ECE 373 Lab 2 Report

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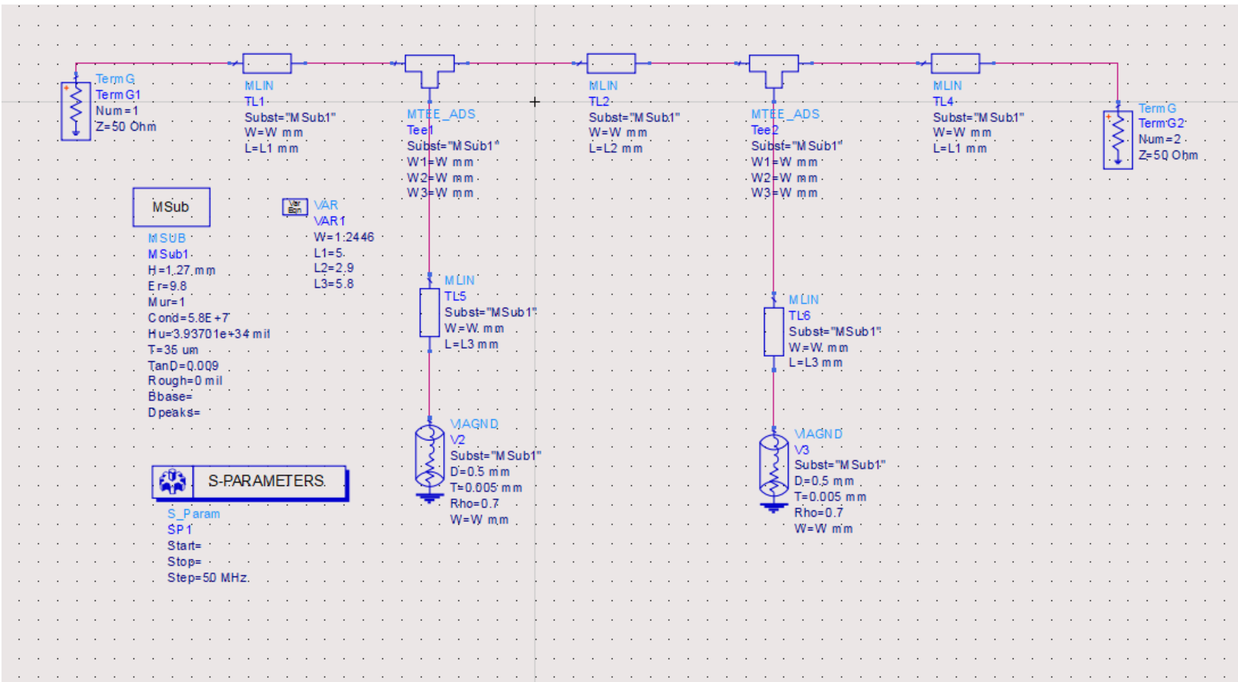
Tables

Wilkinson Power Divider		
	Pre-lab Calculations	**Optimized Values**
Z_0	50	50
Electrical Length	π/2	π/2
Microstrip Length L_0	17.24 mm	17.24 mm
Microstrip Width W_0	2.9 mm	2.9 mm
Microstrip Width W_c	1.574 mm	1.574 mm

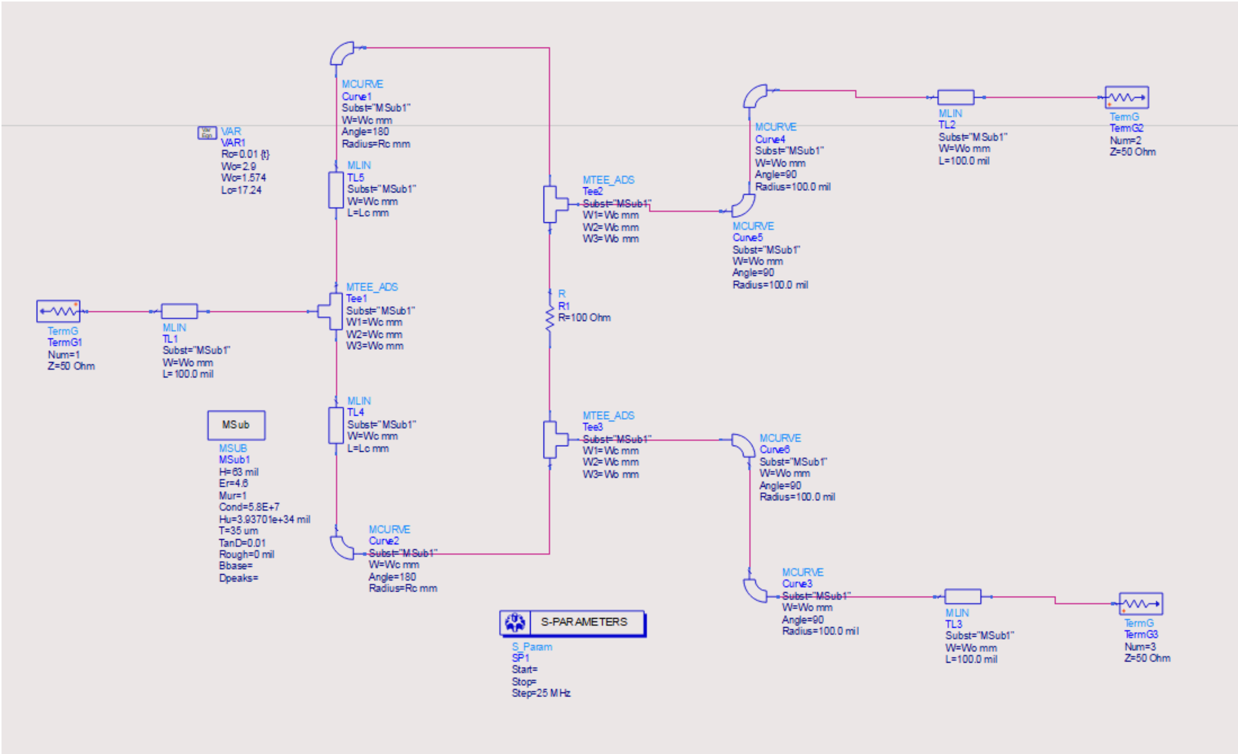
Hybrid 90º Coupler		
	Pre-lab Calculations	**Optimized Values**
Z_0	50	50
Electrical Length L_0	π/2	π/2
Microstrip Length L_0	16.81 mm	16.42 mm
Electrical Length L_c	π/2	79π/200
Microstrip Length L_c	16.42 mm	13.272 mm
Microstrip Width W_0	3.054 mm	3.054 mm
Microstrip Width W_c	5.244 mm	5.0875 mm

Schematics

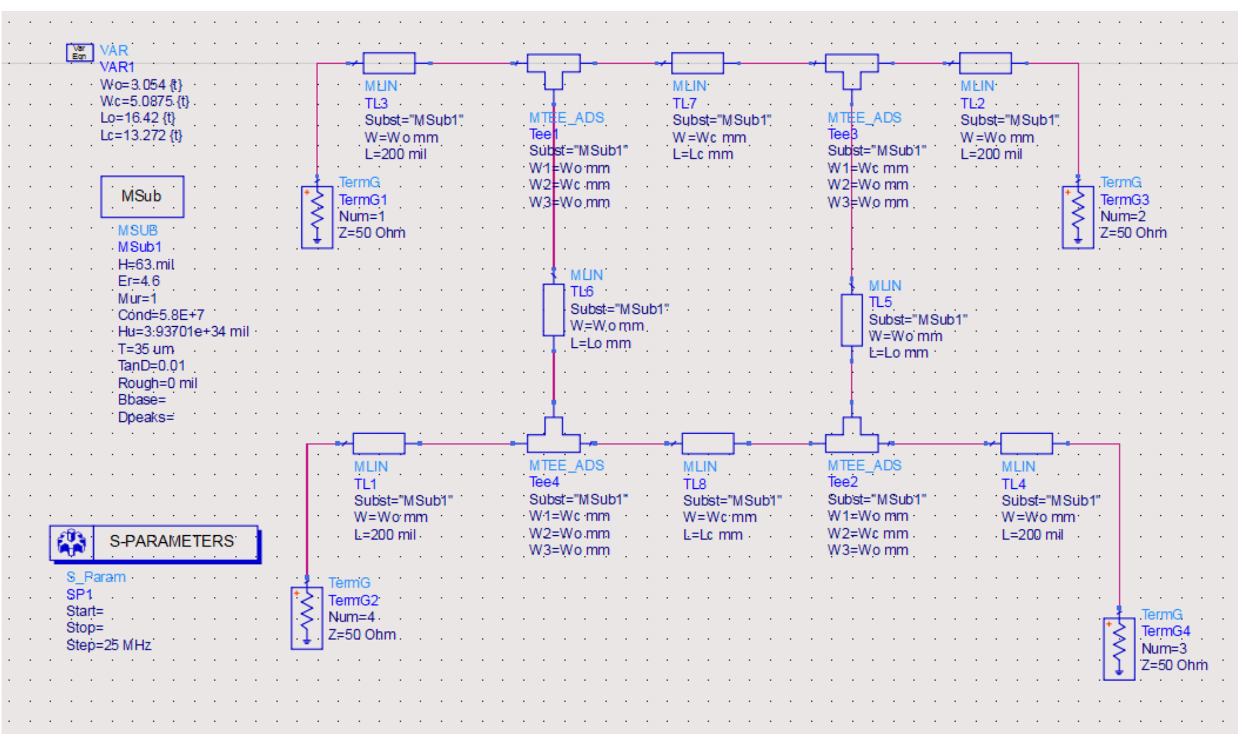
Part 1: T Circuit



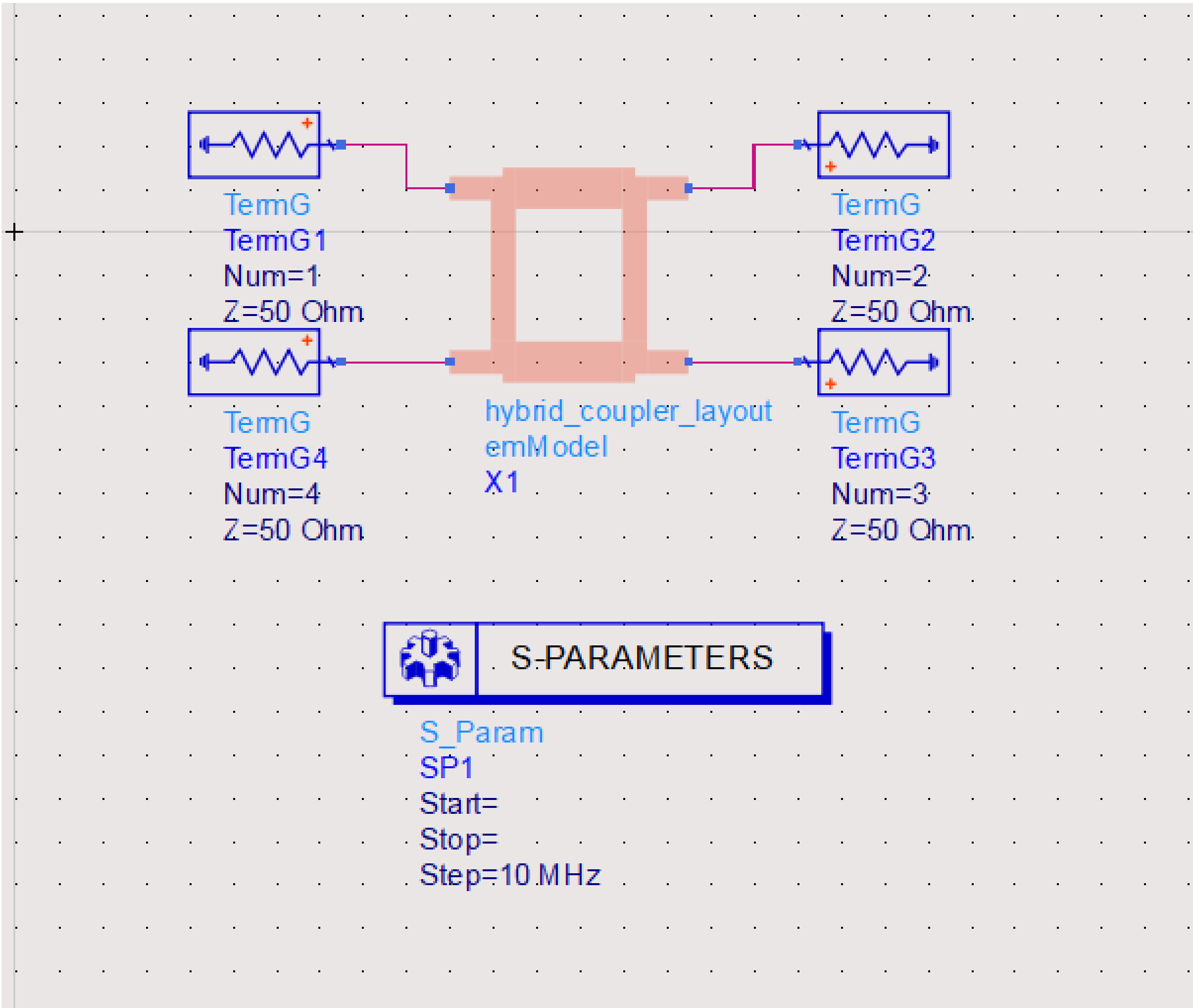
Part 2: Wilkinson Power Divider



Part 3: Hybrid 90º Coupler



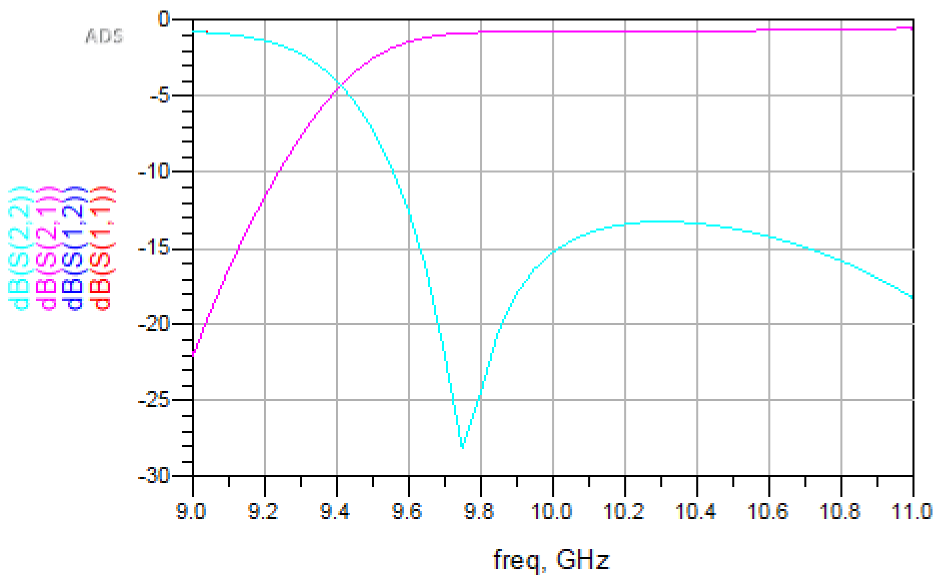
EM Model

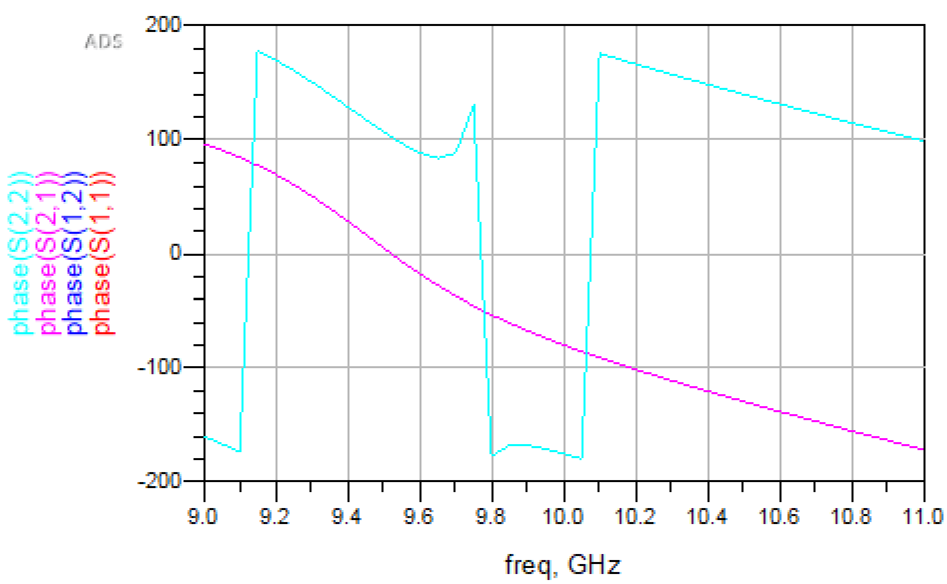


TermG
TermG1
Num=1
Z=50 Ohm
TermG
TermG2
Num=2
Z=50 Ohm
TermG
TermG4
Num=4
Z=50 Ohm
hybrid_coupler_layout
emModel
X1
TermG
TermG3
Num=3
Z=50 Ohm
S-PARAMETERS
S_Param
SP1
Start=
Stop=
Step=10 MHz

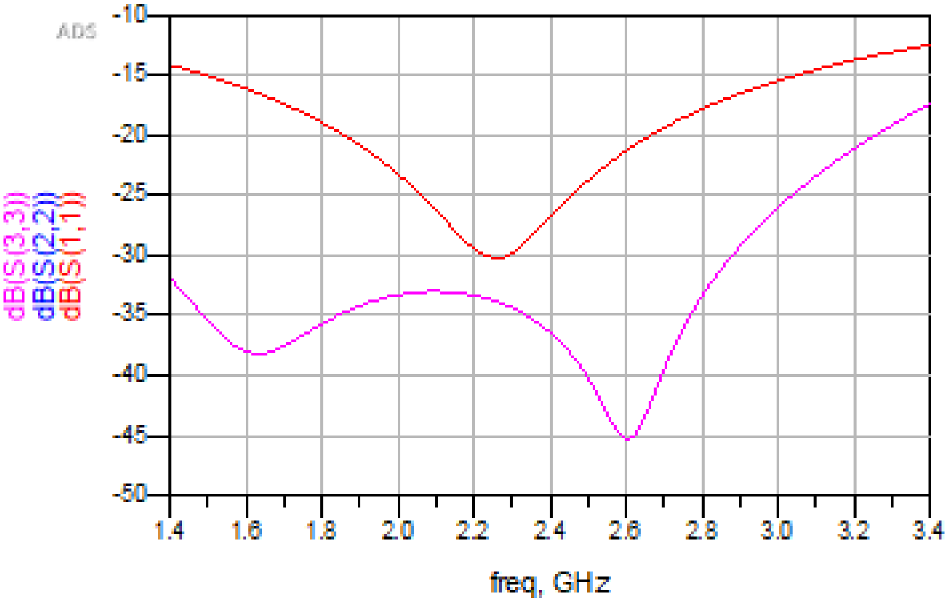
Simulation Results

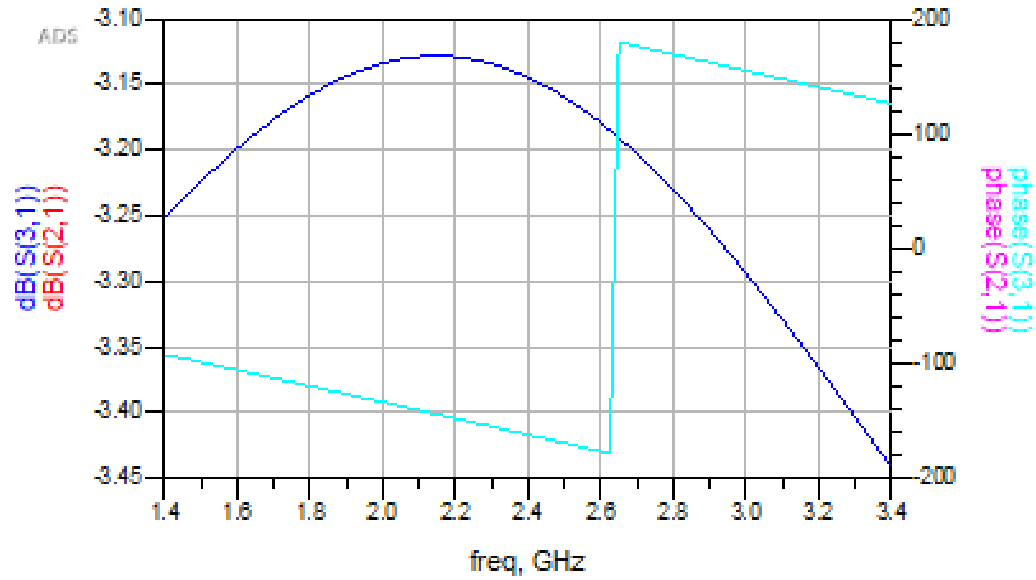
Part 1: Tee Circuit

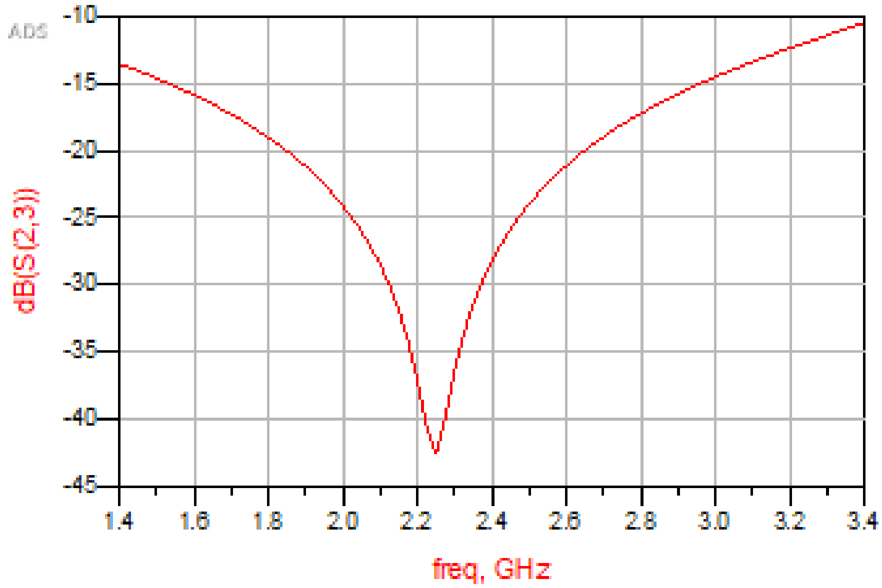




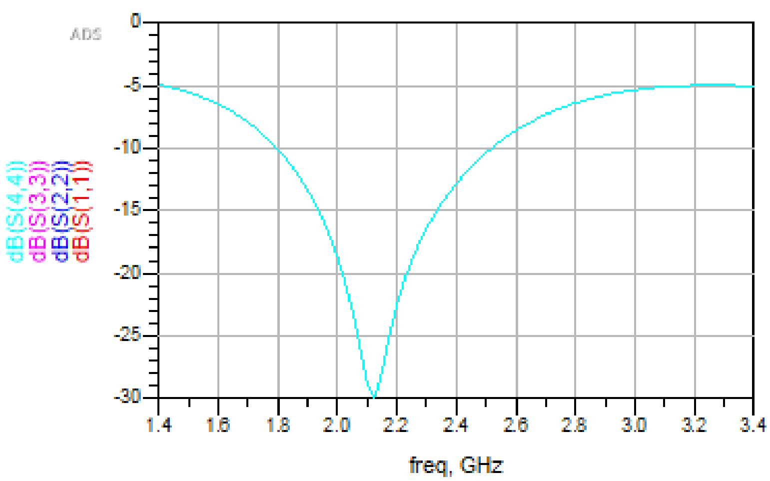
Part 2: Wilkinson Power Divider

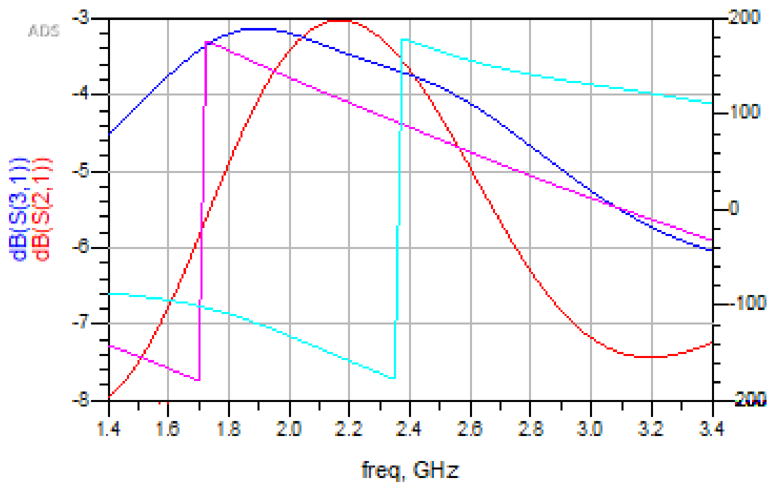

ADS
dB(S(3,3))
dB(S(2,2))
dB(S(1,1))
-10
-15
-20
-25
-30
-35
-40
-45
-50
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
freq, GHz


ADS
dB(S(3,1))
dB(S(2,1))
-3.10
-3.15
-3.20
-3.25
-3.30
-3.35
-3.40
-3.45
200
100
0
-100
-200
phase(S(3,1))
phase(S(2,1))
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
freq, GHz

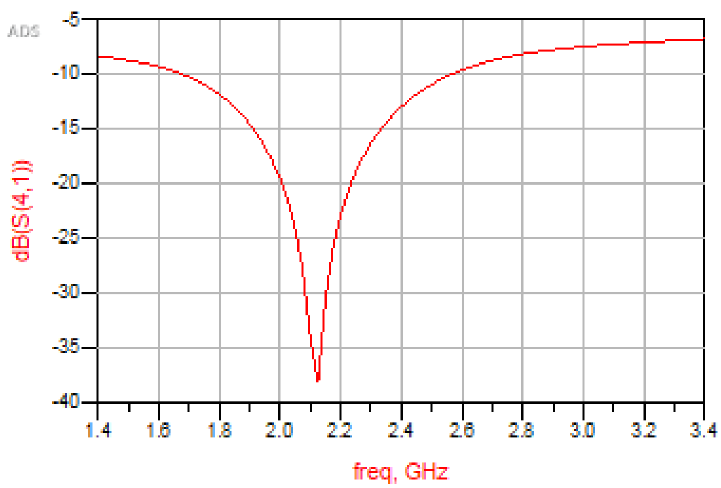


Part 3 (Initial): Hybrid 90º Coupler



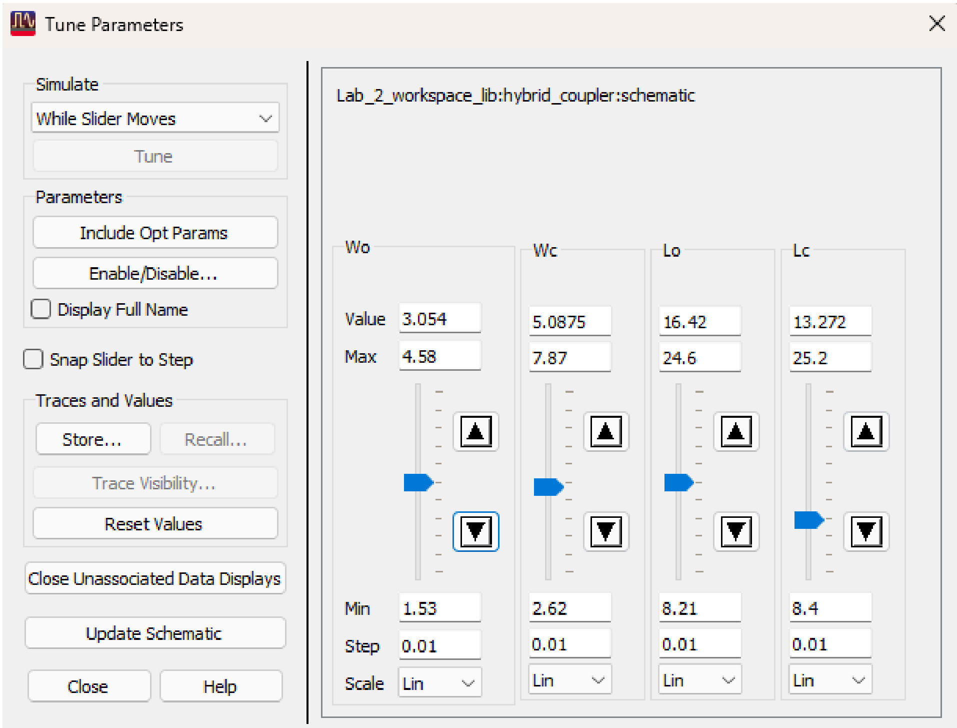


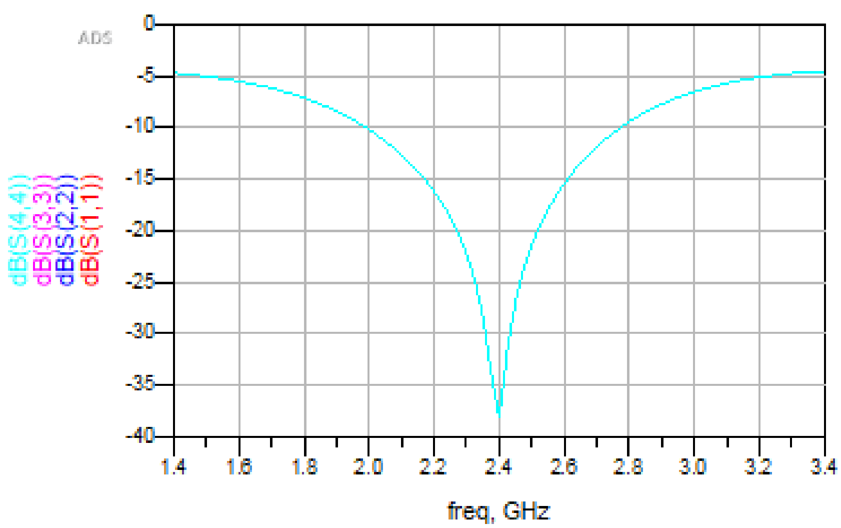
ADS
dB(S(3,1))
dB(S(2,1))
freq, GHz

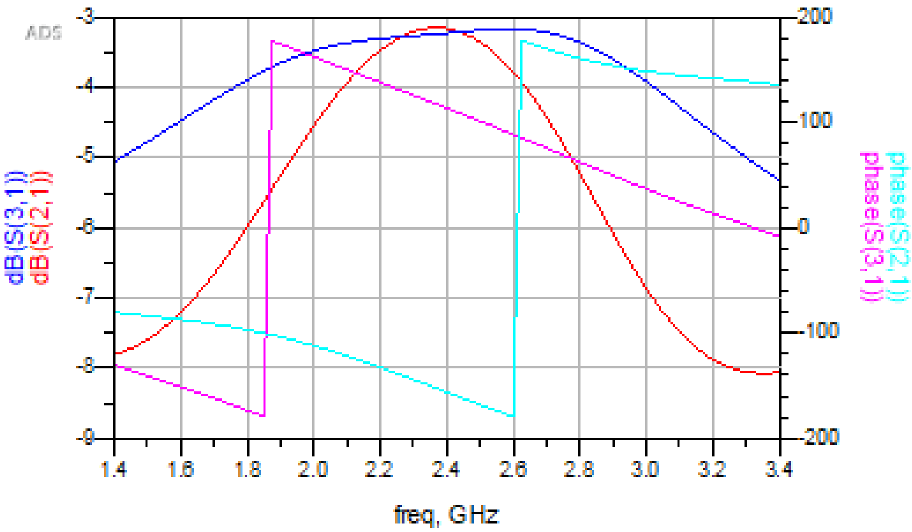


ADS
dB(S(4,1))
freq, GHz

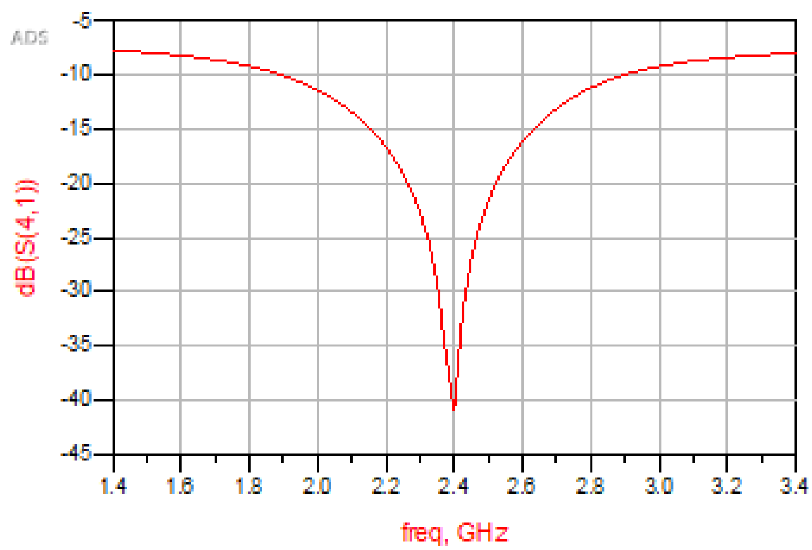
Part 3 (Optimized): Hybrid 90º Coupler





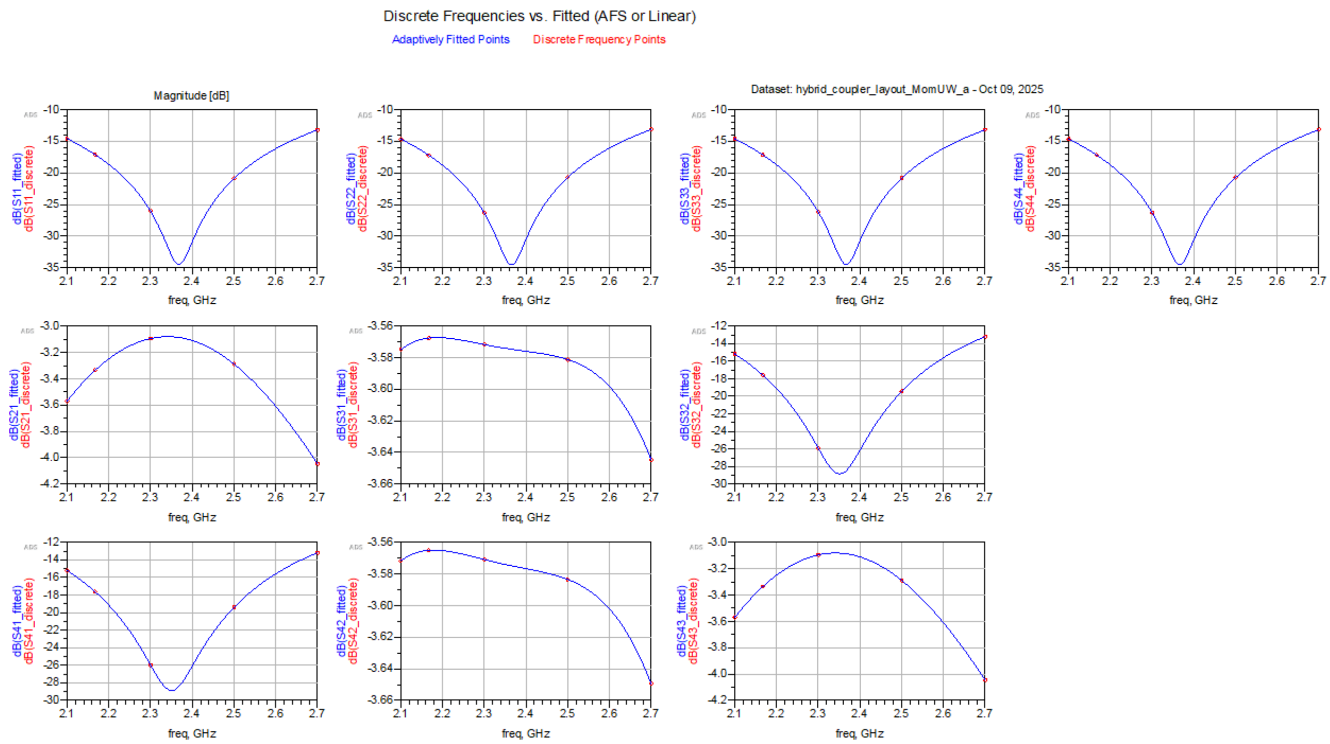


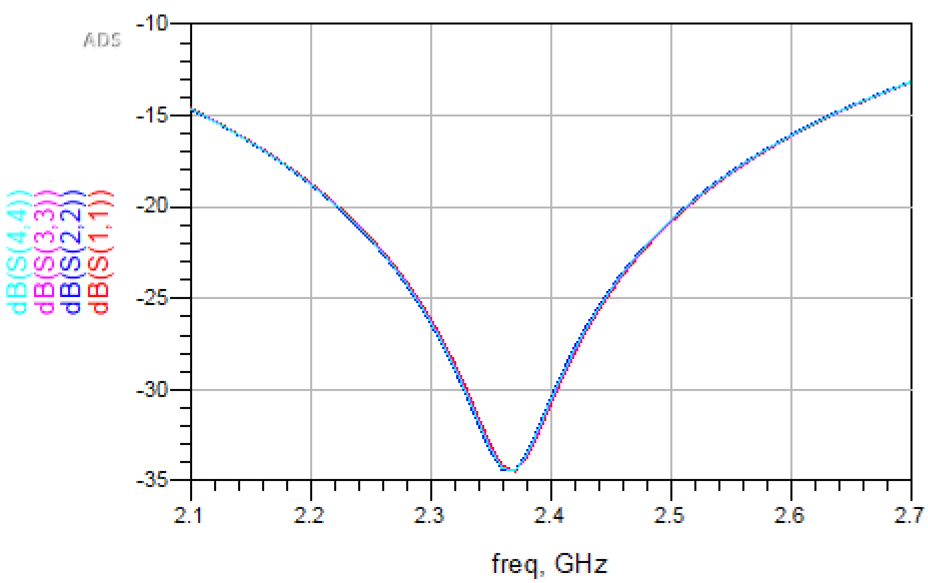
ADS
dB(S(3,1))
dB(S(2,1))
phase(S(2,1))
phase(S(3,1))
-3
-4
-5
-6
-7
-8
-9
200
100
0
-100
-200
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
freq, GHz

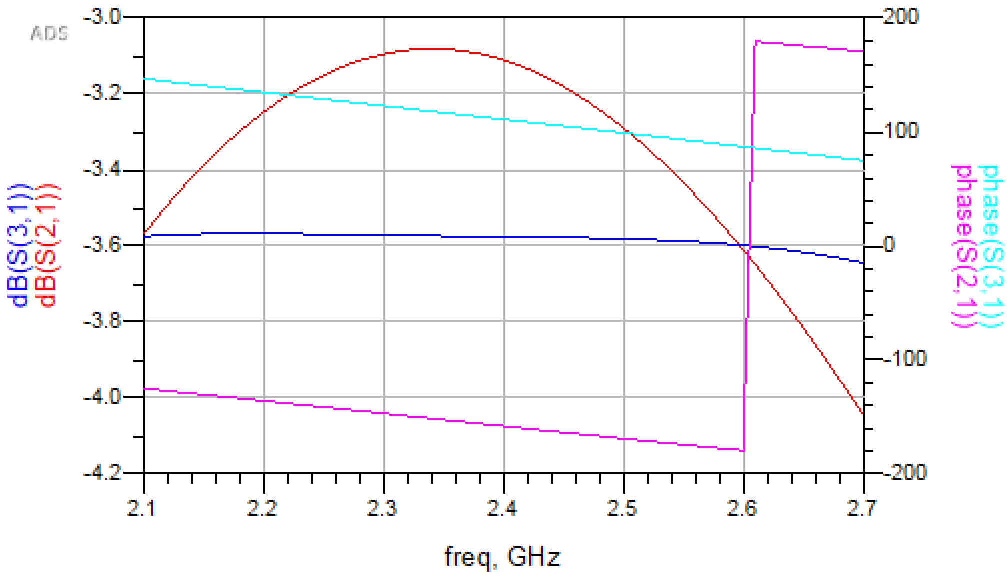


ADS
dB(S(4,1))
-5
-10
-15
-20
-25
-30
-35
-40
-45
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
freq, GHz

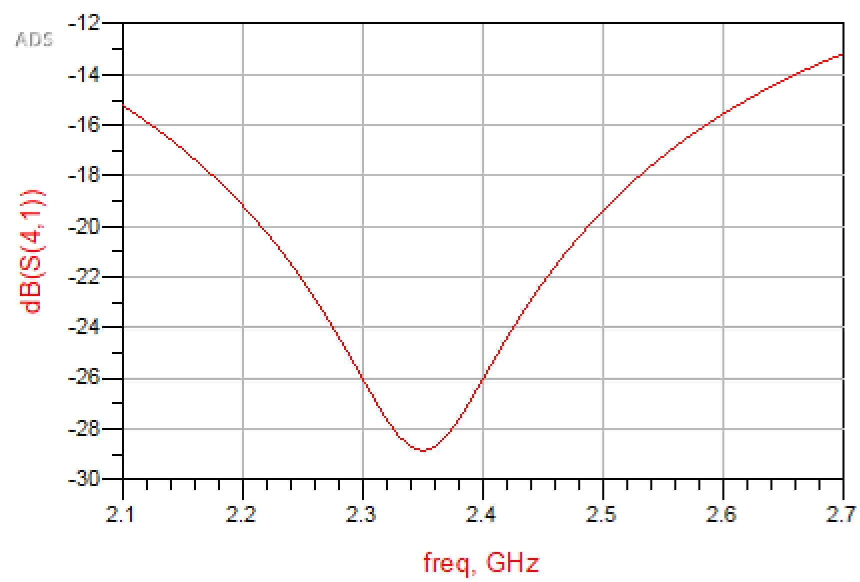
EM Model Results







ADS
-3.0
-3.2
-3.4
-3.6
-3.8
-4.0
-4.2
200
100
0
-100
-200
dB(S(3,1))
dB(S(2,1))
phase(S(3,1))
phase(S(2,1))
2.1
2.2
2.3
2.4
2.5
2.6
2.7
freq, GHz



ADS
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
dB(S(4,1))
2.1
2.2
2.3
2.4
2.5
2.6
2.7
freq, GHz

Discussion and interpretation of simulation results:

Matching:

In ideal Wilkinson and branch line designs, each port is matched at the center frequency (S11 around -25 dB). The circuit simulations typically show near ideal matching at 2.4 GHZ. The EM simulations however often show a degraded S11 due to certain elements such as discontinuities, T-junction parasitics, conductor thicknesses and substrate dispersion. Matching is achieved when each port has an input impedance of 50 ohms in our case. For the Wilkinson and the desired couplers electrical lengths are very important in creating sections of the right characteristic impedance in order to match the ports and create the desired outputs. Therefore, any deviations in electrical length (which cause changes in characteristic impedance) causes unwanted reflections and increases S11.

Likely causes of these issues and mismatches:

1. T junctions and step discontinuities produce relative parasitics that are not present in the ideal circuit models.
2. Possible fabrication effects that are approximated in EM (finite copper thickness, dielectric loss tangent, fringing fields) can shift the effective electrical length and impedance.
3. Layout bends and proximity coupling (in the coupler) can change coupling and port impedances.

Possible improvements:

1. Add small tuning sections at ports to compensate for differences between ideal and EM.
2. Use better optimized step and T parameters in ADS so the circuit model better matches the EM model before layout.
3. Minimize abrupt steps and add gradual tapers to reduce reflection from discontinuities.
4. Reposition the coupled lines slightly to adjust the coupling and minimize unintended parasitic coupling.

Trade Offs:

Tuning lengths and adding stubs can improve matching but may reduce bandwidth or change the phase relationships needed for the equal split or 90 degree phase. Tapers increase area and may change effective line capacitance.

Insertion Loss:

Simulations of circuits generally show ideal insertion loss, which depends on the power division and assumes near infinite isolation. For a system where all characteristic impedances are matched, insertion loss for each output is equal to the magnitude of S_{21}, S_{31}, or S_{41} (for port 2, 3, and 4 respectively). Isolation for the 90º coupler is represented by S_{41}. Thus we can easily observe insertion loss for each of our circuits and isolation for the 90º coupler:

- **Tee Circuit:** Insertion loss -22.5 dB at 9 GHz, rising to –1 dB around 10 GHz and staying steady.
- **Wilkinson:** Insertion loss is equal at each port. Around -3.15 dB at the targeted frequency of 2.4 GHz.
- **90º Coupler:** Insertion loss is around -3.7 dB at 2.4 GHz. Equal at port 2 and 3 at 2.4 GHz. Isolation of almost -40 dB at 2.1 GHz but only -13 dB at 2.4 GHz.
- **Optimized 90º:** Insertion loss of about -3.25 dB at 2.4 GHz. Equal at port 2 and 3. Isolation of less than -40 dB at 2.4 GHz.
- EM Sim. 90º: Insertion loss of -3.1 dB at port 2 and -3.57 dB at port 3 at 2.4 GHz. Isolation of -26 dB at 2.4 GHz.

This makes sense from the theory. For the Wilkinson power divider, ideal insertion loss should be about -3 dB, since perfectly balanced and matched ports means equal division of power and no current through the resistor. The 90º coupler should also have an insertion loss close to -3 dB which we can see from our simulations (-3.25 dB after optimization). Isolation is ideally infinite (no power at port 4), and we see a very low magnitude of -40 dB, which makes sense. The EM model simulation shows slightly higher insertion loss and worse isolation (-3.57 dB at port 2 & isolation of -26 dB) because this model includes conductor/dielectric losses, radiation effects, and coupling effects.

Improvements:

1. Choice of different substrate to lower conductor and dielectric losses.
2. Increase trace width or thickness to reduce conductor resistance.
3. Improve matching to reduce mismatch losses and reflections.
4. Adjust lengths of branches in 90º coupler to correct any imbalances.

Trade-offs:

1. Wider/thicker traces means changes in characteristic impedance which will likely require redesigning of the circuit.
2. Changes to substrate can affect manufacturing constraints.

Bandwidth:

Both the wilkinson and coupler work best around one main frequency. This is expected because they are both based on quarter wave lines that are designed specifically at our target frequency. When we move away from the design frequency the s parameters especially S11 and S21 start to get worse. This happens because the lines only have the exact “correct” electrical length at one frequency. When the frequency changes the electrical length changes and the circuit won't work as intended. That's why the useful frequency range known as bandwidth is limited.

Ways to improve bandwidth:

1. Use more than one quarter wave section instead of a single one. This can spread out matching over a wider frequency range.
2. Use designs that include more coupled lines instead of simple lines to hold performance over a wider band.
3. Add short matching stubs or tuning pieces, this can flatten the S11 curve across frequencies.

Trade offs:

Adding extra sections or stubs makes the circuit larger and more complicated. Increasing the bandwidth can make the coupler “less perfect” at the center frequency.