

# Lab 7

## Introduction/Background

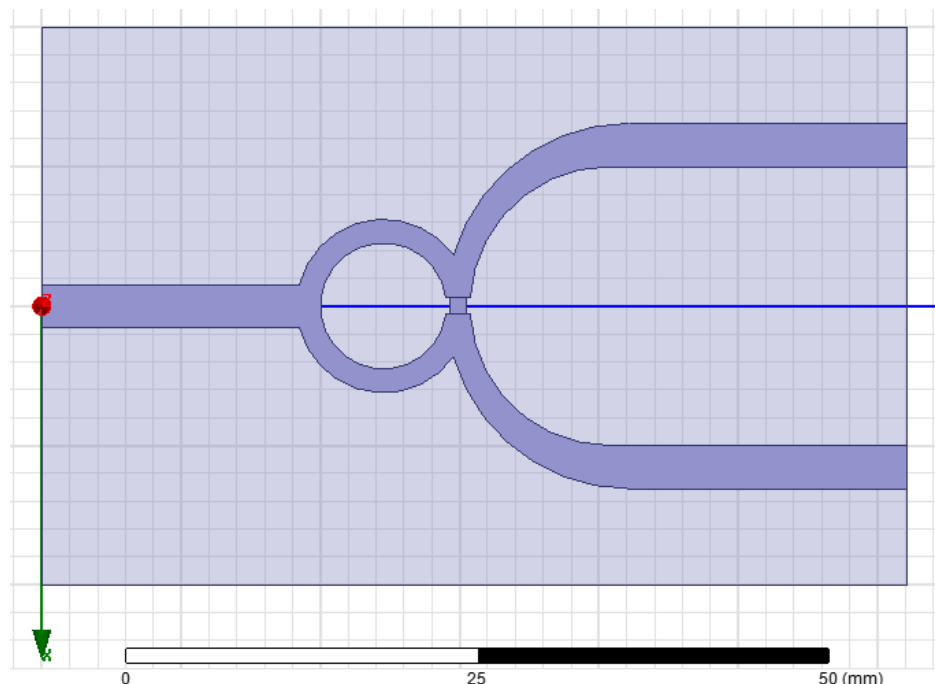
In this lab I worked with Matias Kalaswad and Matthew Walck. This includes pre-lab materials such as parameter calculations and HFSS simulations, as well as post-lab deliverables such as lab reports and plots.

This lab introduced us to different types of power dividers. The following four different types were simulated using Z0lver as part of a homework assignment: delta power divider, splitter, four-way splitter, and Wilkinson power divider. The basic function of power dividers is to split and input signal into two or more identical output signals.

## Design

The 90 degree phase shifter required  $1/8^{\text{th}}$  wavelength T-lines at each side of the thru length. We calculated a quarter wavelength which at 3 GHz is 14.06 mm, so the  $1/8^{\text{th}}$  wavelength is 7.03 mm long. The 180 degree phase shifter required a half wavelength overall so we added a quarter wavelength (14.06 mm) to both ends of the thru. Both designs had an impedance of 50 ohms which corresponds to a copper strip of length 3.1 mm.

The Wilkinson power divider also had a feed line with impedance 50 ohms (3.1 mm). The new frequency was 2.5 GHz so we calculated the quarter wavelength to be 17.4 mm. The line needed to have impedance equal to  $Z_0 * \sqrt{2}$  which was equal to 70.7 ohms. This value corresponds to a width of 1.65 mm. The length of the line was set to about 24 mm to get lower values of S11, S22, and S33.



Wilkinson Power Divider simulated in HFSS

Name	Value	Unit	Evaluated Value	Type
feed_line_width	3.1	mm	3.1mm	Design
QW_line_width	1.7	mm	1.7mm	Design
QW_line_length	16.88	mm	16.88mm	Design
Resistor	100	ohm	100ohm	Design

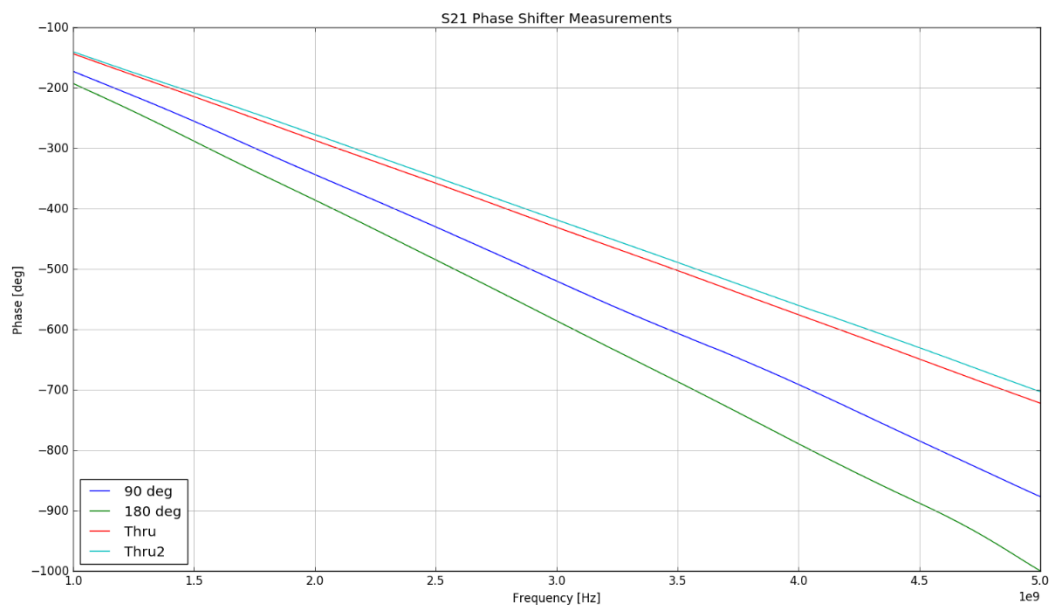
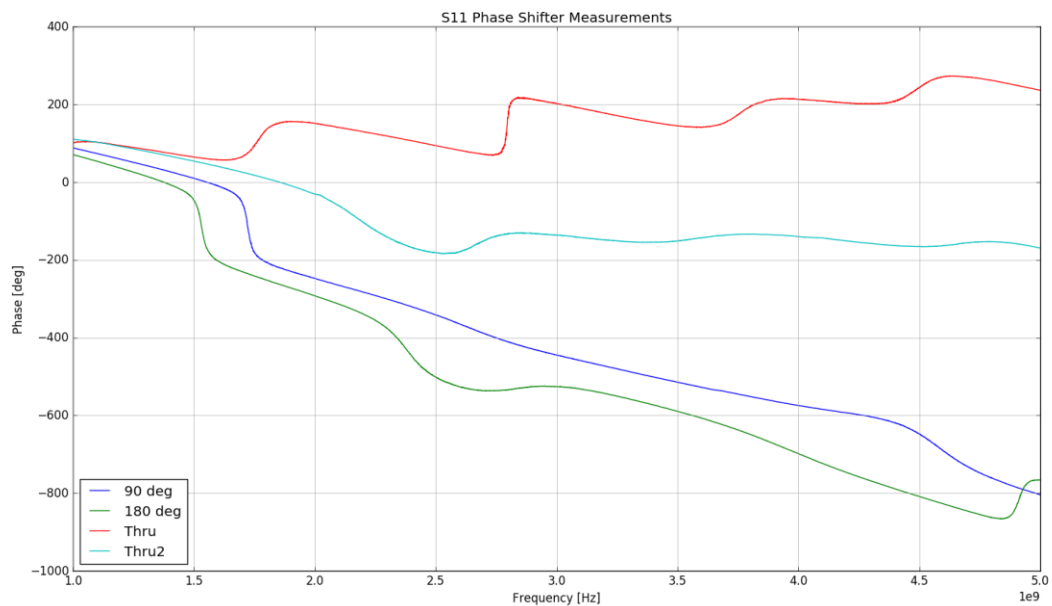
**Wilkinson Power Divider HFSS Parameters**

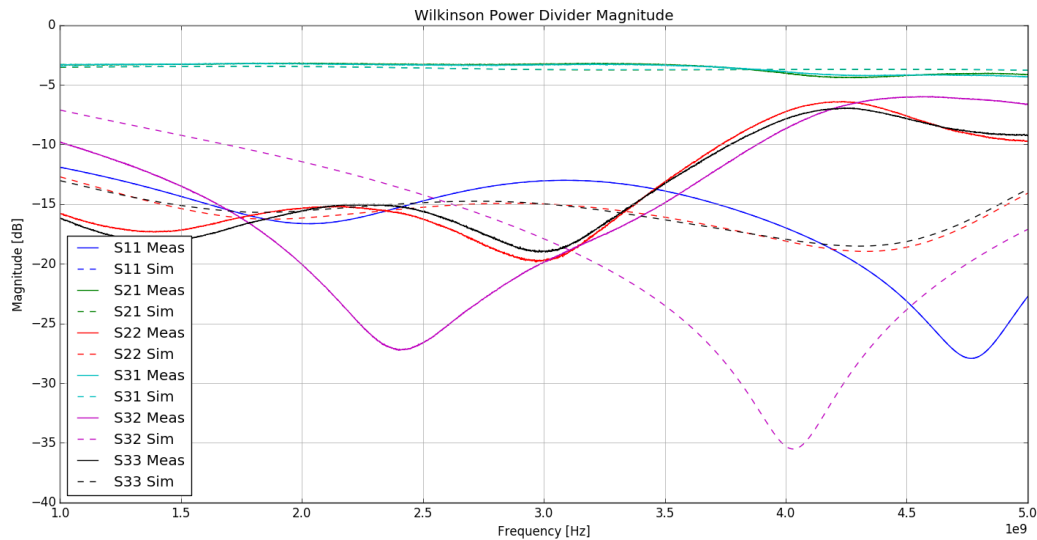
## In Lab Procedure

In lab we built a time delay shifter out of copper tape. This shifter had a 90 degree shift and a 180 degree shift, both of which required separate designs. There was a 50 ohm line with length similar to previous labs and we measured a reference phase of -429.5 degrees. The first delay path we made was for the 90 degree phase shift. We found a quarter wavelength to be 14.0364 mm which was the length of each path leg (the path looked like a boxy U so each “leg” refers to the two parallel sides of the U). There was a small separation between the 50 ohm line and the path legs so we had to solder across the gap to connect the path legs. When David measured our shift it showed to be -516.9 degrees which was approximately 88 degrees of phase shift. The second delay path was created in a similar manner but with lengths to create a 180 degree shift. This time the path legs were calculated to be 23.98 mm. Once the 90 degree path was removed and the 180 degree path soldered onto the 50 ohm line, David once again measured the phase shift. He had warned us ahead of time that the result would not be correct because there was a discontinuity when the shift was this high. The analyzer measured the phase to be -233.9 degrees which David told us to subtract 360 degrees from. The result was 593.9 degrees which from our reference phase was a shift of about 164 degrees instead of 180.

## Results and Discussion

The questions in the lab instructions are answered in this section. The resistor is necessary in the power divider to dissipate half of the input power. We could not see any major differences between THRU and THRU2. If we had time to make a new phase shifter we would have wanted to re-cut our copper strips to make them more accurate widths. We also would have obviously preferred to mill the design instead of cutting it by hand.





## Conclusion

The main point of this lab was to learn about the design of different power dividers and to practice constructing phase shifters. While there were some errors due to the poor connections with the copper tape, our measurements were fairly accurate. Our desired value for the 180 degree shift should have been closer to 609 degrees and we believe that if we had done this shift first it would have been more accurate. Since we had to remove and re-solder on the 50 ohm line, the second shifter was less accurate due to poor connection.

## Hindsight

We were thankful that David had warned us ahead of time that the 180 degree shifter would not work properly because otherwise we would have been very confused with the strange result. We believe it would have been beneficial for us to have done some research about phase shifters prior to completing the lab.

## Reflection

The most challenging part of this lab was getting the copper tape to stay on the board when we had to transition from the 90 degree to 180 degree shifter. The most rewarding part of this lab was getting to build two shifters and having them both work with decent accuracy.