Western New England University
College of Engineering
ECE Department
Microwave Engineering
EE 414/514
Spring 2024
Design Project #4
Due: April 26, 2024

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References: ______________________________________

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Design Project #4

	Score	Max
Butterworth Matching Network Design		200
Butterworth MATLAB Simulation		100
Chebyshev Matching Network Design		200
Chebyshev MATLAB Simulation		100
ADS (Microstrip TRLs)		100
ADS (Microstrip TRLs SD)		100
Summary Graphs		100
Presentation		100
Total		1000

1. Design a Butterworth multi-section transformer to match a 100-Ω load ($R_L = 100\,\Omega$) to a 50-Ω generator ($R_g = 50\,\Omega$).
   - The center frequency is 8 GHz ($f_0 = 8\,\text{GHz}$).
   - The bandwidth must be greater than or equal to 6.4 GHz ($BW_f \geq 6.4\,\text{GHz}$).
   - The return loss must be greater than or equal to 30 dB ($RL \geq +30\,\text{dB}$ or $|S_{11}| \leq -30\,\text{dB}$) over the bandwidth.

2. Using MATLAB, simulate the matching network designed in Task (1). Employ ideal transmission lines and a frequency range of 0 to 16 GHz. In addition, employ "driveway transmission lines" at the input and output with an electrical length of 90°. Determine the actual bandwidth (in GHz) for which the input return loss is greater than or equal to 30 dB ($RL \geq +30\,\text{dB}$ or $|S_{11}| \leq -30\,\text{dB}$).
   - Determine a value for S_{11}, S_{21}, S_{12}, and S_{22} at 8 GHz.

3. Design a Chebyshev multi-section transformer to match a 100-Ω load ($R_L = 100\,\Omega$) to a 50-Ω generator ($R_g = 50\,\Omega$).
   - The center frequency is 8 GHz ($f_0 = 8\,\text{GHz}$).
   - The bandwidth must be greater than or equal to 6.4 GHz ($BW_f \geq 6.4\,\text{GHz}$).
   - The return loss must be greater than or equal to 30 dB ($RL \geq +30\,\text{dB}$ or $|S_{11}| \leq -30\,\text{dB}$) over the bandwidth.

4. Using MATLAB, simulate the matching network designed in Task (3). Employ ideal transmission lines and a frequency range of 0 to 16 GHz. In addition, employ "driveway transmission lines" at the input and output with an electrical length of 90°. Determine the actual bandwidth (in GHz) for which the input return loss is greater than or equal to 30 dB ($RL \geq +30\,\text{dB}$ or $|S_{11}| \leq -30\,\text{dB}$).
   - Determine a value for S_{11}, S_{21}, S_{12}, and S_{22} at 8 GHz.

5. Using ADS, simulate the matching network designed in Task (3). Employ microstrip transmission lines and a frequency range of 0 to 16 GHz. In addition, employ "driveway transmission lines" at the input and output with an electrical length of 90°. Assume that the microstrip transmission lines are to be realized using a 0.635 mm thick Duroid 6010 substrate ($\varepsilon_r = 10.7$, $\tan\delta = 0.0023$, $\sigma_c = 5.8\times10^{+7}\,\text{S/m}$, and $t = 18\,\mu\text{m}$).
   - Determine a value for S_{11}, S_{21}, S_{12}, and S_{22} at 8 GHz.

6. Add the microstrip step element (MSTEP) to the model in Task (5).
   - Determine a value for S_{11}, S_{21}, S_{12}, and S_{22} at 8 GHz.

7. Summarize the results.
   - On the same graph, plot $|S_{11}|$ (in dB) for the Butterworth simulated using MATALB and the Chebyshev simulated using MATALB. Employ a domain of 0 to 16 GHz and a range of -40 to 0 dB.
   - On the same graph, plot $|S_{21}|$ (in dB) for the Butterworth simulated using MATALB and the Chebyshev simulated using MATALB. Employ a domain of 0 to 16 GHz and a range of -0.25 to 0 dB.
   - On the same graph, plot $|S_{11}|$ (in dB) for the Chebyshev simulated using MATALB, ADS (Microstrip TRLs), and ADS (Microstrip TRLs with SD). Employ a range of -40 to 0 dB.
   - On the same graph, plot $|S_{21}|$ (in dB) for the Chebyshev simulated using MATALB, ADS (Microstrip TRLs), and ADS (Microstrip TRLs with SD). Employ a domain of 0 to 16 GHz and a range of -0.45 to 0 dB.

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

Design Project - 4

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Butterworth Matching Network Design

Butterworth Matching Network Design MATLAB Calculations

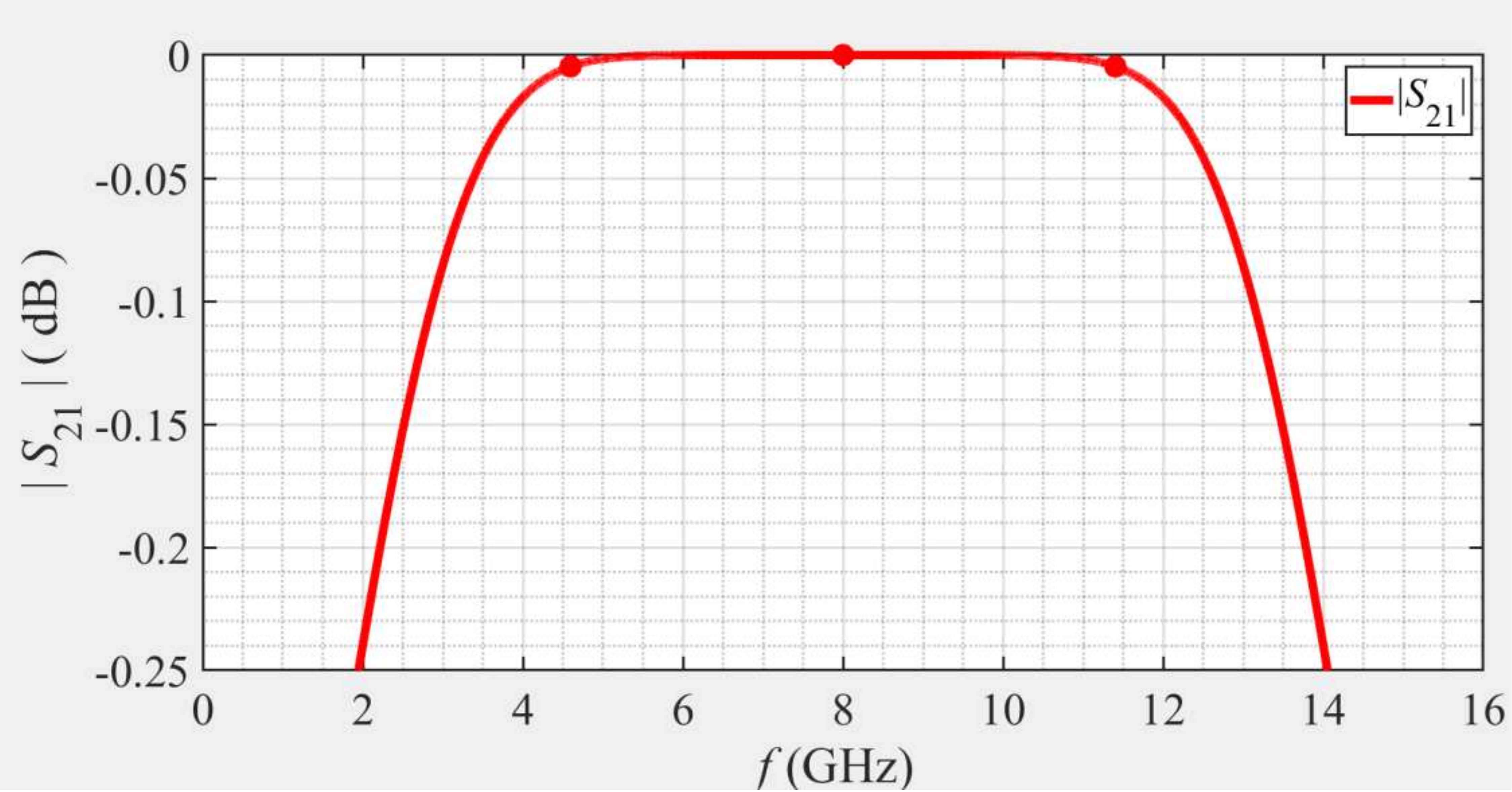
```
new_fL = 4.5974 GHz

new_fH = 11.4026 GHz

wzi = (1.0000 < +180.0000°)

w = (1.0000 < -126.7597°)

-----------------------------------
```

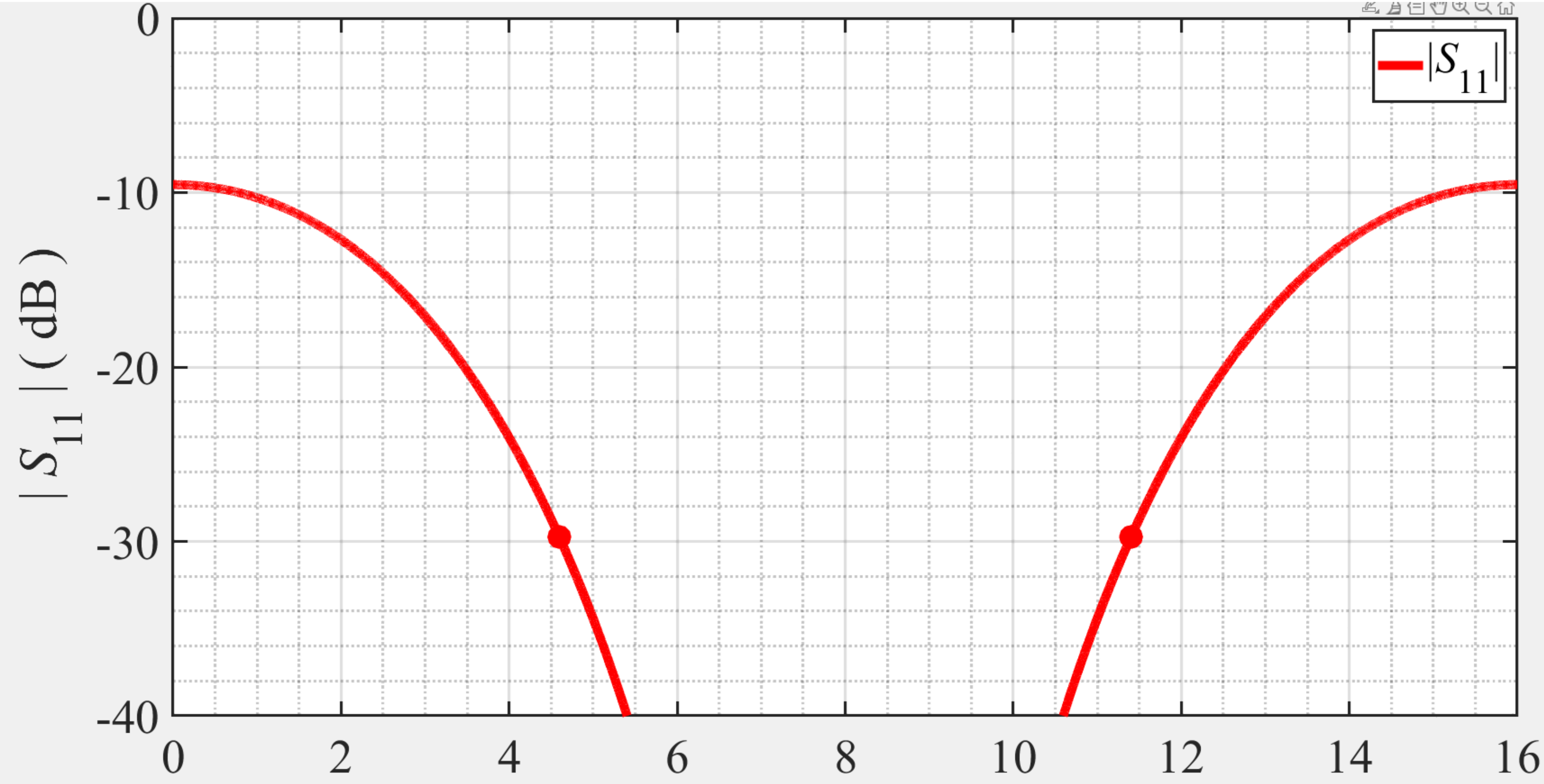
```
------------------------------

Gamma_k( 1) = 0.0108

Gamma_k( 2) = 0.0542

Gamma_k( 3) = 0.1083

Gamma_k( 4) = 0.1083

Gamma_k( 5) = 0.0542

Gamma_k( 6) = 0.0108
```

```
Z1 = 51.0949   Ohms

Z2 = 56.9394   Ohms

Z3 = 70.7107   Ohms

Z4 = 87.8126   Ohms

Z5 = 97.8572   Ohms

Z6 = 100.0000   Ohms
```

```
S21_min (RL) = 0.9995 W/W

S21_min (RL) = -0.0043 dB

Ap (RIPPLE) = 0.0043 dB
>> wzi
```

k	0	1	2	3	4	5	6
Z_k	50.0000	51.0949	56.9394	70.7107	87.8126	97.8572	100.0000
Γ_k	0.0108	0.0542	0.1083	0.1083	0.0542	0.0108	--------------------


0
-0.05
-0.1
-0.15
-0.2
-0.25
|S_{21}| (dB)
0
2
4
6
8
10
12
14
16
f (GHz)
|S_{21}|



0
-10
-20
-30
-40
0
2
4
6
8
10
12
14
16
| S11 | (dB)
|S11|

Chebyshev Matching Network Design

Chebyshev Matching Network Design MATLAB Calculations

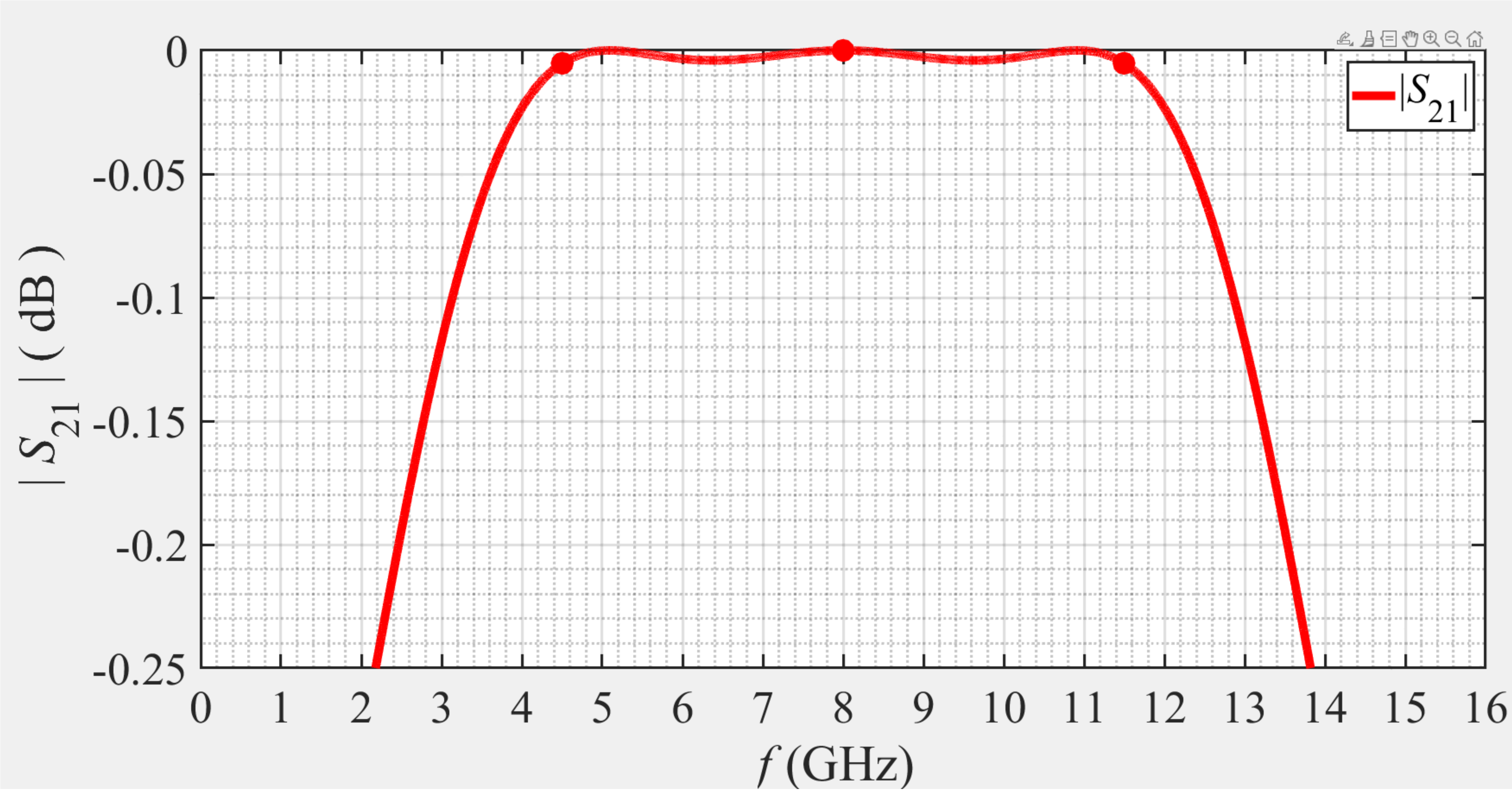
```
new_fL = 4.5021 GHz

new_fH = 11.4979 GHz

uz( 1) = -0.8660

uz( 2) = 0.0000

uz( 3) = 0.8660

T_N( 1) = 4.0000

T_N( 2) = 0.0000

T_N( 3) = -3.0000

T_N( 4) = 0.0000
```

```
Uz_poly( 1) = -0.8660

Uz_poly( 2) = 0.0000

Uz_poly( 3) = 0.8660

wzi( 1) = (1.0000 < +113.3866°)

wzi( 2) = (1.0000 < +180.0000°)

wzi( 3) = (1.0000 < -113.3866°)

Ik( 1) = 1.0000

Ik( 2) = 1.7939

Ik( 3) = 1.7939

Ik( 4) = 1.0000
```

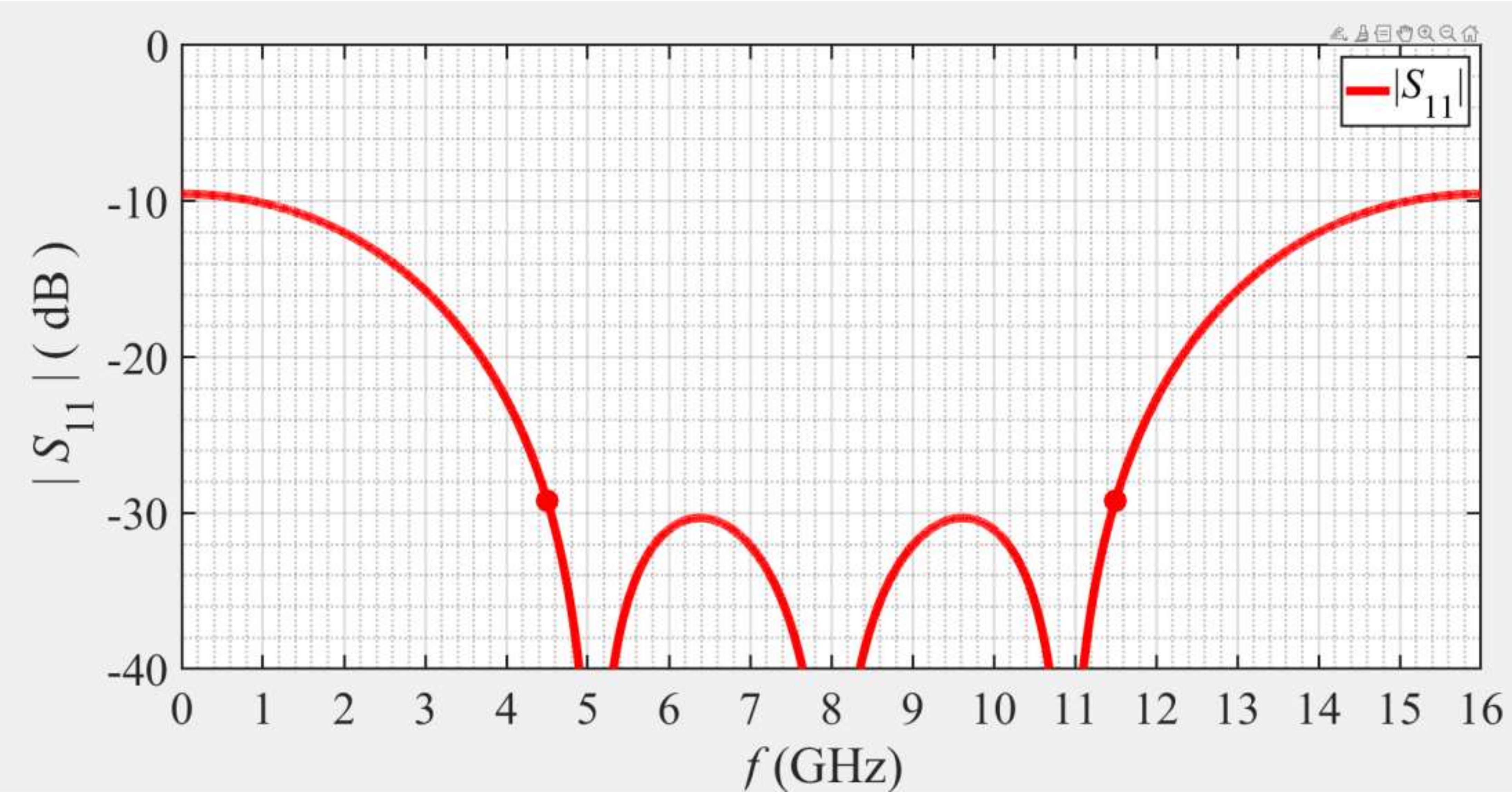
```
Gamma_k( 1) = 0.0620

Gamma_k( 2) = 0.1113

Gamma_k( 3) = 0.1113

Gamma_k( 4) = 0.0620

Z1 = 56.6125  Ohms

Z2 = 70.7874  Ohms

Z3 = 88.5115  Ohms

Z4 = 100.2171  Ohms

S21_min (RL) = 0.9995 W/W

S21_min (RL) = -0.0043 dB

Ap (RIPPLE) = 0.0043 dB
>>
```

i	u_{zi}	θ_{zi}	w_{zi}
1	-0.8660	123.3067	(1.0000 < +113.3866°)
2	0.0000	90.0000	(1.0000 < +180.0000°)
3	0.8660	56.6933	(1.0000 < -113.3866°)

k	0	1	2	3	4	
I_k	1.0000	1.7939	1.7939	1.0000		
Γ_k	0.0620	0.1113	0.1113	0.0620	---------------	
Z_k	50.0000	56.6125	70.7874	88.5115	100.2171	Ohms

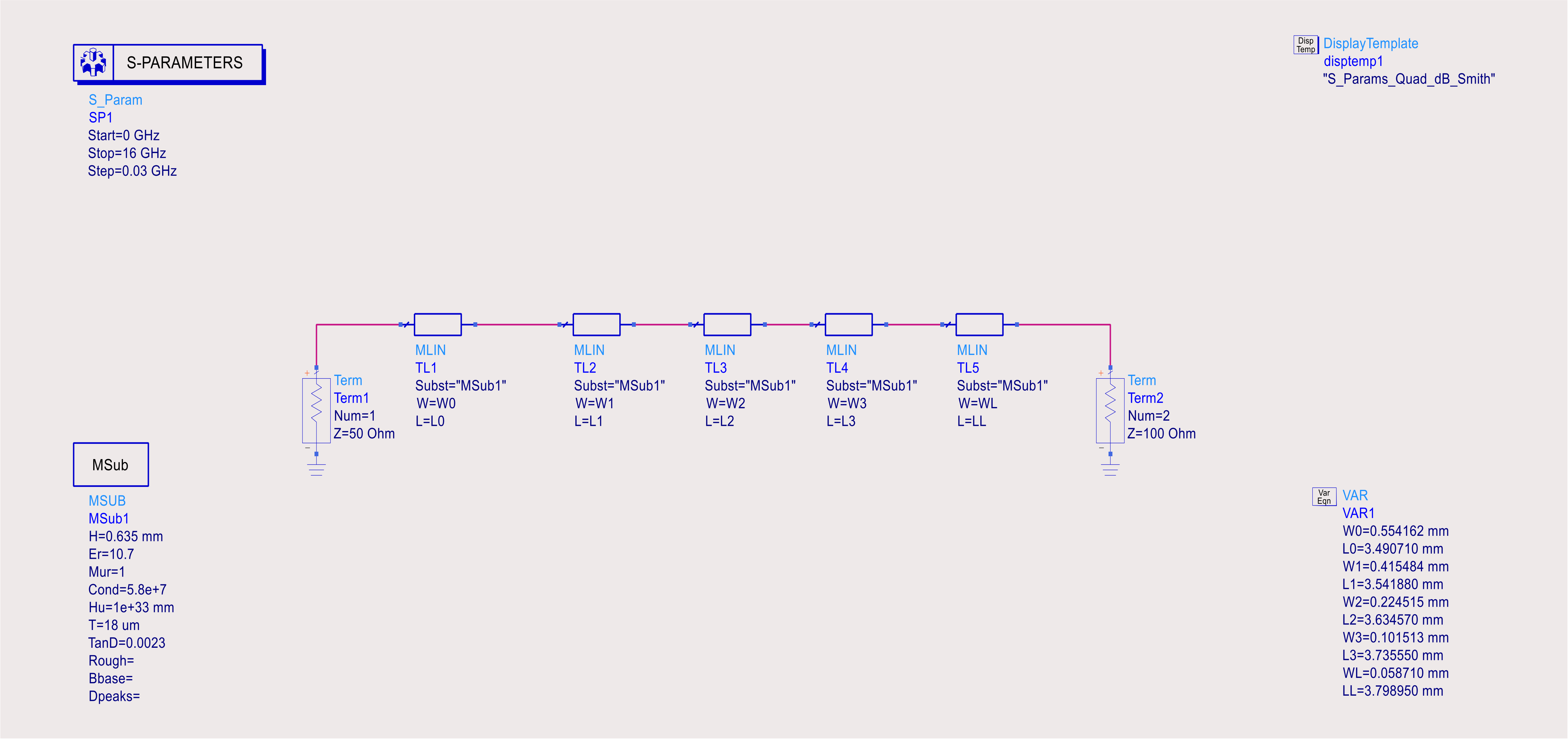


0
-0.05
-0.1
-0.15
-0.2
-0.25
| S21 | (dB)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
f (GHz)
|S21|

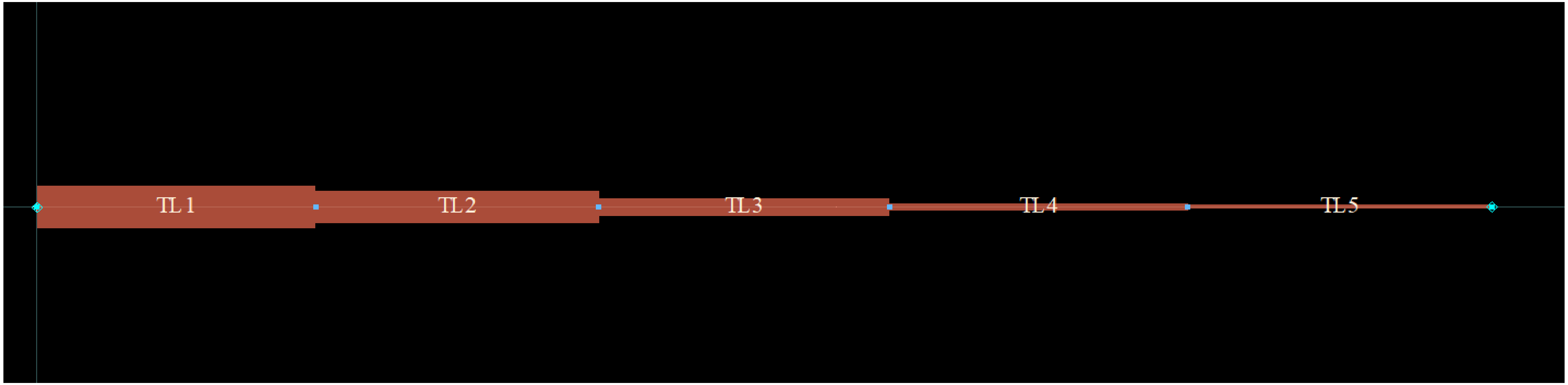


0
-10
-20
-30
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
f (GHz)
$|S_{11}|$ (dB)
$|S_{11}|$

ADS (Microstrip TRLs)

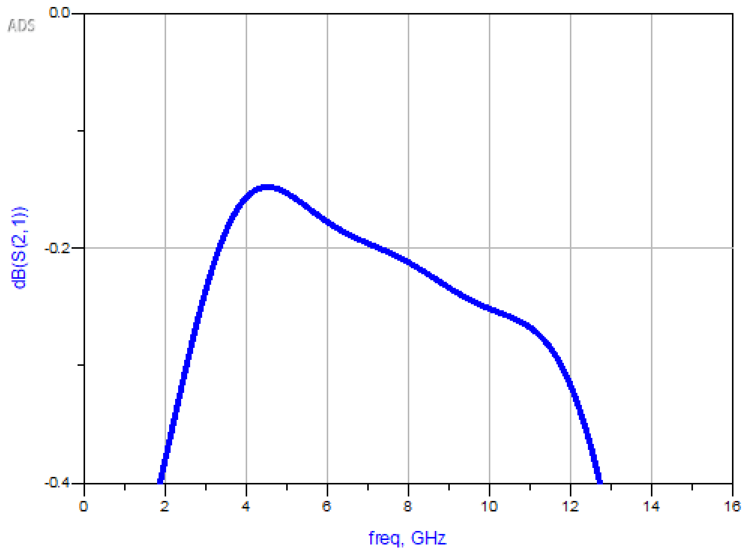


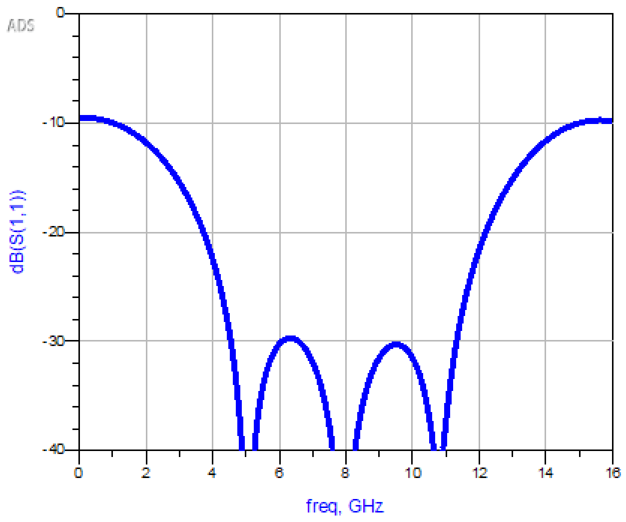
ADS (Microstrip TRLs) Layout

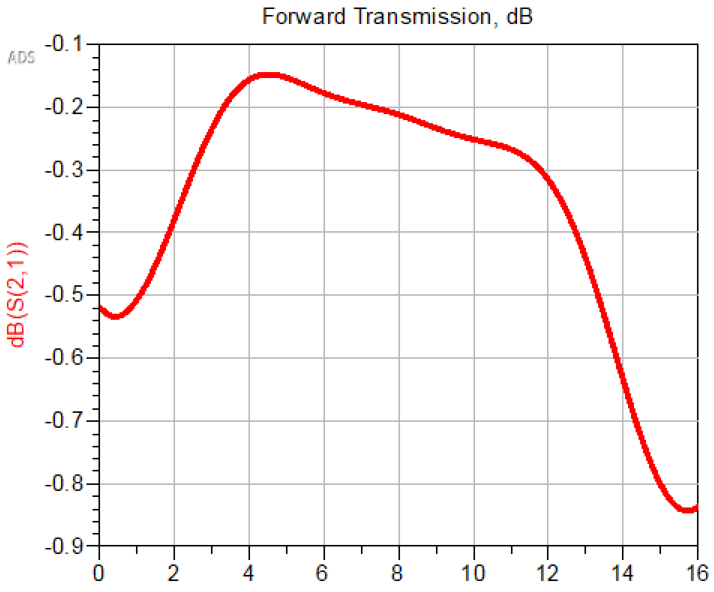


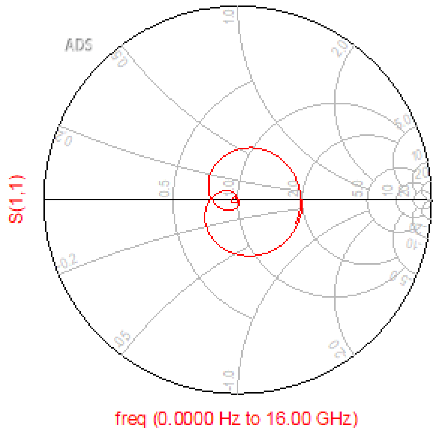
ADS (Microstrip TRLs)

S-Parameters vs. Frequency

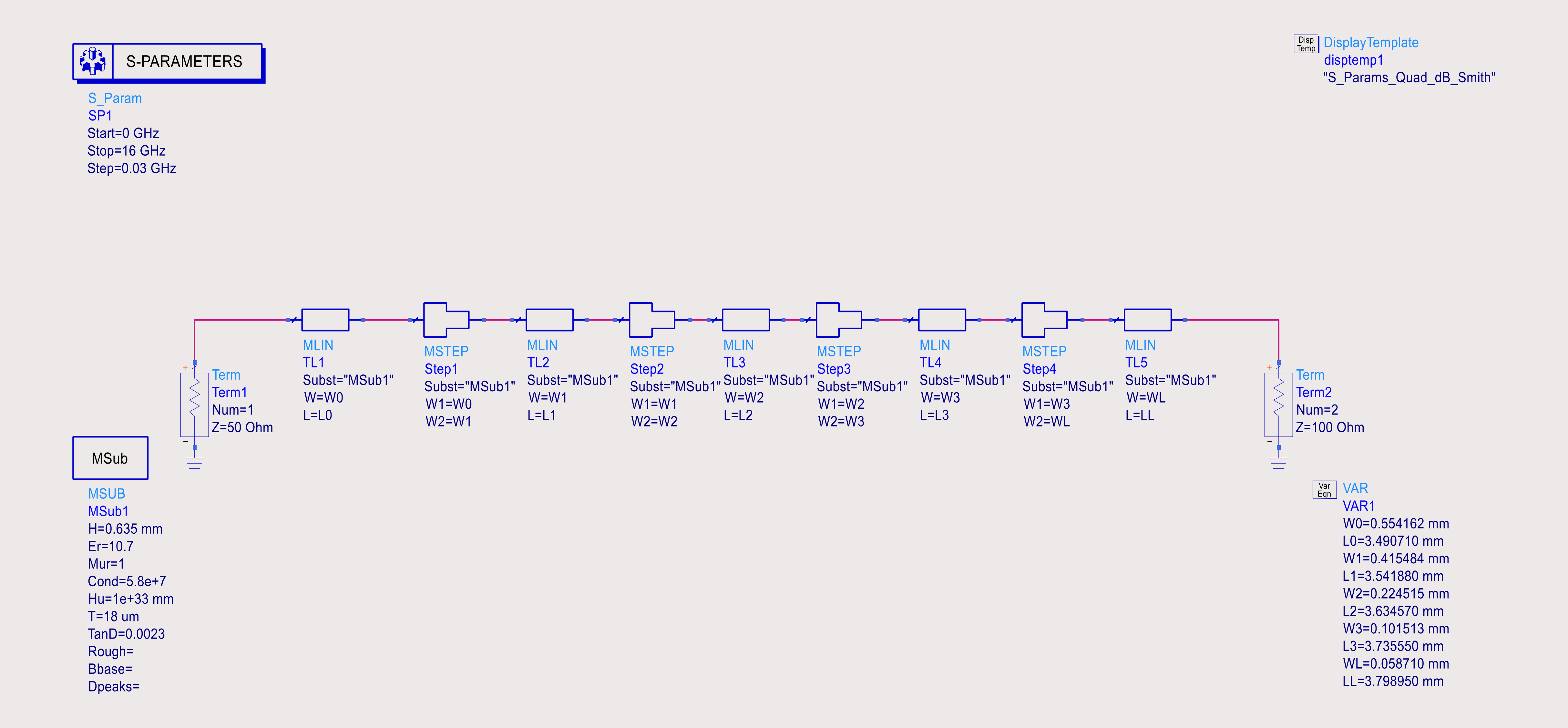




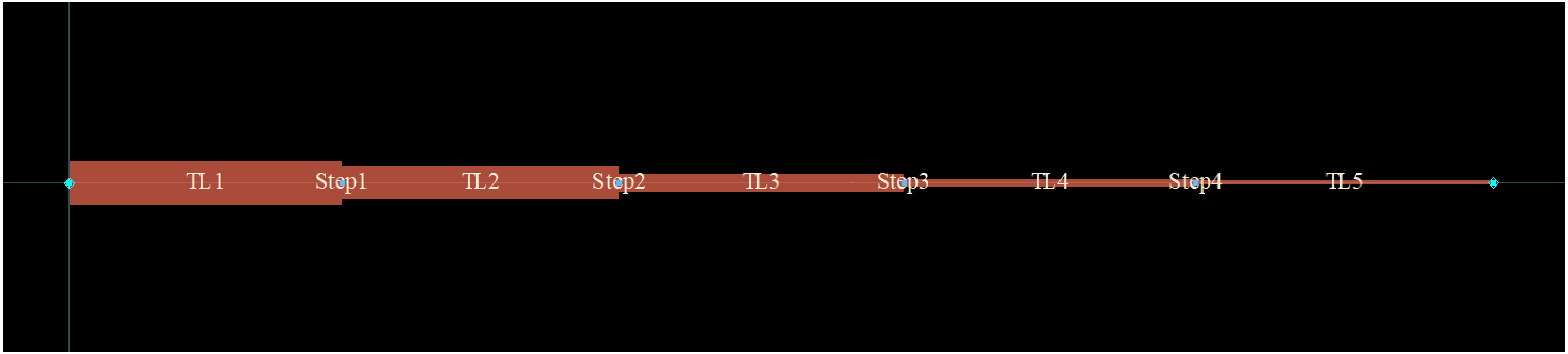




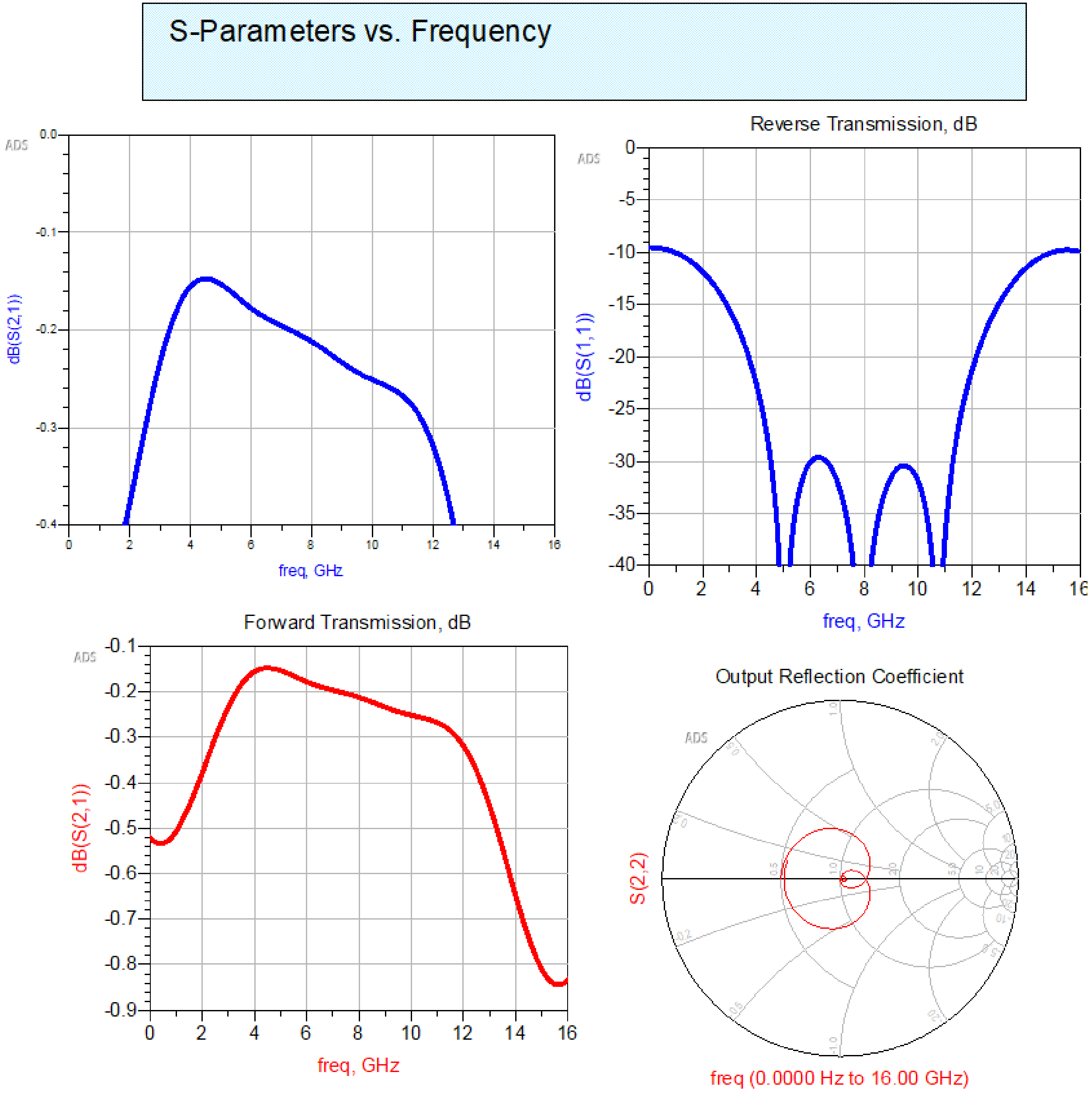
ADS -Microstrip TRLs(MSTEP)



ADS -Microstrip TRLs(MSTEP) Layout



ADS -Microstrip TRLs(MSTEP)



BUTTERWORTH

	Values	dB
S_{11}	-0.0000+j0.0006	-66.7879
S_{21}	0.0150-j0.9999	0.0000
S_{12}	0.0150-j0.9999	0.0000
S_{22}	0.0000-j0.0006	-66.7879

CHEBYSHEV

	Values	dB
S_{11}	0.0000+j0.0000	-166.9889
S_{21}	0.9999+j0.0242	0.0000
S_{12}	0.9999+j0.0242	0.0000
S_{22}	0.0000+j0.0000	-166.9889

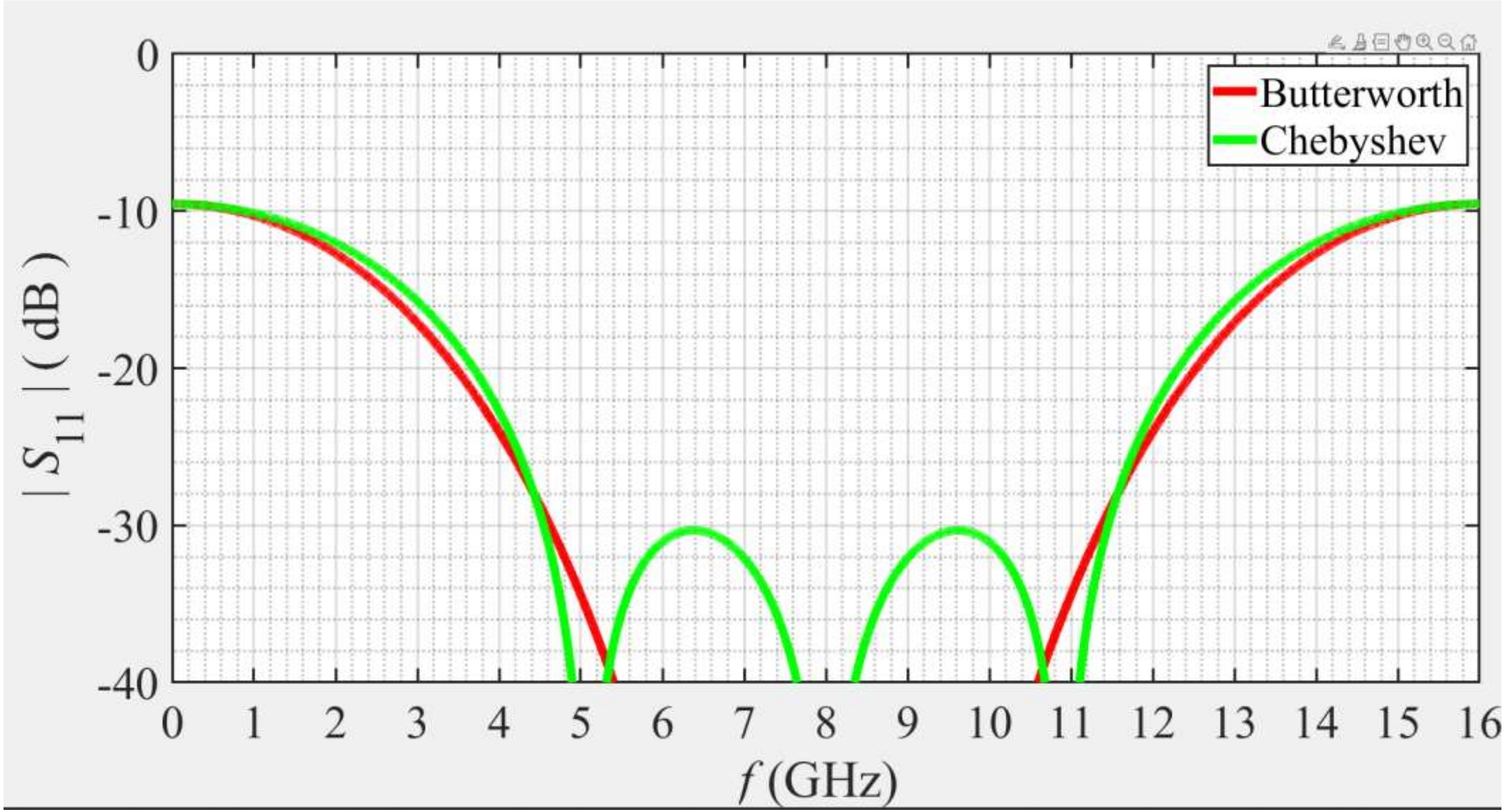
ADS Microstrip

	Values	dB
S_{11}	0.0016-j0.0022	-50.5842
S_{21}	-0.0255-j0.9753	-0.2109
S_{12}	-0.0255-j0.9753	-0.2109
S_{22}	0.0032-j0.0008	-47.0322

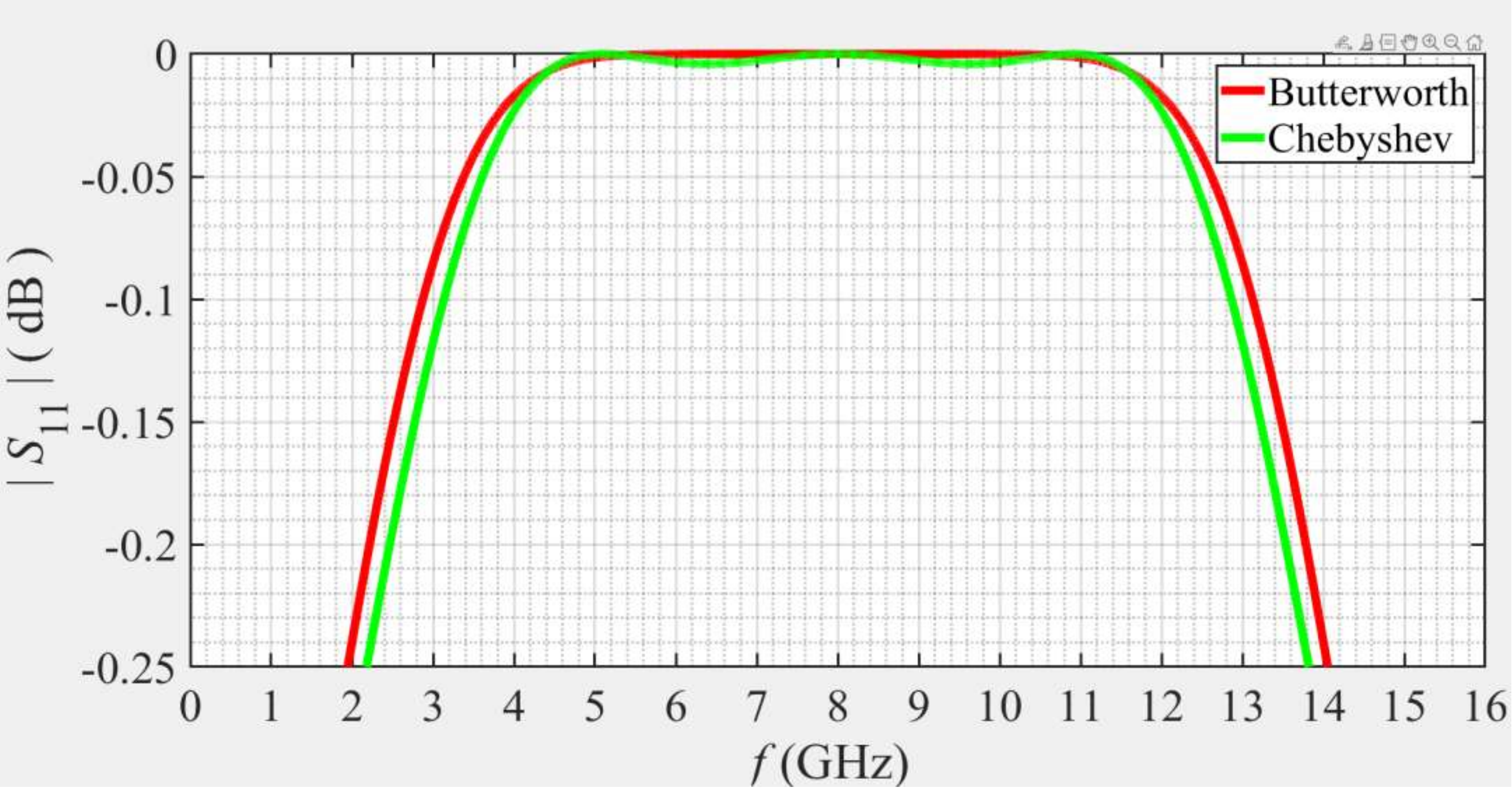
ADS Microstrip Stepped

	Values	dB
S_{11}	0.0016-j0.0028	-48.4752
S_{21}	-0.0394-j0.9750	-0.2119
S_{12}	-0.0394-j0.9750	-0.2119
S_{22}	0.0035-j0.0003	-48.0703

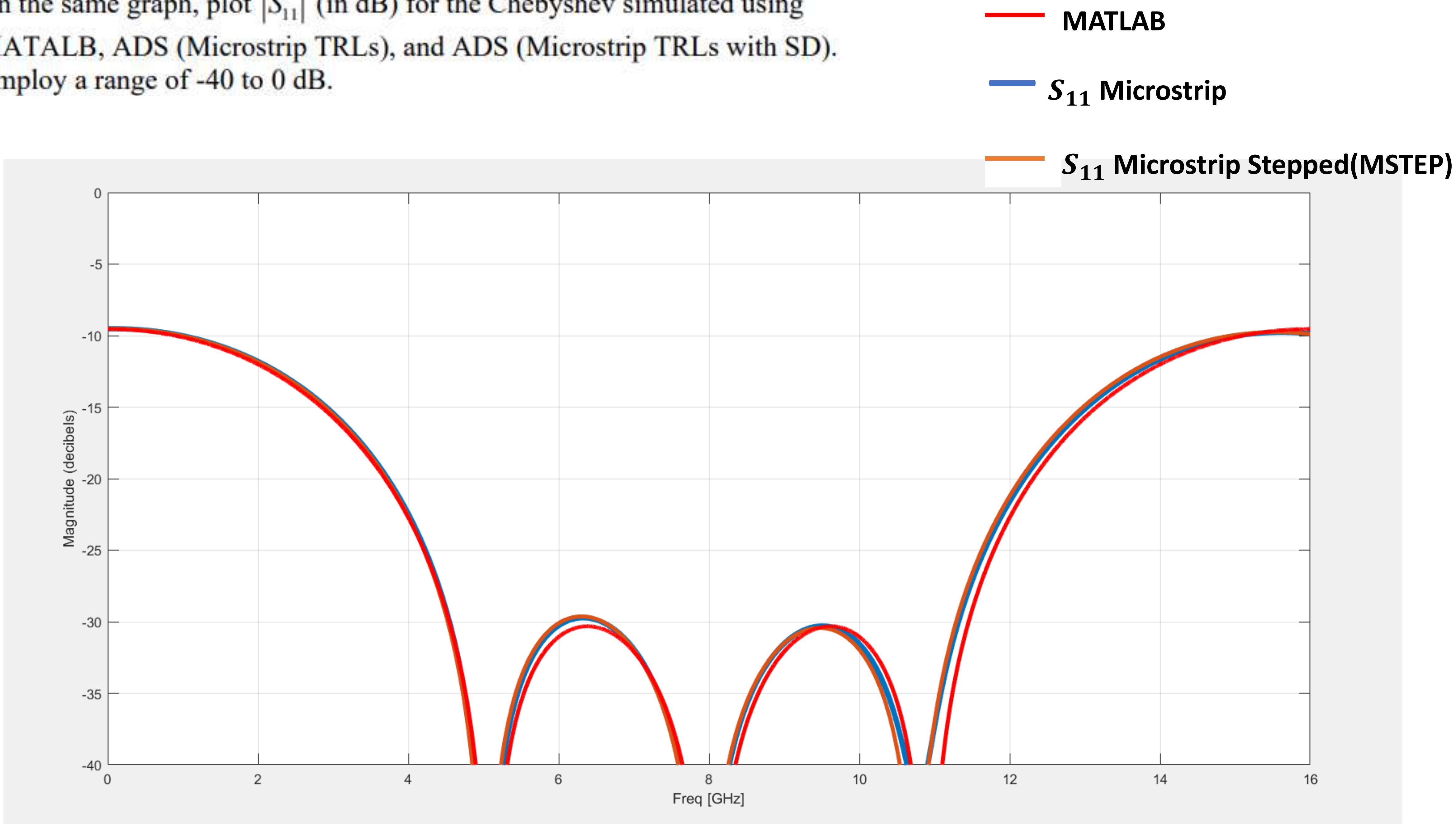
On the same graph, plot $|S_{11}|$ (in dB) for the Butterworth simulated using MATALB and the Chebyshev simulated using MATALB. Employ a domain of 0 to 16 GHz and a range of -40 to 0 dB.



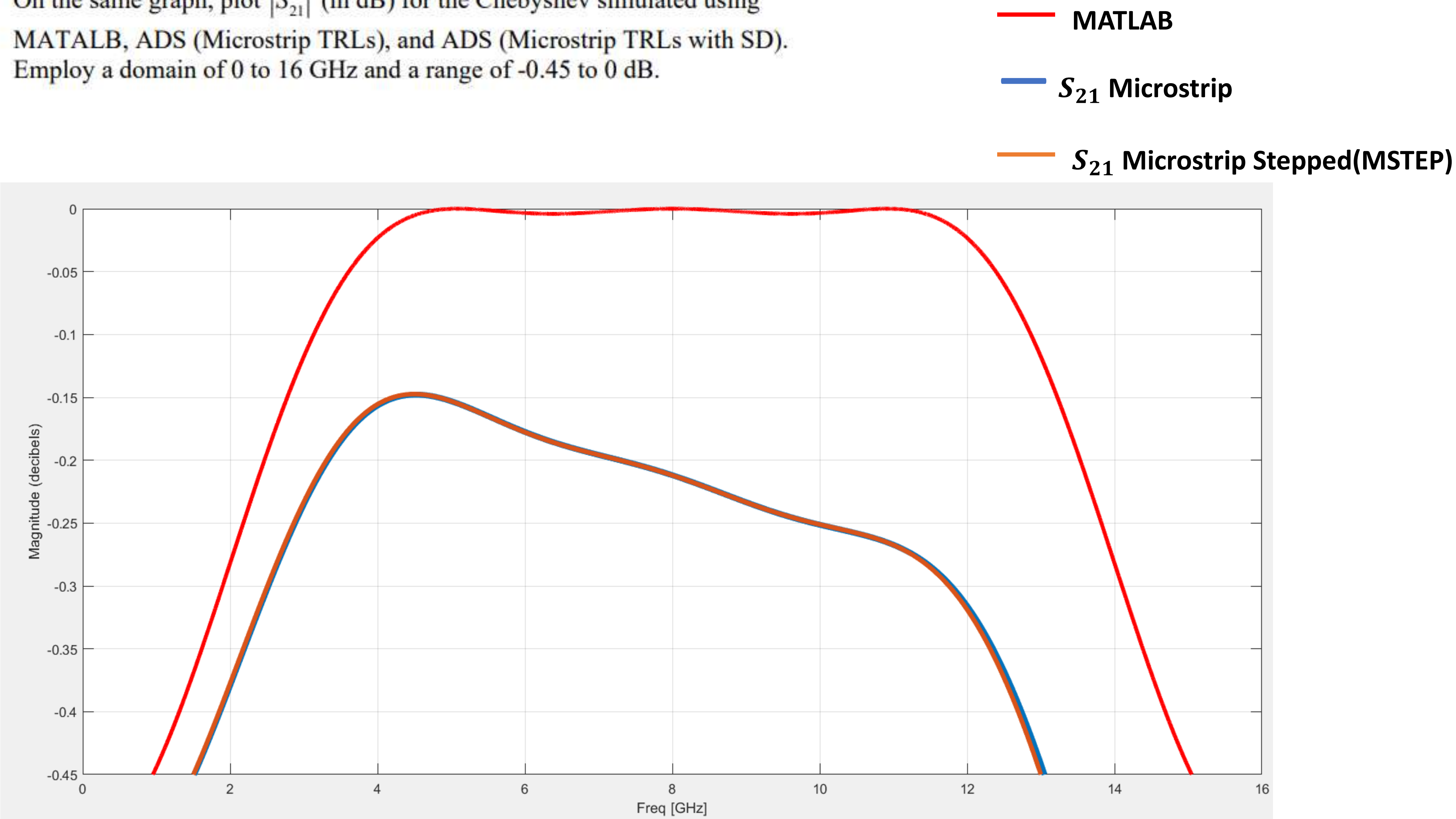
On the same graph, plot $|S_{21}|$ (in dB) for the Butterworth simulated using MATALB and the Chebyshev simulated using MATALB. Employ a domain of 0 to 16 GHz and a range of -0.25 to 0 dB.



On the same graph, plot $|S_{11}|$ (in dB) for the Chebyshev simulated using MATALB, ADS (Microstrip TRLs), and ADS (Microstrip TRLs with SD). Employ a range of -40 to 0 dB.



On the same graph, plot $|S_{21}|$ (in dB) for the Chebyshev simulated using MATALB, ADS (Microstrip TRLs), and ADS (Microstrip TRLs with SD). Employ a domain of 0 to 16 GHz and a range of -0.45 to 0 dB.



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