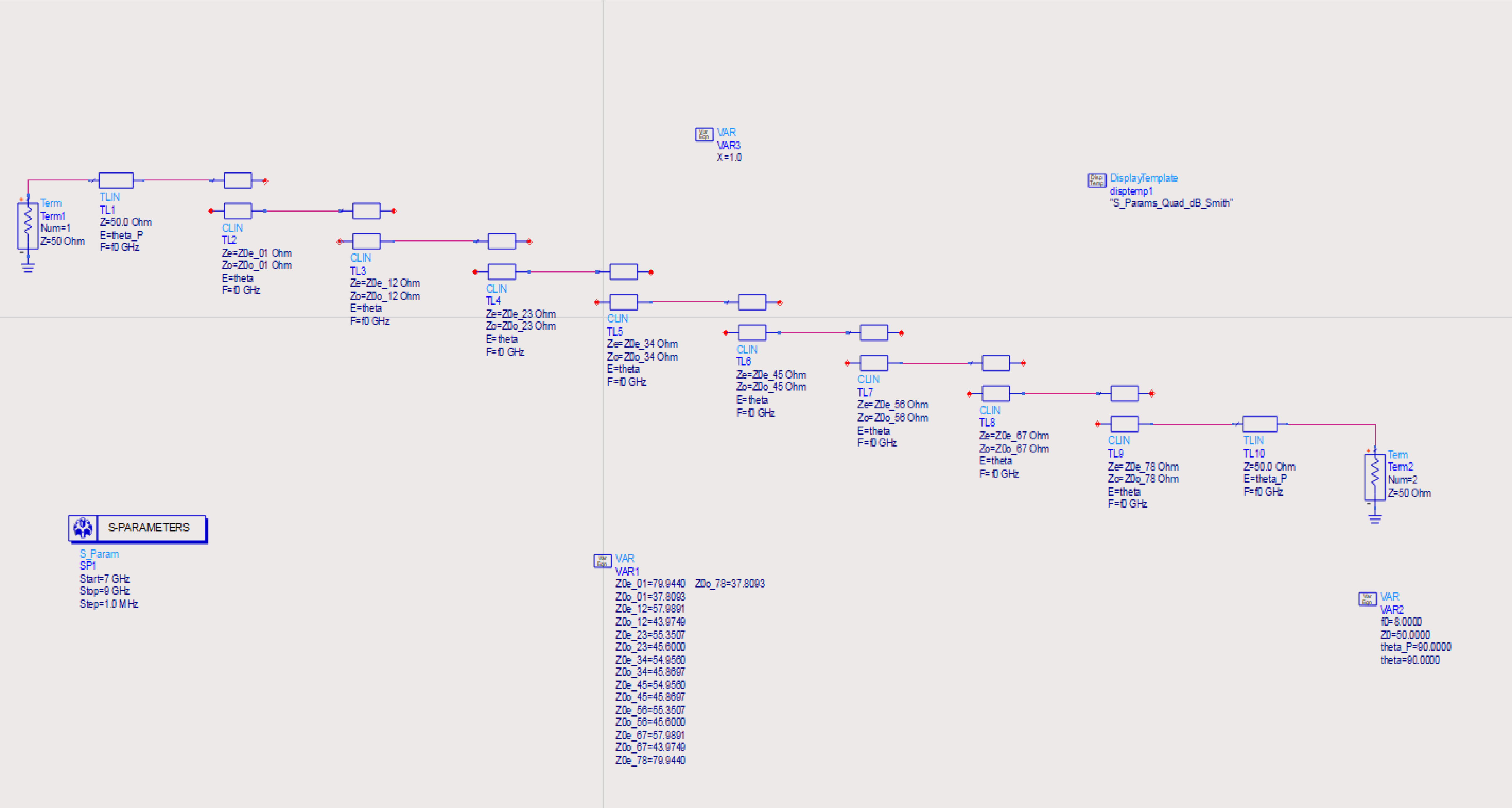
MATLAB Ideal Lumped Elements



MATLAB Ideal Lumped Elements

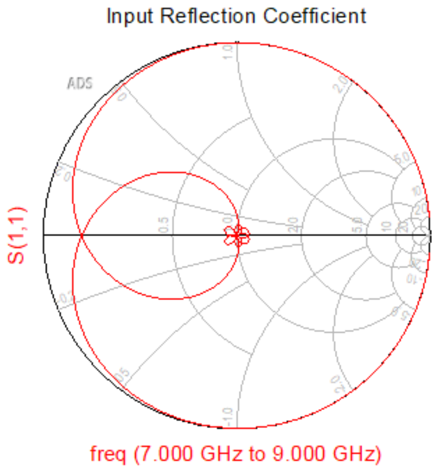


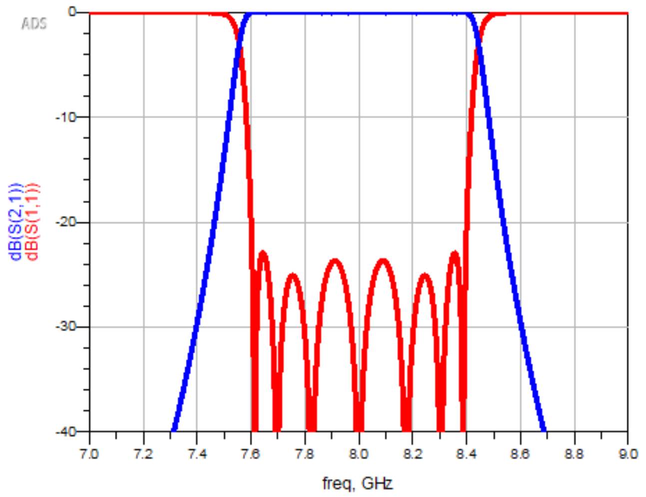
Coupled-Line Bandpass Filter with 90°

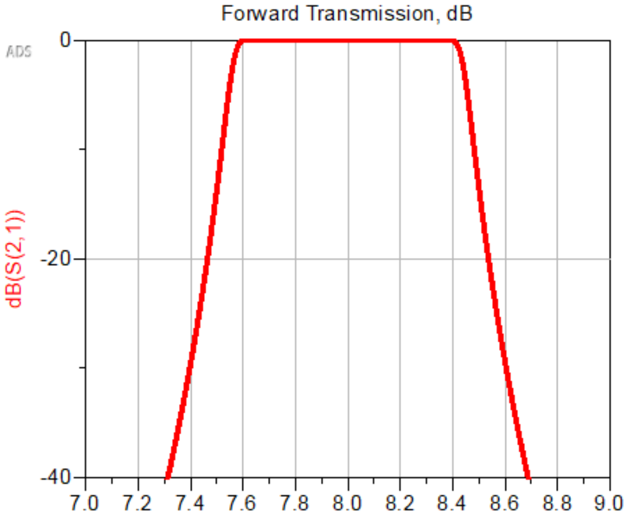


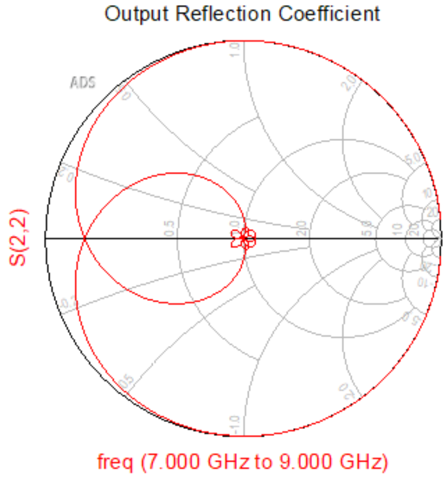
Coupled-Line Bandpass Filter with 90°

S-Parameters vs. Frequency

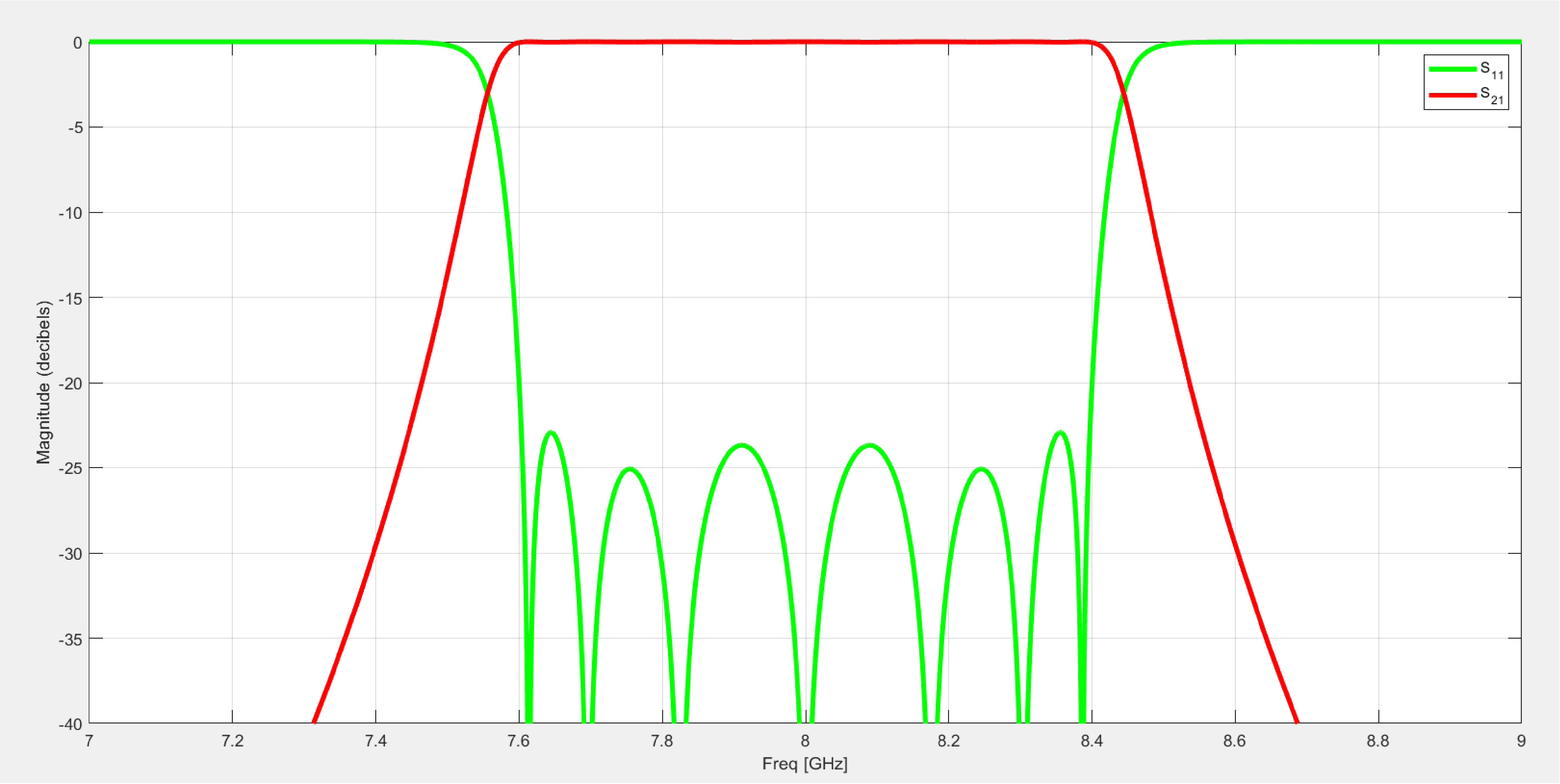




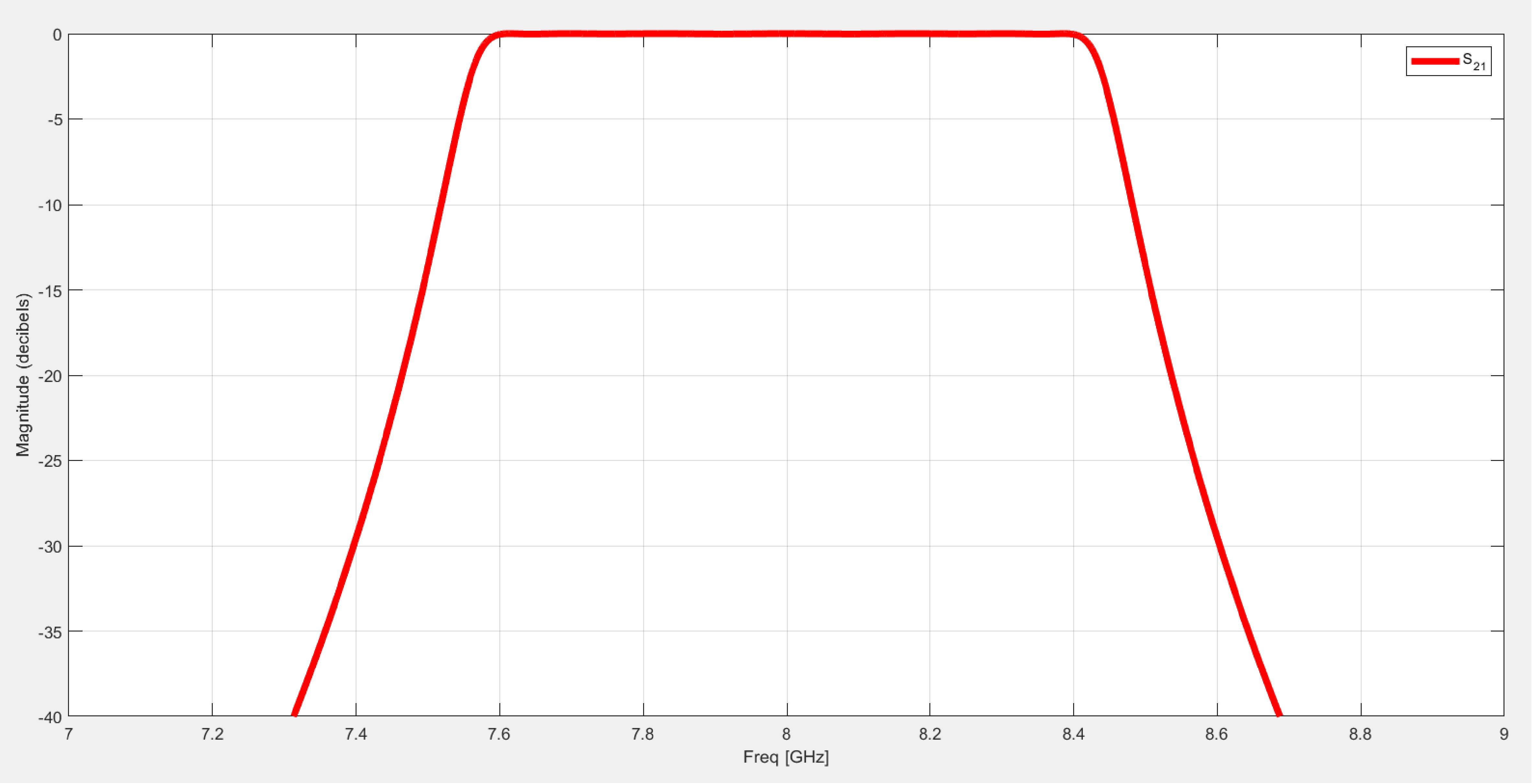




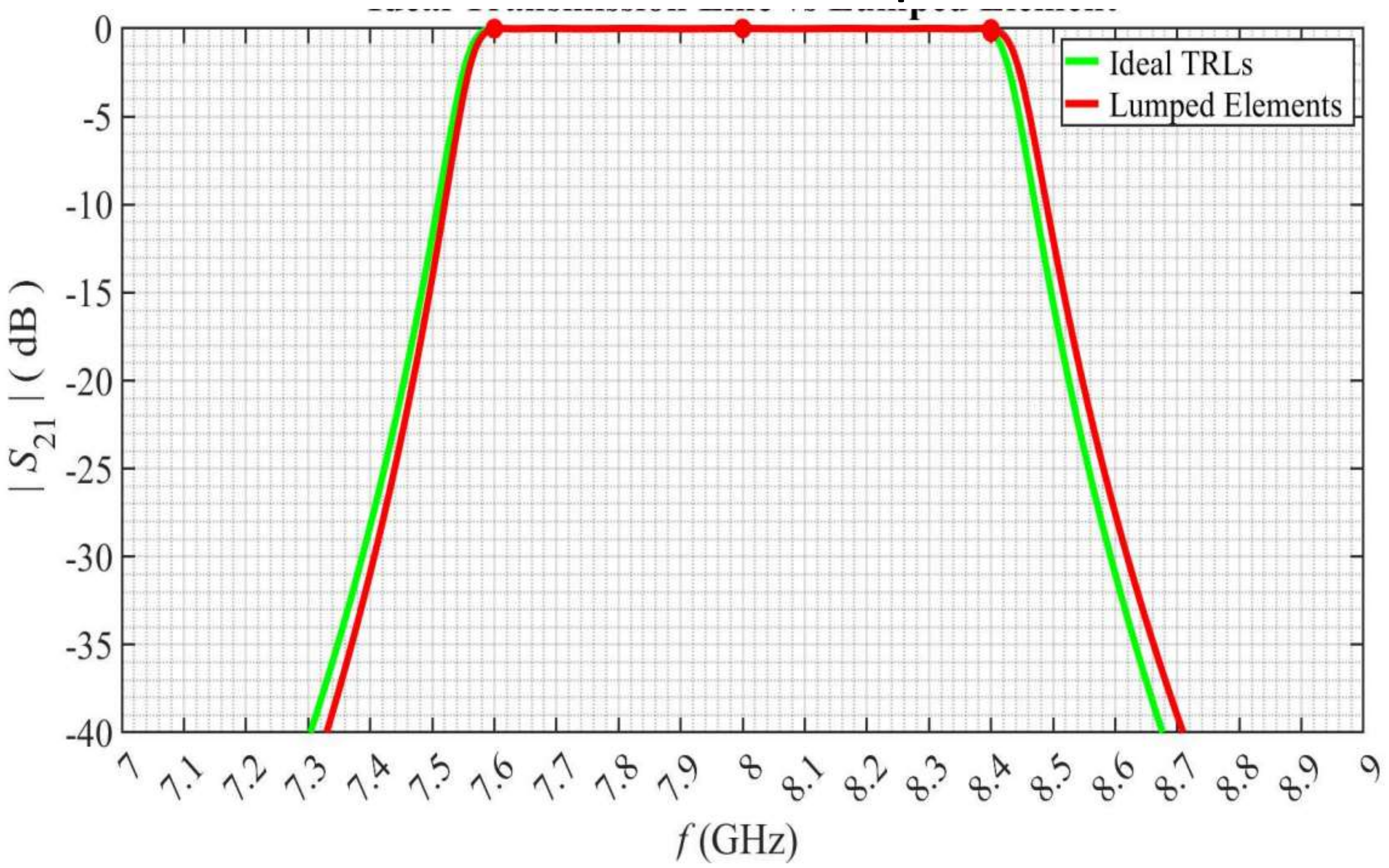
MATLAB Ideal TRL



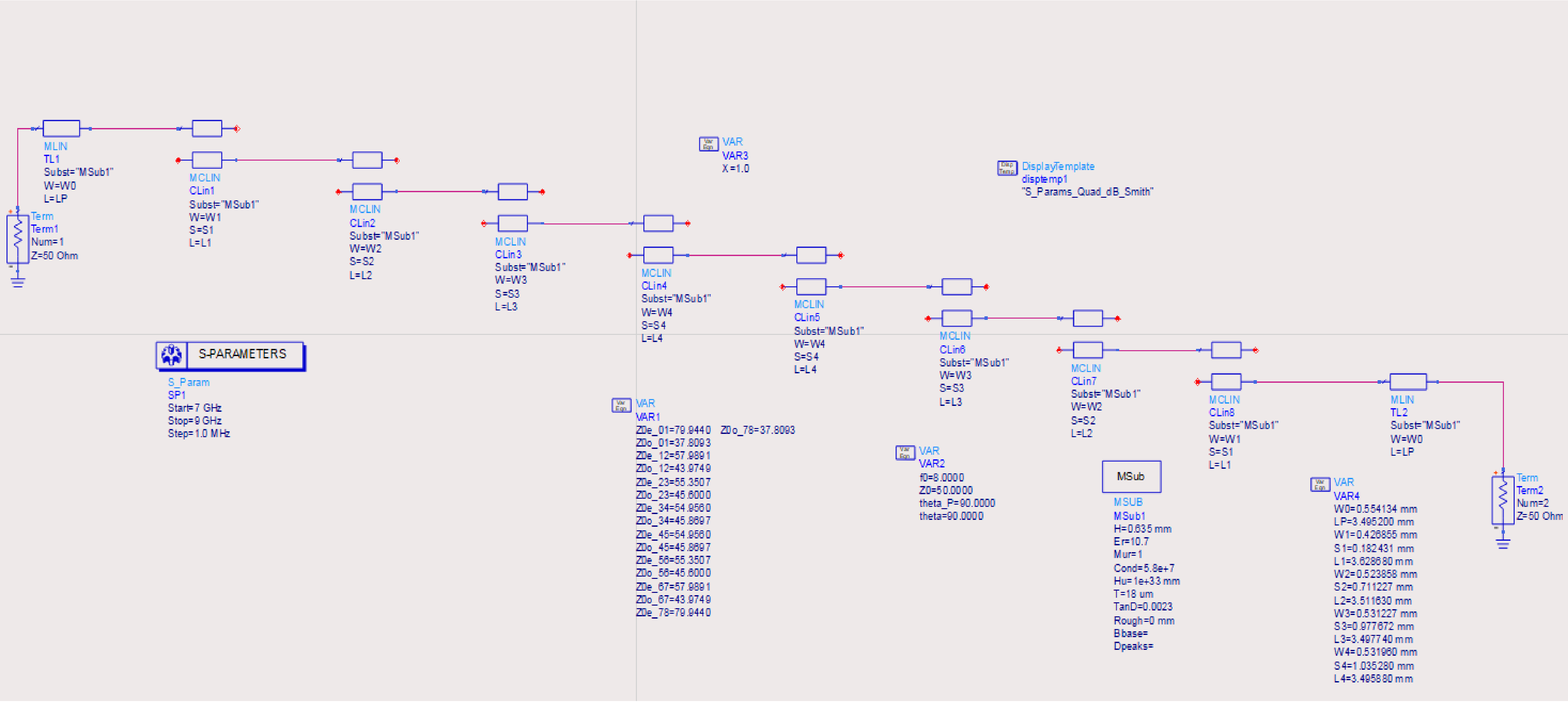
MATLAB Ideal TRL |S21|



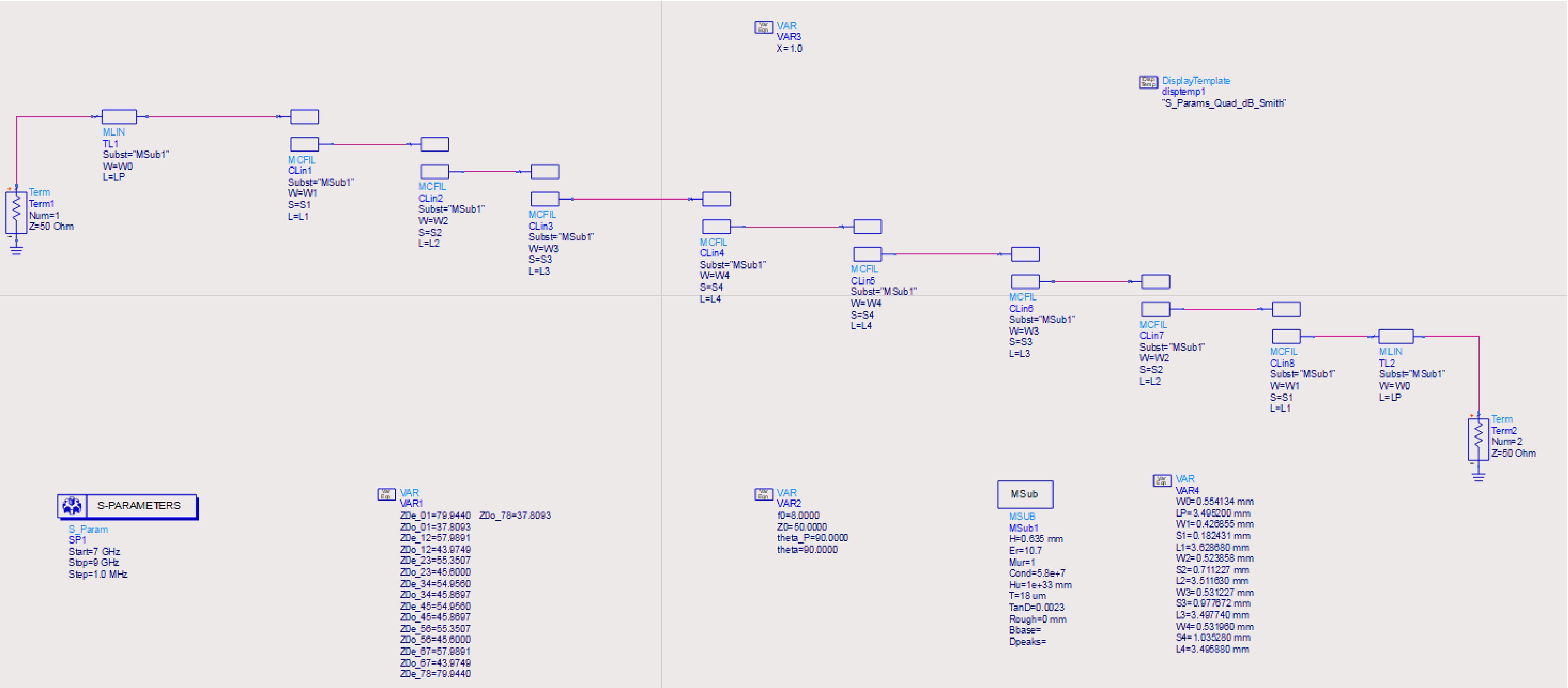
Ideal Transmission Lines vs Lumped Element



Microstrip Implementation of a Coupled-Line Bandpass Filter

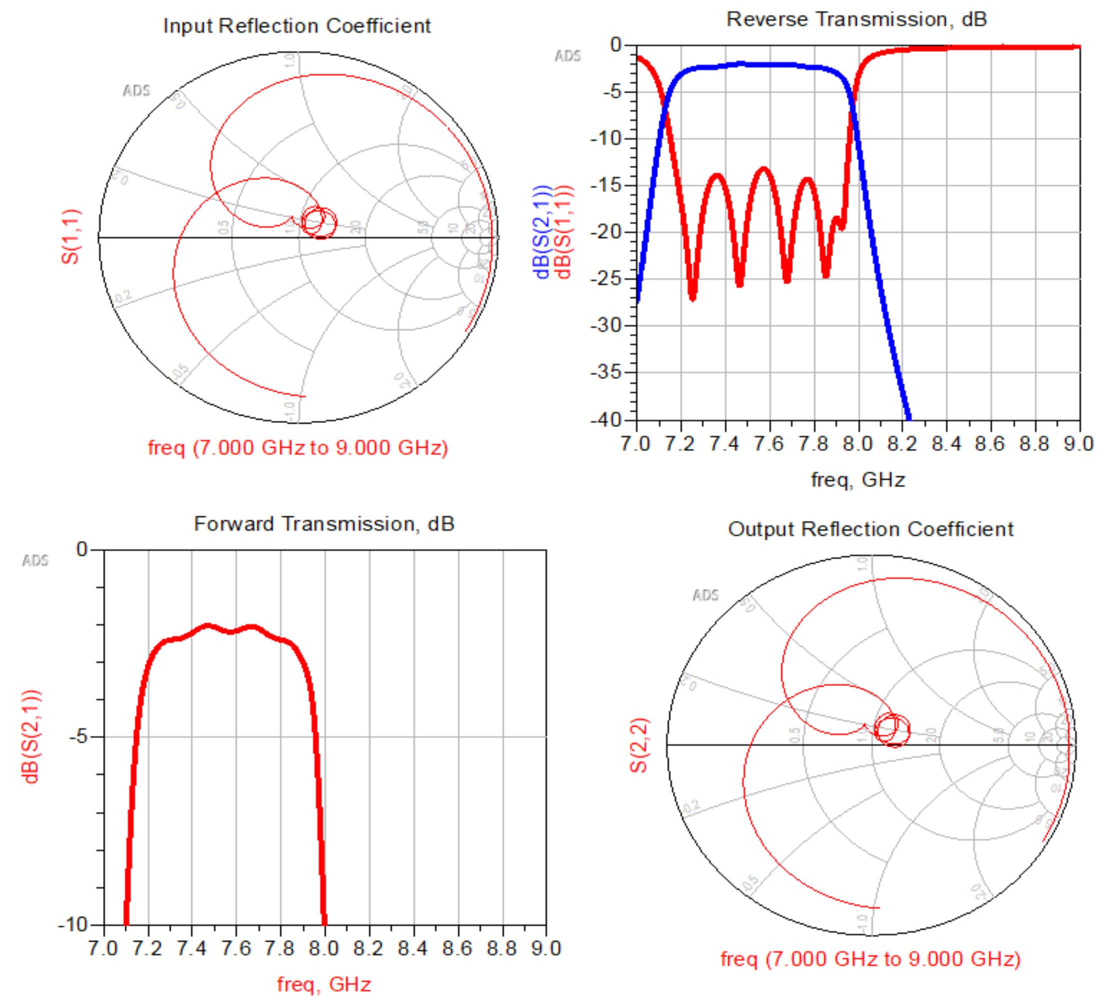


ADS Simulation of a Microstrip Coupled-Line Bandpass Filter (V1) using MCFIL Elements (7 GHz - 9 GHz)

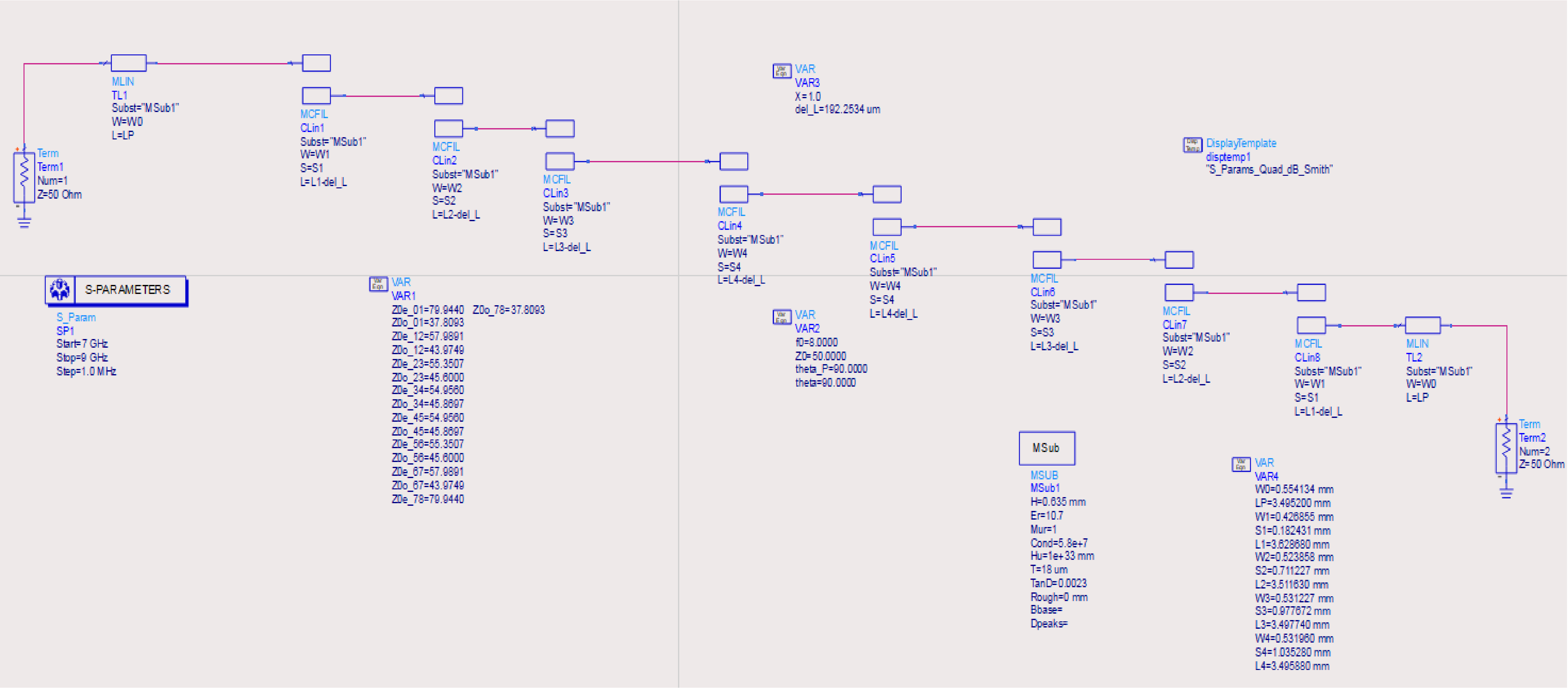


ADS Simulation of a Microstrip Coupled-Line Bandpass Filter (V1) using MCFIL Elements (7 GHz - 9 GHz)

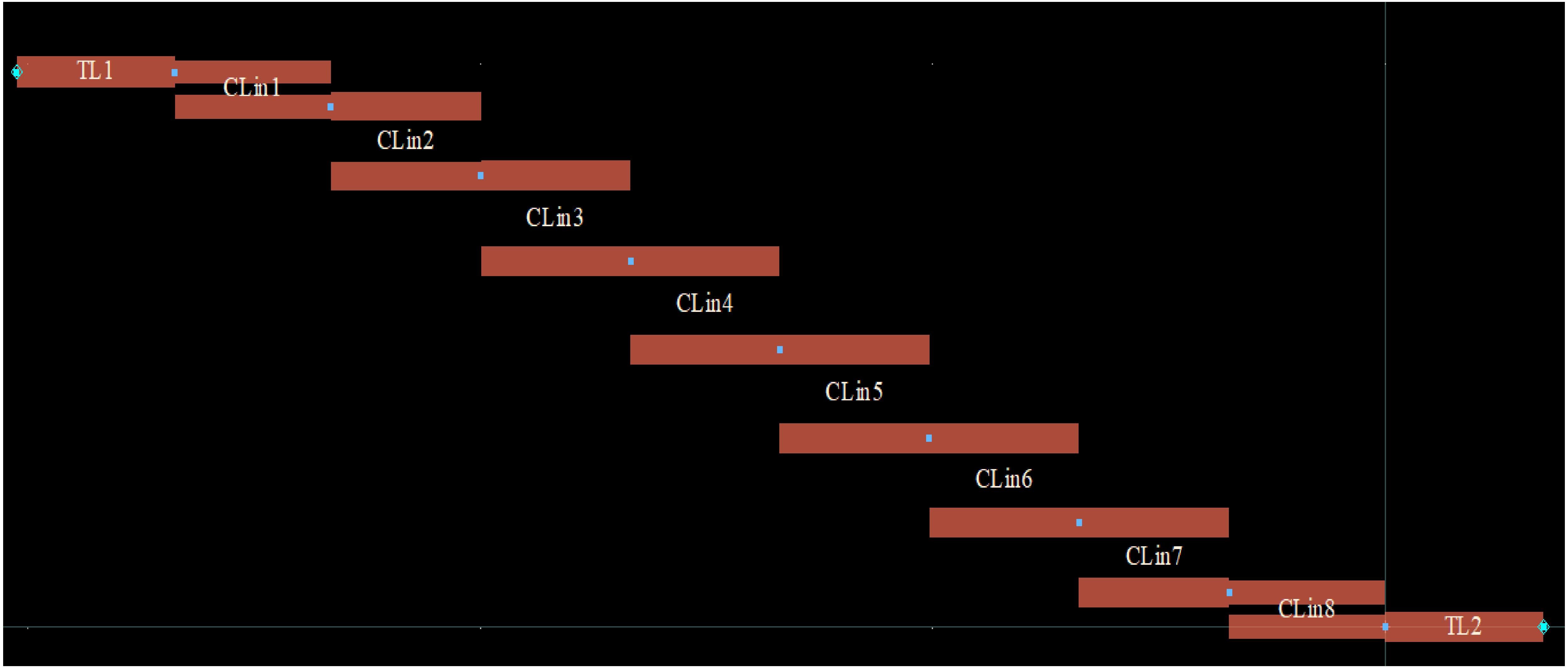
S-Parameters vs. Frequency



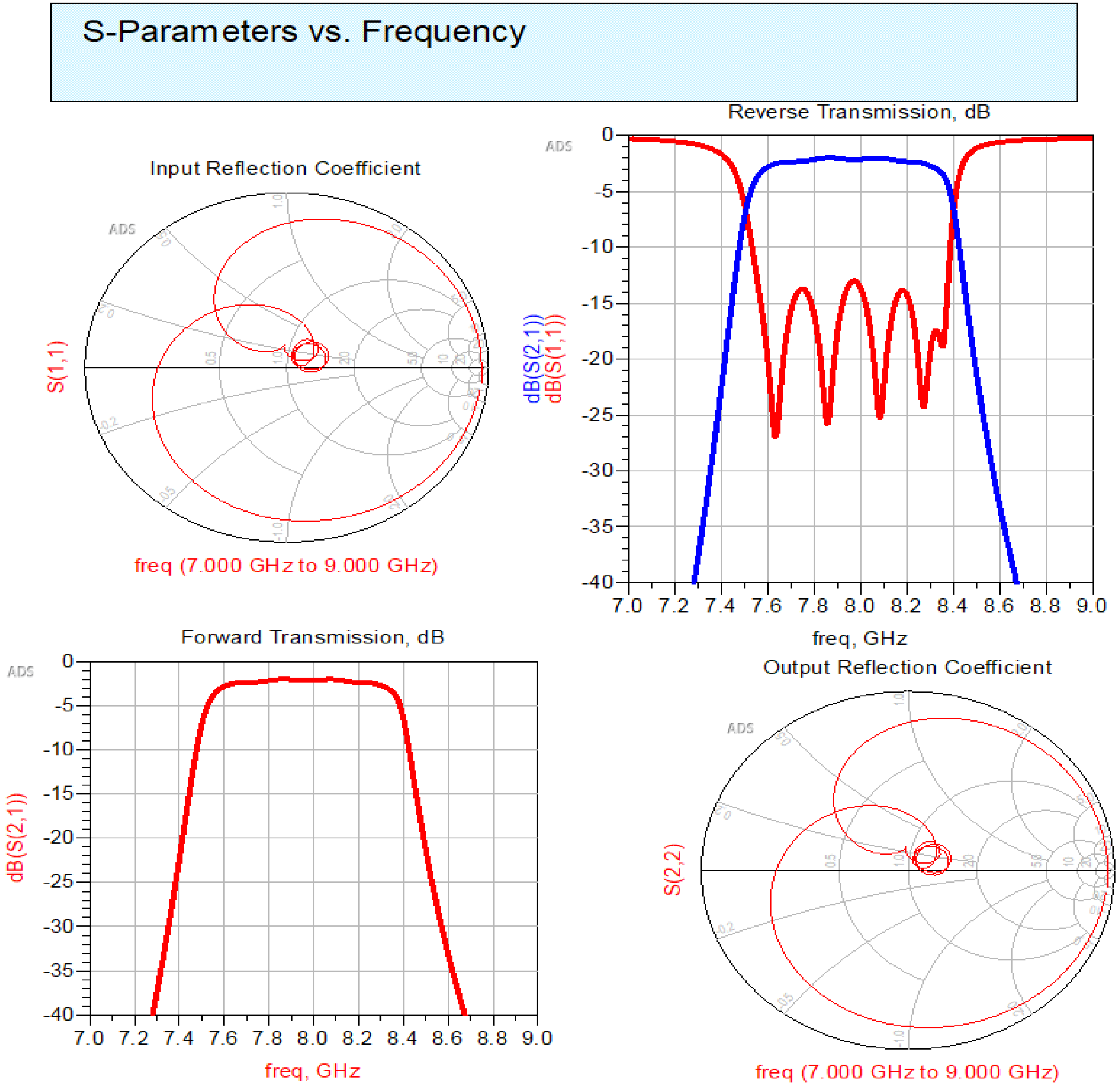
Tuned Microstrip Coupled-Line Bandpass Filter (V2) (7 GHz - 9 GHz)



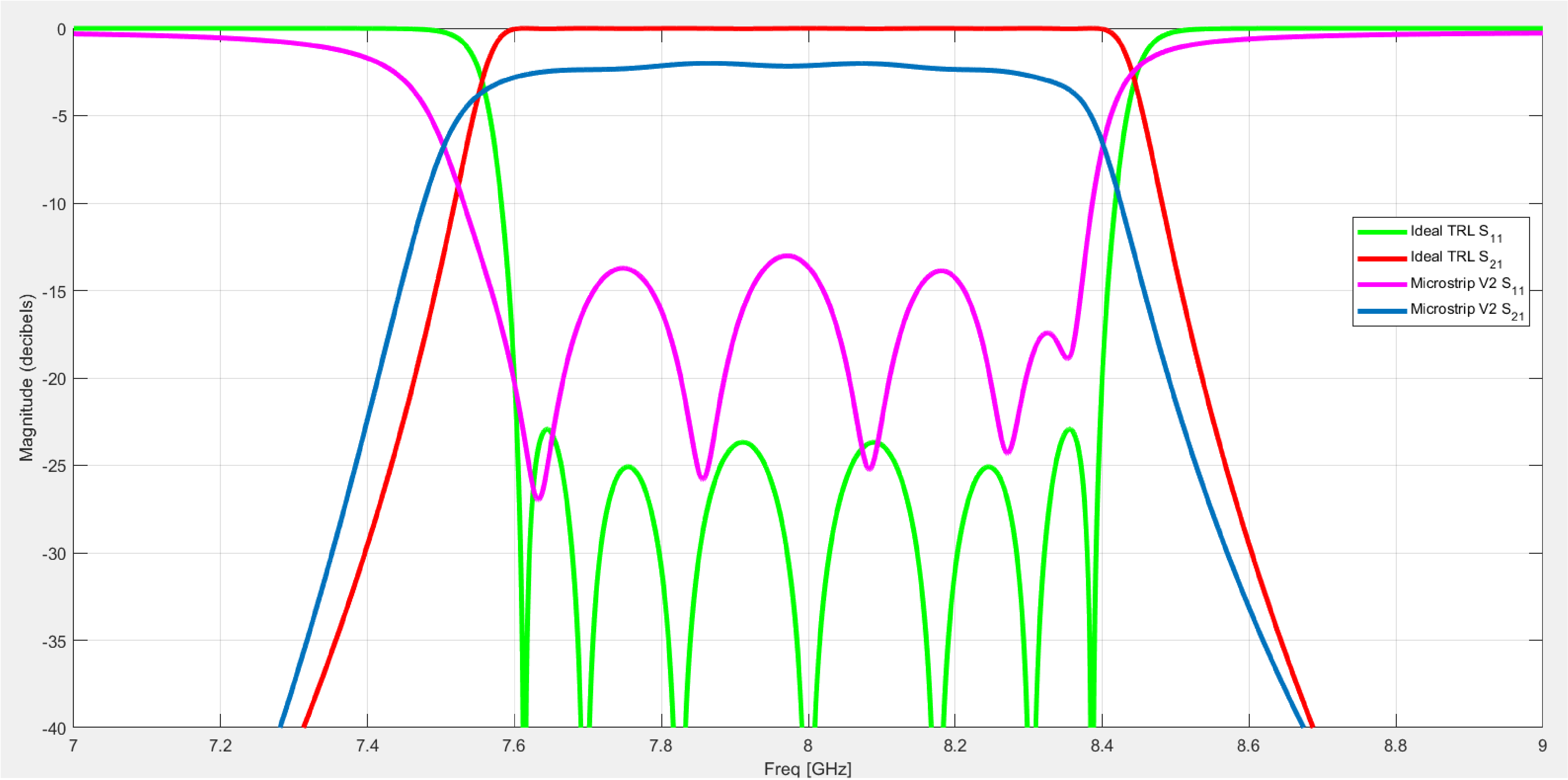
Tuned Microstrip Coupled-Line Bandpass Filter (V2) (7 GHz - 9 GHz)



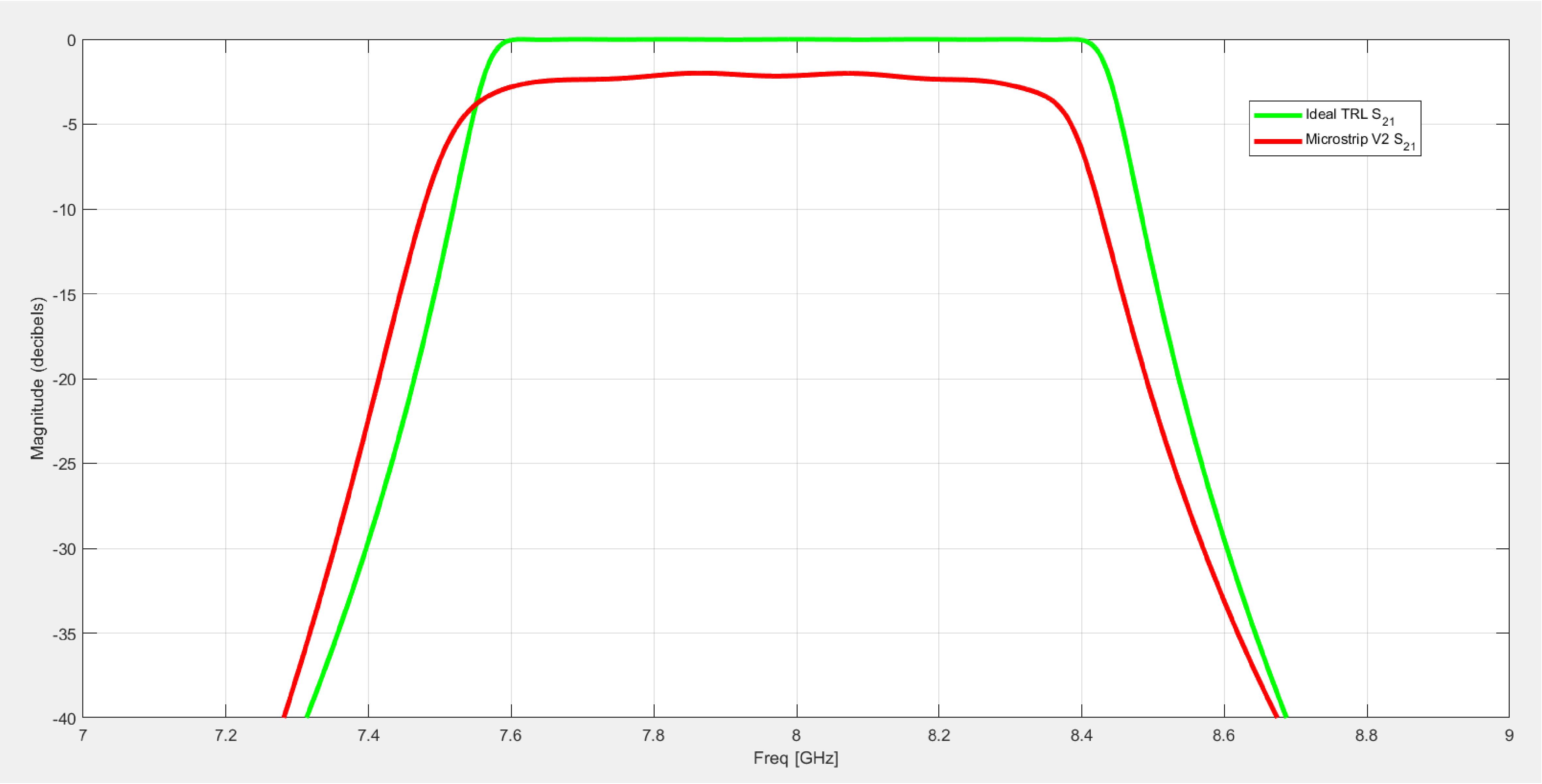
Tuned Microstrip Coupled-Line Bandpass Filter (V2) (7 GHz - 9 GHz)



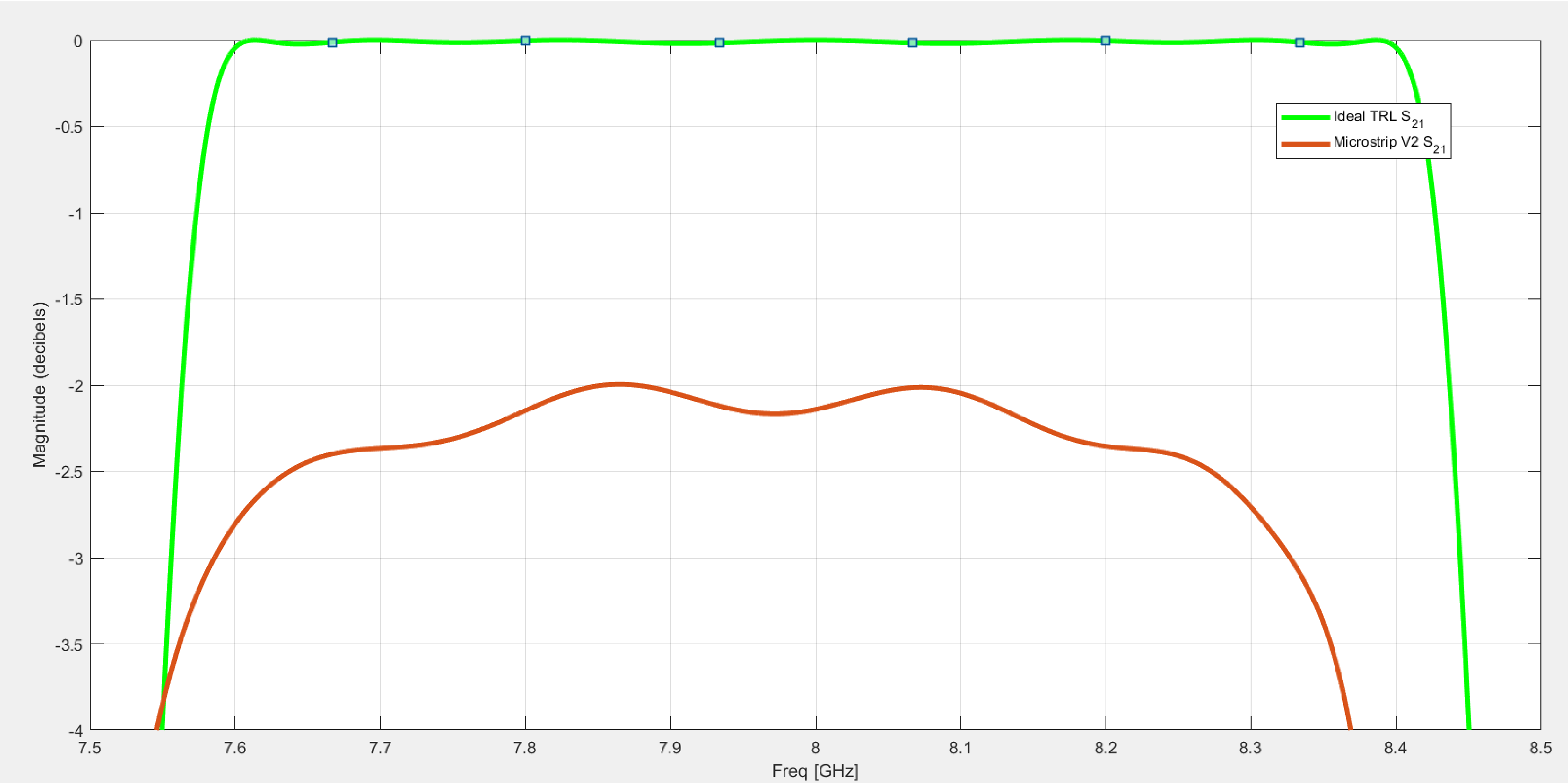
Ideal Transmission Line Vs Microstrip V2



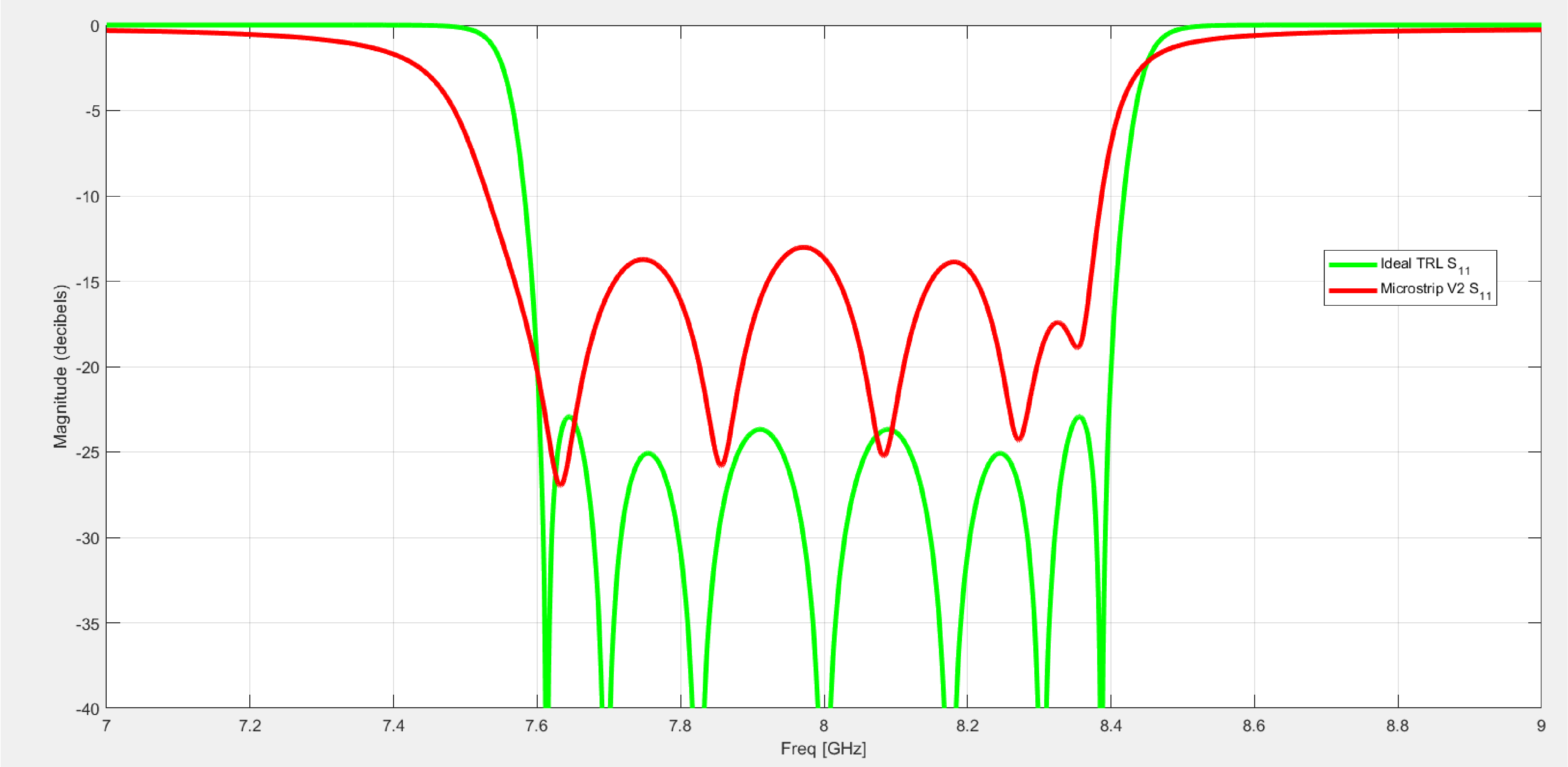
Ideal Transmission Line Vs Microstrip V2



Ideal Transmission Line Vs Microstrip V2



Ideal Transmission Line Vs Microstrip V2



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