

Branch Line Coupler Design Report

Jack Mullen, Jacob Hulvey, Dawid Yerdea

The first step in the design process for the 90-degree hybrid coupler was to review the specifications, and make sure they are consistent with an ideal transmission line design model. Specifications are as follows:

90deg 3dB Hybrid:

< 0.2 dB excess loss

phase difference 90 degrees to within +1 degree

amplitude match to within ± 0.1 dB

> 30 dB isolation

> 15dB return loss

These specifications were compared with a modified version of the hybrid coupler, designed in homework 3 shown in Figure 1. and Figure 2.

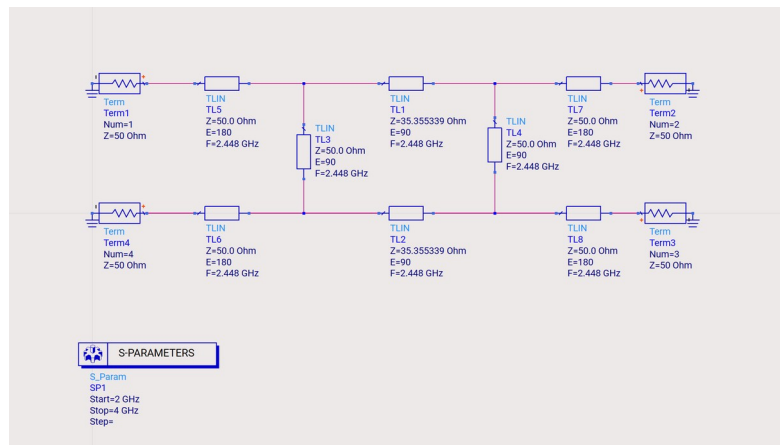


Figure 1. Ideal T-Line Design

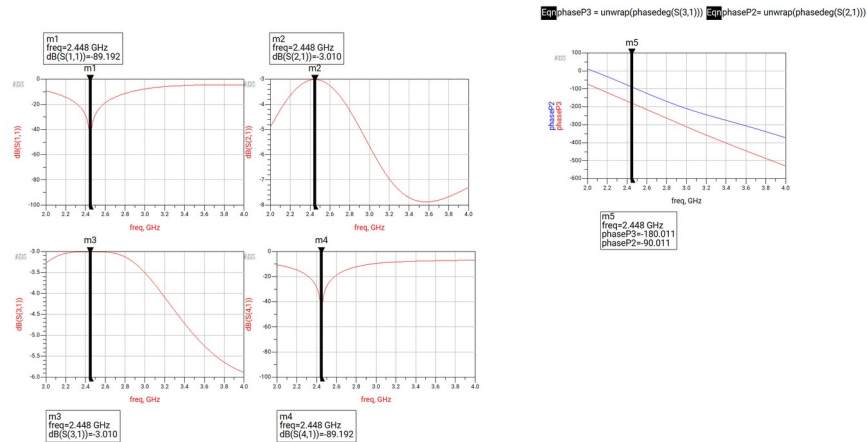


Figure 2. S-Parameters at Design Frequency

Based on the above results from the ideal transmission line design, it should be feasible to move on to inputting specifications into LineCalc with physical lines. All specifications are met with the ideal design at the midpoint design frequency. To widen that band and further refine the design to meet as many specifications as possible, we will use the optimizer.

Excess loss will be highly dependent on substrate and resistance of transmission lines, meaning the priority to keep loss at +/- 0.2dB could be challenging. This specification may need to be tweaked later on. Phase difference is also not the most important factor in the functionality of this coupler, so its goal weight will also be lowered. Optimization goals can be found below:

Optim Goal Input:8

ads_simulation:Goal Instance Name

pututDB2

Goal Information

Display

Expression: dB(S21)

Help on Expressions

Analysis: SP1

Weight: 1.0

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit2	>	-3.2		1.0	2.401G	2.495G

Optim Goal Input:8

ads_simulation:Goal Instance Name

pututDB3

Goal Information

Display

Expression: dB(S31)

Help on Expressions

Analysis: SP1

Weight: 1.0

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit1	>	-3.2		1.0	2.401G	2.495G

Optim Goal Input:8

ads_simulation:Goal Instance Name

PhaseP2

Goal Information

Display

Expression: unwrap(phase(S21))

Help on Expressions

Analysis: SP1

Weight: .5

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit1	Inside	-91	-89	1.0	2.401G	2.495G

Optim Goal Input:8

ads_simulation:Goal Instance Name

PhaseP3

Goal Information

Display

Expression: unwrap(phase(S31))

Help on Expressions

Analysis: SP1

Weight: .5

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit1	Inside	-181	-179	1.0	2.401G	2.495G

Optim Goal Input:8

ads_simulation:Goal Instance Name

returnLoss

Goal Information

Display

Expression: -1*dB(S11)

Help on Expressions

Analysis: SP1

Weight: 1.0

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit1	>	15		1.0	2.401G	2.495G

Optim Goal Input:8

ads_simulation:Goal Instance Name

Isolation

Goal Information

Display

Expression: dB(S41)

Help on Expressions

Analysis: SP1

Weight: 1.0

Sweep variables: freq

☒ freq

☐ time

Edit...

Limit lines

Name	Type	Min	Max	Weight	freq min	freq max
1 limit1	<		-30	1.0	2.401G	2.495G

Figure 3. Optimization Goals

An interesting problem arose trying to run the optimization as is. Because we had limited the phase on the output ports to be within a narrow band (Ex: 89-90 degrees), the optimizer focused on keeping phase close to that region. This cost major performance in almost all other specifications. Figure 4. depicts this problem.

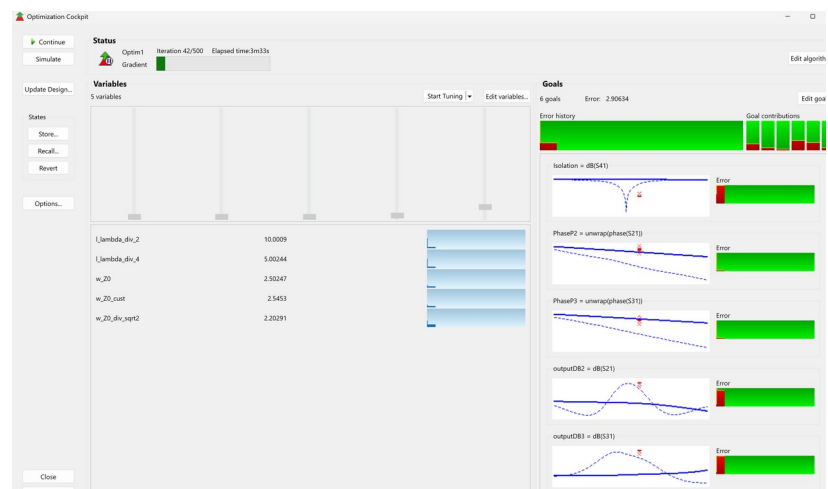


Figure 4. Initial Optimization Run

This can be easily fixed because the design specifies 90 degrees of phase difference, not specific phase bands the output needs to fall into. The new phase goal is depicted in Figure 5.

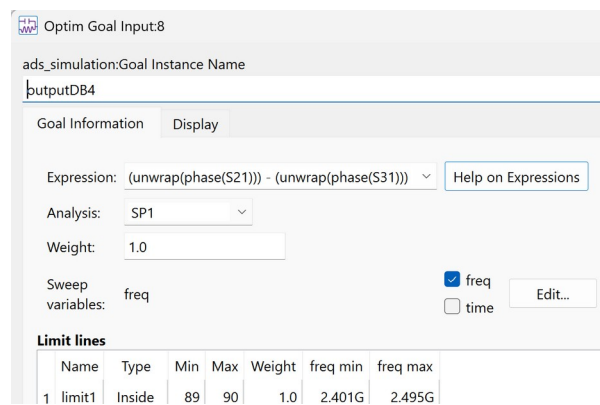


Figure 5. Improved Phase Goal for Optimization

This worked well and we produced a design very close to the design specifications.

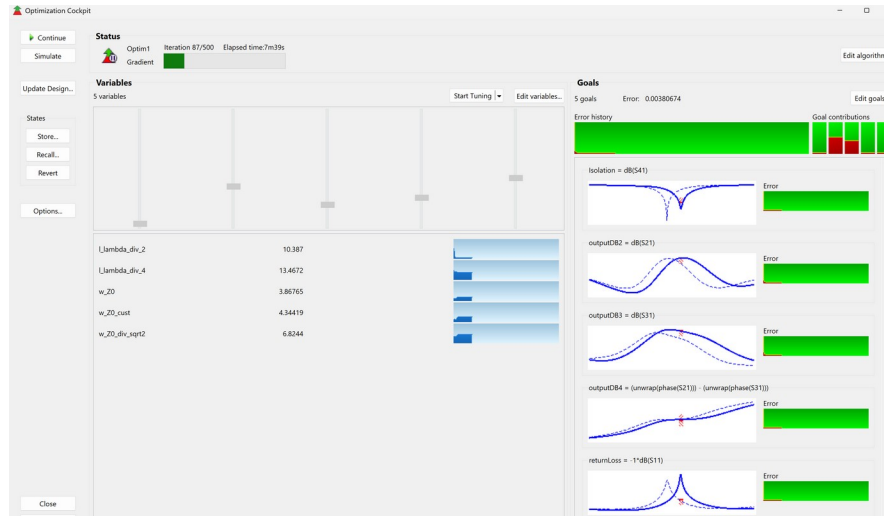


Figure 6. Improved Optimization Run

After updating design values, there were a few small discrepancies remaining between the physical design and the design specifications (Figure 7.). The total excess loss was still below the 3.2dB minimum for output ports 2 and 3. Unfortunately, this can only be amended by letting the output transmission line length decrease. Because the lines are lossy, they absorb power and contribute to excess loss. To maintain constructability, we have capped this length at a minimum of 10 mm.

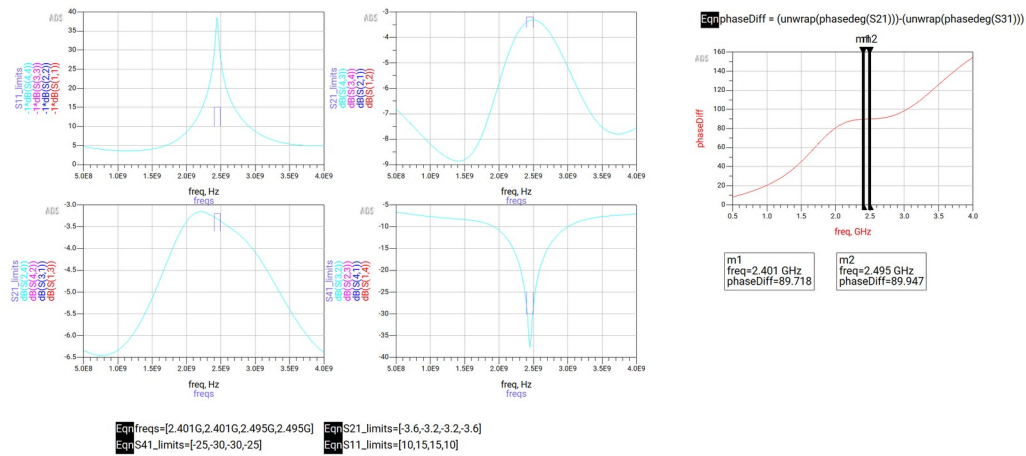


Figure 7. Post-Optimization S-Parameters

Amending the design specification to +/- 0.4 dB excess loss allows the design to meet spec. Furthermore, design values were rounded within the tolerance of the milling machine (0.1 mm), and the final S-parameter output can be seen in Figure 8.

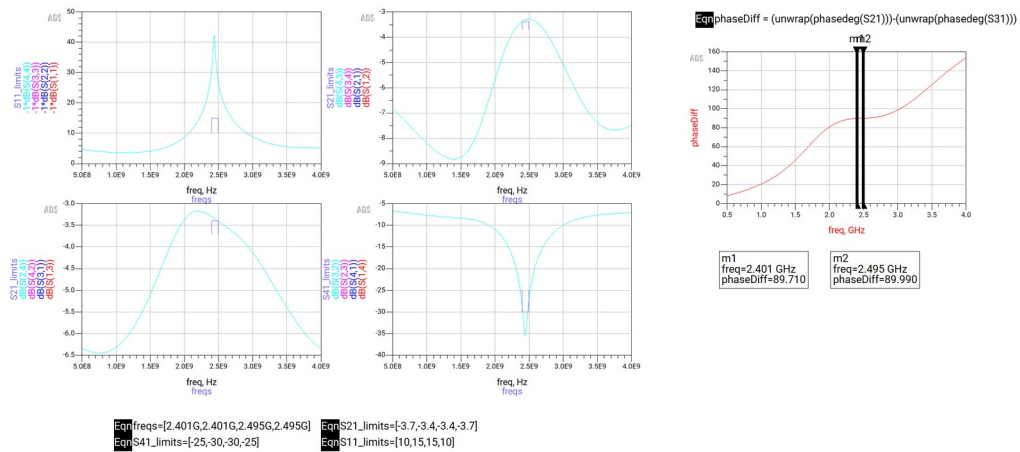


Figure 8. Component Performance with Rounded Values and Updated Design Specifications

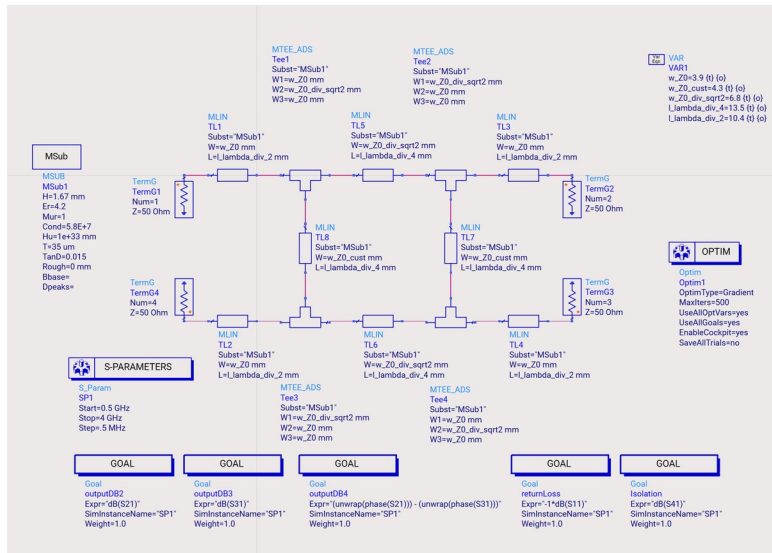


Figure 9. Final Design and Values