UNIVERSITY OF UTAH
ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

ECE 5320/6322 LABORATORY #3

DESIGN AND TESTING OF MICROSTRIP COUPLERS

Introduction and Goal

Couplers are used in microwave circuits for the purpose of dividing and combining signals in transmission lines or sampling the signals. You should always remember that power conservation in a lossless multi-port requires a "unitary" scattering matrix ($S^{*T}S = 1$) and that one result of this is that **all lossless, perfectly matched 4-ports are directional couplers.** In this case, it is always possible to identify the ports as (1) "input", (2) "through", (3) "coupled", and (4) "isolated".

There are only two possible types of lossless, perfectly matched 4-ports. Both have the same general matrix structure of zeros on both diagonals so that the input signals always combine in pairs to form the outputs (See p. 312). In one case, the combinations are 90º out of phase (related by "j") and, in the other, they are just signed "±" (0 or 180º phase relation). When the coupling is 3 dB (i.e., a power divider), these two type couplers are called "90º hybrids" or "180º hybrids".

The **goal** of this lab is to implement and simulate the design of three common microstrip couplers and to build and test one of them.

Preliminary Designs

Before this lab, you should read Pozar, Chapter 7 so that you understand 4-port couplers and then prepare three <u>electronic designs</u> for simulation in the lab. The three designs are (1) a (90º hybrid) branch line coupler (p. 333), (2) a 10 to 20 dB parallel line coupler (p. 337-345), and (3) a 180º hybrid ring coupler (p. 353, sometimes called a "rat race"). You should note from your reading that the standard parallel line coupler cannot be implemented as a 3-dB coupler because the coupling mechanism is relatively weak. The "Lange" coupler (p. 349, which we cannot build because we do not have the wire bonding tools required) is designed to overcome this problem. You should attempt a 10 dB parallel line coupler and see what happens to the line separation distance. Then adjust the coupling value until it can be built in our microstrip media. (The minimum separation we can achieve and still keep the edges of the coupled microstrips straight and parallel is about 9 mils.)

Although it is good to understand how the physical line dimensions can be determined from design formulas such as equations 3.195-6 (pp. 145, 146) and figure 7.30 (p. 340), it is much more accurate to use LINECALC in the lab. If you select the coupled line element "MCLIN" in LINECALC, you can use your electrical design, including the even and odd characteristic impedances, to compute the physical dimensions of the parallel coupled lines.

If you have access to the lab before your specific time, you are welcome to get started on the physical design and simulation.

Laboratory Procedure

In Lab 3 you should proceed as follows:

1. Use your electrical designs for the three couplers in LINECALC to obtain the physical dimensions required for ADS simulations. Select a center band of 2.45 GHz (802.11 b/g bands) for your designs and make sure that the parameters in LINECALC reflect this frequency.

2. Use ADS to simulate the design of each coupler. Adjust the designs as required to obtain the desired performance around center band. Be sure to collect the printouts needed to demonstrate that the designs are working as desired to document your work for your report.

   As a part of Steps 1 and 2, study the effects of the following using ADS circuit simulations.

   a. The effect on S_{11}, S_{12}, S_{13}, and S_{14}, of using all branches of characteristic impedance $Z_o = 50\Omega$ in the **branch line coupler** of Fig. 7.21 on p. 333 of the text instead of $Z_o/\sqrt{2}$ or 35.36Ω for two of the branches. Note that the circuit is no longer well matched $(S_{11} \approx 0)$ at any of the frequencies. Compare the S-parameters thus calculated with those of a properly designed branch line coupler (similar to those given in Fig. 7.25 on p. 336 of the text).

   b. The effect on S_{11}, S_{12}, S_{13}, and S_{14}, of using the ring as well as all input/output ports of characteristic impedance $Z_o = 50\Omega$ for a **ring hybrid** coupler instead of the ring of characteristic impedance $\sqrt{2}\, Z_o = 70.7\Omega$. Compare the S-parameters thus calculated with those calculated for a properly designed ring hybrid coupler (similar to those given in Fig. 7.46 on p. 357 of the text).

   c. Using ADS software, calculate and tabulate the spacings S needed for 20, 10, 6, and 3 dB parallel line couplers. (Do you find any calculation error at 6 and 3 dB?) In particular, answer the following questions:

      (1) Is it possible to get a 3 dB coupler using coplanar coupled microstrips geometry?
      (2) What is the maximum coupling possible for a parallel line coupler using a spacing $S \to 0$ for coplanar coupled microstrips?

3. Select one of the coupler designs for implementation in microstrip and then reduce its simulation schematic to a layout drawing and transport the result to AutoCAD. In AutoCAD you will need to connect the four ports of your coupler to the template positions which will make the circuit fit nicely into the microstrip test adapters. If you do not use this template to get the connector spacing correct, you will not be able to test your circuit. (Ask TA for help on Auto CAD.) In the case of the ring coupler, it is OK to make the circuit wider than the template between the two connector ends. Make sure your name or ID is on your mask.

4. When your microstrip circuit is returned, you will need to test its performance and compare the results to the ADS simulation. To save time, it will be sufficient to select one port as the input port and to make 2-port NA measurements to the remaining three ports. Remember

that this requires all ports to be terminated with a matched load! This is where our present measurement system is inadequate. We will have to assume that the scattering errors introduced by our coax-to-microstrip adapters are insignificant because we do not have any microstrip loads. The loads we will need to use are in the coax calibration kit and thus the microstrip adapters remain as part of the circuit to be measured. Draw out the resulting measurement schematic in your report and explain why this is a source of error in your measurements.

Before changing any coax connections, you will need to listen to instructions from your TA on how this is to be done. The main thing to avoid is connector damage due to misalignment and over tightening. Also, you should never tighten a cheap SMA connector into one of our precision 3.5 mm connectors due to the possibility of damage. The precision 3.5 mm connectors (~ $100 each) on the NA and test adapters are designed to be connected thousands of times without connector damage (if done correctly) while cheap SMA connectors (~ $10 each) are designed to go together a few times and rely on crushing to make a good connection.

5. After the coupler measurements are complete, you will need to recalibrate your microstrip test adapter because the original calibrated coaxial connectors were disconnected. Ask your TA to help you do this, and in any case, make sure you get to see this process because it is so crucial to using the NA. Then, if you have a circuit from a previous lab that needs to be measured and compared to its ADS simulation, you can complete this work.

Write-Up

Report for Lab 3 should be written according to the format used for the previous two experiments. Hole-punch your report and put it in a three-ring binder. After it is organized and documented so that it reads like a report, staple it together in the upper left-hand corner and turn it in to your TA for grading. Use a three-ring binder to store your lab reports so that they can be reviewed together, if necessary, at the end of the semester.