

## Wireless Local Area Network Lab 4 Couplers and Power Dividers

### Objective:

Design, layout and simulate a T-junction, Wilkinson, and Quadrature Coupler  
Build and test EITHER a T-junction or a Wilkinson power divider.  
Measure a Quadrature Coupler (especially observe the phase response)

### Prelab:

- 1) Read Pozar, Chapter 7 so that you understand power dividers and 4-port couplers.
- 2) Prepare three designs for simulation in the lab. Do all of the “book design” before coming to lab. You will do the layout and simulation in ADS in the lab. The three designs are:
  - a. A T-junction 3-dB power divider with quarter wave transformers on ports 2 and 3 to match the output ports to 50 ohms for frequencies of  $f_1 = 5.4$  GHz and  $f_2 = 5.6$  GHz (p.315).
  - b. A Wilkinson 3-dB Power divider with inputs and outputs of 50 ohms at 5.5GHz (p. 318).
  - c. A Quadrature coupler with 50 ohm inputs and outputs (p. 333).
- 3) Write a Matlab<sup>TM</sup> program to calculate the width of microstrip needed for a given impedance  $Z_0$ . Use equation (3.197) in your text to compute the width of the microstrip,  $W$ . The relative permittivity of the Rogers RO4350 substrate material ([www.rogerscorporation.com](http://www.rogerscorporation.com)) is  $\epsilon_r = 3.38$ ,  $\tan\delta = 0.0035$ . The conductivity of copper  $\sigma_c = 5.81 \times 10^7$  S/m. The copper thickness = 35  $\mu$ m.
- 4) The thickness of the substrate is  $d = 30$  mils (million of an inch).
- 5) Write a Matlab<sup>TM</sup> program to calculate the wavelength in the microstrip. Use equation (3.195) to compute the effective relative dielectric constant,  $\epsilon_e$ . This value accounts for the fringing of the electric fields in the air about the microstrip and should always be less than  $\epsilon_r$ . Then compute the wavelength in the microstrip using  $\lambda_e = \frac{c}{f\sqrt{\epsilon_e}}$  (m). Use this wavelength when calculating the length (in mils or meters) of the quarter wave transformers in your coupler designs.

### Procedure

#### Equipment:

HP8510C Network Analyzer  
Circuit board holder and TRL calibration kit centered at 5.5 GHz

#### Simulation, Preparation for Milling:

#### T-Junction power splitter:

1. Simulate the 3dB T-power splitter as described in the text (p.315) for the frequencies of 5.4 and 5.6 GHz where the input line is 50 ohms. Look at the match at each port to note the resulting mismatch for 50 ohm loads on ports 2 and 3.
2. Add the quarter-wave matching sections for the output ports  
Simulate the two quarter-wave matching sections for the output ports. Use the top output port for 5.4 GHz, and the bottom for 5.6 GHz.
3. Note that even though the design of the power splitter has 100 ohm lines, the length of these lines can be ZERO. You will not need to mill any 100 ohm lines.
4. Verify that the design is a 3-dB splitter at 5.4 and 5.6 GHz (S12,S21,S13,S31, etc)
5. Verify that it is matched on all ports (S11, S22, S33)
6. Save your data from ADS, so you can compare it with measured values.

### Wilkinson power divider

1. Simulate the 3-dB Wilkinson power divider. Verify that the design is a 3-dB splitter at 5.4 and 5.6 GHz (S12,S21,S13,S31, etc.)
2. Verify that it is matched on all ports (S11, S22, S33)
3. Save your data from ADS, so you can compare it with measured values.
4. A note on layout for the Wilkinson power divider: The size of the resistor is 012-06, which means the resistor is 12 mil long x 6 mil. The space between the two arms of the Wilkinson Power Divider.

### Quadrature coupler

1. Simulate the quadrature coupler at 5.5 GHz, but instead of the  $\frac{Z_0}{\sqrt{2}}$  sections use just  $Z_0$ .
2. Plot transmission and reflection coefficients on each port to evaluate the match (which shouldn't be as good as for the correct design). Notice the response for the isolated port. Create a new simulation with correct values calculated for  $Z_0$ .
5. Verify that it is matched on all ports (S11, S22, S33)
6. Save your data from ADS, so you can compare it with measured values.

### Circuit Fabrication

**Discuss with your TA which power divider (T or Wilkinson) your group will fabricate.**

#### Layout Size Constraints:

- a. *Distance between output ports:* Adjust the distance between the output ports so that it can be held in the circuit board holder. When using this circuit with the test holder, the centers of the output lines need to be 2.54 cm (1000 mil= 1 inch) apart. Make sure that your circuit conforms to this separation so that

you can match one output port while finding the S-parameters for the other port using the network analyzer.

- b. **Add a length of at least half of the THRU calibration** to each input and output line, to account for the location of the measurement plane after calibration.
- c. *The total length of the circuit* should not exceed 2000 mils.
- d. *Convert your design to a layout and verify the layout on ADS.* Adjust the lengths, sizes, etc. as needed.
- e. Export your layout as a Gerber file. Rename the .gbr file to a group name to keep each group separate and give a copy to the TA. (disk, zip drive, email)

### **Measurements:**

The quadrature coupler design will be the same for all students. Pre-fabricated boards will be supplied for measurement.

To measure the quadrature coupler:

1. Calibrate the network analyzer using a Full Two-Port cal. This will require the 3.5mmD calibration standard set. Have your TA show you how to perform the CAL. Notes on how to do this are on the lab website as supplement to this lab.
2. Attach two ports of the circuit to the cables of the analyzer. Match the “loose” ports by screwing a 50 ohm termination to those connectors.
3. View the S parameters on the network analyzer and capture the response into ADS to compare with simulation.
4. Repeat measurements and capture for S11, S12, S13 and S14. You will have to attach the cables and terminations onto different ports in order to make all the measurements.

**At this point you will need to wait for the fabricated T or Wilkinson circuit to be returned to you. This is the end of the lab for this week.**

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### **When your circuit is returned:**

#### **Measurements continued:**

Perform measurements of the power-splitter you fabricated using the test jig.

- a) Perform a TRL calibration.
- b) Measure and capture the responses of S11, S12 and S13 by terminating the extra port and swapping the cable arm connectors.

### **Analysis and Write up:**

1. Plot your network analyzer results against your ADS results on the same graph, one for each type of power divider.
2. Draw conclusions: How well matched are all of your ports? Did the power divider function as expected? What losses were observed? (Where did this power go?)

3. Include your observations from each section of the lab.
4. Describe (in your intro and conclusion and elsewhere if applicable) how this lab fits within the design of the FSK system.