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Lab 7

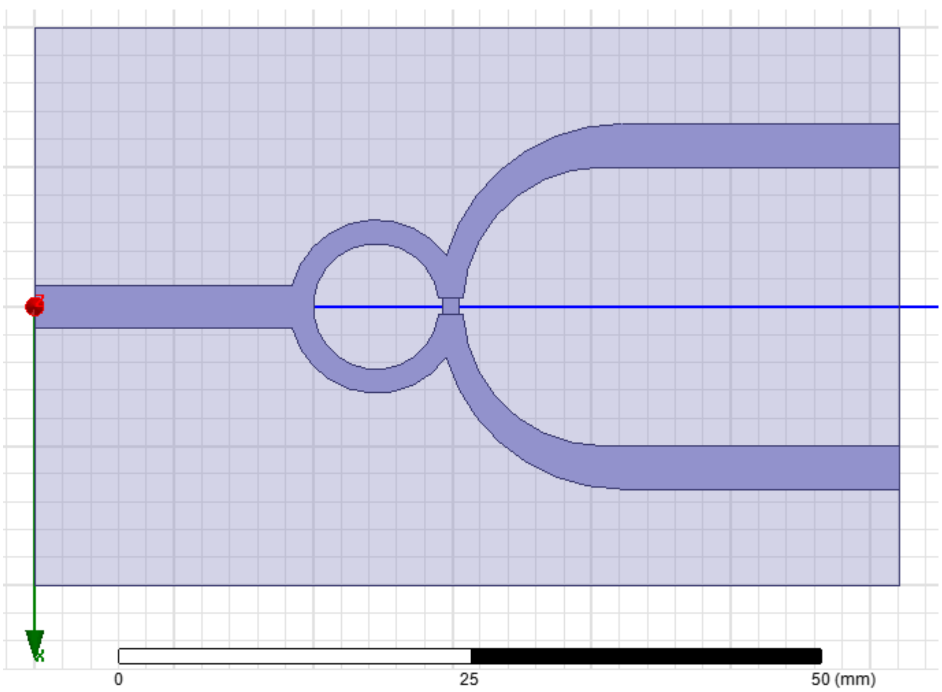
Introduction/Background

This lab introduced us to power dividers and phase shifters. The basic function of power dividers is to split and input signal into two separate signals, whereas a phase shifter's function is to change the phase of an input signal.

Design

In order to get a 90 degree phase shift, we needed to add a quarter wavelength to the path. We accomplished this by adding two 1/8th wavelength t-lines. We calculated a quarter wavelength which at 3 GHz is 14.03 mm, so the 1/8th wavelength is 7 mm long. In order to get 180 degrees of phase shift, we needed to add a half wavelength overall, so we added two quarter wavelength (14.03 mm) t-lines. Both designs had a Z_0 of 50 ohms which corresponds to a copper strip of length 3.12 mm.

The Wilkinson power divider also had a feed line with impedance 50 ohms (3.12 mm). The frequency we were looking at was 2.5 GHz, which equates to a quarter wavelength of 16.9 mm. The line needed to have impedance equal to $Z_0 * \sqrt{2}$ which was equal to 70.7 ohms or a line width of 1.68 mm.



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

We built the phase shifter in lab out of copper tape. The first step was to simply lay down the Thru line and measure its phase shift as a reference (-429.5 degrees). After we had that, we built the 90 and 190 degree phase shift sections.

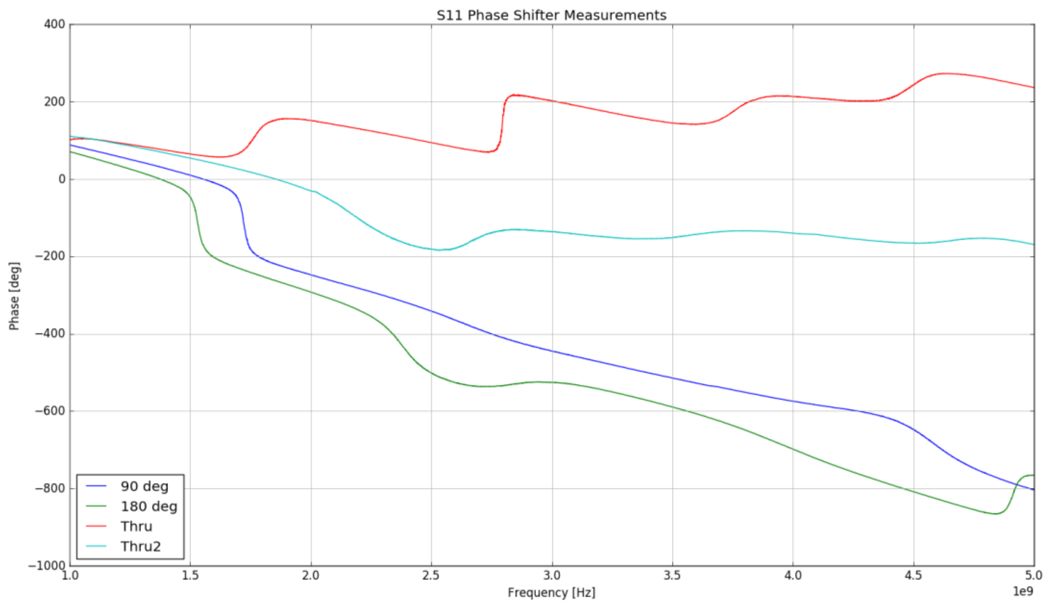
For the 90 degree phase shift, we added measured and added two 1/8th wavelength lines perpendicular to and on the same side of the Thru line and connected them by a line parallel to the Thru line. This gave us, when the perpendicular lines were connected and the center of the Thru line was disconnected, a path ¼ wavelength longer than the original Thru line.

For the 180 degree phase shift, we added measured and added two 1/4th wavelength lines also perpendicular to the Thru line, but on the opposite side of the Thru line to the 90 degree phase shift path, and connected them by a line parallel to the Thru line. This gave us, when the perpendicular lines were connected and the center of the Thru line as well as the 90 degree phase shift path were disconnected, a path ½ wavelength longer than the original Thru line.

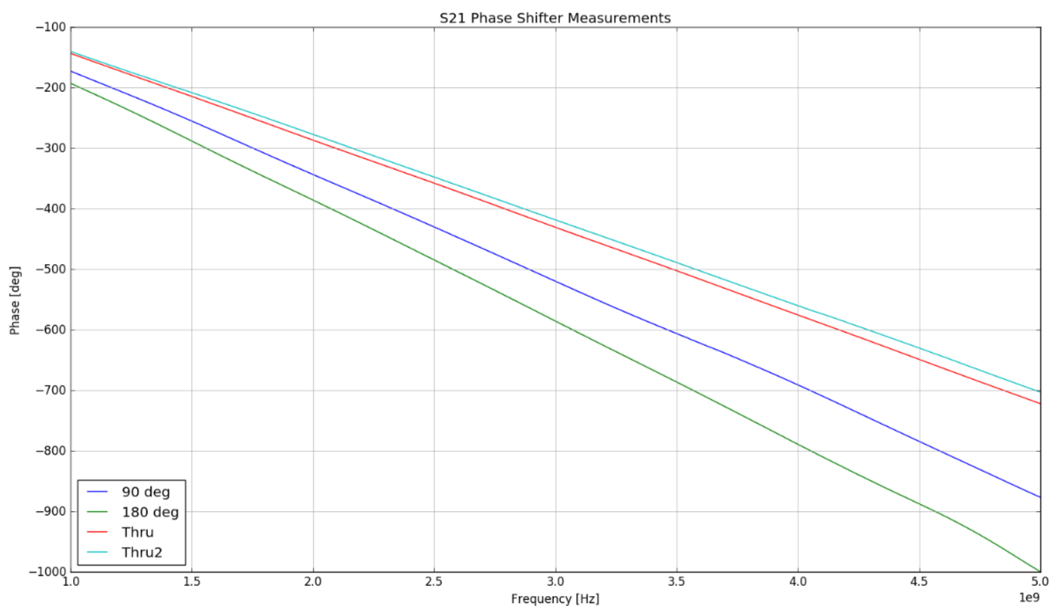
We then measured the two added paths by soldering one to connect it to the Thru line (and cutting the Thru line to remove the middle section surrounded by the two phase shifted paths) connecting it to the network analyzer, then removing the solder and connecting the other path and measuring it (so no two paths were connected at the same time). The results of the 90 degree phase shift line was -516.9 degree, or an 88 degree shift. The results of the 180 degree line was -233.9 degrees, which was equivalent to -593.9 degrees due to the network analyzer wrapping the graph. This is a phase shift of 164 degrees. We could have improved this shift by lengthening the perpendicular ¼ wavelength lines slightly.

Results and Discussion

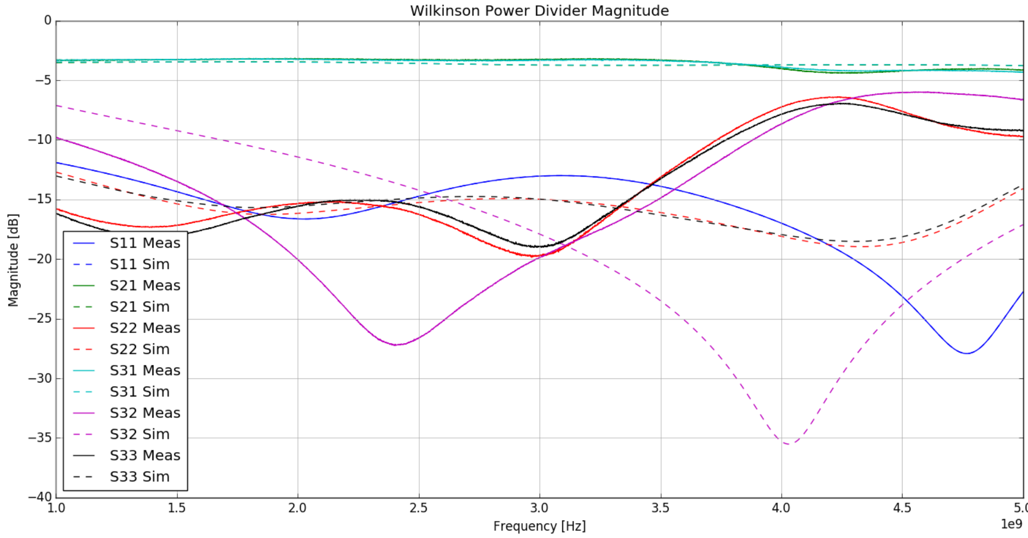
The questions in the lab instructions are answered in this section. The resistor is necessary in the power divider to dissipate half of the input power. We could not see any major differences between THRU and THRU2. If we had time to make a new phase shifter we would have wanted to re-cut our copper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



The addition of the extra lines caused there to be some phase shift in the reflection from the Thru.



The addition of the extra lines slightly shifted the phase of the S21 measurement of the Thru.



We can see that the S21 and S31 lines of our simulation are both at -3 dB, which is what we were expecting (and also what was measured on the milled power divider)

Conclusion

This lab served to introduce us to the design of power dividers and phase shifters. It cemented our previous classroom education on those designs by allowing us to actually sit down and experiment with the devices (either with copper tape and substrate or HFSS simulations). Our results from the in lab portion of this assignment was somewhat off from the design goals, but overall the results were fairly close for hand cut copper tape. We seemed to have cut the 180 degree phase shift line a little too short.

Hindsight

We were thankful that David had warned us ahead of time that the phase of the 180 degree line would be wrapped, and thus not appear correct at first glance, on the network analyzer.

Reflection

The most challenging part of this lab was connecting and disconnecting the lines when measuring each line. The most rewarding part of this lab was getting to first phase shift so close to what we were trying to get.