Faculty of Engineering
Cairo University
EECE Department
ELC 465
Advanced Microwaves

BY:

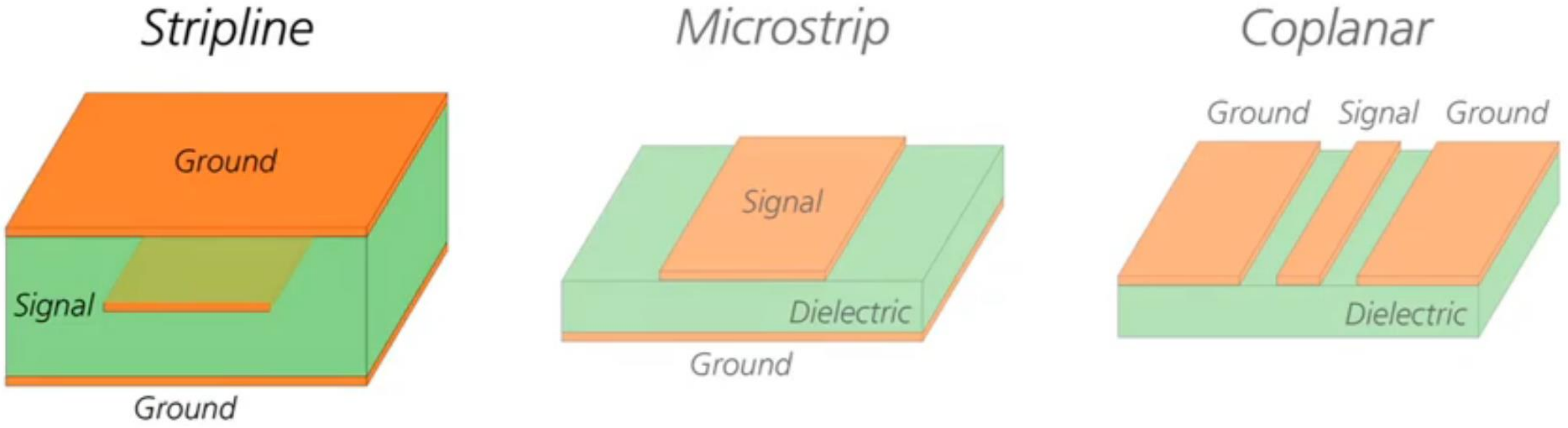
MOAMEN NASSER SAAD

SECTION 3 BN 37

SUBMITTED TO DR. ISLAM ESHRAH

Assignment 1 comparison of different TL types on PCB

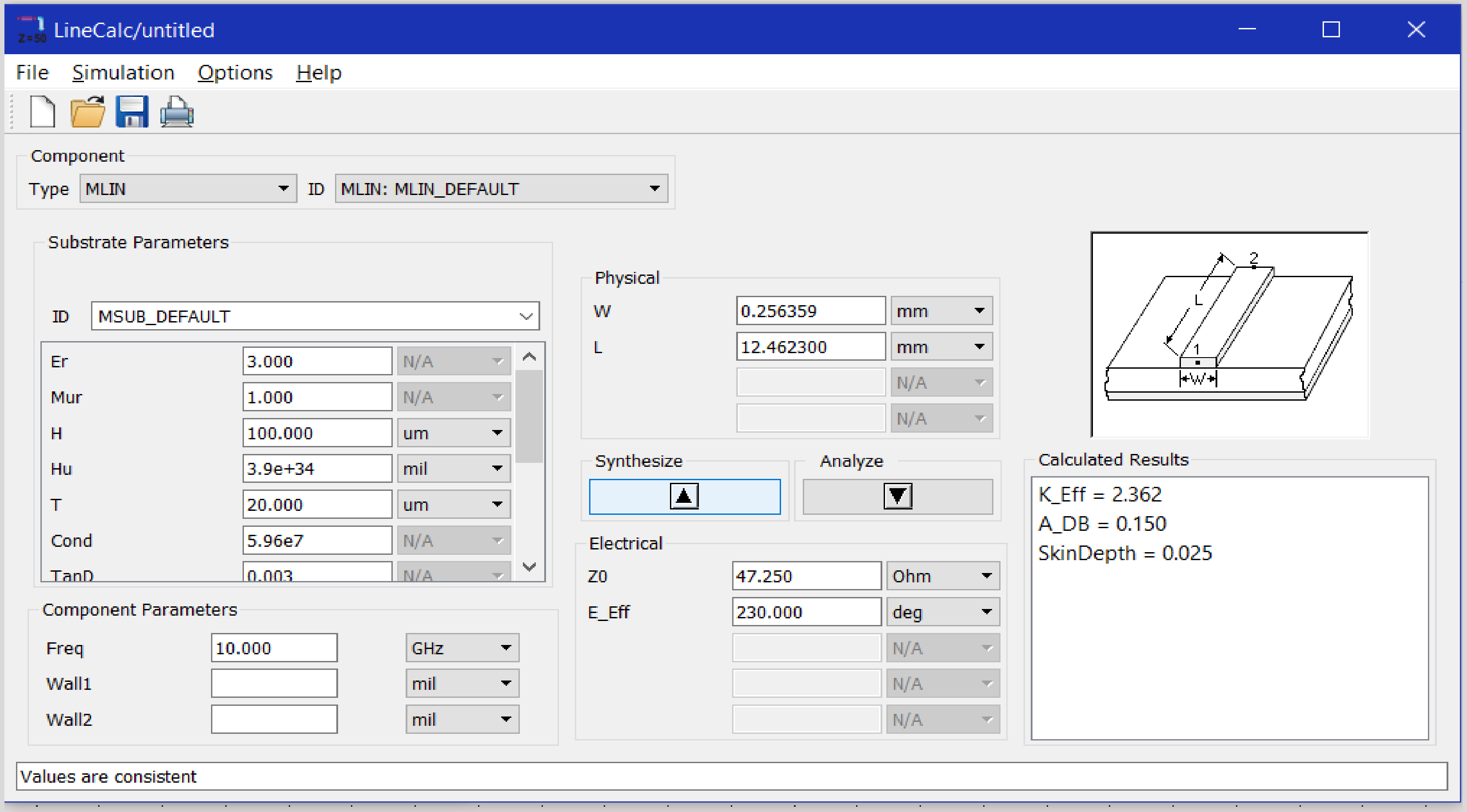
1- Microstrip Line
2- Strip Line
3- CPW (coplanar waveguide)



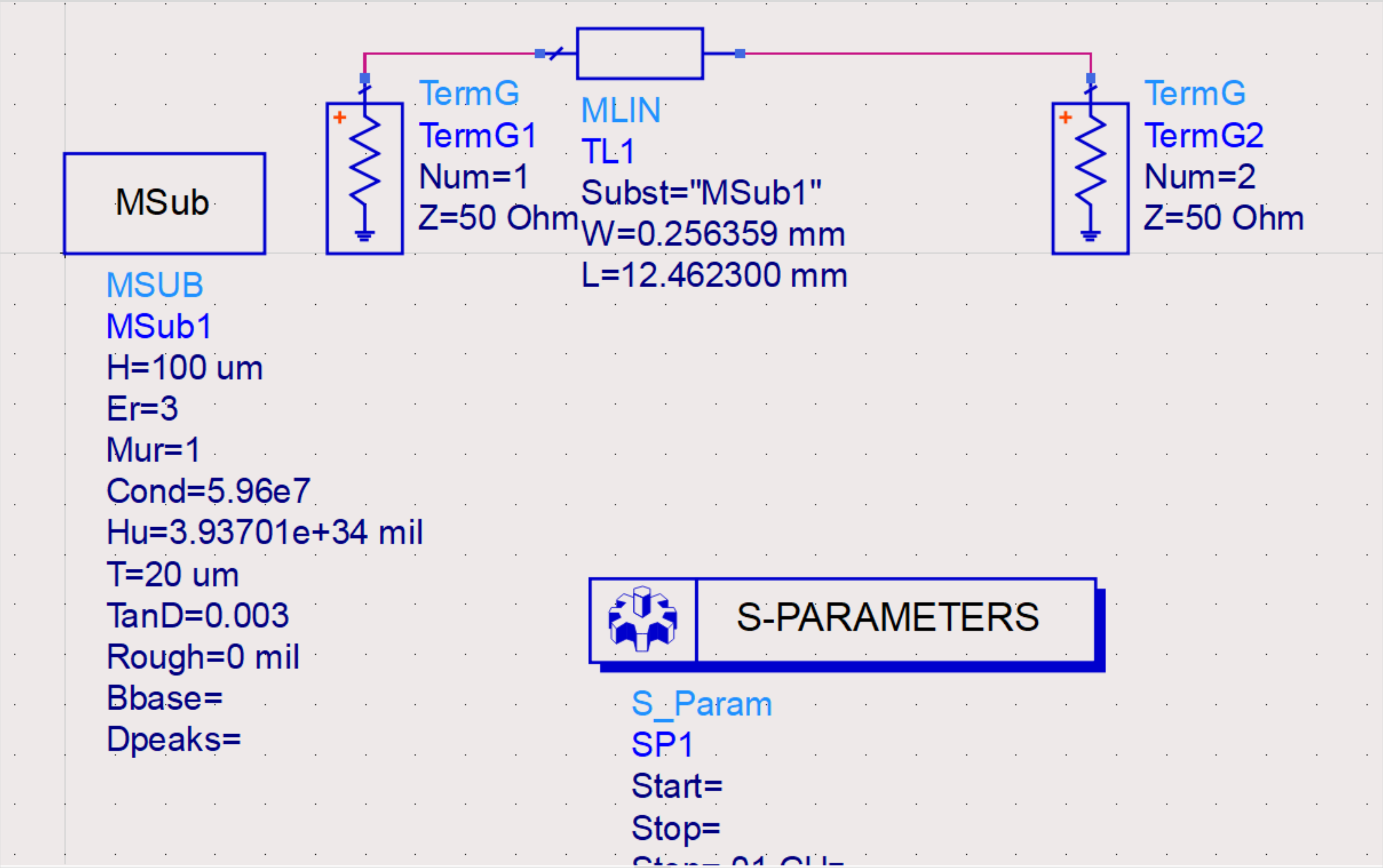
1-MICROSTRIP LINE

Line calc to get the values of W and L

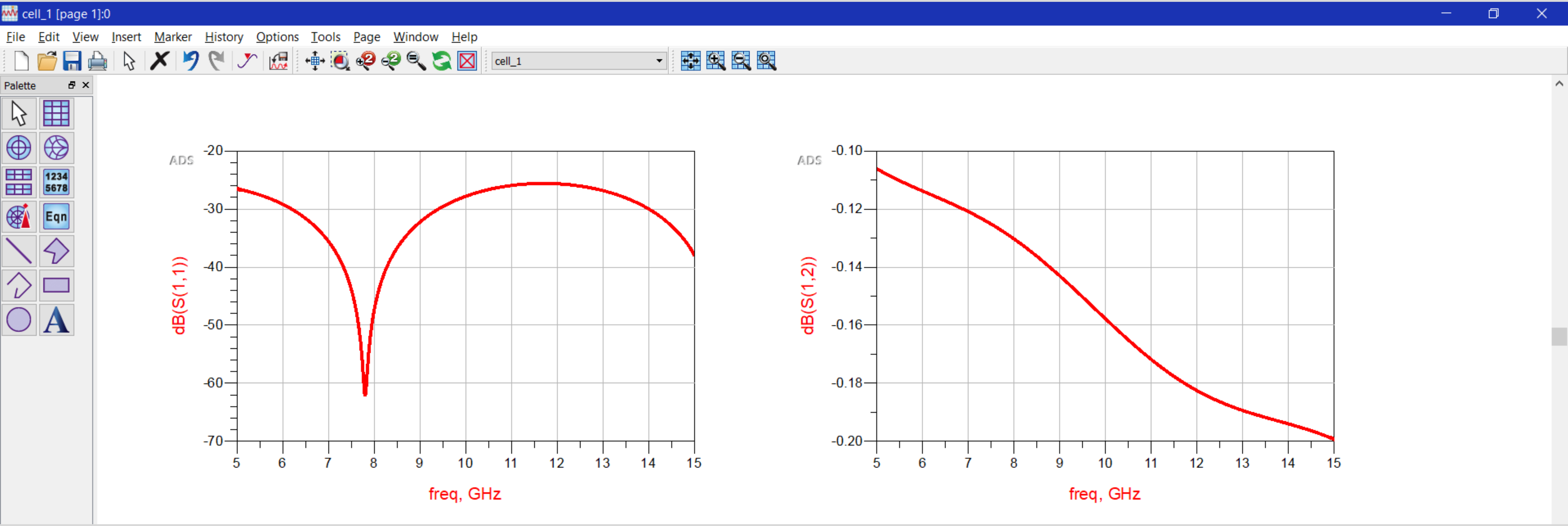
W = 0.2563 mm
L = 12.4632 mm



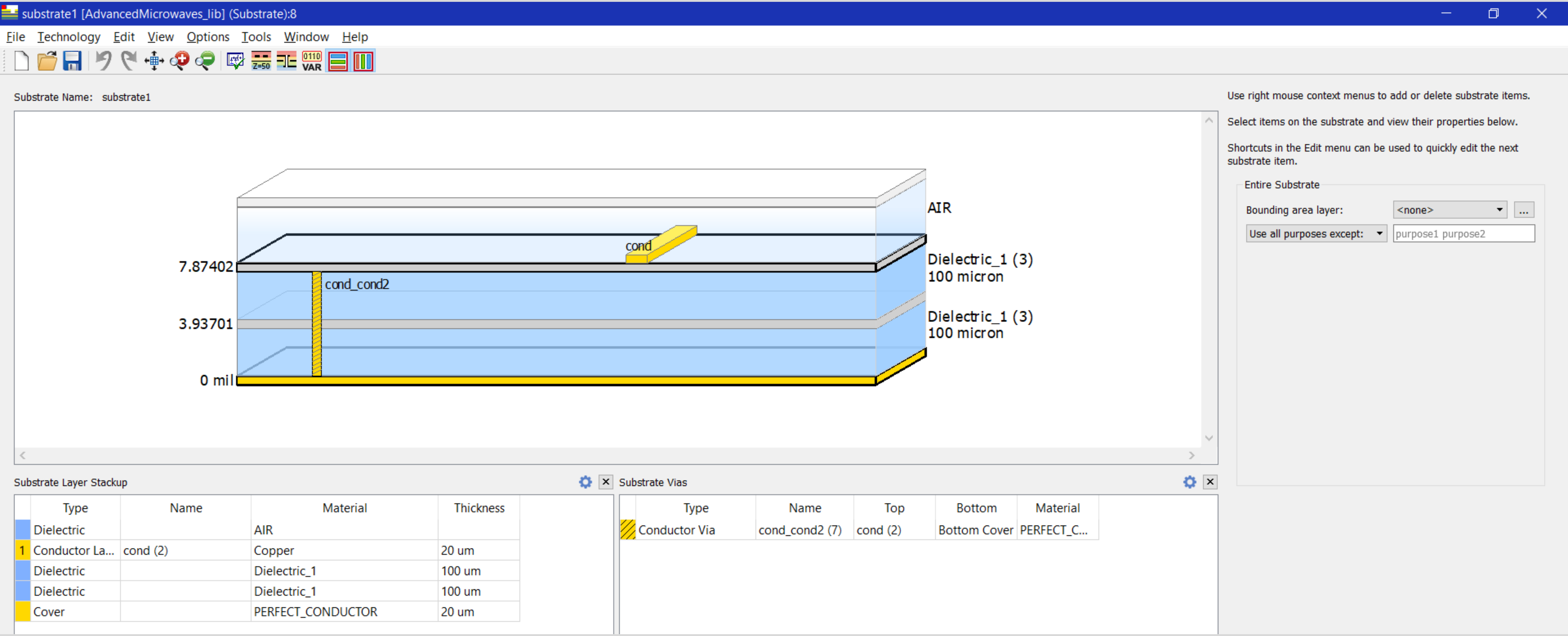
SCHEMATIC DESIGN



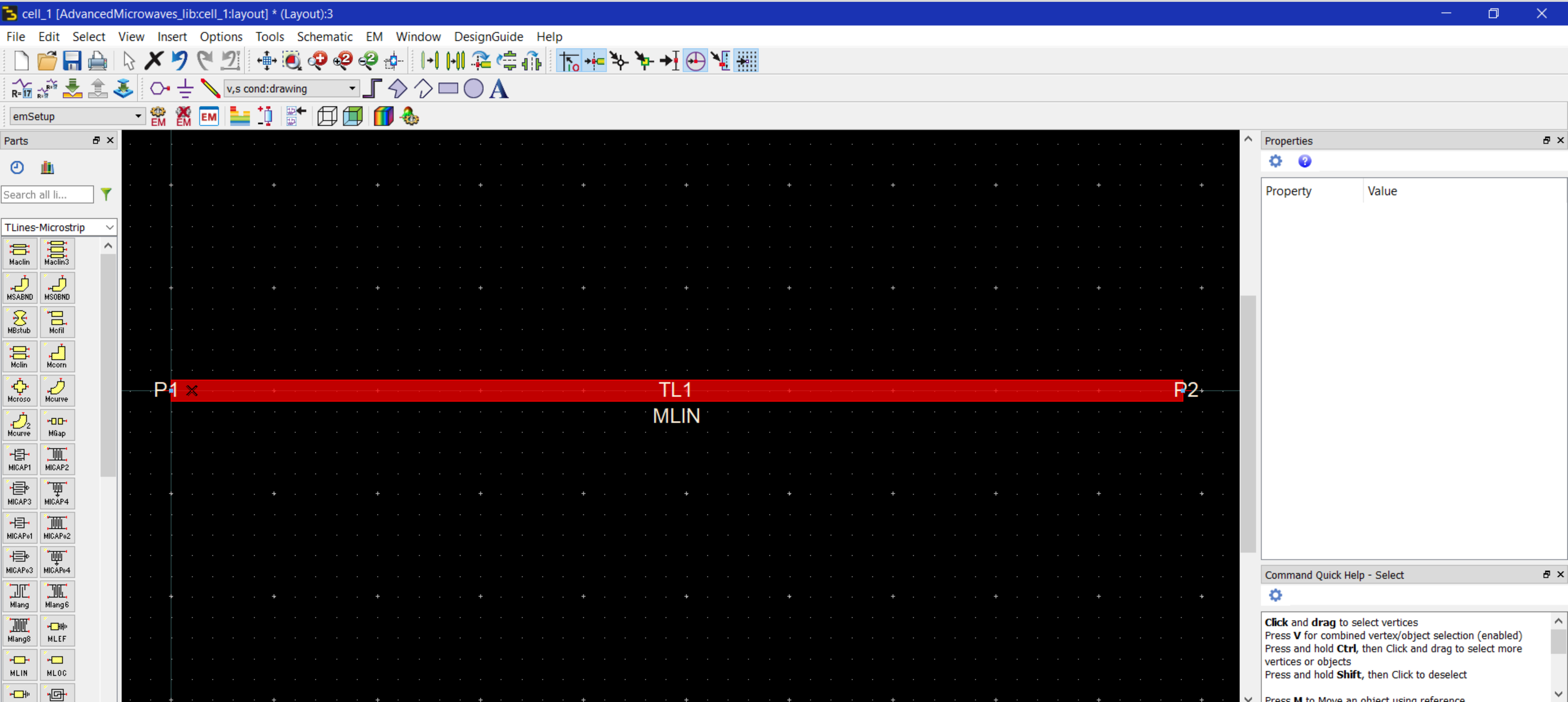
VALUES FROM SCHEMATIC



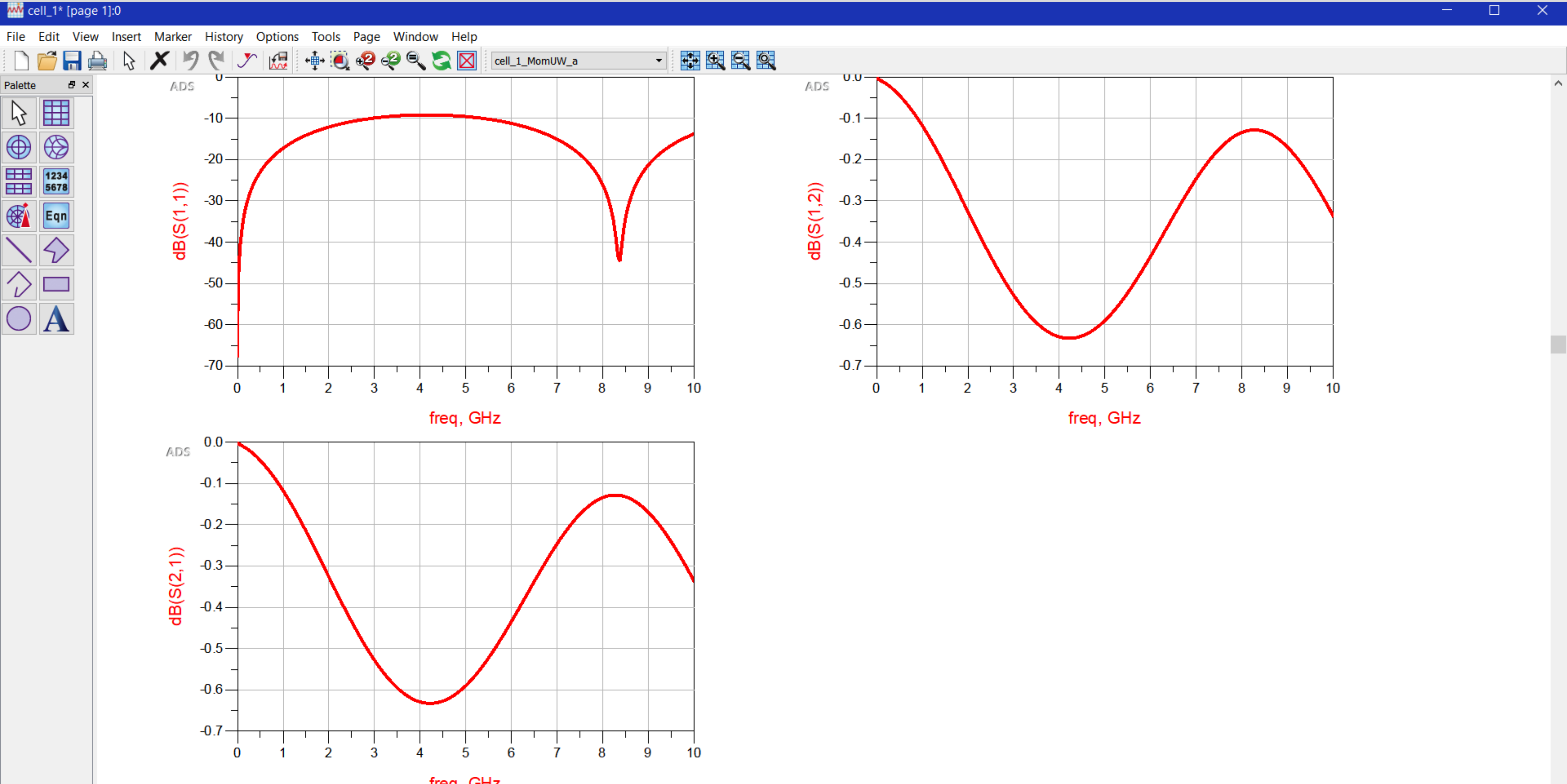
VIA AND LAYERS



PCB DESIGN


cell_1 [AdvancedMicrowaves_lib:cell_1:layout] * (Layout):3
File Edit Select View Insert Options Tools Schematic EM Window DesignGuide Help
v,s cond:drawing
emSetup
Parts
Search all li...
TLines-Microstrip
Maclin
Maclin3
MSABND
MSOBND
MBstub
Mcfil
Mclin
Mcorn
Mcross
Mcurve
Mcurve2
MGap
MICAP1
MICAP2
MICAP3
MICAP4
MICAPo1
MICAPo2
MICAPo3
MICAPo4
Mlang
Mlang6
Mlang8
MLEF
MLIN
MLOC
P1
TL1
MLIN
P2
Properties
Property
Value
Command Quick Help - Select
Click and drag to select vertices
Press V for combined vertex/object selection (enabled)
Press and hold Ctrl, then Click and drag to select more vertices or objects
Press and hold Shift, then Click to deselect

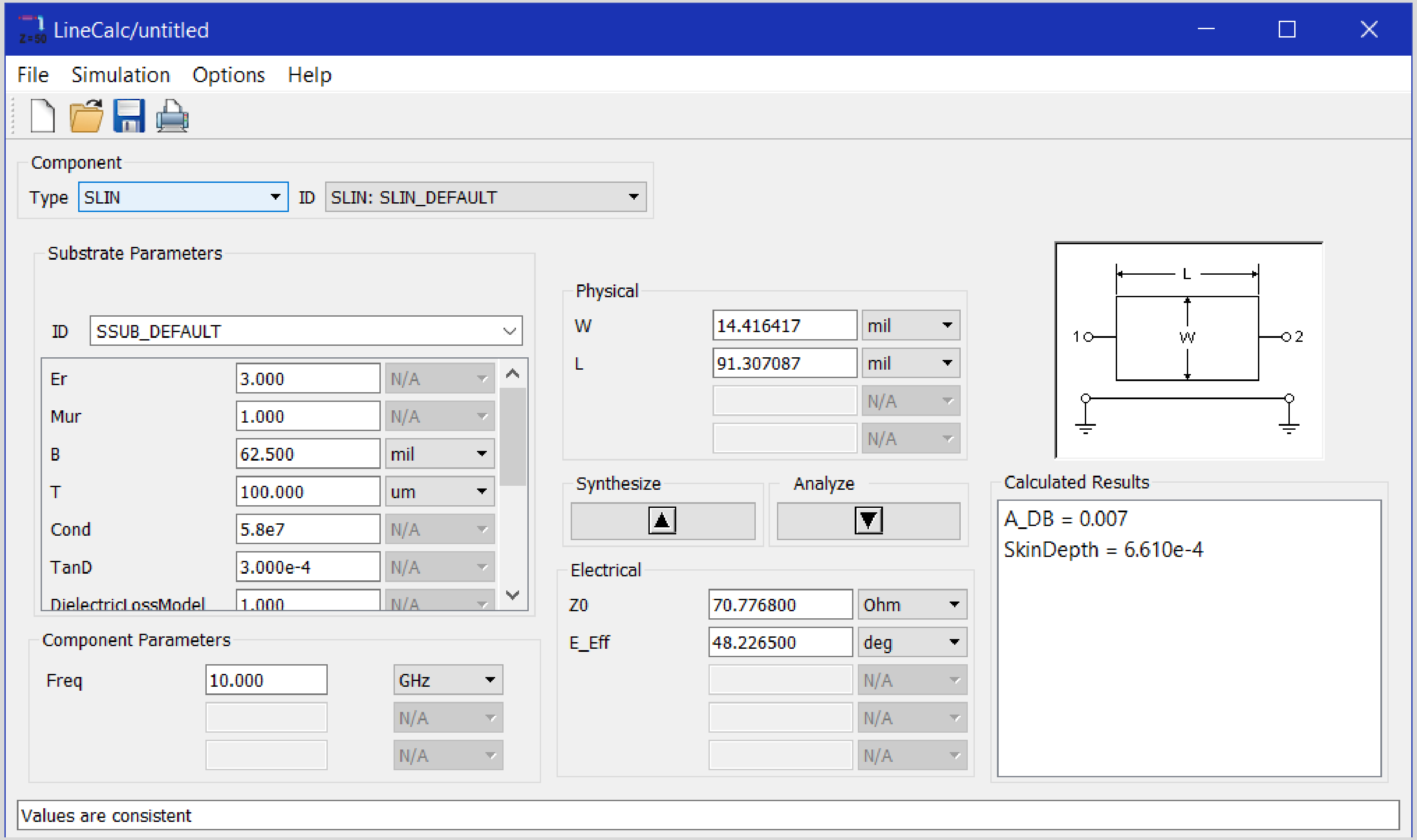
LOSS VALUES FROM PCB



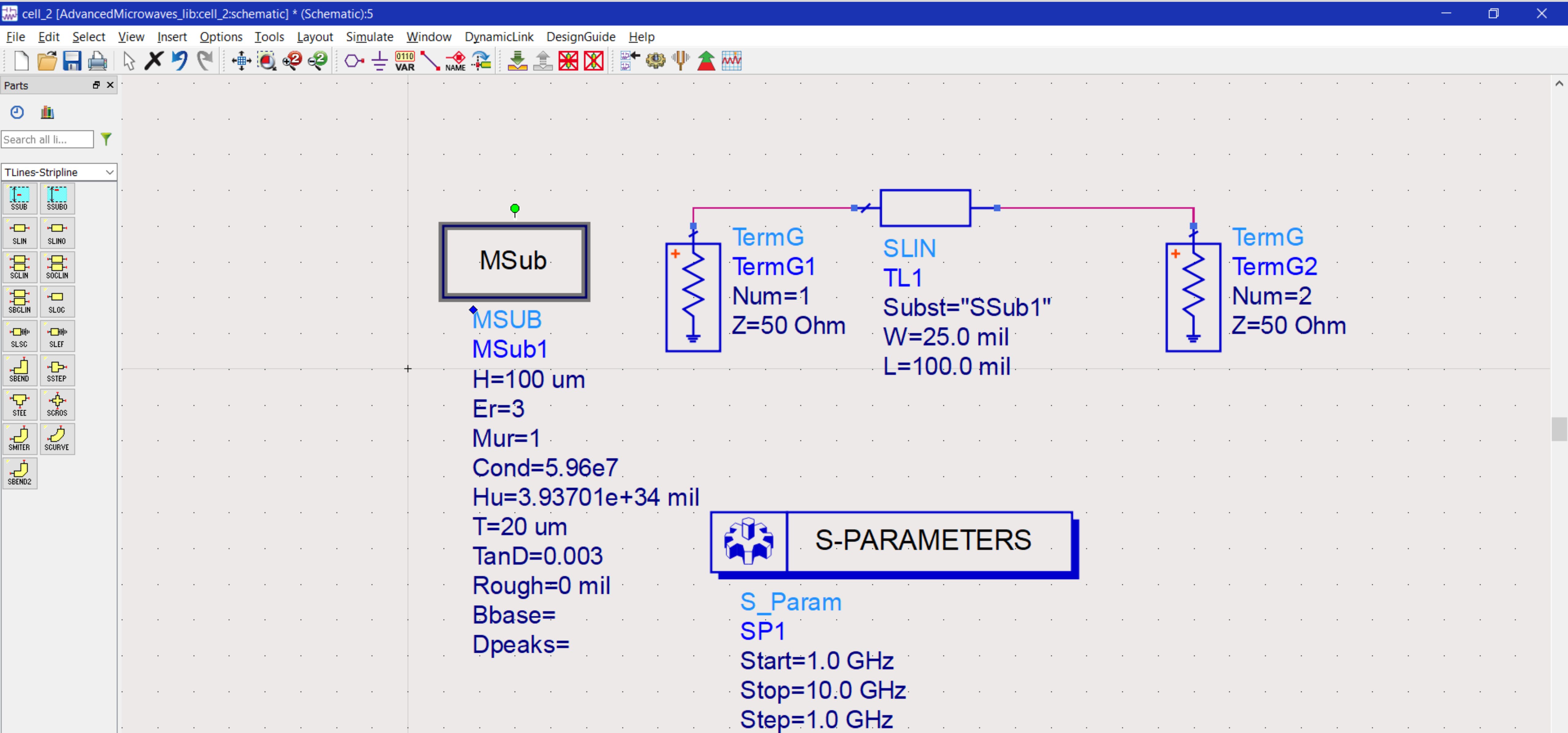
2- STRIP LINE

Line calc to get the values of W and L

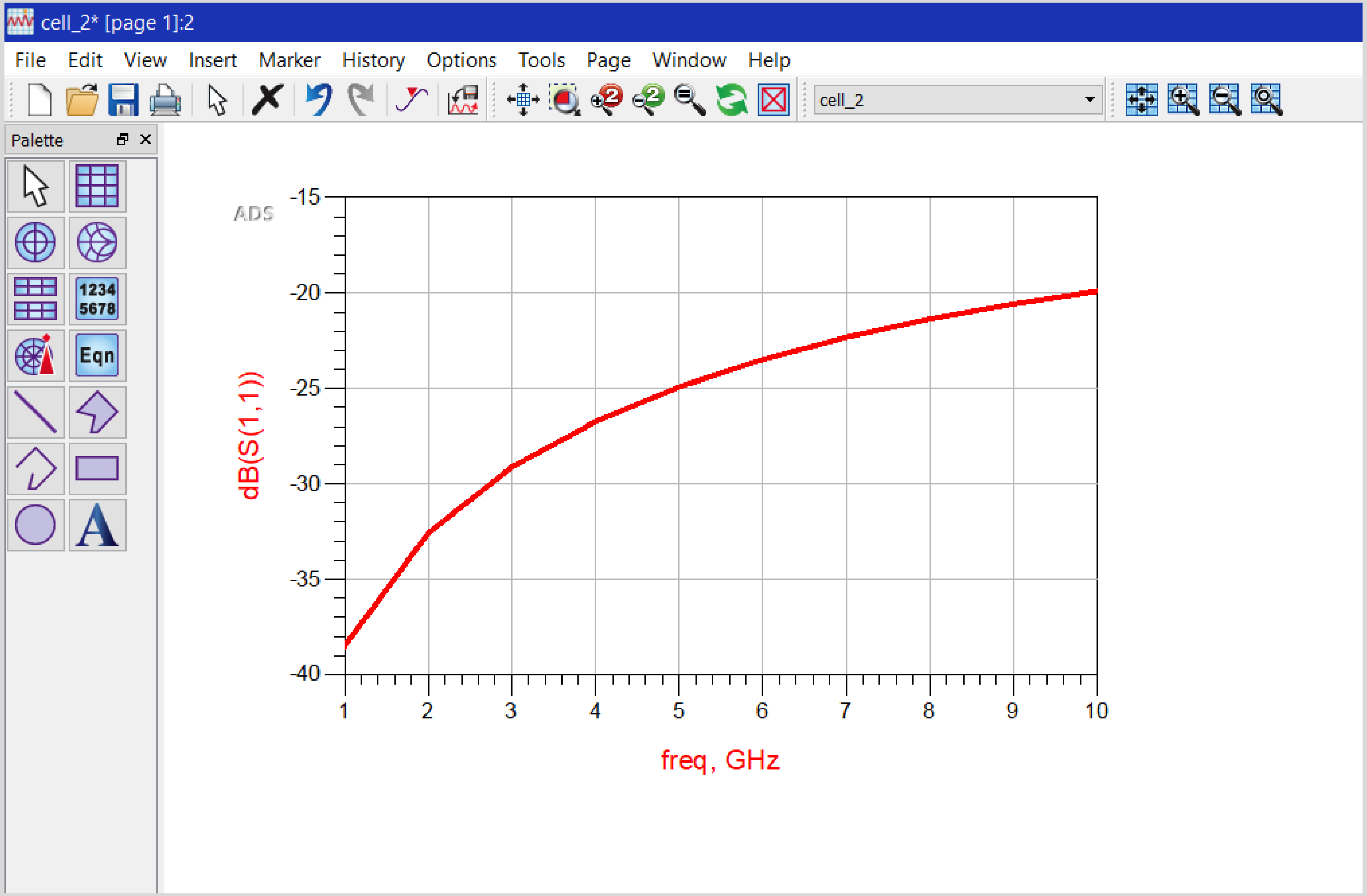
W = 14.416417 mil
L = 91.307087 mil



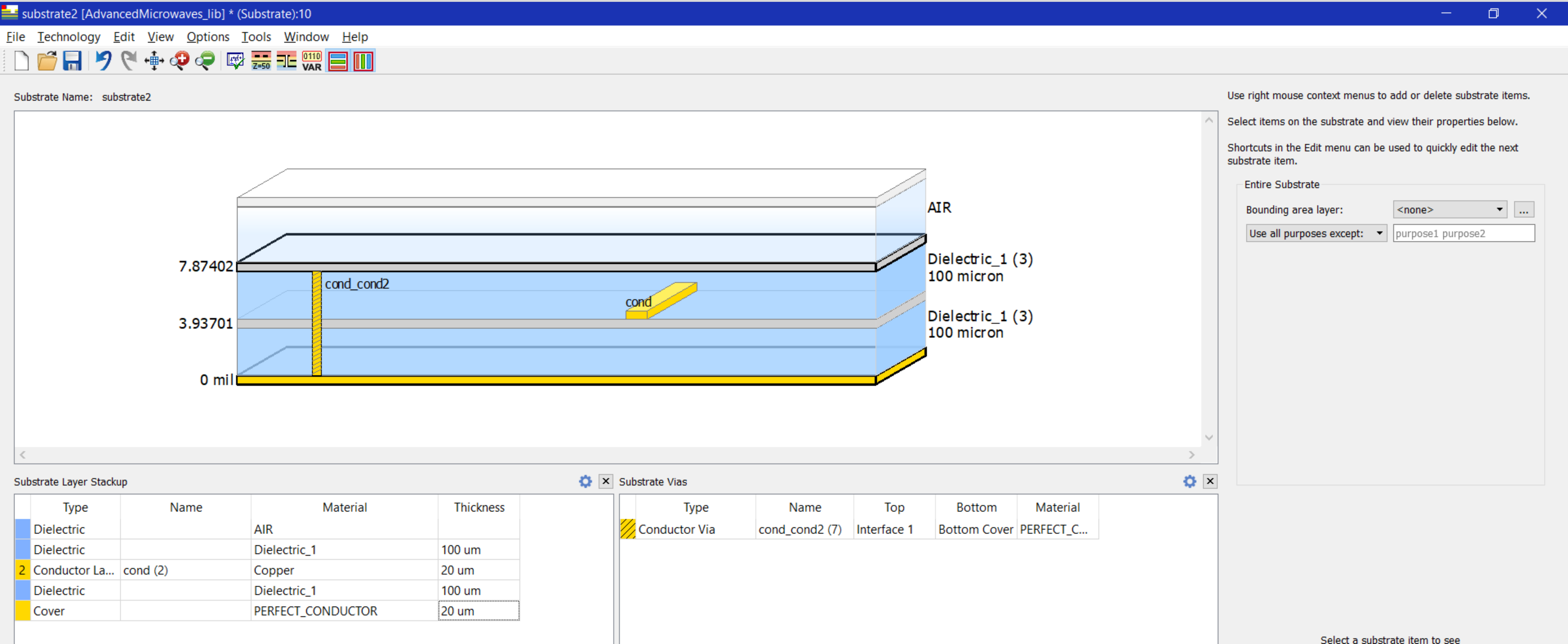
SCHEMATIC DESIGN



LOSSES VALUES FROM SCHEMATIC

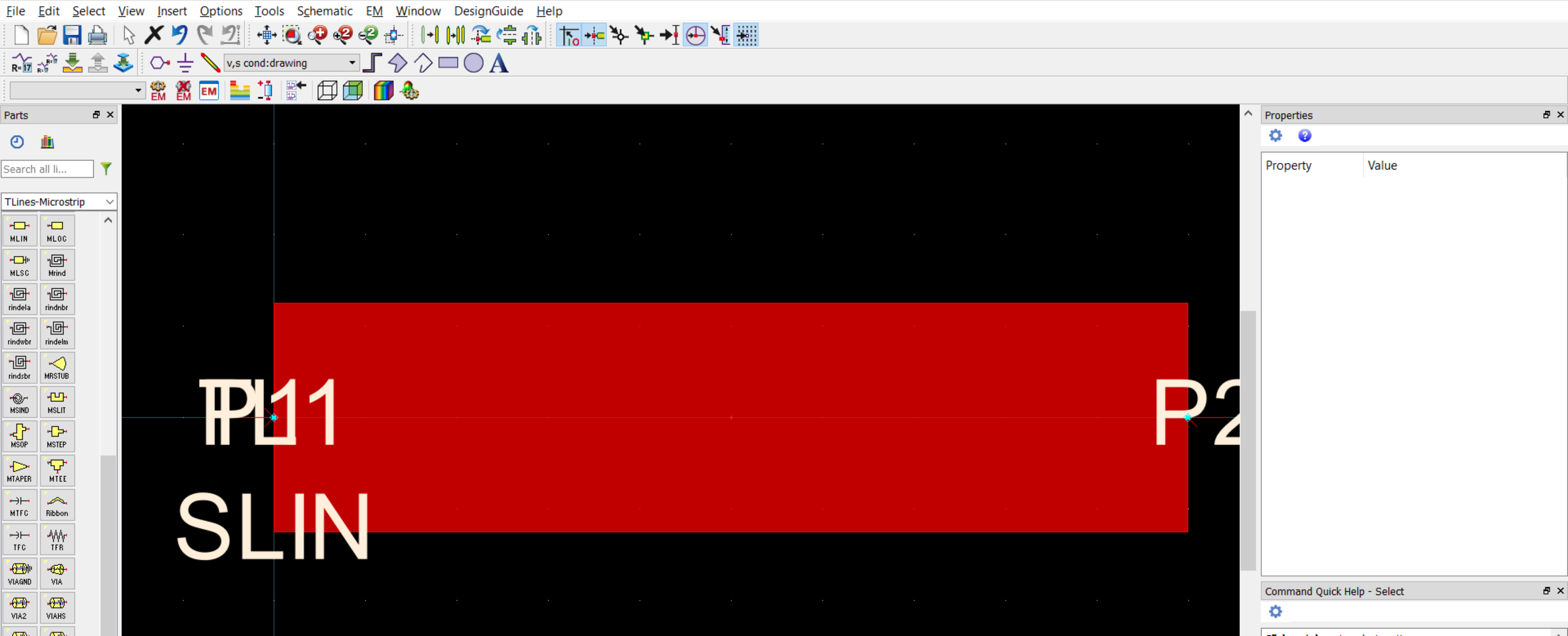


VIA AND LAYERS

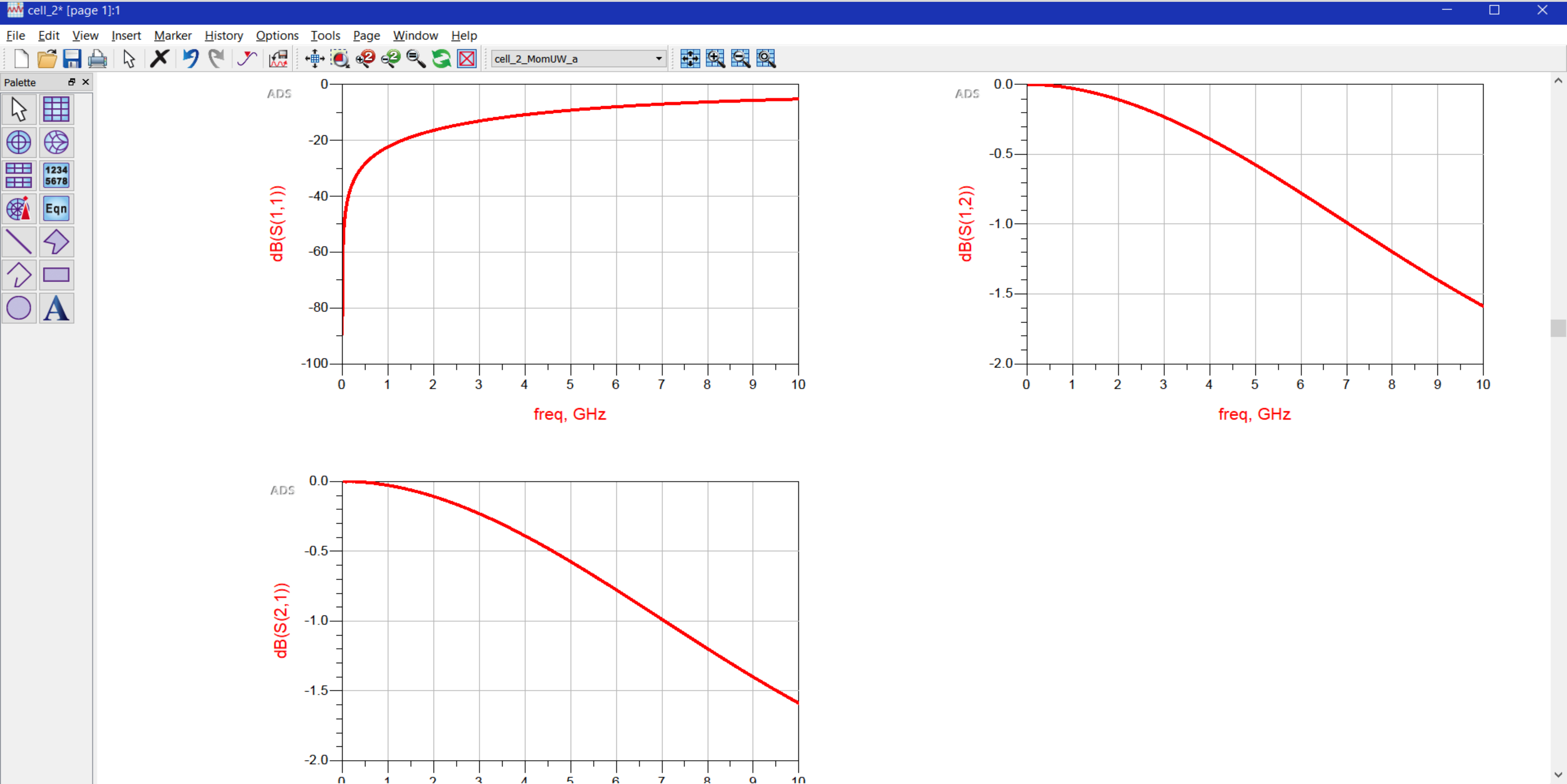


PCB DESIGN

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



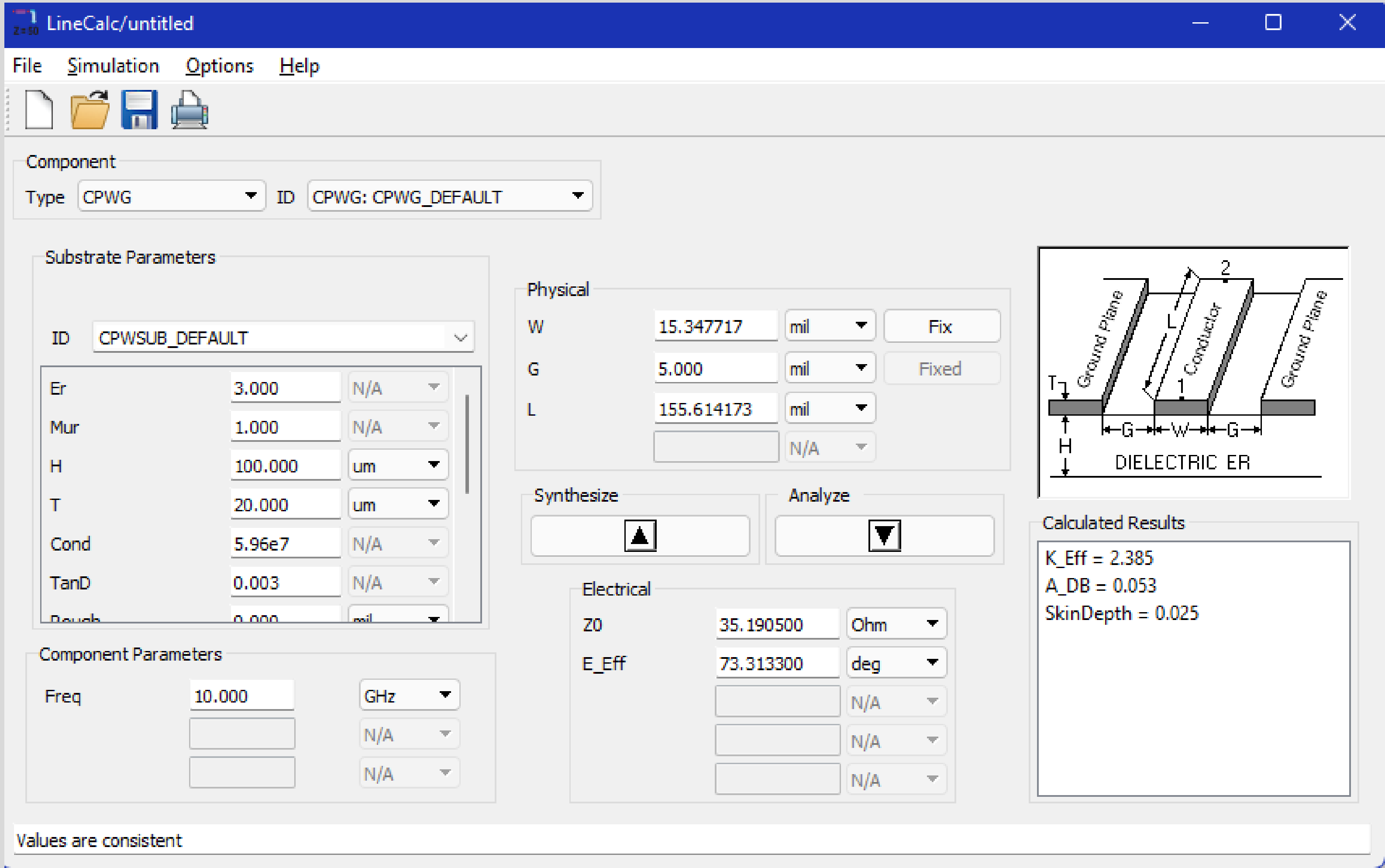
LOSS VALUES FROM PCB



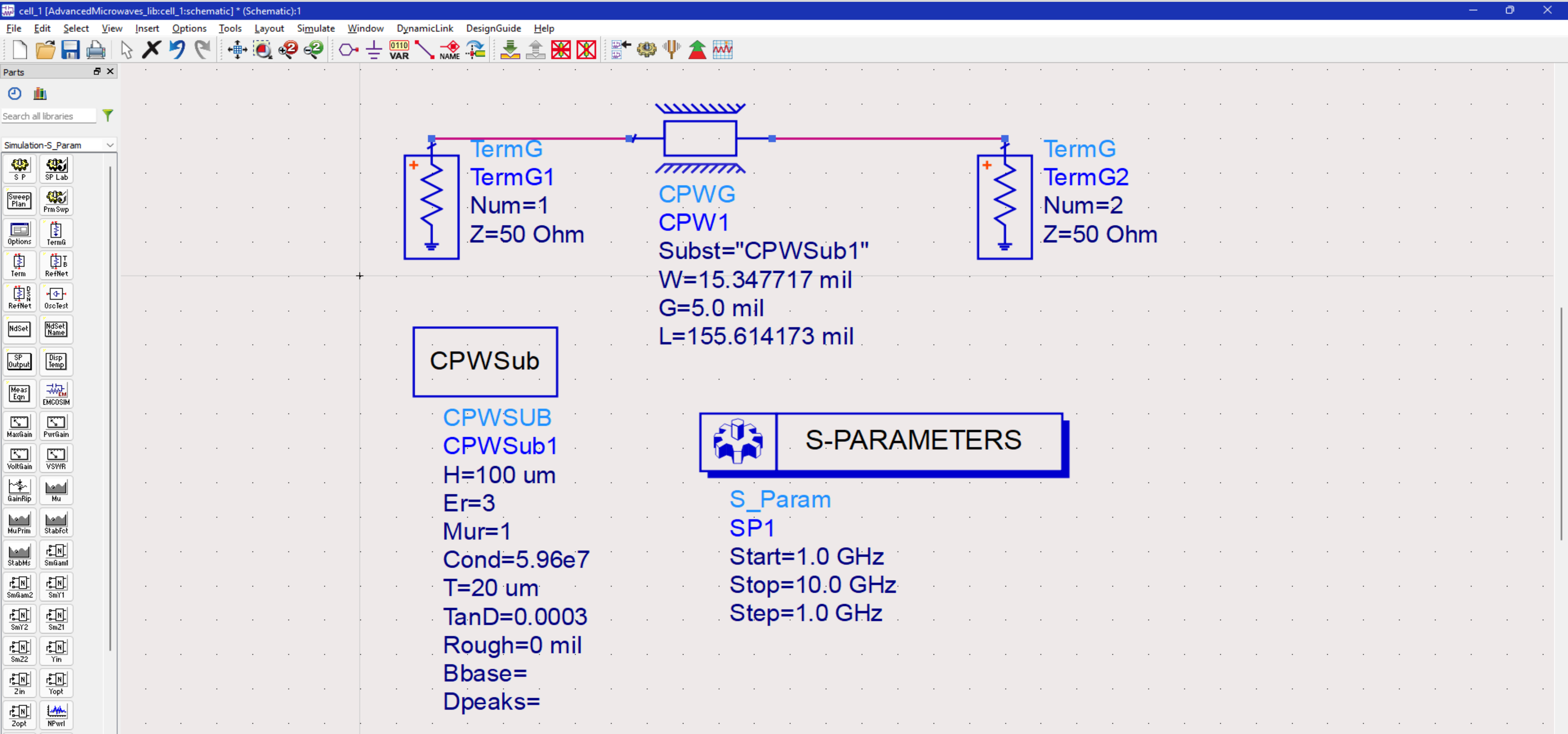
3- CPW

Line calc to get the values of W and L

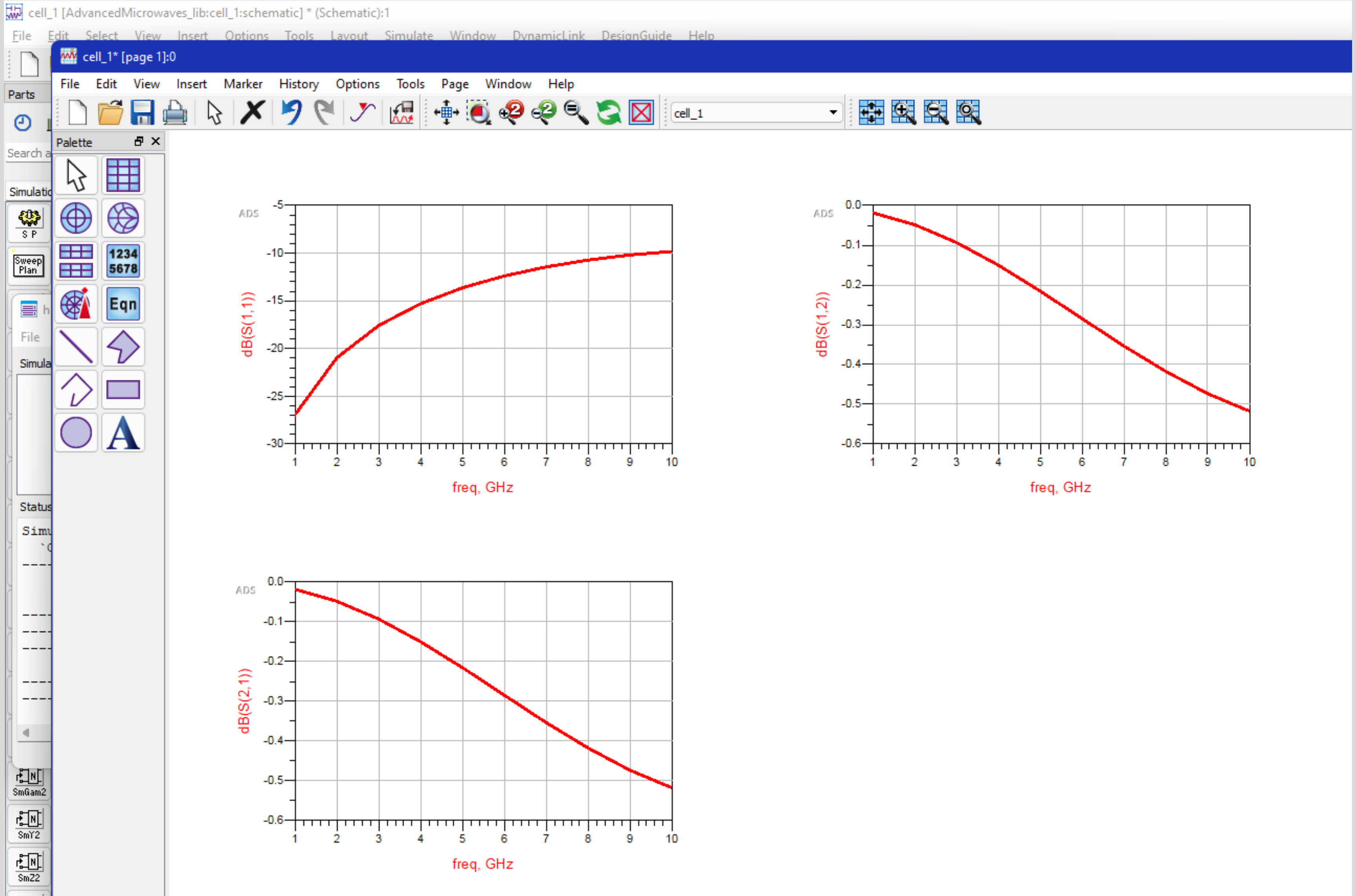
W = 14.416417 mil
L = 91.307087 mil



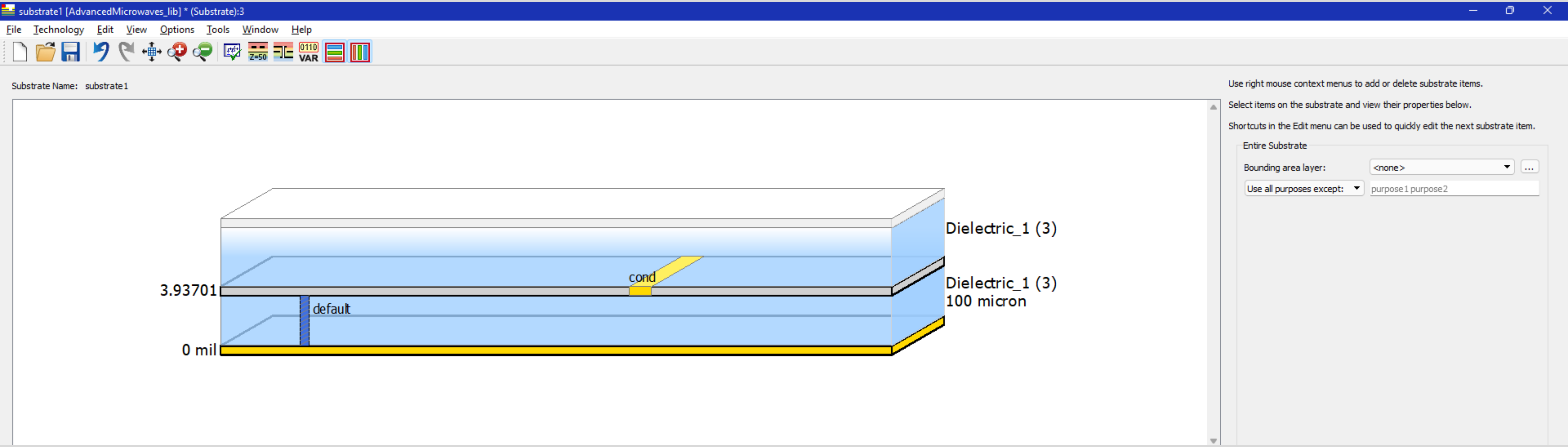
SCHEMATIC DESIGN



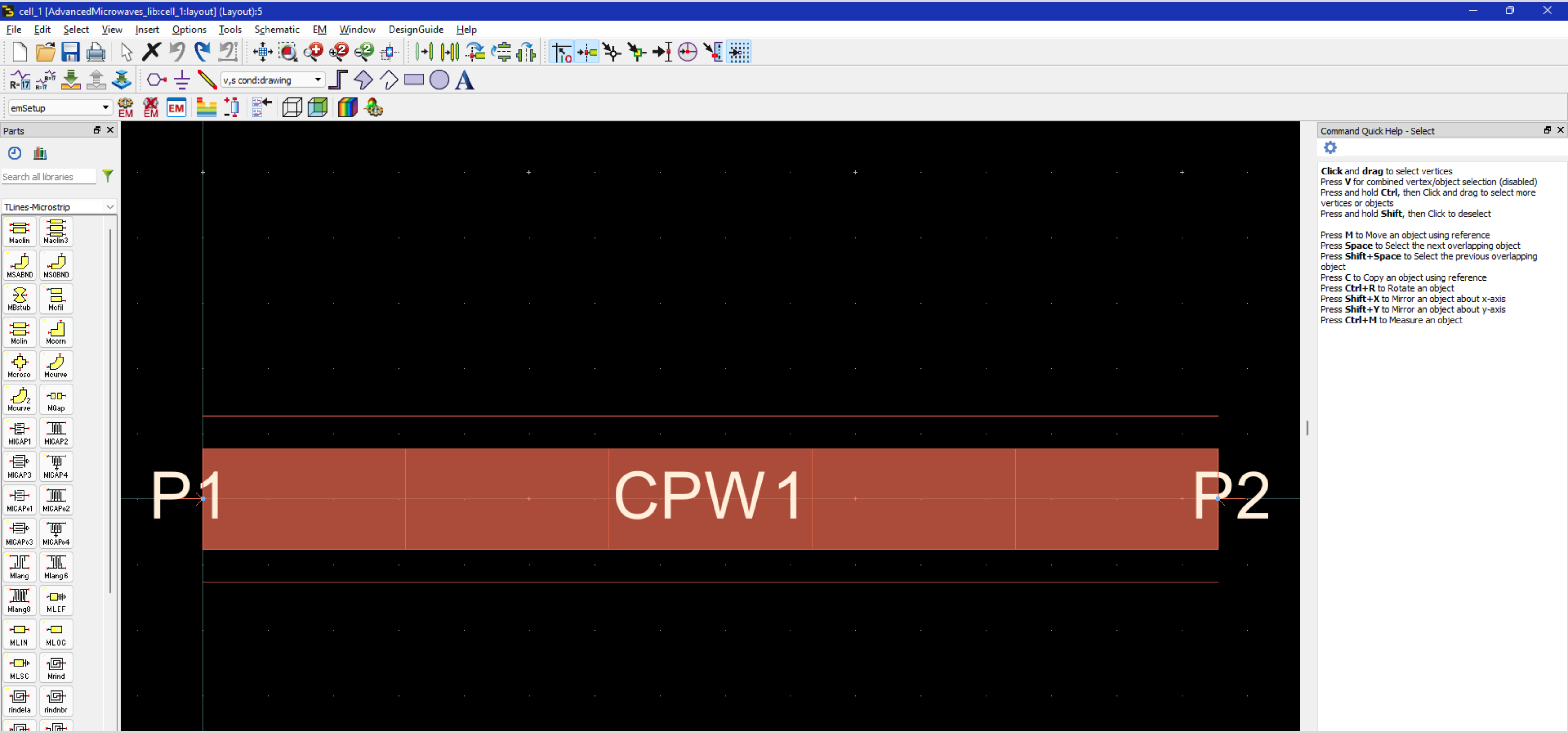
LOSSES VALUES FROM SCHEMATIC



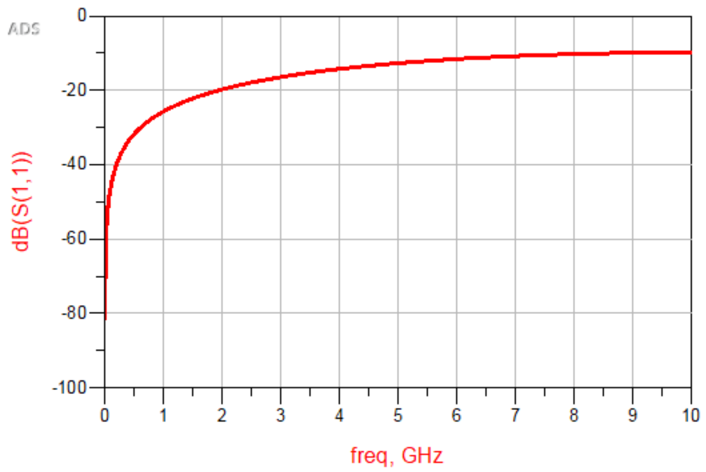
VIA AND LAYERS

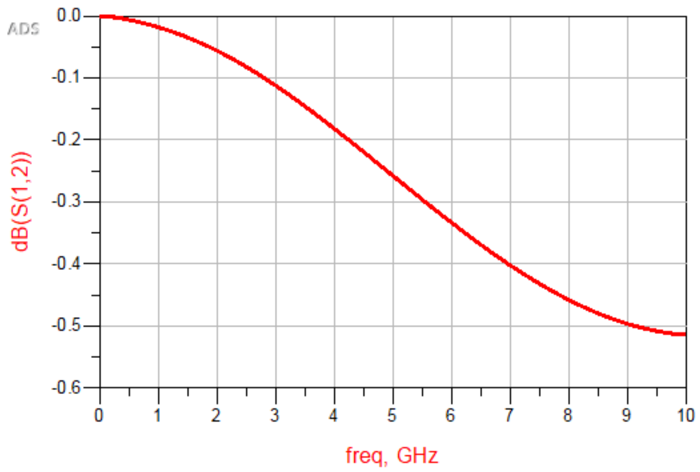


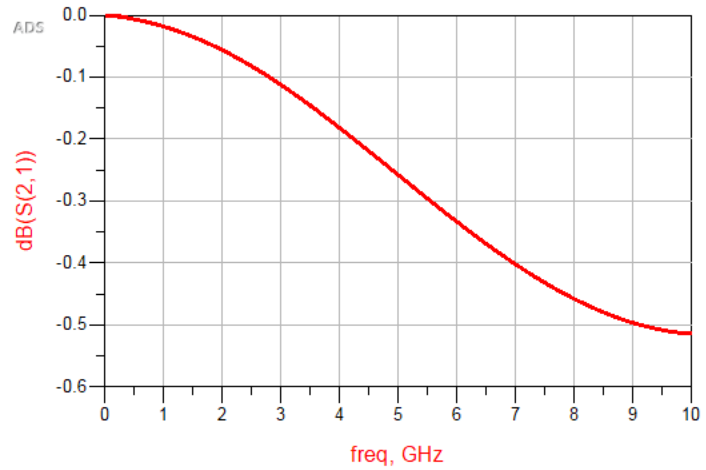
LAYOUT DESIGN



LOSS VALUES FROM LAYOUT







Assignment 2
Mat-Lab Code

ASSIGNMENT 2
MAT LAB CODE TO DETERMINE THE CHARGE DISTRIBUTION ON A CHARGED CONDUCTING STRIP

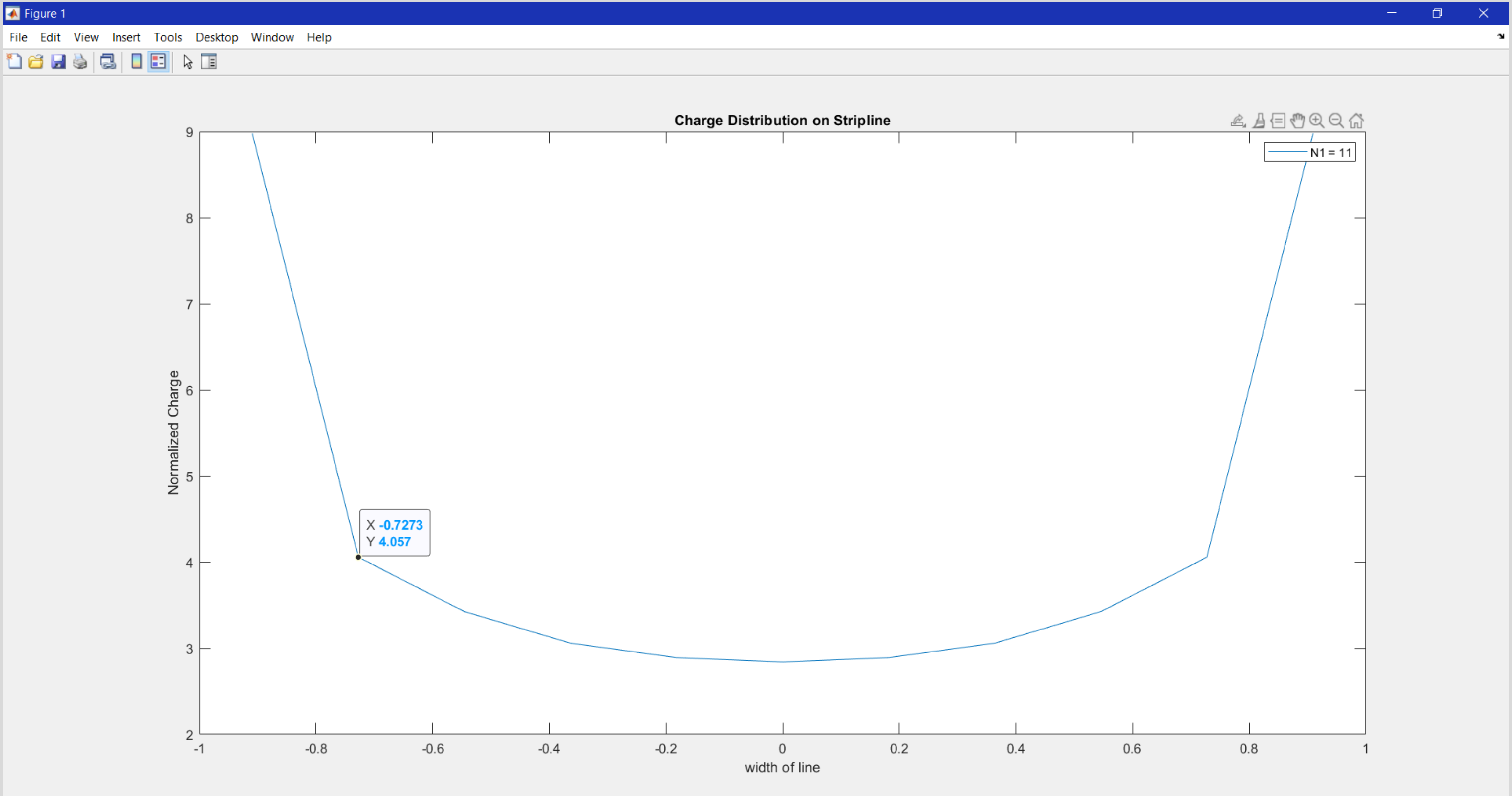
Code is here for more info : for part 1: 1D My code for part 2: 2D

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

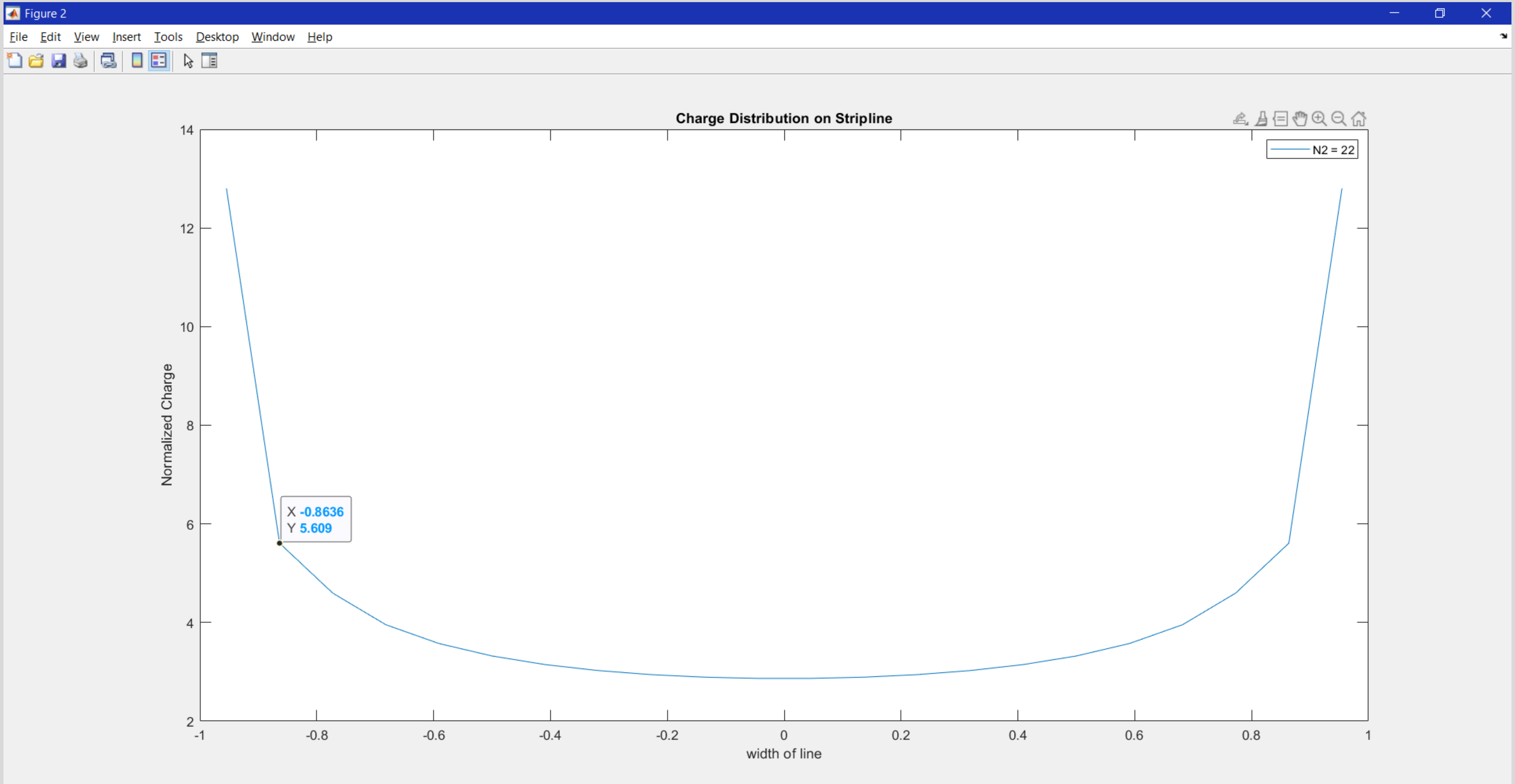
My code only plot 4 figures 1+2+4+5

```
%% Plotting total charge
N_samples = 5:2:100;
for counter = 1:length(N_samples)
    Q_total(counter) = sum(Charge_Calculation(Width,N_samples(counter),V0)*2/(Epsolon0*V0*N_samples(
end
Axis_3 = 1./N_samples;
figure(3);
plot(Axis_3,Q_total);
xlabel('1/N_samples');
ylabel('Qtotal Normalized');
title('Variation of Charge due to number of samples');
```

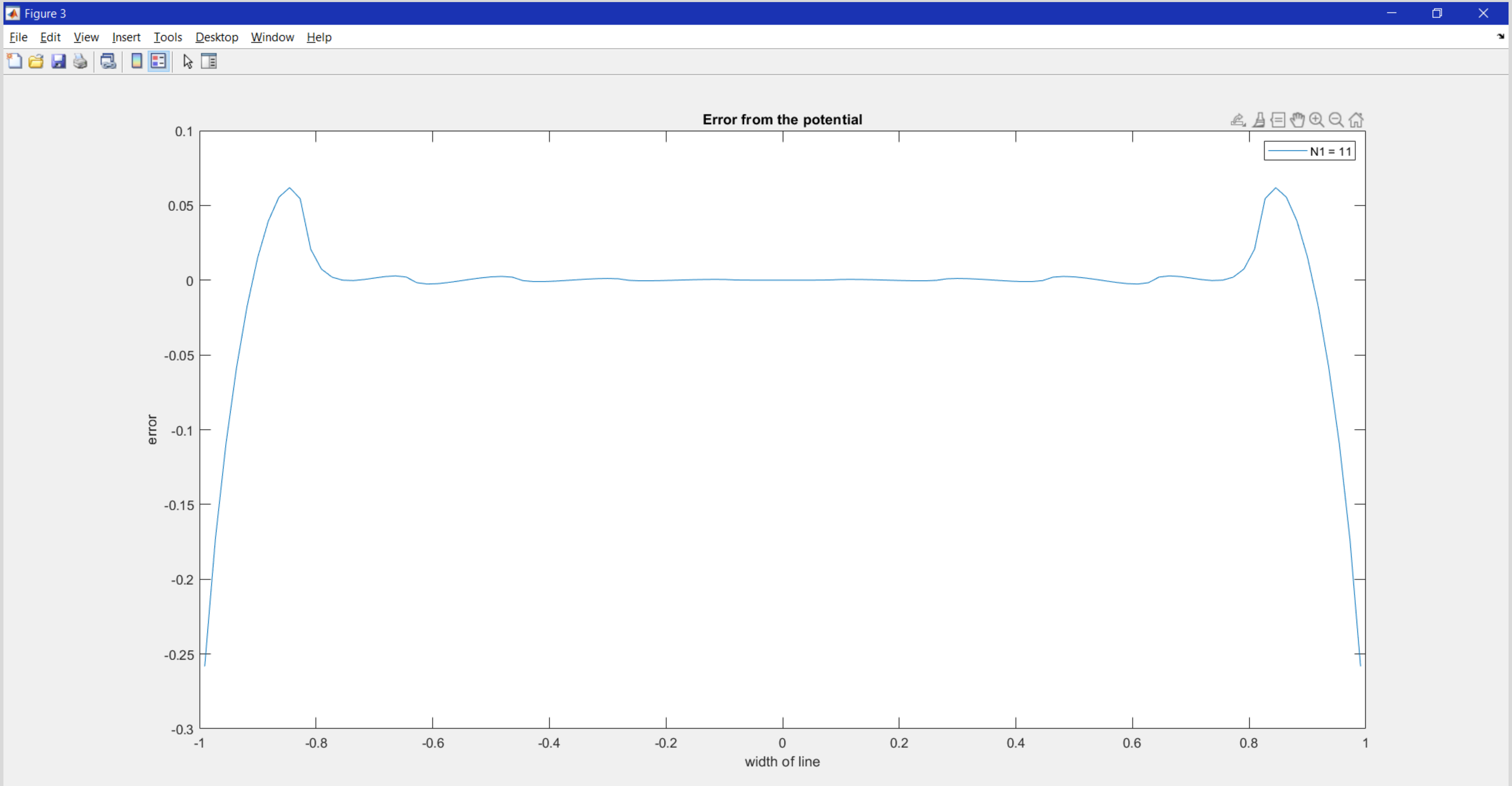
CHARGE DISTRIBUTION PLOT WHEN N = 11



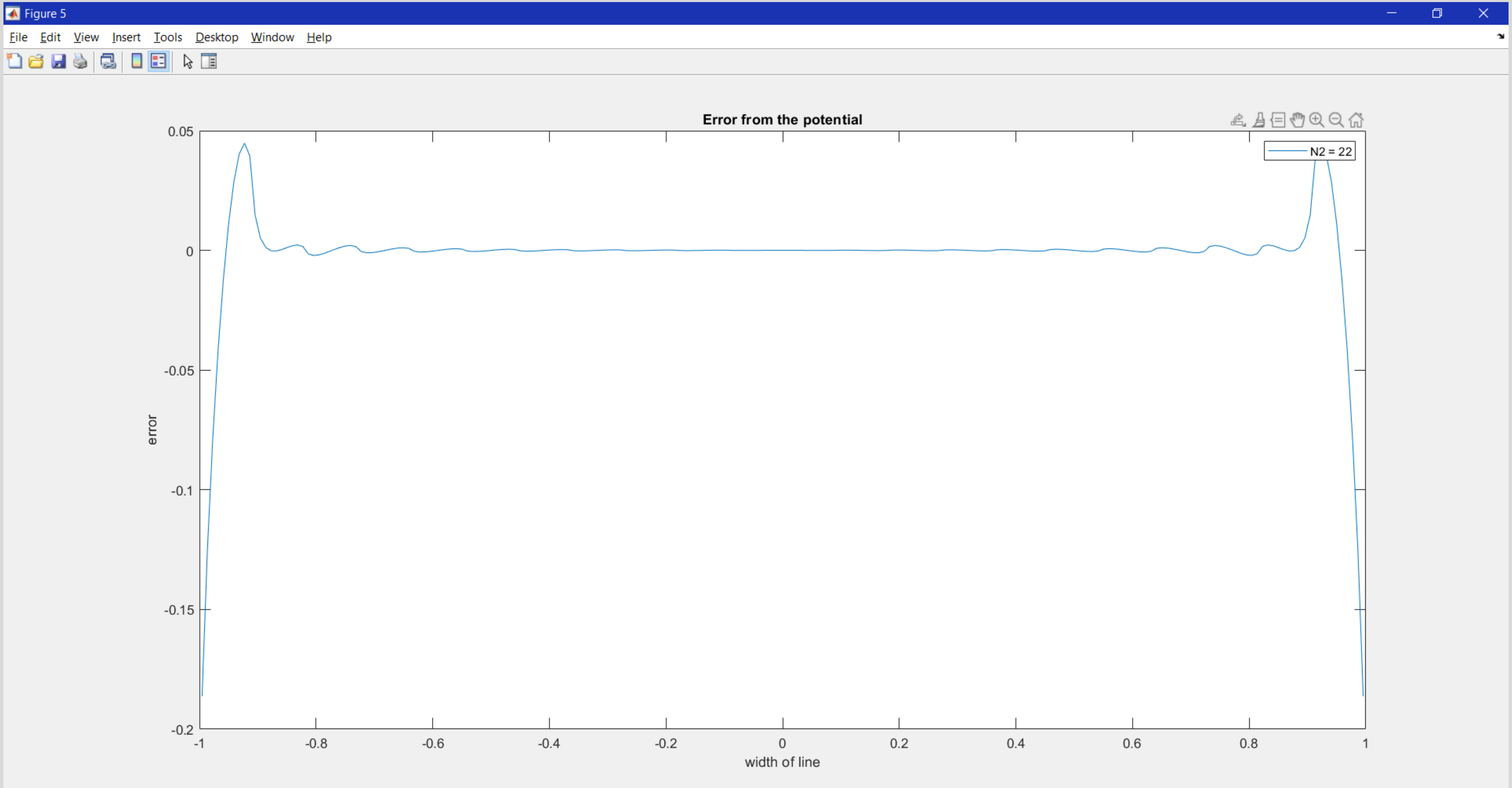
CHARGE DISTRIBUTION PLOT WHEN N = 22



ERROR FROM THE POTENTIAL WHEN N = 11

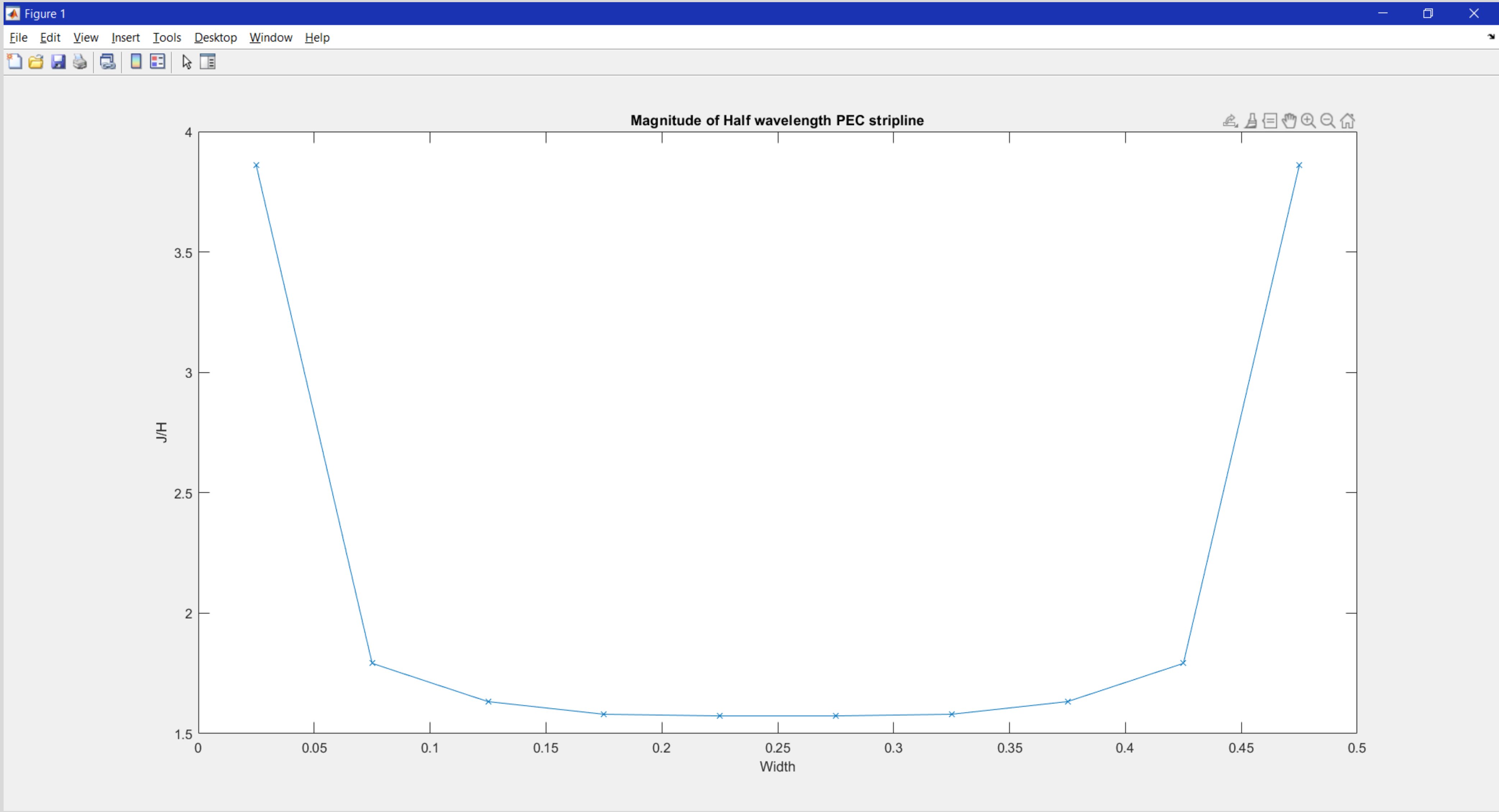


ERROR FROM THE POTENTIAL WHEN N = 22



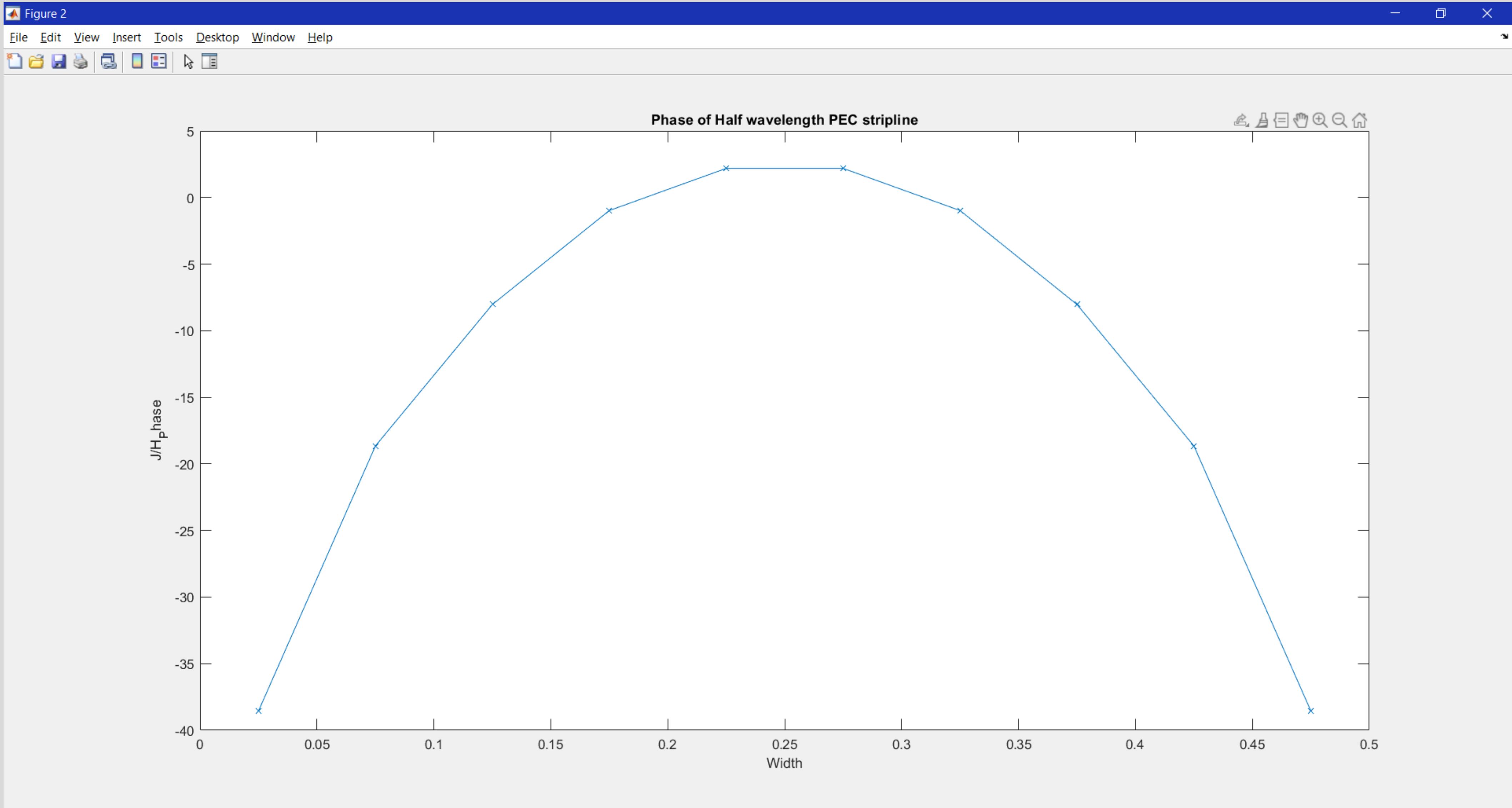
2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Half Wavelength PEC:
Magnitude



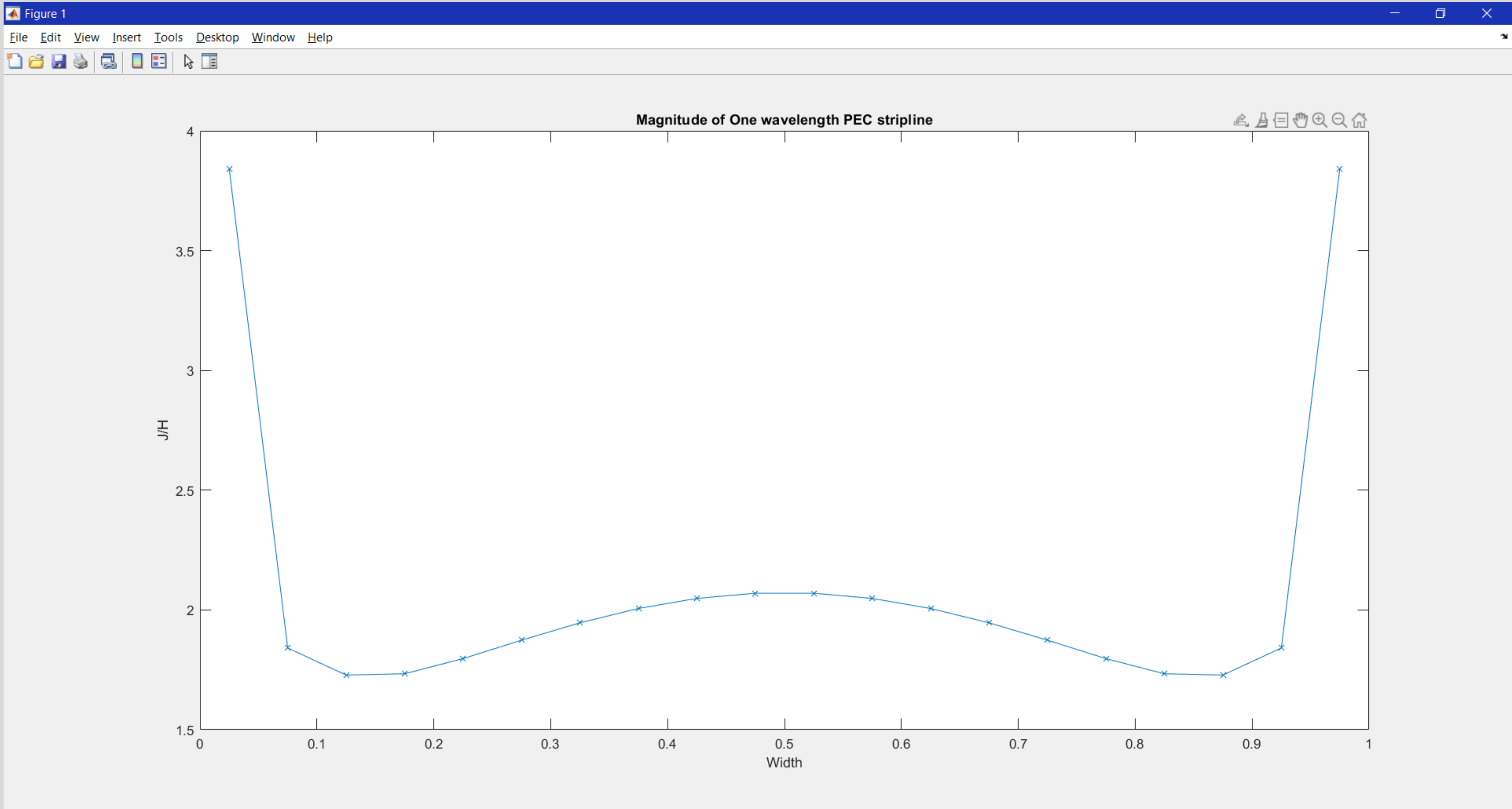
2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

Half Wavelength PEC:
Phase



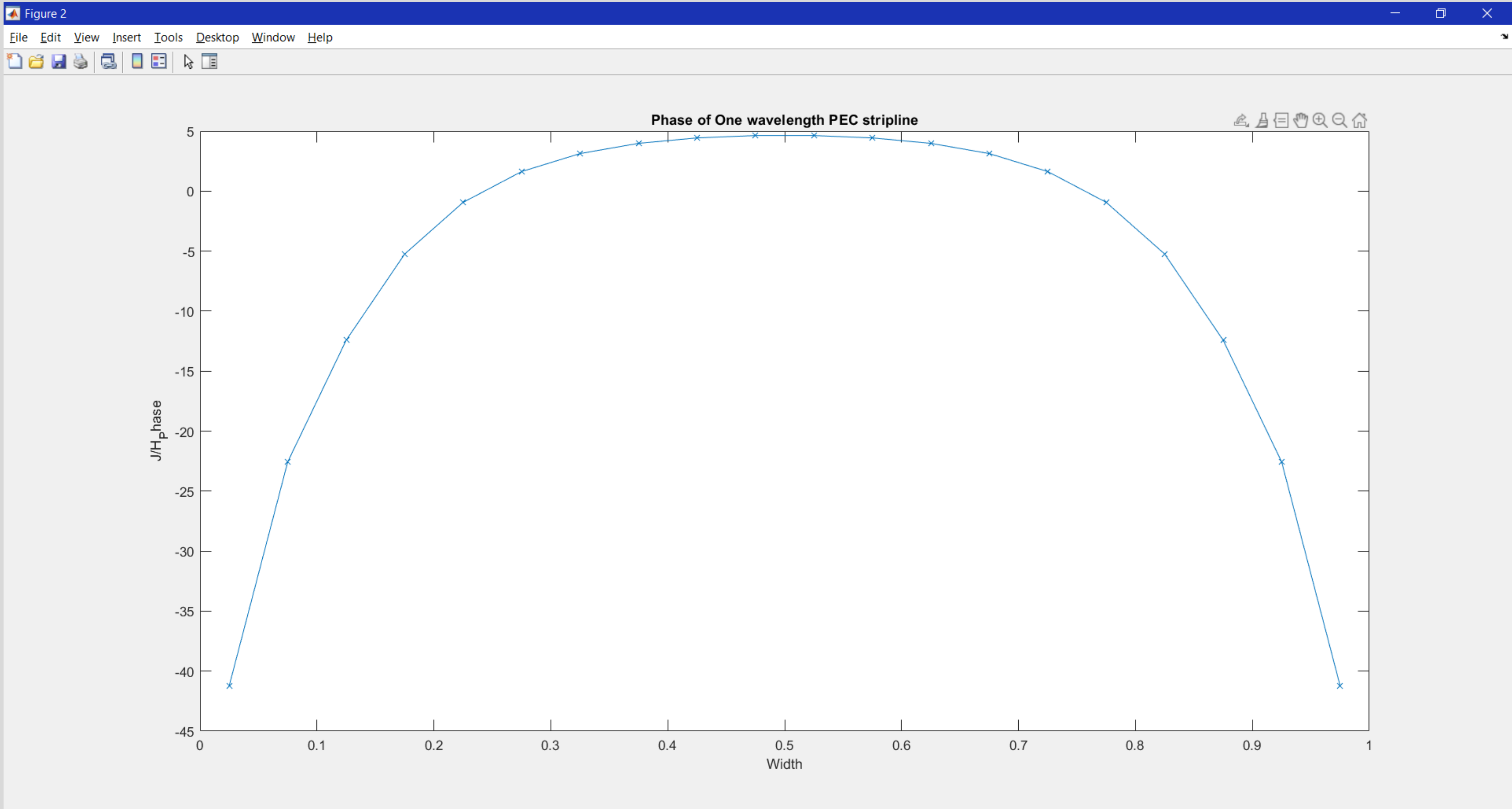
2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

One Wavelength PEC:
Magnitude



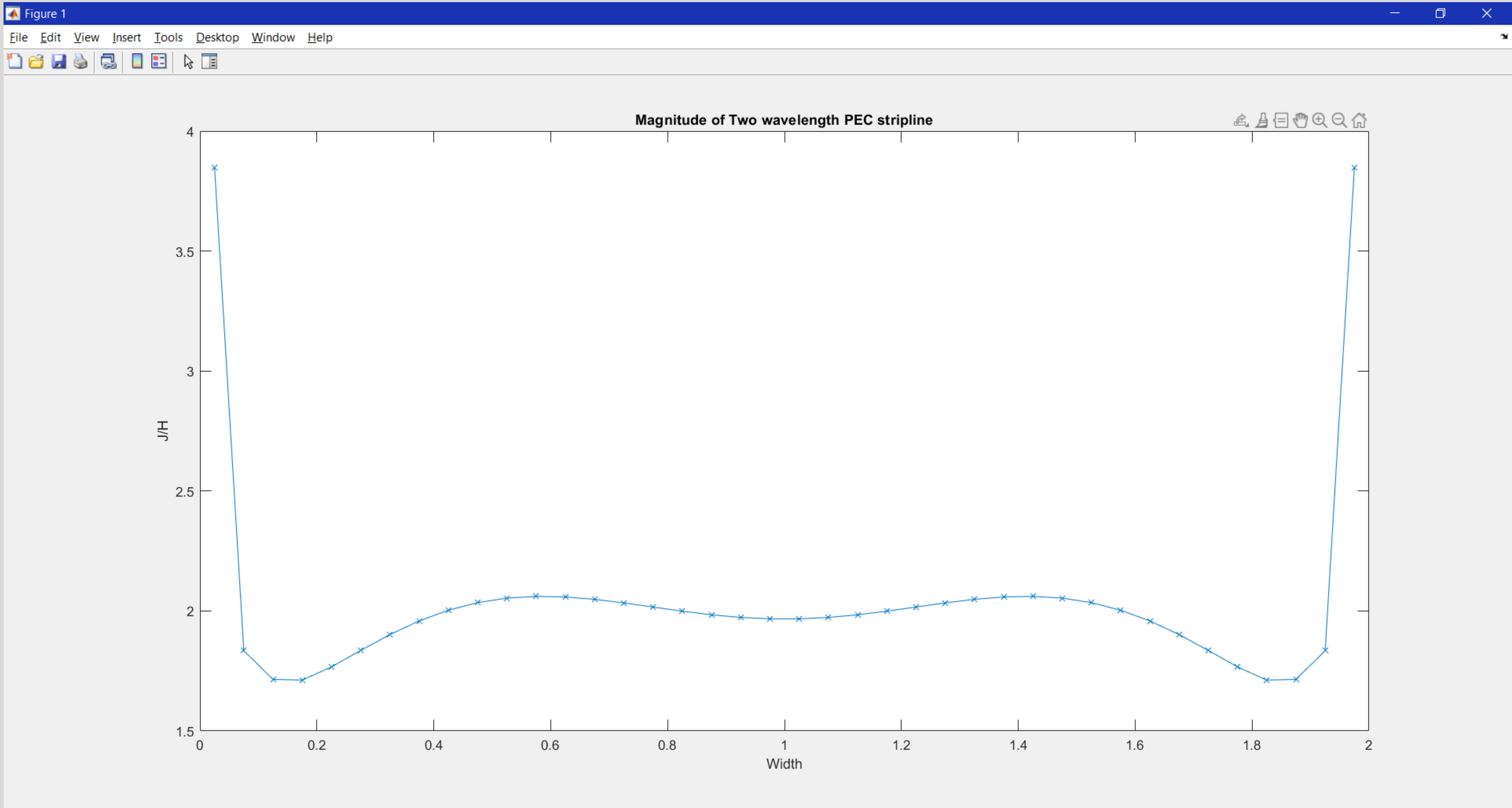
2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

One Wavelength PEC:
Phase



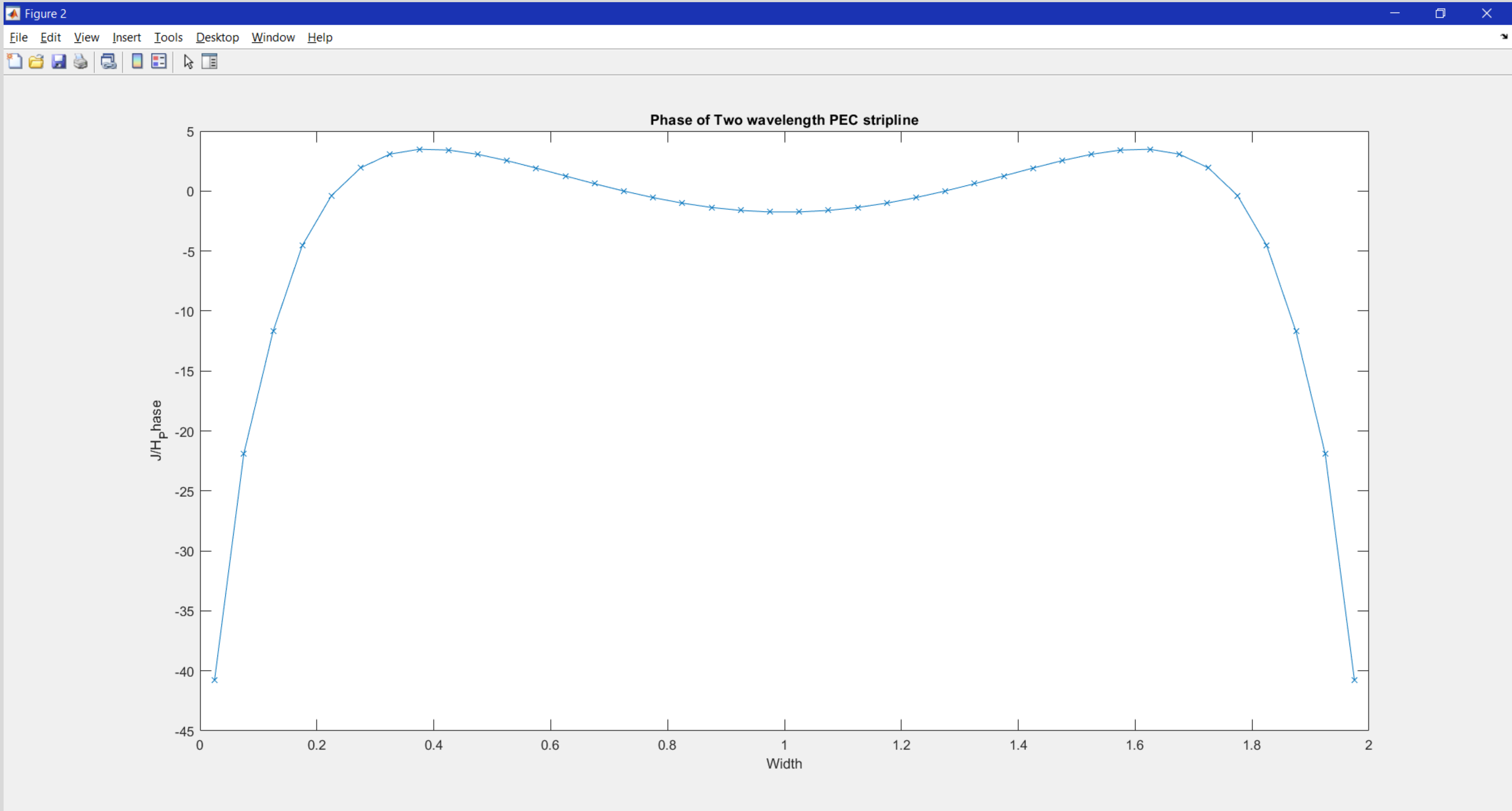
2D ELECTROMAGNETIC SCATTERING FROM AN ARBITRARY-SHAPED CONDUCTING OBJECT UNDER TM ILLUMINATION

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

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{pmatrix} 1 + Yc2 \ * Zl1 & Zl1 \\ Yc1 + Yc2 + Yc1 * Yc2 * Zl1 & 1 + Yc1 * Zl1 \end{pmatrix}$$

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

By equating both matrices we obtain the corresponding Xl, Xc and The values of the inductor and capacitor

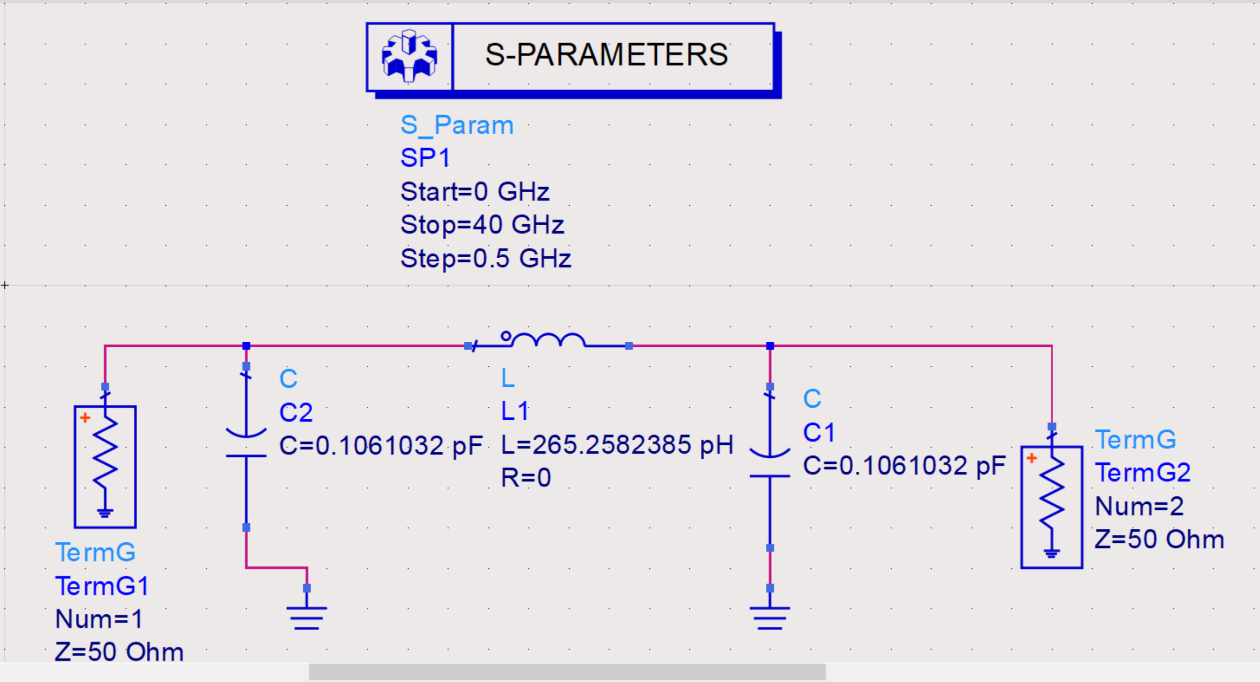
$$Xl = Xc = Z0$$

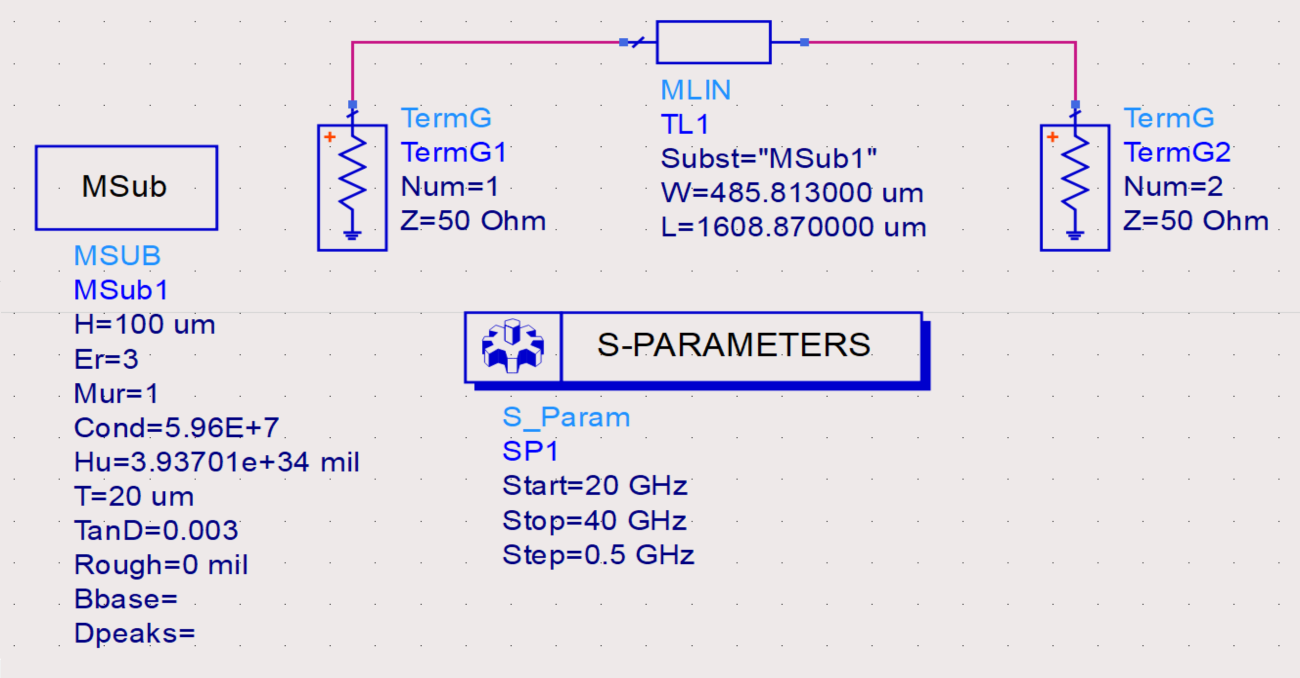
$$C = \frac{1}{2*\pi*f*Z0} \, , L = \frac{Z0}{2*\pi*f} >>>$$

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

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

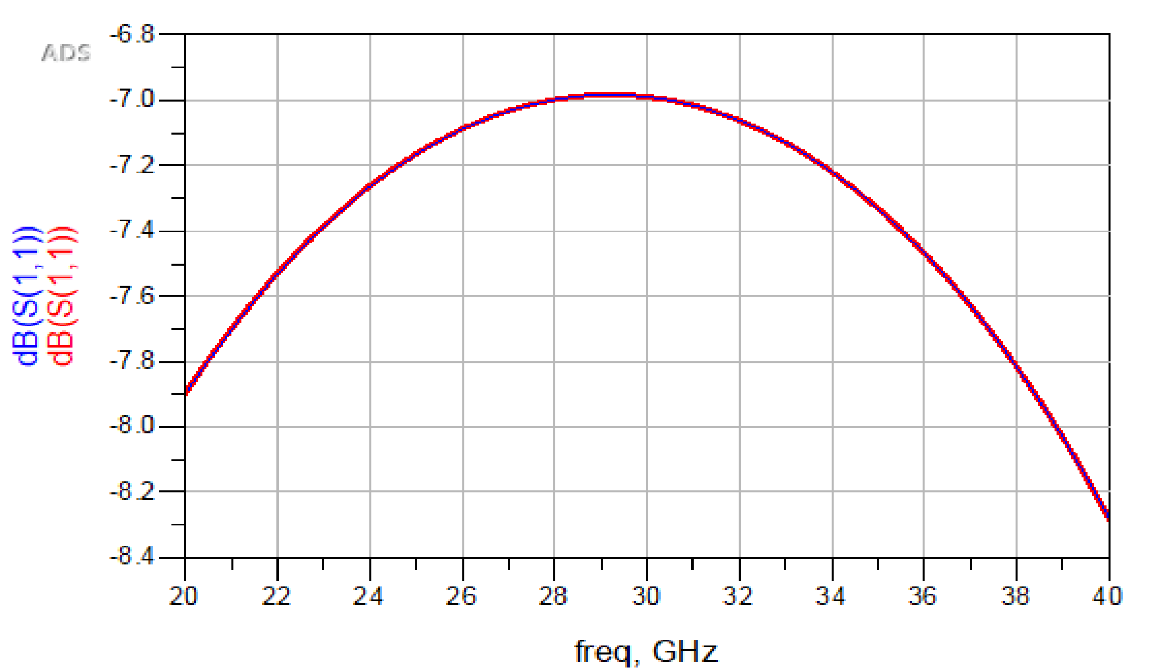
LC VS TL SCHEMATIC DESIGN





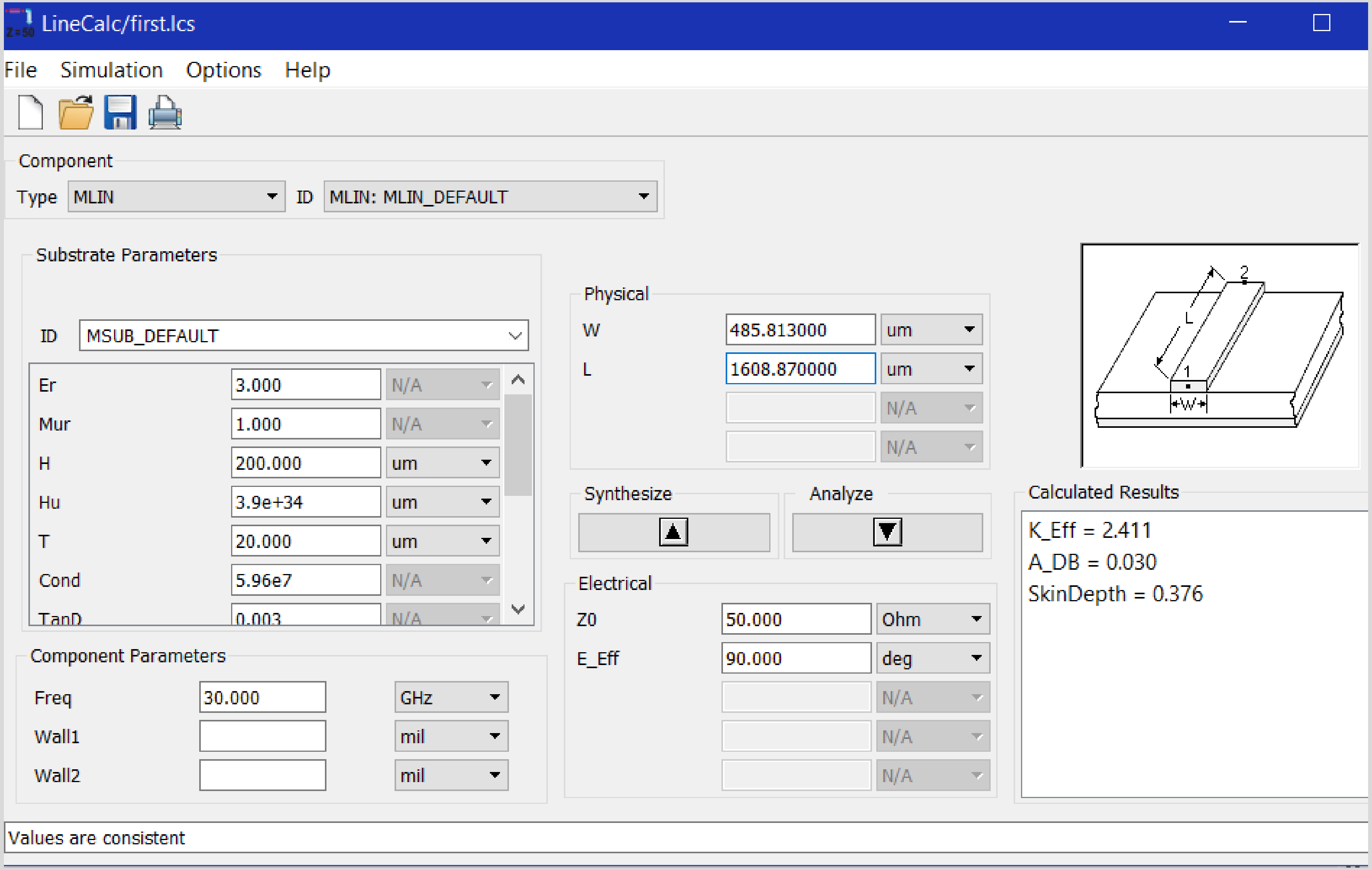
S11 LC VS TL

LC

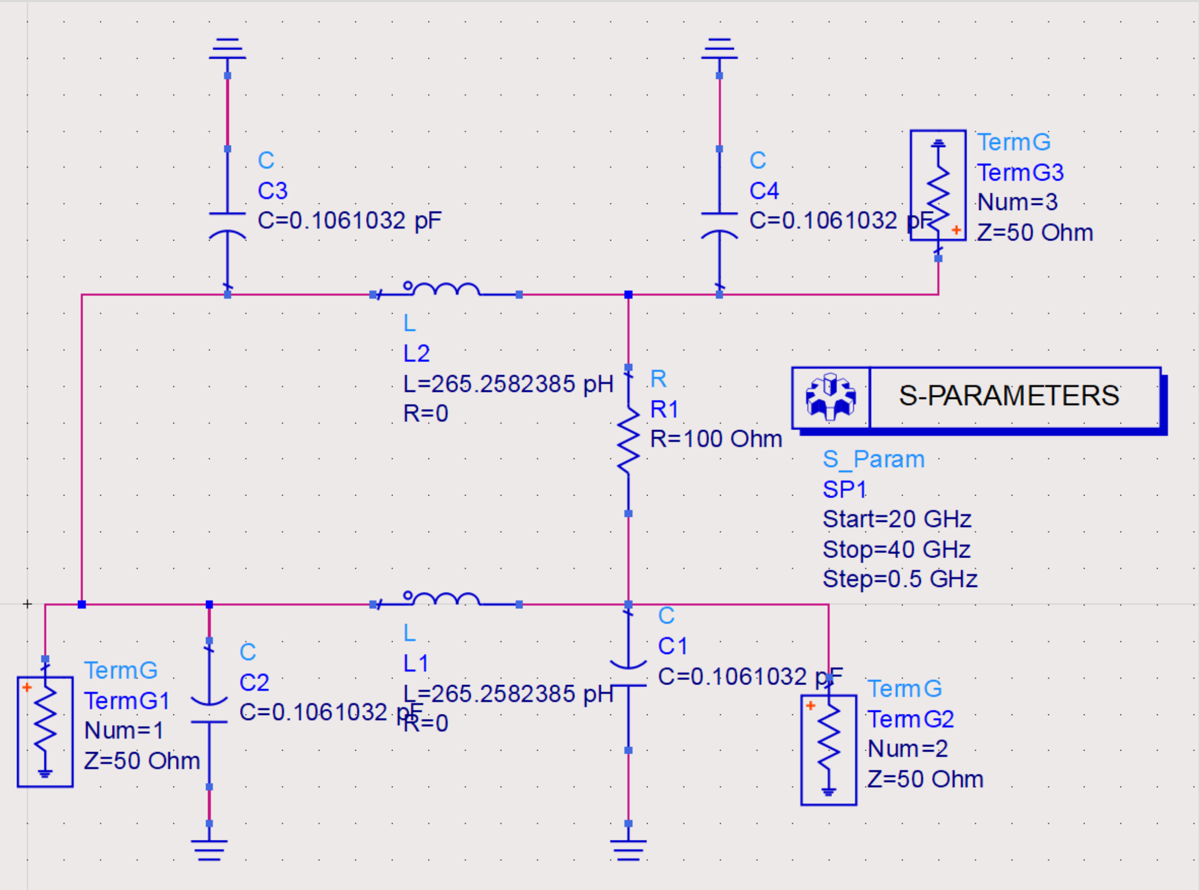


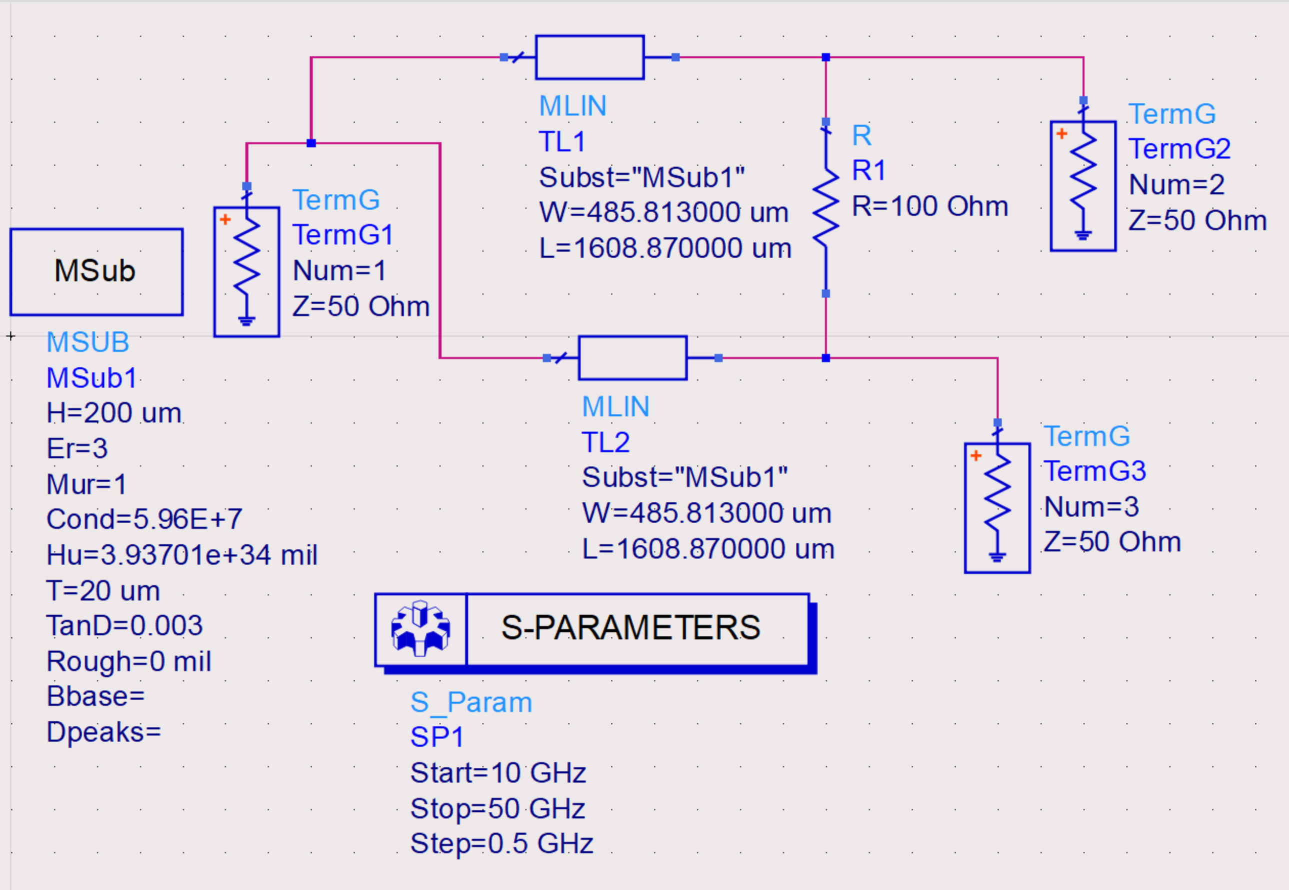
TL

2-WAY WILKINSON

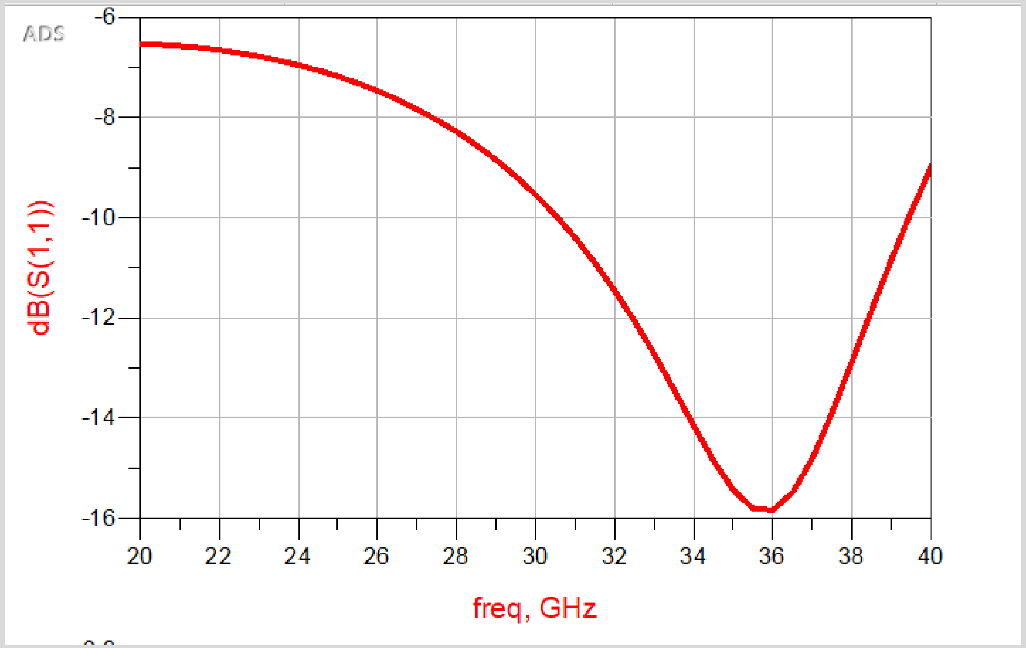


LC VS TL SCHEMATIC DESIGN

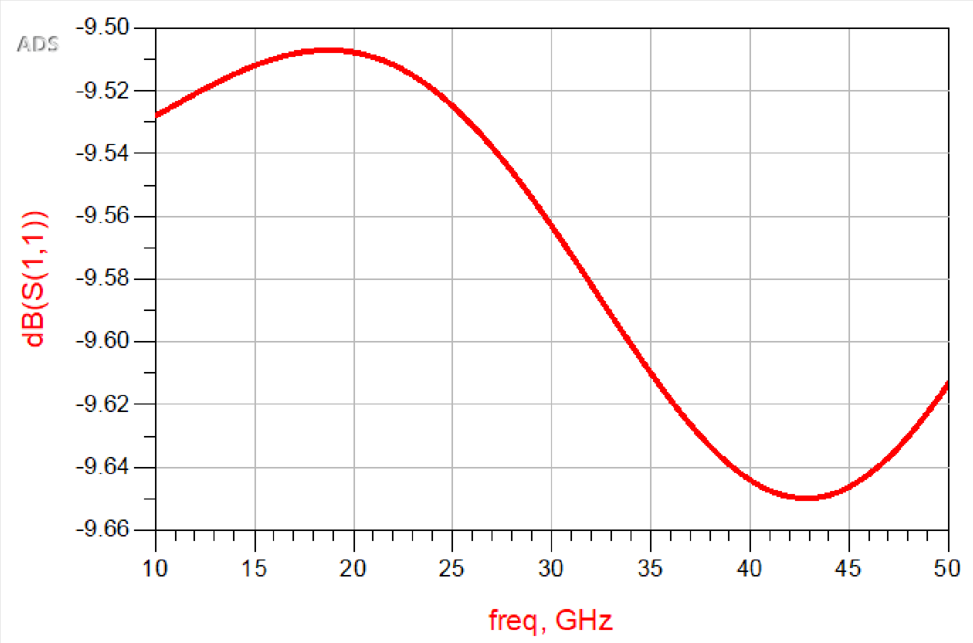




S11 LC VS TL

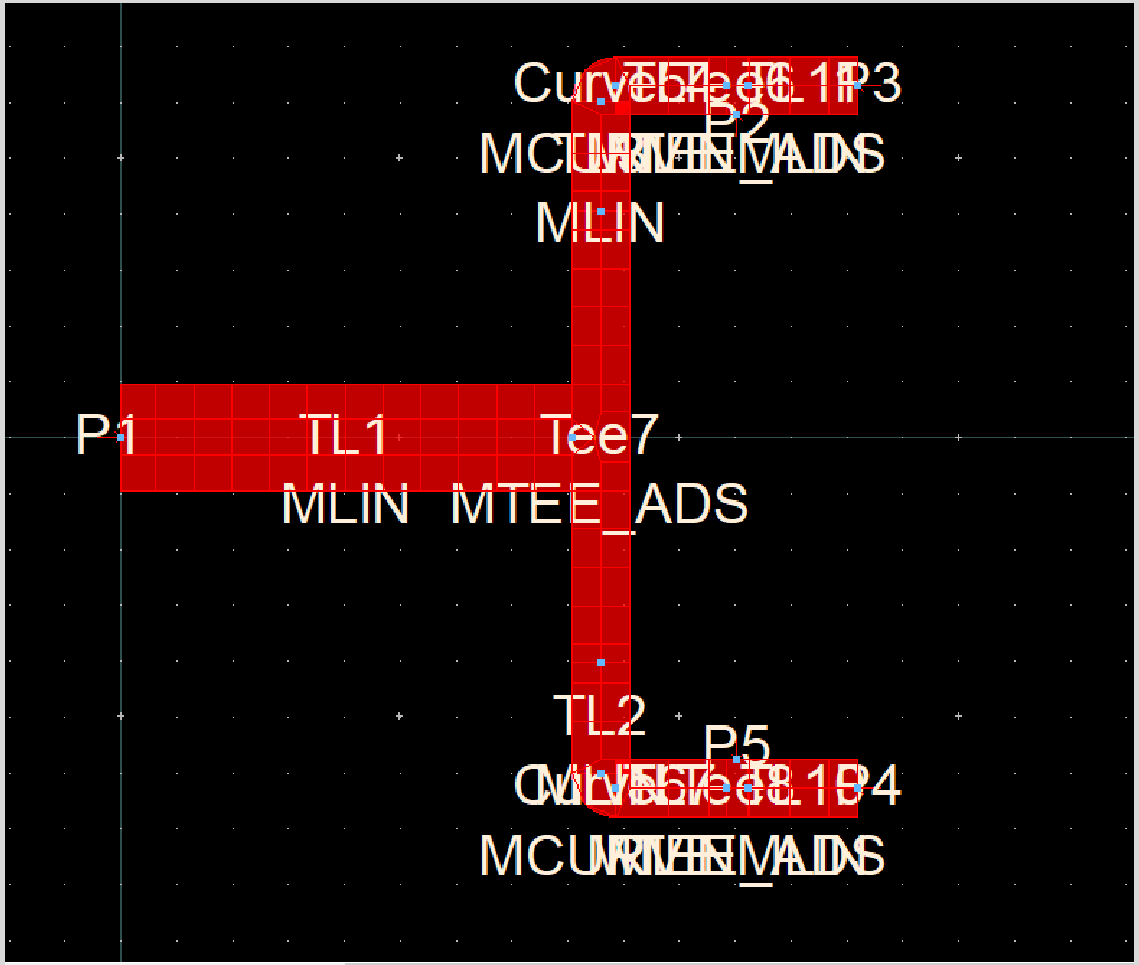


LC



TL

WILKINSON LAYOUT

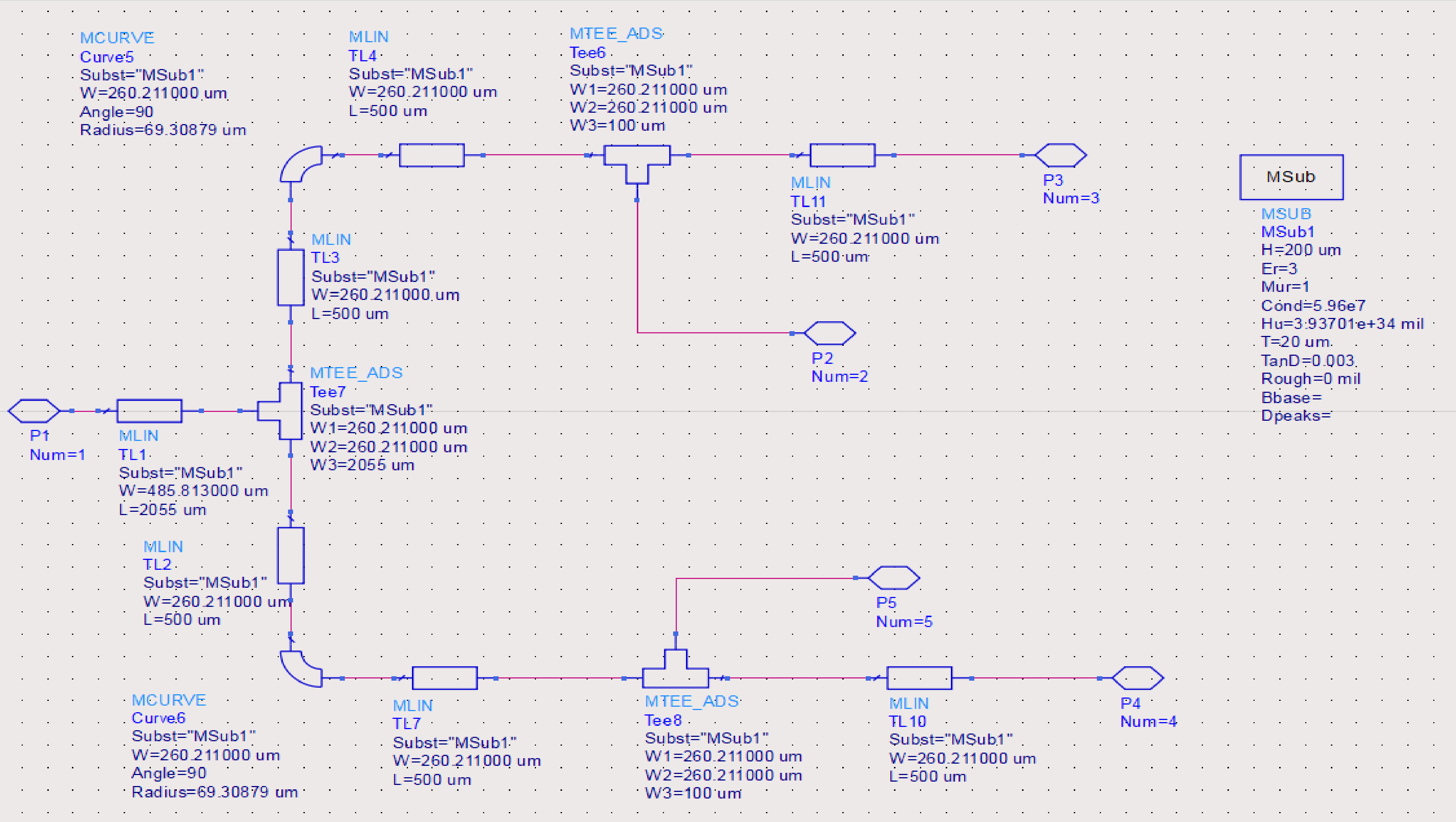


Part 3:

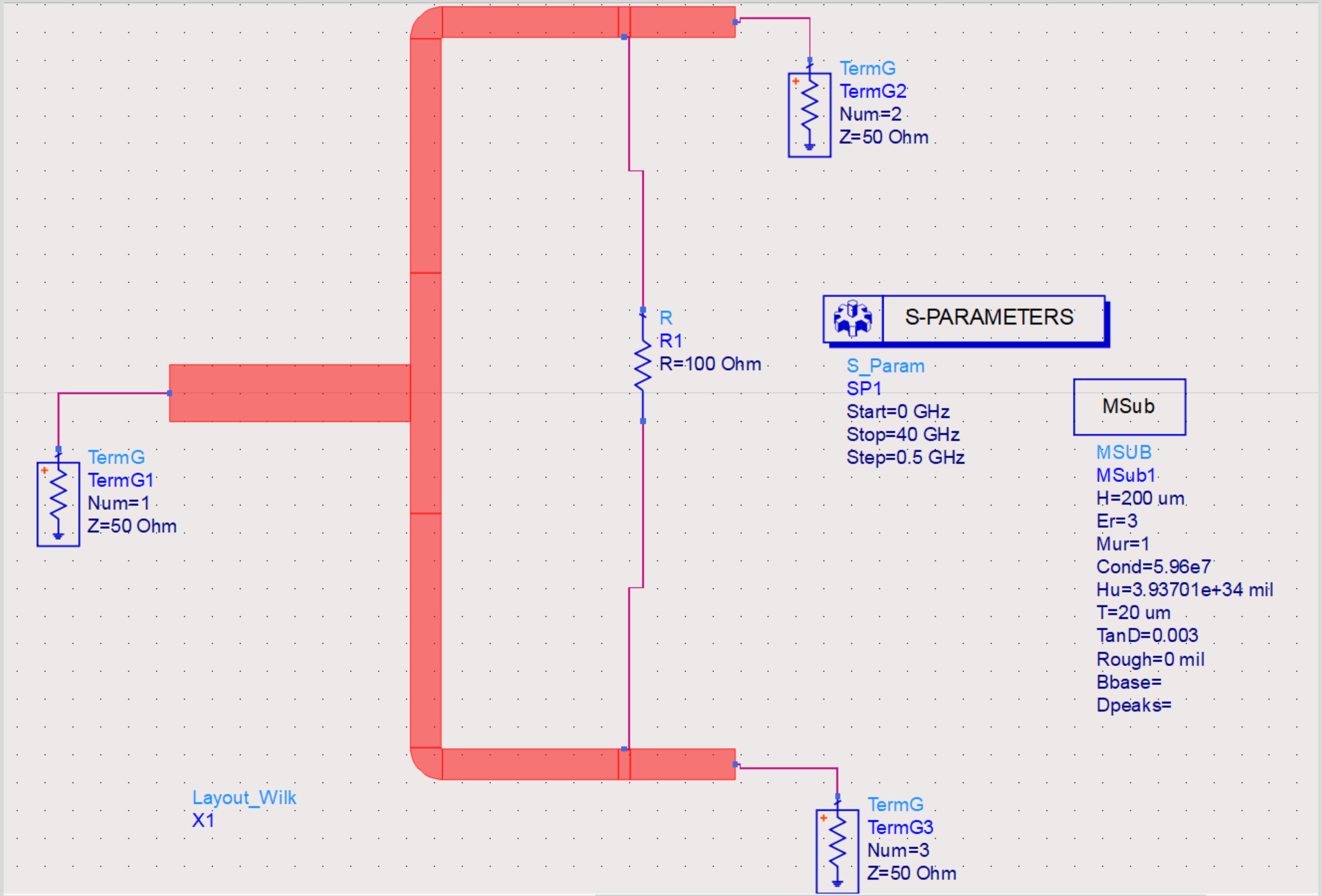
Calculate the radius of the curve:

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

$$radius = 69.30879um$$

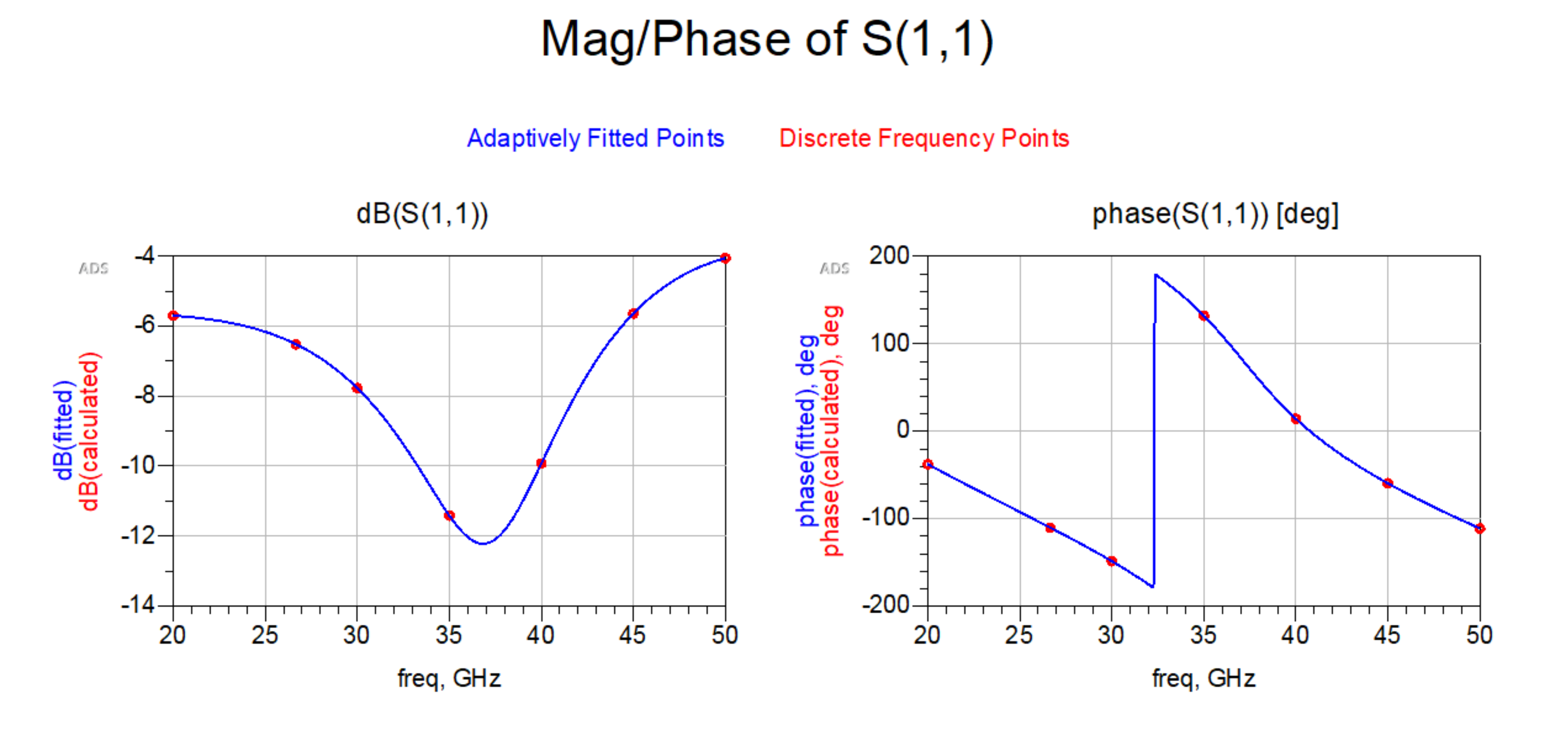


LAYOUT ADDED TO SCHEMATIC



S11

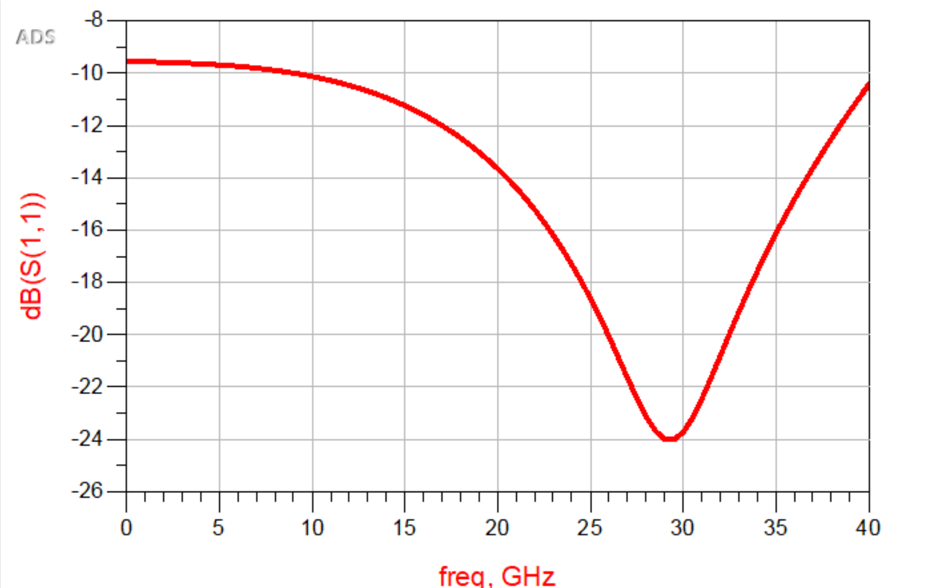
From layout



S11

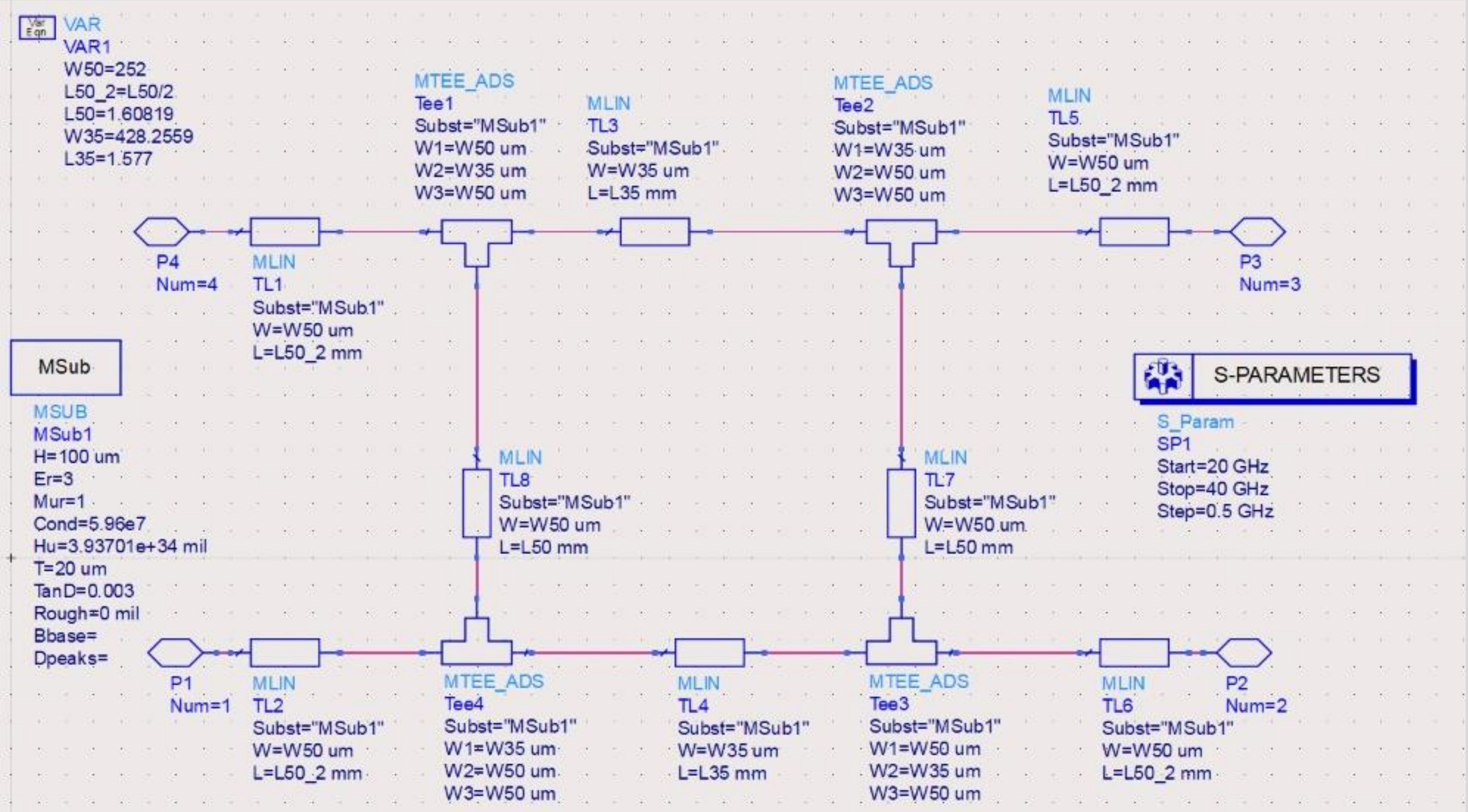
After adding layout to schematic

And the resistors



PART 2: QUADRATURE COUPLER IMPLEMENTATION

SCHEMATIC



Calculations

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

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

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

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

H = substrate height, W = width of microstrip line

$$A = \frac{Z0}{60} * \sqrt{\frac{\varepsilon + 1}{2}} + \frac{\varepsilon - 1}{\varepsilon + 1}\left(0.23 + \frac{0.11}{\varepsilon}\right)$$

$$B = \frac{377\pi}{2Z0 * \sqrt{\varepsilon}}$$

$$A50 = \frac{50}{60} * \sqrt{\frac{3 + 1}{2}} + \frac{3 - 1}{3 + 1}\left(0.23 + \frac{0.11}{3}\right) = 1.311844635$$

$$W50 = \frac{8h * e^A}{e^{2A} - 2} = \frac{8 * 100 * e^{1.311844635}}{e^{2 * 1.311844635} - 2} = 252um$$

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

$$L50 = \frac{\lambda}{4} = \frac{\lambda 0}{4 * \sqrt{\varepsilon eff}} = \frac{10}{4 * \sqrt{2}.4166} = 1.60819mm$$

Calculate width of the 35 ohm microstrip line

$$A35 = \frac{35.35}{60} * \sqrt{\frac{3+1}{2}} + \frac{3-1}{3+1}\left(0.23 + \frac{0.11}{3}\right) = 0.966554$$

$$W35 = \frac{8h * e^{A}}{e^{2A} - 2} = \frac{8 * 100 * e^{0.966554}}{e^{2 * 0.966554} - 2} = 428.2559um$$

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

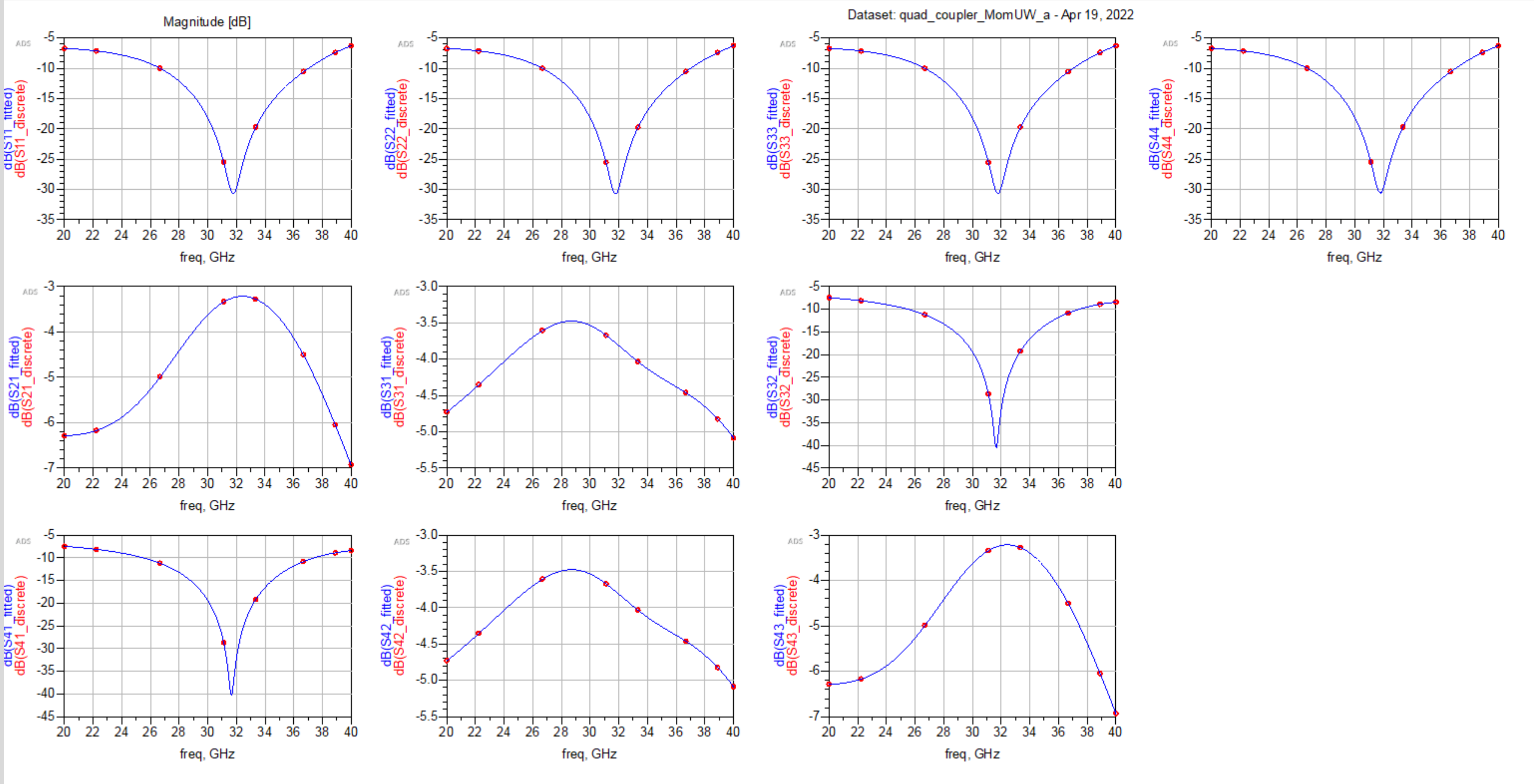
Calculate length of the 35 ohm quarter wave line

$$L35 = \frac{\lambda}{4} = \frac{\lambda 0}{4 * \sqrt{\varepsilon eff}} = \frac{10}{4 * \sqrt{(2.51285)}} = 1.577mm$$

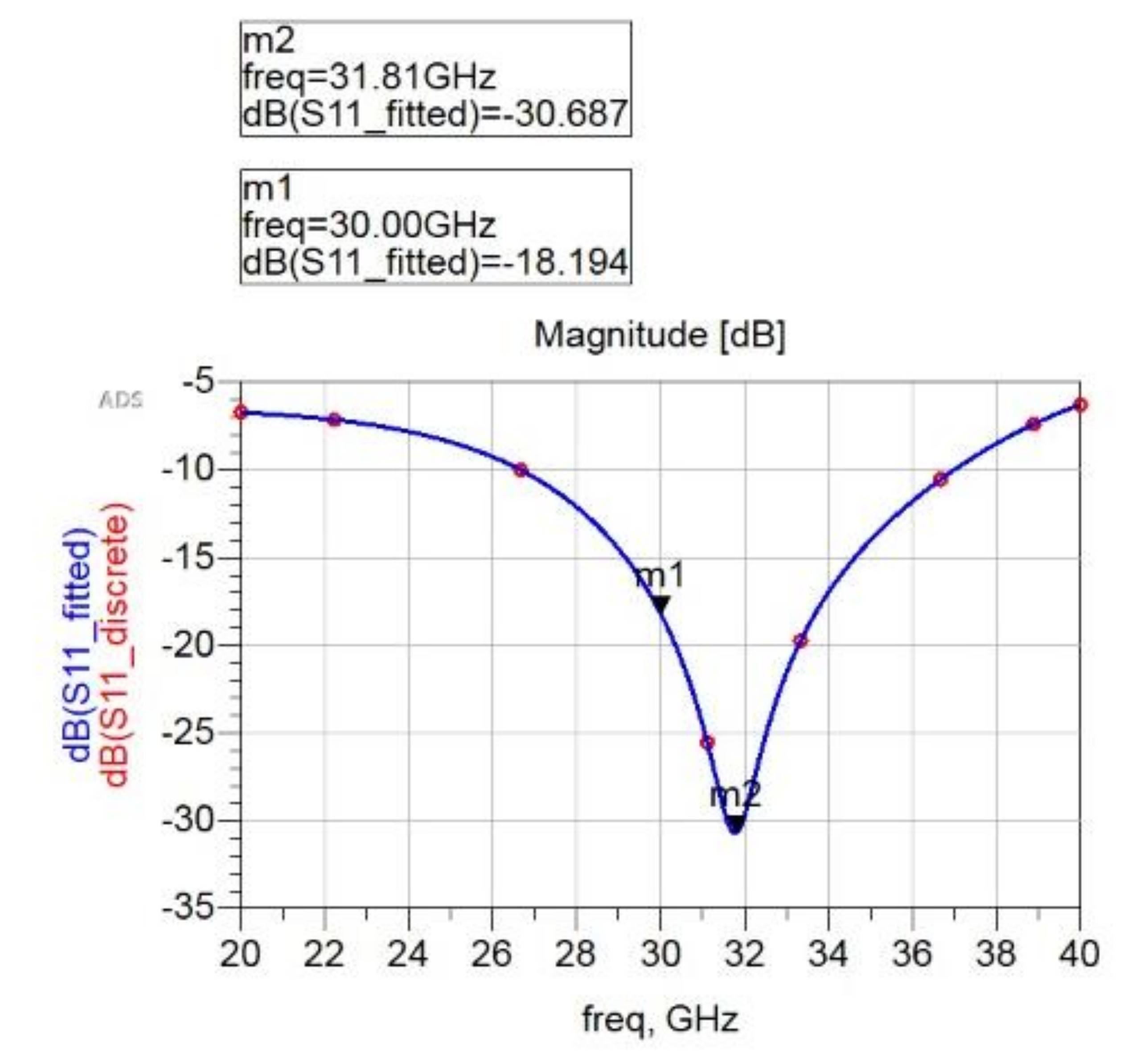
LAYOUT


P4
TL1
Tee1
TL3
Tee2
TL5
P3
TL8
MLIN
TL7
MLIN
P1
TL2
Tee4
TL4
Tee3
TL6
P2

S PARAMETERS FOR THE COUPLER



S11 FROM LAYOUT



PART 3: BALUN IMPLEMENTATION

1- HIGH PASS – LOW PASS BALUN

Design Steps:

1- f0 = 60GHz

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

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

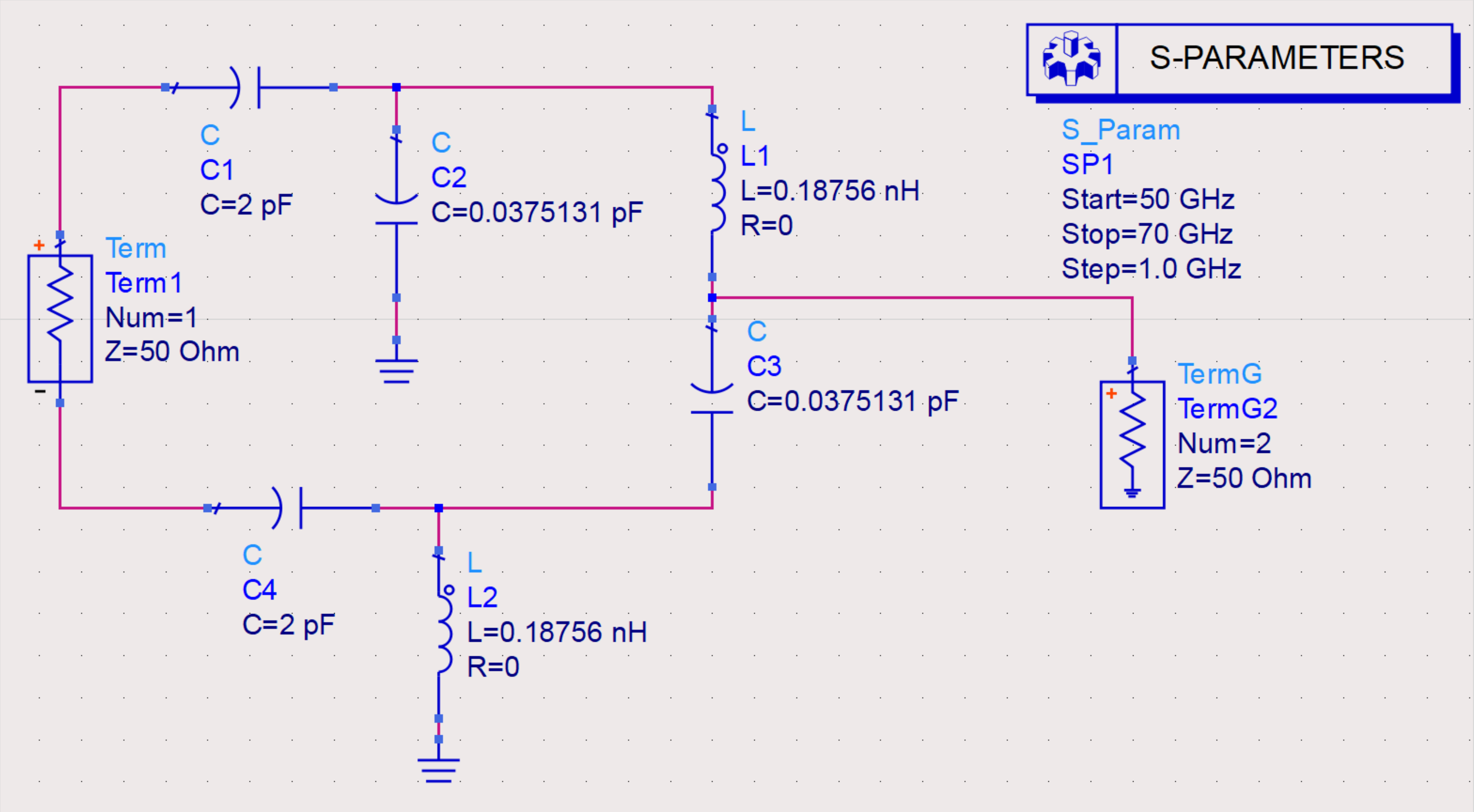
$$L = \frac{50\sqrt{2}}{2 * \pi * 60\ * 10^9} = 1.8756 * 10^{-10} H,$$

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

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

PART 3: **BALUN IMPLEMENTATION**

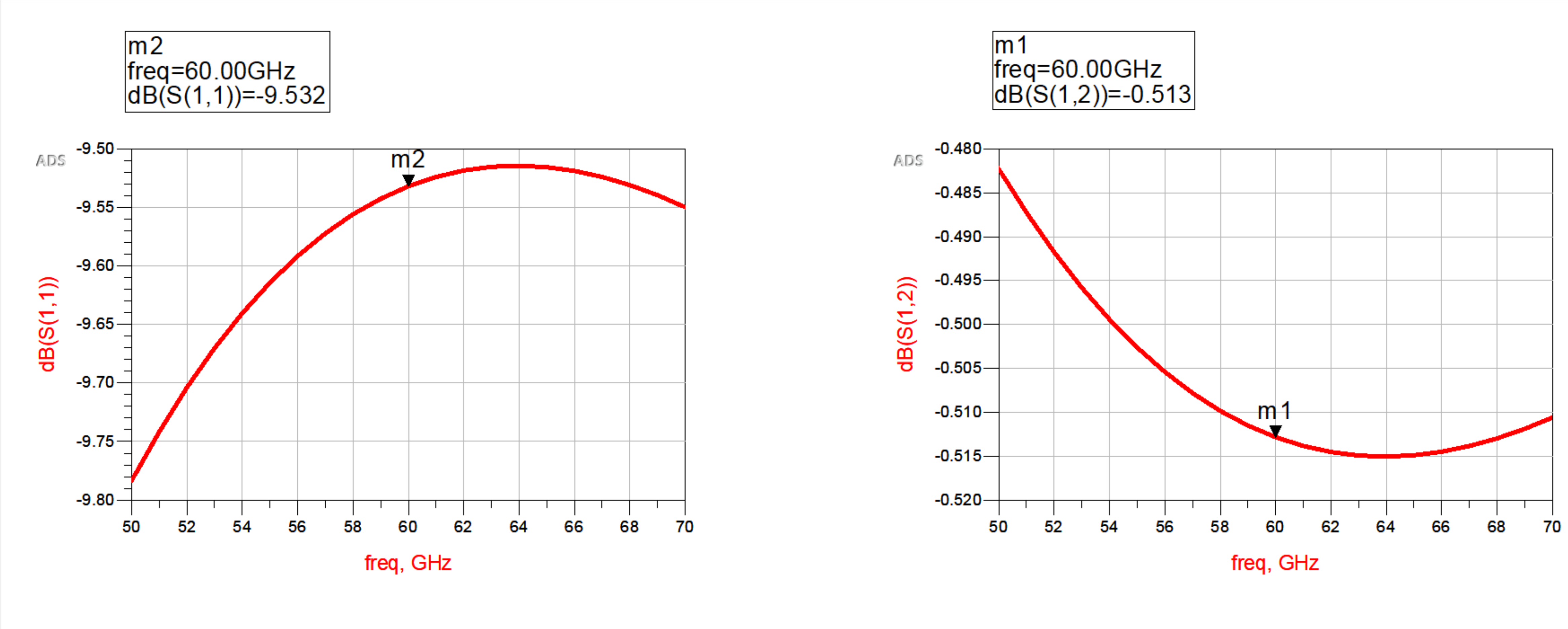
1- HIGH PASS – LOW PASS BALUN SCHEMATIC



PART 3: BALUN IMPLEMENTATION

1- HIGH PASS – LOW PASS BALUN S PARAMETERS

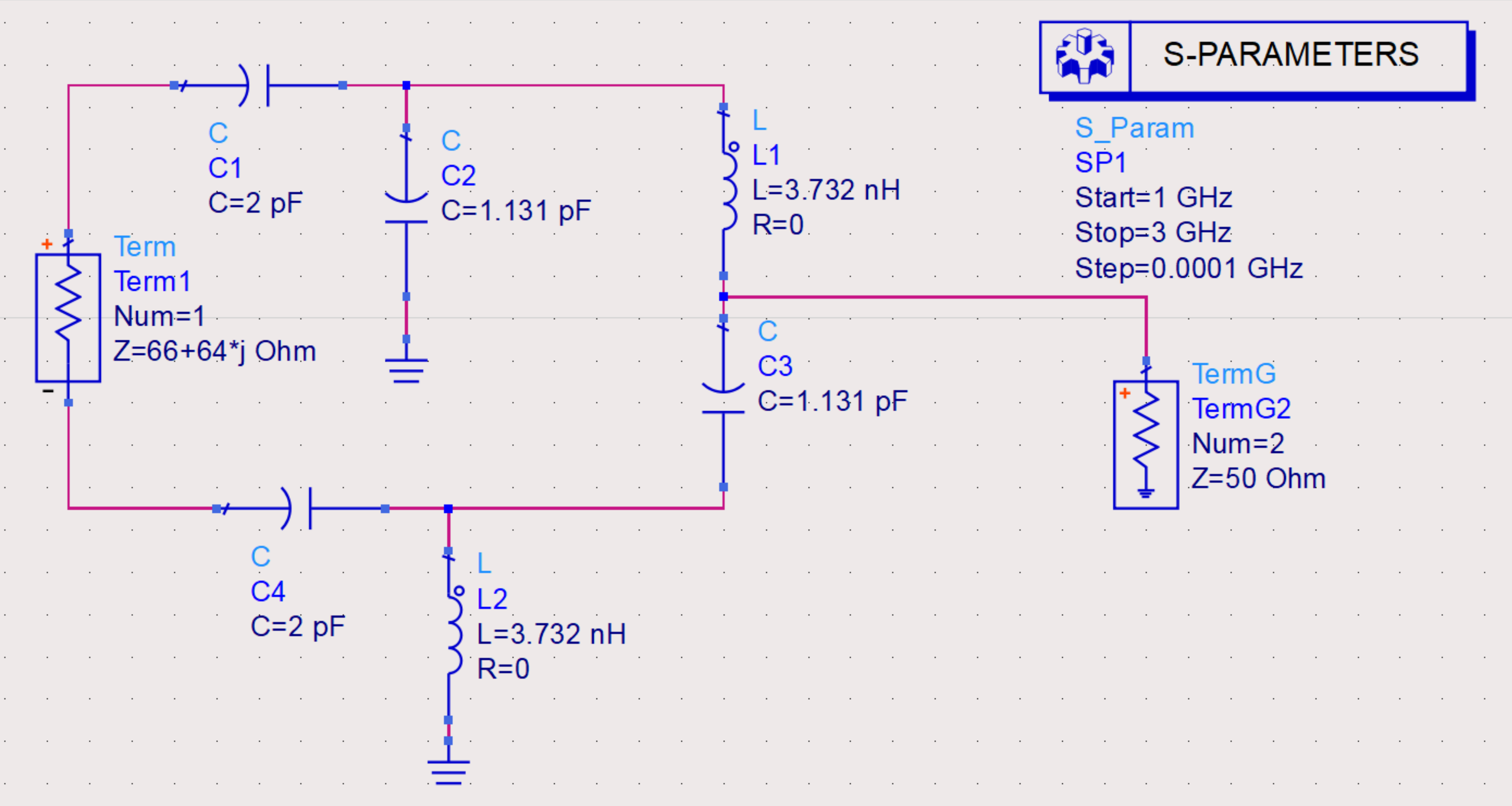
60 GHz was a bad idea to test this implementation so I will test it on 2.45 GHz



PART 3: **BALUN IMPLEMENTATION**

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

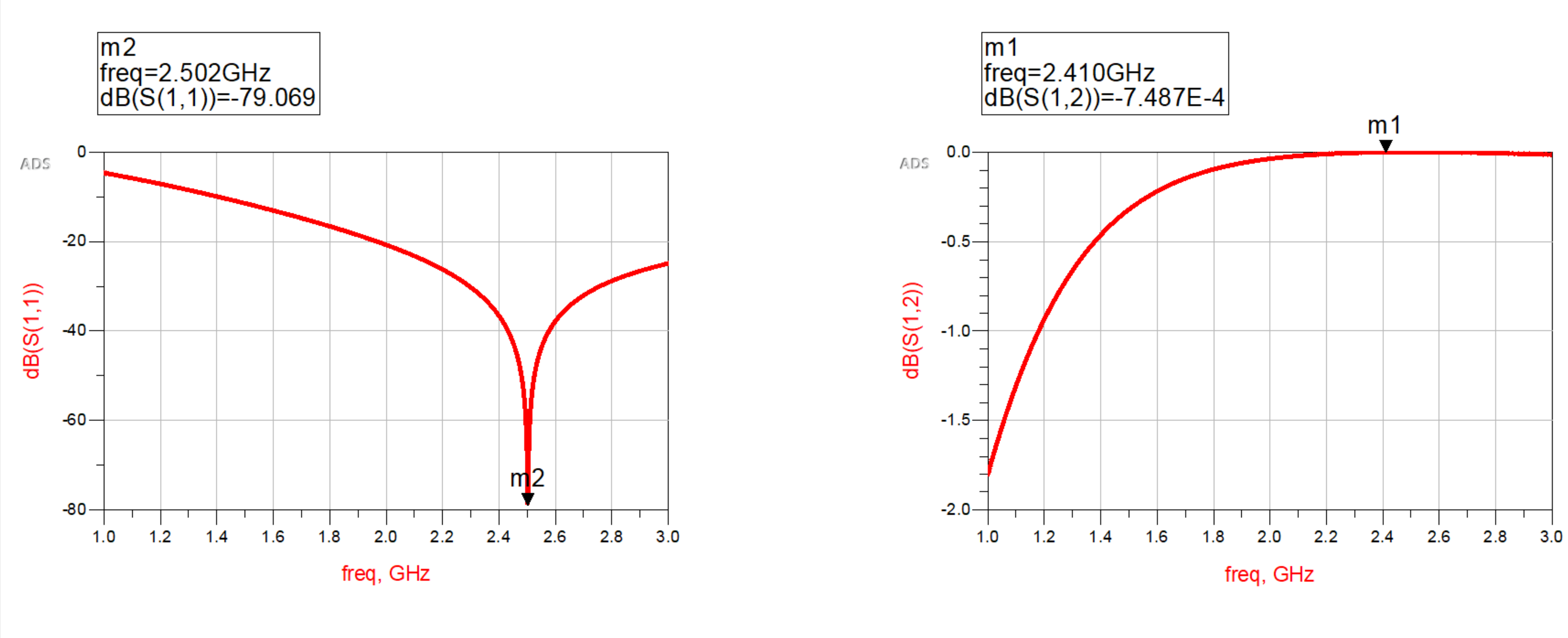
60 GHz was a bad idea to test this implementation so I will test it on 2.45 GHz



PART 3: **BALUN IMPLEMENTATION**

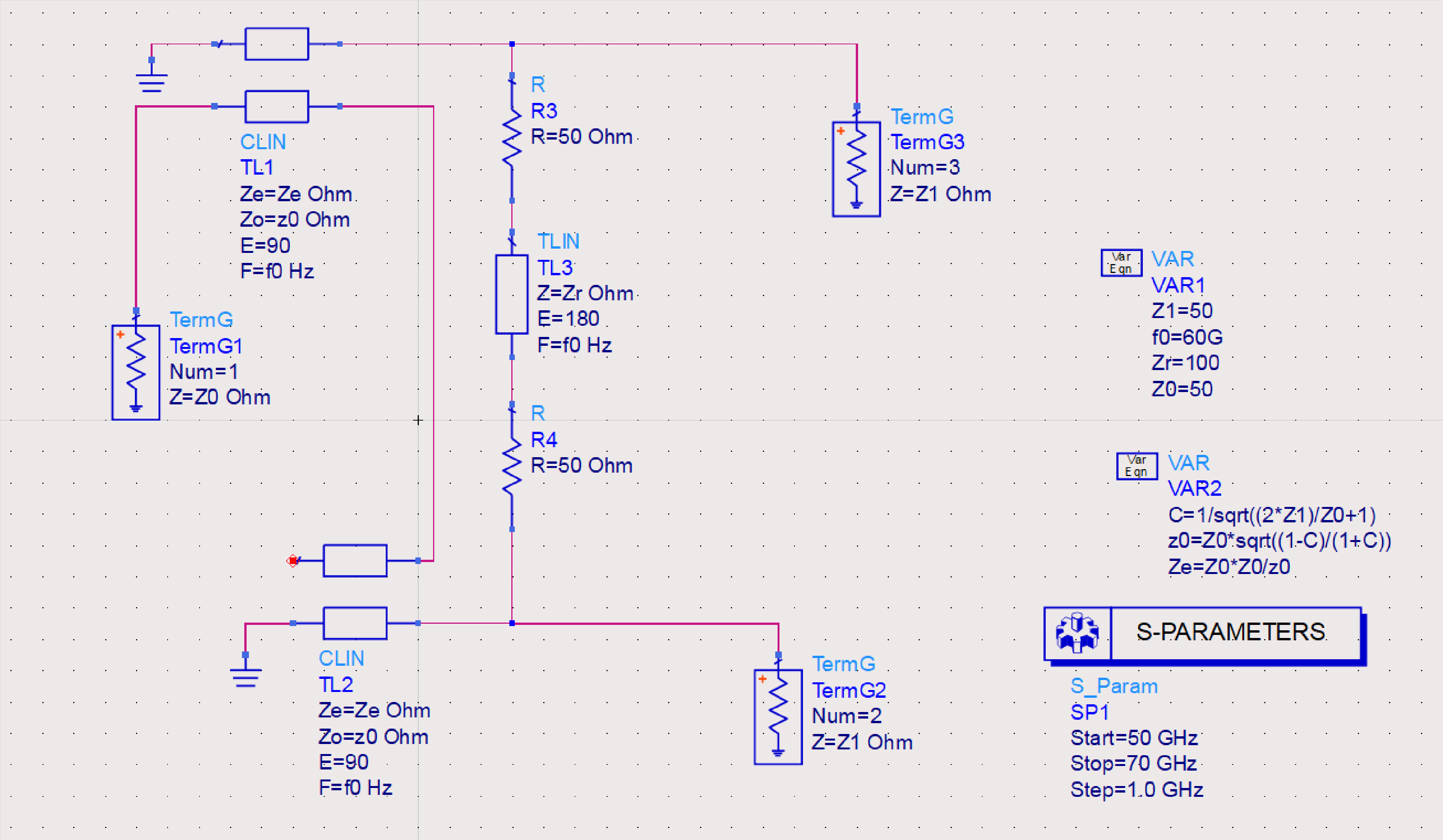
1- HIGH PASS – LOW PASS BALUN S PARAMETERS

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



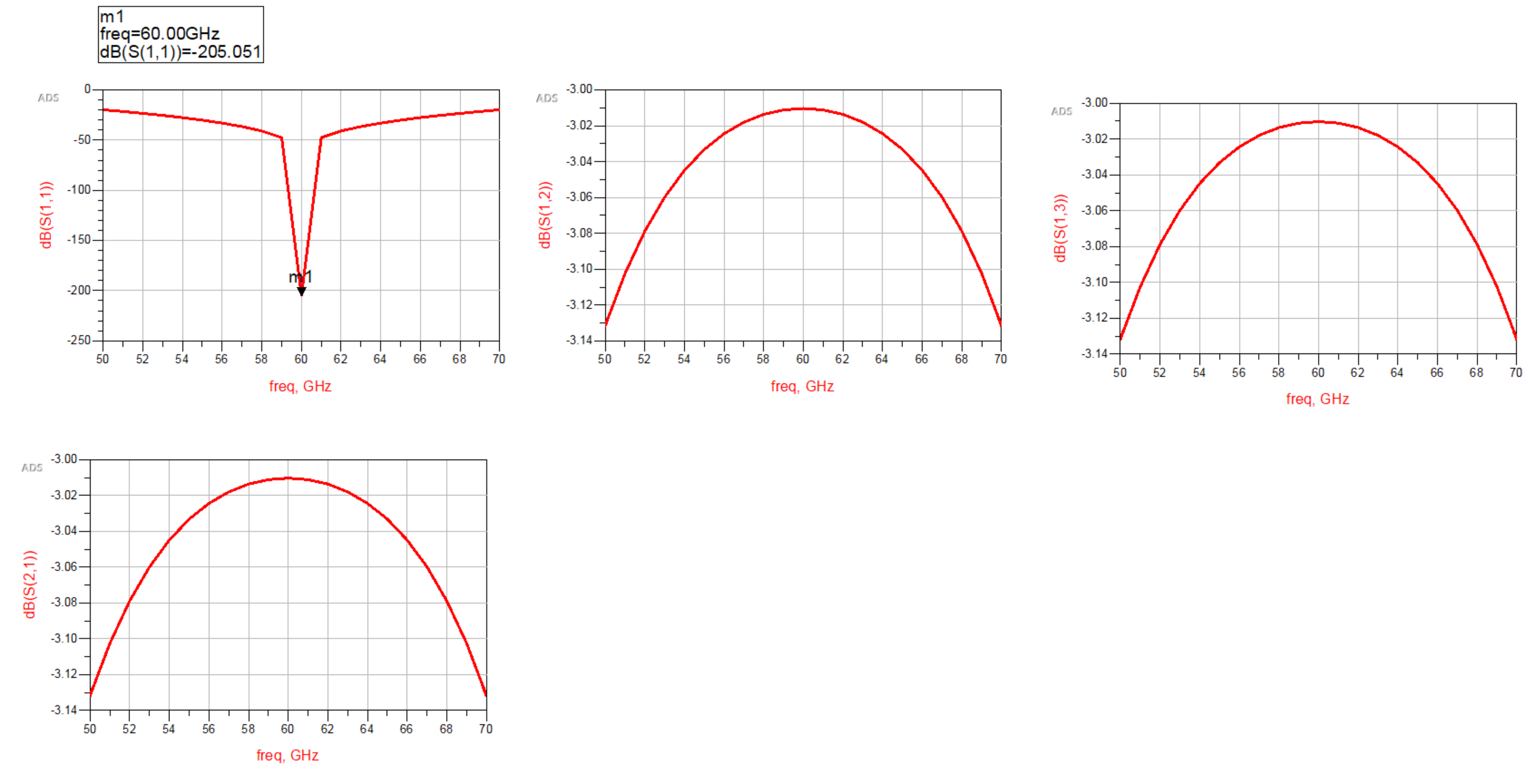
PART 3: **BALUN IMPLEMENTATION**

2- MARCHAND BALUN



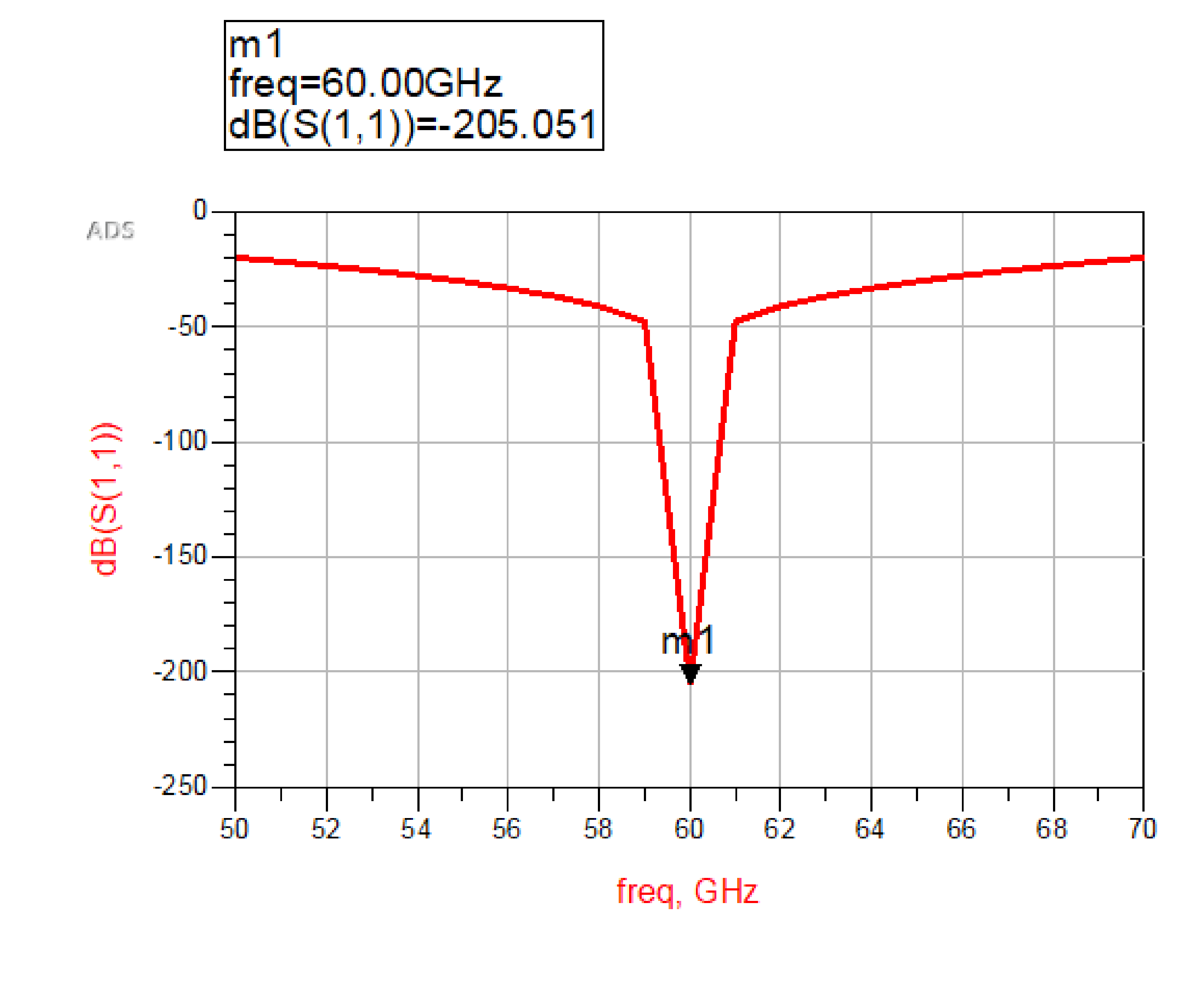
PART 3: BALUN IMPLEMENTATION

2- MARCHAND BALUN S PARAMETERS



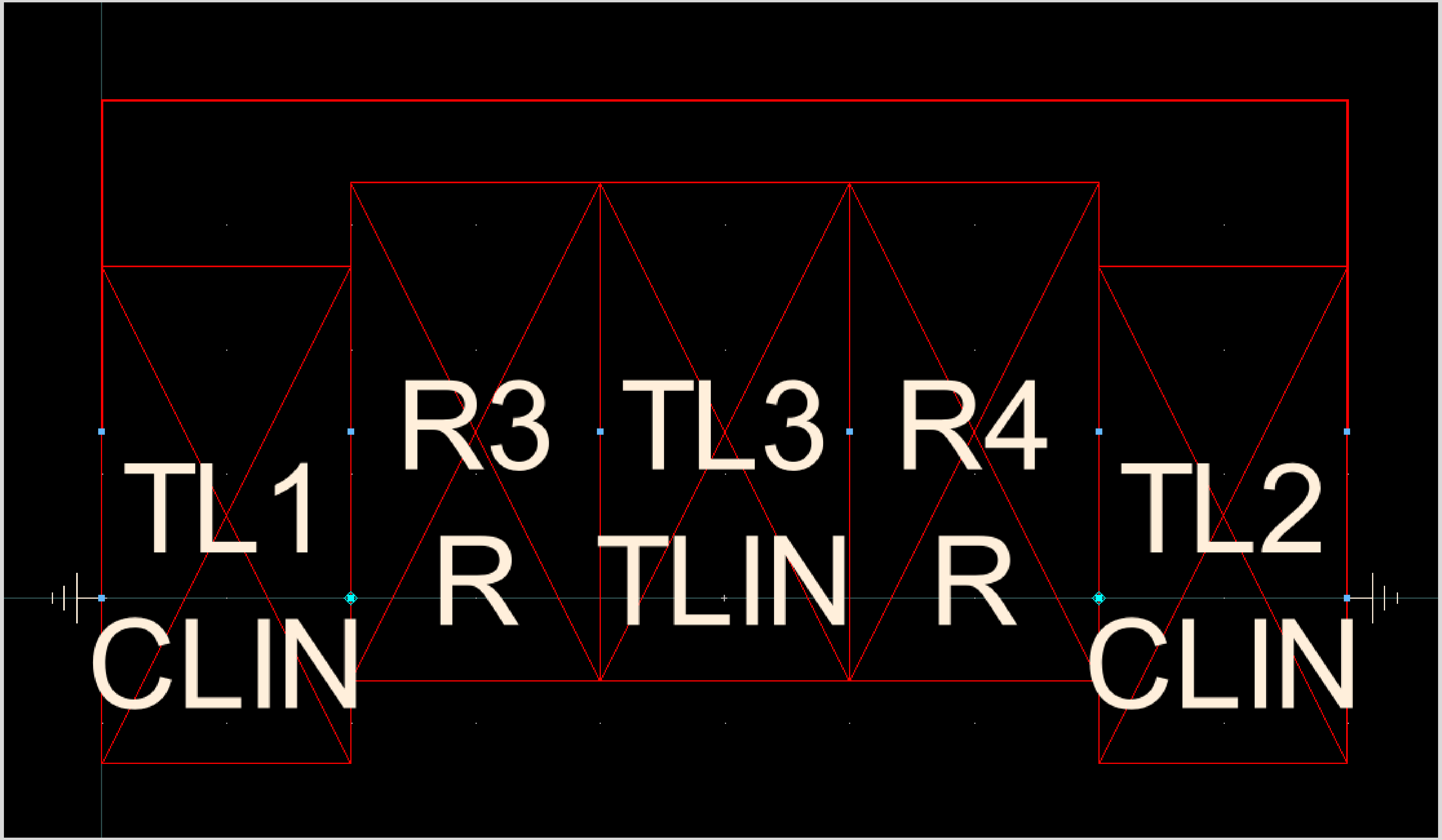
PART 3: **BALUN IMPLEMENTATION**

2- MARCHAND BALUN S PARAMETERS S11



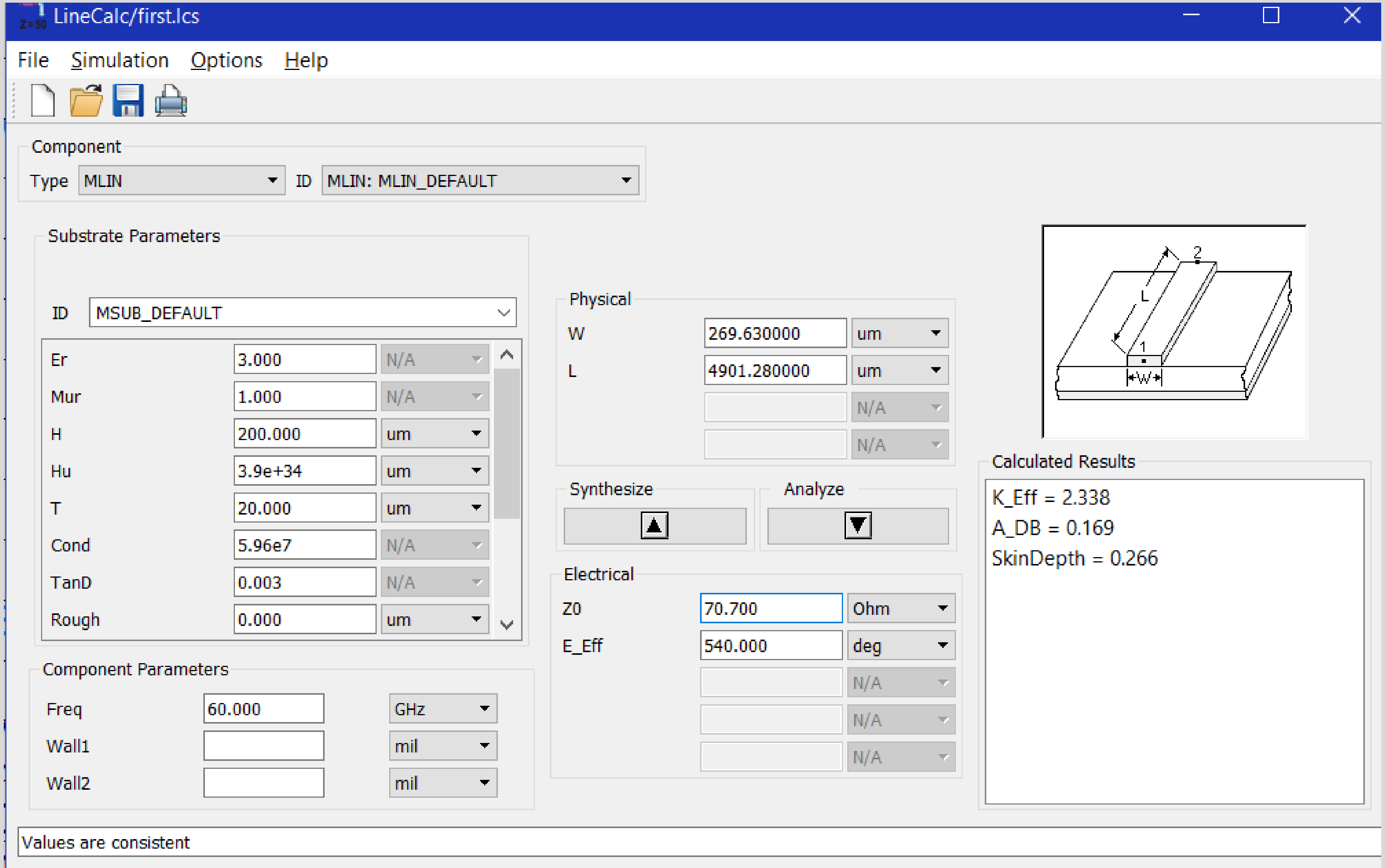
PART 3: **BALUN IMPLEMENTATION**

2- MARCHAND BALUN LAYOUT



PART 3: **BALUN IMPLEMENTATION**

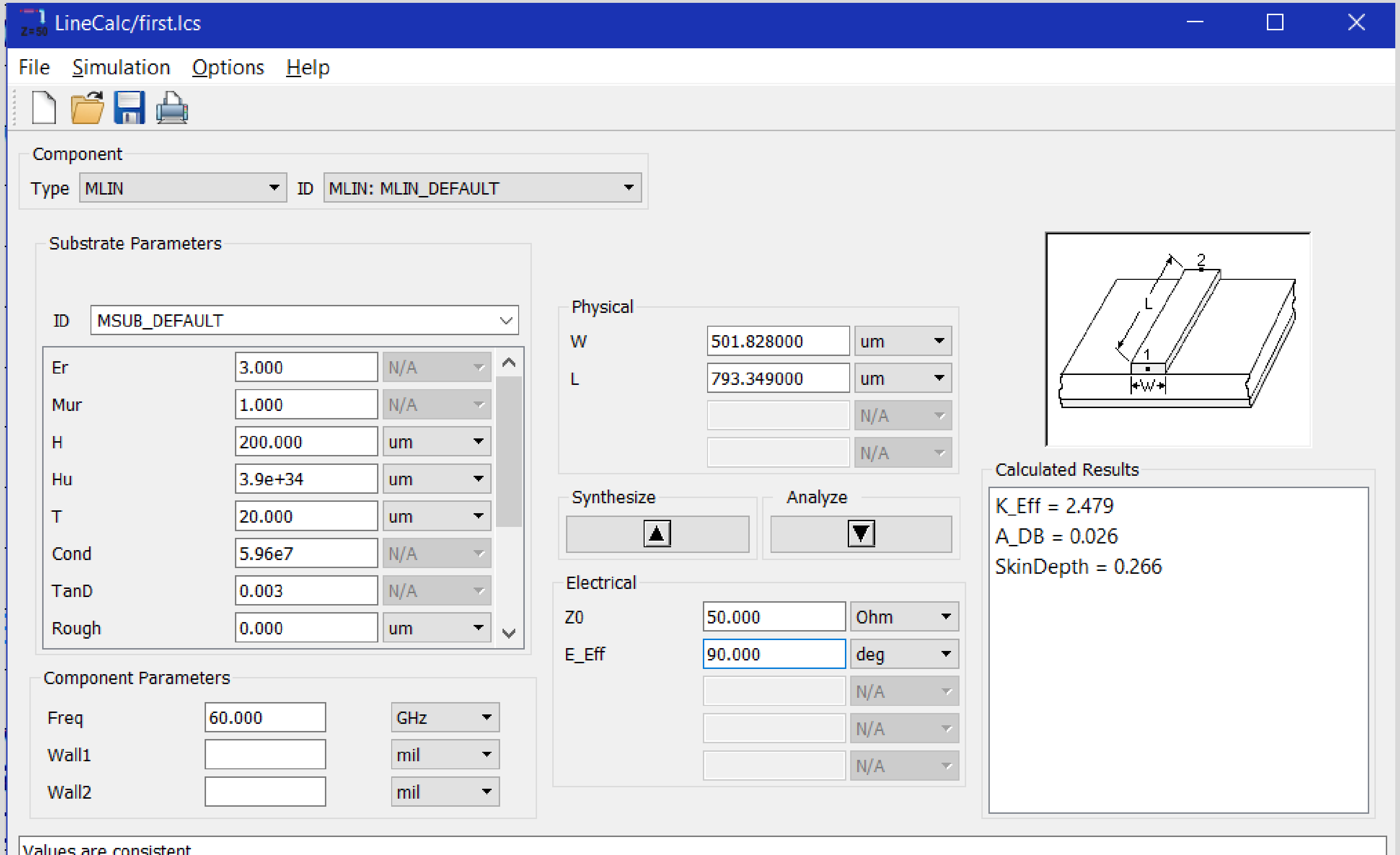
3- RAT RACE BALUN TO GET THE RADIUS OF THE CURVES



PART 3: **BALUN IMPLEMENTATION**

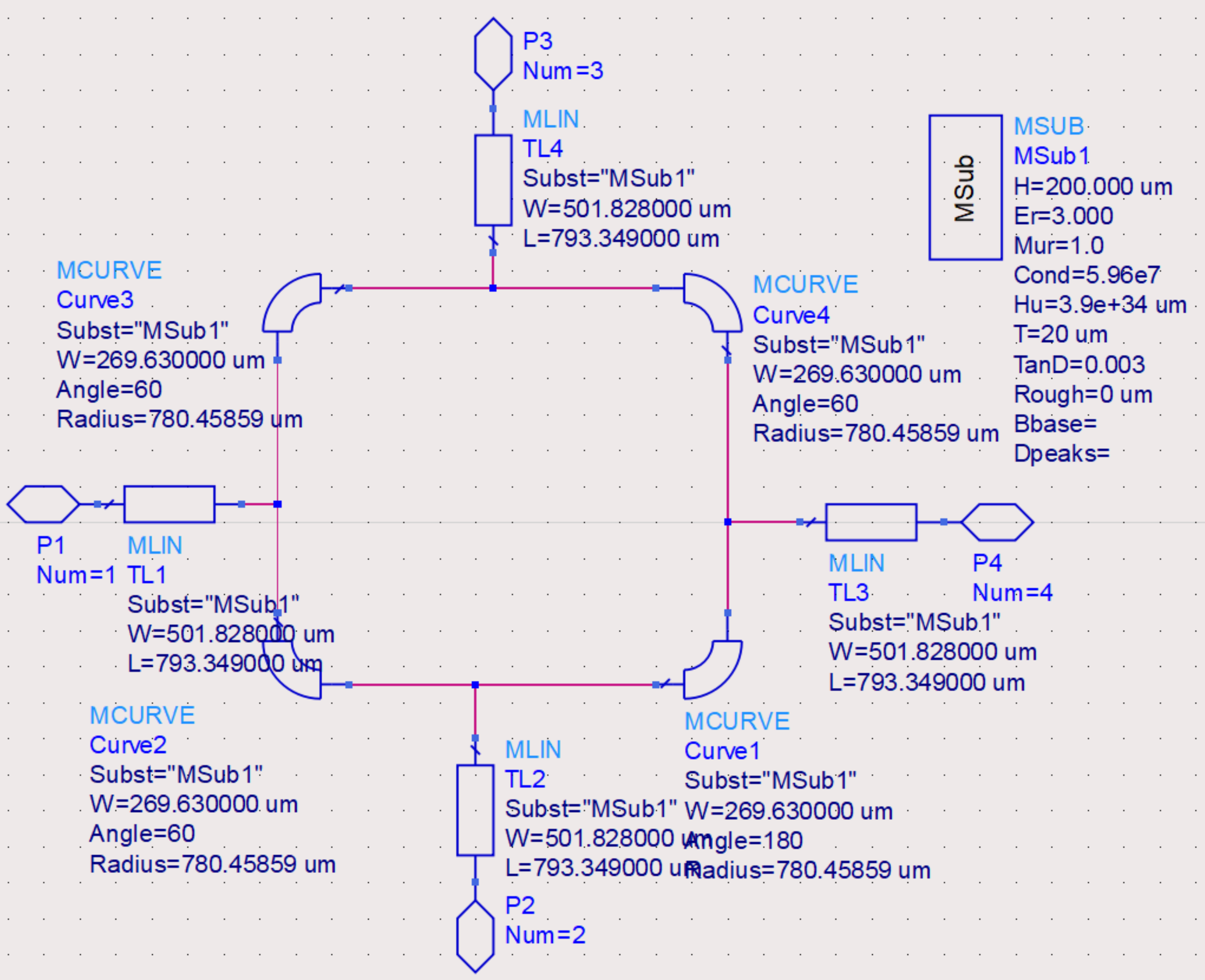
3- RAT RACE BALUN TO GET THE RADIUS OF THE CURVES

R = length / 2*pi   >> length calculated from the line calc
R = 4901.28 / 2*pi = 780.45859 um
Now we have the curves
We need to get the lines which have 50 ohm



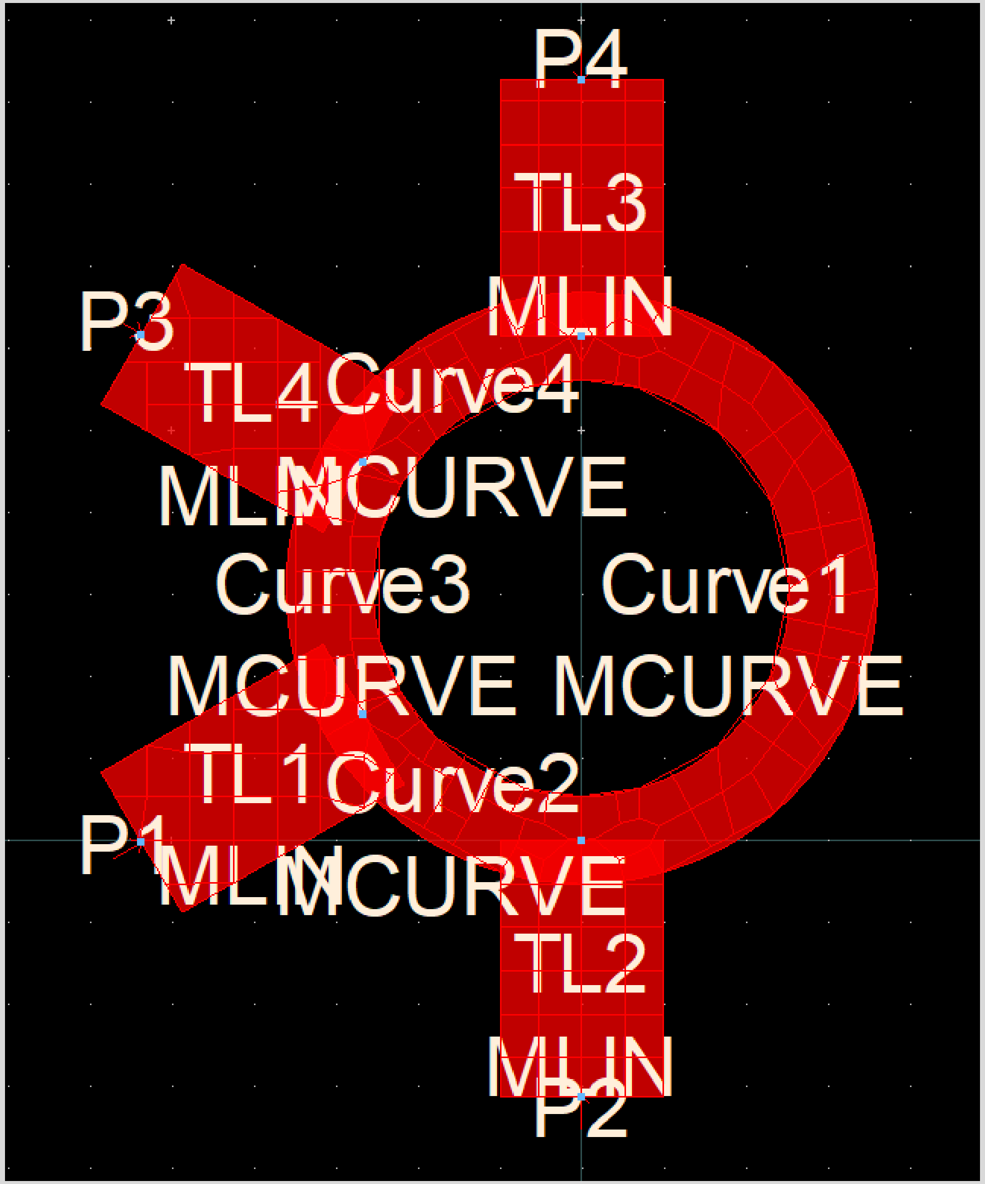
PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN SCHEMATIC



PART 3: **BALUN IMPLEMENTATION**

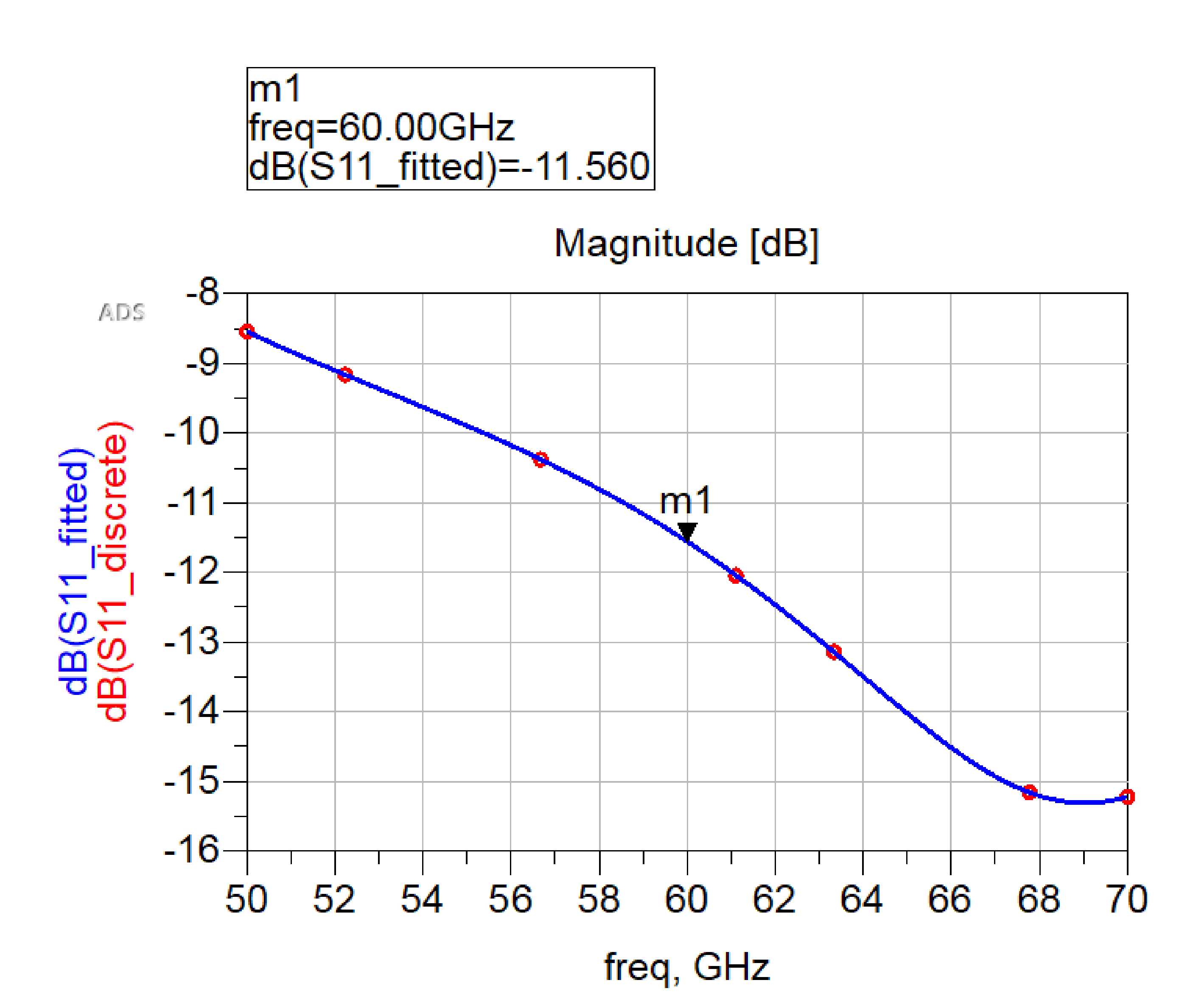
3- RAT RACE BALUN LAYOUT



PART 3: BALUN IMPLEMENTATION

3- RAT RACE BALUN LAYOUT

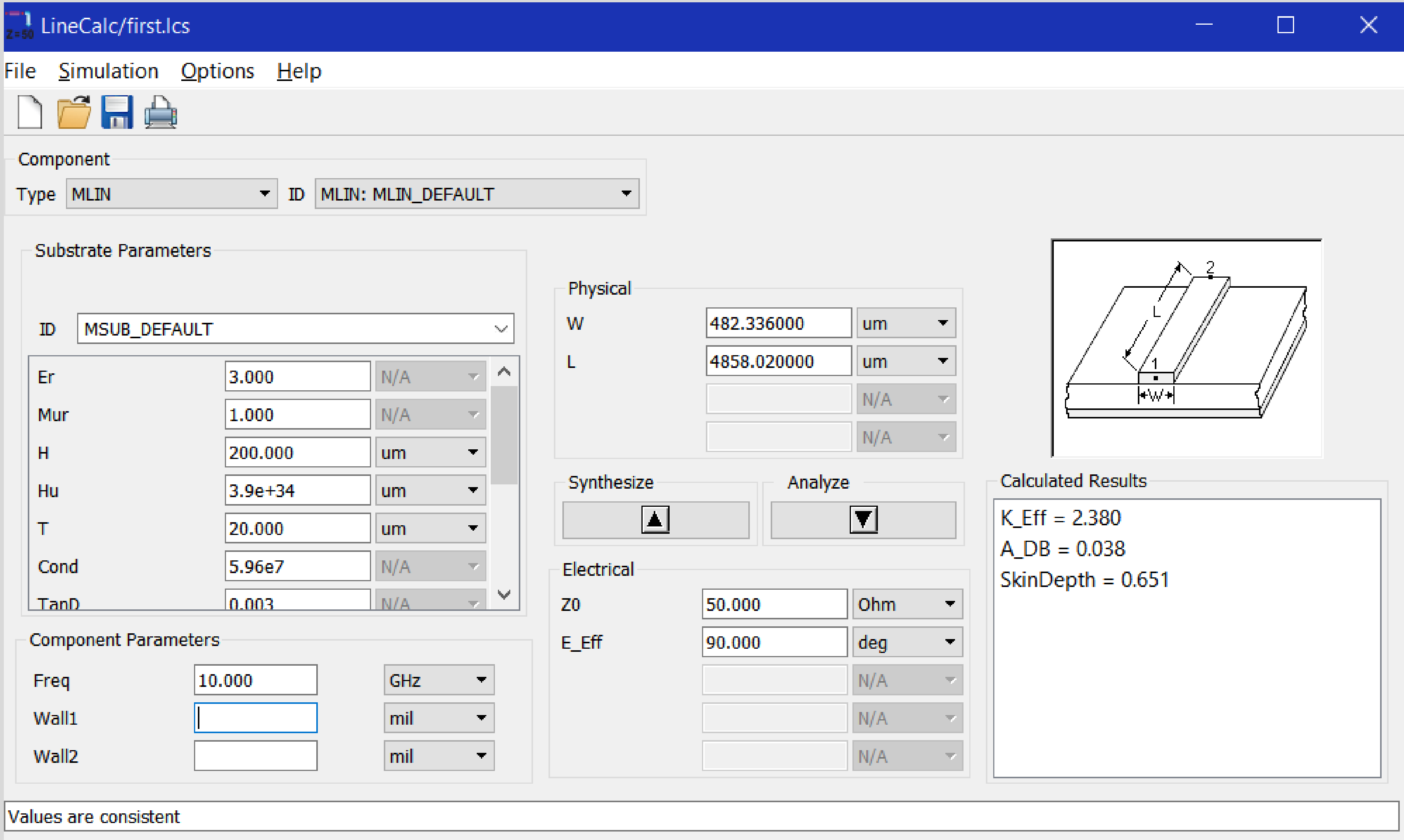
At very high frequency rat race gives bad losses values
So I redesign at 2.45 GHz



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

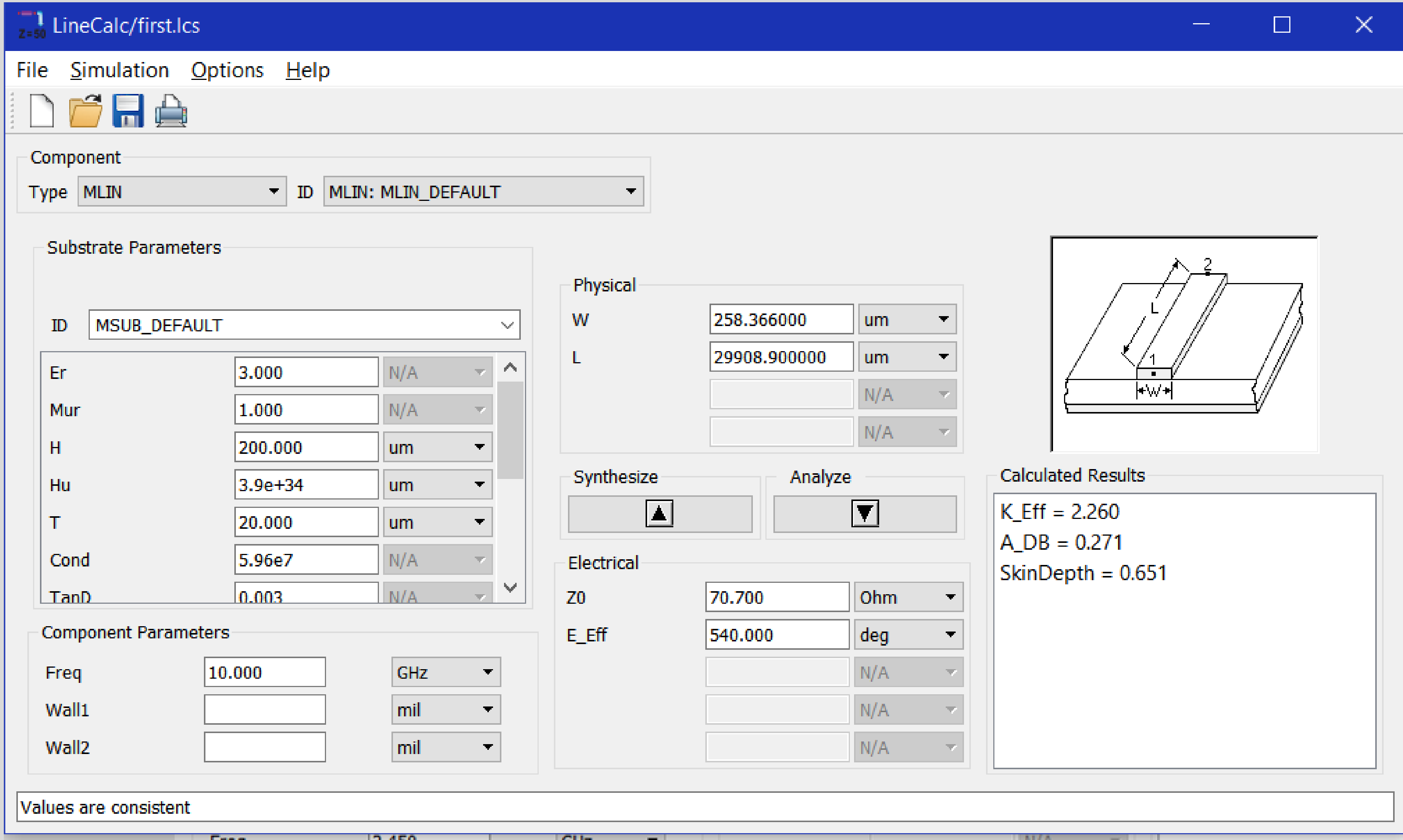


PART 3: **BALUN IMPLEMENTATION**

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

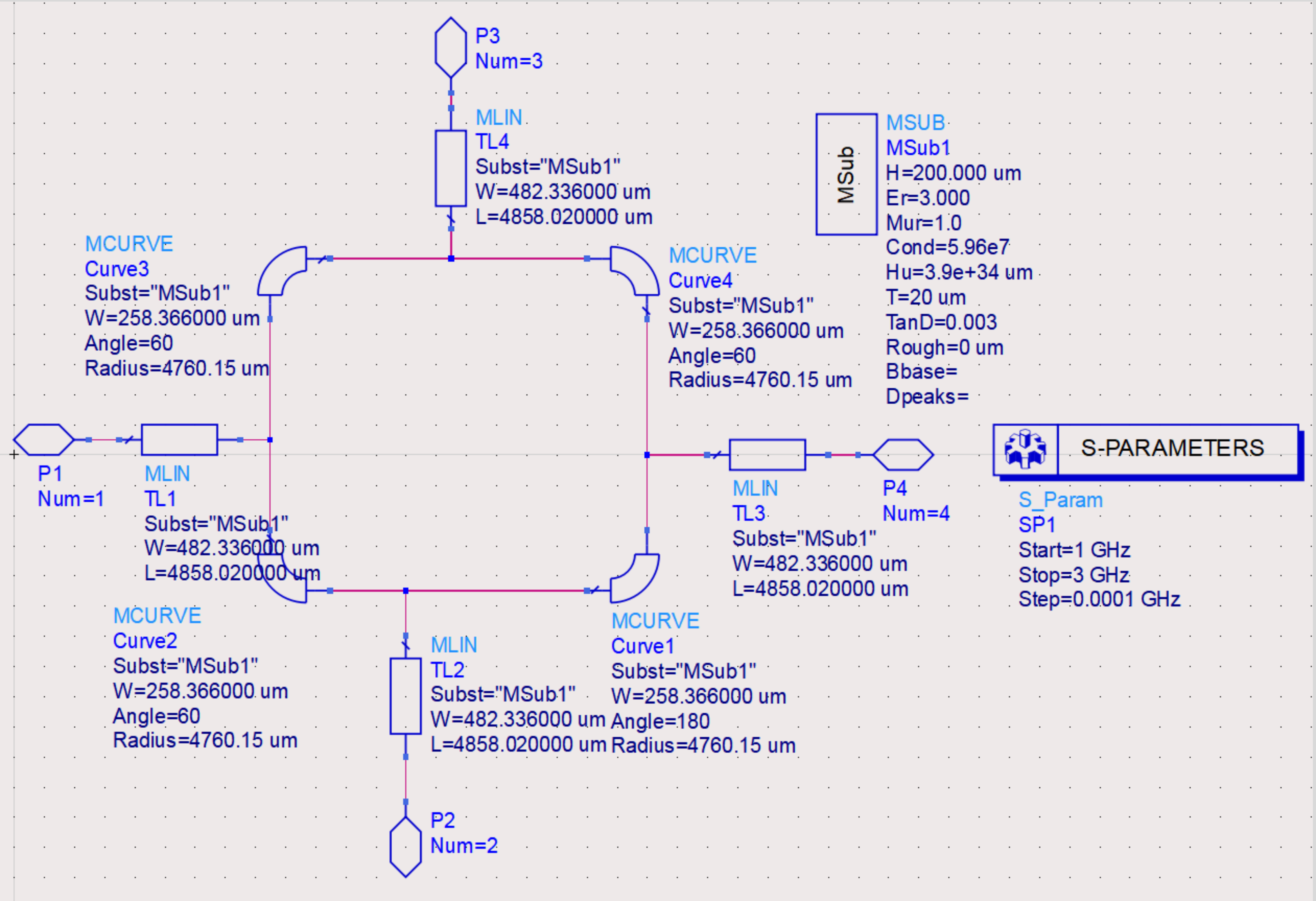
At very high frequency rat race gives bad losses values
So I redesign at 10 GHz

R = length / 2*pi >> length calculated from the line calc
R = 29908.9 / 2*pi = 4760.15 um
Now we have the curves
We need to get the lines which have 50 ohm



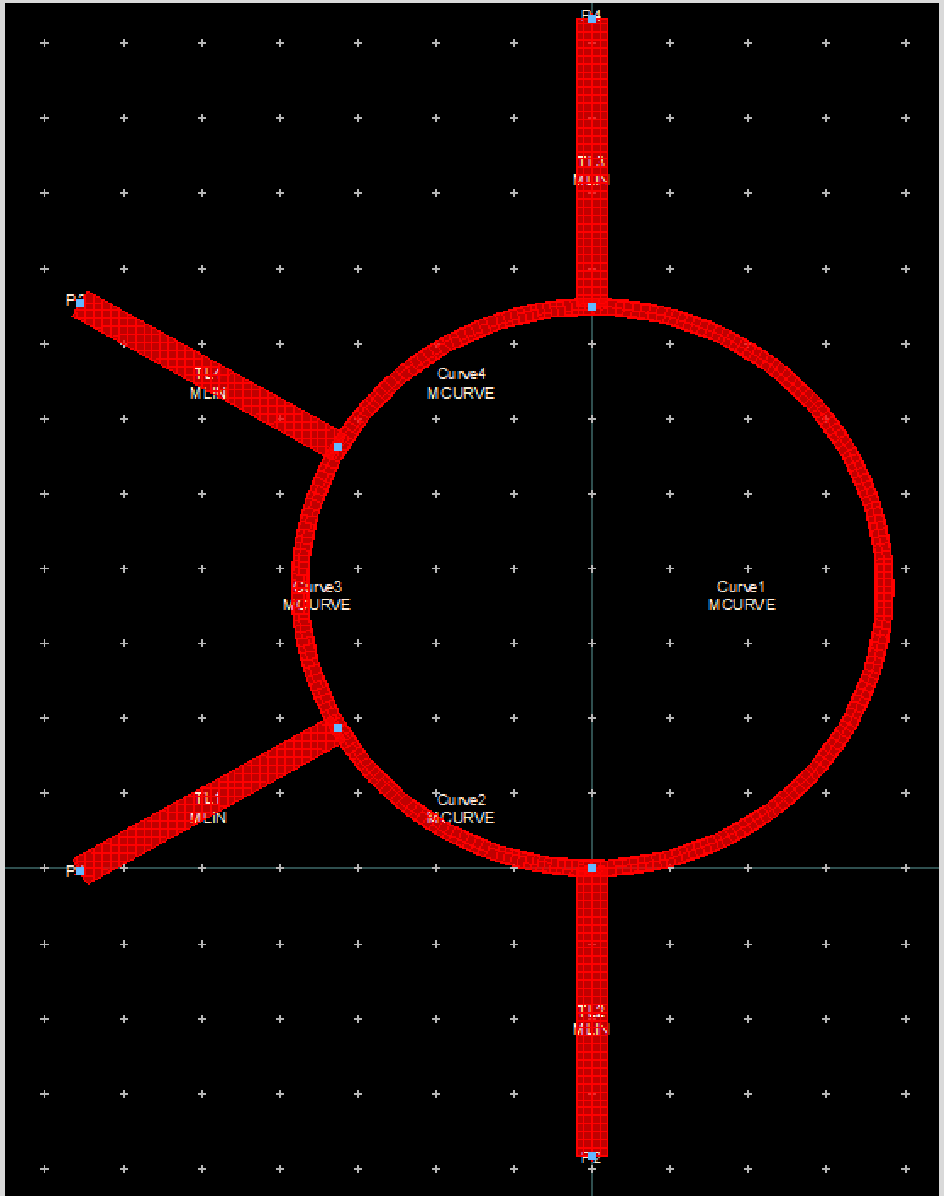
PART 3: **BALUN IMPLEMENTATION**

3- RAT RACE BALUN SCHEMATIC AT F0 = 10 GHZ



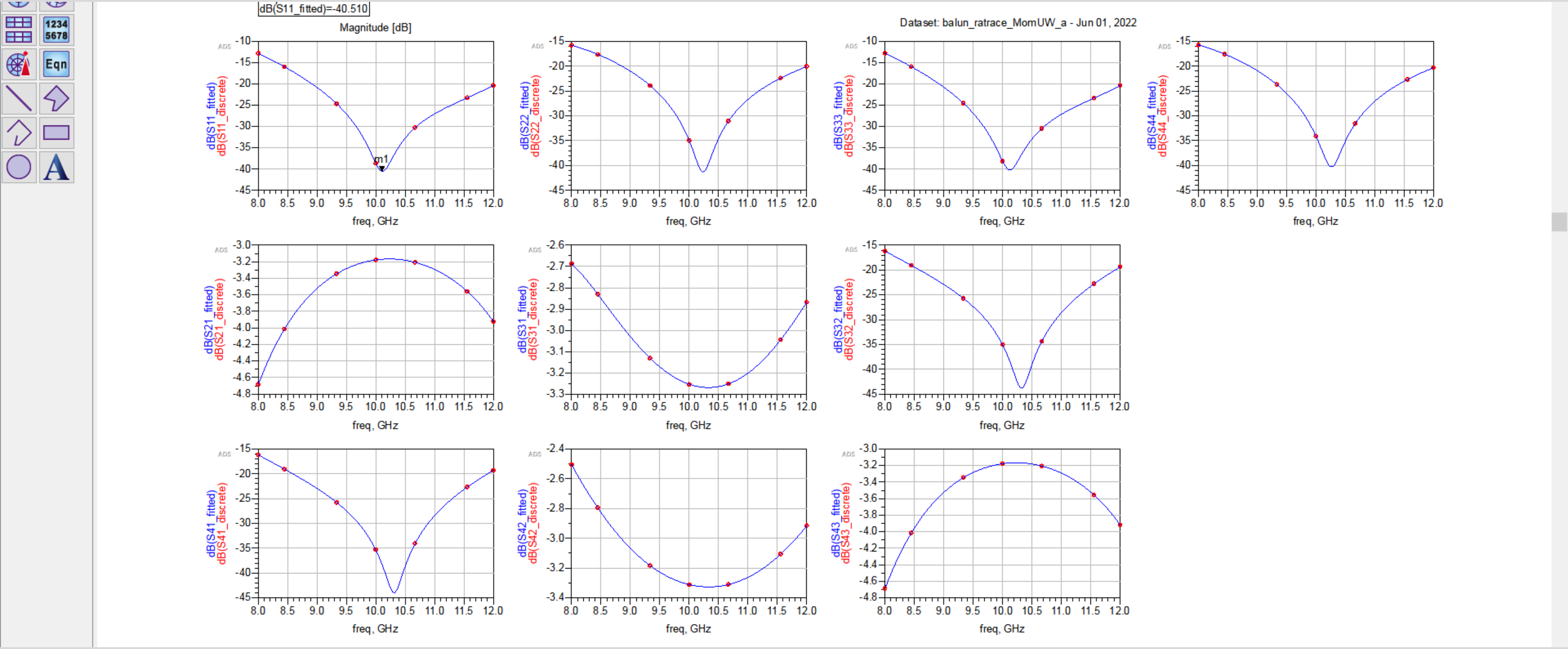
PART 3: **BALUN IMPLEMENTATION**

3- RAT RACE BALUN LAYOUT AT F0 = 10 GHZ



PART 3: **BALUN IMPLEMENTATION**

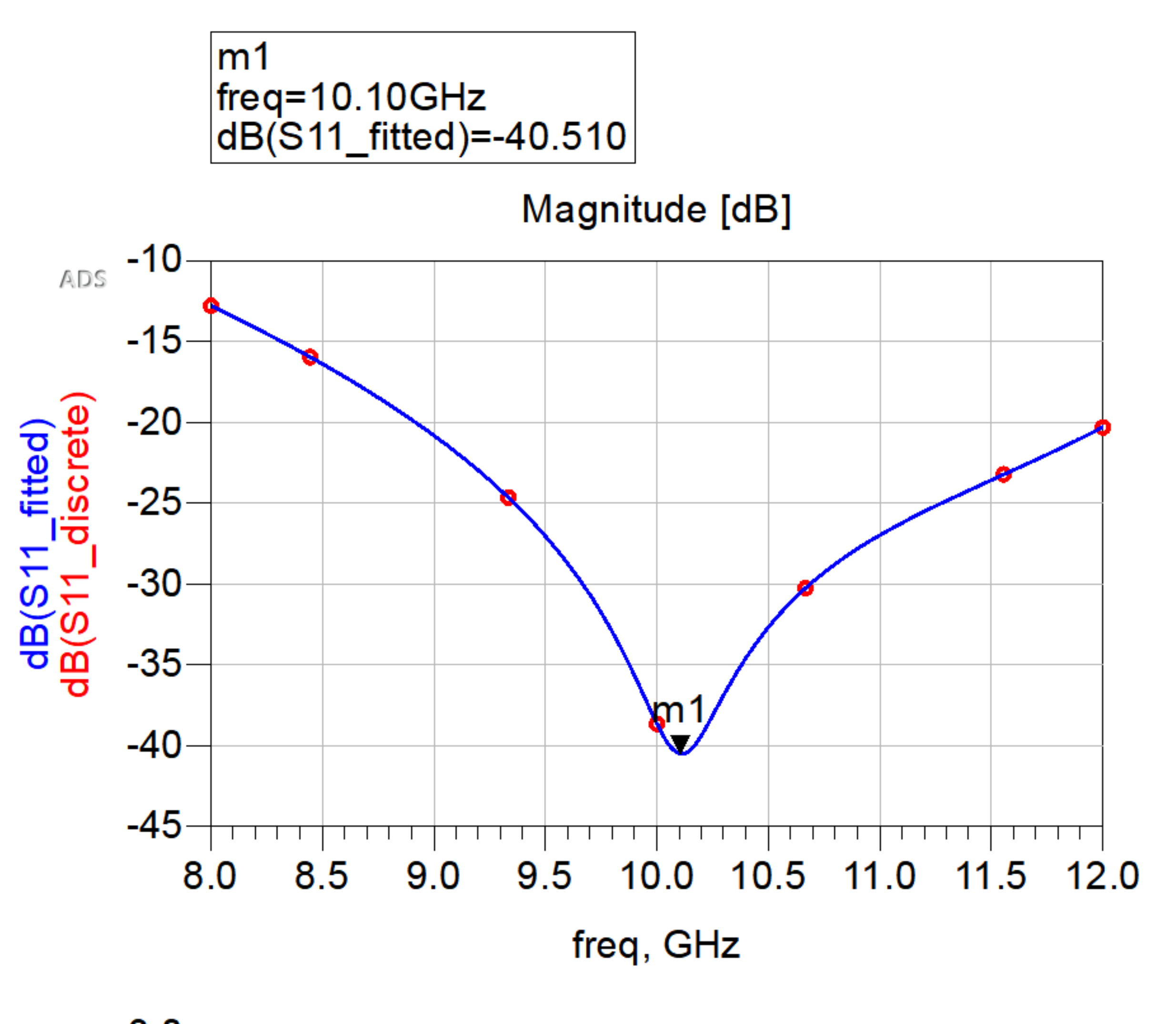
3- RAT RACE BALUN LAYOUT S PARAMETERS AT F0 = 10GHZ



PART 3: **BALUN IMPLEMENTATION**

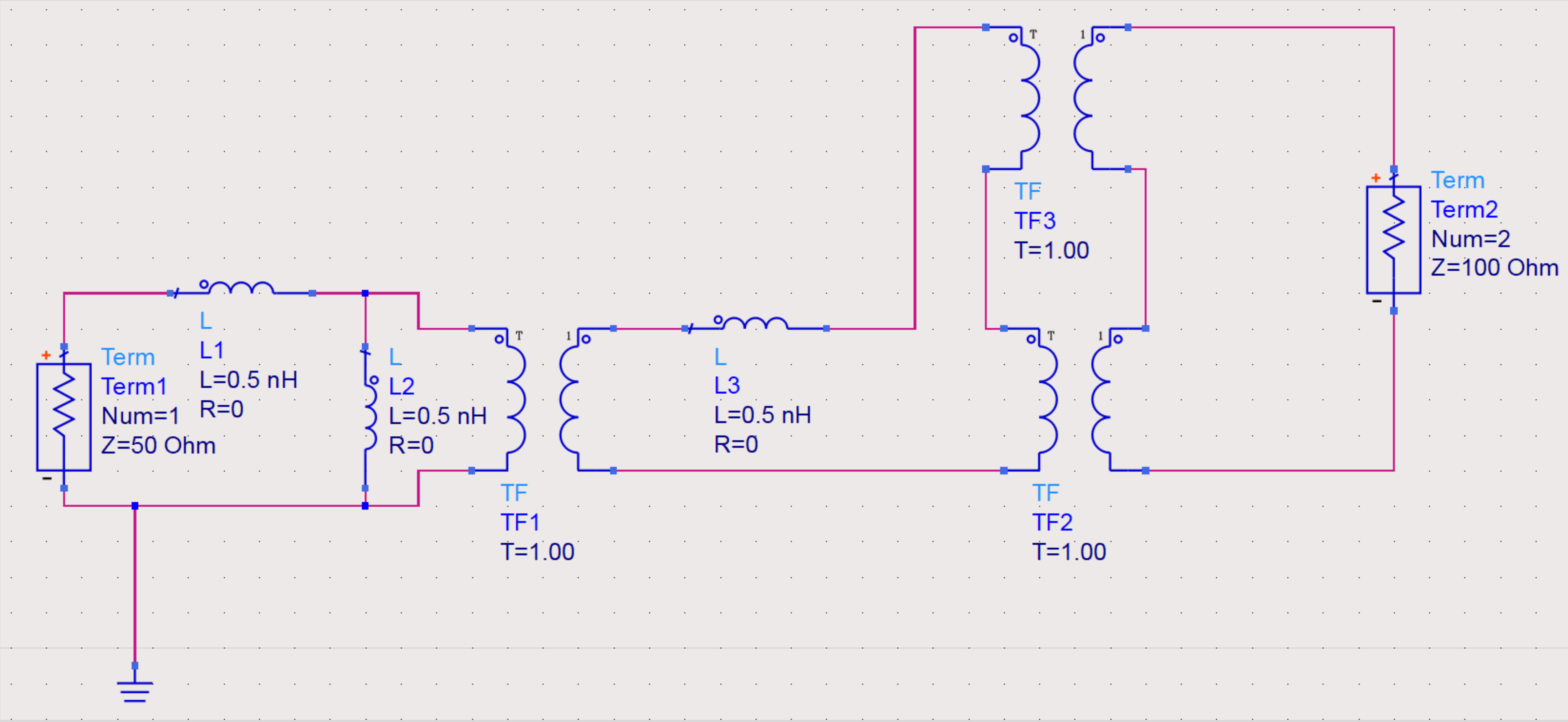
3- RAT RACE BALUN LAYOUT S11

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



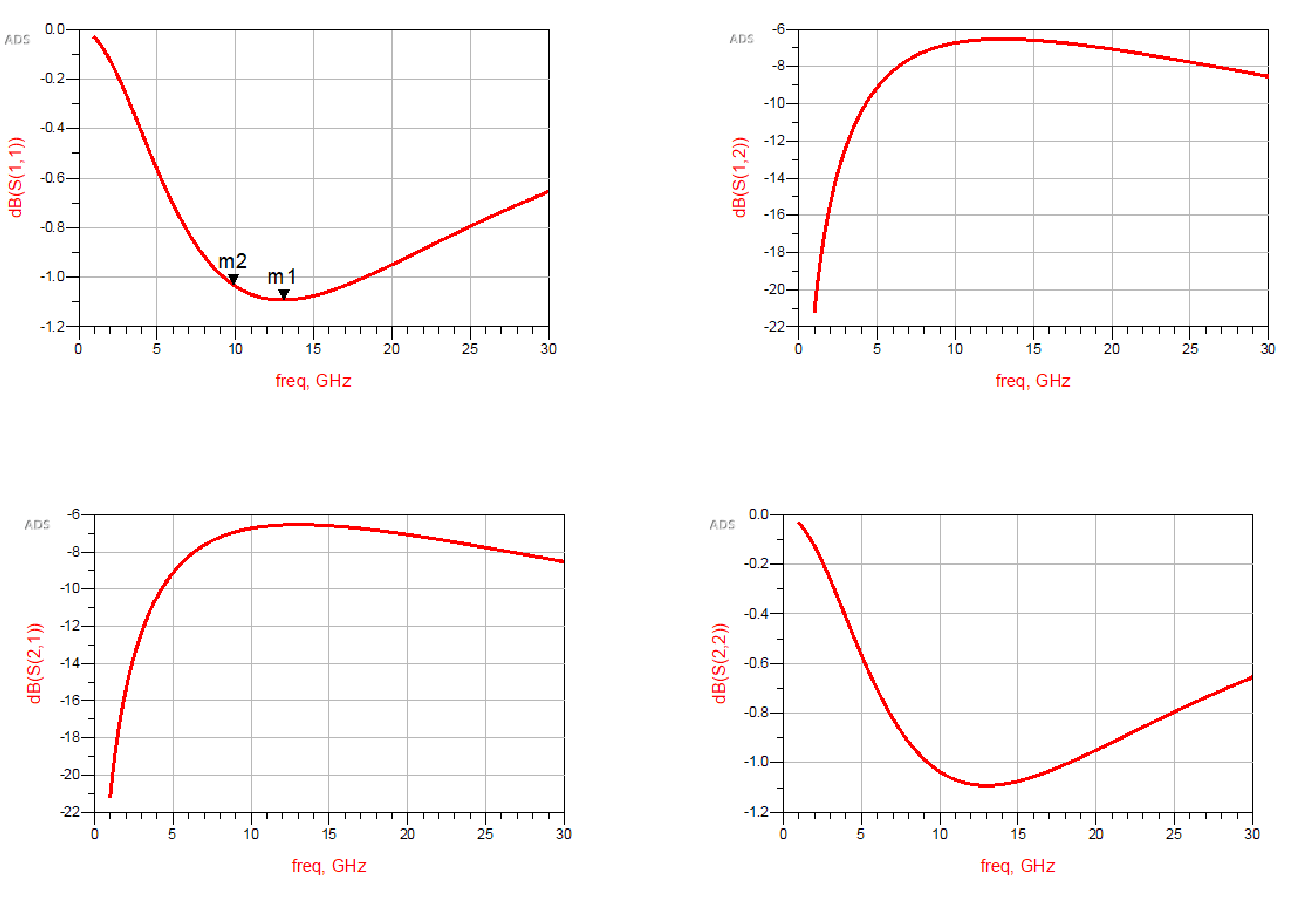
PART 3: BALUN IMPLEMENTATION

4- TRANSFORMER BASED BALUN



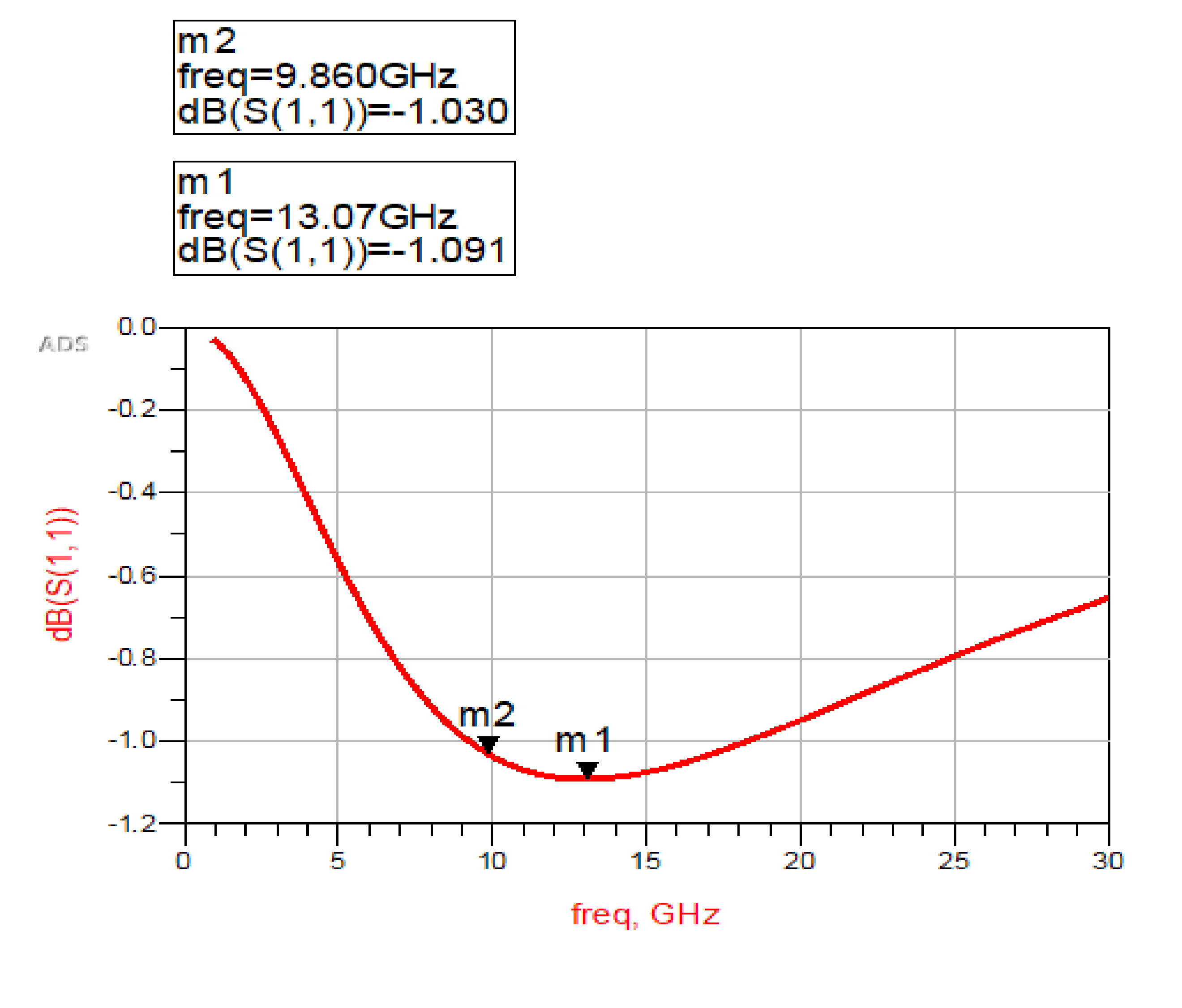
PART 3: **BALUN IMPLEMENTATION**

4- TRANSFORMER BASED BALUN S PARAMETERS



PART 3: **BALUN IMPLEMENTATION**

4- TRANSFORMER BASED BALUN S PARAMETERS S11



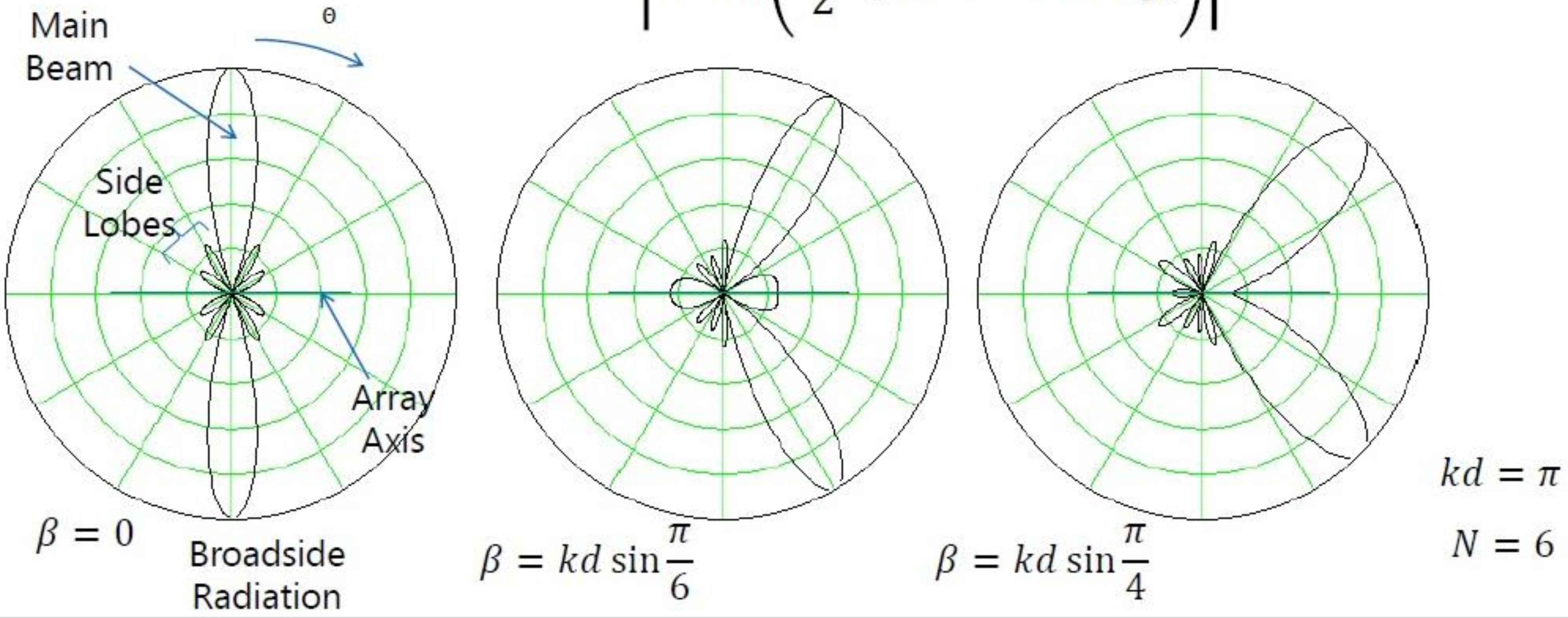
Assignment 3b
Beam-Squint in Phased Arrays

DERIVATION

Measured from the normal

Normalized

$$|SF_n(\Theta)| = \left| \frac{\sin\left(N\frac{kd}{2}(\sin\Theta - \sin\Theta_0)\right)}{N\sin\left(\frac{kd}{2}(\sin\Theta - \sin\Theta_0)\right)} \right| \qquad \beta = kd\sin\Theta_0$$



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

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

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

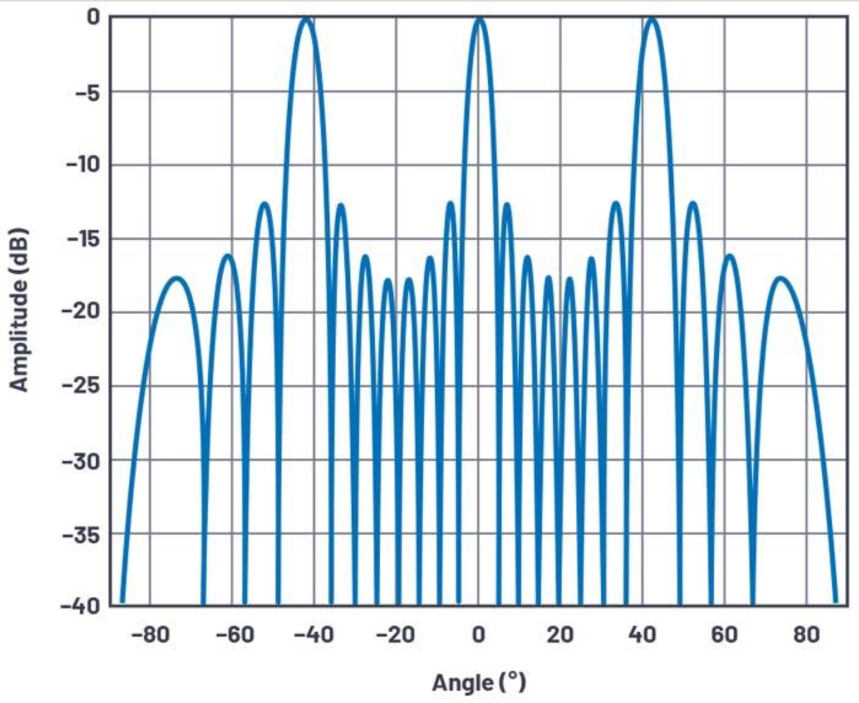
$$\theta = \arcsin\left(\frac{\Delta\emptyset}{2\pi} * \frac{\lambda}{d}\right)$$

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

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

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

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



DERIVATION

From the SF equation

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

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

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

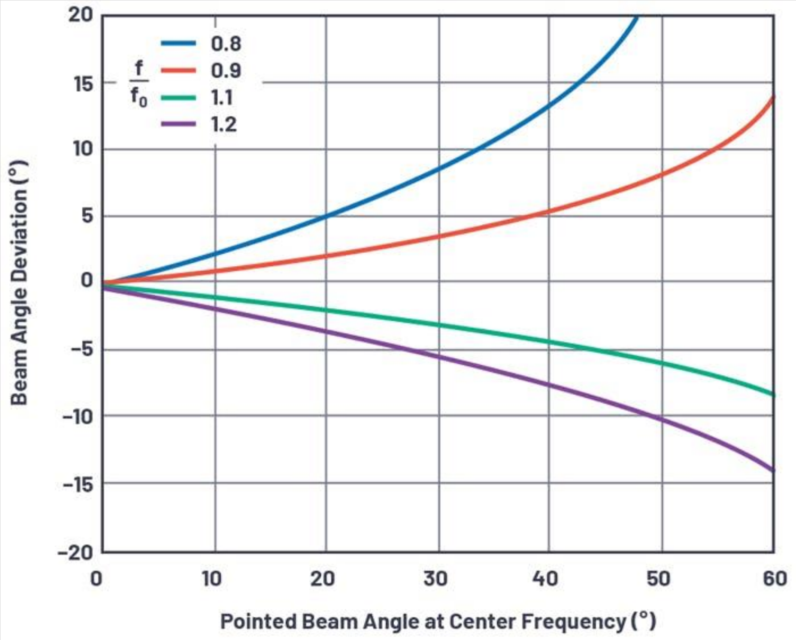
To avoid grating lobes, our goal is to obtain a single real solution

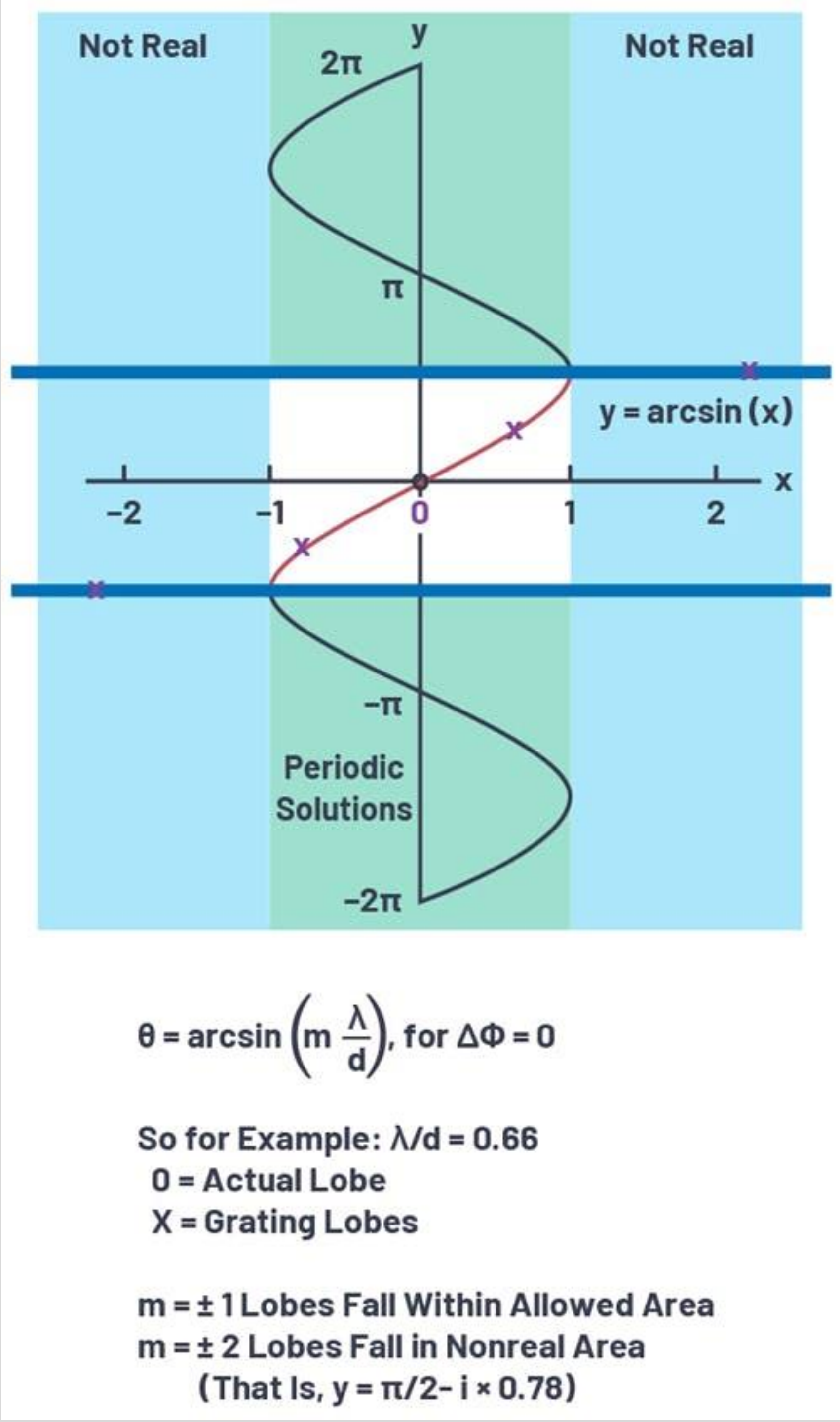
$\left|\frac{m*2\pi+\Delta\emptyset}{2\pi} * \frac{\lambda}{d}\right| > 1$ for all m >= 1

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

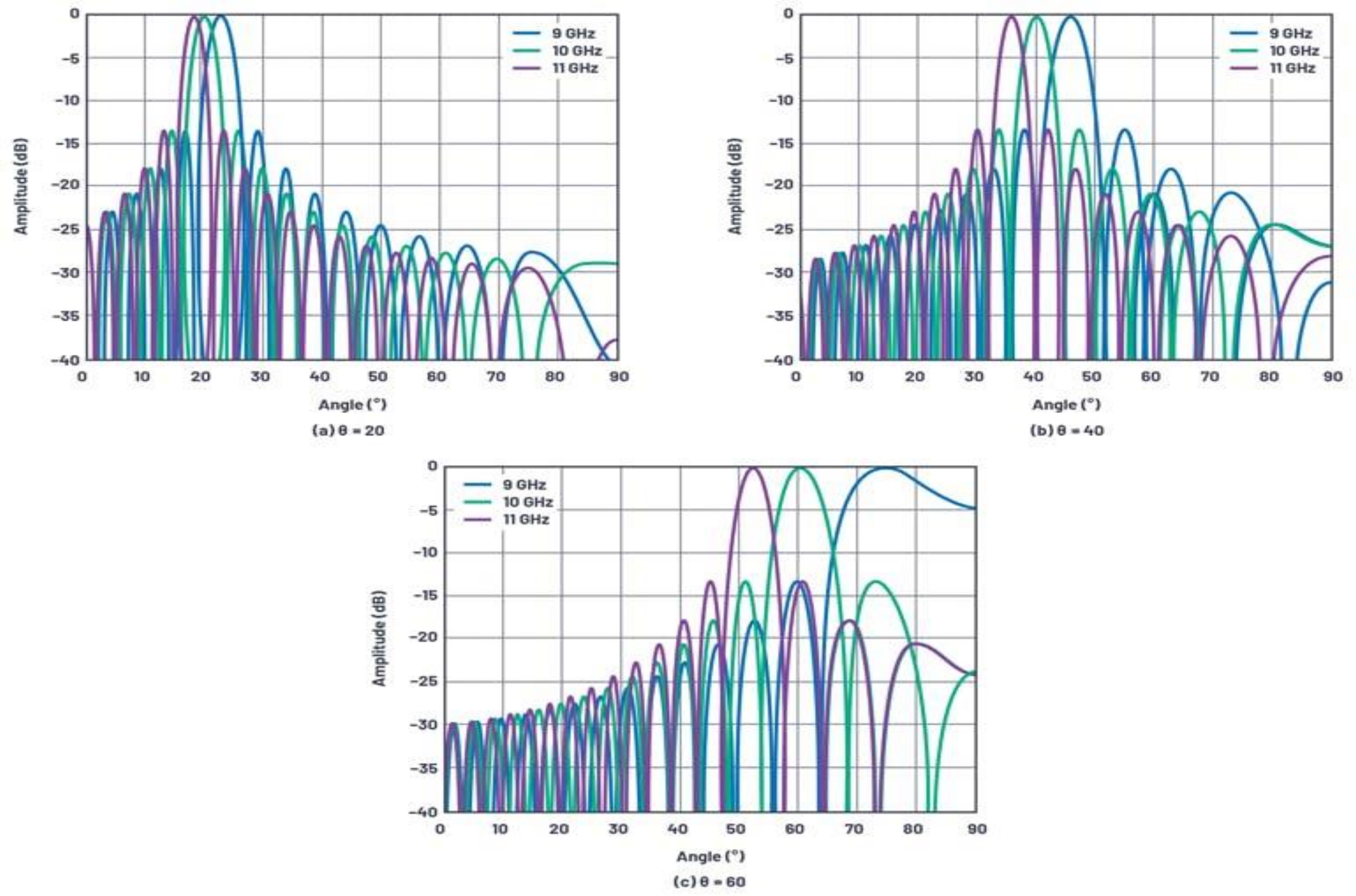
$$\Delta\theta = \arcsin\left(\frac{f_0}{f}\sin(\theta_0)\right) - \theta_0$$

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



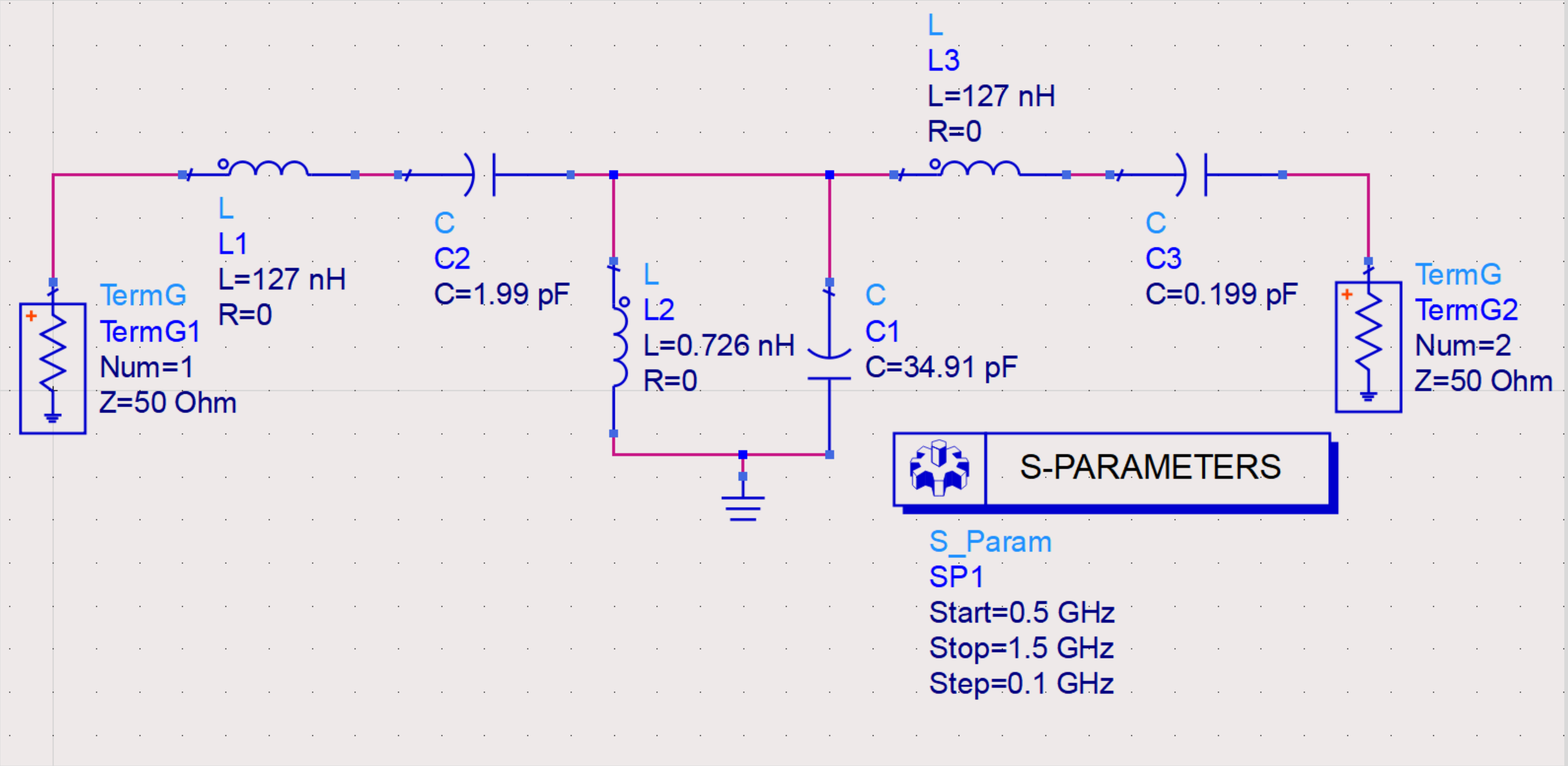


PLOT

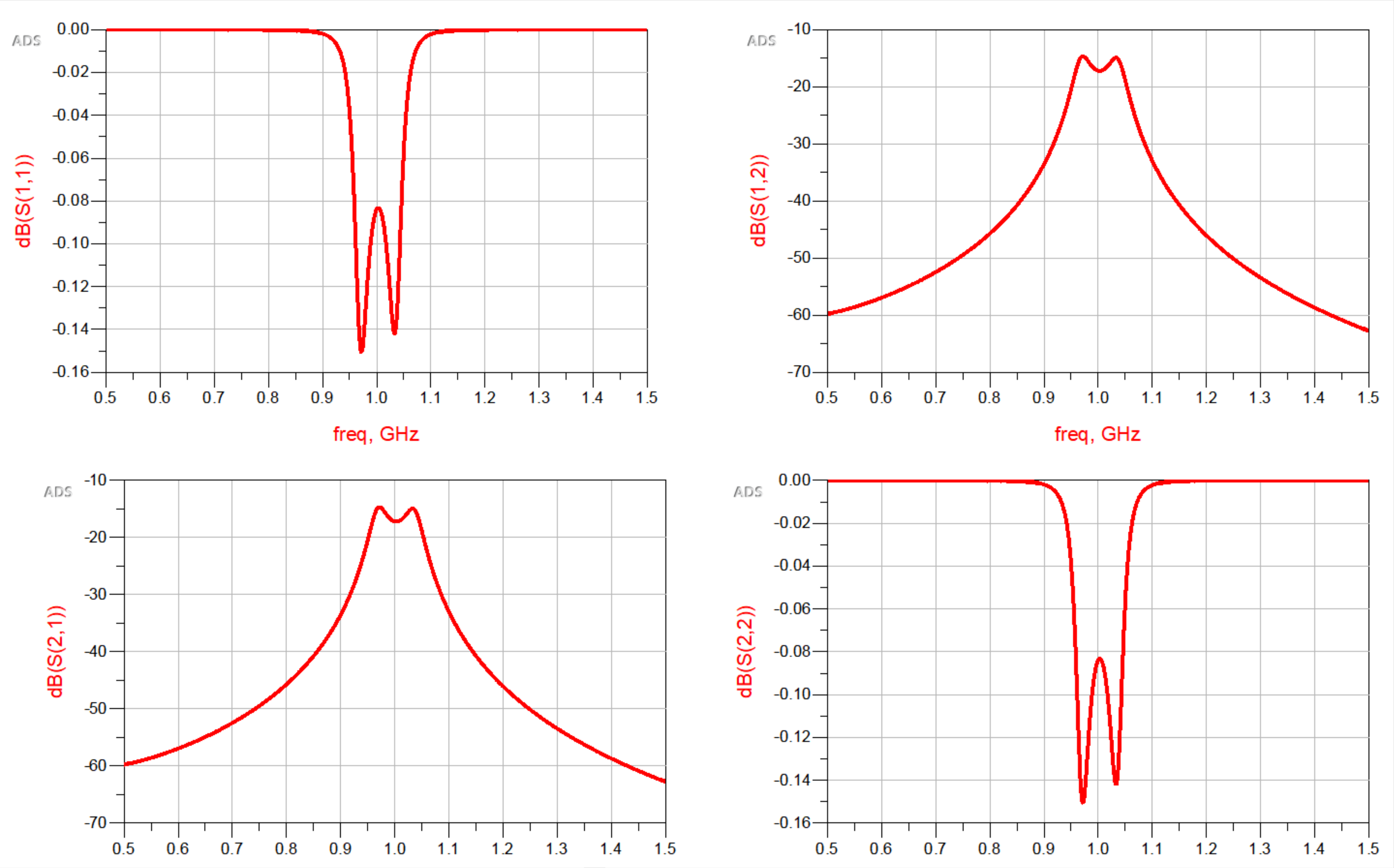


Assignment 4a
The Insertion Loss Method

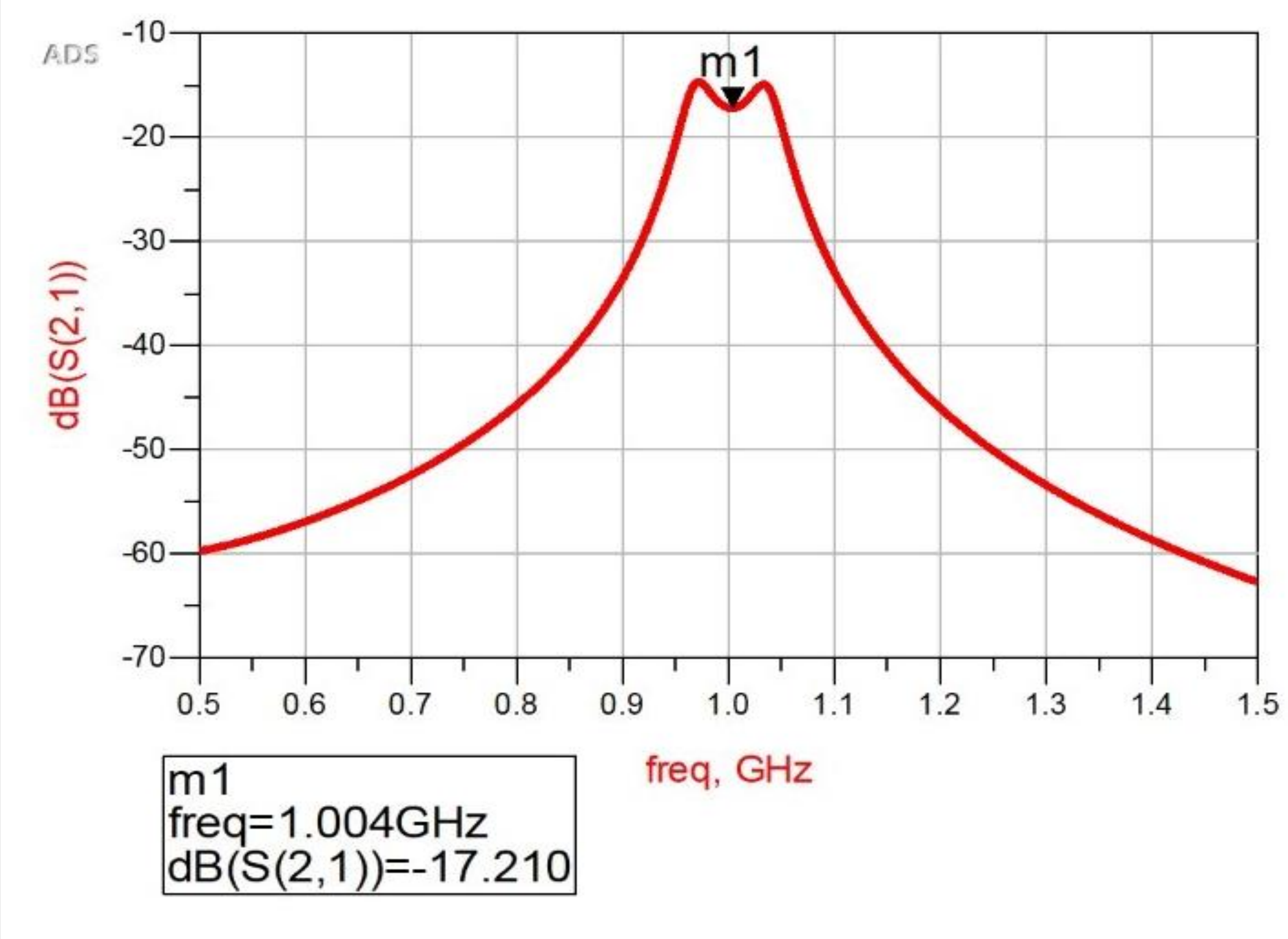
SCHEMATIC DESIGN



S PARAMETERS

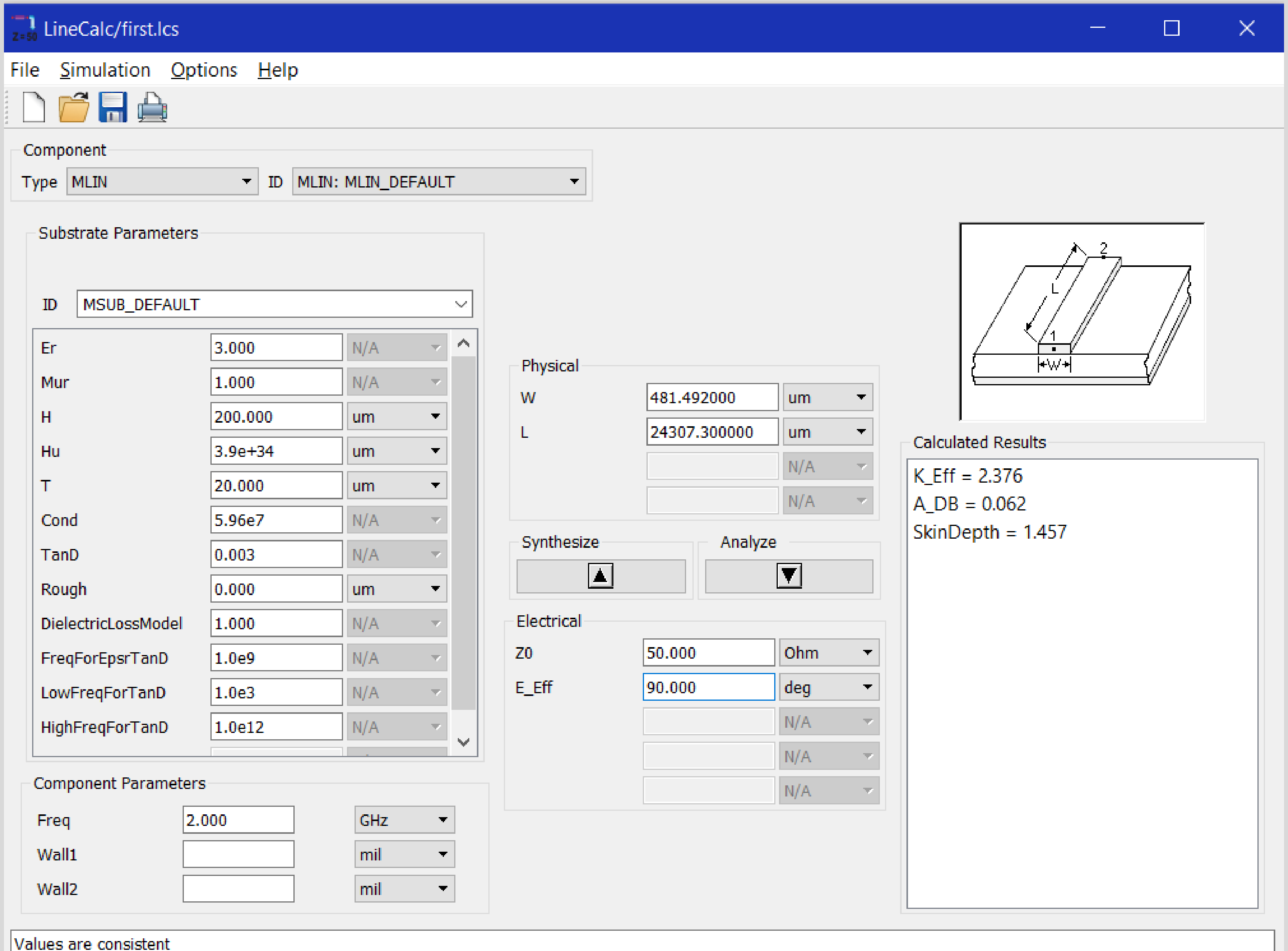


ATTENUATION S21

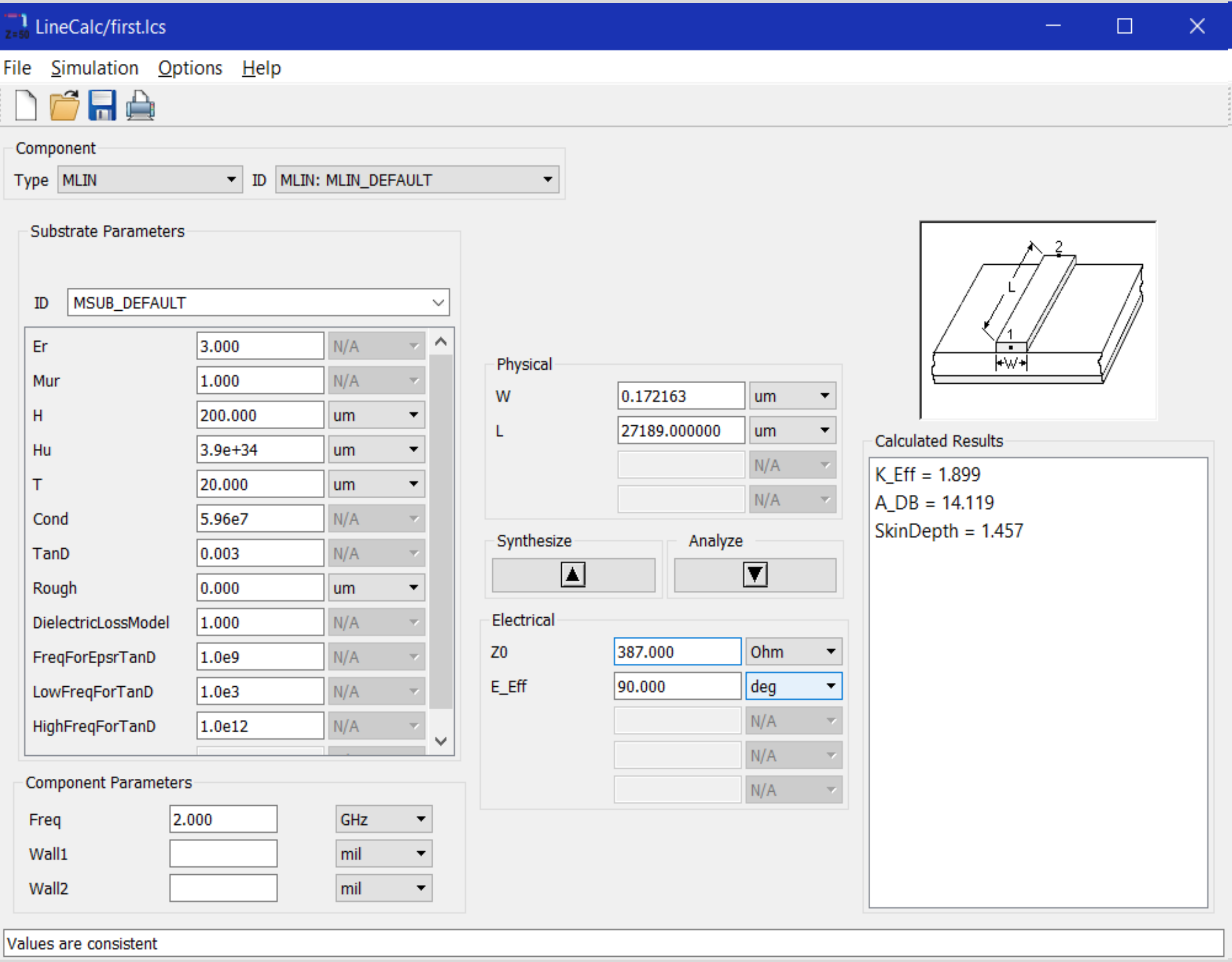


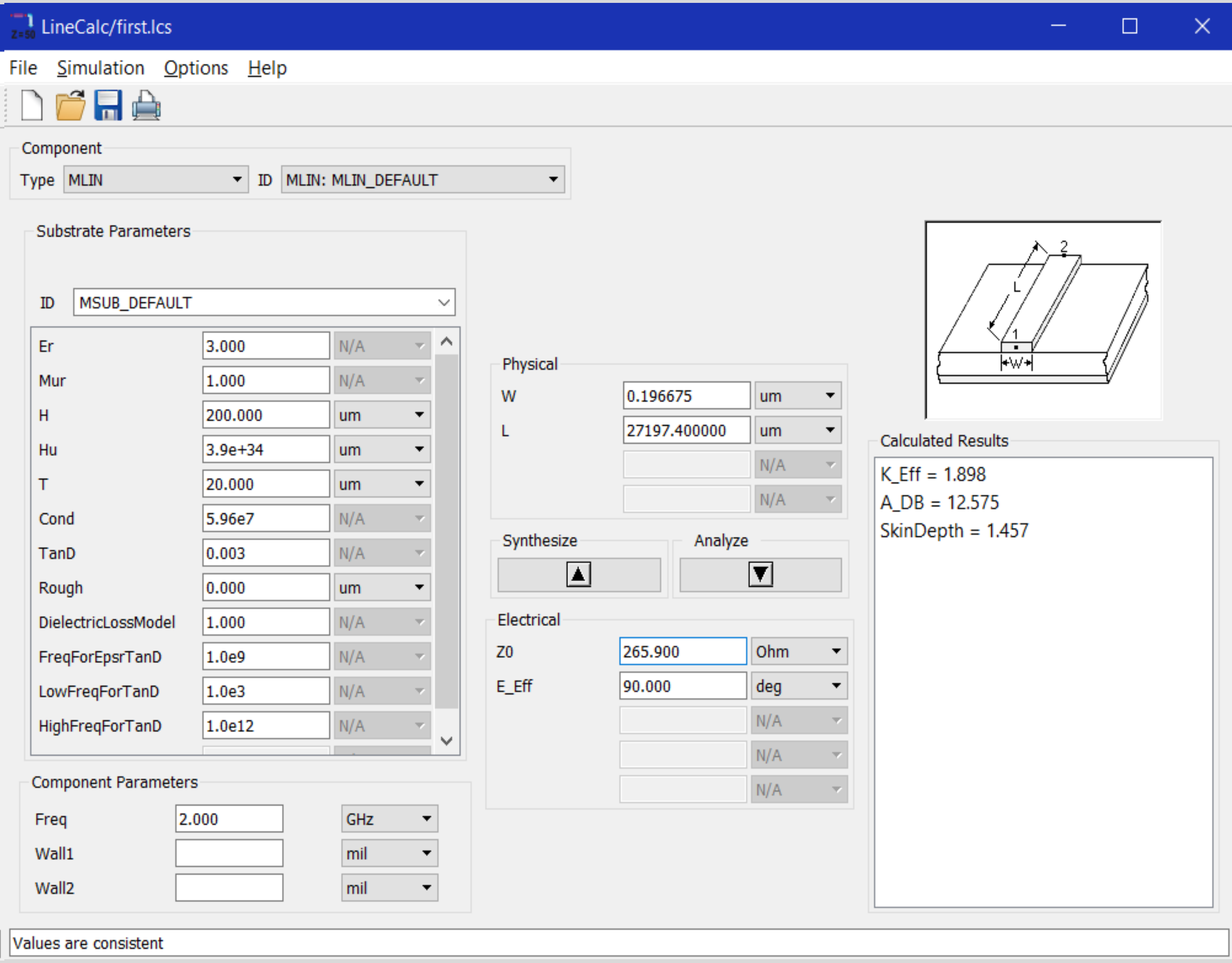
Assignment 4b
Coupled-Resonator Filters

LINE CALC Z0=50 OHM
EXAMPLE 1 BANDSTOP FILTER

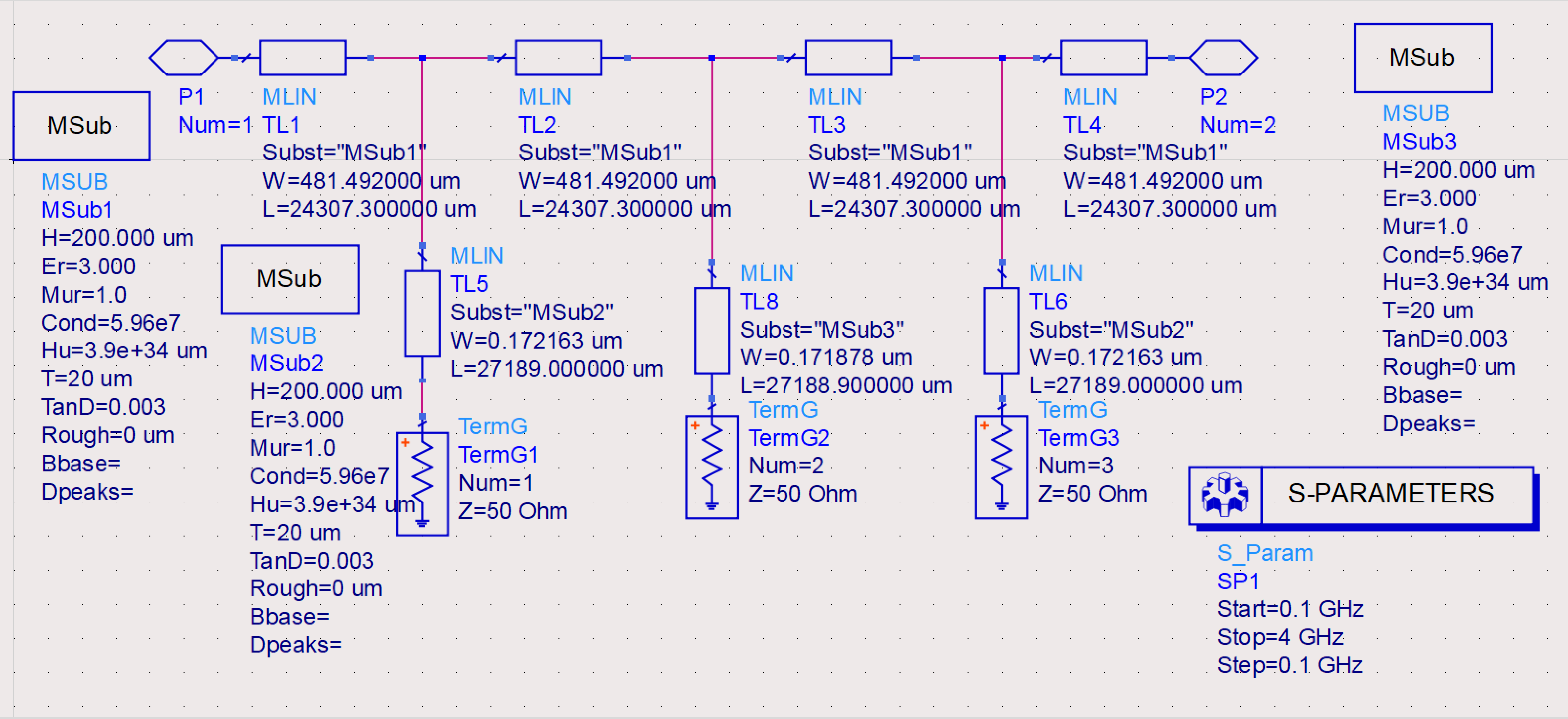


LINE CALC Z0 = 265.9 AND 387

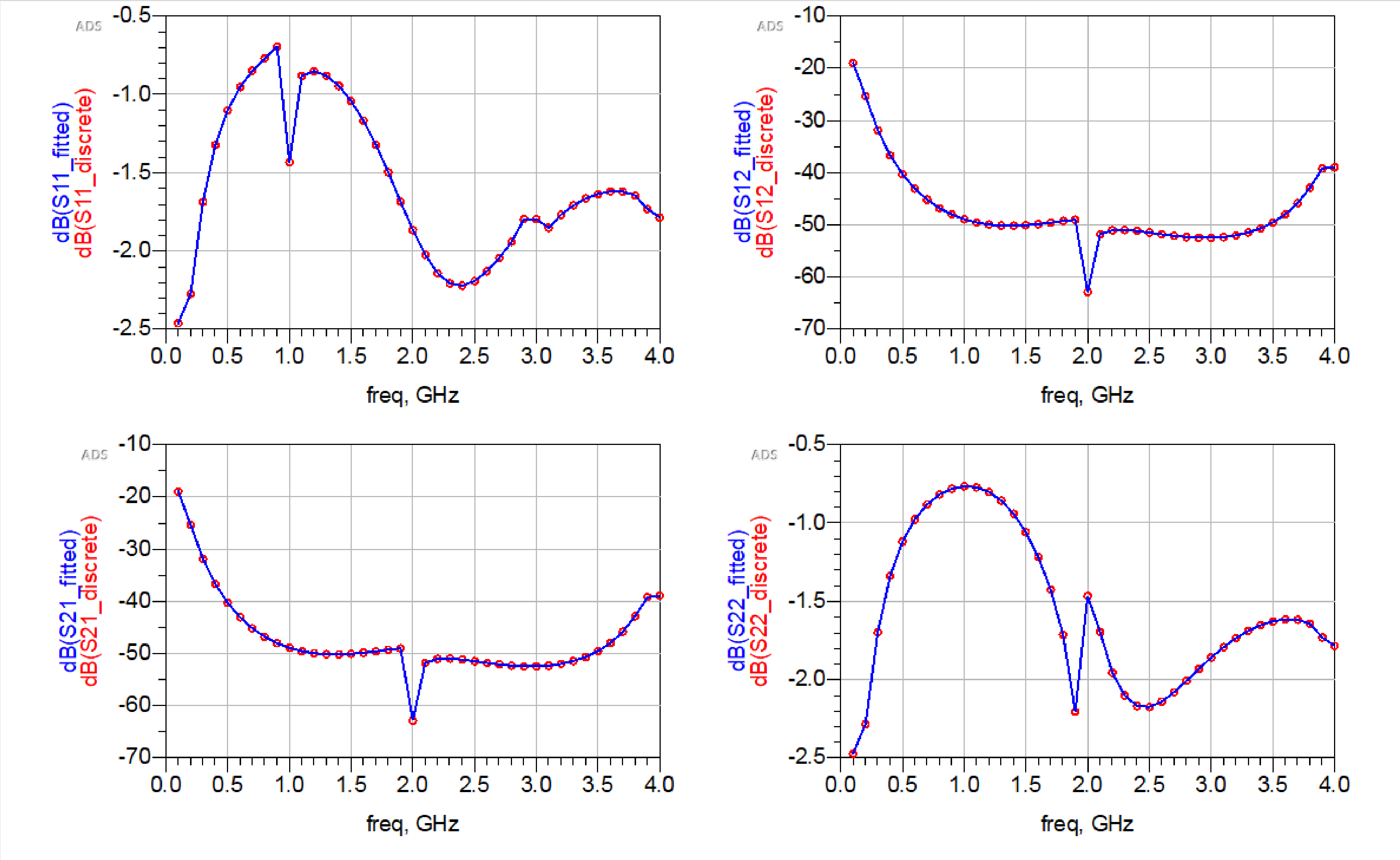




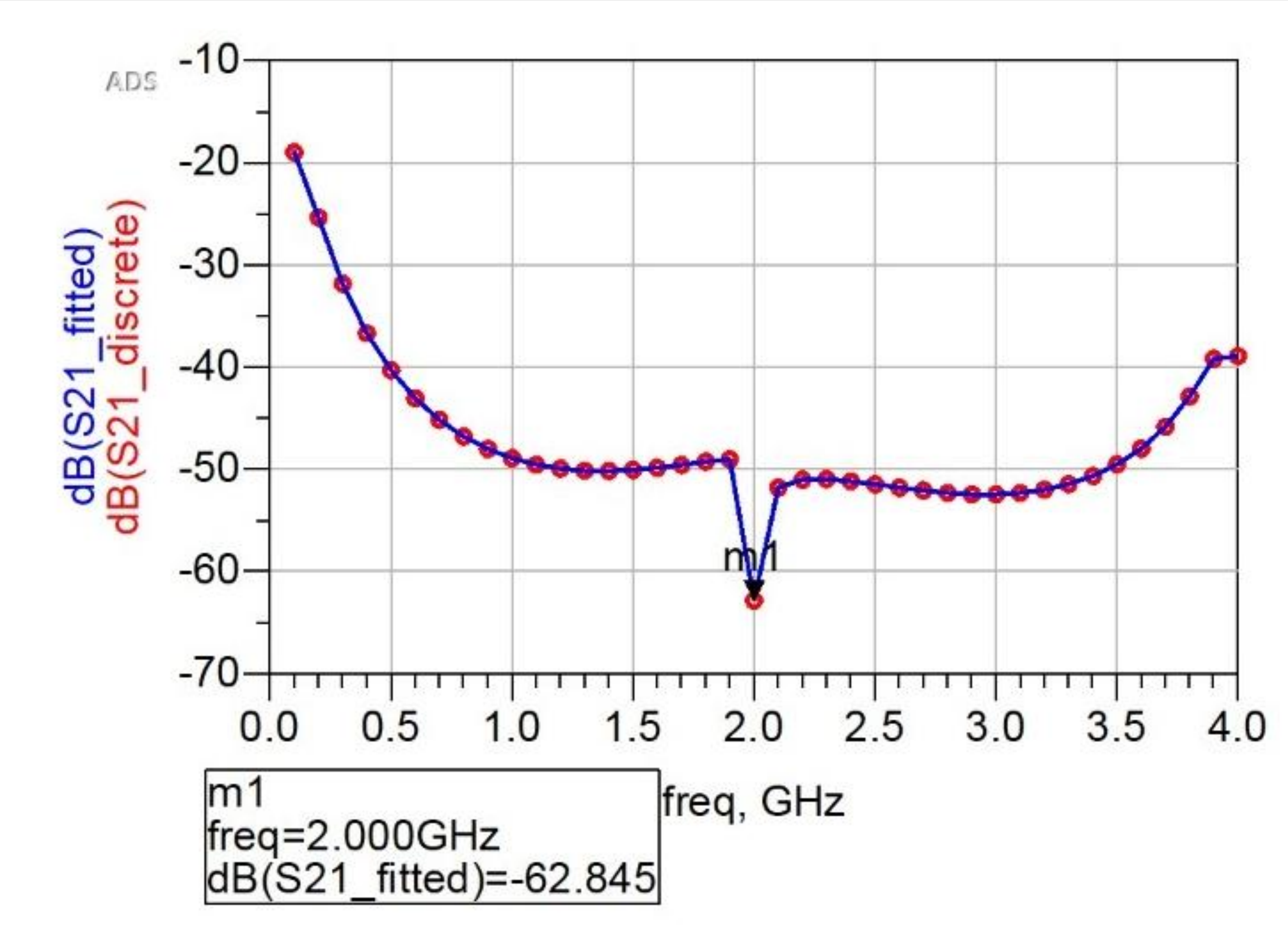
SCHEMATIC DESIGN



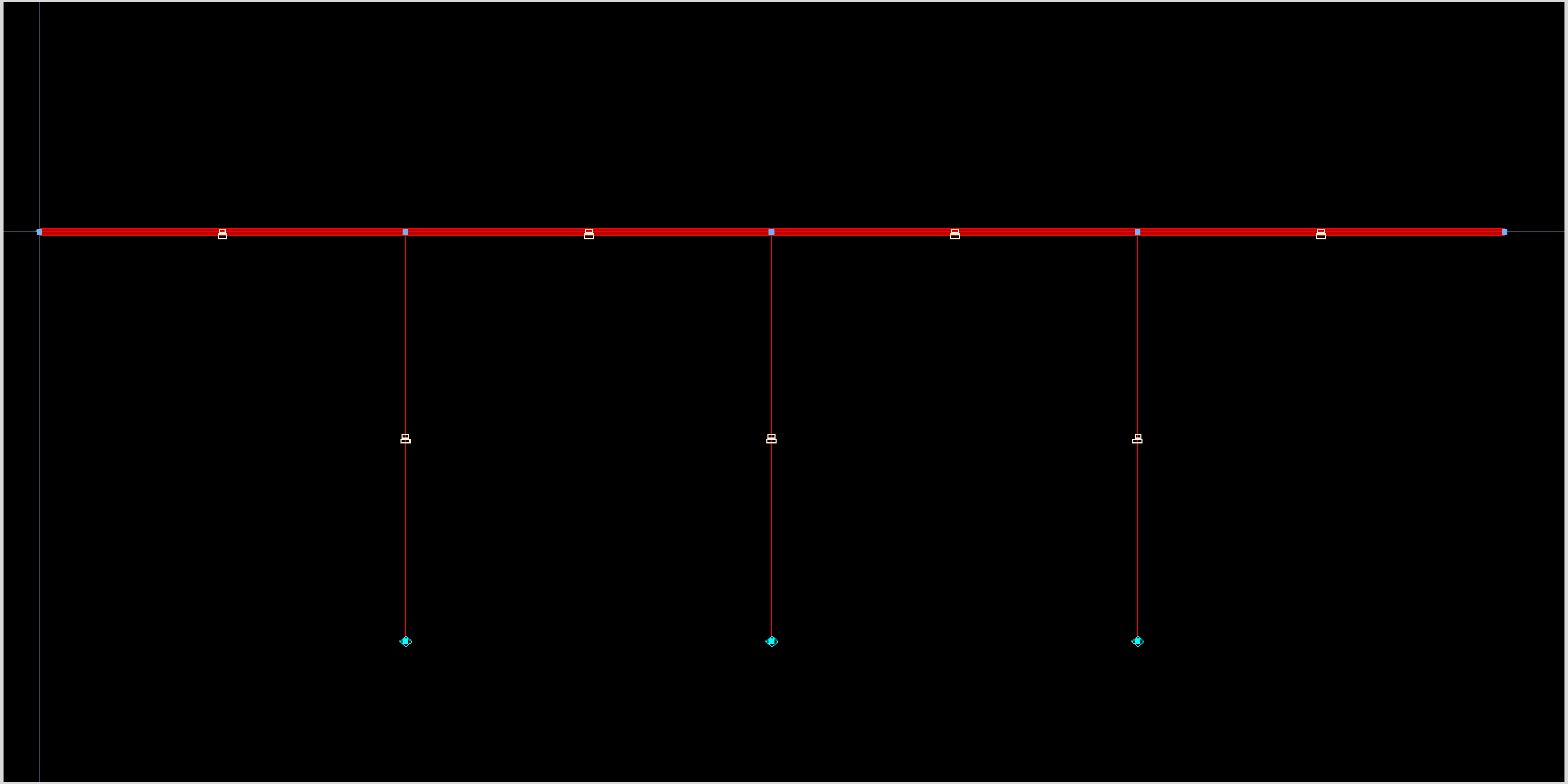
S PARAMETERS FROM SCHEMATIC



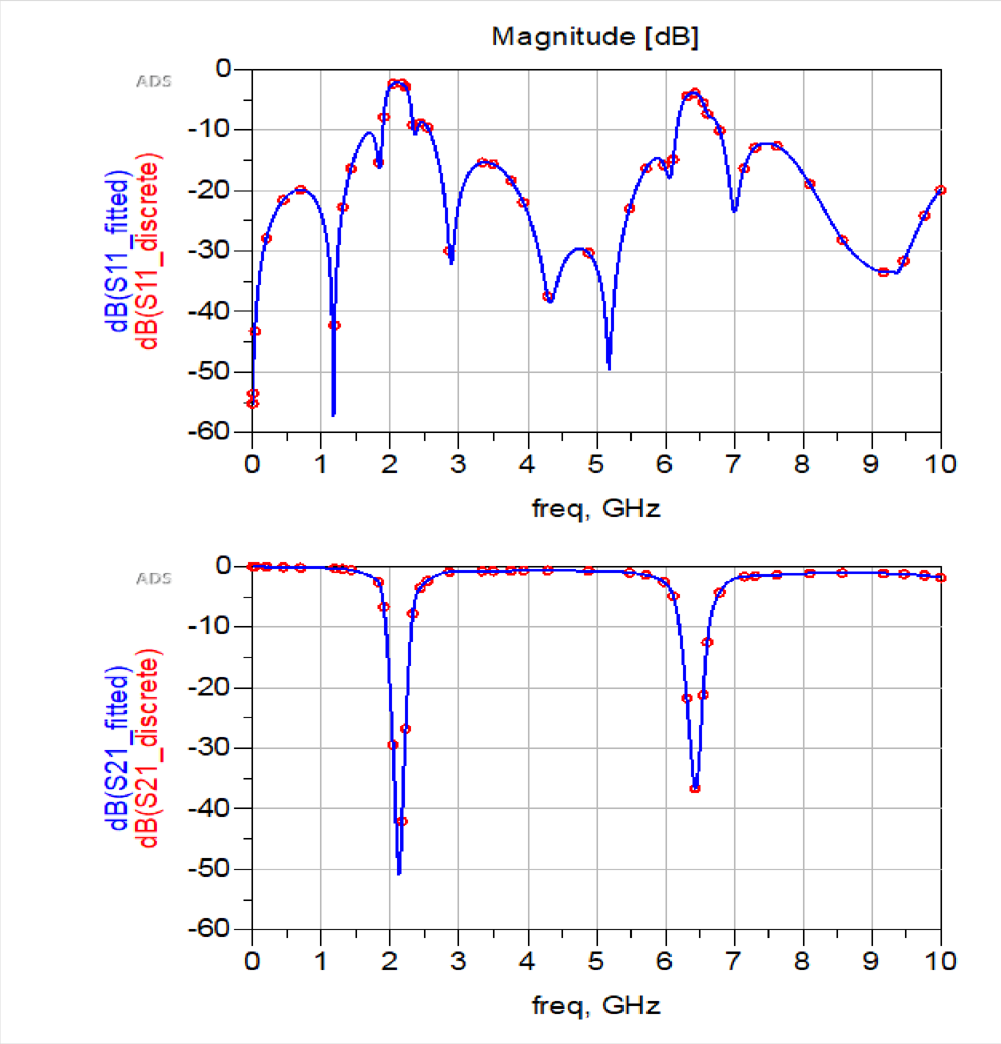
ATTENUATION FROM SCHEMATIC S21

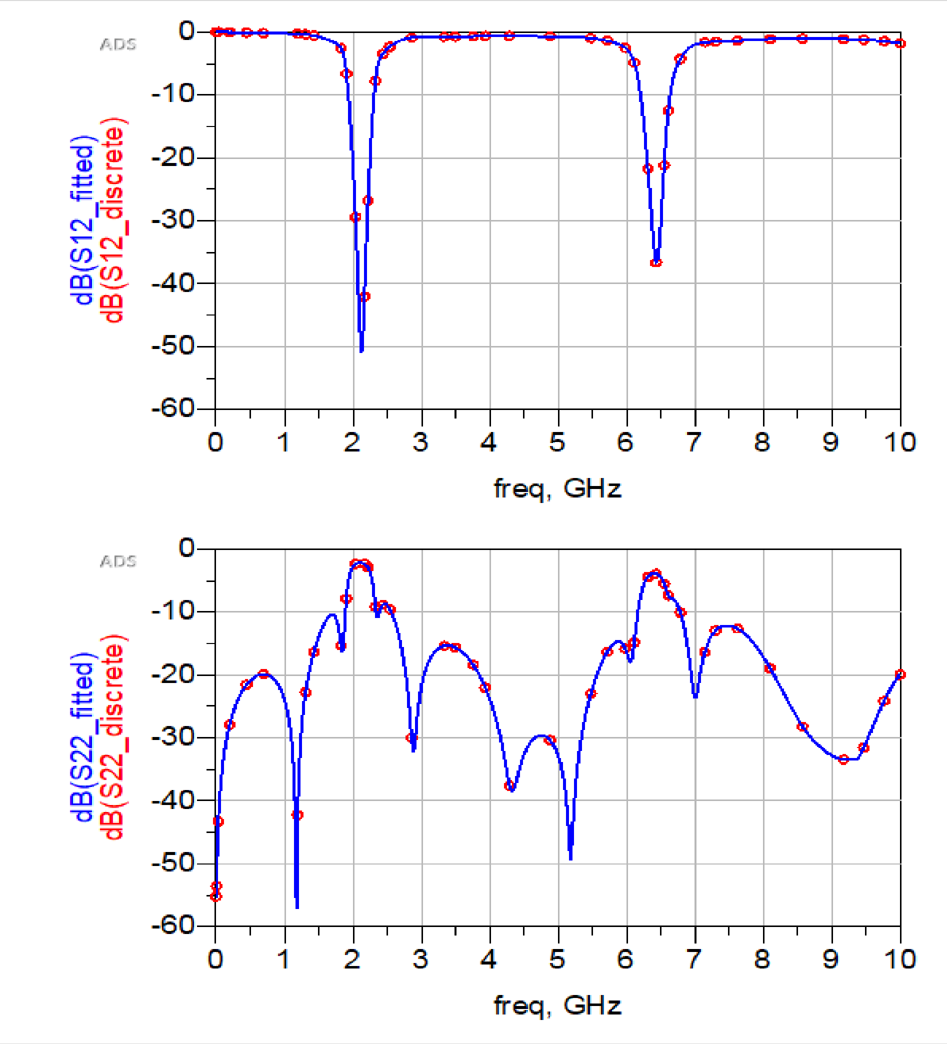


LAYOUT DESIGN

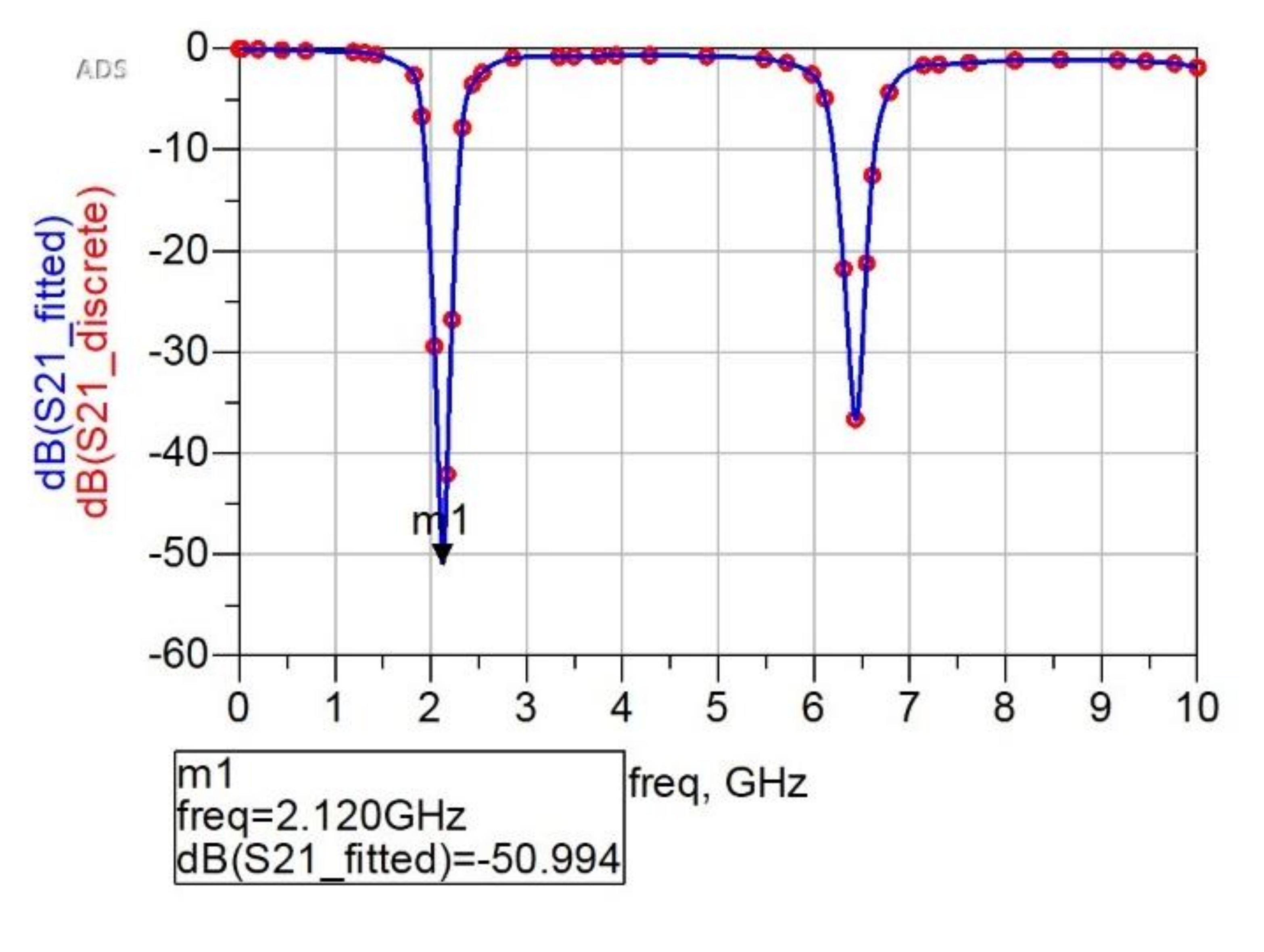


S PARAMETERS FROM LAYOUT

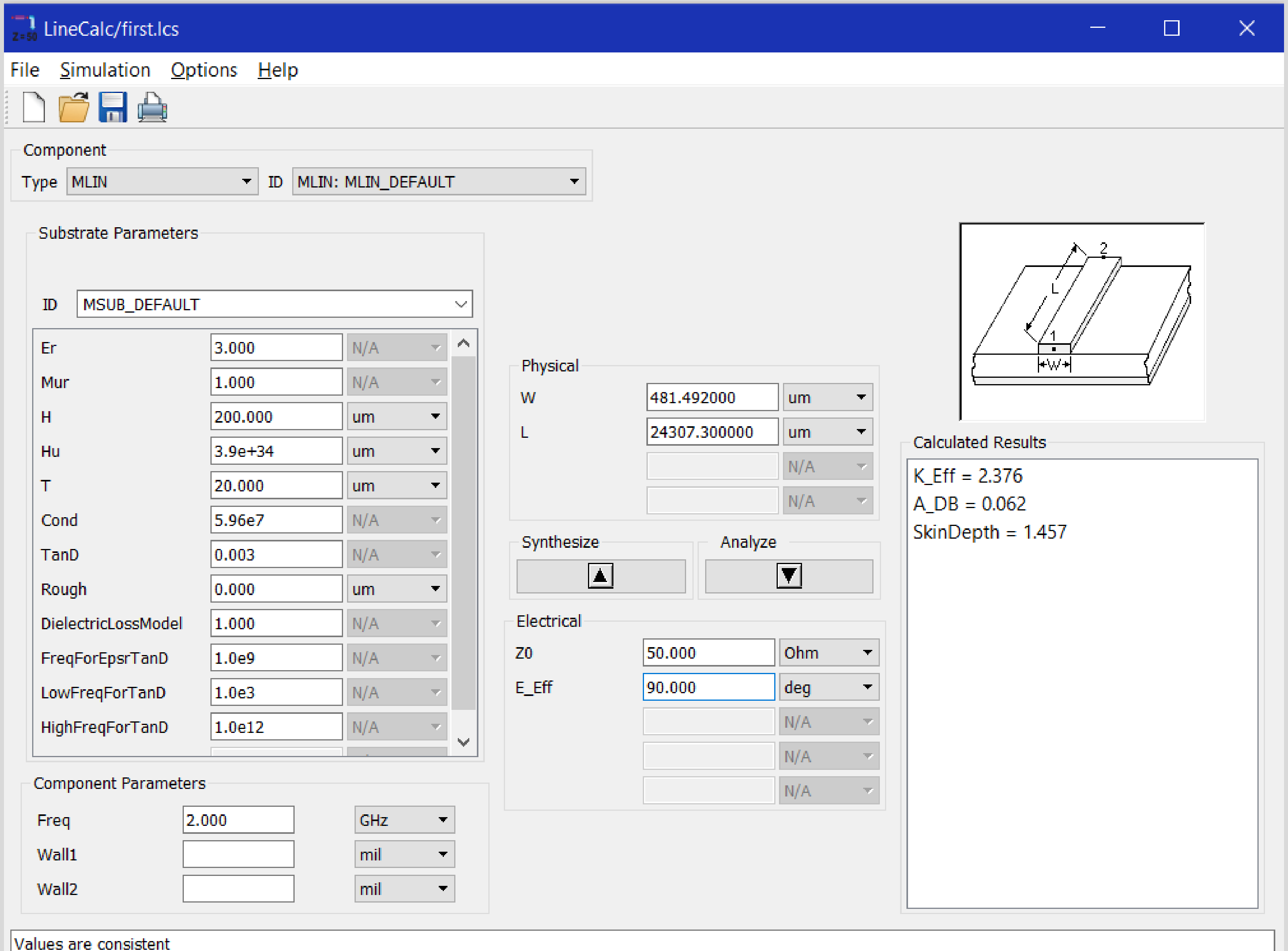




ATTENUATION FROM LAYOUT S21

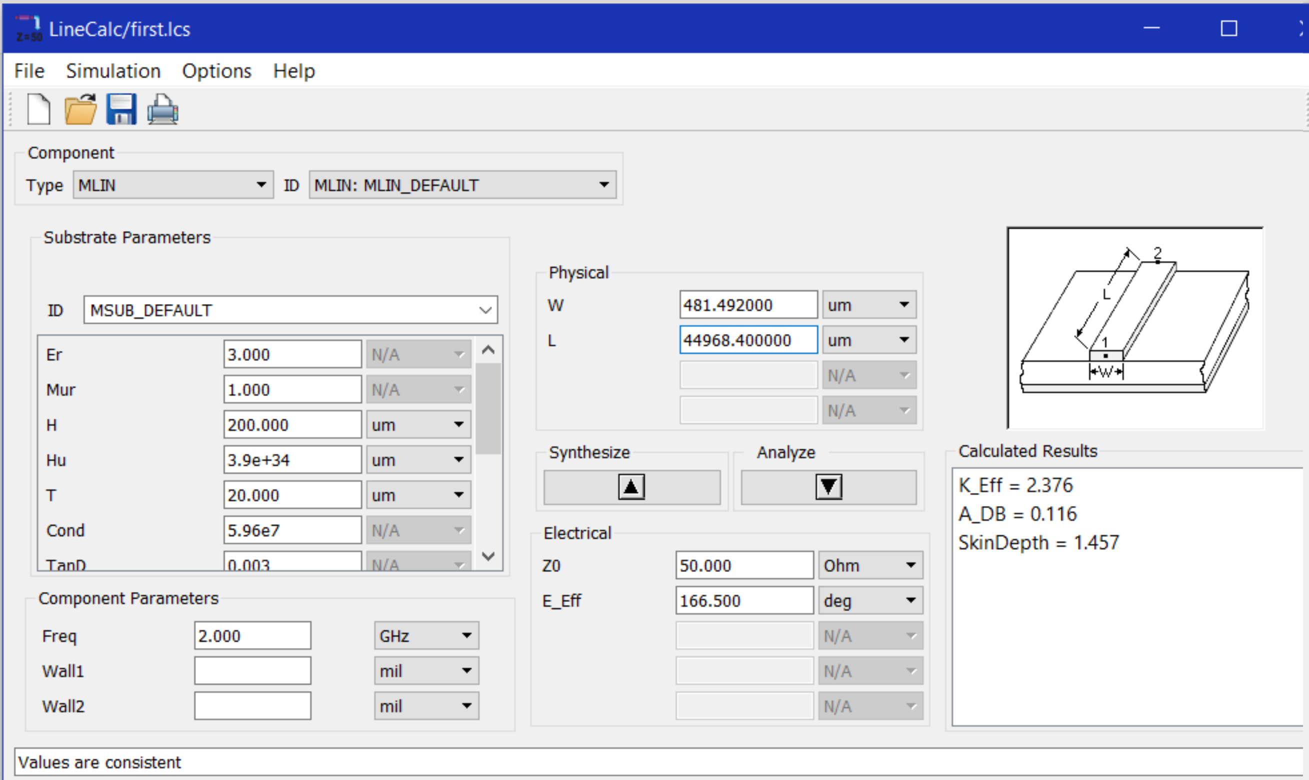


LINE CALC Z0=50 OHM
EXAMPLE 2 BANDPASS FILTER

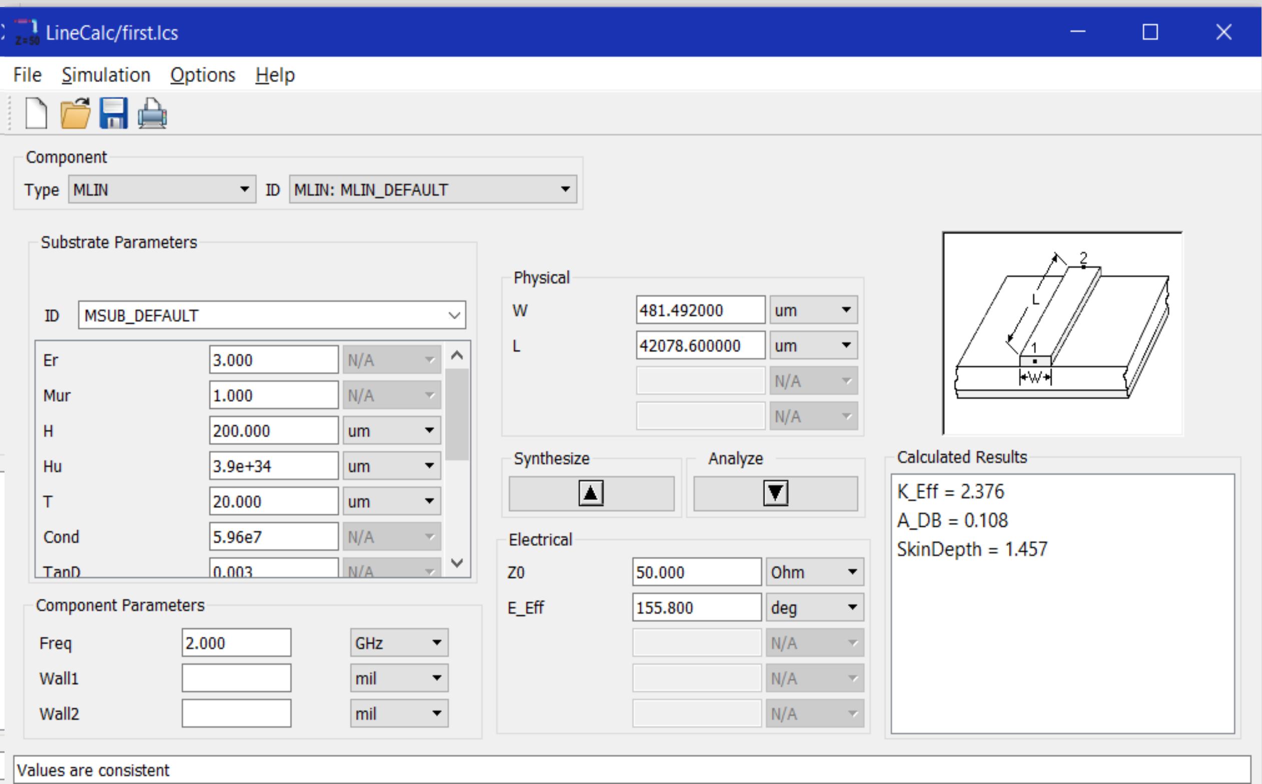


EXAMPLE 2 BANDPASS FILTER

Line calc z0=50 ohm and theta = 166.5



Line calc z0=50 ohm and theta = 155.8



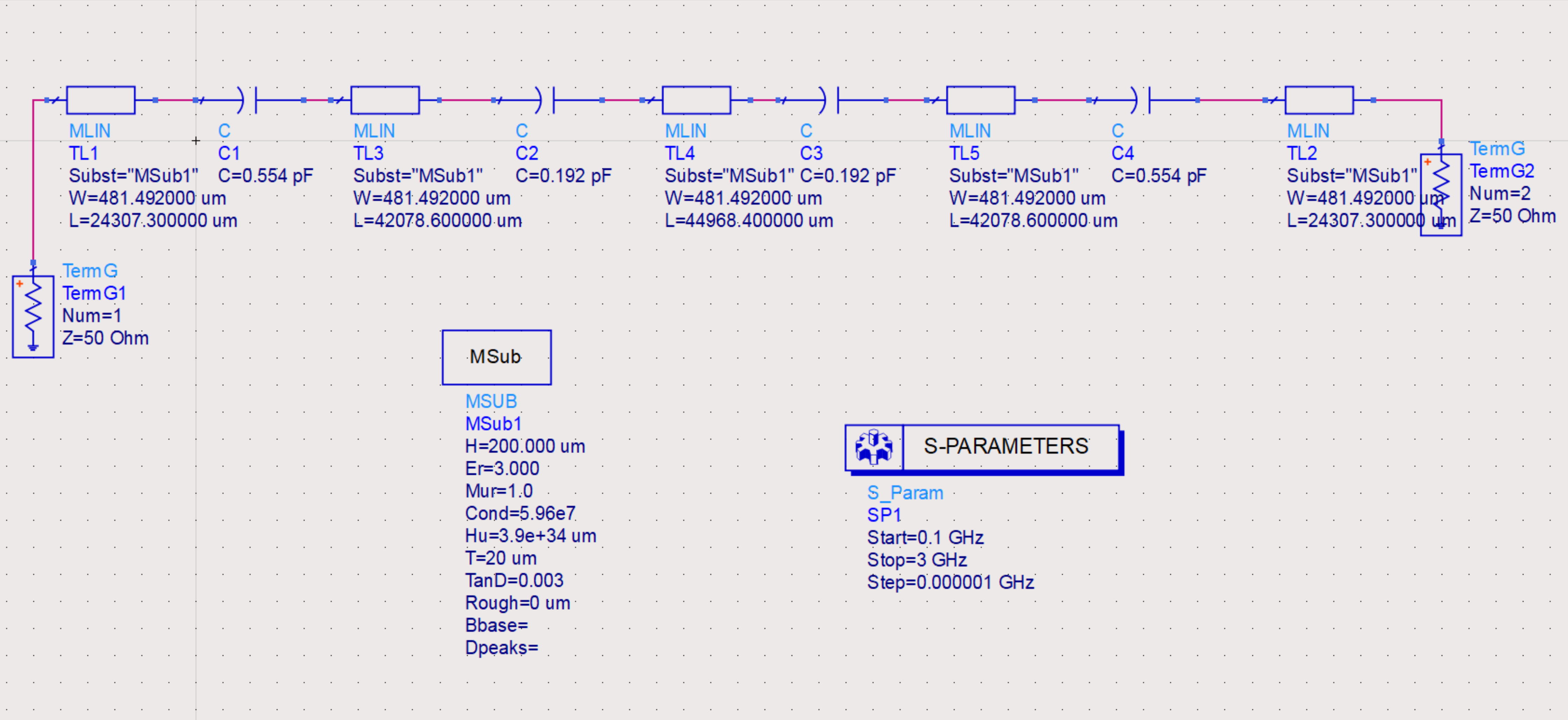
EXAMPLE 2 CONSTRAINS:

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

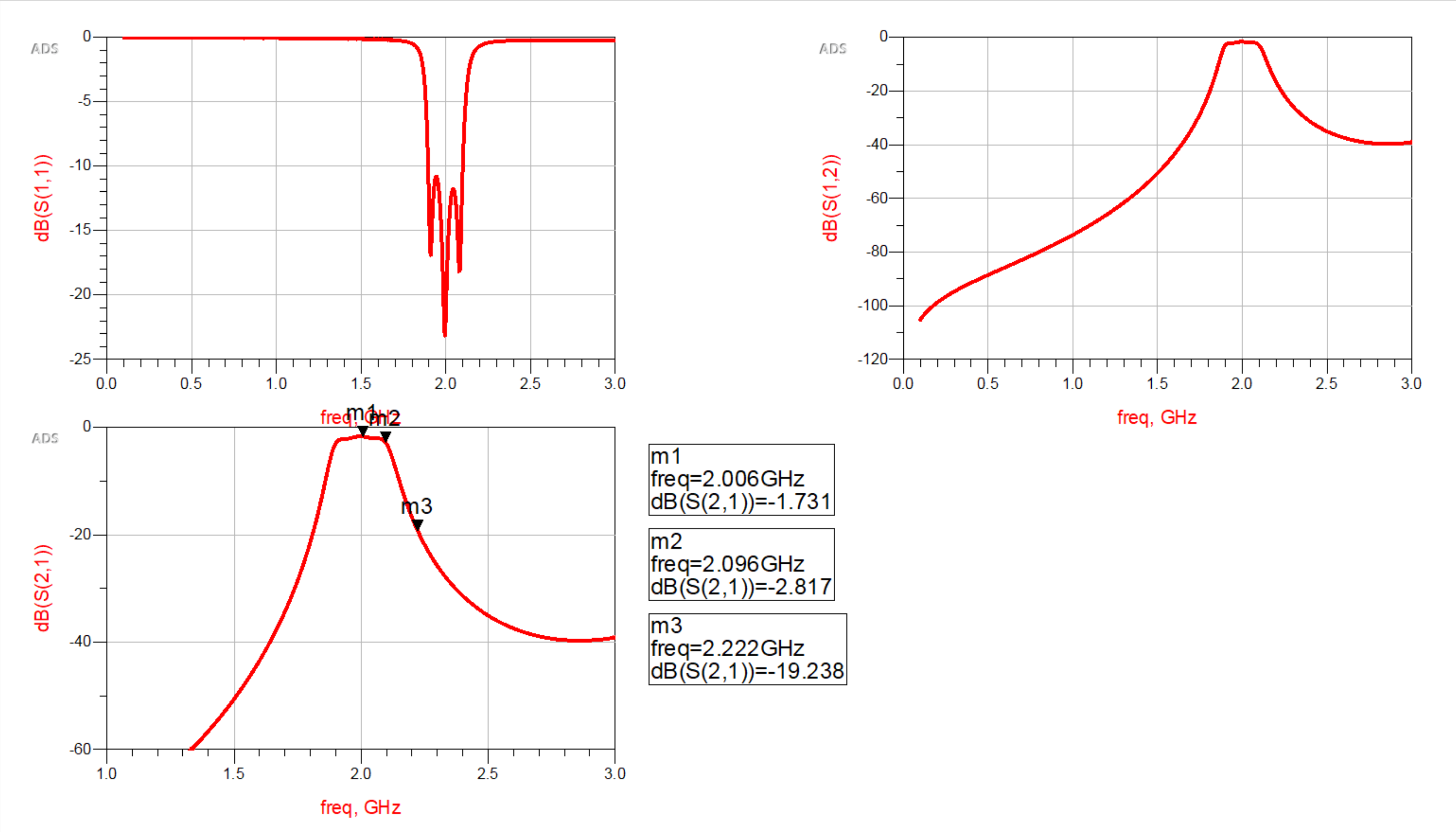
From the attenuation at 2.2 GHz, get N=3. Then:

n	g_n	Z_0J_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:

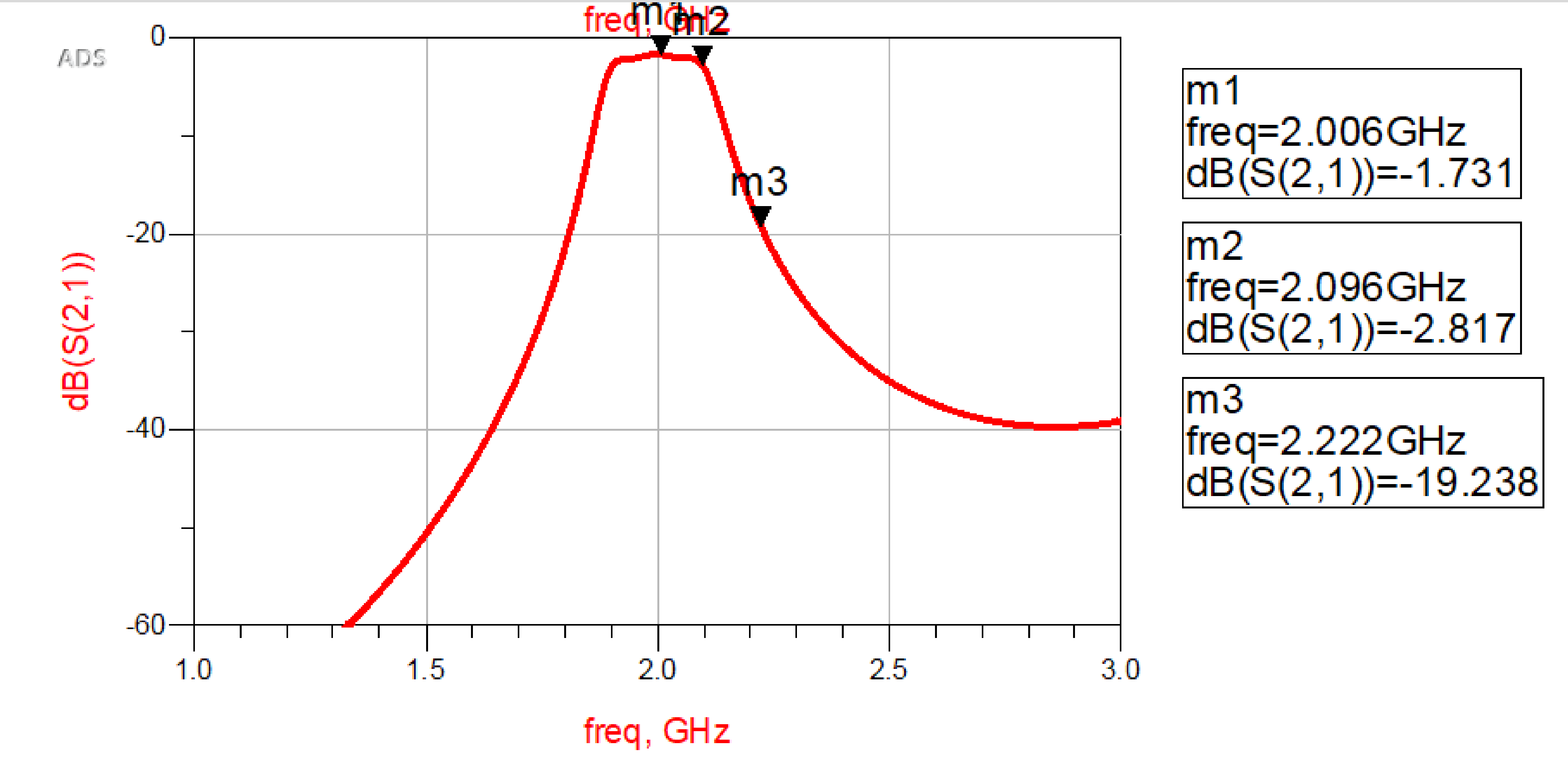


S PARAMETERS FROM SCHEMATIC



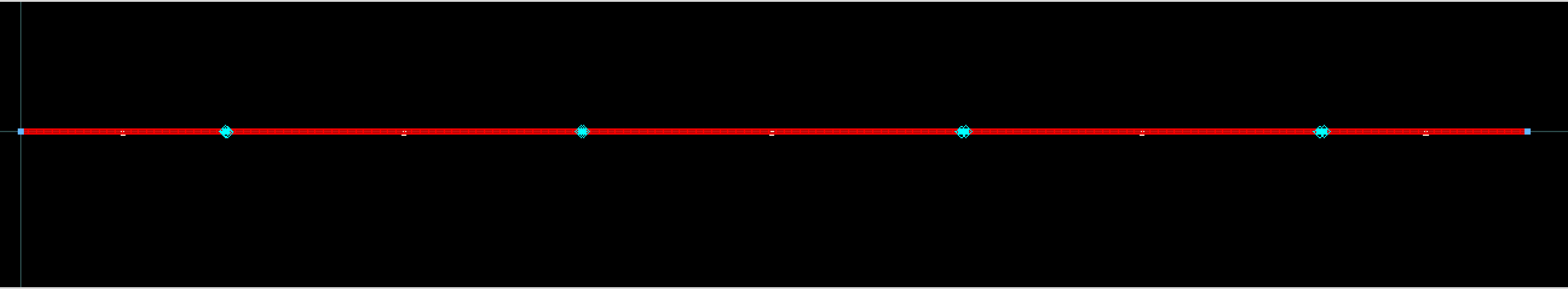
ATTENUATION FROM SCHEMATIC S21

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



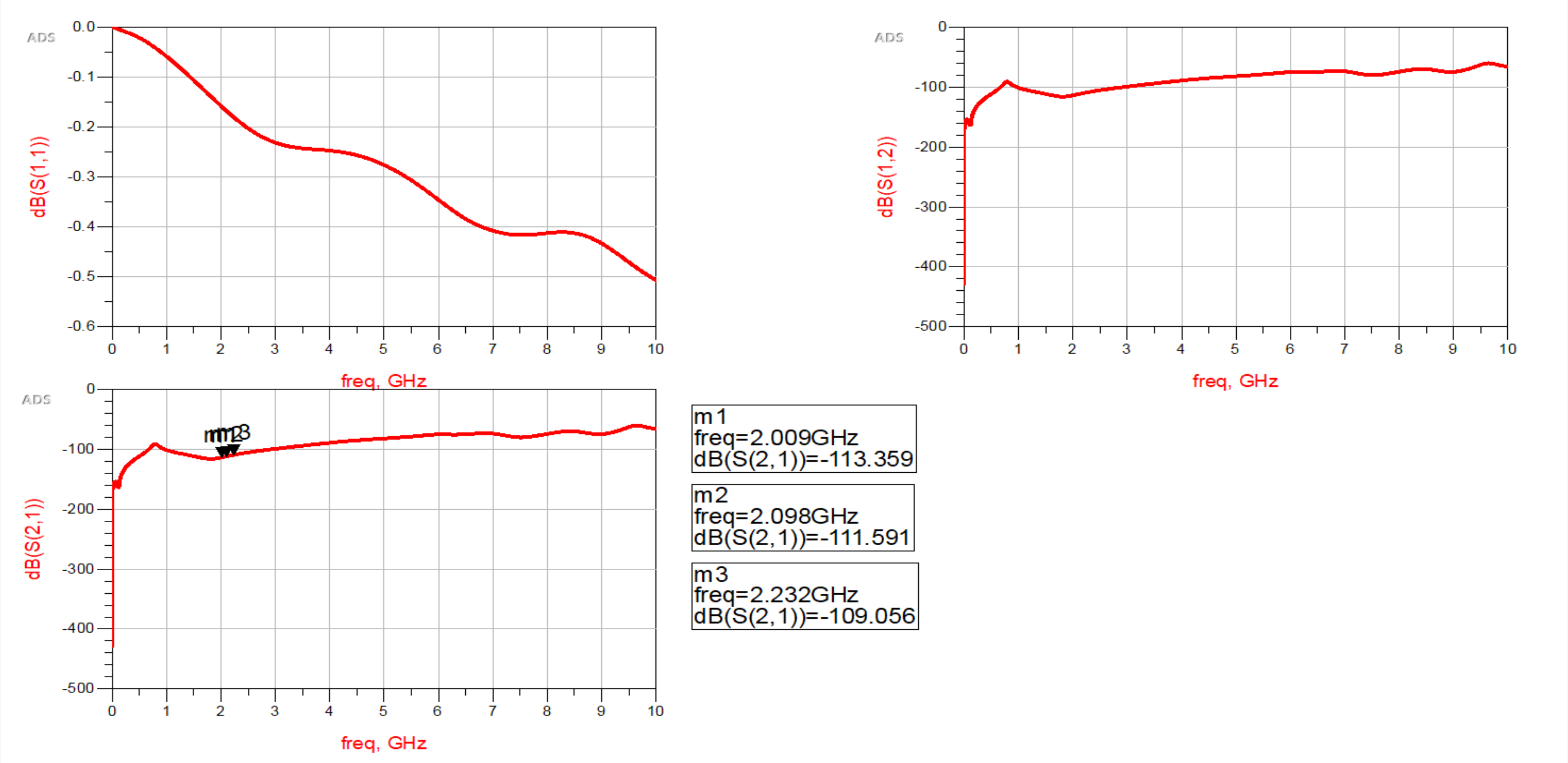
LAYOUT

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

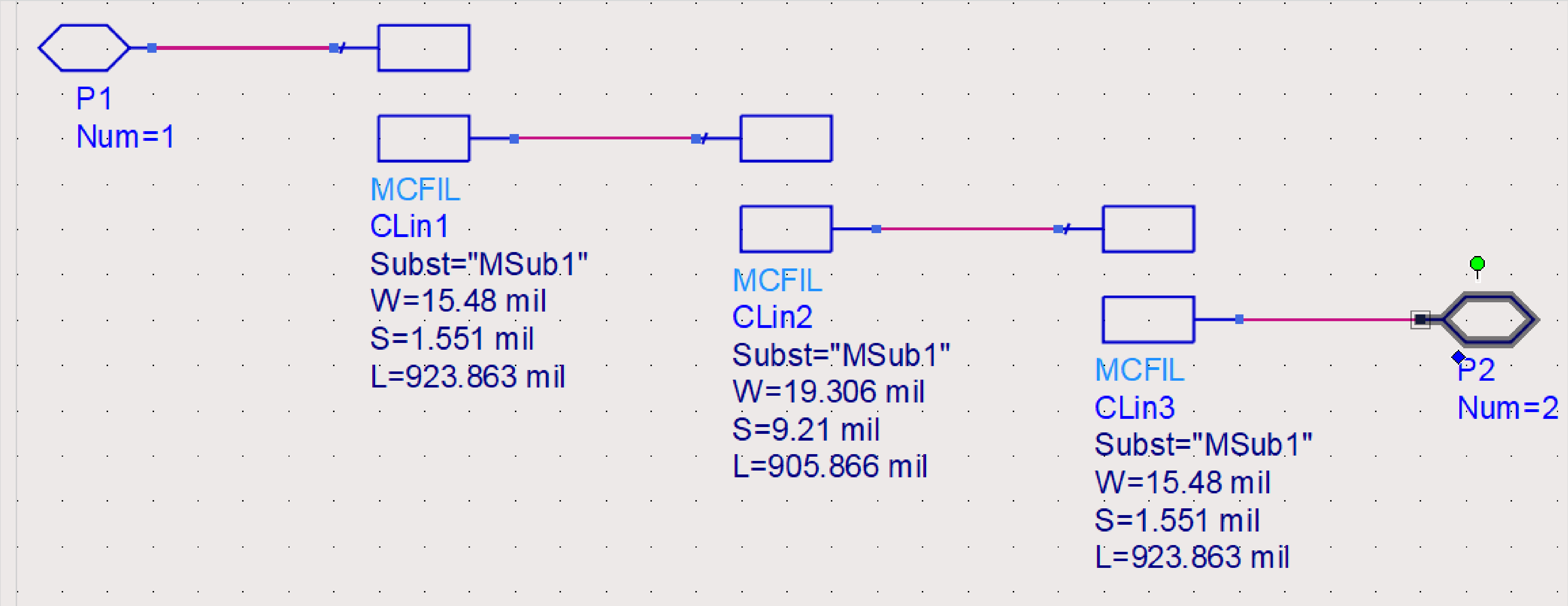


S PARAMETERS FROM LAYOUT

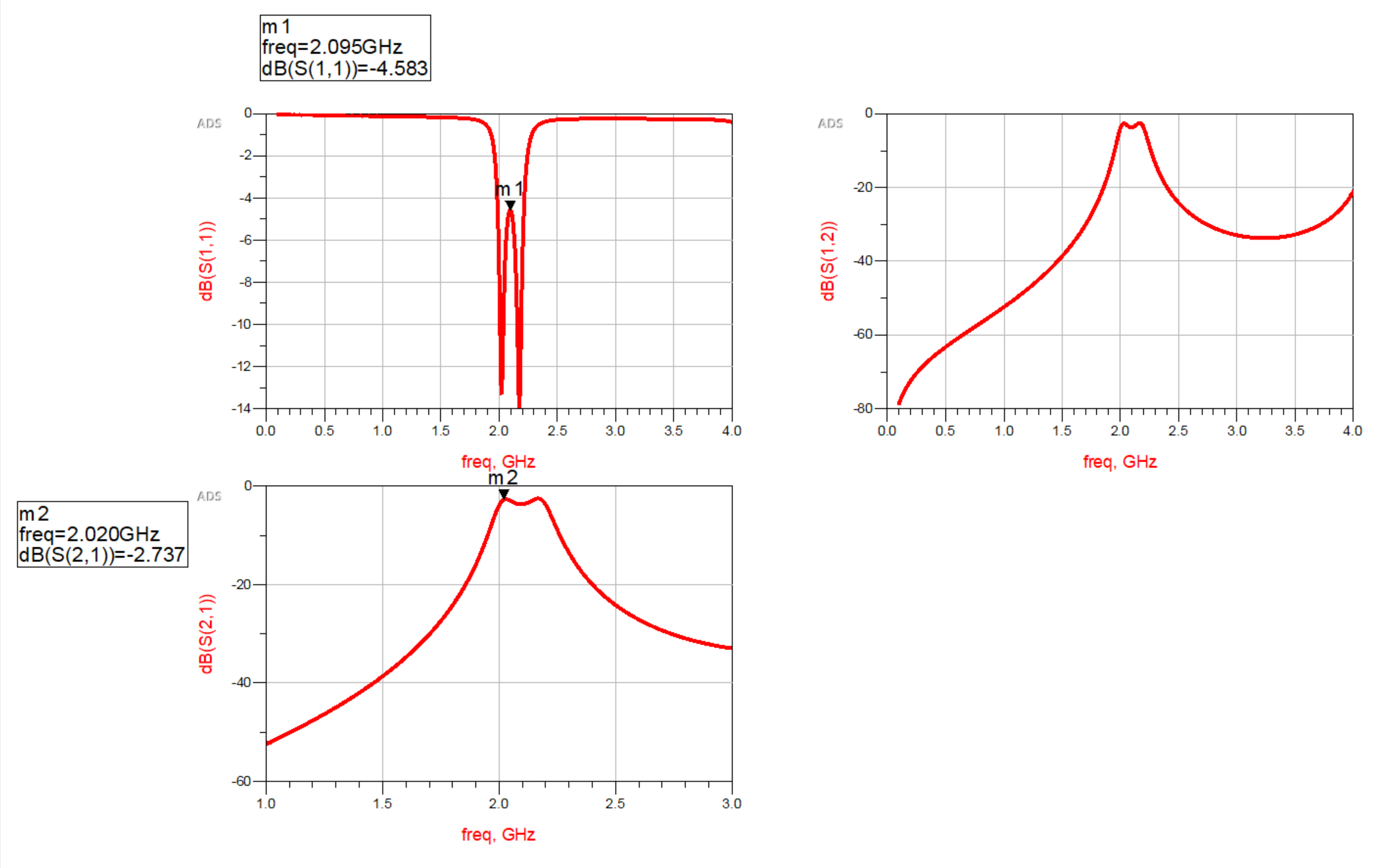
I wasn't able to get the right values from the layout



SCHEMATIC USING THE COUPLED LINES



S PARAMETERS FROM SCHEMATIC USING THE COUPLED LINES



ATTENUATION FROM SCHEMATIC USING THE COUPLED LINES S21