

**Faculty of Engineering
Cairo University
EECE Department
ELC 465
Advanced Microwaves**

BY:

MOAMEN NASSER SAAD

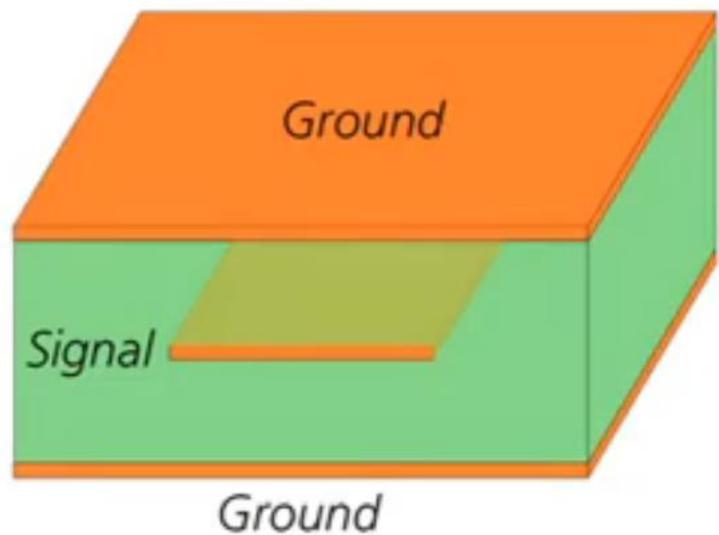
SECTION 3 BN 37

SUBMITTED TO DR. ISLAM ESHRAH

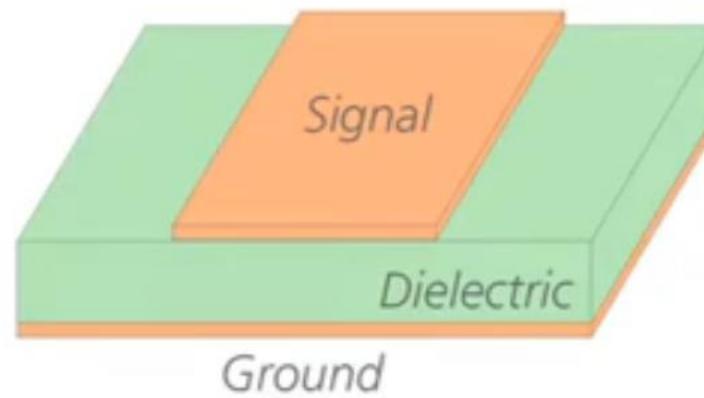
Assignment 1 comparison of different TL types on PCB

- 1- Microstrip Line
- 2- Strip Line
- 3- CPW (coplanar waveguide)

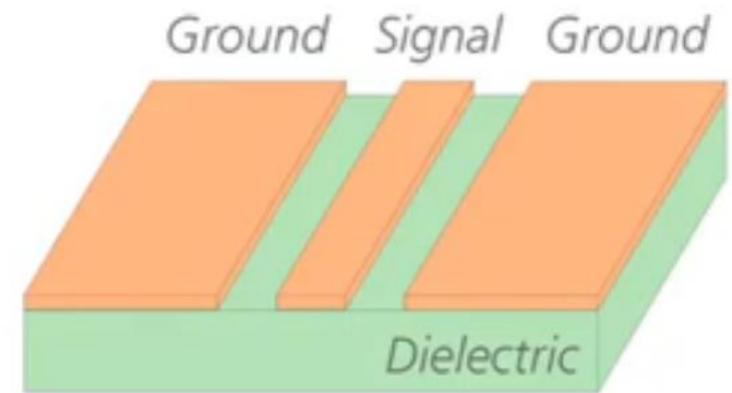
Stripline



Microstrip



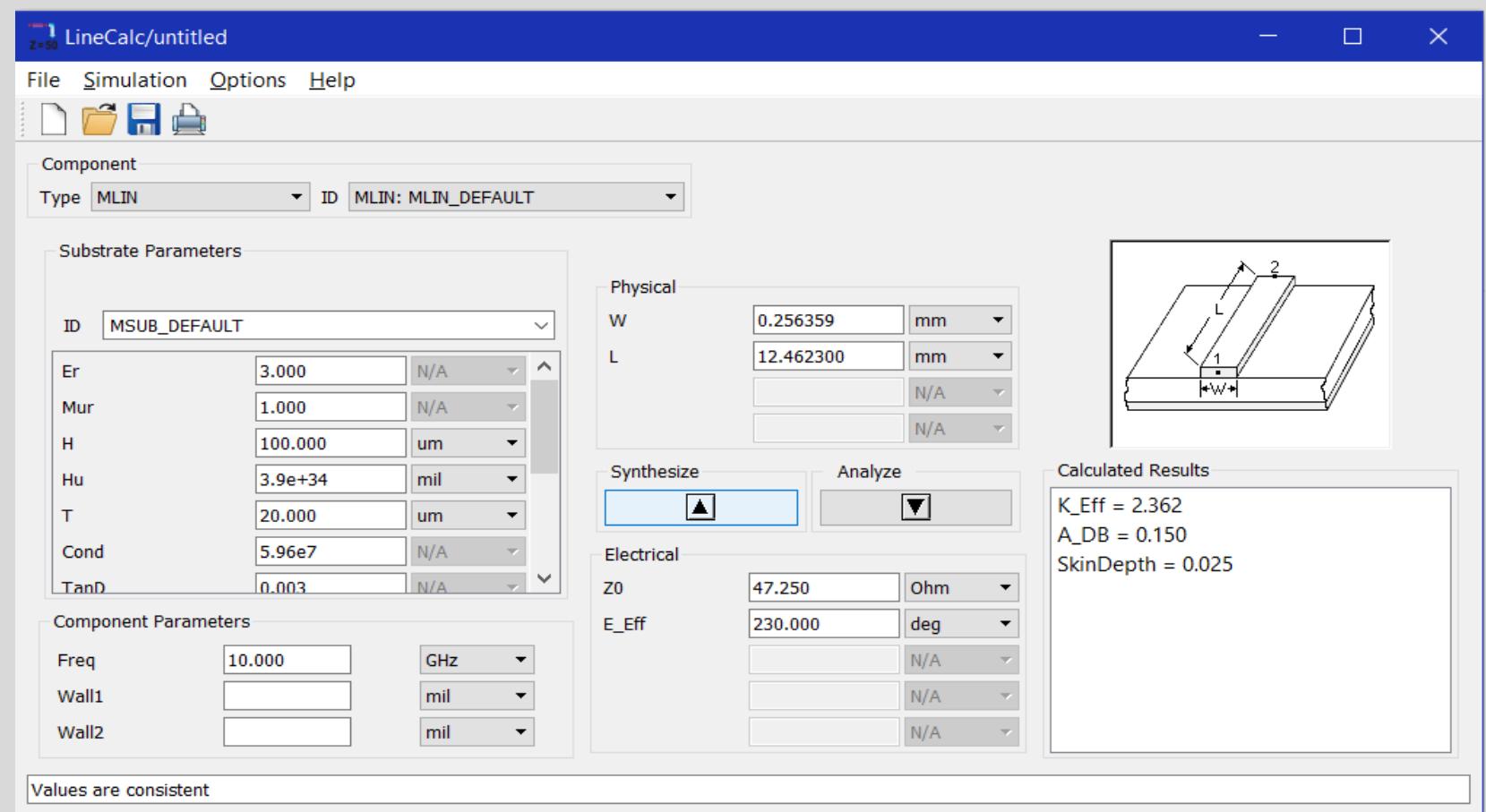
Coplanar



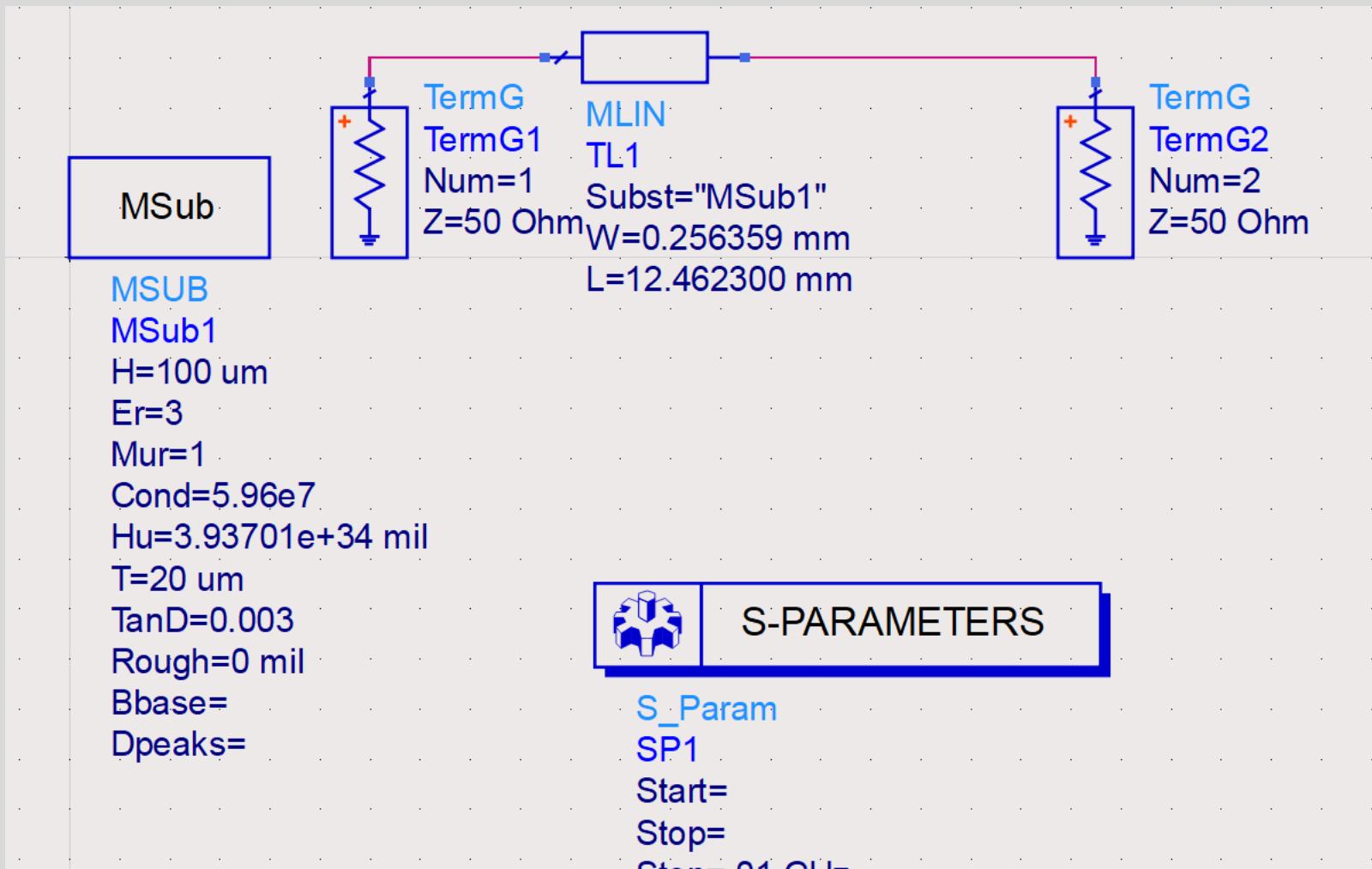
1-MICROSTRIP LINE

Line calc to get the values of W and L

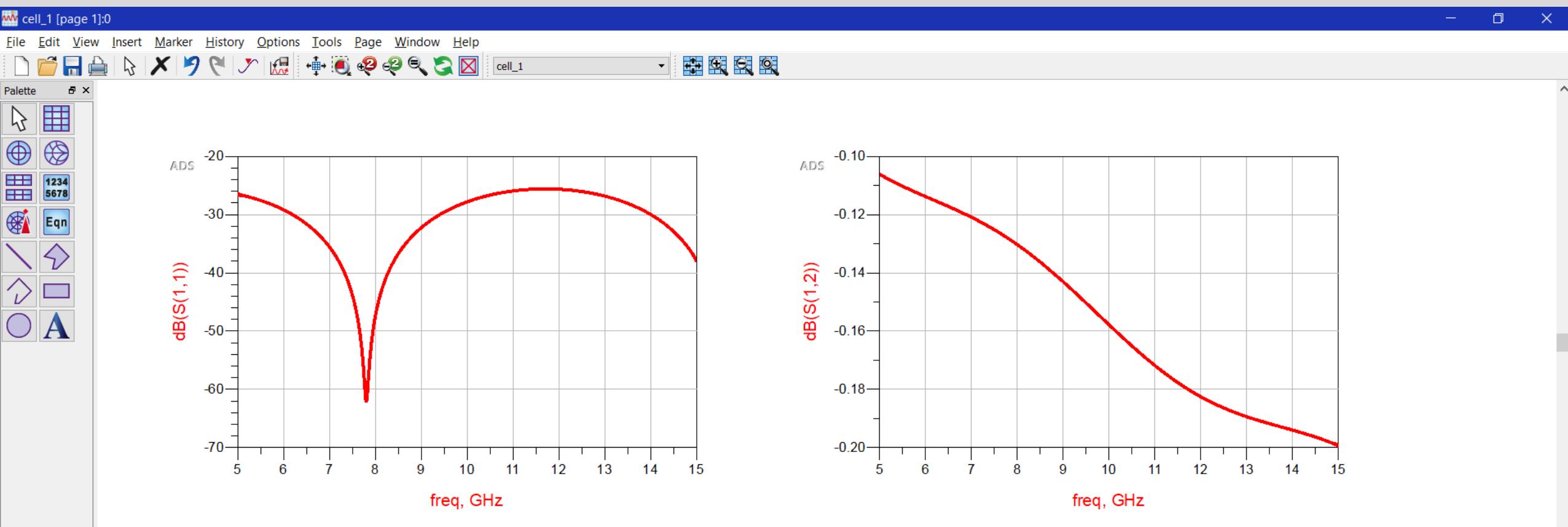
$$W = 0.2563 \text{ mm}$$
$$L = 12.4632 \text{ mm}$$



SCHEMATIC DESIGN



VALUES FROM SCHEMATIC



VIA AND LAYERS

substrate1 [AdvancedMicrowaves.lib] (Substrate):8

File Technology Edit View Options Tools Window Help

Substrate Name: substrate1

Use right mouse context menus to add or delete substrate items.

Select items on the substrate and view their properties below.

Shortcuts in the Edit menu can be used to quickly edit the next substrate item.

Entire Substrate

Bounding area layer: <none>

Use all purposes except: purpose1 purpose2

7.87402

3.93701

0 mil

AIR

Dielectric_1 (3)
100 micron

Dielectric_1 (3)
100 micron

cond

cond_cond2

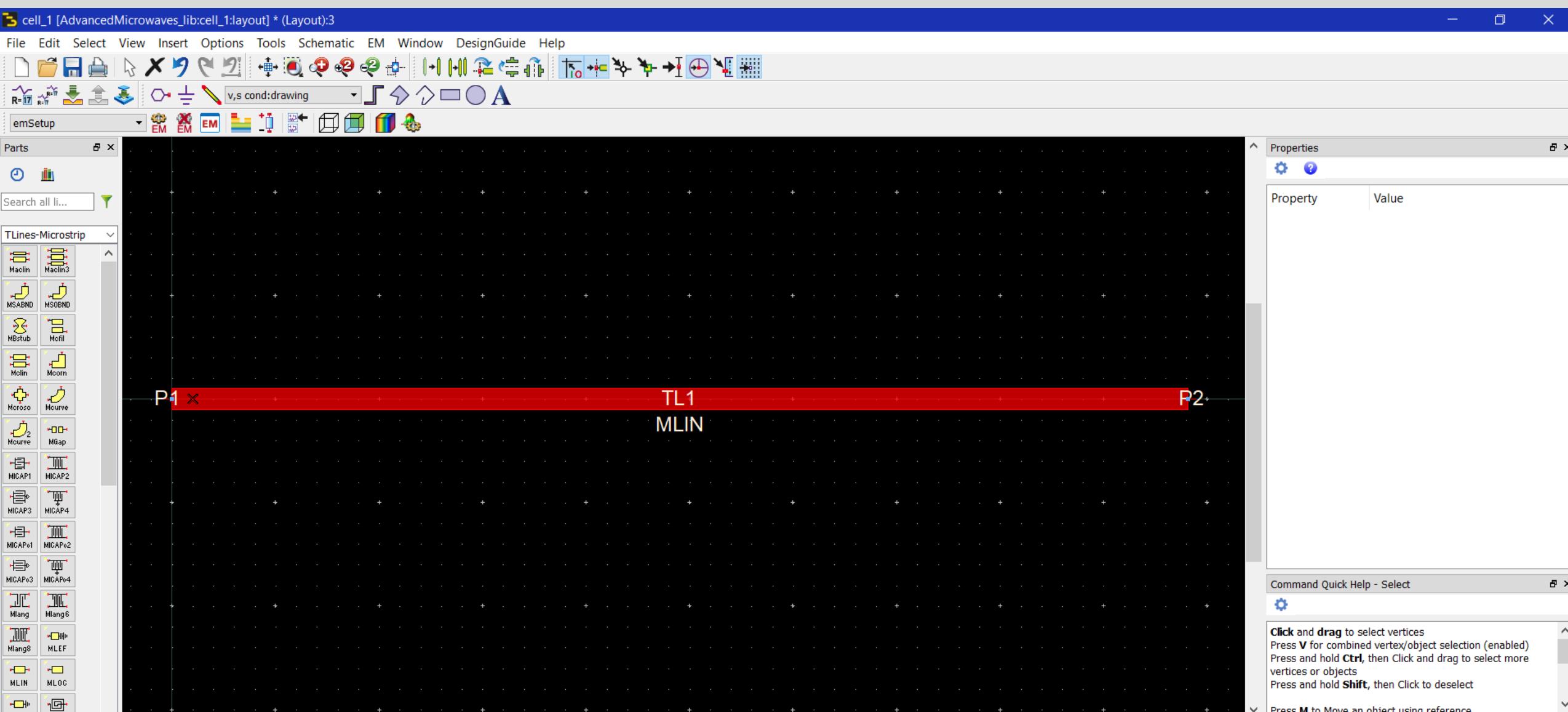
Substrate Layer Stackup

Type	Name	Material	Thickness
Dielectric	AIR		
Conductor La...	cond (2)	Copper	20 um
Dielectric	Dielectric_1		100 um
Dielectric	Dielectric_1		100 um
Cover	PERFECT_CONDUCTOR		20 um

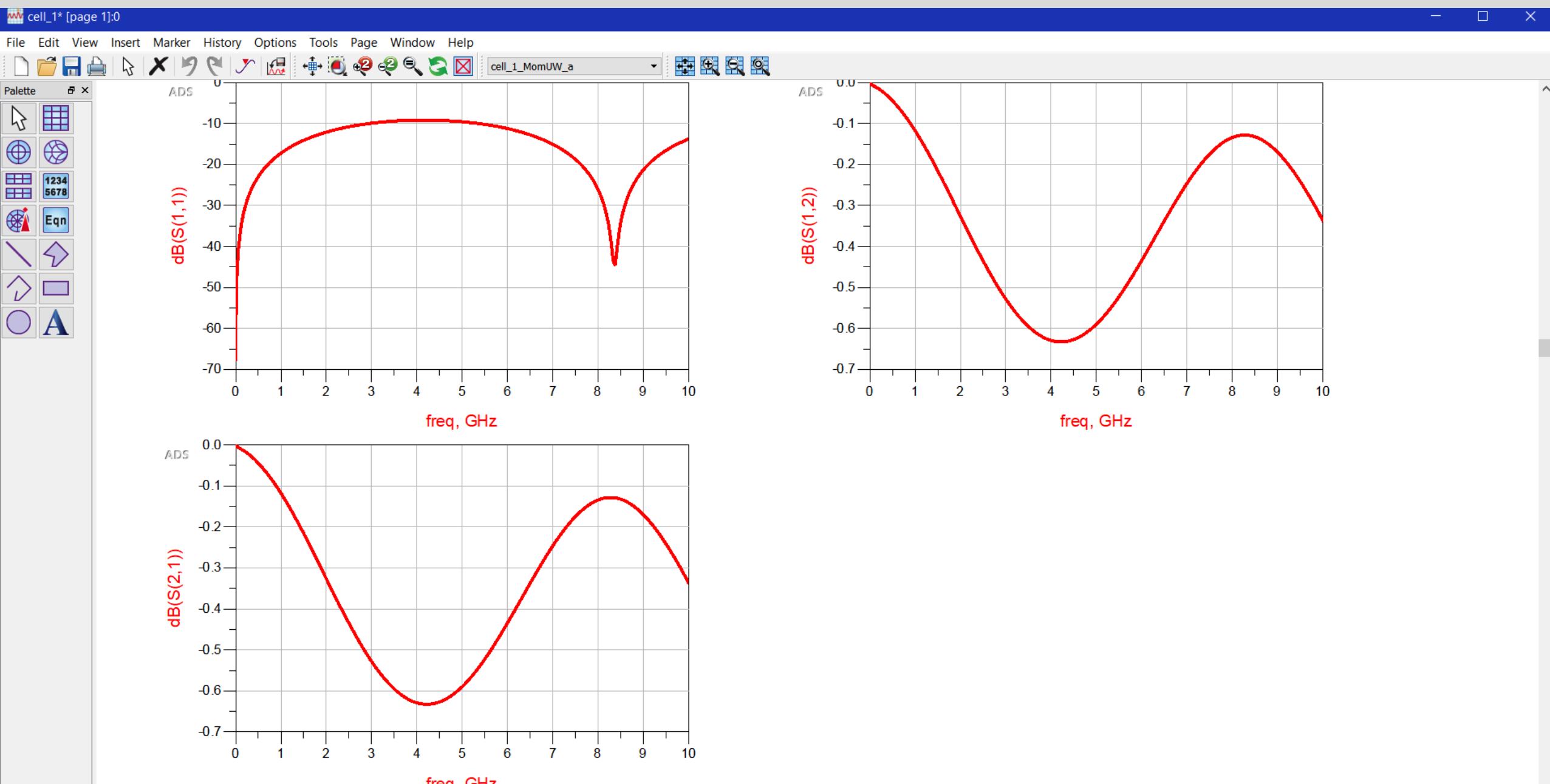
Substrate Vias

Type	Name	Top	Bottom	Material
Conductor Via	cond_cond2 (7)	cond (2)	Bottom Cover	PERFECT_C...

PCB DESIGN



LOSS VALUES FROM PCB

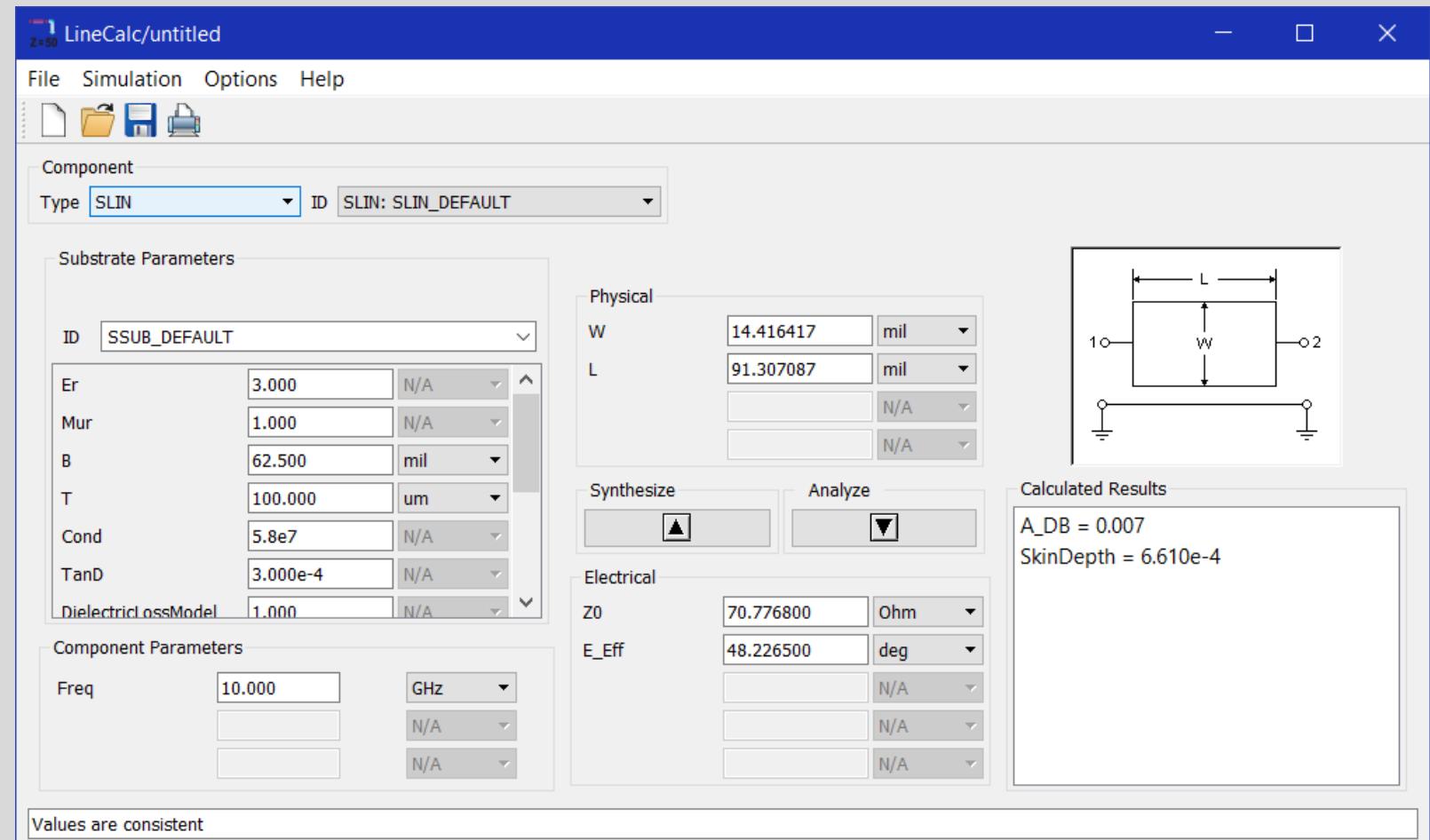


2- STRIP LINE

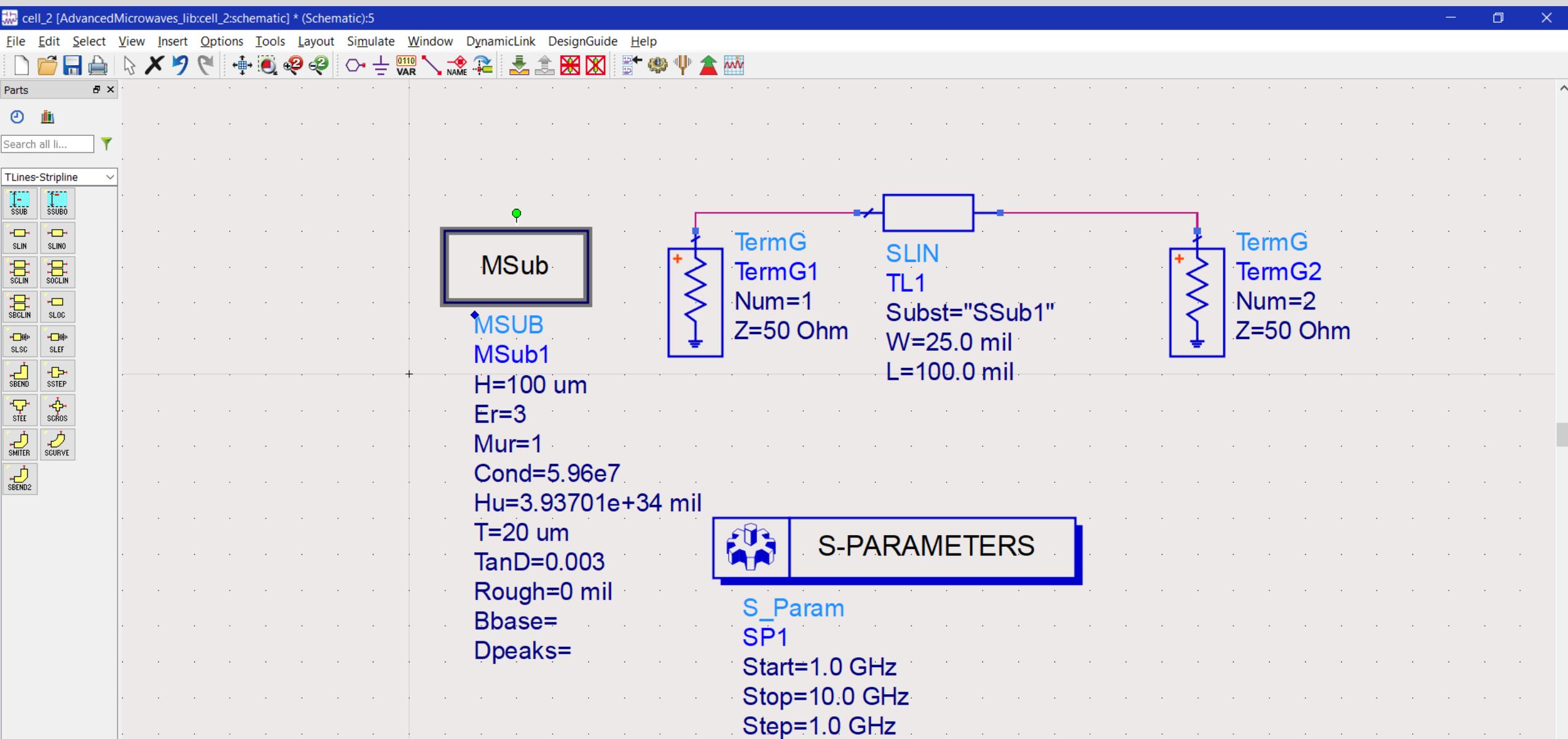
Line calc to get the values of W and L

$$W = 14.416417 \text{ mil}$$

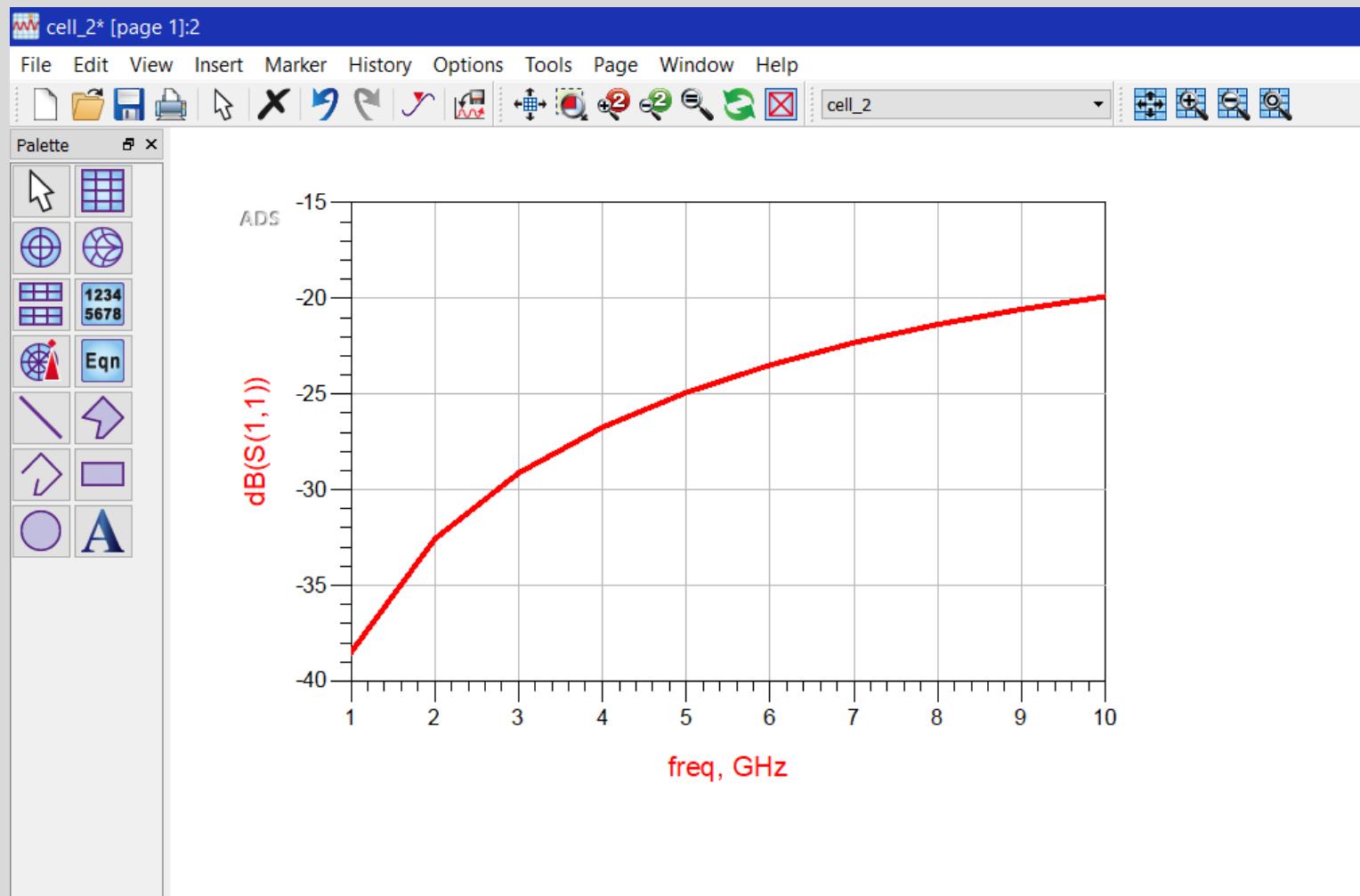
$$L = 91.307087 \text{ mil}$$



SCHEMATIC DESIGN



LOSSES VALUES FROM SCHEMATIC



VIA AND LAYERS

substrate2 [AdvancedMicrowaves.lib] * (Substrate):10

File Technology Edit View Options Tools Window Help

Substrate Name: substrate2

Use right mouse context menus to add or delete substrate items.

Select items on the substrate and view their properties below.

Shortcuts in the Edit menu can be used to quickly edit the next substrate item.

Entire Substrate

Bounding area layer: <none> ...

Use all purposes except: purpose1 purpose2

The 3D rendering shows a cross-section of the substrate stackup. It consists of several layers: an air gap at the top, followed by two 100 micron thick Dielectric_1 layers, a 20 um thick Copper conductor layer labeled 'cond', another 100 micron thick Dielectric_1 layer, and a bottom layer labeled 'PERFECT_CONDUCTOR'. A vertical via is labeled 'cond_cond2' and is located between the first and second dielectric layers. A horizontal conductor is labeled 'cond' and is located in the middle dielectric layer. The stackup is labeled with its height: 7.87402, 3.93701, and 0 mil.

Substrate Layer Stackup

Type	Name	Material	Thickness
Dielectric	AIR		
Dielectric	Dielectric_1	100 um	
Conductor La...	cond (2)	Copper	20 um
Dielectric	Dielectric_1	100 um	
Cover	PERFECT_CONDUCTOR	20 um	

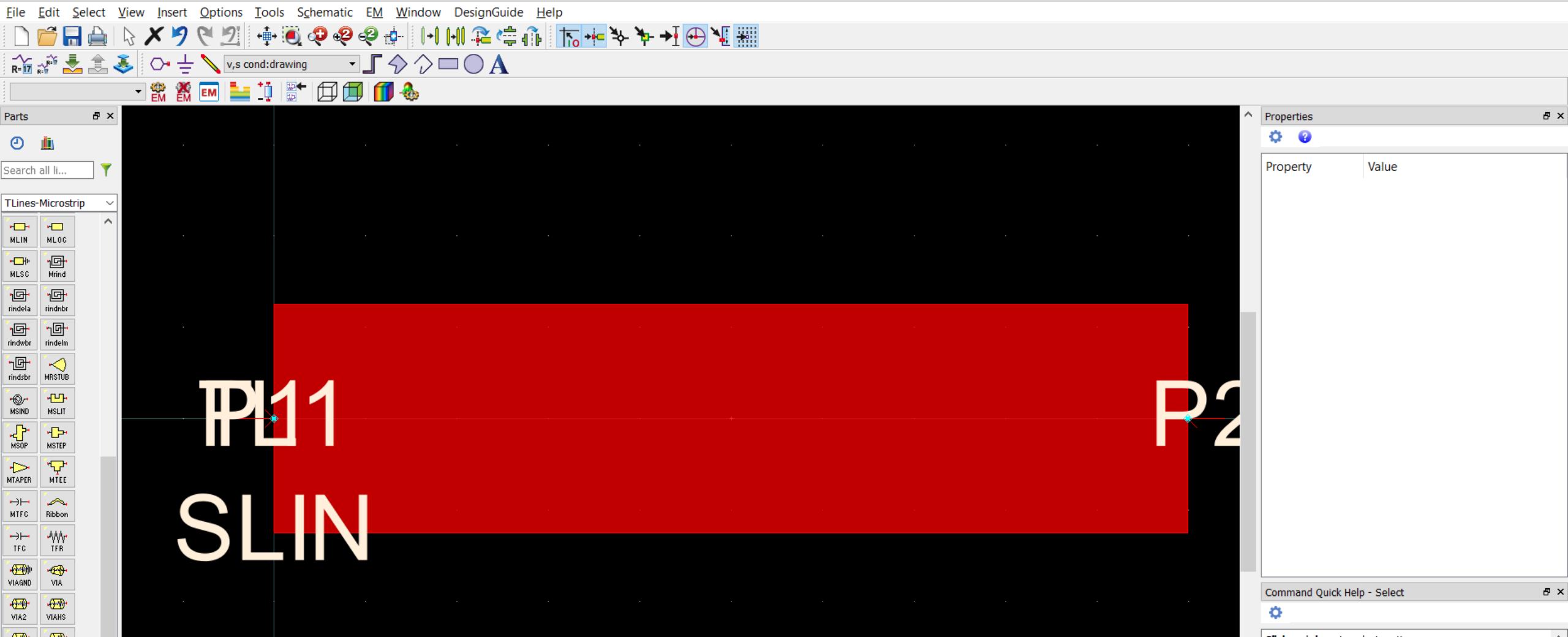
Substrate Vias

Type	Name	Top	Bottom	Material
Conductor Via	cond_cond2 (7)	Interface 1	Bottom Cover	PERFECT_C...

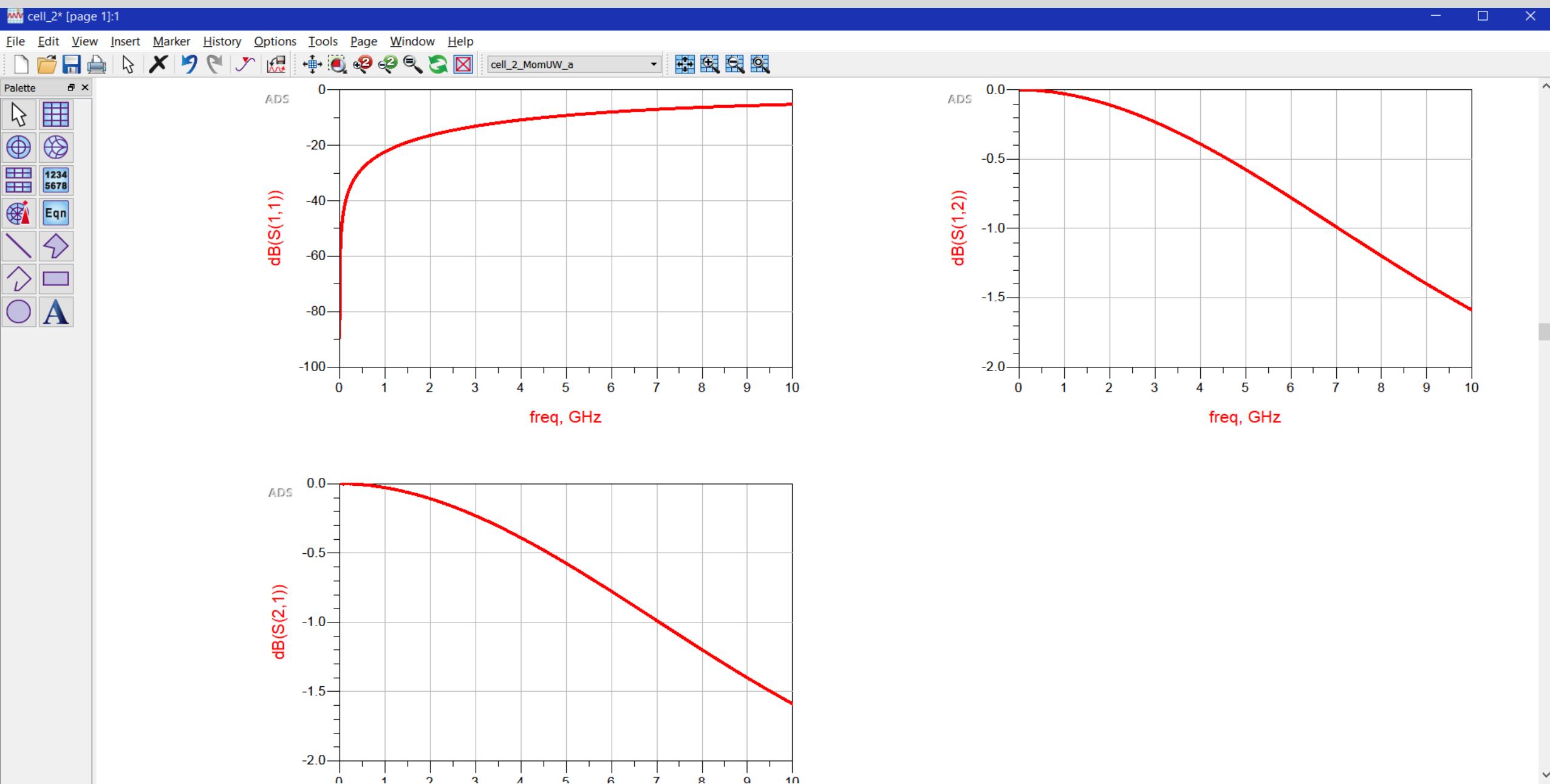
Select a substrate item to see

PCB DESIGN

I am still learning ads and layout so this isn't the final results
My GP not in analog



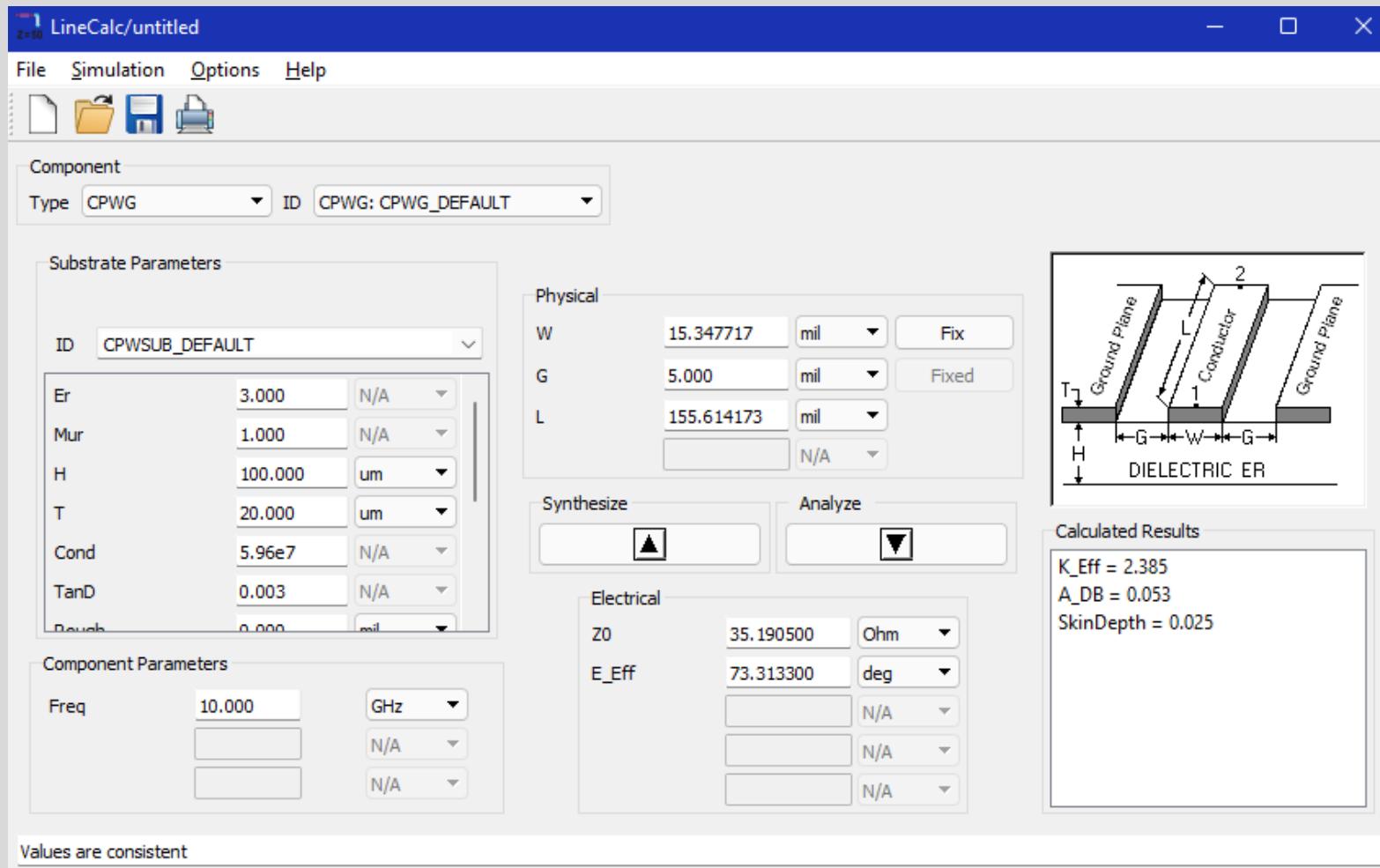
LOSS VALUES FROM PCB



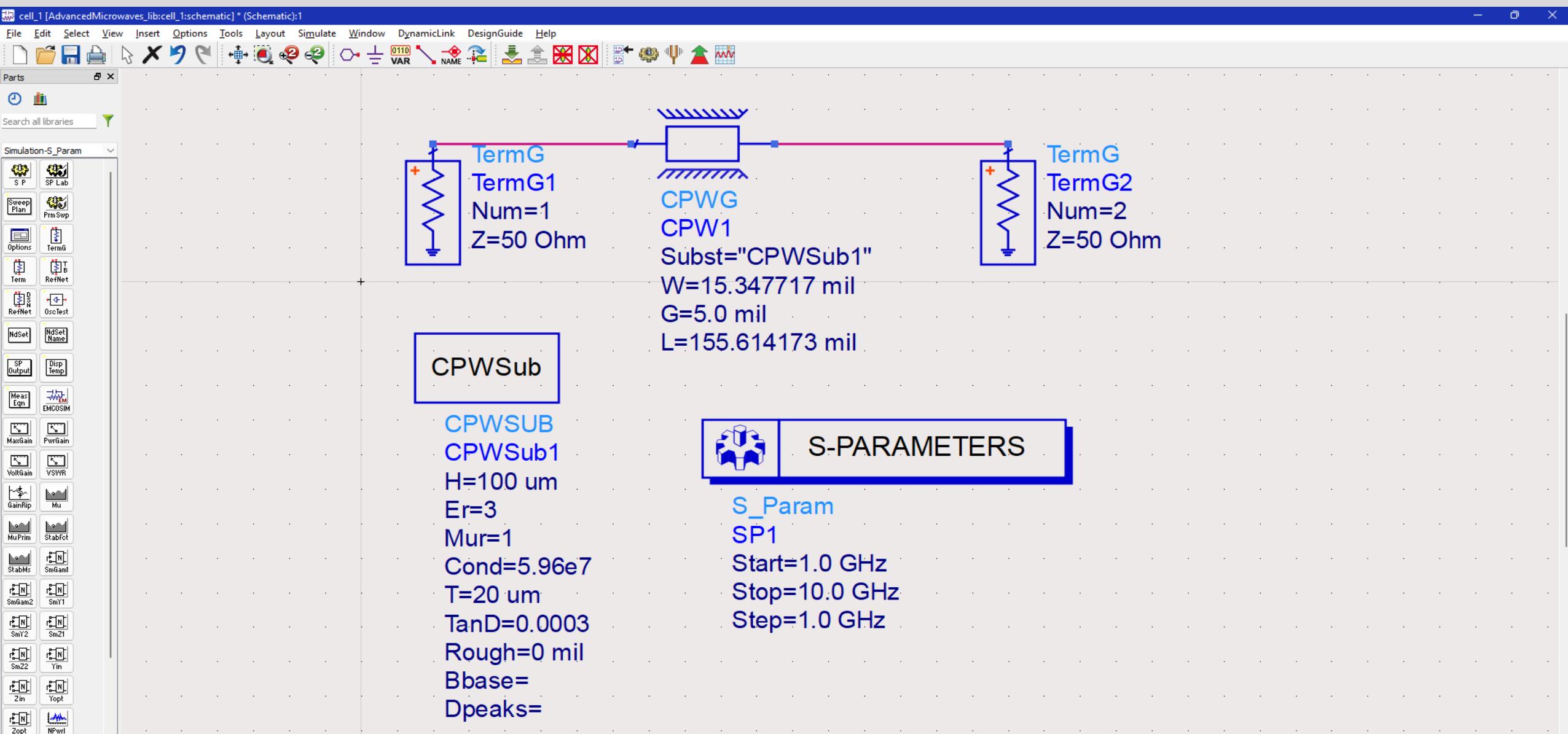
3- CPW

Line calc to get the values of W and L

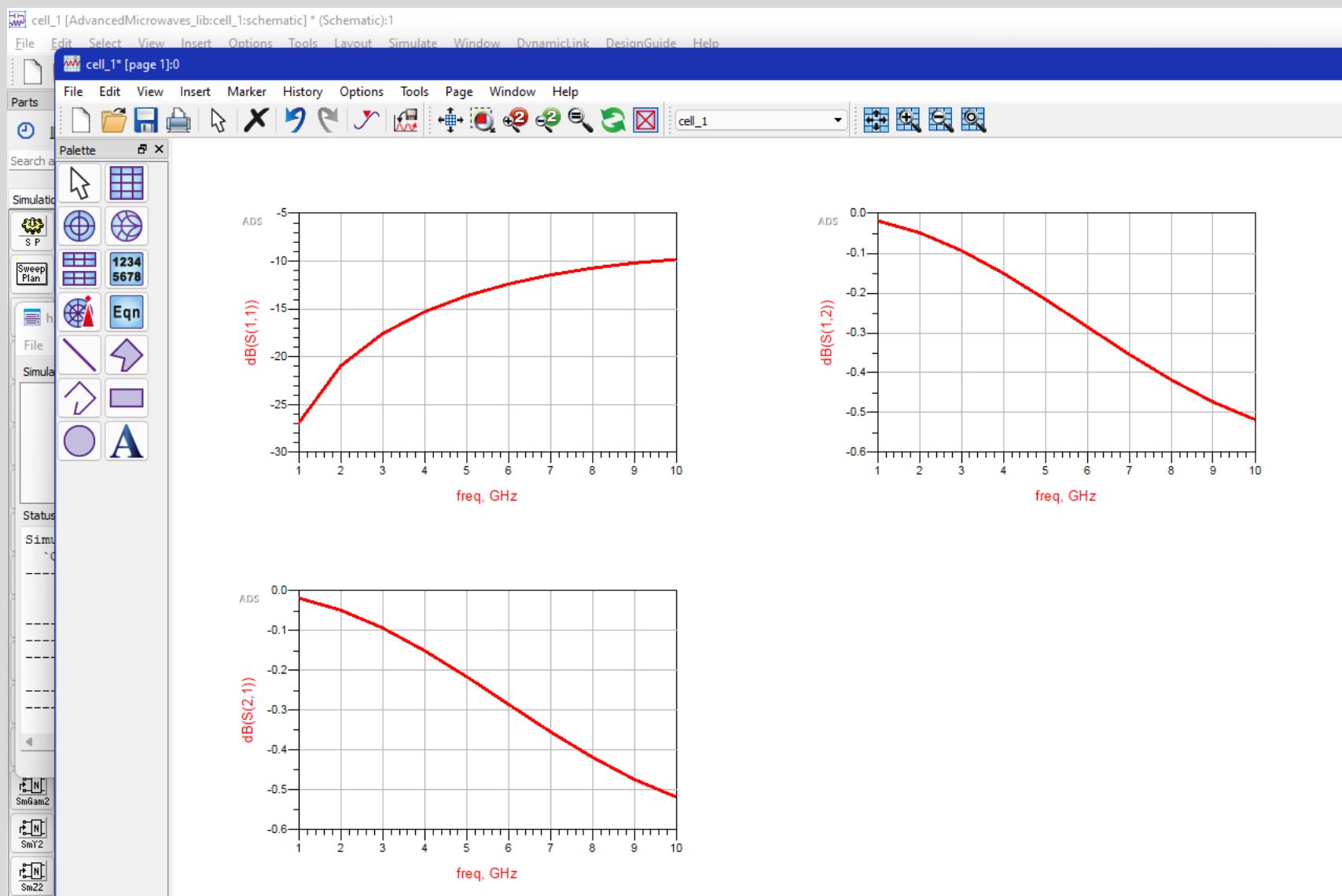
$$W = 14.416417 \text{ mil}$$
$$L = 91.307087 \text{ mil}$$



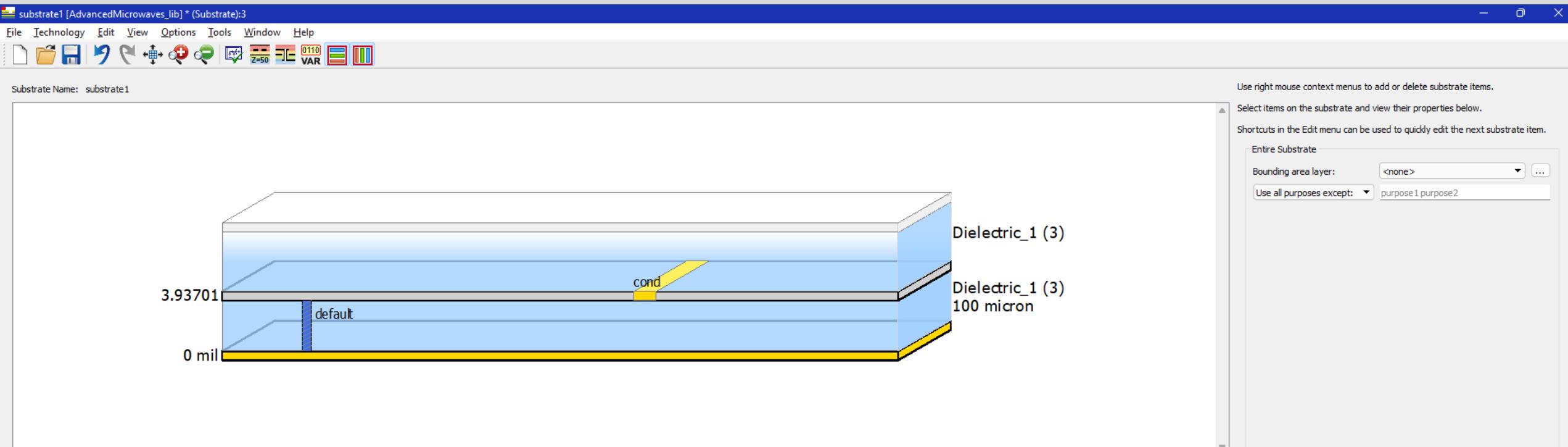
SCHEMATIC DESIGN



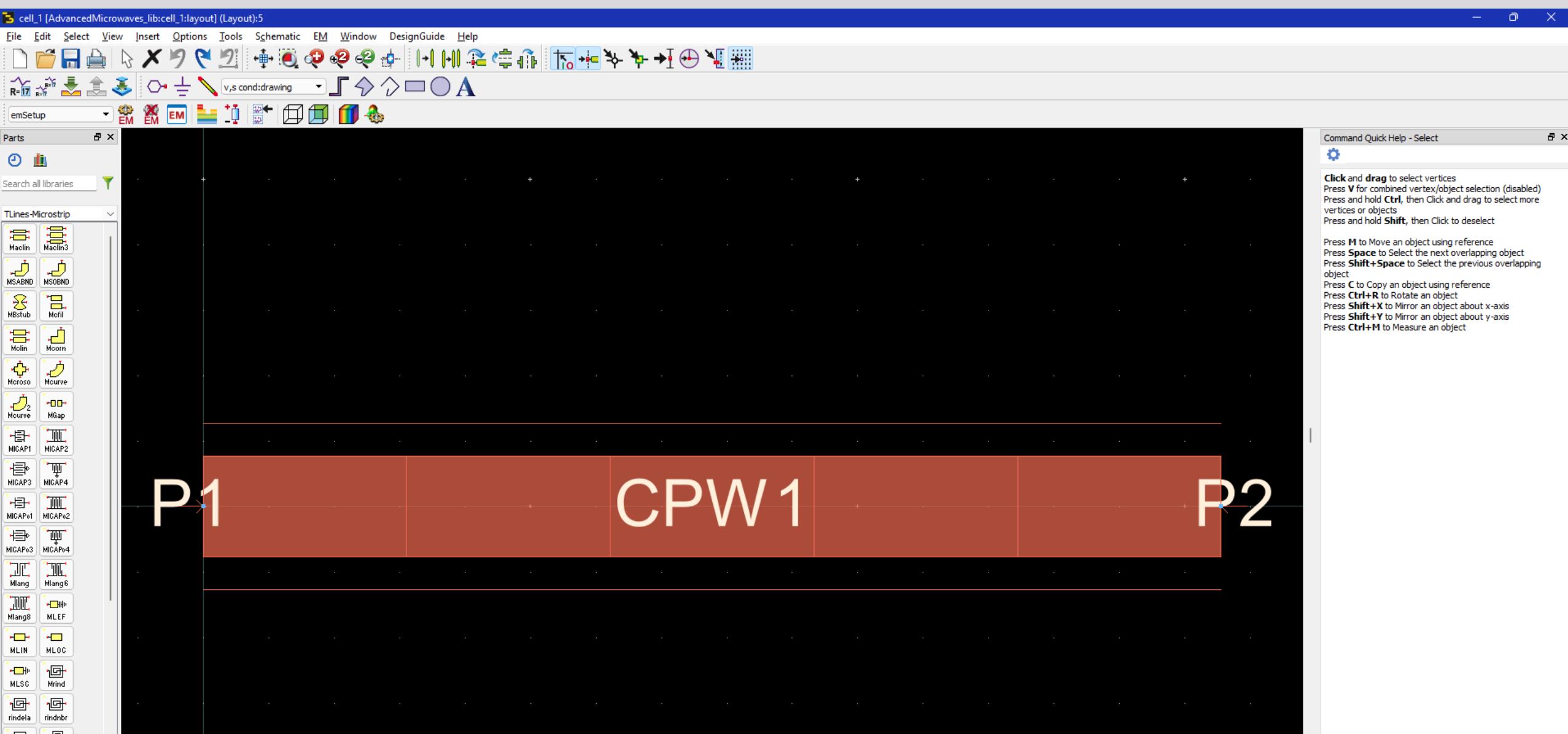
LOSSES VALUES FROM SCHEMATIC



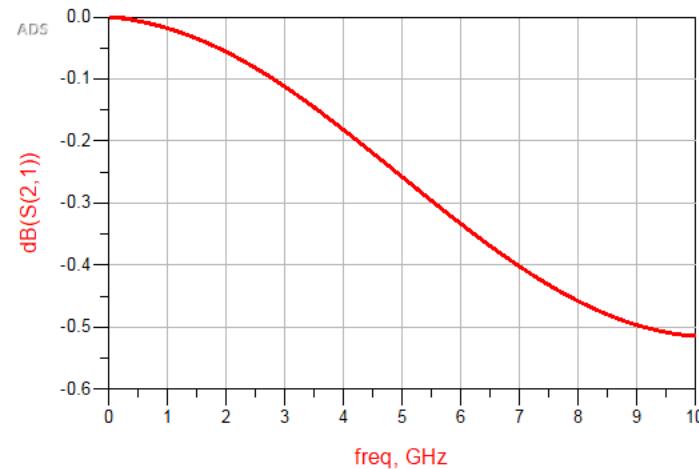
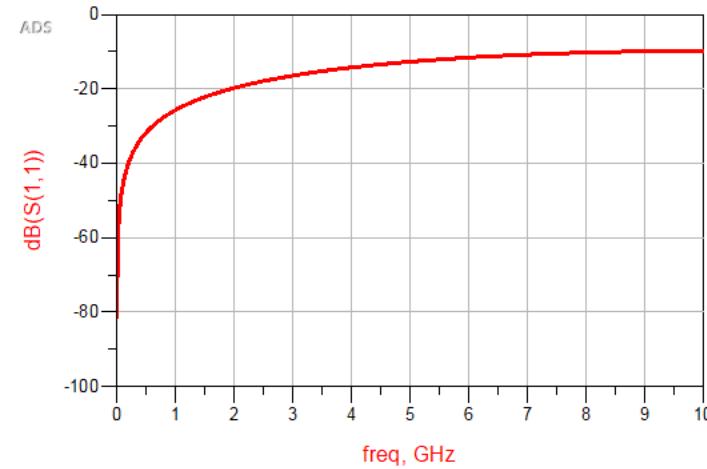
VIA AND LAYERS



LAYOUT DESIGN



LOSS VALUES FROM LAYOUT



Assignment 2

Mat-Lab Code

ASSIGNMENT 2

MAT LAB CODE TO DETERMINE THE CHARGE DISTRIBUTION ON A CHARGED CONDUCTING STRIP

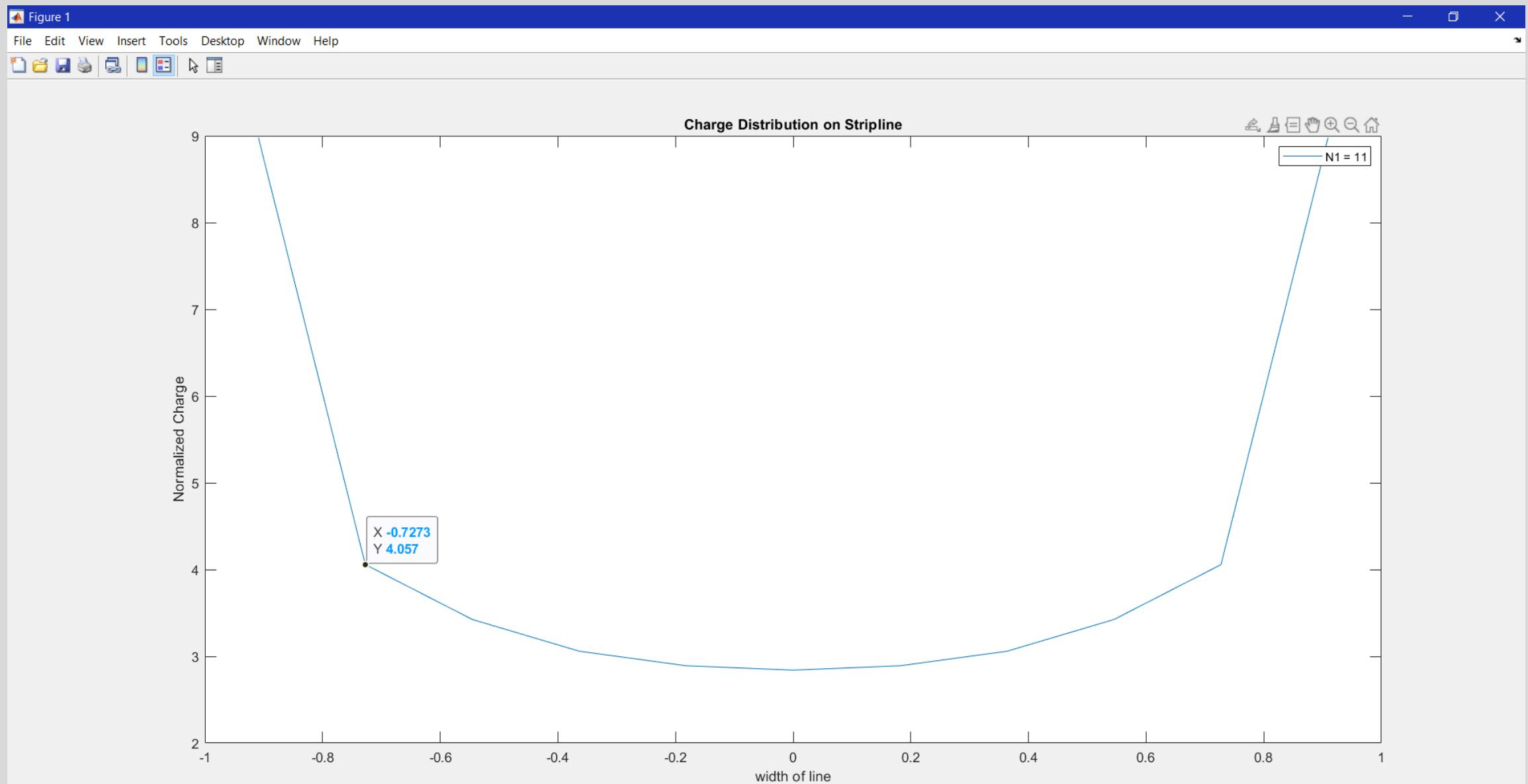
Code is here for more info : for part 1: 1D [My code](#) for part 2: 2D

I have a problem in plotting graph number 3 in the code it doesn't work

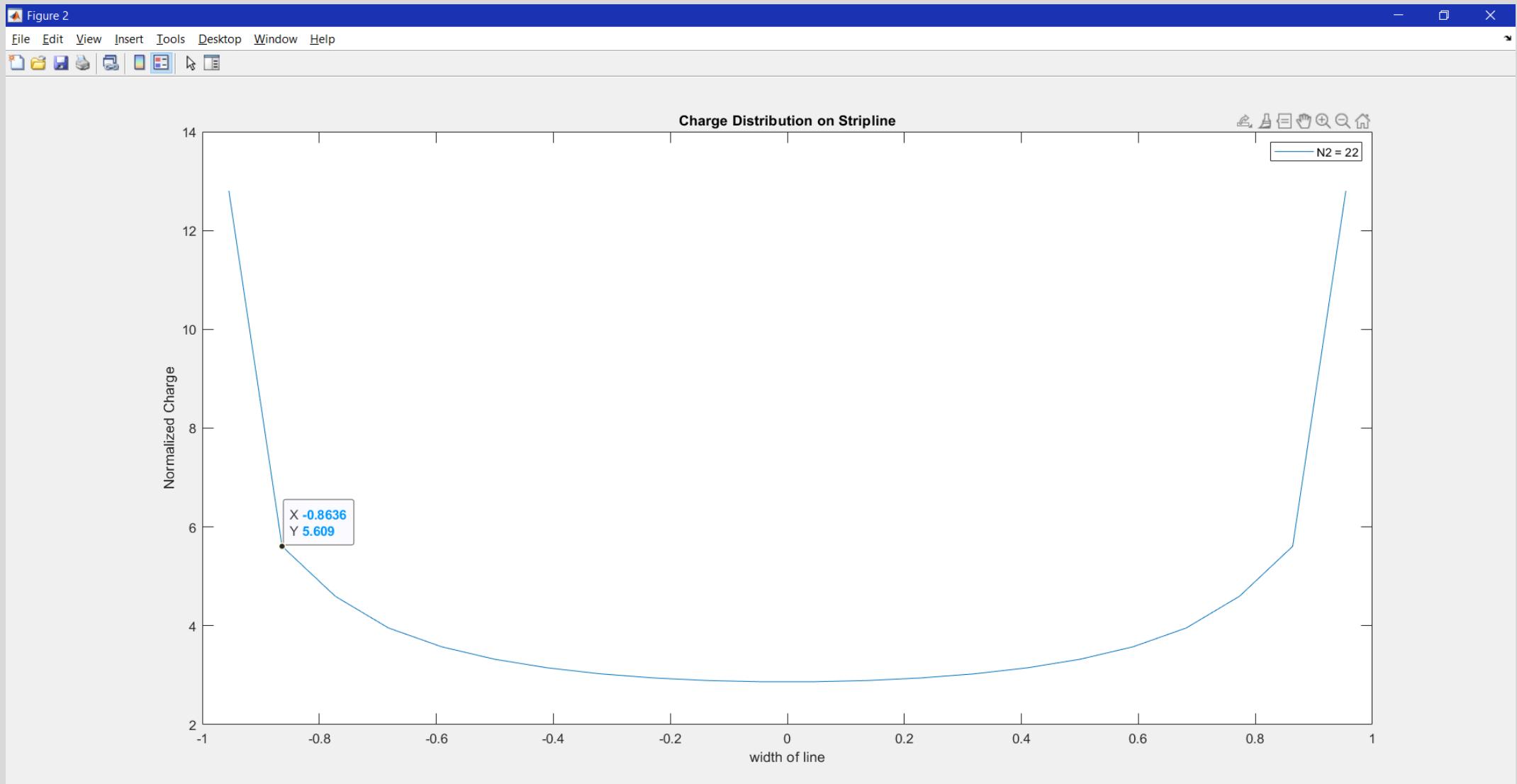
My code only plot 4 figures 1+2+4+5

```
%
37 %% Plotting total charge
38 N_samples = 5:2:100;
39 for counter = 1:length(N_samples)
40     Q_total(counter) = sum(Charge_Calculation(Width,N_samples(counter),V0)*2/(Epsolon0*V0*N_samples(counter)));
41 end
42 Axis_3 = 1./N_samples;
43 figure(3);
44 plot(Axis_3,Q_total);
45 xlabel('1/N_samples');
46 ylabel('Qttotal Normalized');
47 title('Variation of Charge due to number of samples');
48
```

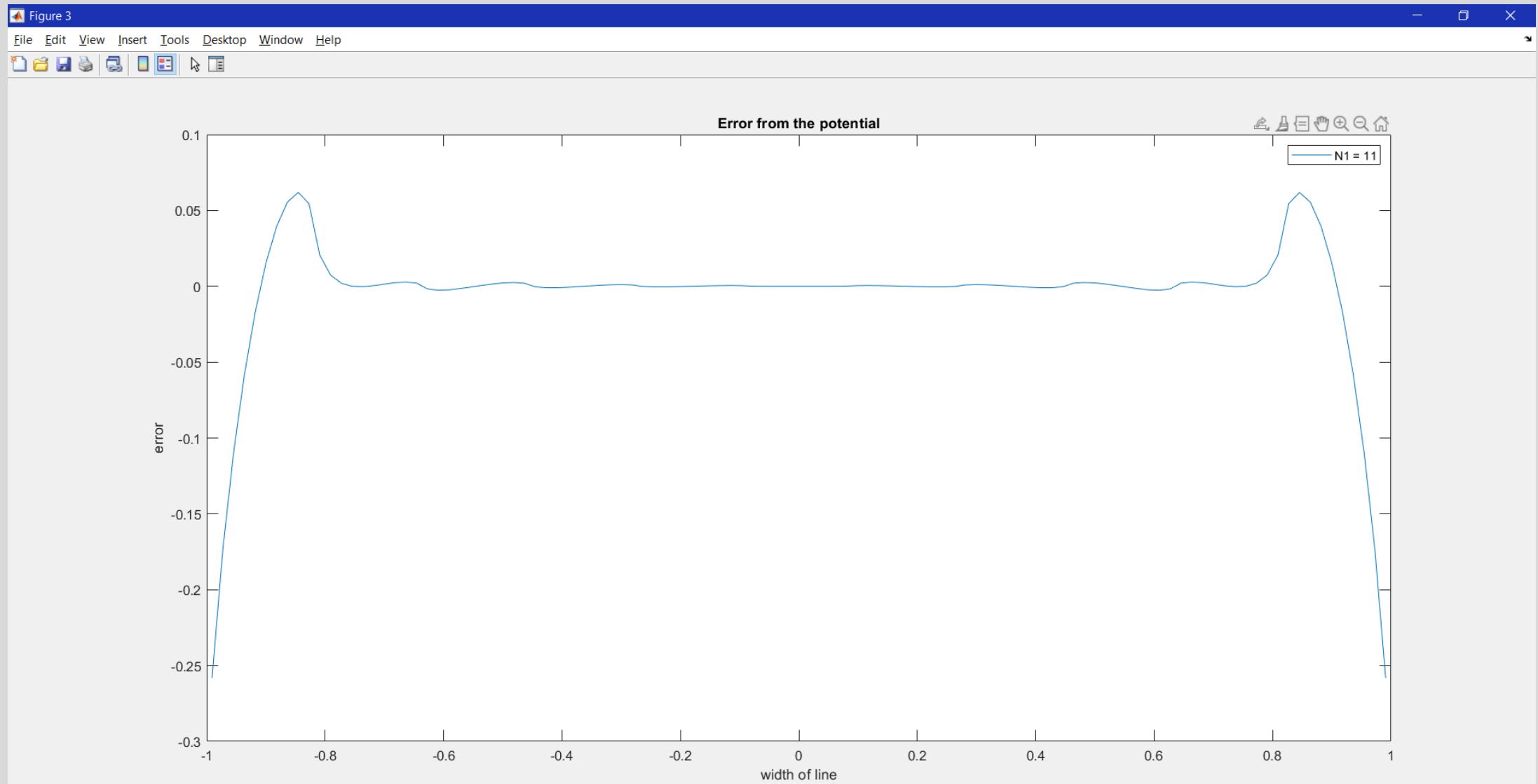
CHARGE DISTRIBUTION PLOT WHEN N = 11



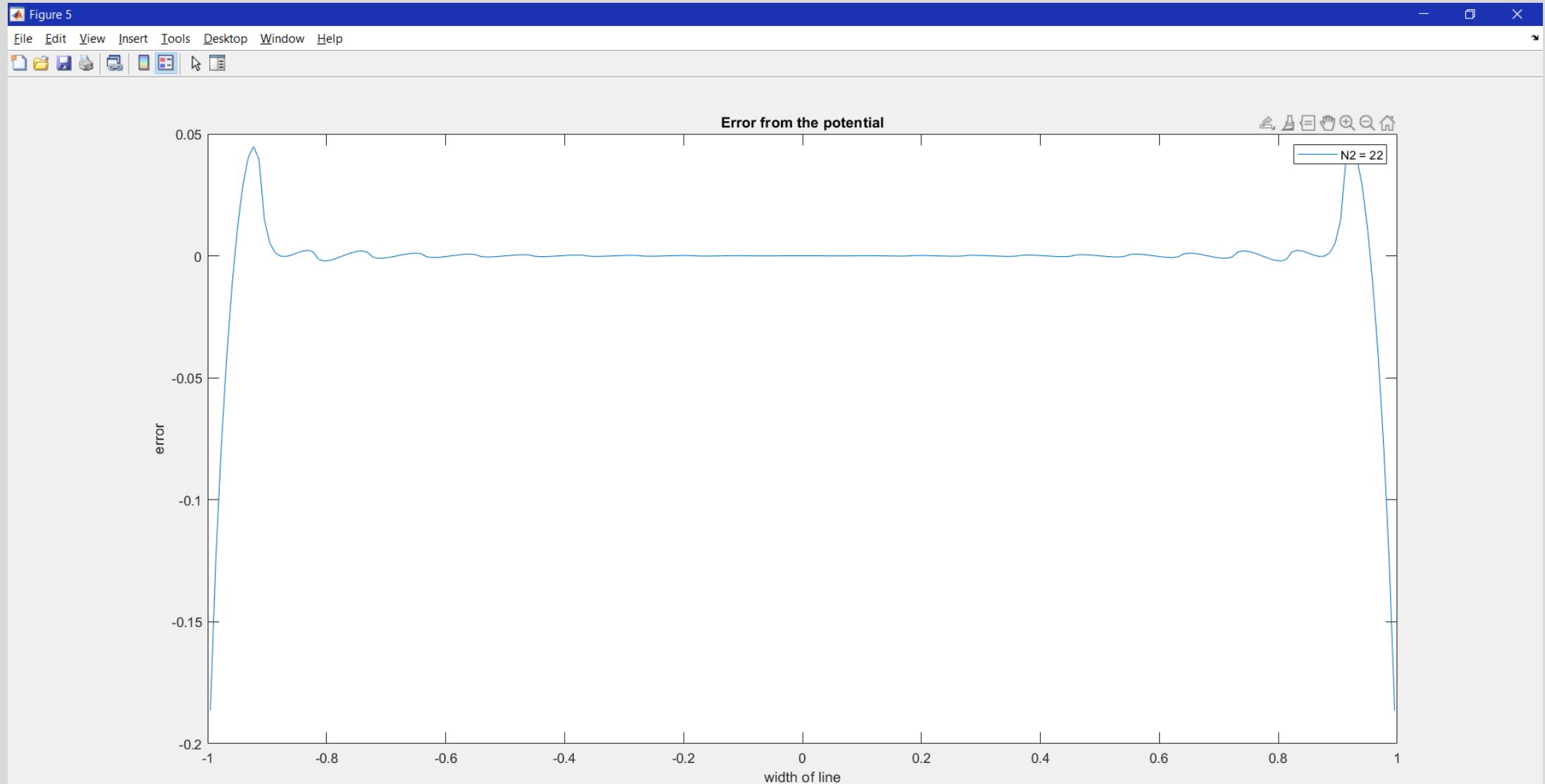
CHARGE DISTRIBUTION PLOT WHEN N = 22



ERROR FROM THE POTENTIAL WHEN N = 11



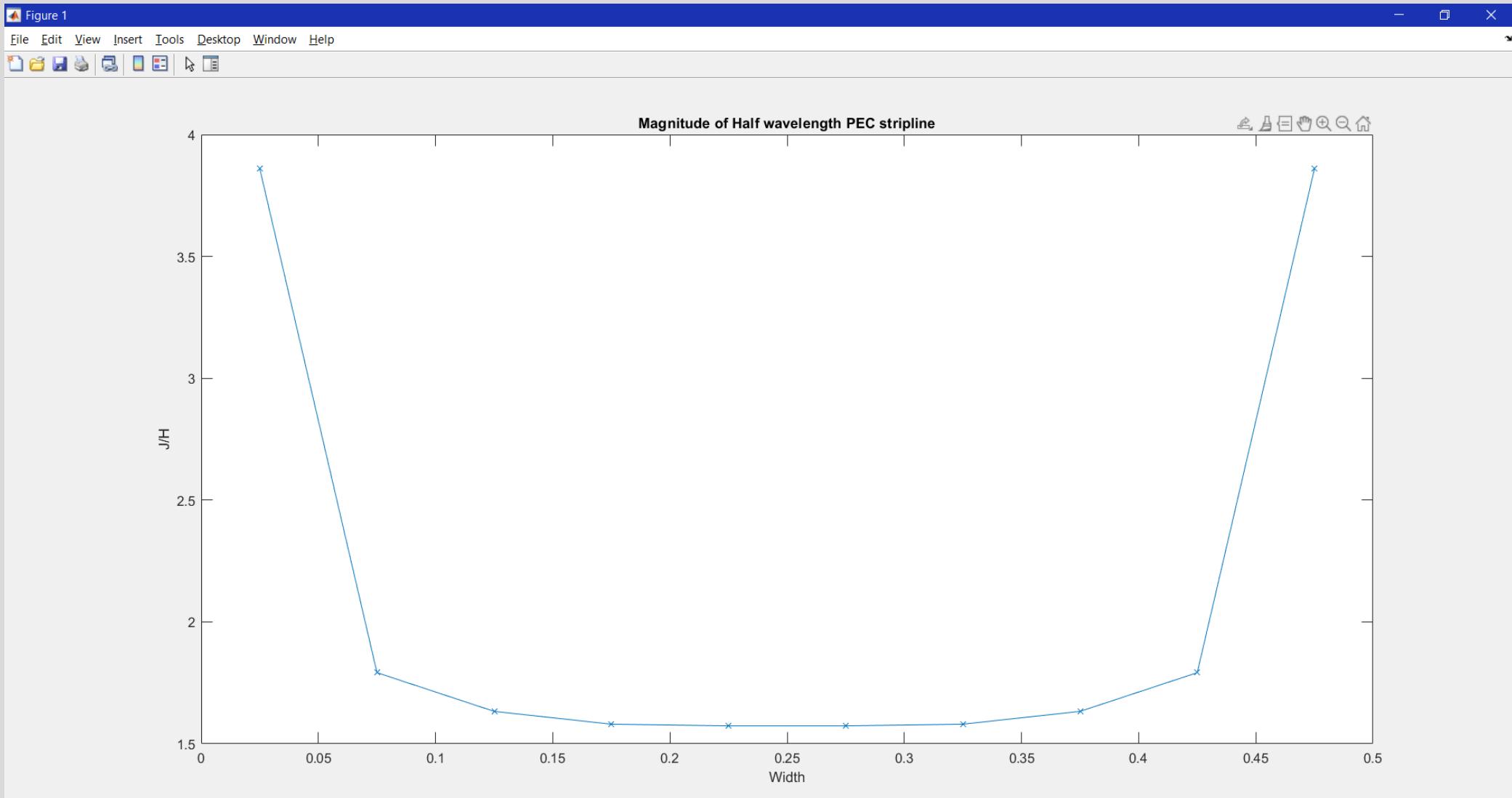
ERROR FROM THE POTENTIAL WHEN N = 22



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Half Wavelength PEC:

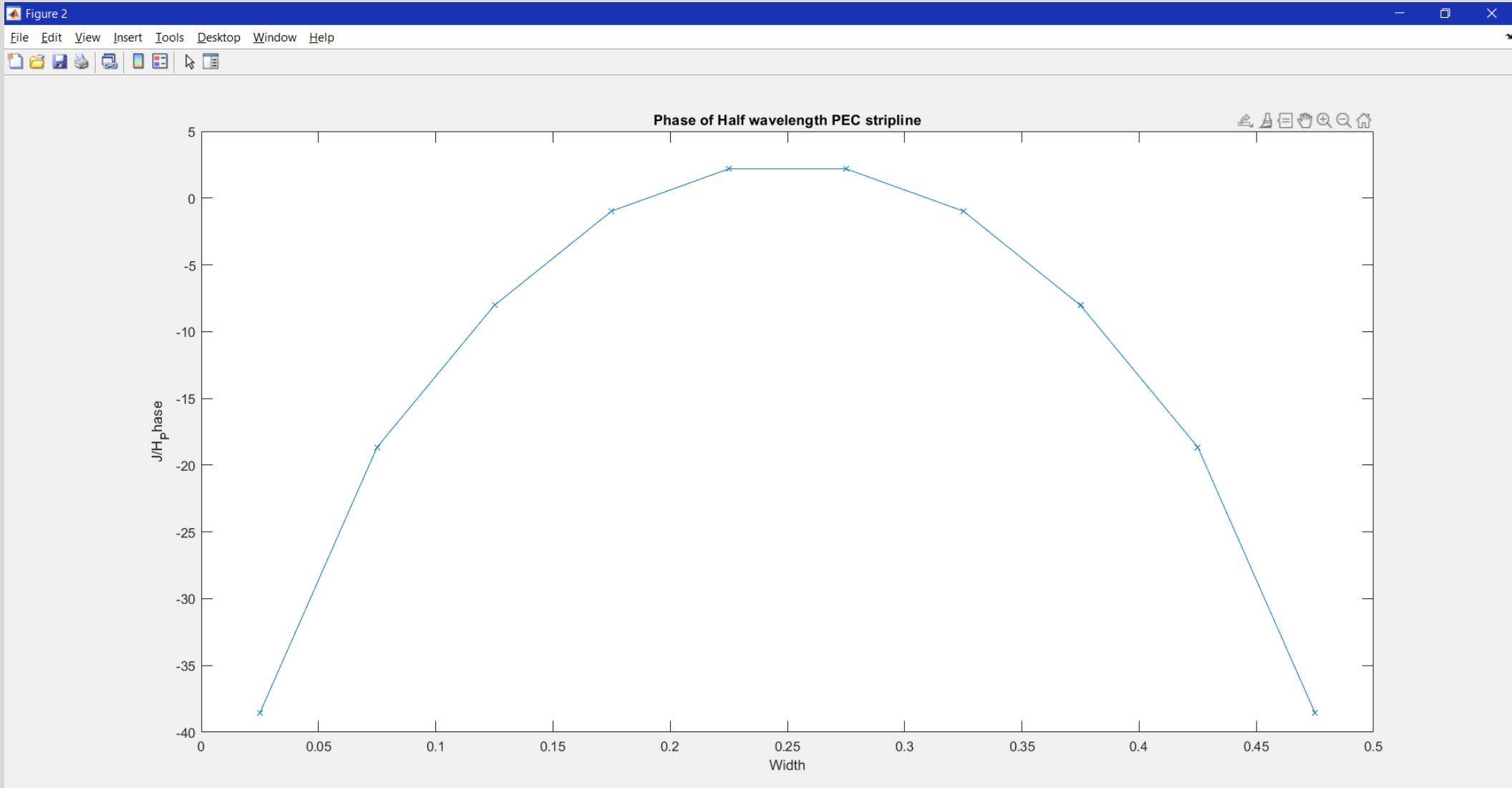
Magnitude



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Half Wavelength PEC:

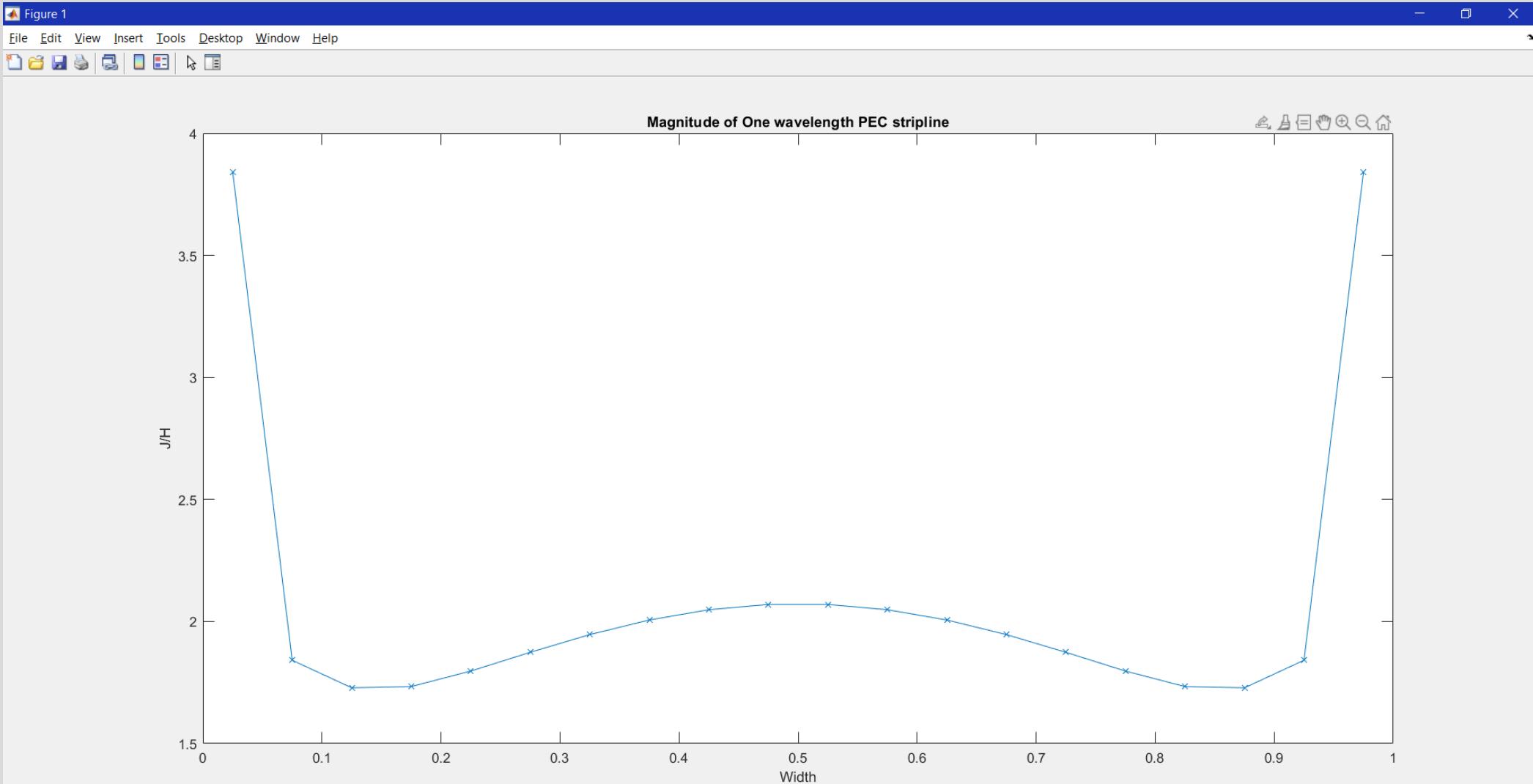
Phase



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

One Wavelength PEC:

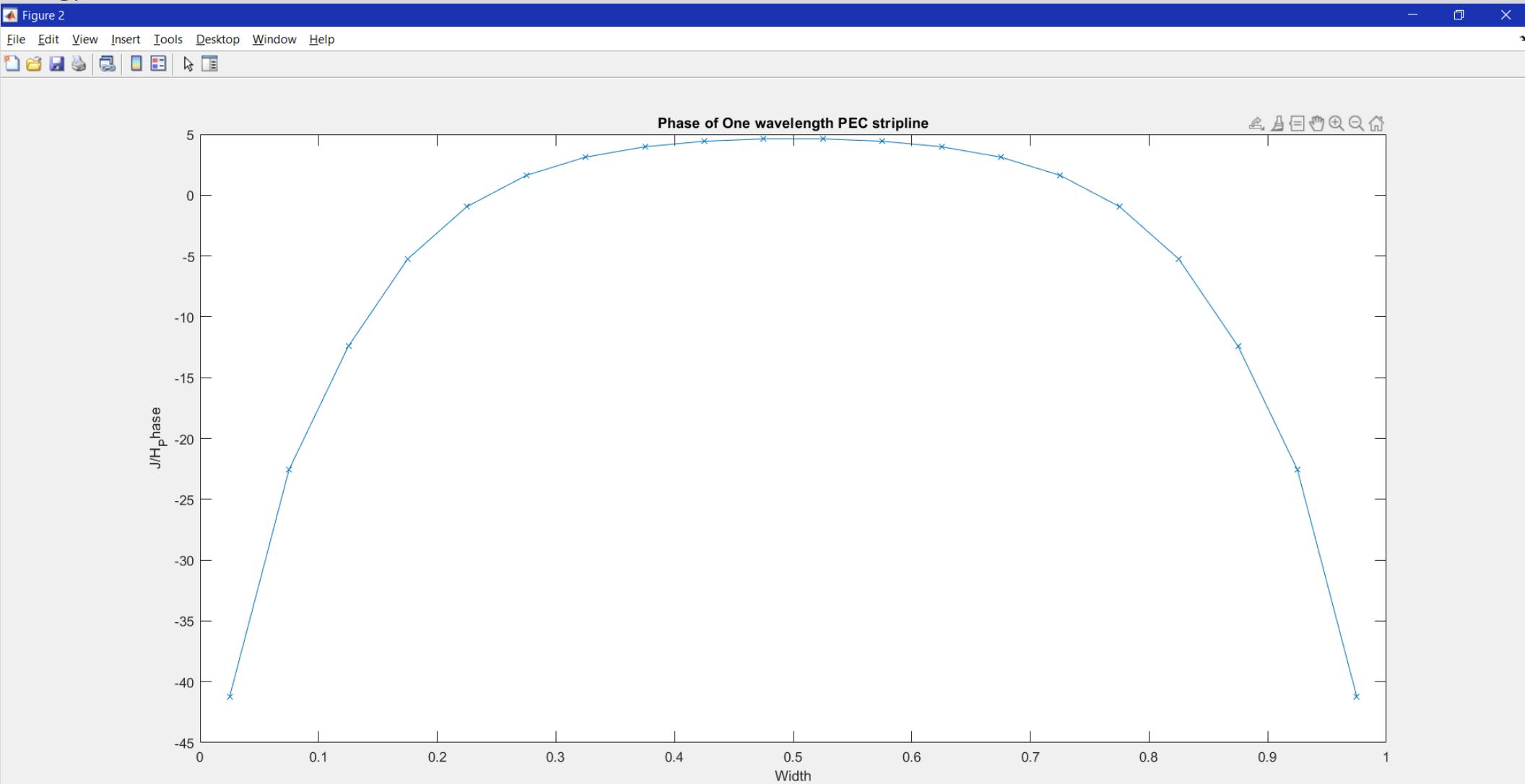
Magnitude



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

One Wavelength PEC:

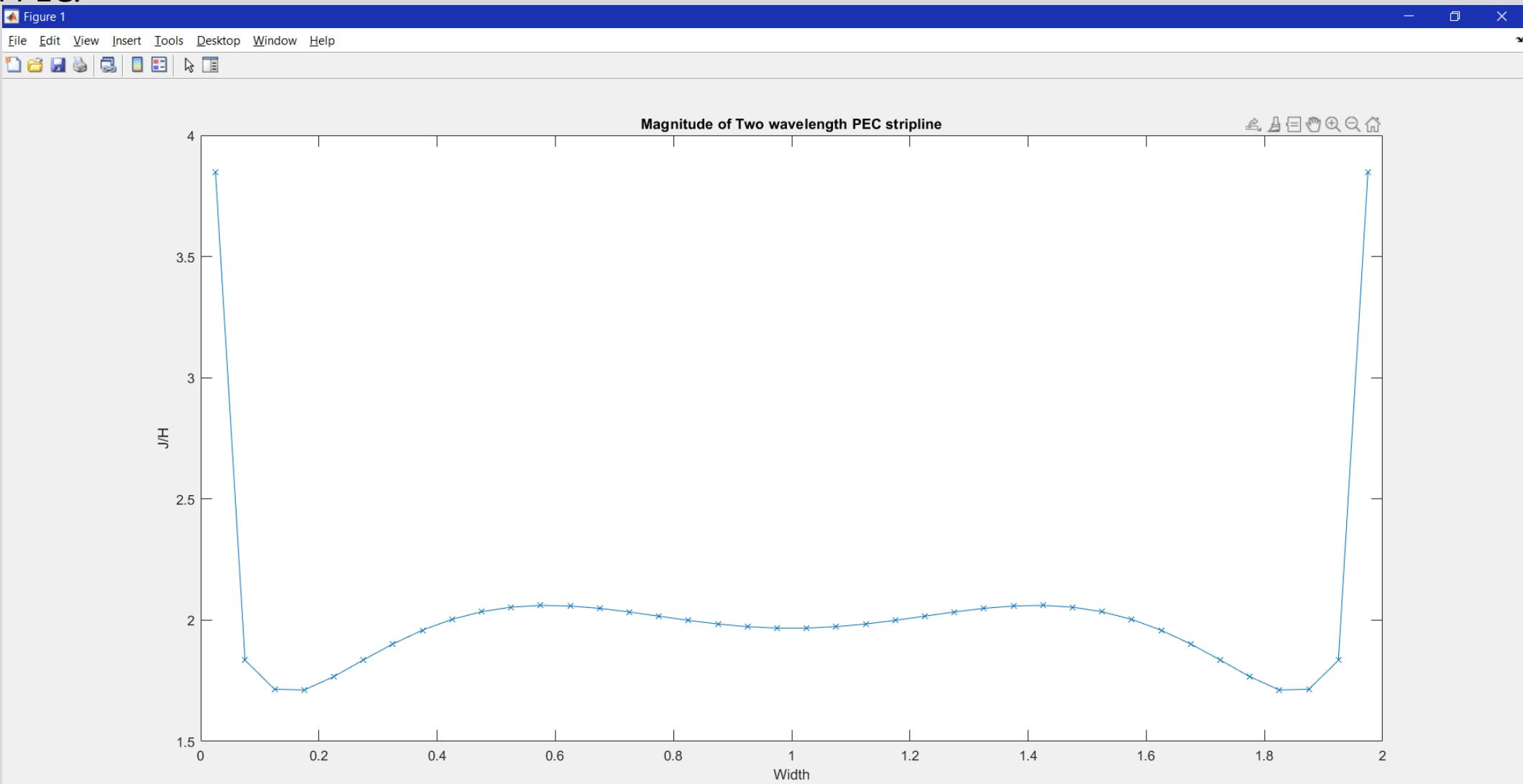
Phase



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Two Wavelength PEC:

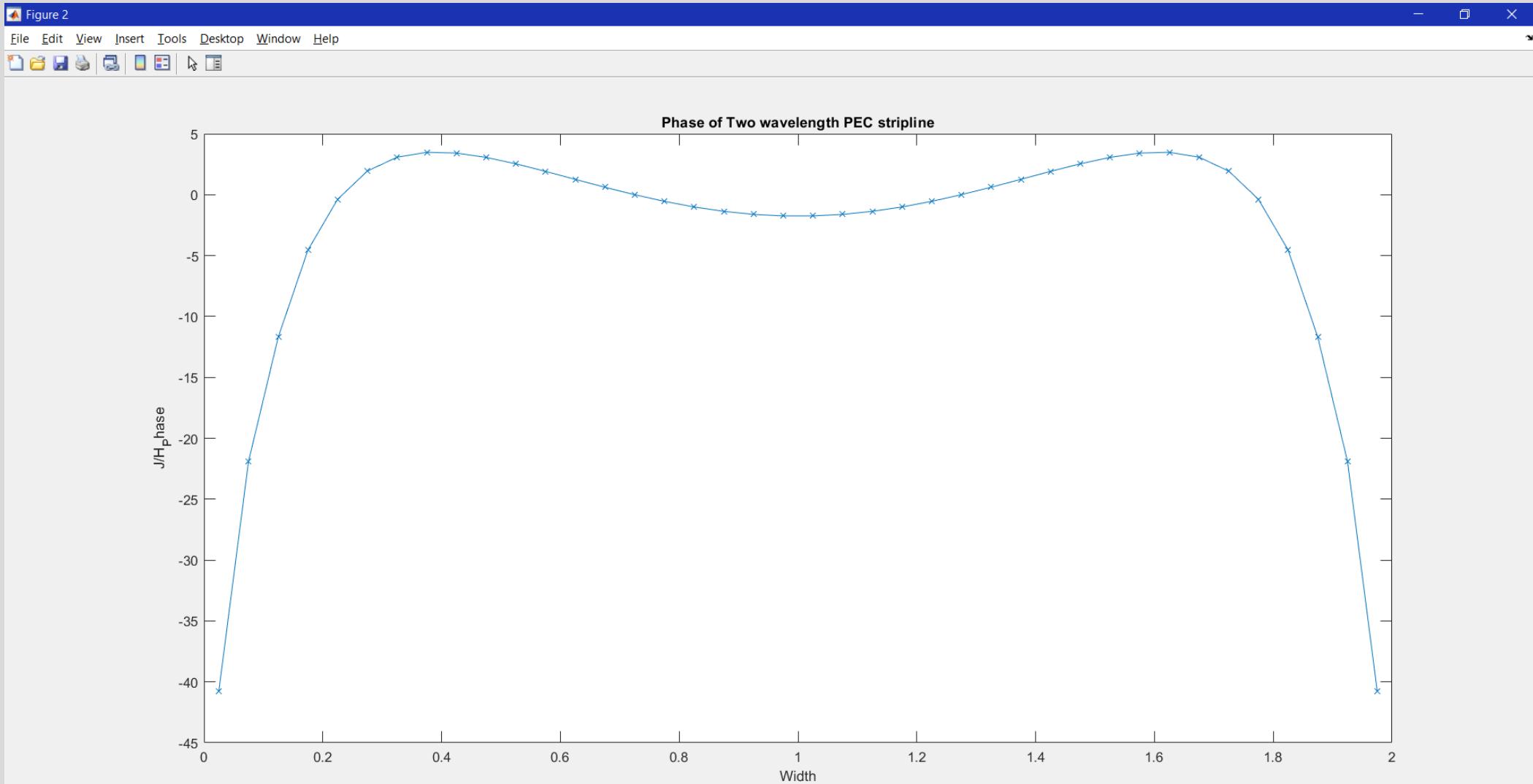
Magnitude



2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Two Wavelength PEC:

Phase



Assignment 3a

Microwave passive components

WILKINSON POWER SPLITTER/COMBINER IMPLEMENTATION

Part 1: LC Model for quarter wave section

Pi section

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{pmatrix} 1 + Y_{c2} * Z_{l1} & Z_{l1} \\ Y_{c1} + Y_{c2} + Y_{c1} * Y_{c2} * Z_{l1} & 1 + Y_{c1} * Z_{l1} \end{pmatrix}$$

By equating both matrices we obtain the corresponding X_l , X_c and
The values of the inductor and capacitor

$$X_l = X_c = Z_0$$

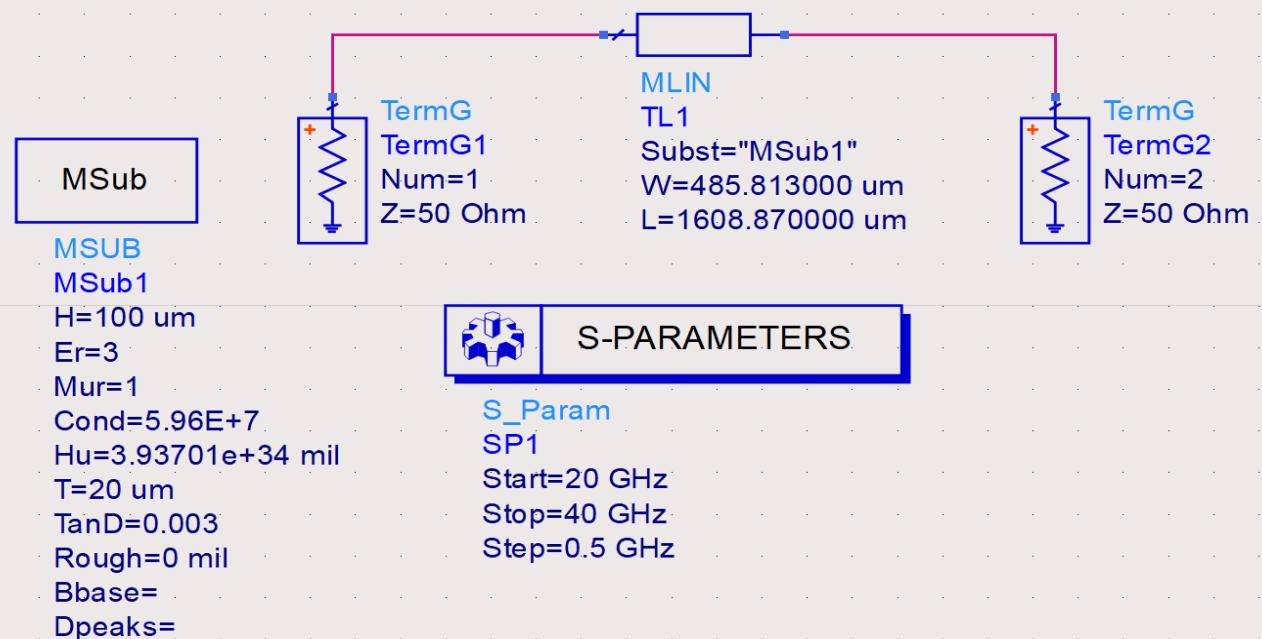
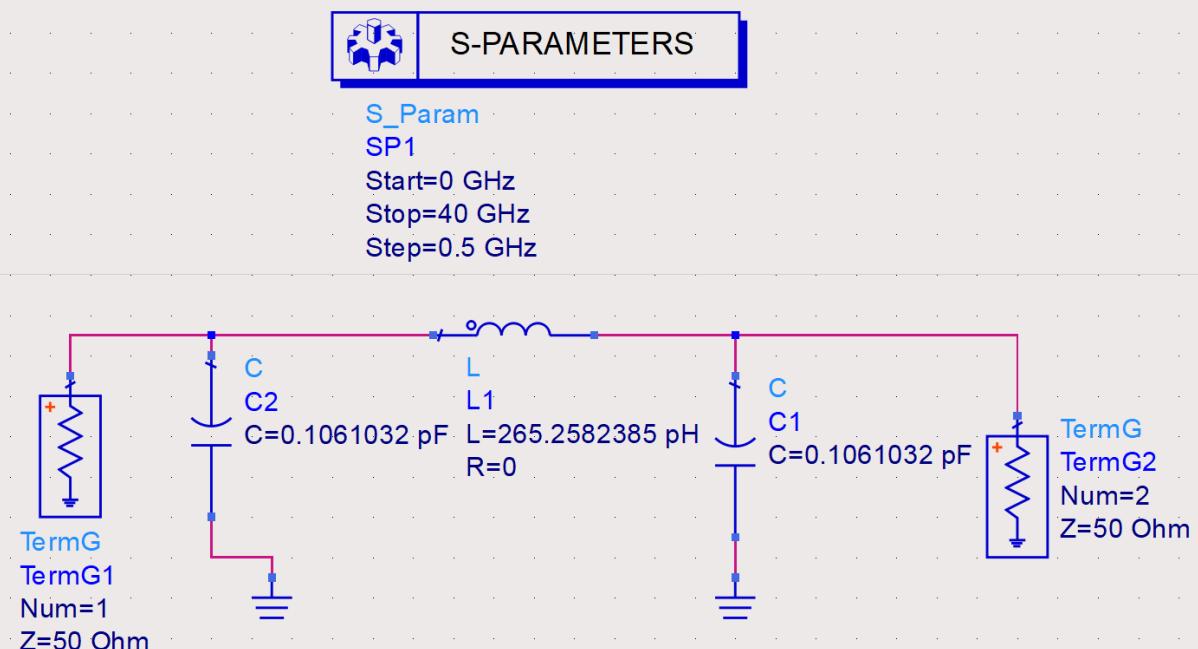
$$C = \frac{1}{2\pi f Z_0}, L = \frac{Z_0}{2\pi f} >>>$$

$$C = \frac{1}{2 \cdot \pi \cdot 30 \cdot 10^9 \cdot 50} = 0.1061032954 \text{ pF}$$

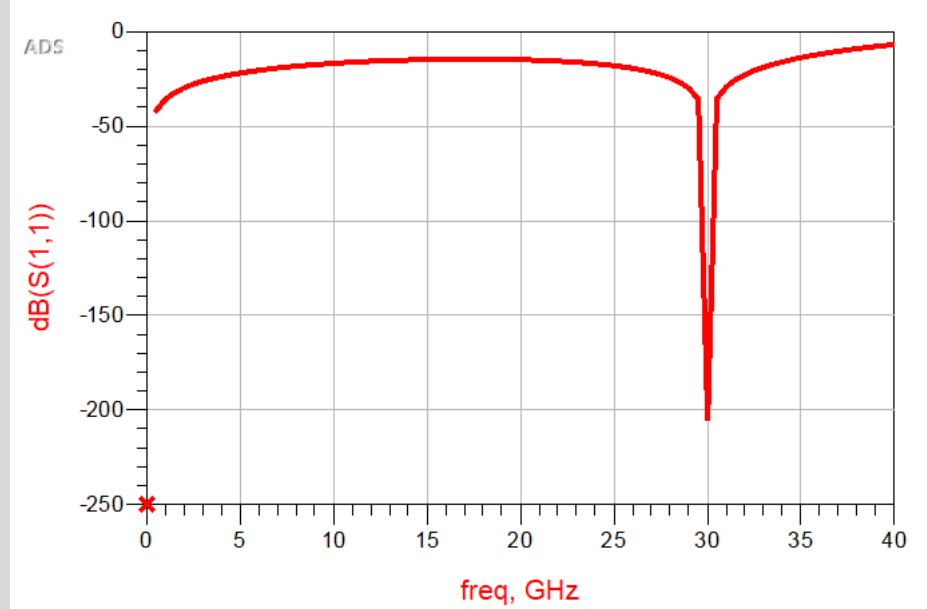
$$L = \frac{50}{2 \cdot \pi \cdot 30 \cdot 10^9} = 265.2582385 \text{ pH}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos \beta l & j Z_0 \sin \beta l \\ (1/Z_0) j \sin \beta l & \cos \beta l \end{bmatrix}$$

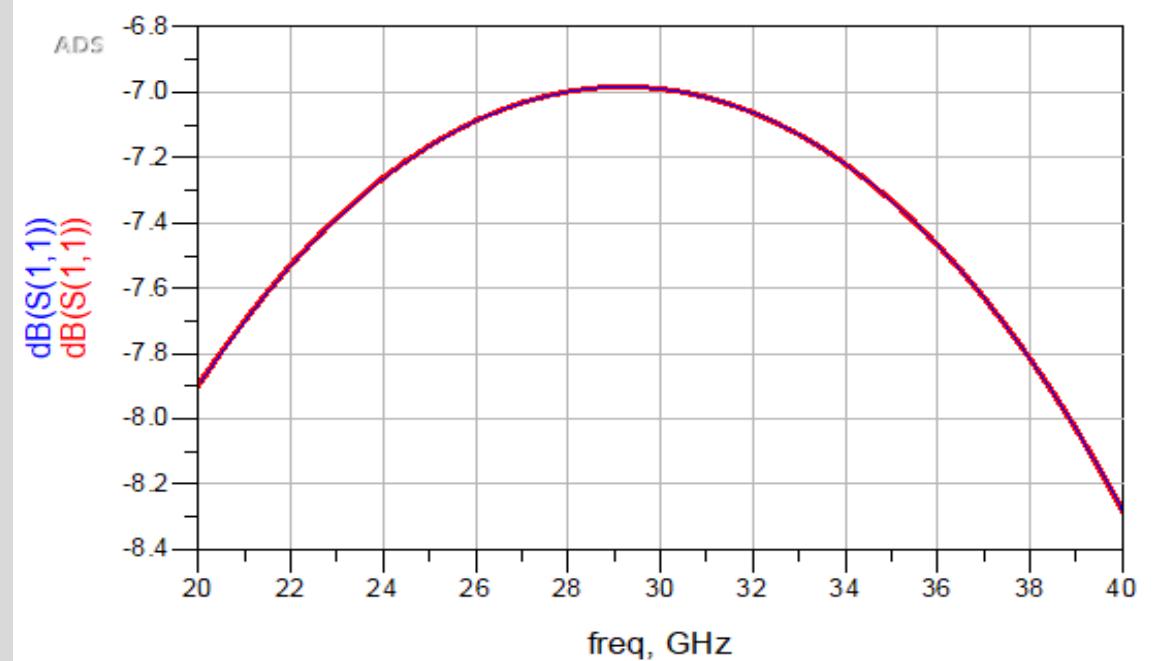
LC VS TL SCHEMATIC DESIGN



S11 LC VS TL



LC



TL

2-WAY WILKINSON

LineCalc/first.lcs
Z=50

File Simulation Options Help

Component

Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT	
Er	3.000	N/A
Mur	1.000	N/A
H	200.000	um
Hu	3.9e+34	um
T	20.000	um
Cond	5.96e7	N/A
TanD	0.003	N/A

Physical

W	485.813000	um
L	1608.870000	um
		N/A
		N/A

Synthesize Analyze

Electrical

Z0	50.000	Ohm
E_Eff	90.000	deg
		N/A
		N/A
		N/A

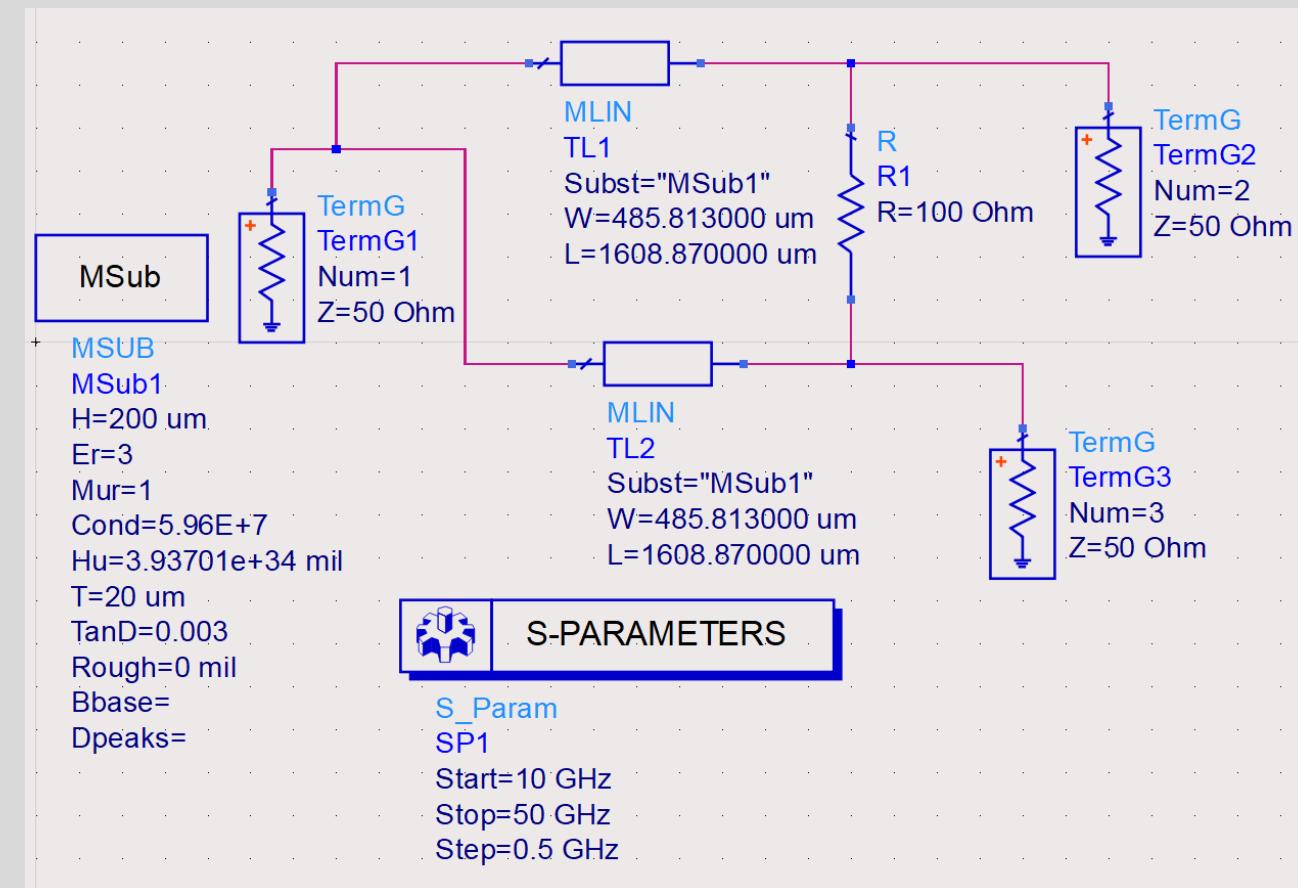
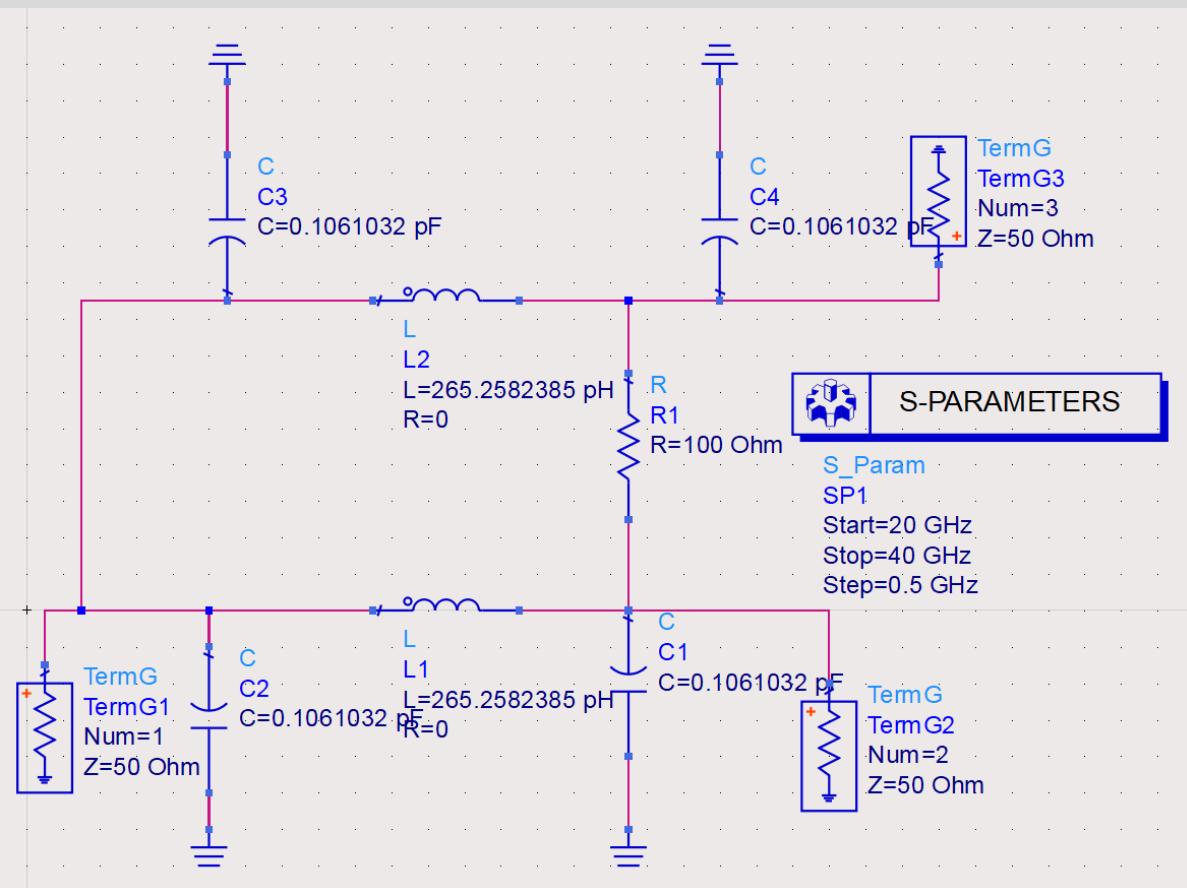
Calculated Results

K_Eff = 2.411
A_DB = 0.030
SkinDepth = 0.376

Values are consistent

The diagram illustrates a 2-way Wilkinson power divider. It features a central input port labeled '1' at the bottom, which splits into two output ports labeled '2' at the top. The structure is a stepped waveguide, consisting of a wide section on the left and a narrow section on the right. Dimension 'W' indicates the width of the narrow section, and dimension 'L' indicates the length of the narrow section.

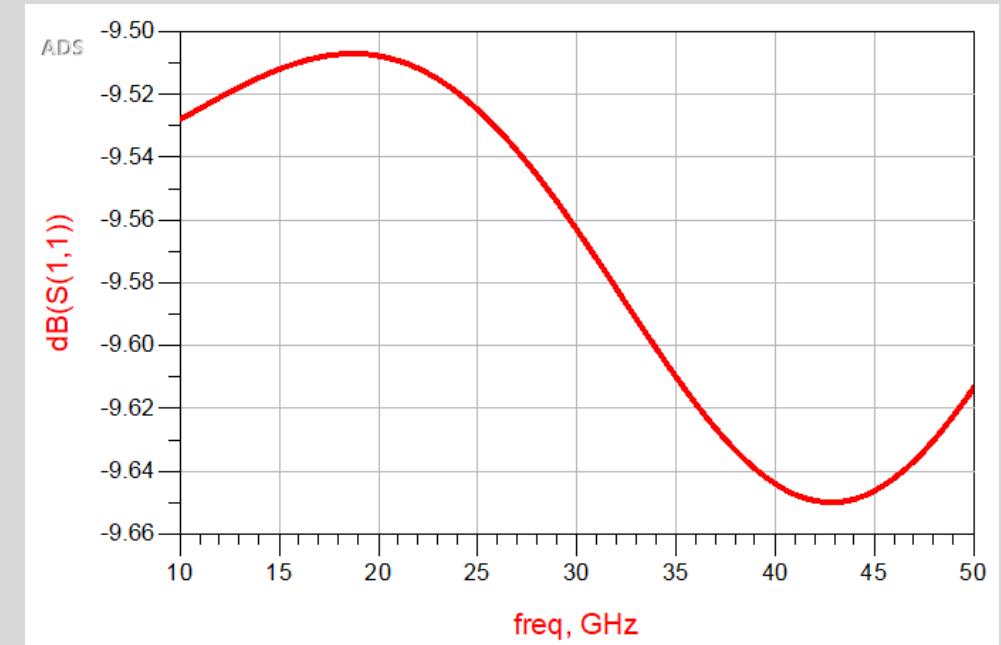
LC VS TL SCHEMATIC DESIGN



S11 LC VS TL

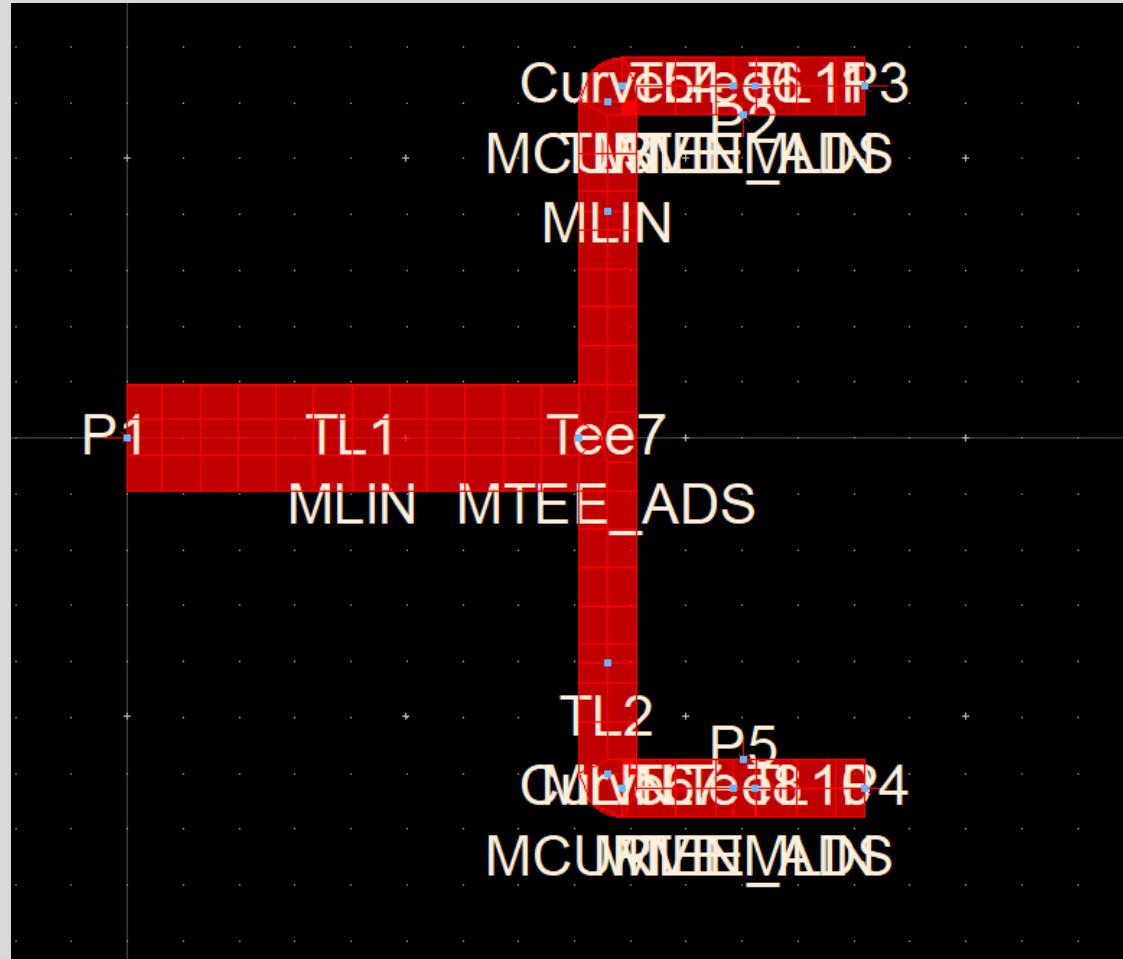


LC



TL

WILKINSON LAYOUT

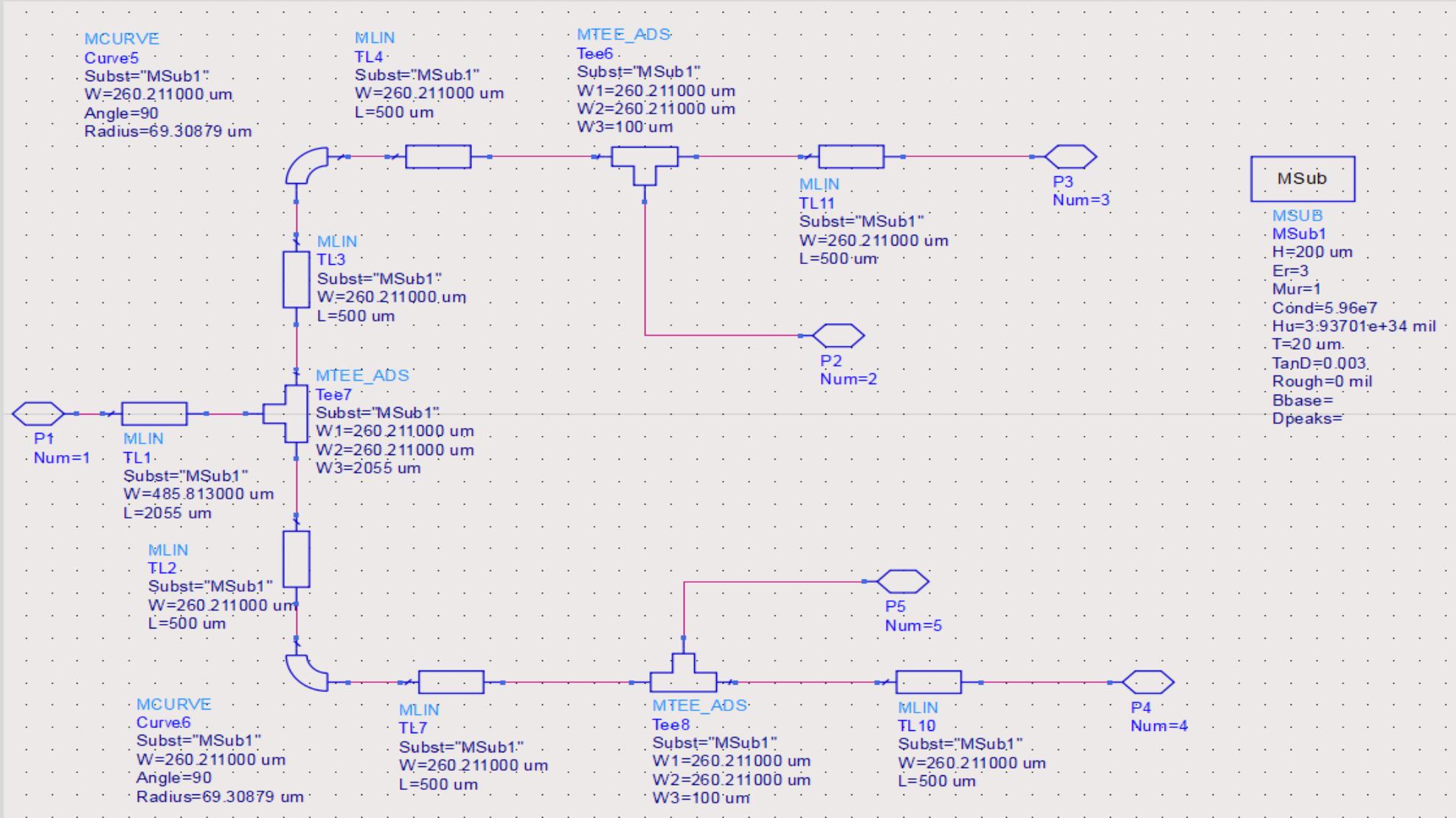


Part 3:

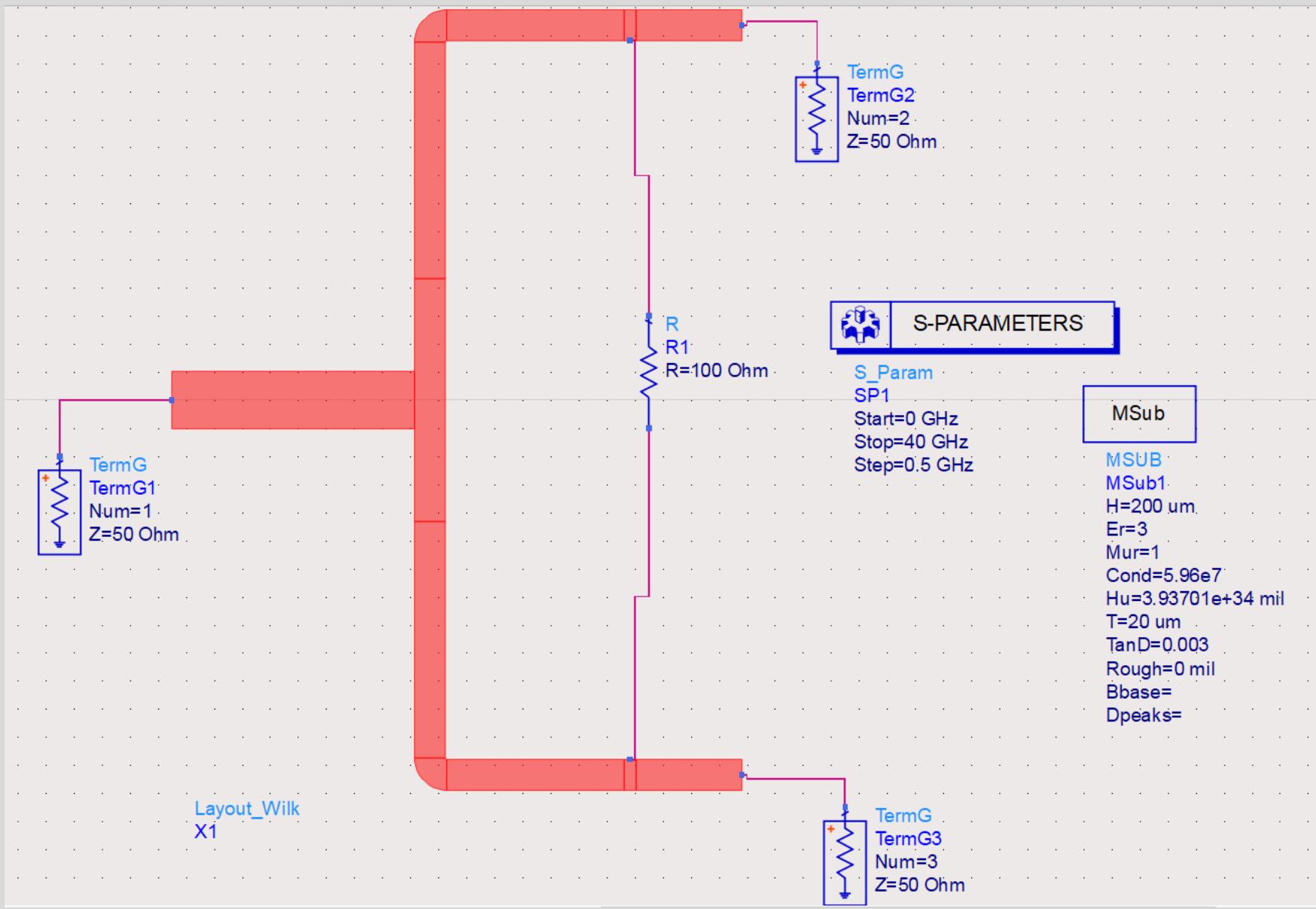
Calculate the radius of the curve:

$$\frac{\pi}{2} * \text{radius} = 108.87$$

$$\text{radius} = 69.30879 \mu\text{m}$$

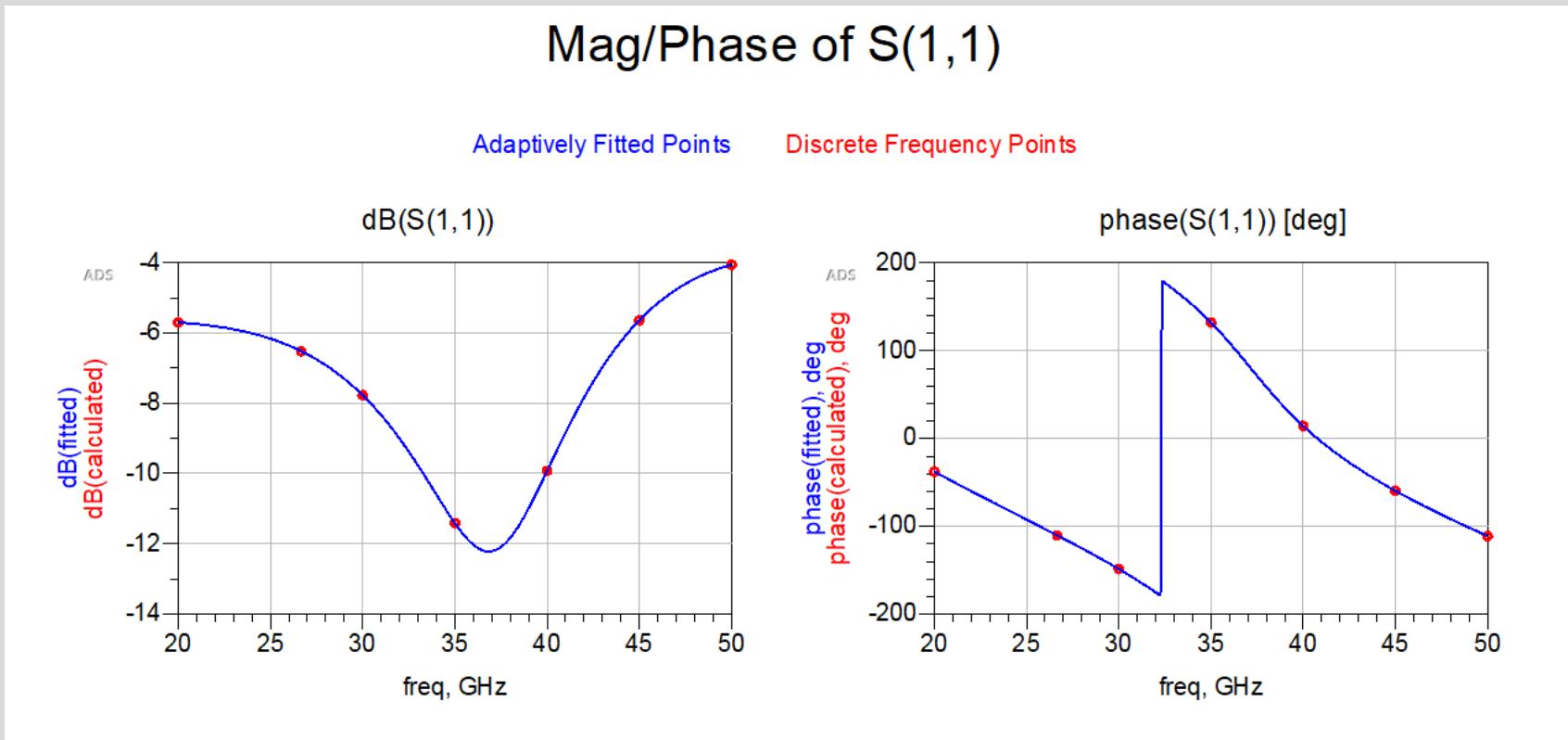


LAYOUT ADDED TO SCHEMATIC



S11

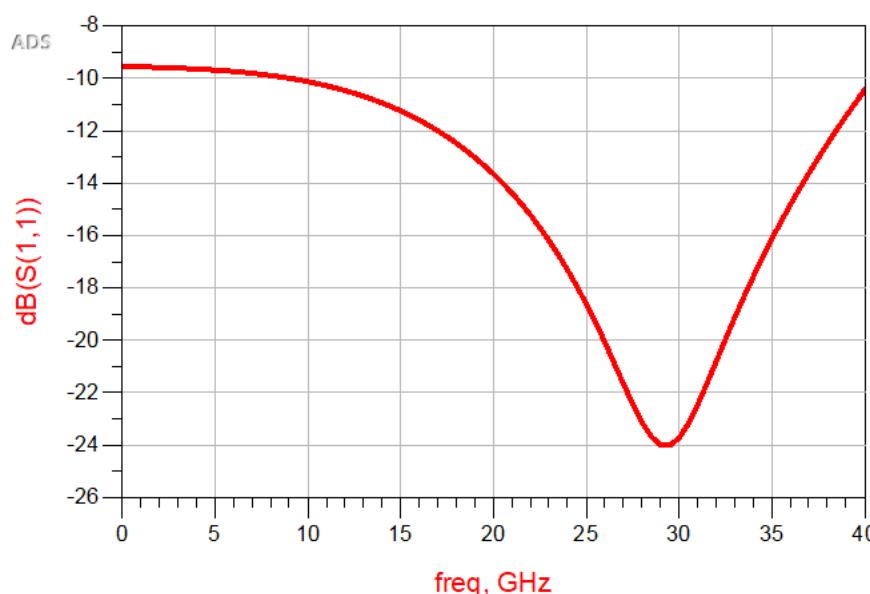
From layout



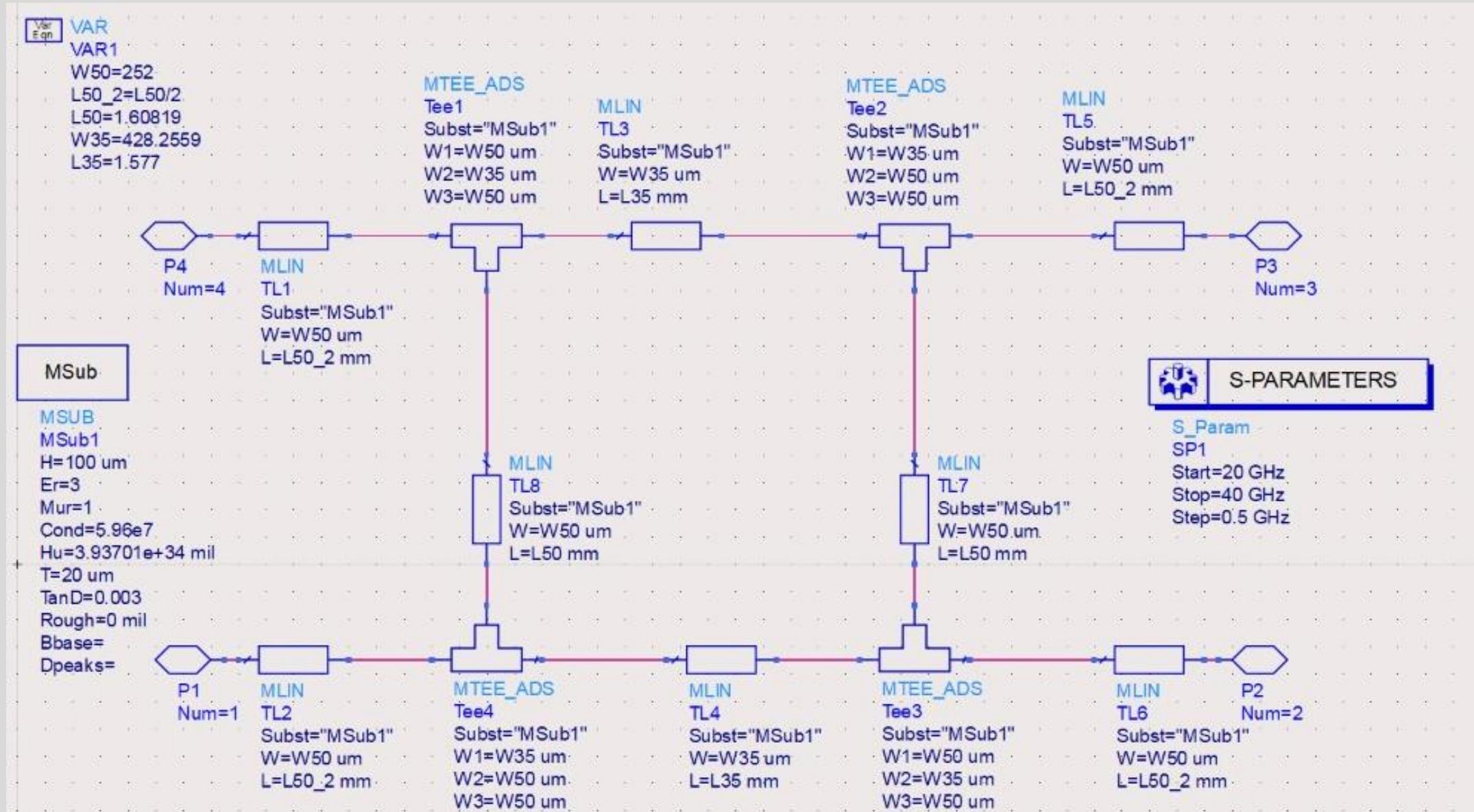
S11

After adding layout to schematic

And the resistors



PART 2: QUADRATURE COUPLER IMPLEMENTATION SCHEMATIC



Calculations

$$\lambda = \frac{c}{f} \gg \text{so we get the corresponding lambda}$$

$$\lambda = \frac{3 * 10^8}{30 * 10^9} = 0.01m = 10mm$$

$$W = \frac{8h * e^A}{e^{2A} - 2} \quad \text{for } W < 2h$$

$$W = \frac{2h}{\pi} * (B - 1 - \ln(B - 1) + \left(\frac{\varepsilon - 1}{2\varepsilon}\right) * \ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon}) \quad W > 2h$$

H = substrate height, W = width of microstrip line

$$A = \frac{Z_0}{60} * \sqrt{\frac{\varepsilon + 1}{2}} + \frac{\varepsilon - 1}{\varepsilon + 1} \left(0.23 + \frac{0.11}{\varepsilon} \right)$$

$$B = \frac{377\pi}{2Z_0 * \sqrt{\varepsilon}}$$

$$A_{50} = \frac{50}{60} * \sqrt{\frac{3 + 1}{2}} + \frac{3 - 1}{3 + 1} \left(0.23 + \frac{0.11}{3} \right) = 1.311844635$$

$$W_{50} = \frac{8h * e^A}{e^{2A} - 2} = \frac{8 * 100 * e^{1.311844635}}{e^{2 * 1.311844635} - 2} = 252\mu m$$

CALCULATE QUARTER WAVE LENGTH LINE

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12d}{W} \right)^{-1/2} = \frac{3 + 1}{2} + \frac{3 - 1}{2} \left(1 + \frac{12 * 100}{252} \right)^{-1/2}$$

= 2.4166

Calculate length of the 50 ohm quarter wave line

$$L_{50} = \frac{\lambda}{4} = \frac{\lambda_0}{4 * \sqrt{\varepsilon_{eff}}} = \frac{10}{4 * \sqrt{2.4166}} = 1.60819\text{mm}$$

Calculate width of the 35 ohm microstrip line

$$A_{35} = \frac{35.35}{60} * \sqrt{\frac{3 + 1}{2} + \frac{3 - 1}{3 + 1} \left(0.23 + \frac{0.11}{3} \right)} = 0.966554$$

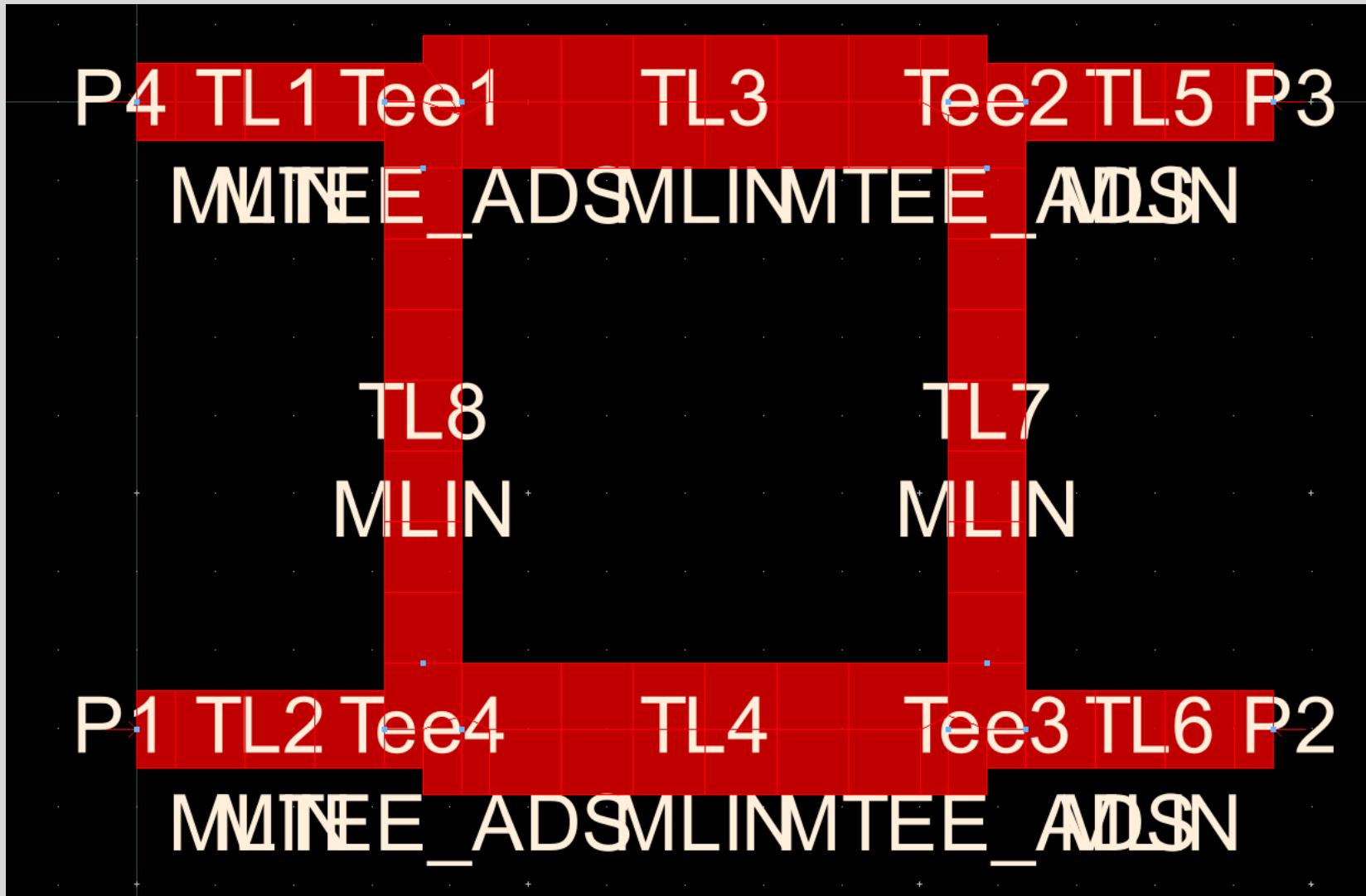
$$W_{35} = \frac{8h * e^A}{e^{2A} - 2} = \frac{8 * 100 * e^{0.966554}}{e^{2 * 0.966554} - 2} = 428.2559\mu\text{m}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12d}{W} \right)^{-1/2} = \frac{3 + 1}{2} + \frac{3 - 1}{2} \left(1 + \frac{12 * 100}{428.2559} \right)^{-1/2} = 2.51285$$

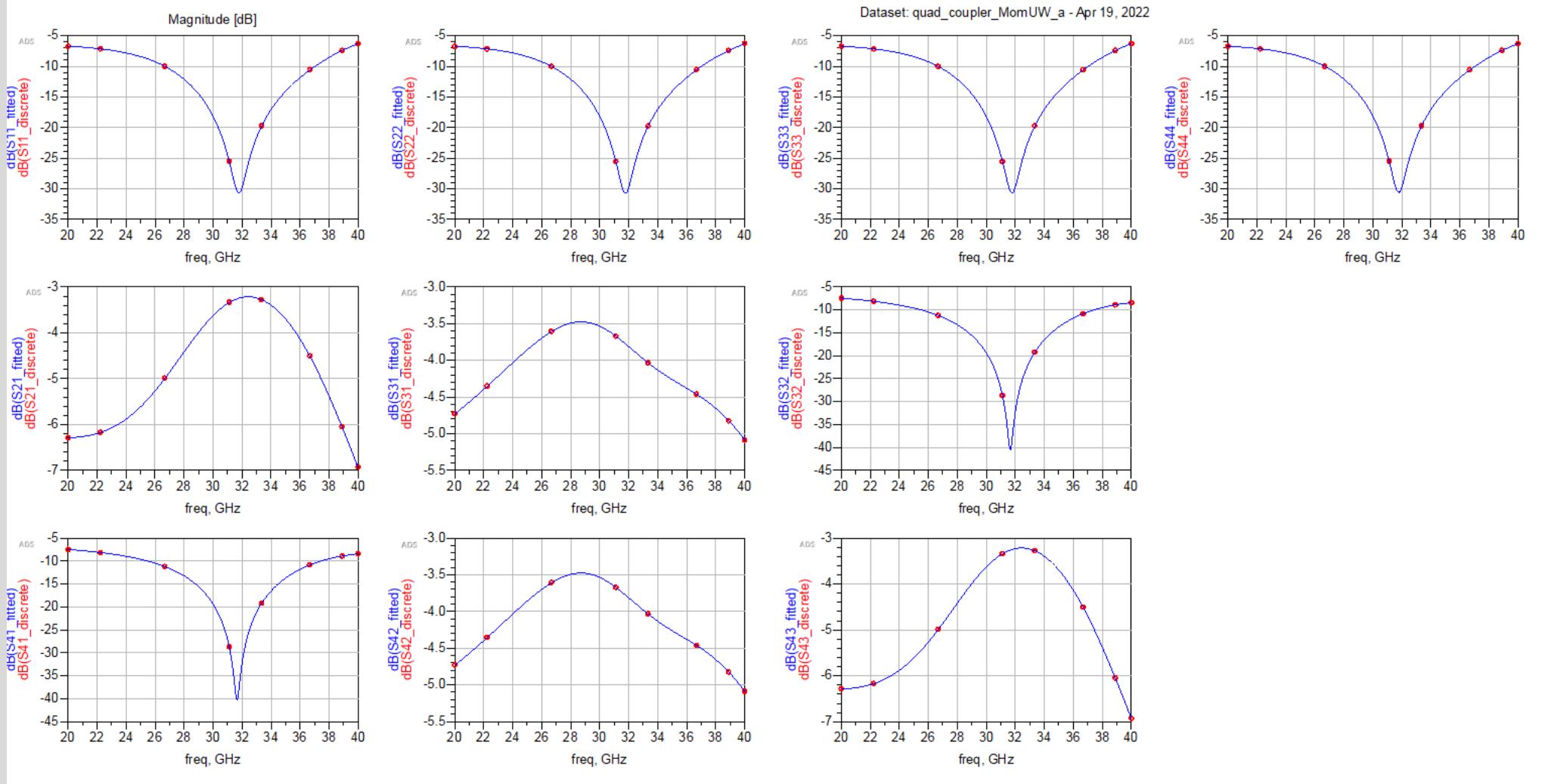
Calculate length of the 35 ohm quarter wave line

$$L_{35} = \frac{\lambda}{4} = \frac{\lambda_0}{4 * \sqrt{\varepsilon_{eff}}} = \frac{10}{4 * \sqrt{(2.51285)}} = 1.577mm$$

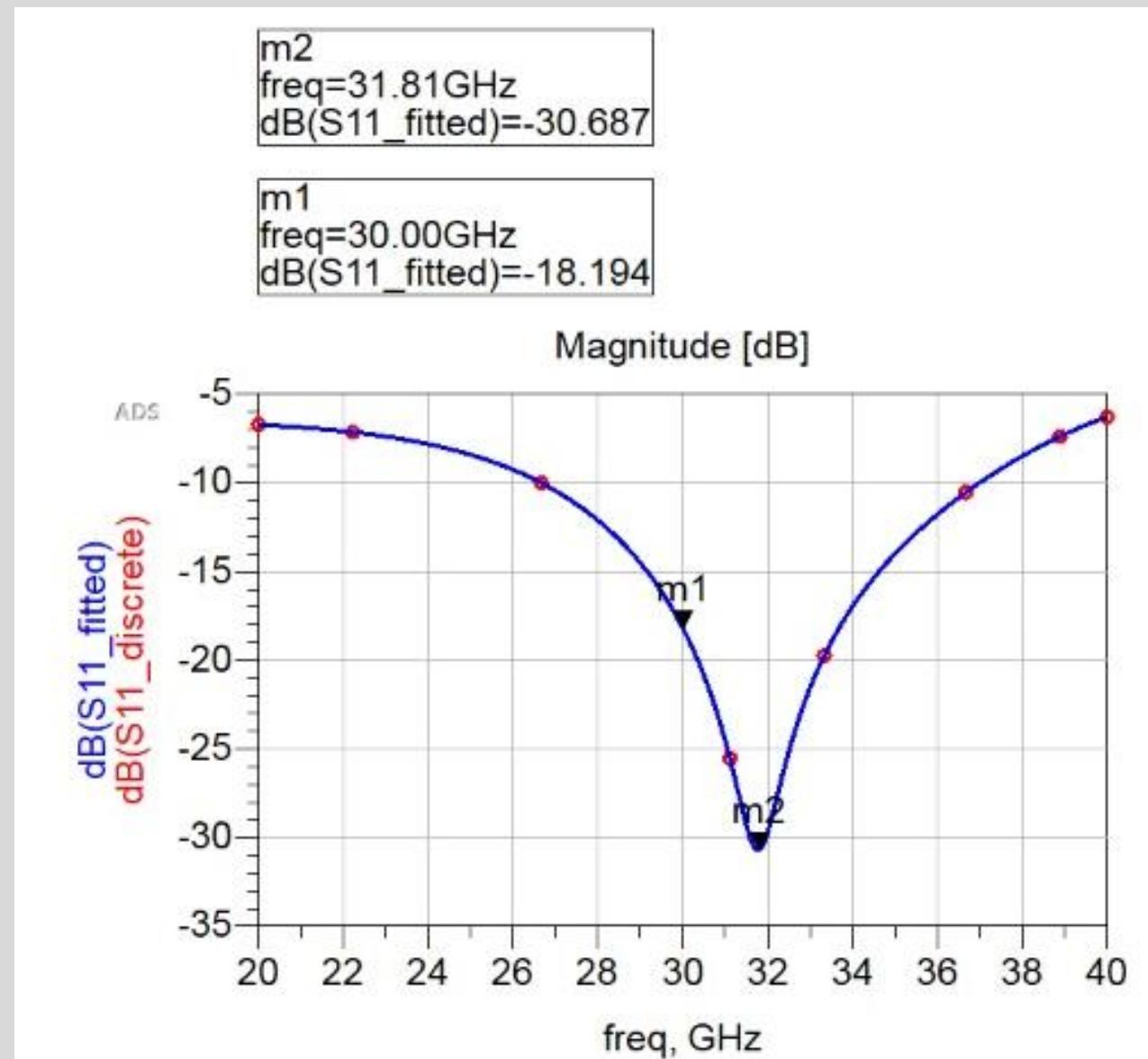
LAYOUT



S PARAMETERS FOR THE COUPLER



S11 FROM LAYOUT



PART 3: BALUN IMPLEMENTATION

1- HIGH PASS – LOW PASS BALUN

Design Steps:

1- $f_0 = 60\text{GHz}$

2- $X = \sqrt{R_{in} * R_L}$

3- $L = \frac{X}{2*\pi*f_0}, C = \frac{1}{X*2*\pi*f_0}$

I choose 60 GHz to test my 4 implementations

$$f_0 = 60\text{ GHz} \gg X = 50\sqrt{2}$$

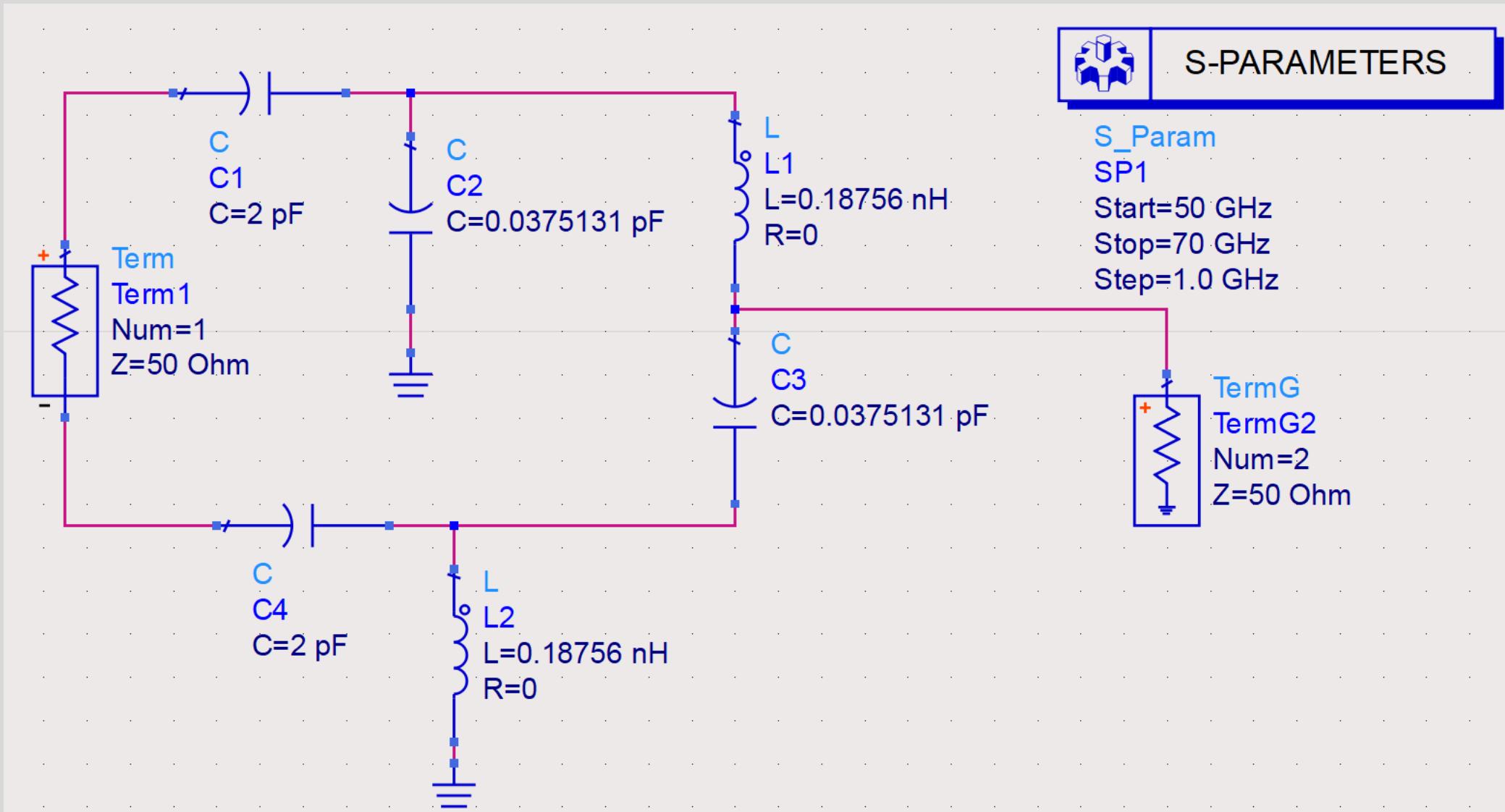
$$L = \frac{50\sqrt{2}}{2 * \pi * 60 * 10^9} = 1.8756 * 10^{-10}\text{H},$$

$$C = \frac{1}{50\sqrt{2} * 2 * \pi * 60 * 10^9} = 3.75131 * 10^{-14}\text{F}$$

The same technique goes for the 2.45 GHz to get the new L and C values

PART 3: BALUN IMPLEMENTATION

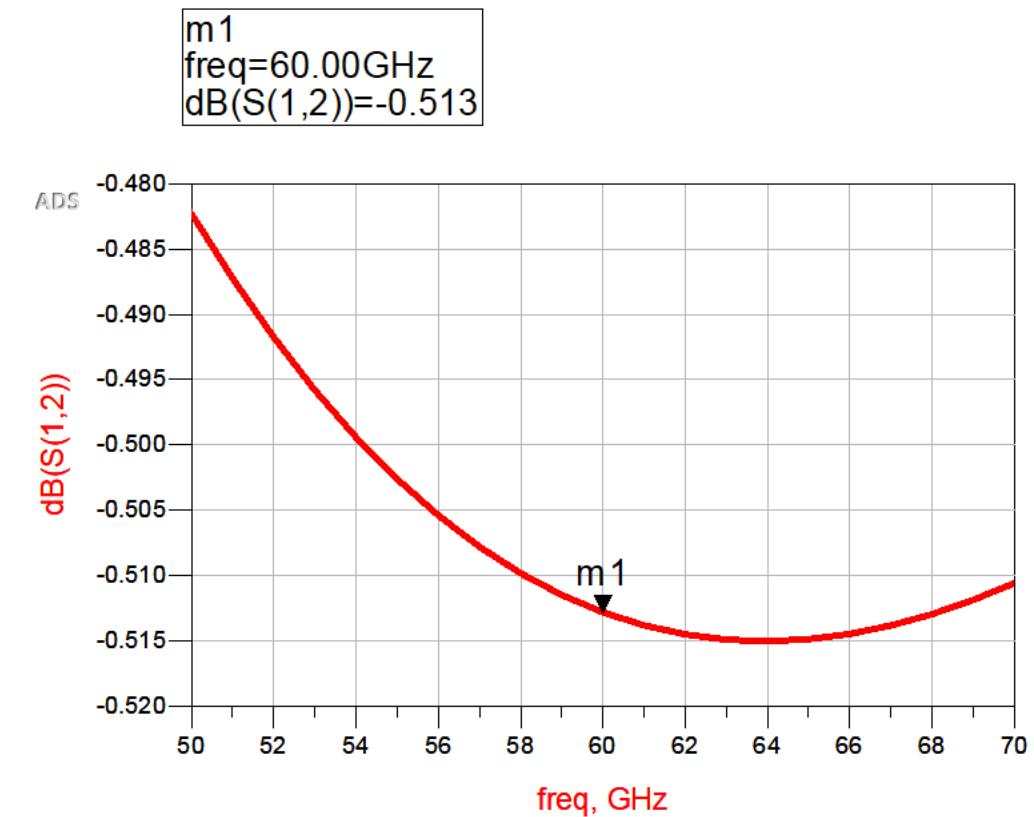
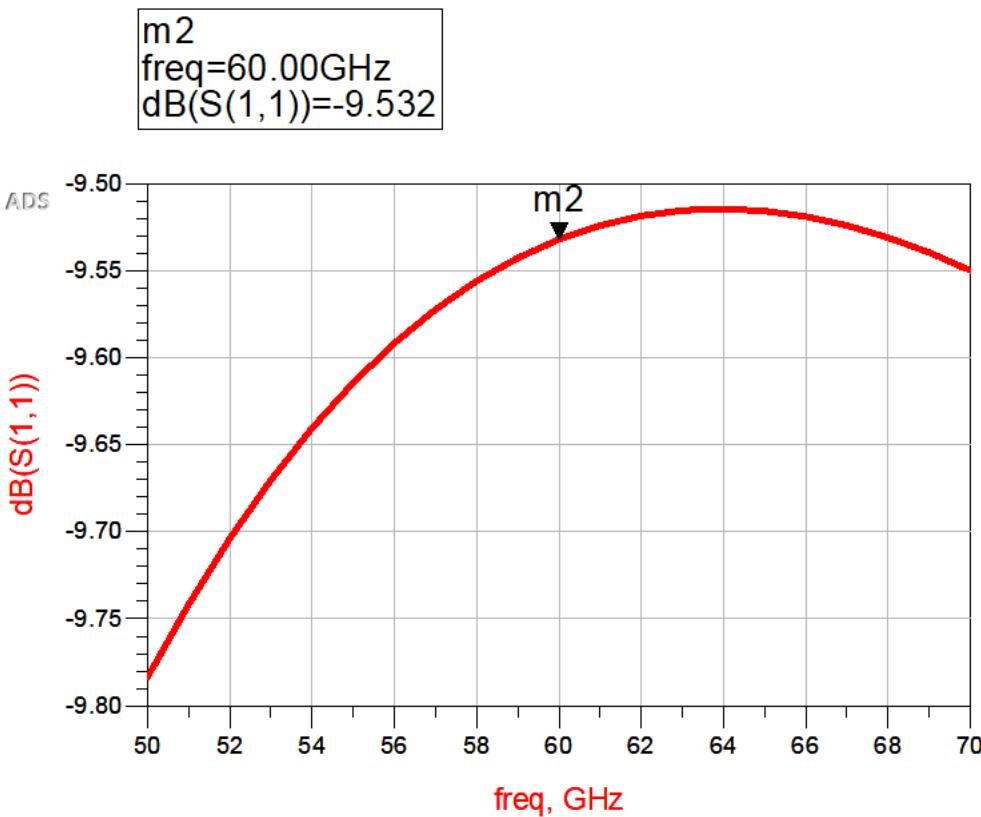
1- HIGH PASS – LOW PASS BALUN SCHEMATIC



PART 3: BALUN IMPLEMENTATION

1- HIGH PASS – LOW PASS BALUN S PARAMETERS

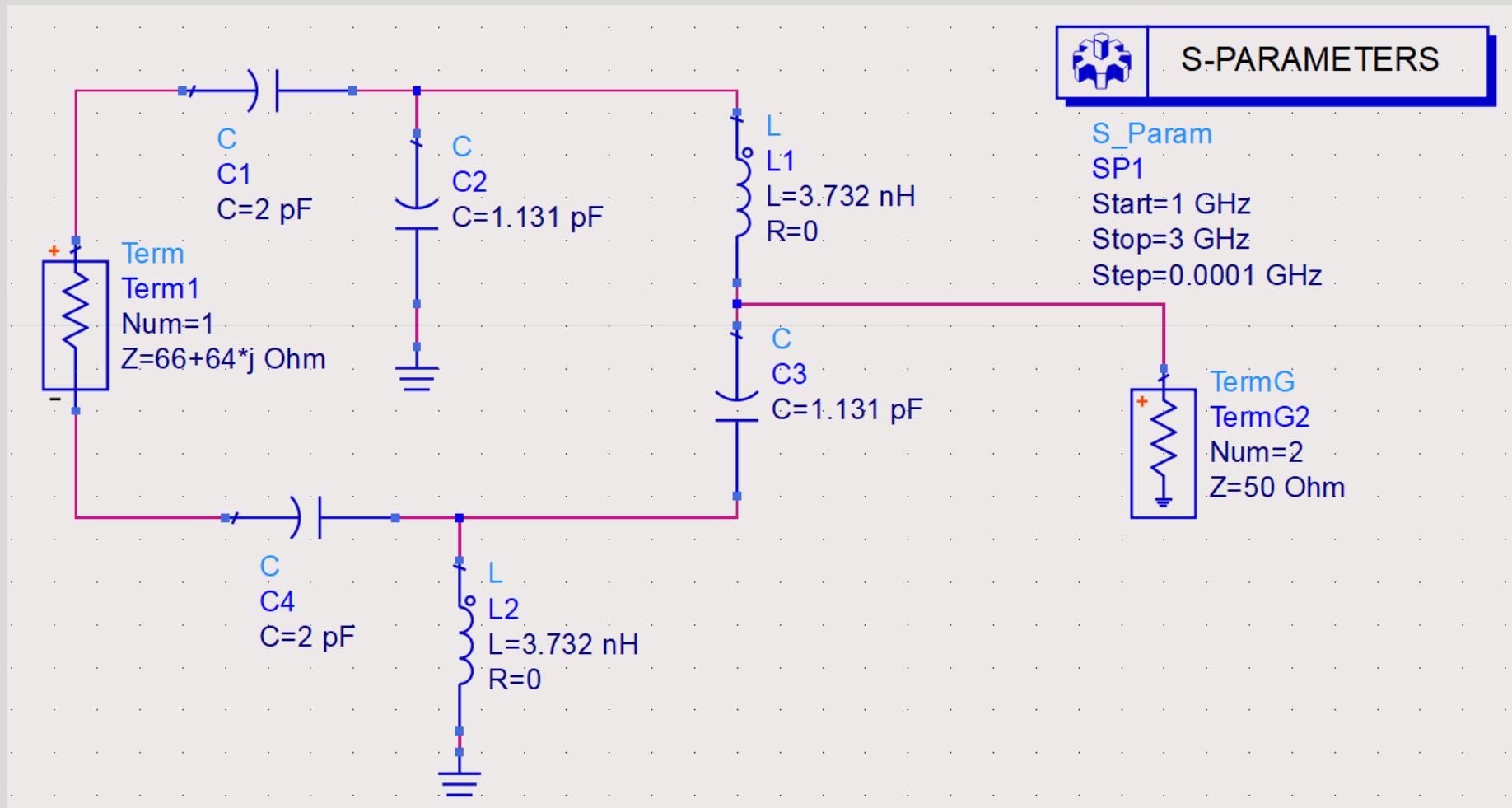
60 GHz was a bad idea to test this implementation so I will test it on 2.45 GHz



PART 3: BALUN IMPLEMENTATION

1- HIGH PASS – LOW PASS BALUN SCHEMATIC AT F0 = 2.45 GHZ

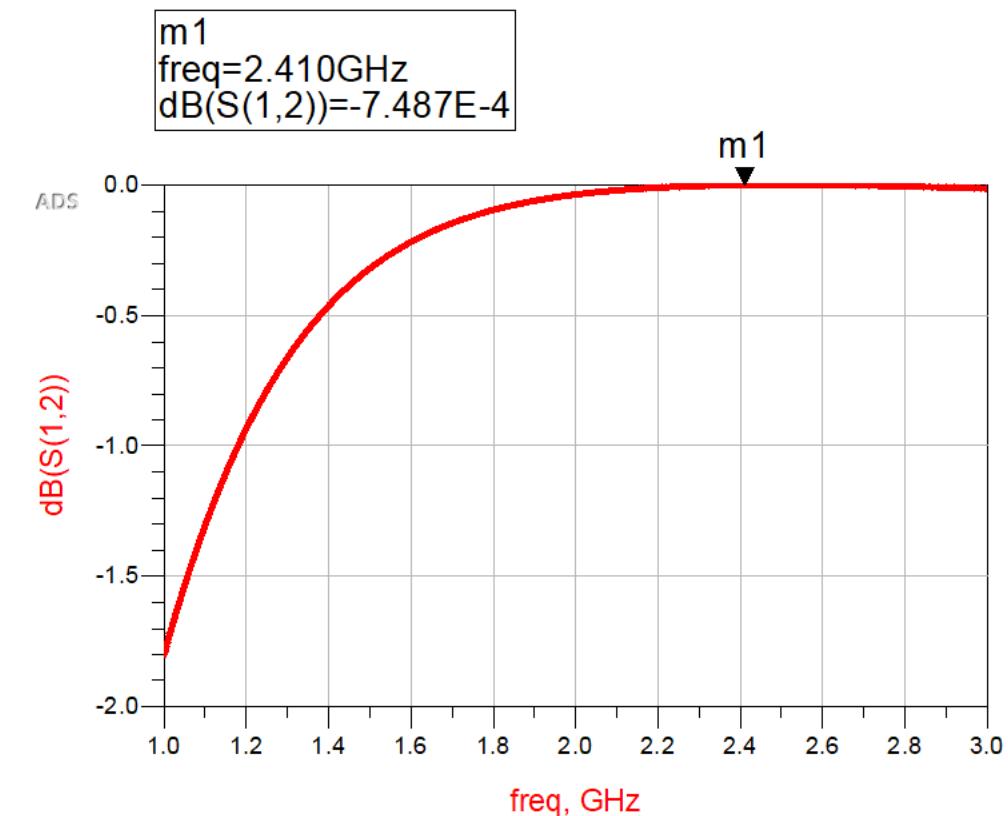
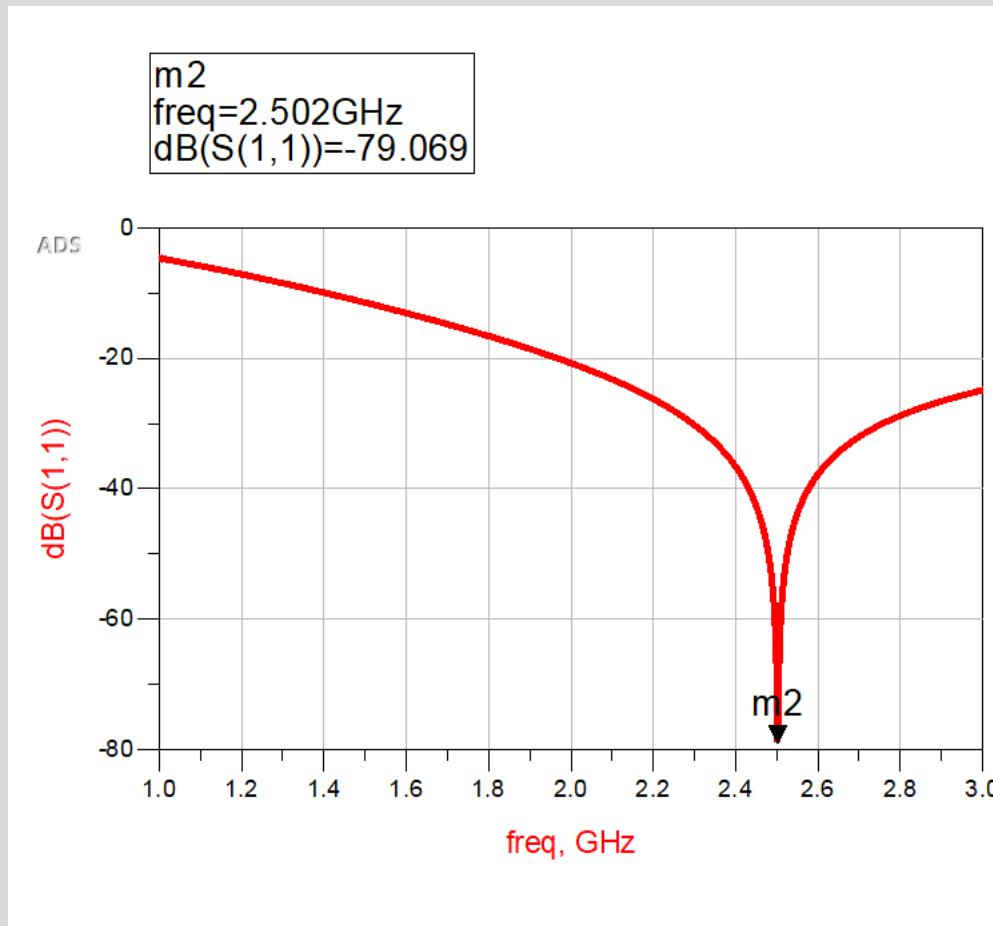
60 GHz was a bad idea to test this implementation so I will test it on 2.45 GHz



PART 3: BALUN IMPLEMENTATION

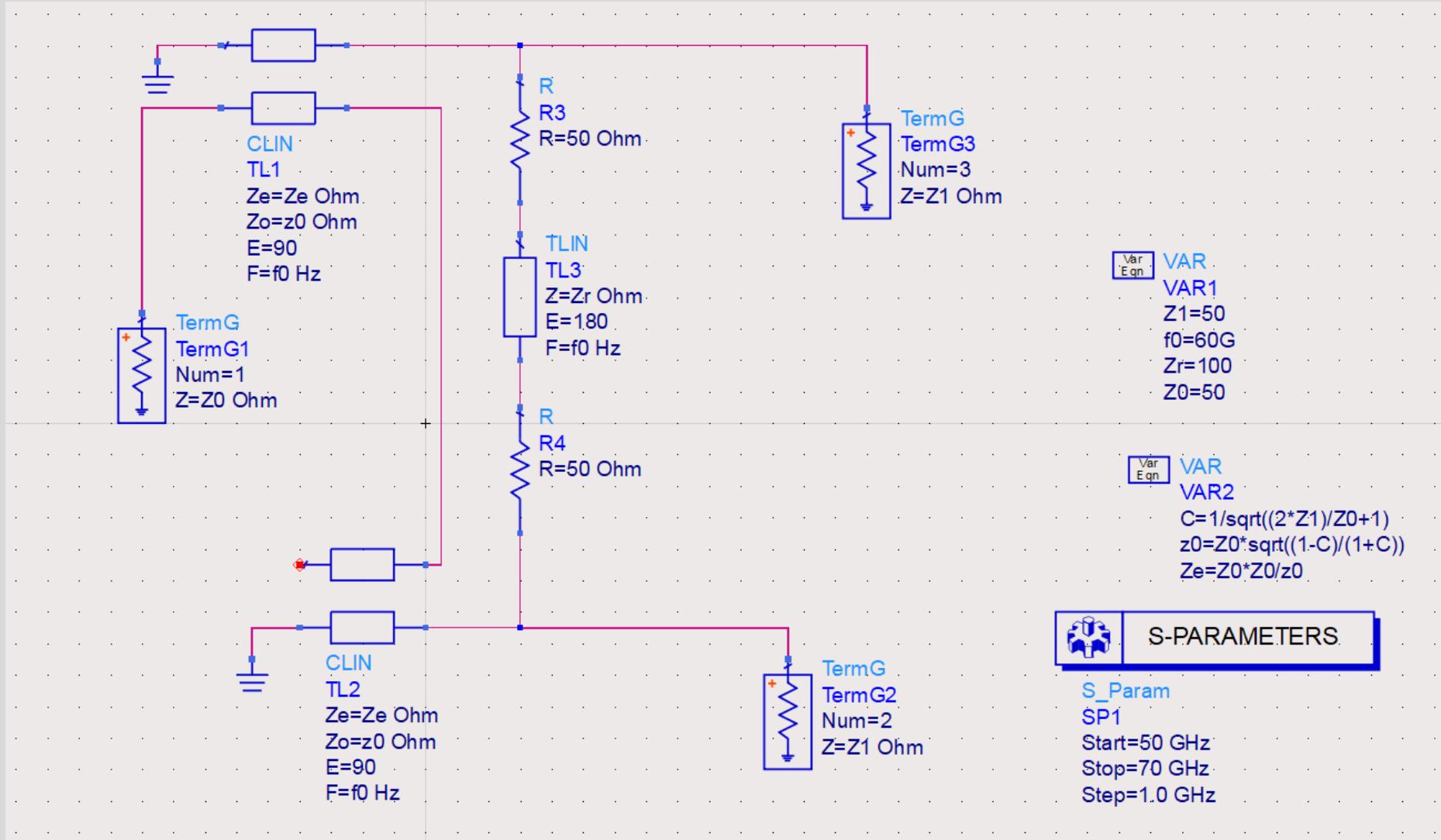
1- HIGH PASS – LOW PASS BALUN S PARAMETERS

60 GHz was a bad idea to test this implementation so I will test it on 2.45 GHz



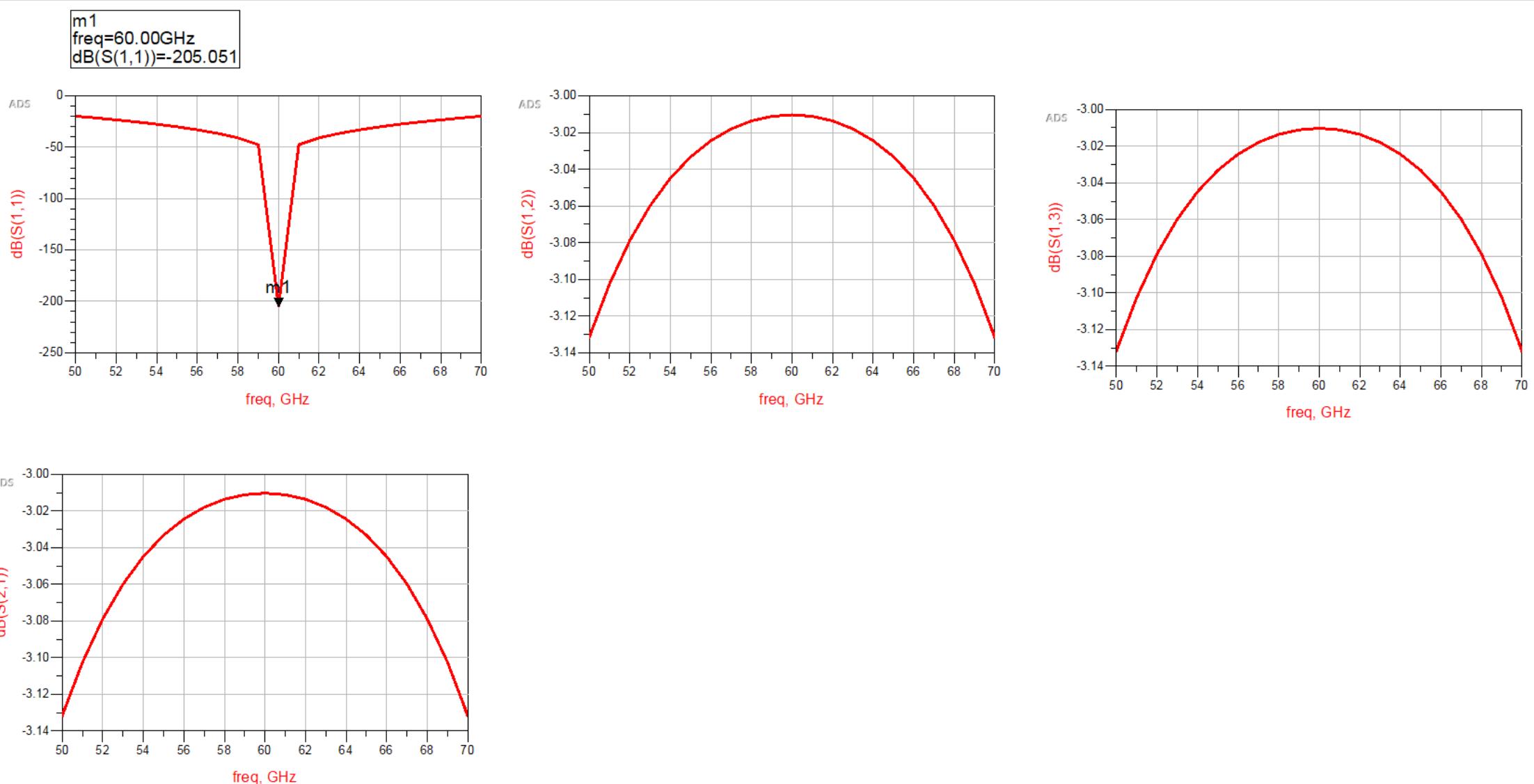
PART 3: BALUN IMPLEMENTATION

2- MARCHAND BALUN



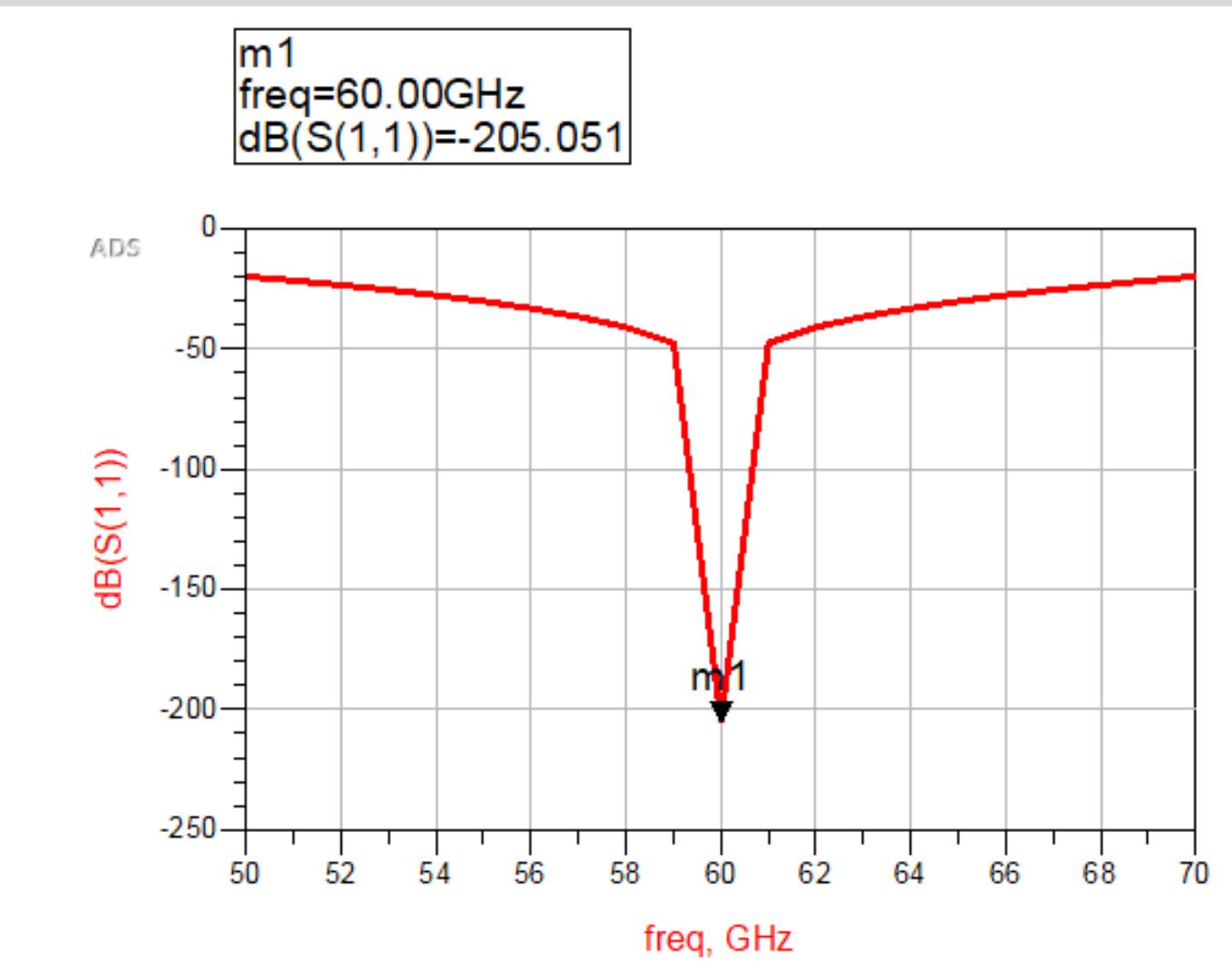
PART 3: BALUN IMPLEMENTATION

2- MARCHAND BALUN S PARAMETERS



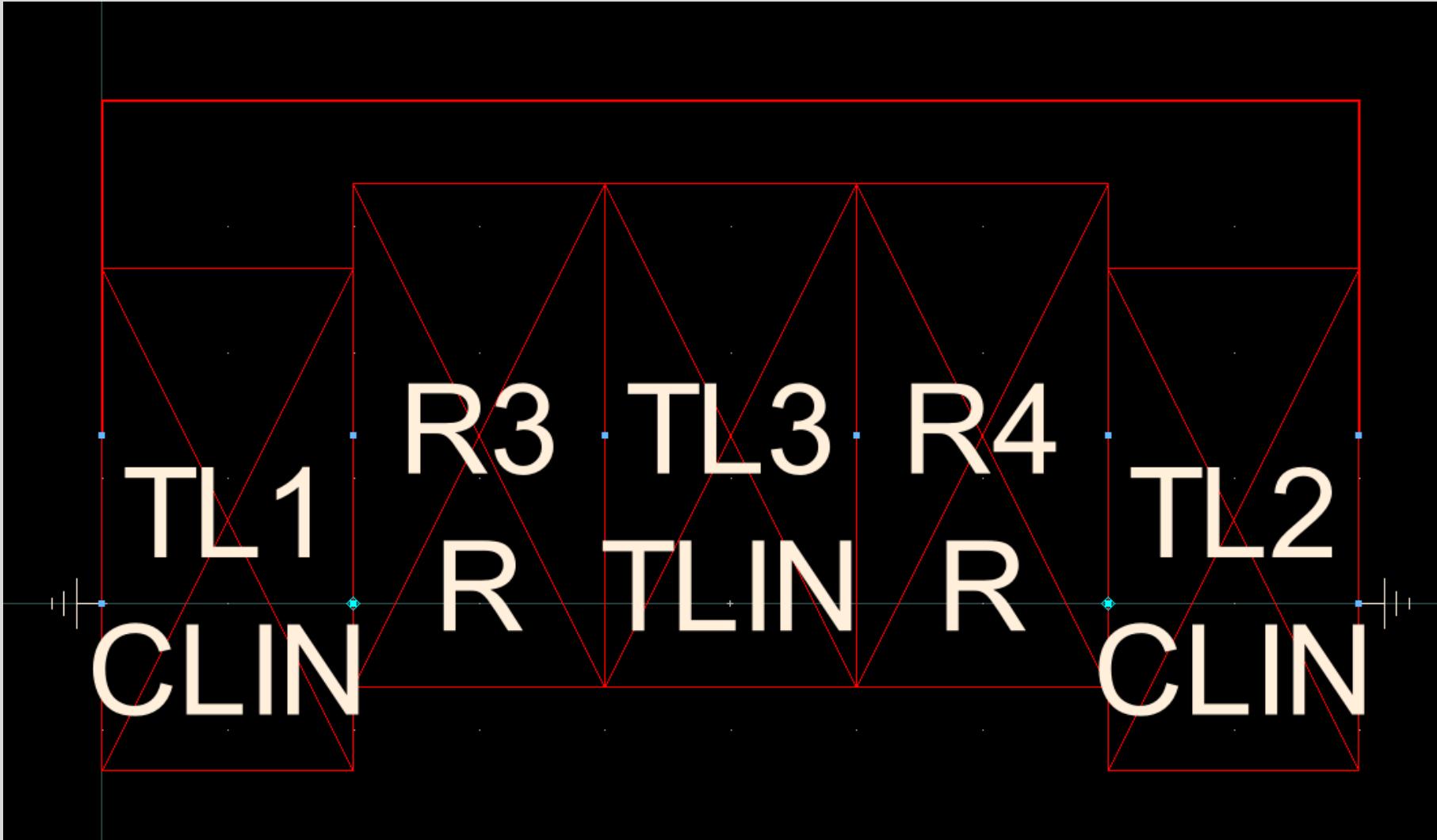
PART 3: BALUN IMPLEMENTATION

2- MARCHAND BALUN S PARAMETERS S11



PART 3: BALUN IMPLEMENTATION

2- MARCHAND BALUN LAYOUT



PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN TO GET THE RADIUS OF THE CURVES

LineCalc/first.lcs

File Simulation Options Help

Component
Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters
ID MSUB_DEFAULT
Er 3.000 N/A
Mur 1.000 N/A
H 200.000 um
Hu 3.9e+34 um
T 20.000 um
Cond 5.96e7 N/A
TanD 0.003 N/A
Rough 0.000 um

Physical
W 269.630000 um
L 4901.280000 um
N/A N/A
N/A N/A

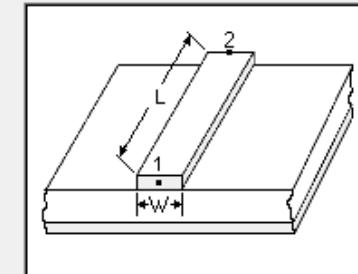
Synthesize Analyze

Electrical
Z0 70.700 Ohm
E_Eff 540.000 deg
N/A N/A
N/A N/A
N/A N/A

Calculated Results
K_Eff = 2.338
A_DB = 0.169
SkinDepth = 0.266

Component Parameters
Freq 60.000 GHz
Wall1 mil
Wall2 mil

Values are consistent



PART 3: BALUN IMPLEMENTATION

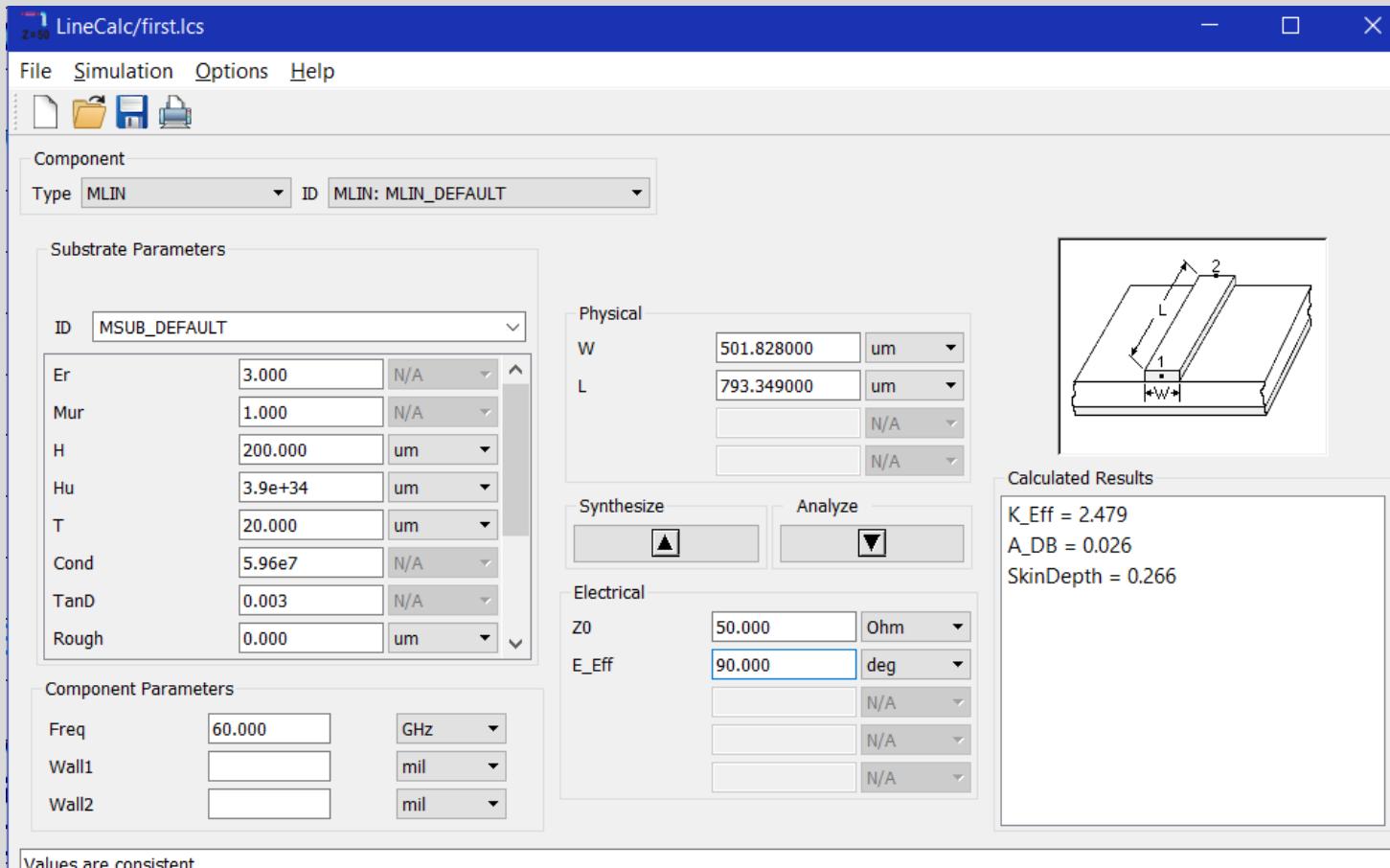
3- RAT RACE BALUN TO GET THE RADIUS OF THE CURVES

$R = \text{length} / 2\pi \gg \text{length calculated from the line calc}$

$$R = 4901.28 / 2\pi = 780.45859 \text{ um}$$

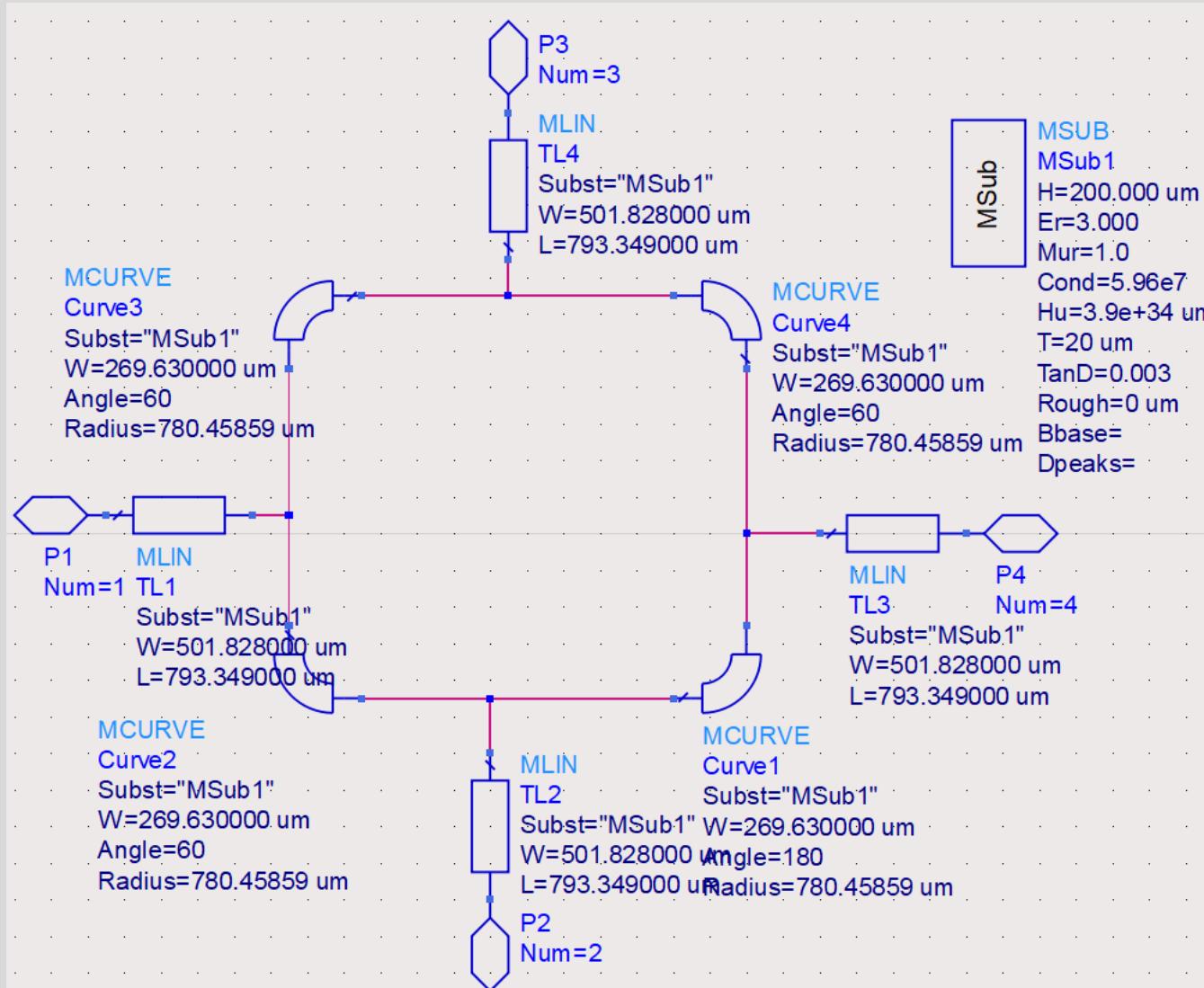
Now we have the curves

We need to get the lines which have 50 ohm



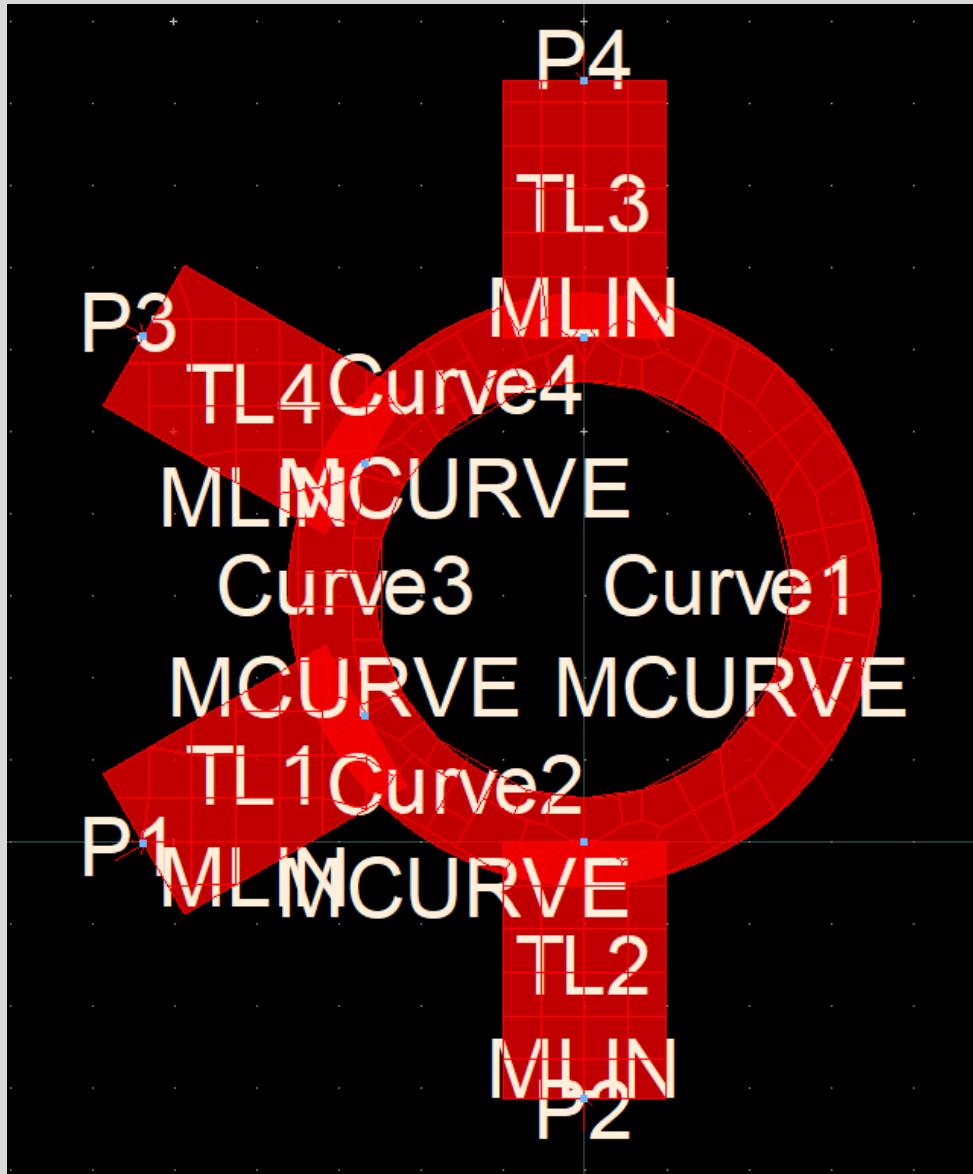
PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN SCHEMATIC



PART 3: BALUN IMPLEMENTATION

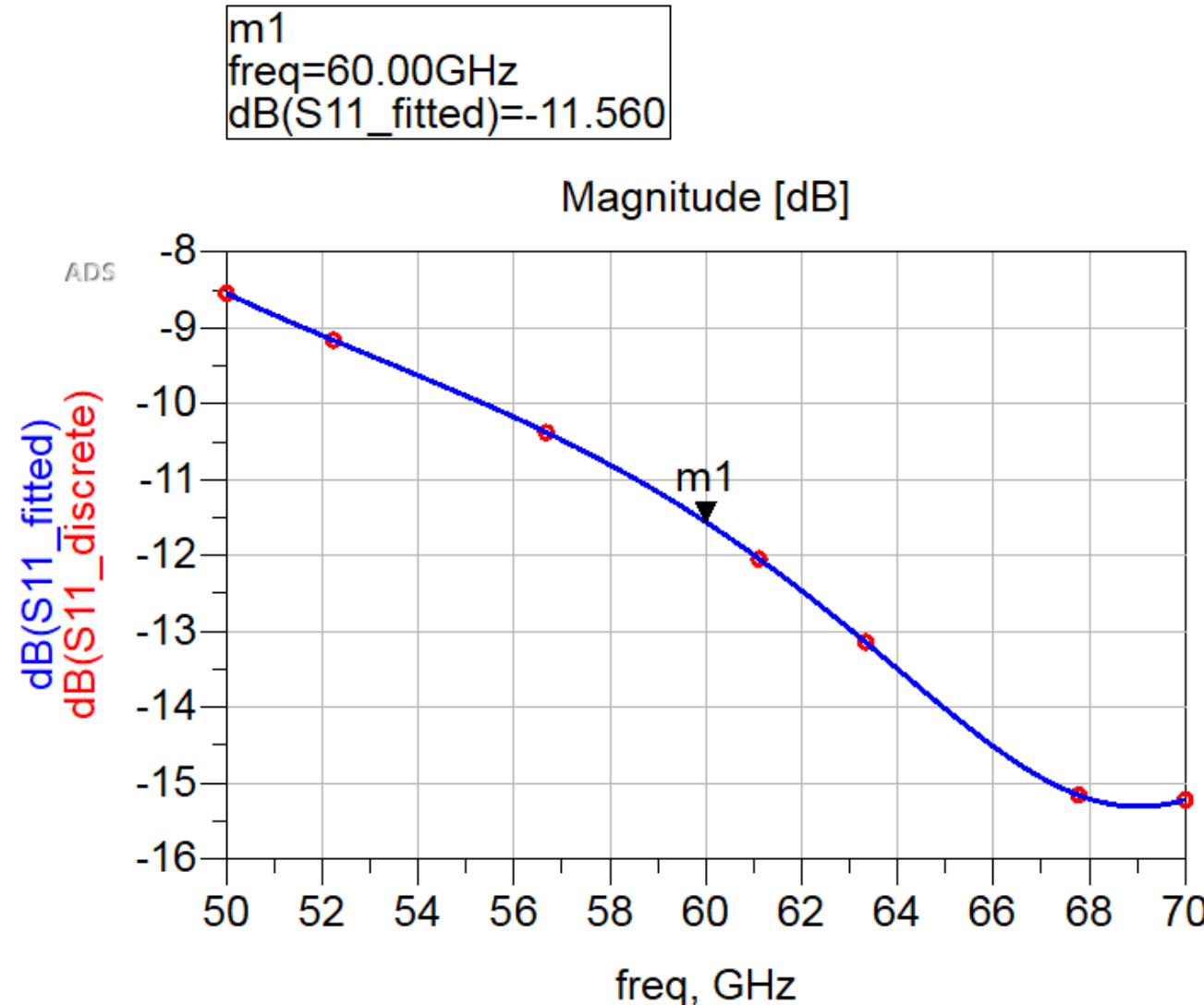
3- RAT RACE BALUN LAYOUT



PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN LAYOUT

At very high frequency rat race gives bad losses values
So I redesign at 2.45 GHz



PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN LINE CALC FOR TL Z0 = 50 OHM

At very high frequency rat race gives bad losses values
So I redesign at 2.45 GHz

LineCalc/first.lcs

File Simulation Options Help

Component

Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A

Physical

W	482.336000 um
L	4858.020000 um
	N/A
	N/A

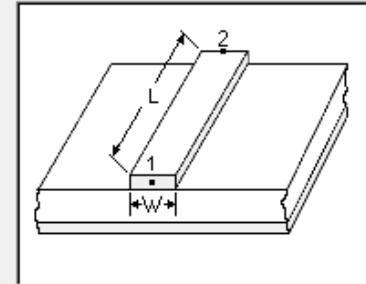
Synthesize Analyze

Electrical

Z0	50.000 Ohm
E_Eff	90.000 deg
	N/A
	N/A
	N/A

Calculated Results

K_Eff = 2.380
A_DB = 0.038
SkinDepth = 0.651



Component Parameters

Freq	10.000	GHz
Wall1		mil
Wall2		mil

Values are consistent

PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN LINE CALC FOR TL Z0 =70.7 OHM

At very high frequency rat race gives bad losses values
So I redesign at 10 GHz

$R = \text{length} / 2\pi$ >> length calculated from the line calc

$$R = 29908.9 / 2\pi = 4760.15 \mu\text{m}$$

Now we have the curves
We need to get the lines which have 50 ohm

LineCalc/first.lcs

File Simulation Options Help

Component Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A

Physical

W	258.366000 um
L	29908.900000 um
	N/A
	N/A

Synthesize Analyze

Calculated Results

K_Eff	2.260
A_DB	0.271
SkinDepth	0.651

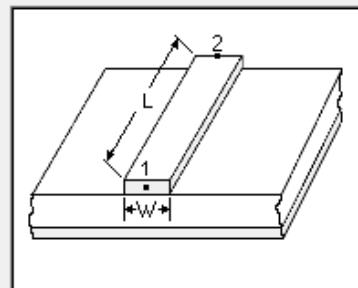
Component Parameters

Freq	10.000 GHz
Wall1	
Wall2	

Electrical

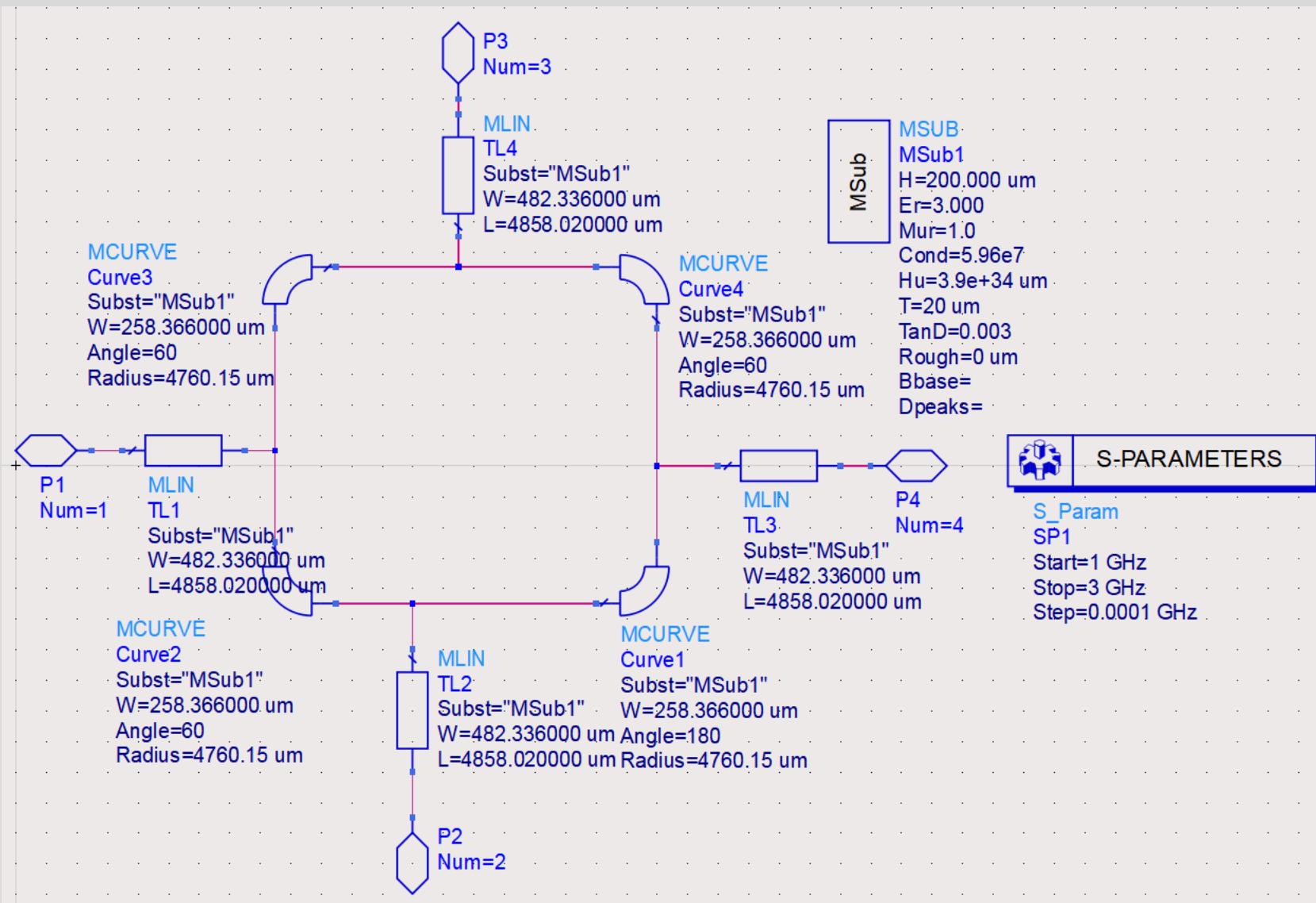
Z0	70.700 Ohm
E_Eff	540.000 deg
	N/A
	N/A

Values are consistent



PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN SCHEMATIC AT F0 = 10 GHZ



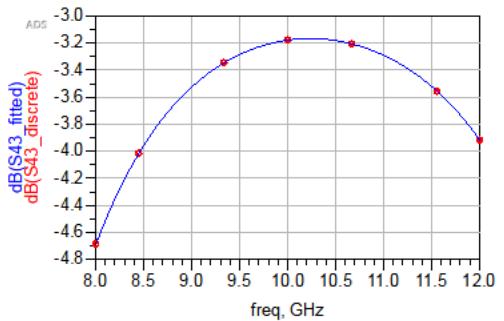
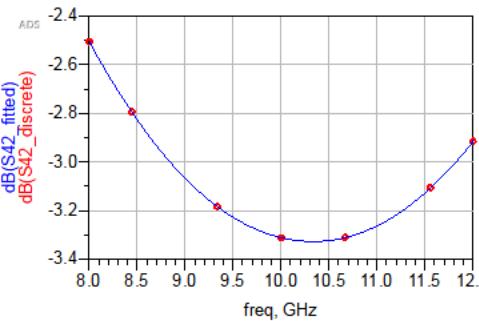
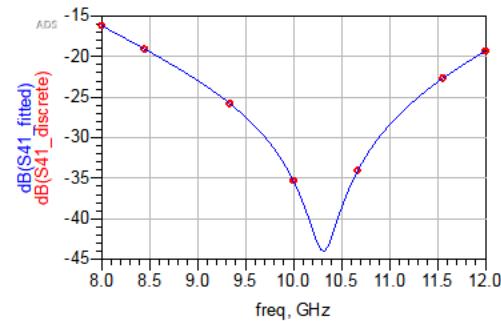
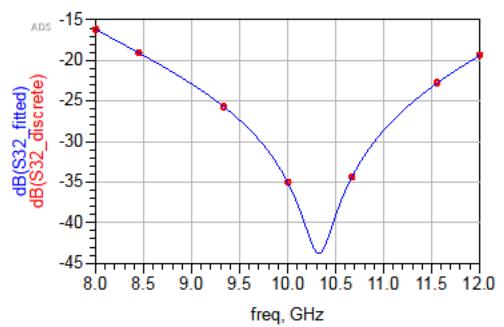
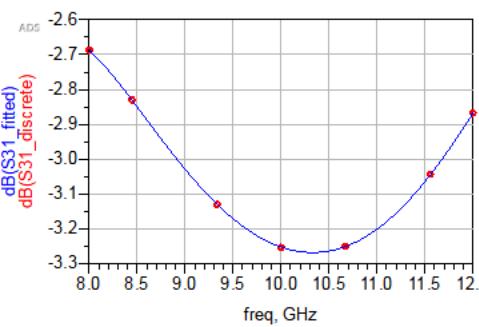
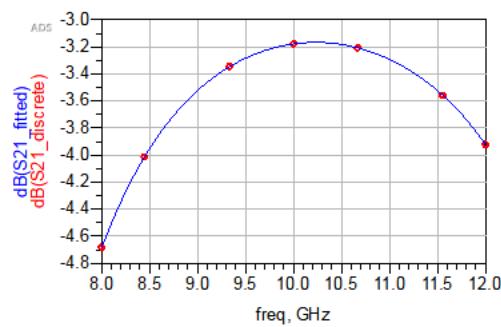
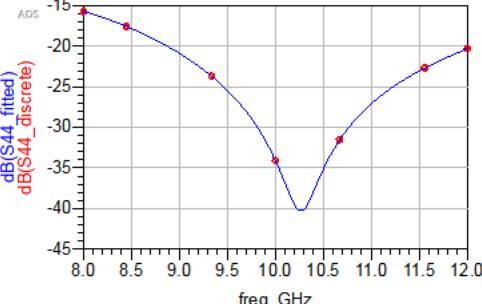
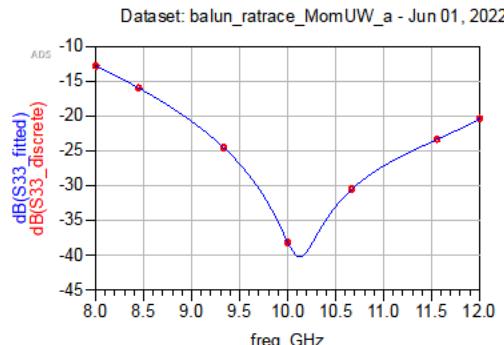
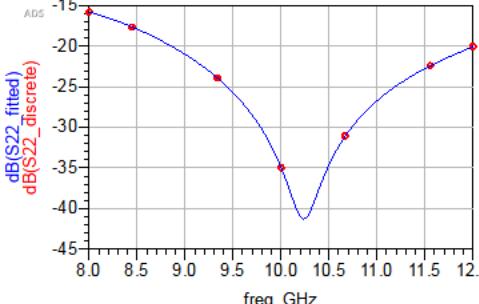
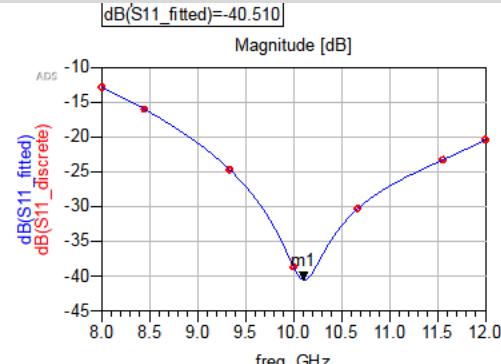
PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN LAYOUT AT F0 = 10 GHZ



PART 3: BALUN IMPLEMENTATION

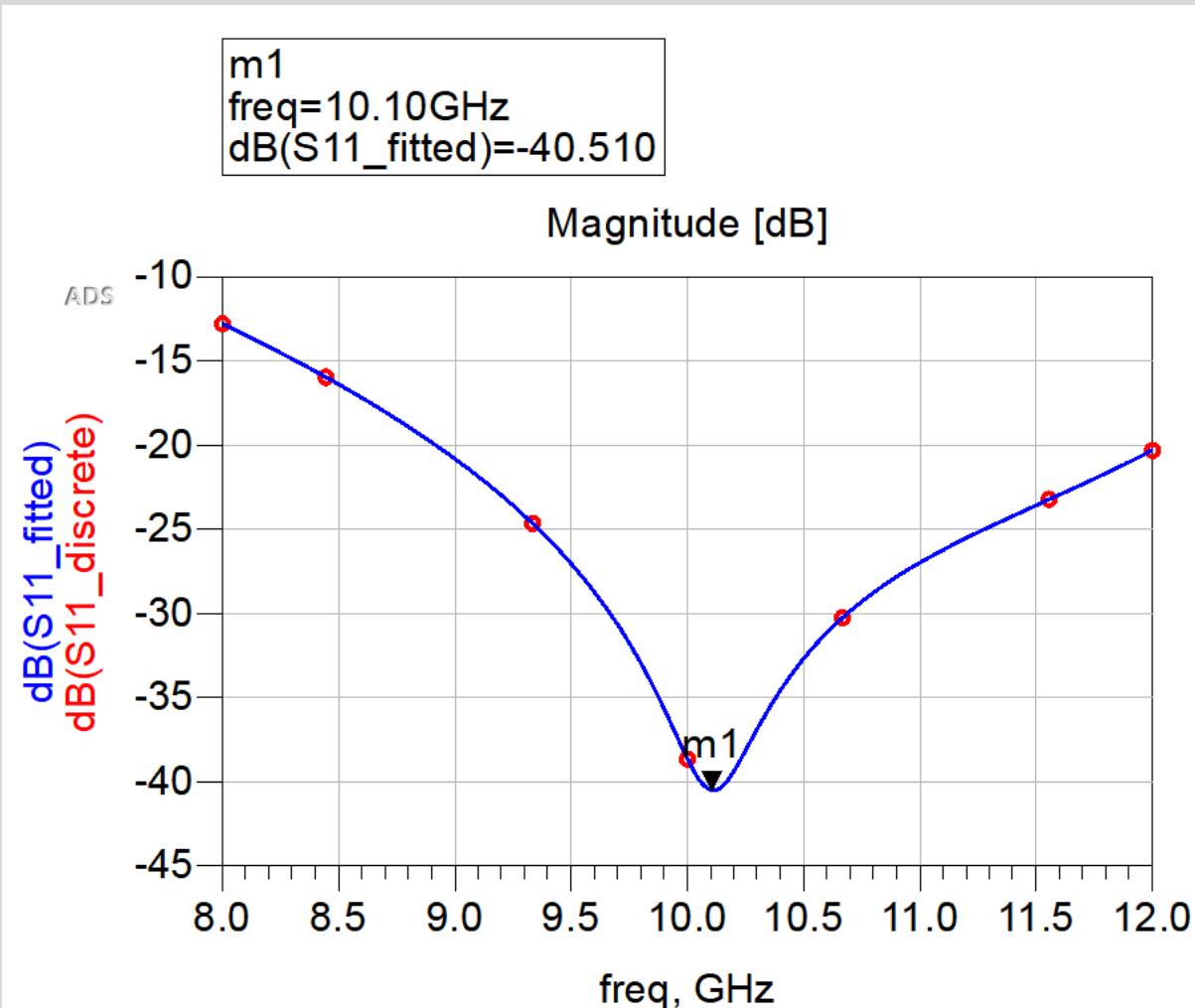
3- RAT RACE BALUN LAYOUT S PARAMETERS AT F0 = 10GHz



PART 3: BALUN IMPLEMENTATION

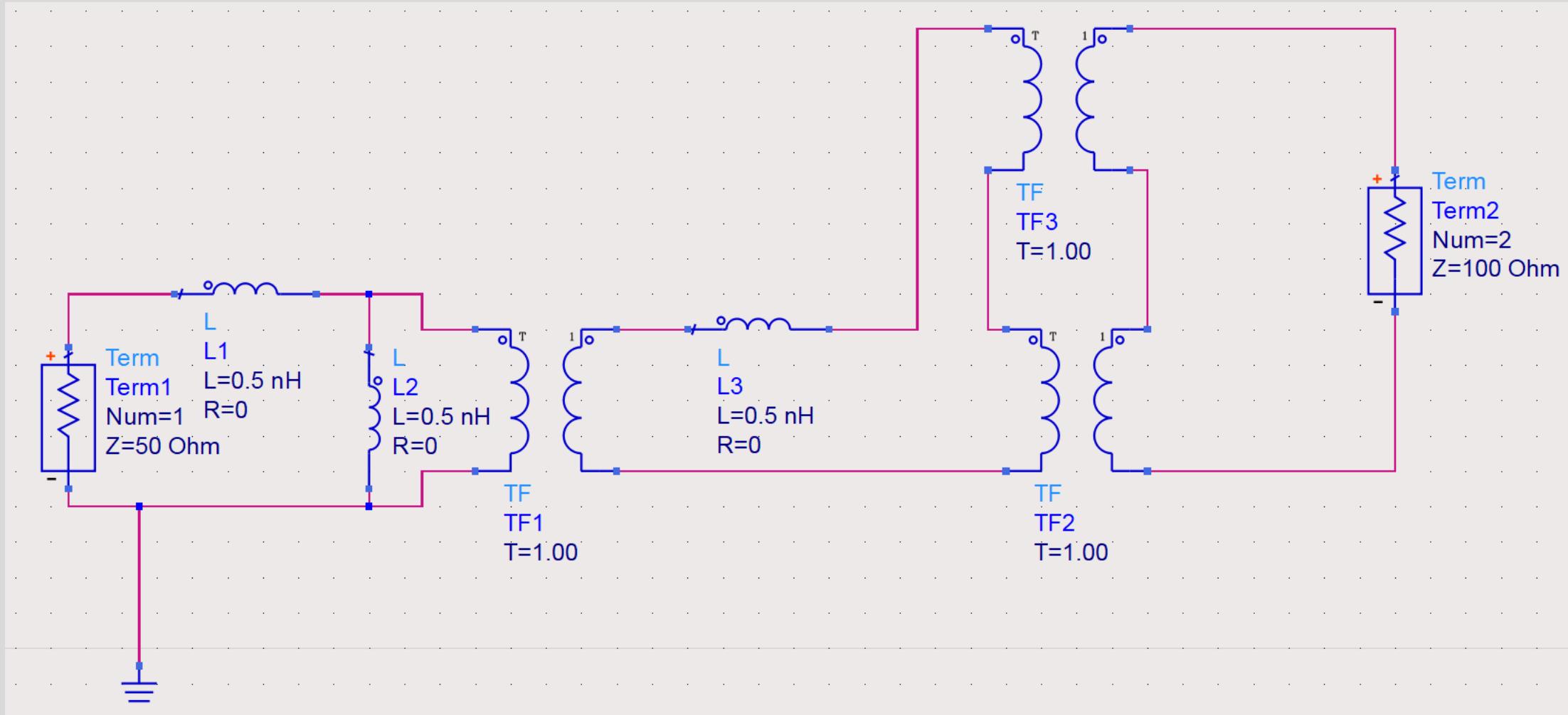
3- RAT RACE BALUN LAYOUT S11

At very high frequency rat race gives bad losses values
So I redesign at 10 GHz



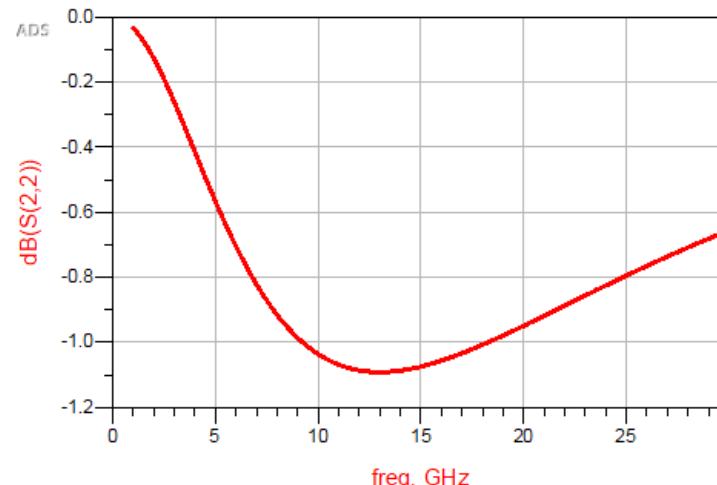
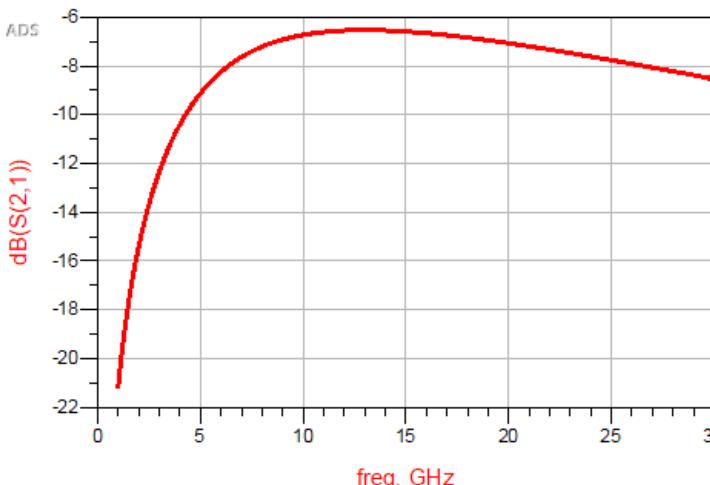
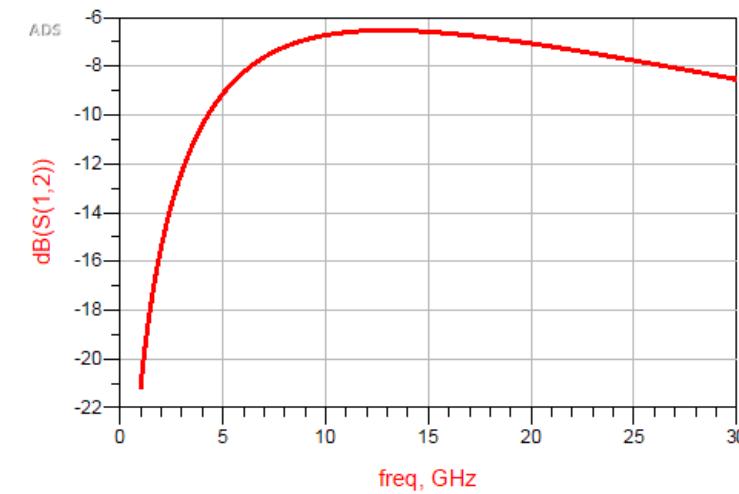
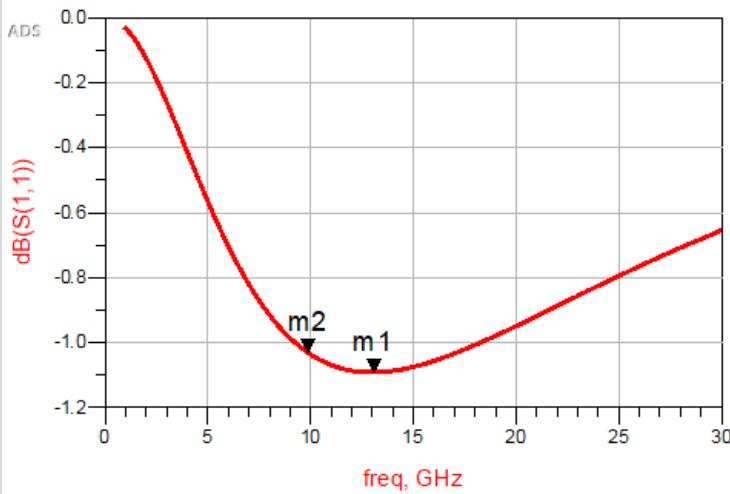
PART 3: BALUN IMPLEMENTATION

4- TRANSFORMER BASED BALUN



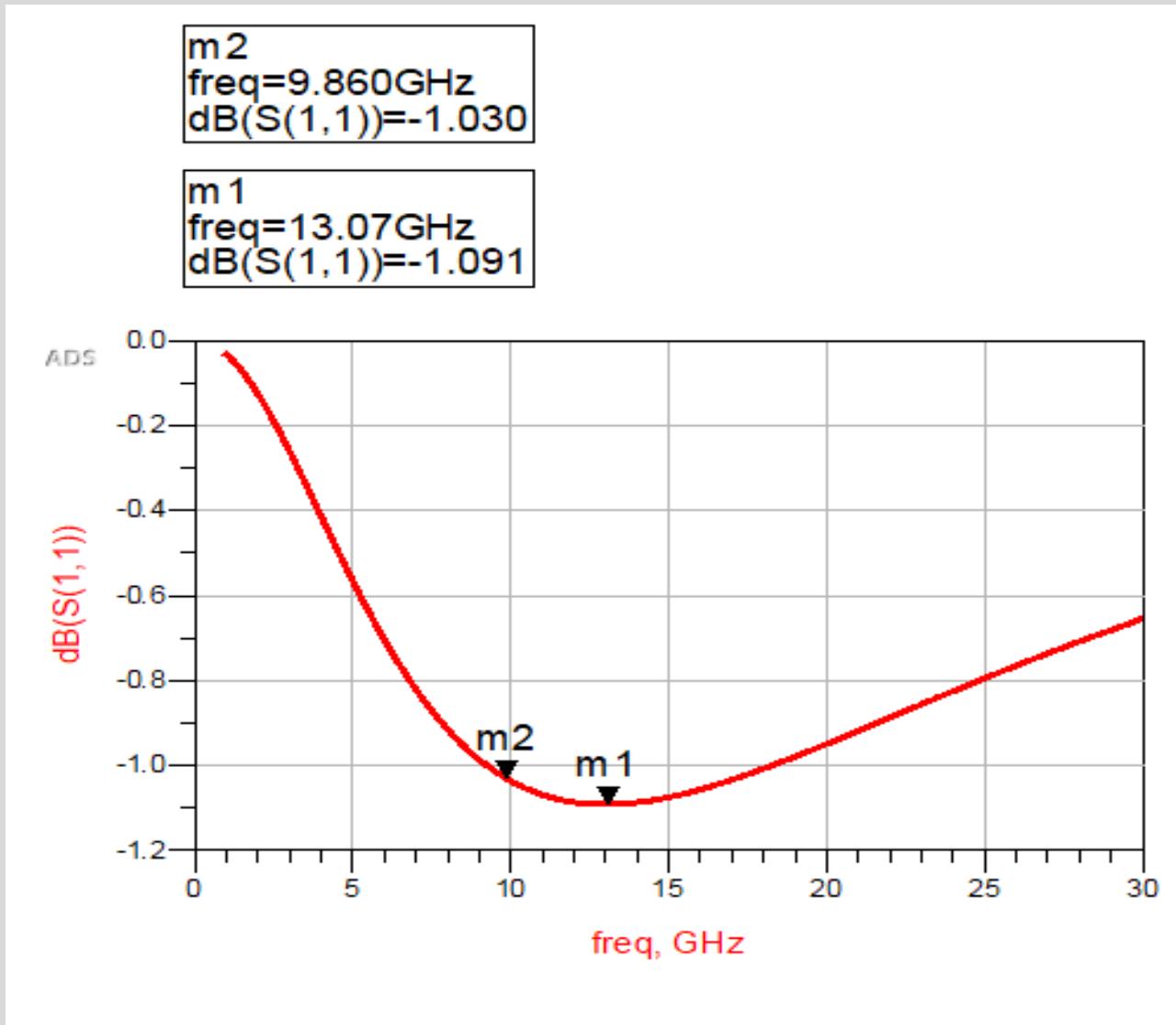
PART 3: BALUN IMPLEMENTATION

4- TRANSFORMER BASED BALUN S PARAMETERS



PART 3: BALUN IMPLEMENTATION

4- TRANSFORMER BASED BALUN S PARAMETERS S11



Assignment 3b

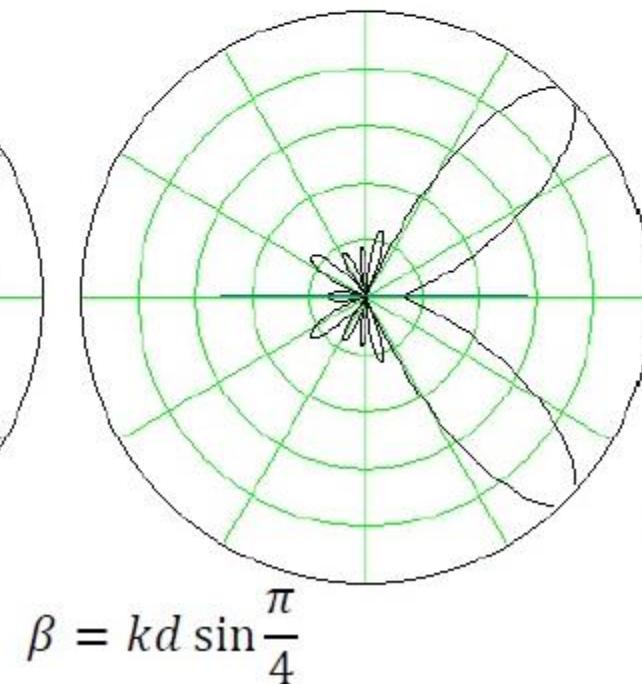
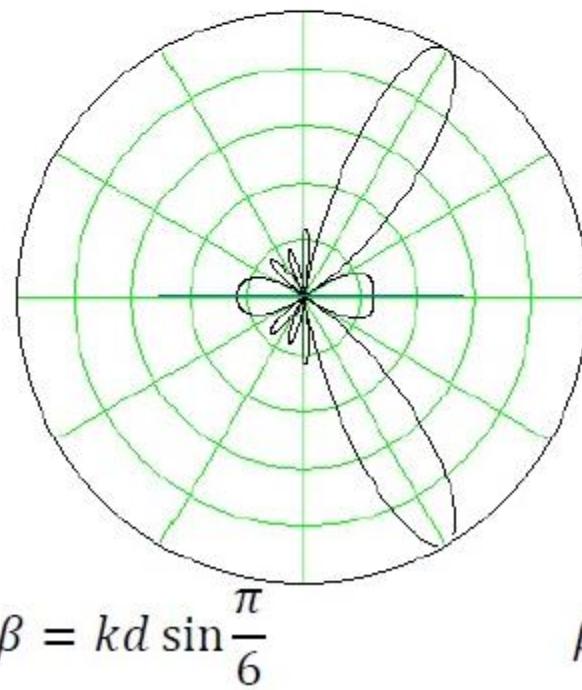
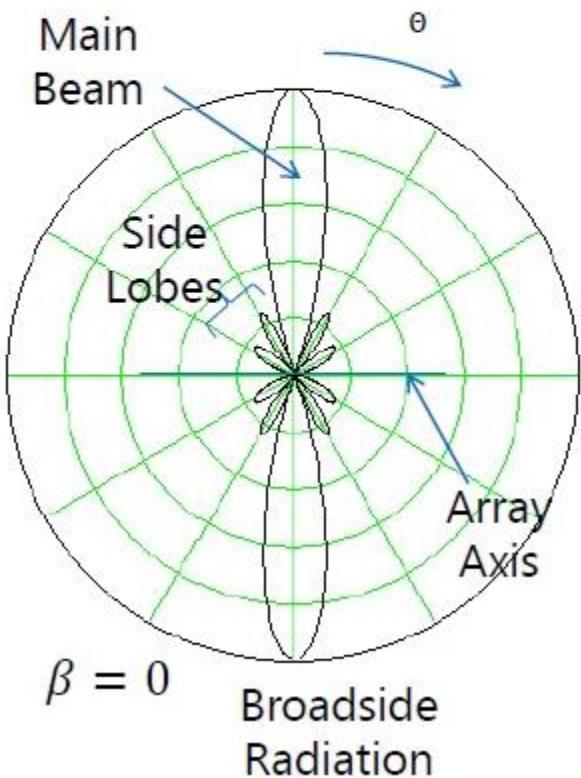
Beam-Squint in Phased Arrays

DERIVATION

Measured from
the normal

Normalized

$$|SF_n(\theta)| = \left| \frac{\sin\left(N \frac{kd}{2} (\sin \theta - \sin \theta_0)\right)}{N \sin\left(\frac{kd}{2} (\sin \theta - \sin \theta_0)\right)} \right| \quad \beta = kd \sin \theta_0$$



$$kd = \pi$$
$$N = 6$$

DERIVATION

From the SF equation

$$\beta = k * d * \sin(\theta)$$

$$\beta = \frac{2 * \pi * d}{c} * \left(f_0 + \frac{\Delta f}{2} \right) * \sin(\theta)$$

To derive the expression we want to know where the grating loops appear

$$\Delta\phi = \frac{2\pi d \sin(\theta)}{\lambda}$$

we can compute the beam angle as a function of phase shift

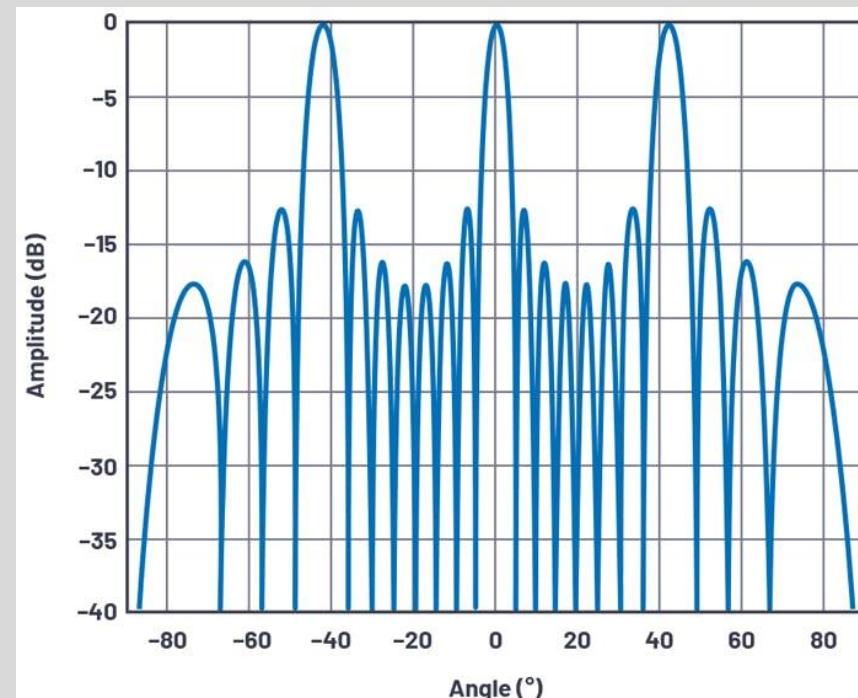
$$\theta = \arcsin\left(\frac{\Delta\phi}{2\pi} * \frac{\lambda}{d}\right)$$

$$\theta = \arcsin\left(\frac{m * 2\pi + \Delta\phi}{2\pi} * \frac{\lambda}{d}\right)$$

To avoid grating lobes, our goal is to obtain a single real solution

$$\left| \frac{m * 2\pi + \Delta\phi}{2\pi} * \frac{\lambda}{d} \right| > 1 \text{ for all } m \geq 1$$

$$\theta = \arcsin\left(m * \frac{\lambda}{d}\right) \text{ for } \Delta\phi=0$$



DERIVATION

From the SF equation

$$\beta = k * d * \sin(\theta)$$

$\frac{m*2\pi + \Delta\phi}{2\pi} * \frac{\lambda}{d}$ will range from 0 to $0.5 * \frac{\lambda}{d}$ for $m = 0$

$$\theta = \arcsin\left(\frac{m * 2\pi + \Delta\phi}{2\pi} * \frac{\lambda}{d}\right)$$

To avoid grating lobes, our goal is to obtain a single real solution

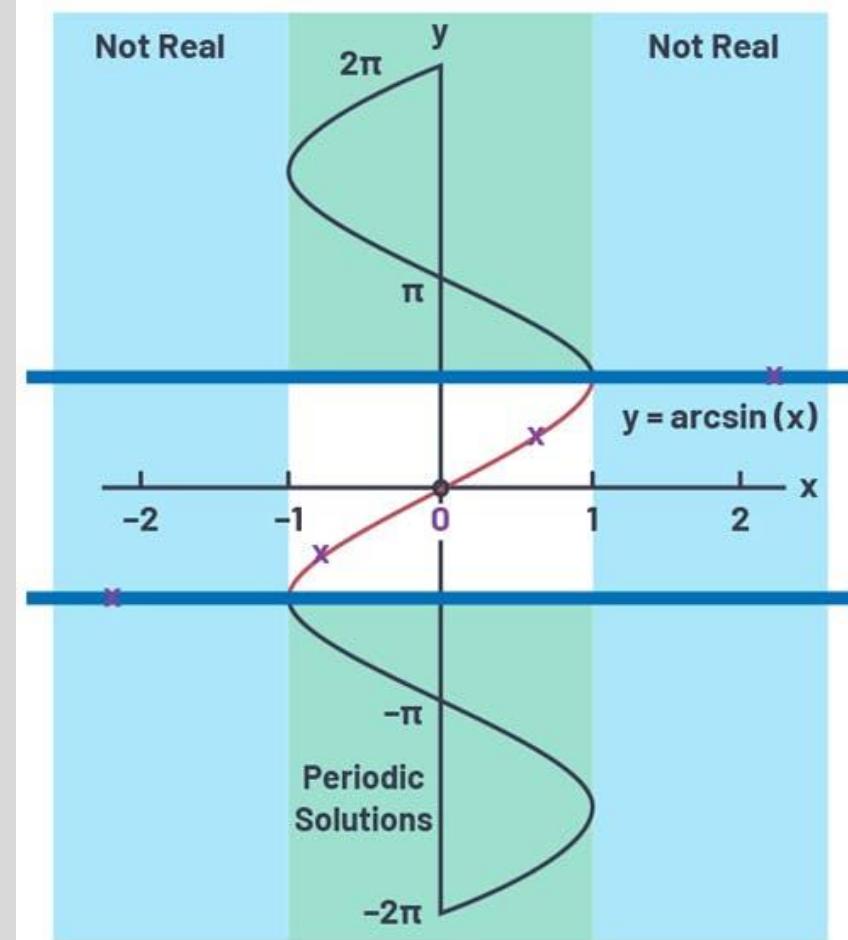
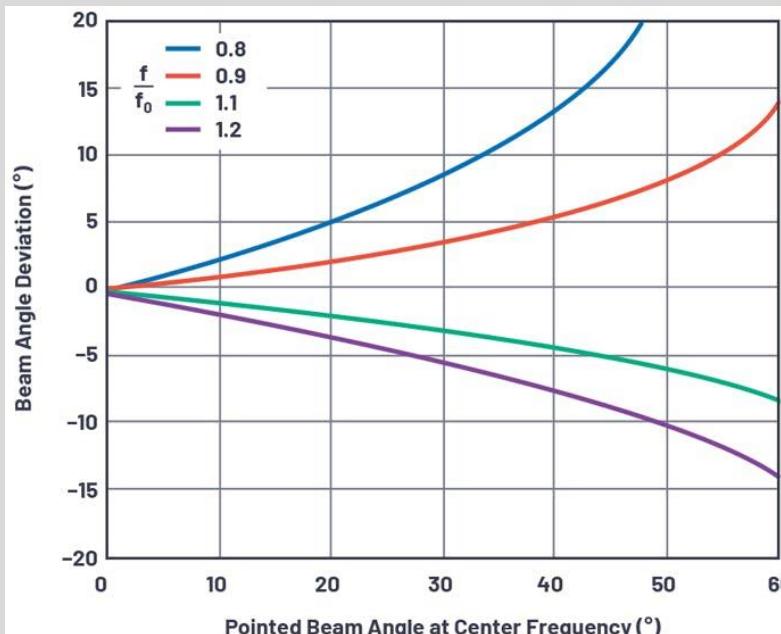
$$\left|\frac{m*2\pi + \Delta\phi}{2\pi} * \frac{\lambda}{d}\right| > 1 \text{ for all } m \geq 1$$

$$\theta = \arcsin\left(m * \frac{\lambda}{d}\right) \text{ for } \Delta\phi=0$$

$$\Delta\theta = \arcsin\left(\frac{f_0}{f} \sin(\theta_0)\right) - \theta_0$$

The beam squint, or deviation in steering angle vs. frequency, is caused by approximating a time delay with a phase shift.

Implementing beam steering with true time-delay units doesn't have this problem



$$\theta = \arcsin\left(m \frac{\lambda}{d}\right), \text{ for } \Delta\Phi = 0$$

So for Example: $\lambda/d = 0.66$

O = Actual Lobe

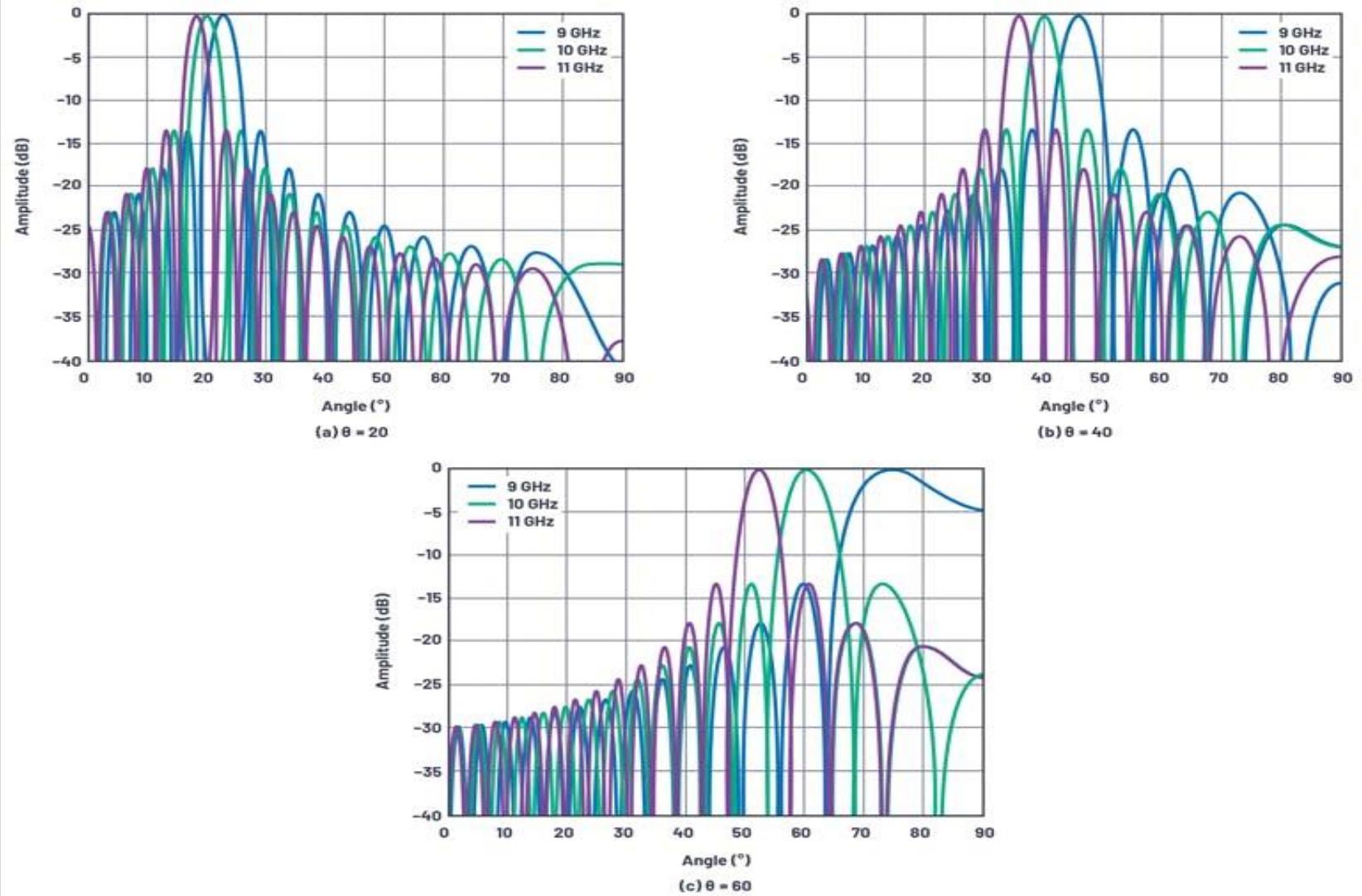
X = Grating Lobes

$m = \pm 1$ Lobes Fall Within Allowed Area

$m = \pm 2$ Lobes Fall in Nonreal Area

(That Is, $y = \pi/2 - i \times 0.78$)

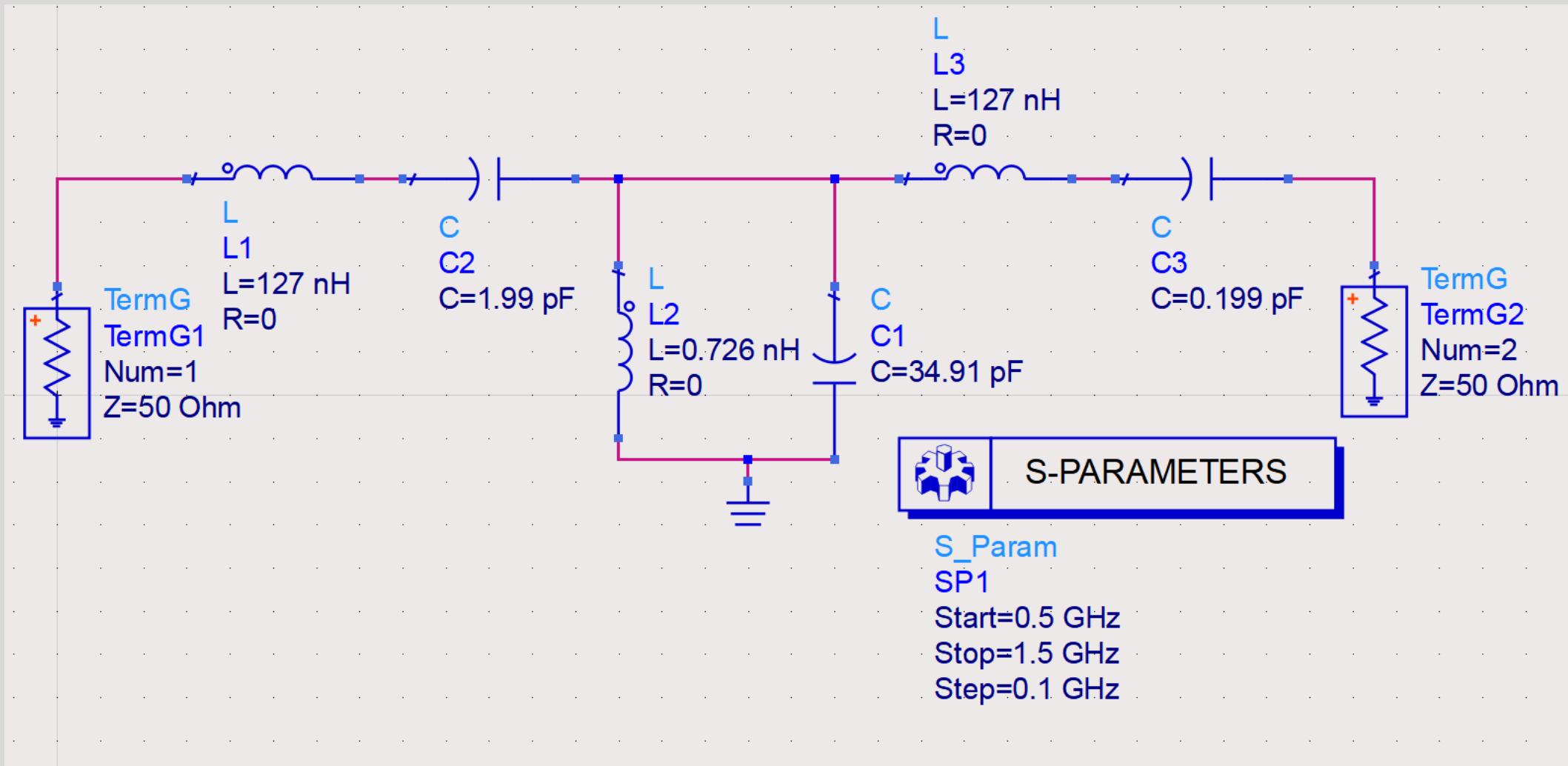
PLOT



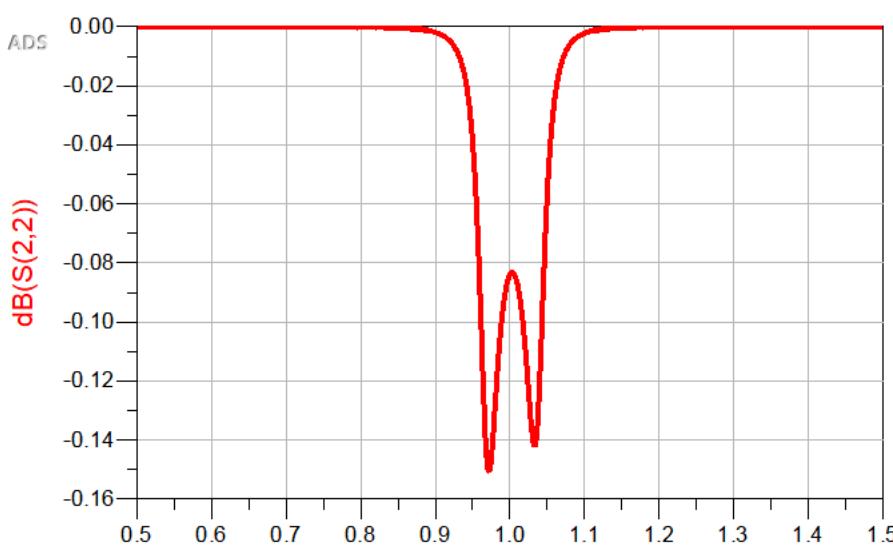
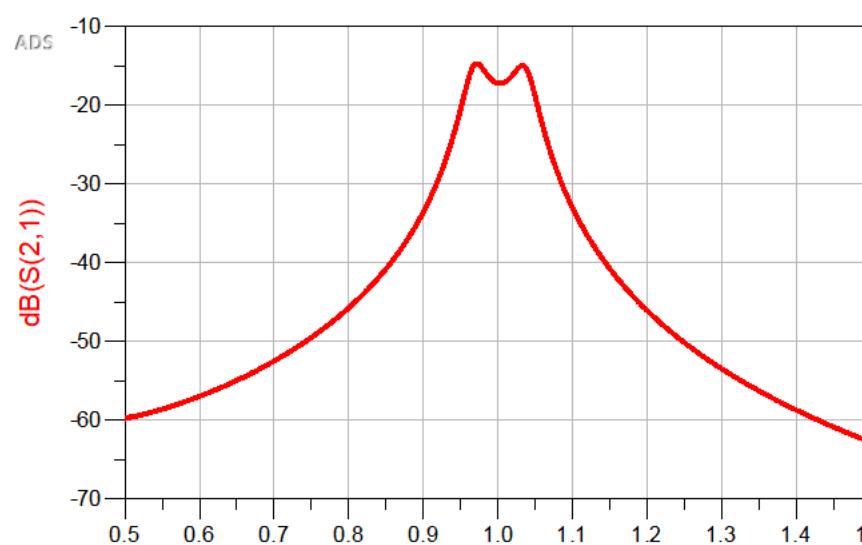
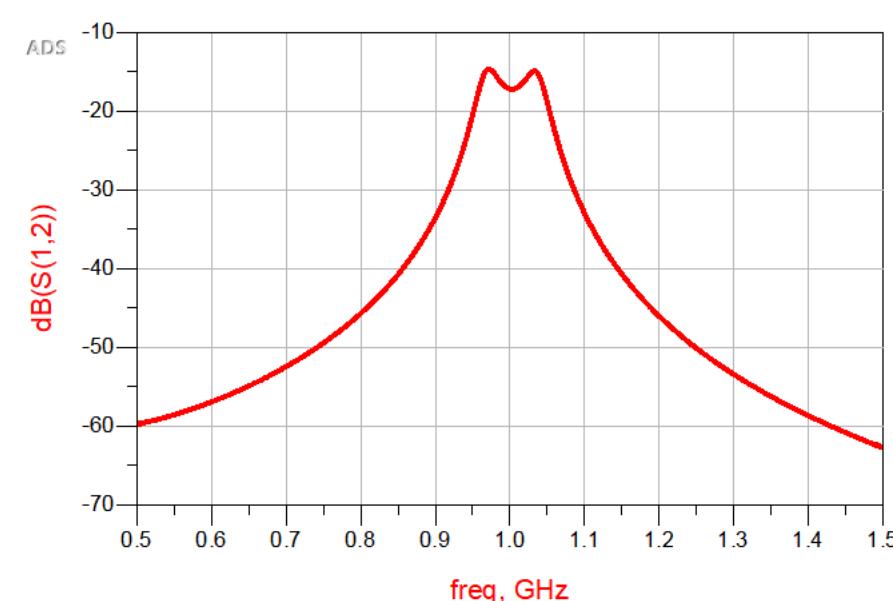
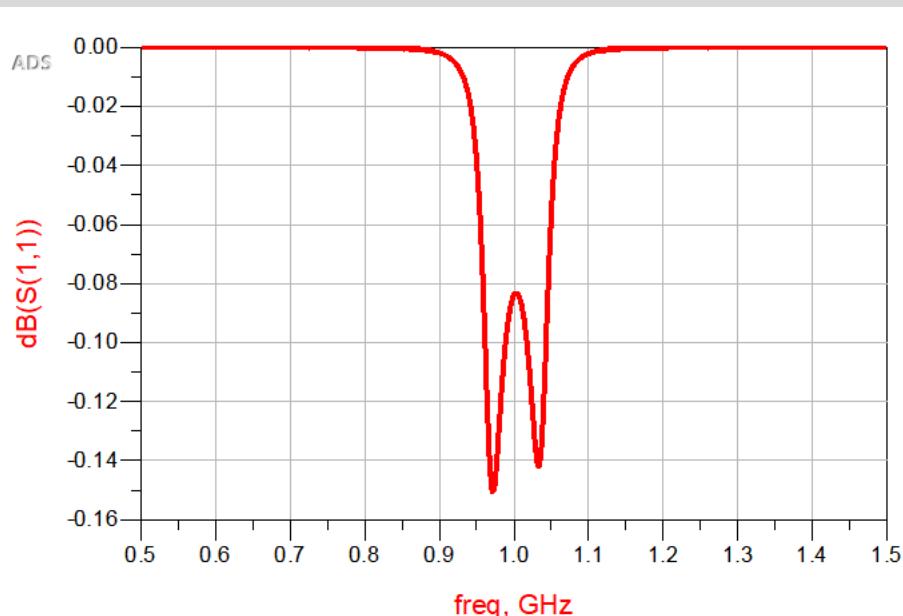
Assignment 4a

The Insertion Loss Method

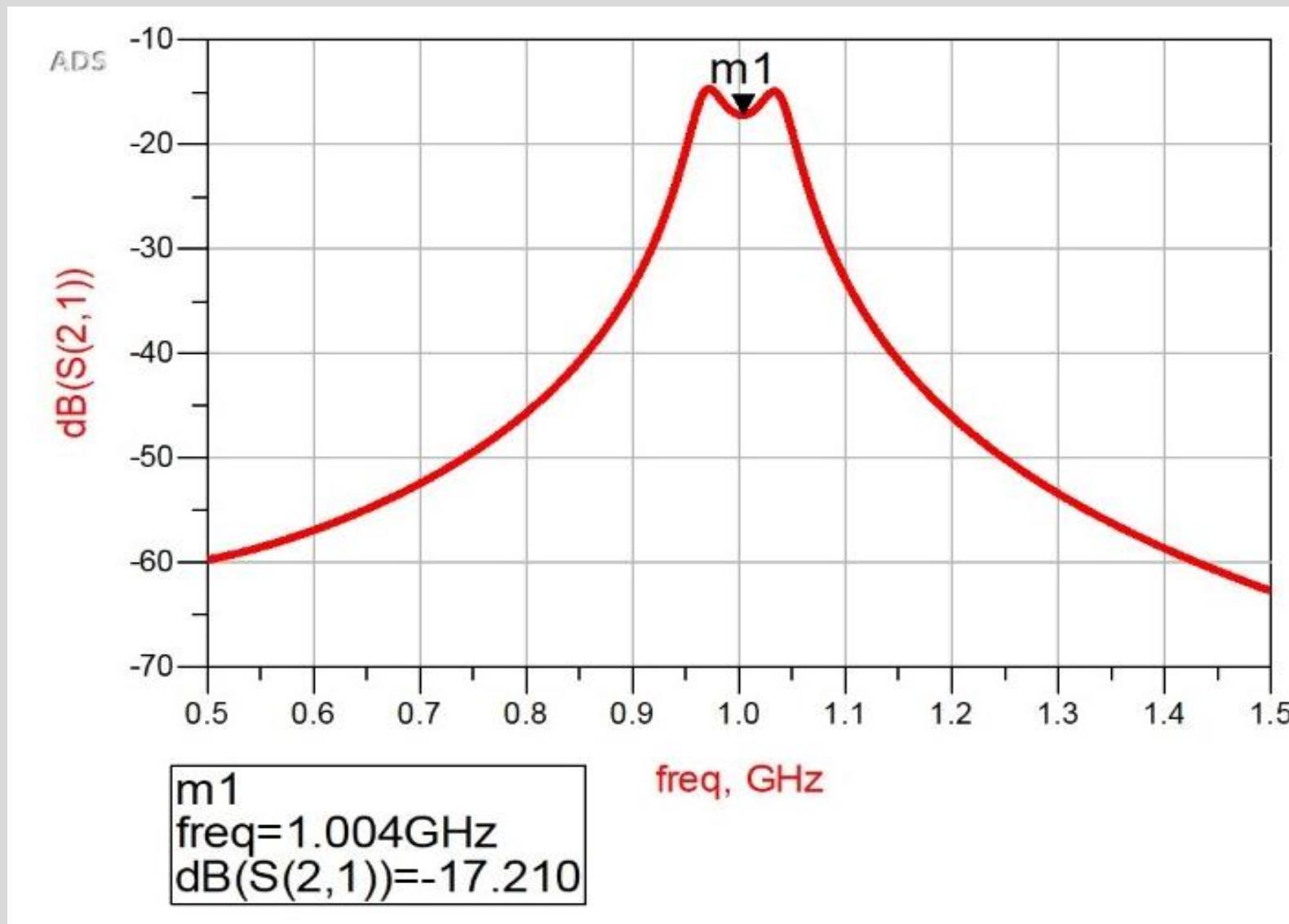
SCHEMATIC DESIGN



S PARAMETERS



ATTENUATION S21



Assignment 4b

Coupled-Resonator Filters

LINE CALC Z0=50 OHM

EXAMPLE 1 BANDSTOP FILTER

LineCalc/first.lcs

Z=50

File Simulation Options Help

Component

Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A
Rough	0.000 um
DielectricLossModel	1.000 N/A
FreqForEpsrTanD	1.0e9 N/A
LowFreqForTanD	1.0e3 N/A
HighFreqForTanD	1.0e12 N/A

Physical

W	481.492000 um
L	24307.300000 um
	N/A
	N/A

Synthesize Analyze

Electrical

Z0	50.000 Ohm
E_Eff	90.000 deg
	N/A
	N/A

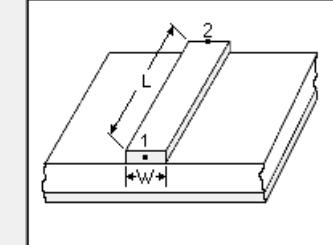
Calculated Results

K_Eff = 2.376
A_DB = 0.062
SkinDepth = 1.457

Component Parameters

Freq	2.000 GHz
Wall1	
Wall2	

Values are consistent



LINE CALC Z0 = 265.9 AND 387

LineCalc/first.lcs

File Simulation Options Help

Component Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A
Rough	0.000 um
DielectricLossModel	1.000 N/A
FreqForEpsrTanD	1.0e9 N/A
LowFreqForTanD	1.0e3 N/A
HighFreqForTanD	1.0e12 N/A

Physical

W	0.172163 um
L	27189.000000 um

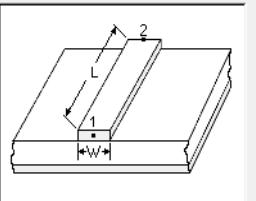
Synthesize Analyze

Electrical

Z0	387.000 Ohm
E_Eff	90.000 deg

Calculated Results

K_Eff = 1.899
A_DB = 14.119
SkinDepth = 1.457



LineCalc/first.lcs

File Simulation Options Help

Component Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000 N/A
Mur	1.000 N/A
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A
Rough	0.000 um
DielectricLossModel	1.000 N/A
FreqForEpsrTanD	1.0e9 N/A
LowFreqForTanD	1.0e3 N/A
HighFreqForTanD	1.0e12 N/A

Physical

W	0.196675 um
L	27197.400000 um

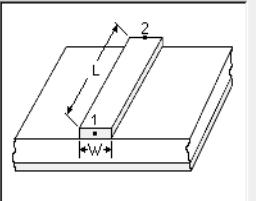
Synthesize Analyze

Electrical

Z0	265.900 Ohm
E_Eff	90.000 deg

Calculated Results

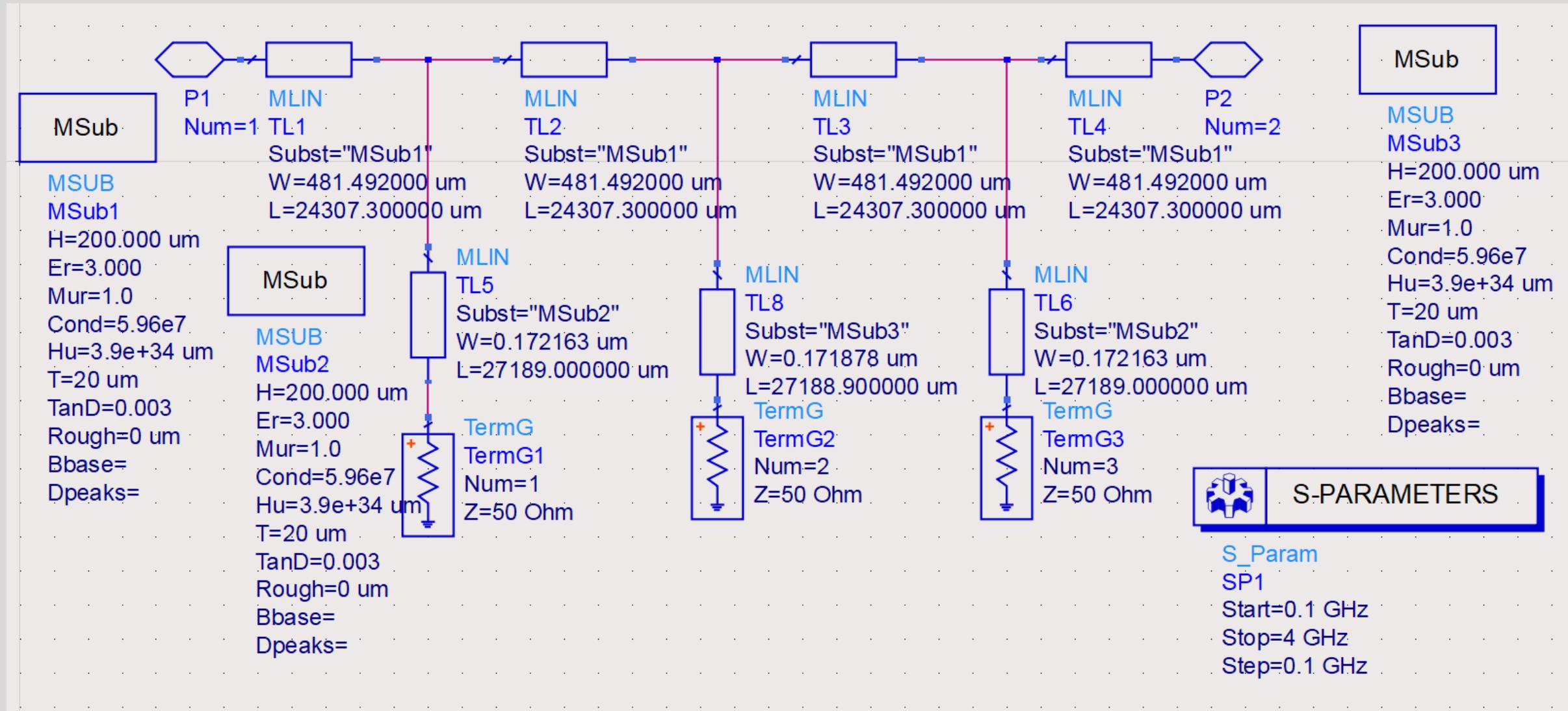
K_Eff = 1.898
A_DB = 12.575
SkinDepth = 1.457



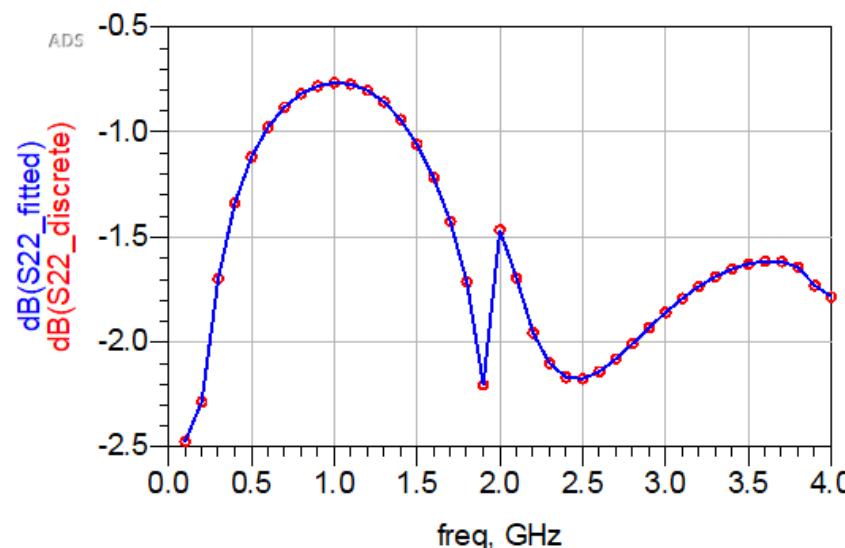
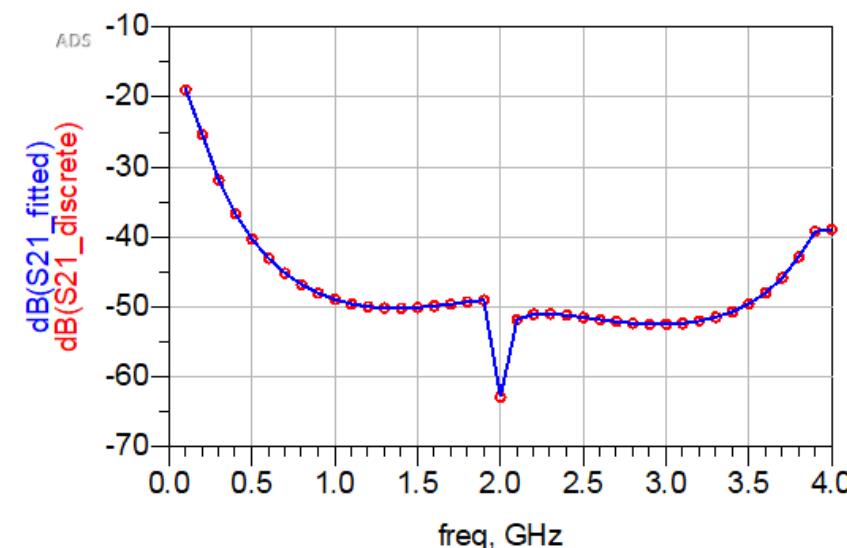
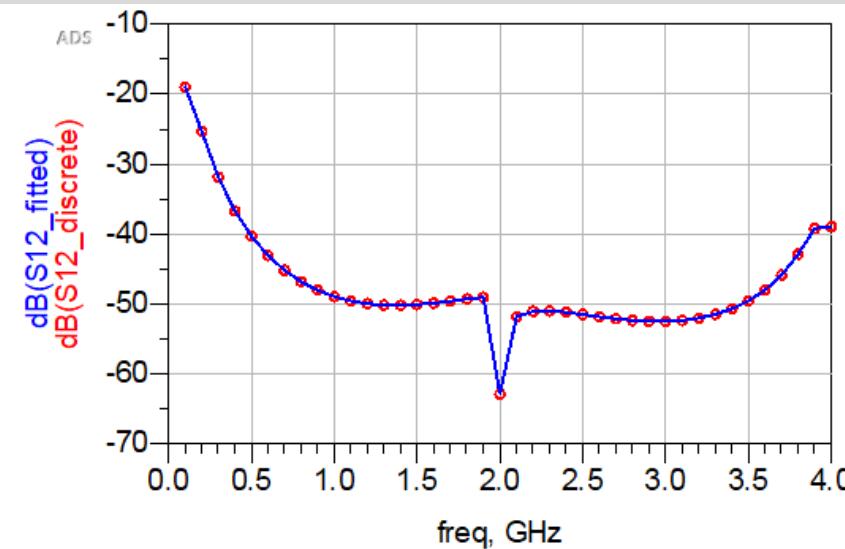
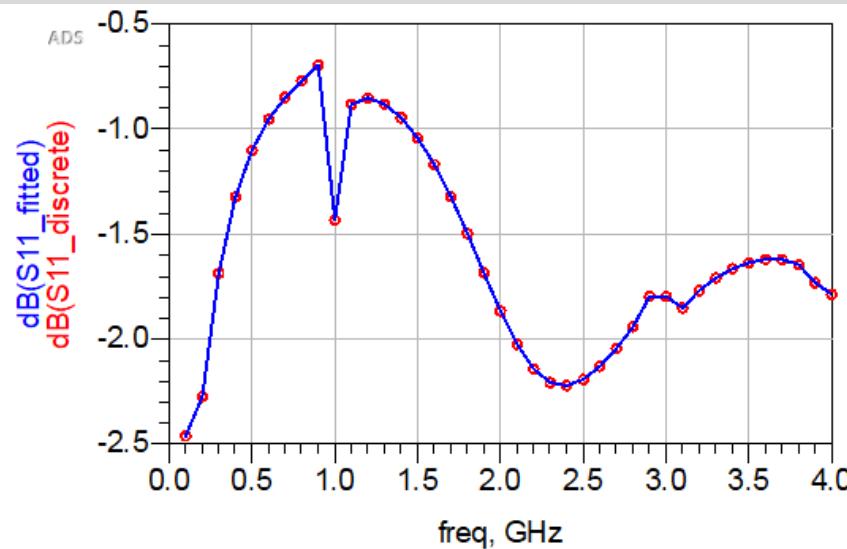
Values are consistent

Values are consistent

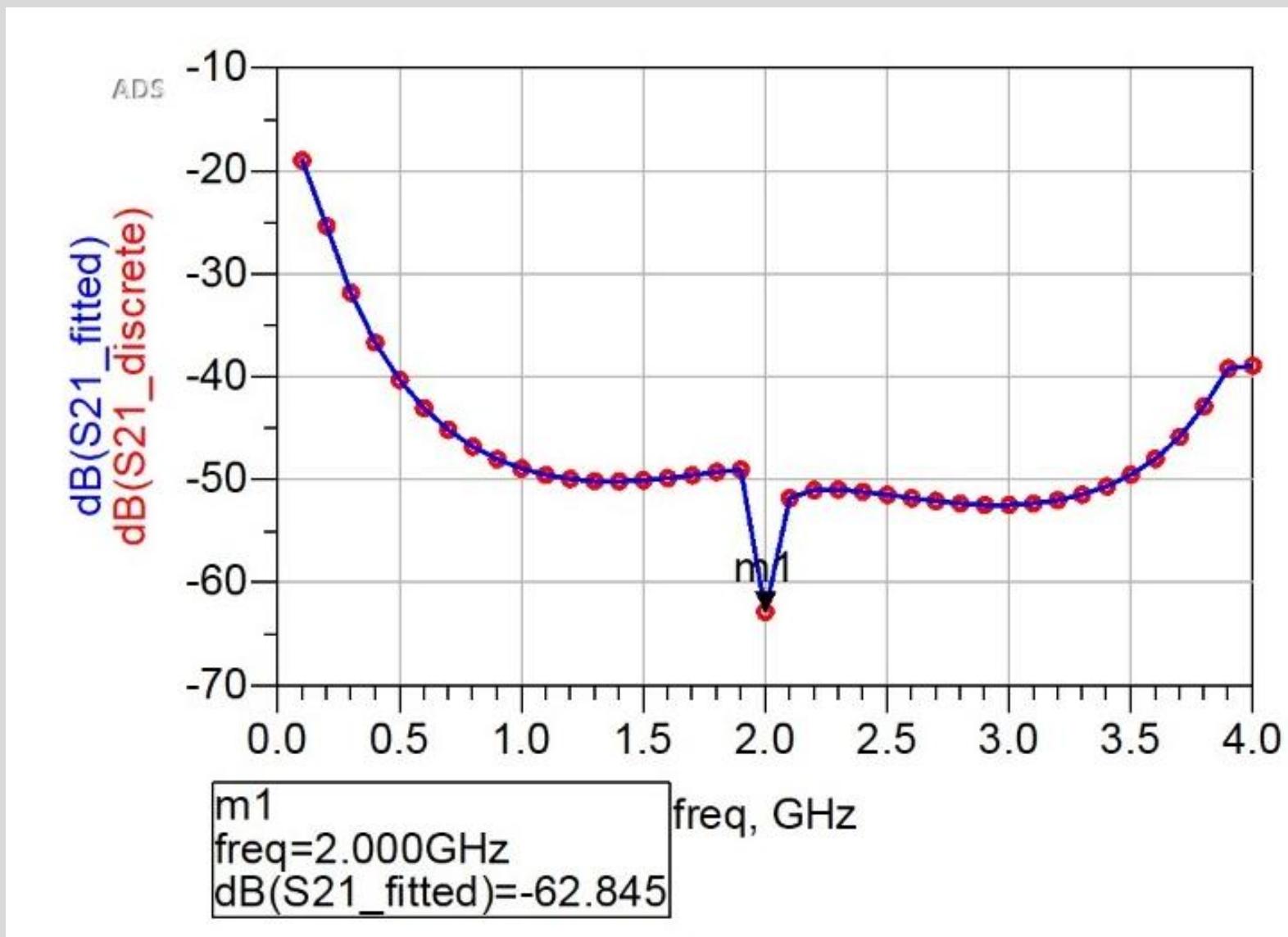
SCHEMATIC DESIGN



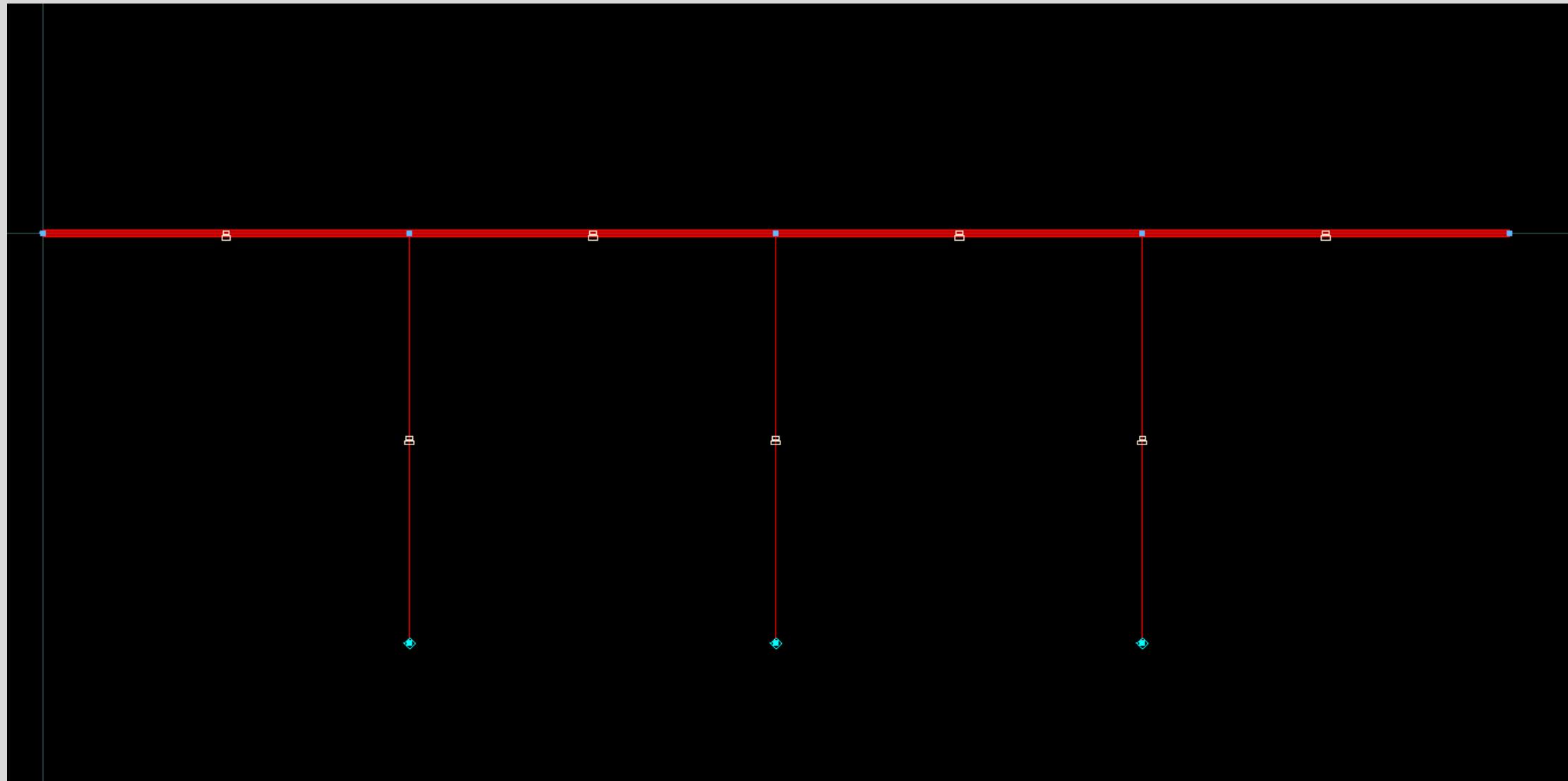
S PARAMETERS FROM SCHEMATIC



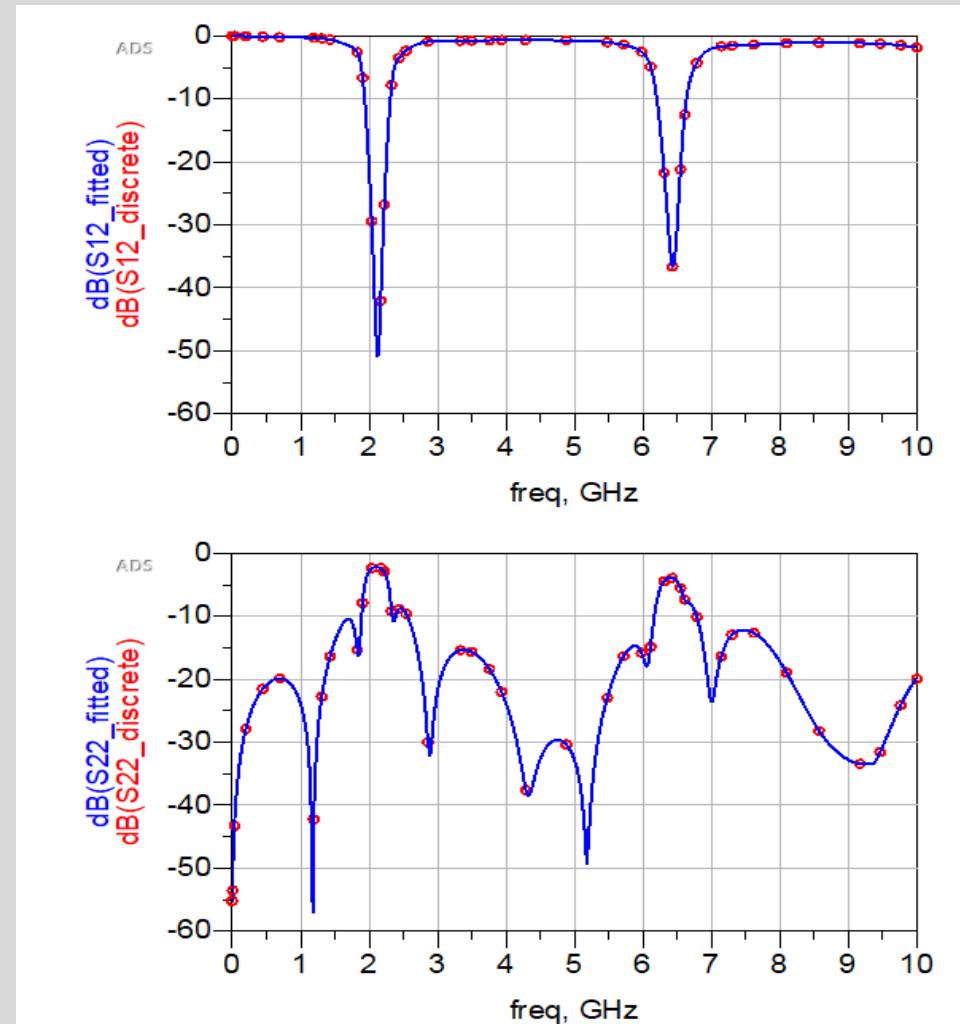
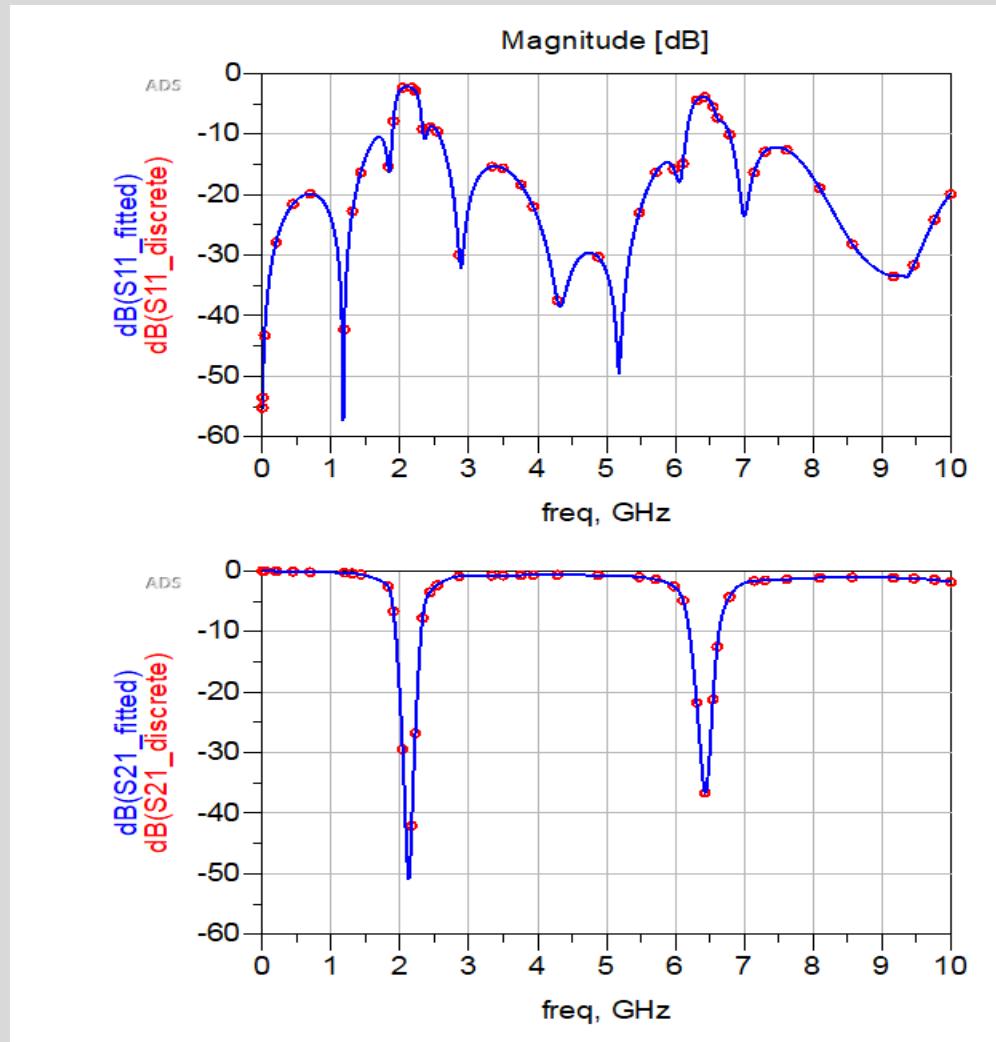
ATTENUATION FROM SCHEMATIC S21



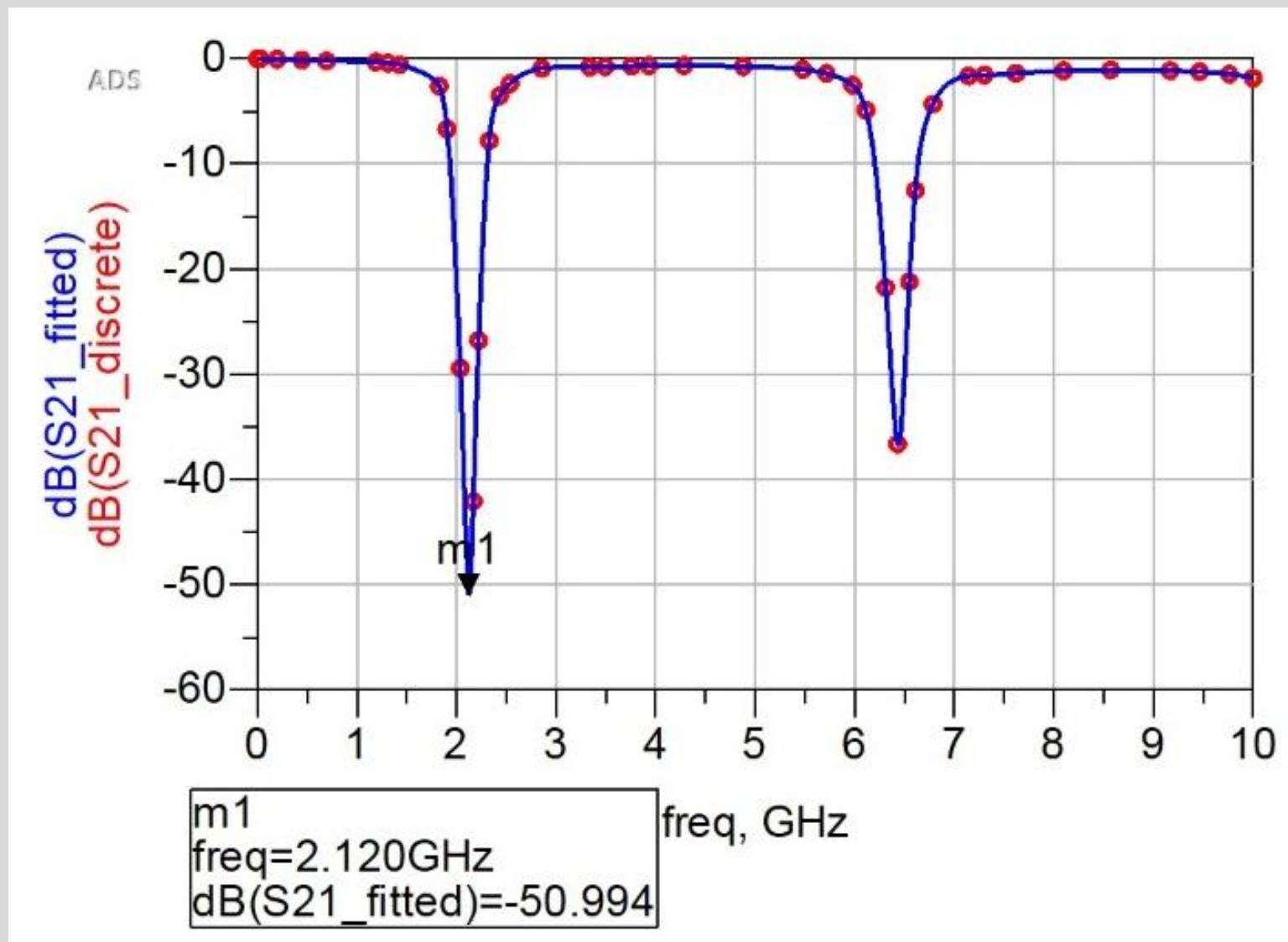
LAYOUT DESIGN



S PARAMETERS FROM LAYOUT



ATTENUATION FROM LAYOUT S21



LINE CALC Z0=50 OHM EXAMPLE 2 BANDPASS FILTER

LineCalc/first.lcs

Z=50

File Simulation Options Help

Component

Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A
Rough	0.000 um
DielectricLossModel	1.000 N/A
FreqForEpsrTanD	1.0e9 N/A
LowFreqForTanD	1.0e3 N/A
HighFreqForTanD	1.0e12 N/A

Physical

W	481.492000 um
L	24307.300000 um
	N/A
	N/A

Synthesize Analyze

Electrical

Z0	50.000 Ohm
E_Eff	90.000 deg
	N/A
	N/A

Calculated Results

K_Eff = 2.376
A_DB = 0.062
SkinDepth = 1.457

Component Parameters

Freq	2.000 GHz
Wall1	
Wall2	

Values are consistent

EXAMPLE 2 BANDPASS FILTER

Line calc z0=50 ohm and theta = 166.5

LineCalc/first.lcs

File Simulation Options Help

Component Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A

Physical

W	481.492000 um
L	44968.400000 um
	N/A
	N/A

Synthesize Analyze

Calculated Results

Z0 = 50.000 Ohm
E_Eff = 166.500 deg
K_Eff = 2.376
A_DB = 0.116
SkinDepth = 1.457

Component Parameters

Freq	2.000 GHz
Wall1	
Wall2	

Values are consistent

Line calc z0=50 ohm and theta = 155.8

LineCalc/first.lcs

File Simulation Options Help

Component Type MLIN ID MLIN: MLIN_DEFAULT

Substrate Parameters

ID	MSUB_DEFAULT
Er	3.000
Mur	1.000
H	200.000 um
Hu	3.9e+34 um
T	20.000 um
Cond	5.96e7 N/A
TanD	0.003 N/A

Physical

W	481.492000 um
L	42078.600000 um
	N/A
	N/A

Synthesize Analyze

Calculated Results

Z0 = 50.000 Ohm
E_Eff = 155.800 deg
K_Eff = 2.376
A_DB = 0.108
SkinDepth = 1.457

Component Parameters

Freq	2.000 GHz
Wall1	
Wall2	

Values are consistent

EXAMPLE 2 CONSTRAINTS:

F1 = 1.8 GHz

Fc = 2 GHz

F2 = 2.2 GHz

Z0 = 50 ohm

Attenuation(alpha) = 20 dB at 2.2 GHz

Delta = (f2-f1) / fc = 0.4/2 = 0.2

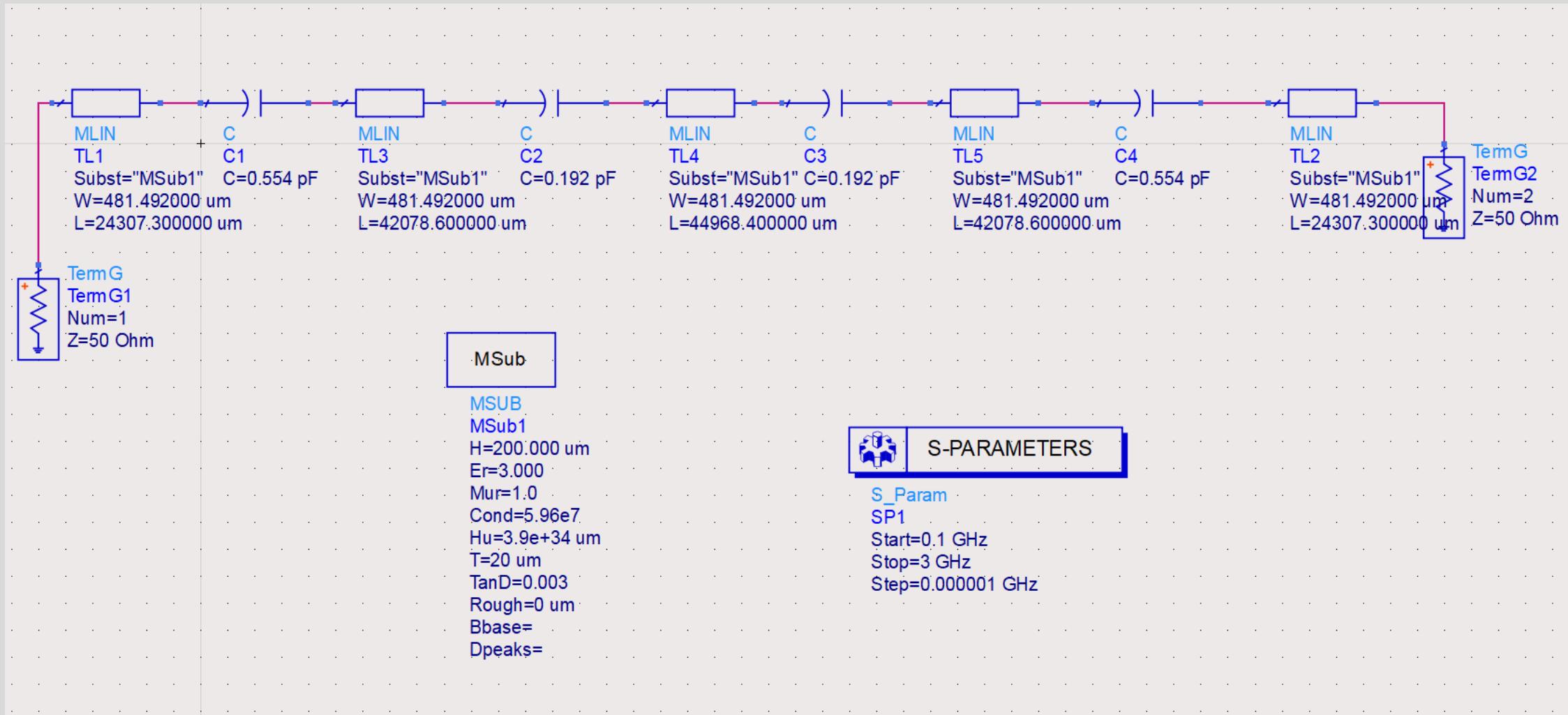
Filter order = 3

Number of sections 4

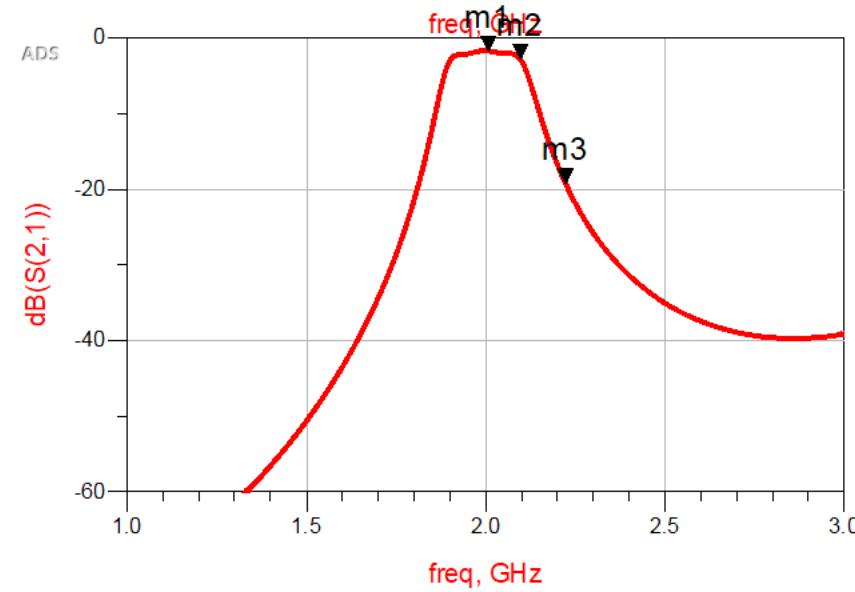
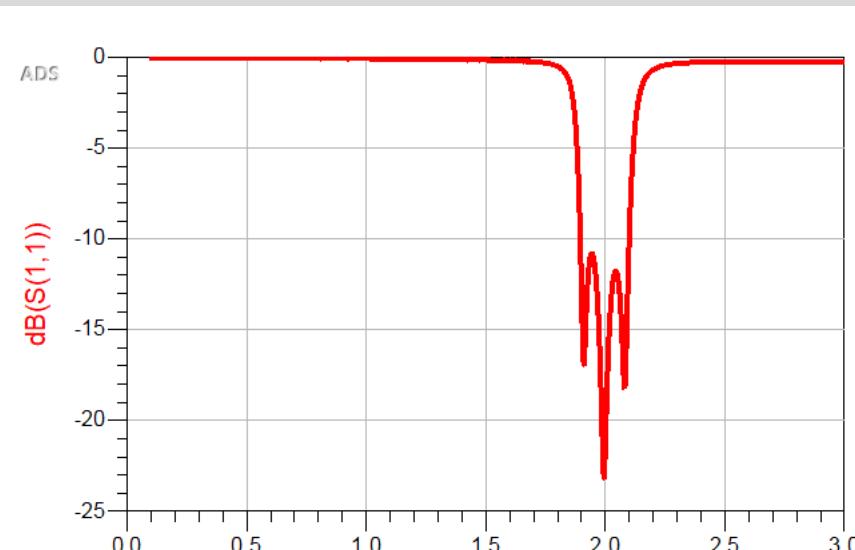
From the attenuation at 2.2 GHz, get N=3. Then:

n	g_n	$Z_0 J_n$	B_n	C_n (pF)	ϑ_n
1	1.5963			0.554	155.8°
2	1.0967			0.192	166.5°
3	1.5963			0.192	155.8°
4	1.0000			0.554	

EXAMPLE 2 SCHEMATIC USING TL MODEL:



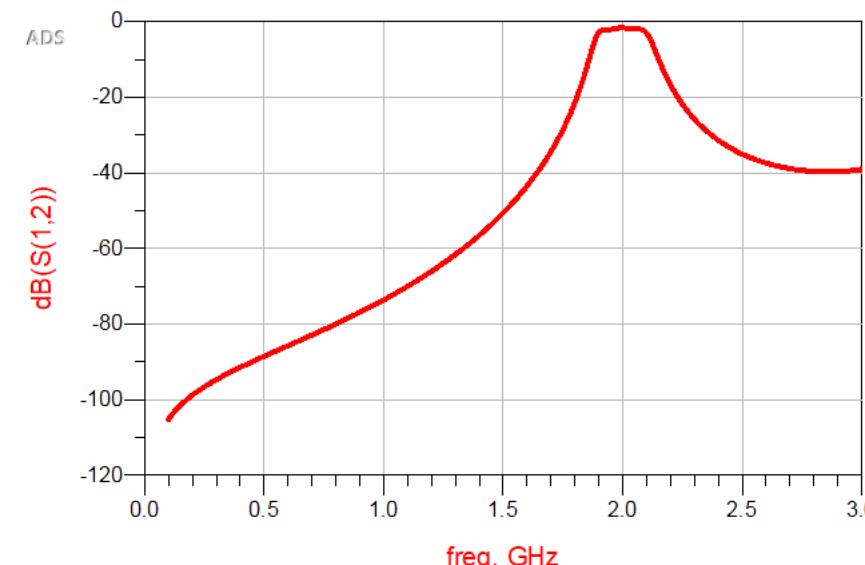
S PARAMETERS FROM SCHEMATIC



m1
freq=2.006GHz
 $\text{dB}(S_{2,1})=-1.731$

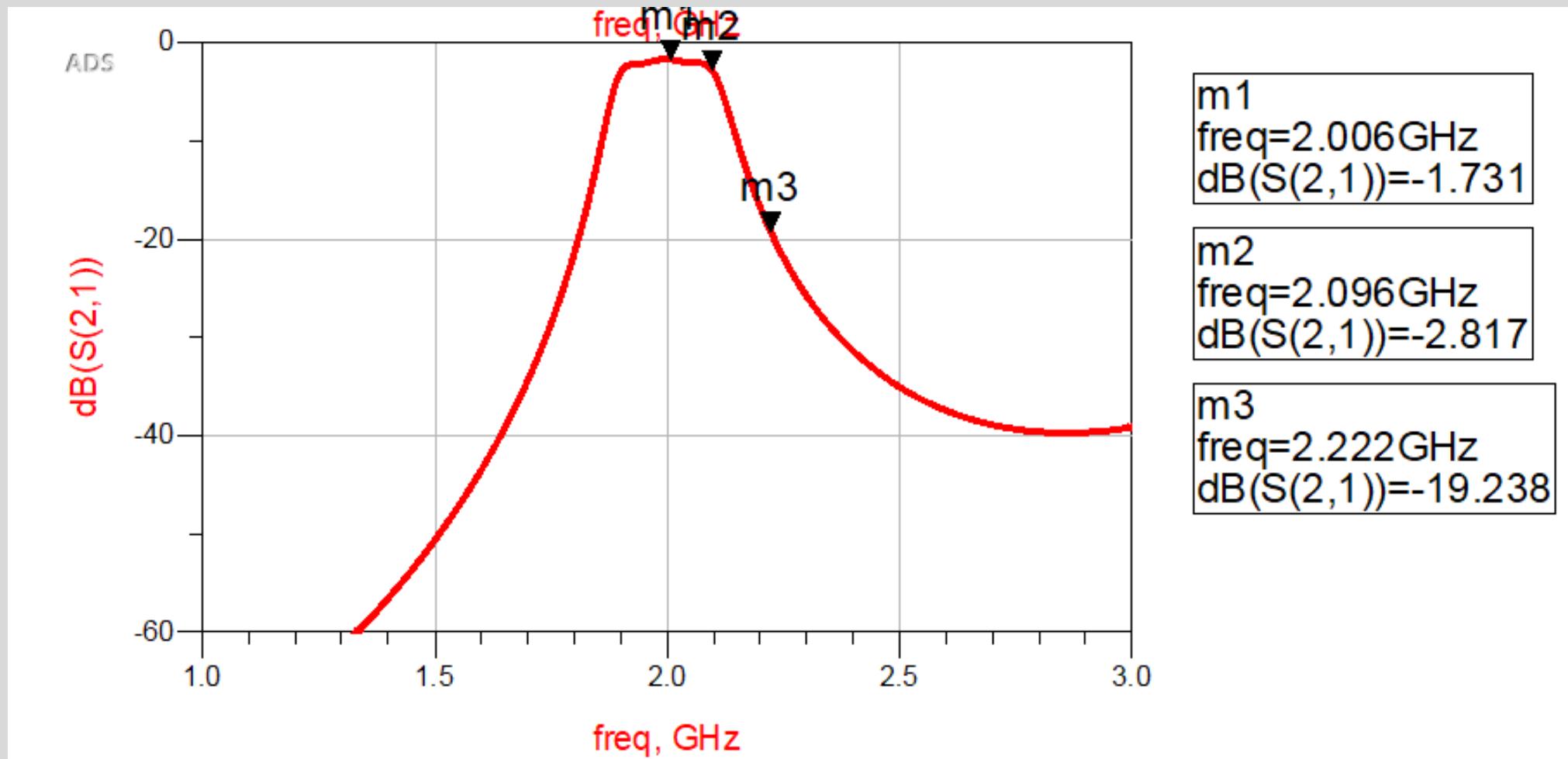
m2
freq=2.096GHz
 $\text{dB}(S_{2,1})=-2.817$

m3
freq=2.222GHz
 $\text{dB}(S_{2,1})=-19.238$



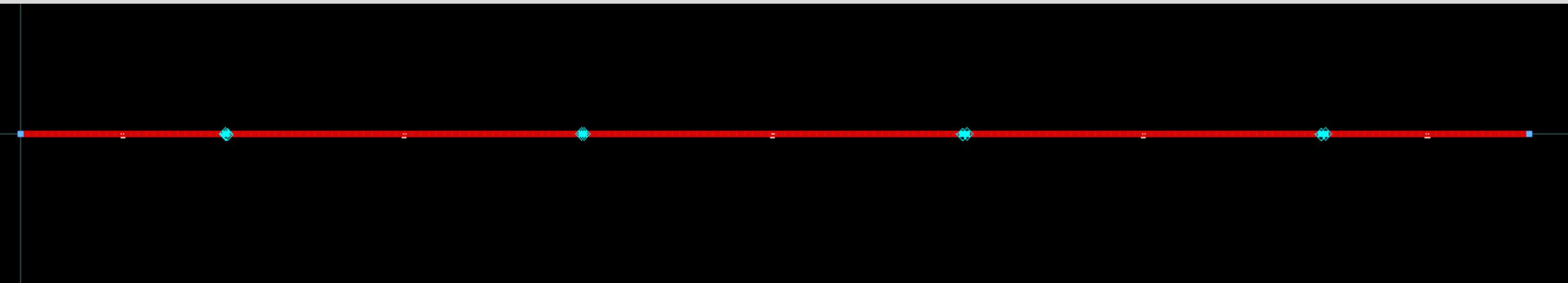
ATTENUATION FROM SCHEMATIC S21

From marker number 3 at frequency = 2.2 GHz it is achieved that attenuation is -20 dB



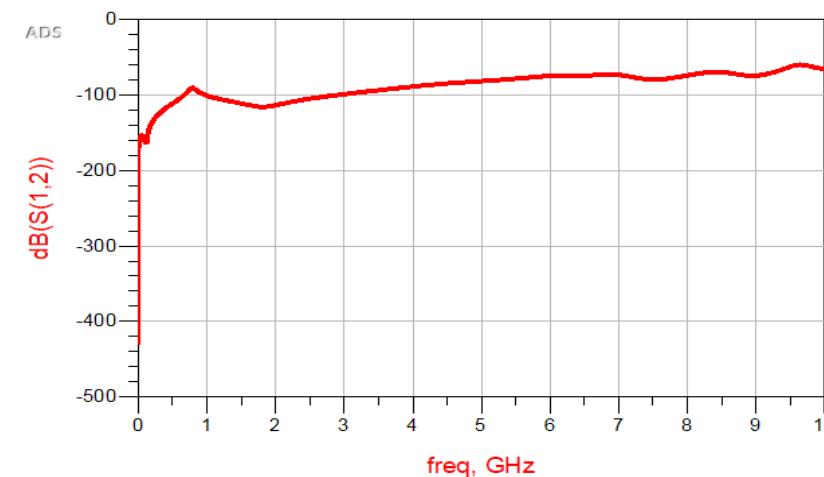
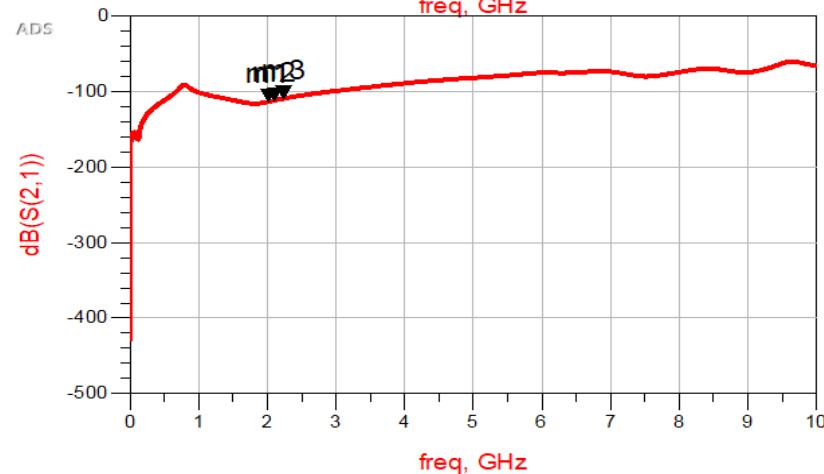
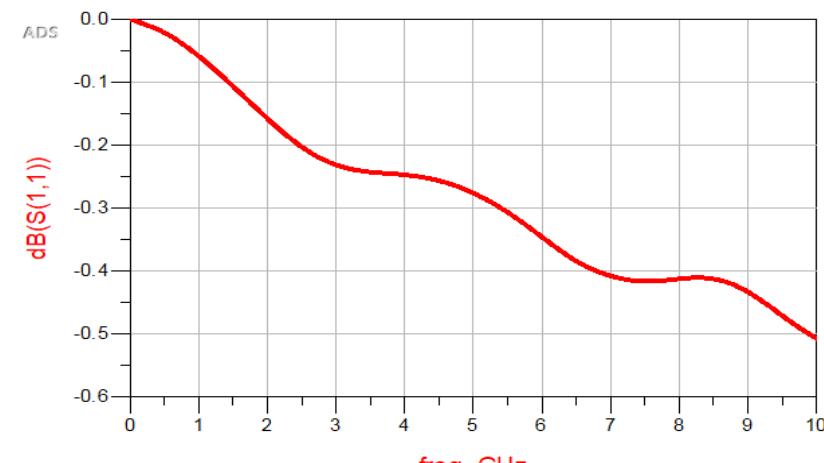
LAYOUT

I wasn't able to get the right values from the layout



S PARAMETERS FROM LAYOUT

I wasn't able to get the right values from the layout

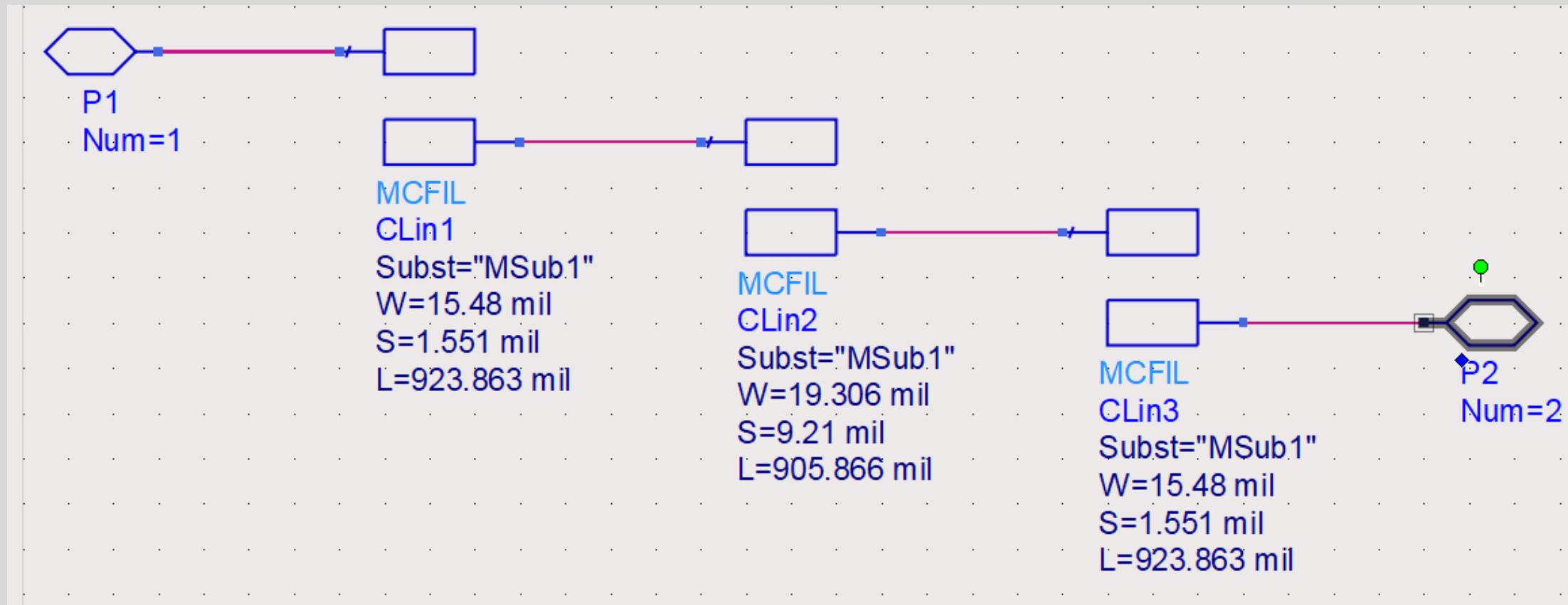


m1
freq=2.009GHz
dB(S(2,1))=-113.359

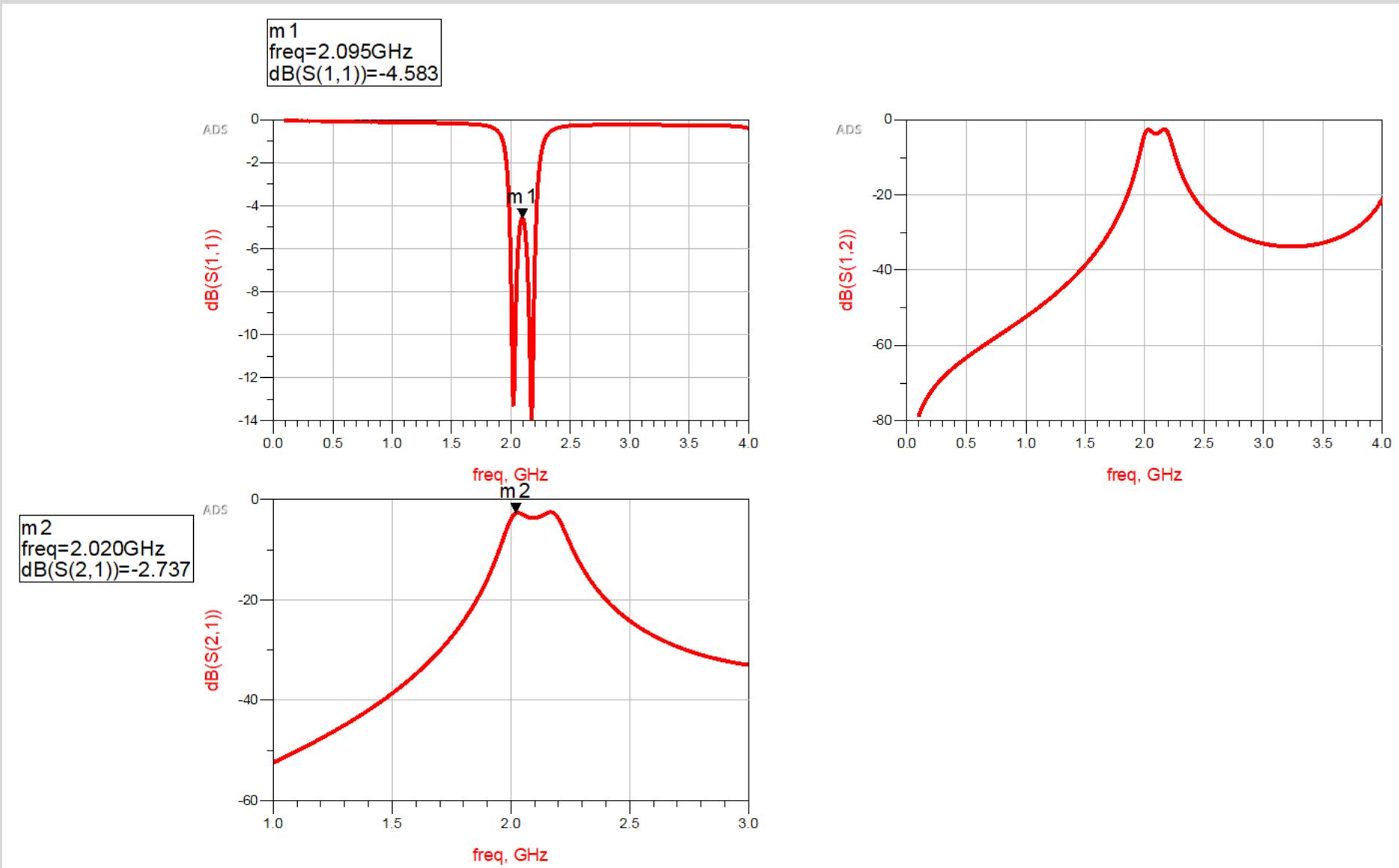
m2
freq=2.098GHz
dB(S(2,1))=-111.591

m3
freq=2.232GHz
dB(S(2,1))=-109.056

SCHEMATIC USING THE COUPLED LINES



S PARAMETERS FROM SCHEMATIC USING THE COUPLED LINES



ATTENUATION FROM SCHEMATIC USING THE COUPLED LINES S21

