ELC 4383 RF/Microwave Circuits I
Laboratory 7: Microstrip Coupled-Line Coupler

Note: This lab procedure has been adapted from a procedure written by Dr. Larry Dunleavy and Dr. Tom Weller at the University of South Florida for the WAMI Laboratory. It has been modified for use at Baylor University.

Printed Name:_____

Please read the reminder on general policies and sign the statement below. Attach this page to your Post-Laboratory report.

General Policies for Completing Laboratory Assignments:

For each laboratory assignment you will also have to complete a Post-Laboratory report.   For this report, you are strongly encouraged to collaborate with classmates and discuss the results, but the descriptions and conclusions must be completed individually. You will be graded primarily on the quality of the technical content, <u>not the quantity</u> or style of presentation. Your reports should be neat, accurate and concise (the Summary portion must be less than one page). <u>Laboratory reports are due the week following the laboratory experiment</u>, unless notified otherwise, and should be turned in at the start of the laboratory period.   See the syllabus and/or in-class instructions for additional instructions regarding the report format.

This laboratory report represents my own work, completed according to the guidelines described above. I have not improperly used previous semester laboratory reports, or cheated in any other way.

Signed: _____

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Laboratory Assignment:

Overview

In this laboratory assignment, you will calculate the necessary geometry for a coupled-line coupler using the Linecalc simulator in ADS. You will then measure the S-parameters of a microstrip coupled-line coupler with a two-port vector network analyzer by using the two ports of the VNA and two 50-ohm terminations. You will make observations about how accuracy of the simulation can be improved by adding corner and line elements to the simulation circuit.

Procedure

A. ADS Simulation of Coupled Microstrip Lines

1. Open the Linecalc software within ADS. You will use Linecalc to synthesize coupled microstrip lines with the following substrate parameters: h = 1.58 mm, t = 0.035 mm, ε_r = 4.3, tand = 0.02. Your design frequency will be 2 GHz.

2. In the Component area, select the Type as MCLIN. This stands for "Microstrip Coupled Lines." This will allow you to calculate line width, length, and separation depending on the characteristic impedance, electrical length, and coupling factor, or vice versa.

3. Enter the above substrate parameters in the Substrate Parameters window. Set the Frequency to 2 GHz.

4. In the bottom right side of the window, you will see ZE (even mode characteristic impedance), ZO (odd mode characteristic impedance), Z0 (characteristic impedance), C_DB (the coupling coefficient in dB), and E_Eff (electrical length). You must enter the electrical length (quarter-wave) and one of two of the following choices: (1) ZE and ZO or (2) Z0 and C_DB. The parameters not entered will be automatically calculated. For example, if you enter Z0 and C_DB, the values of ZE and ZO will be calculated and vice versa. Note: The value of C_DB will be negative.

5. Perform appropriate syntheses to fill in the following table, finding the values of separation, line width, line length, and even and odd mode characteristic impedances for the listed coupling values:

Coupling Value (dB)	S (mm)	W(mm)	L (mm)	ZE (Ω)	ZO(Ω)
-10					
-12					
-14					
-16					
-18					
-20					

Table 1: Coupled line coupler values and dimensions

6. Create a new ADS schematic called "lab7_10db.dsn".

7. Add an MSUB element to the schematic with the same parameters used above.

8. Add a microstrip coupled-line element by going to the Tlines – Microstrip palette and selecting the MCLIN element. Place the element in the schematic and double-click to open its parameter window. Set the values for W, S, and L according to the calculated results for the **-10 dB** coupler in Table 1.

5. Place a port at each corner of the MCLIN element; place Port 1 on the upper left (input), Port 2 on the upper right (through), Port 3 on the lower left (coupled), and Port 4 on the lower right (isolated). Your schematic should look similar to the schematic in Figure 1. Save your design.
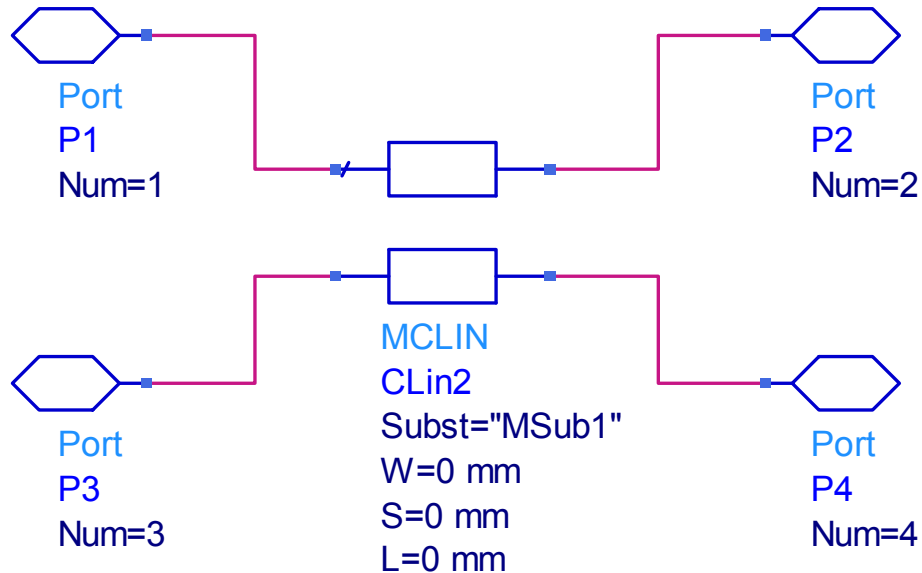
Port
P1
Num=1

Port
P2
Num=2

MCLIN
CLin2
Subst="MSub1"
W=0 mm
S=0 mm
L=0 mm

Port
P3
Num=3

Port
P4
Num=4

Figure 1: Coupled Line Schematic

9. Now save your design as "lab7_20db.dsn". Edit the parameters of the MCLIN element to match the W, S, and L values for the **-20 dB** coupler from the table in step 5.

10. Create a higher-level schematic and title it as **"lab7_lab"**. Place a reference to the lab7_10db and lab7_20db schematics into the higher-level schematic. Add an S-parameter simulation control block to the schematic. Set the frequency sweep to go from 0 to 6 GHz and 401 points.
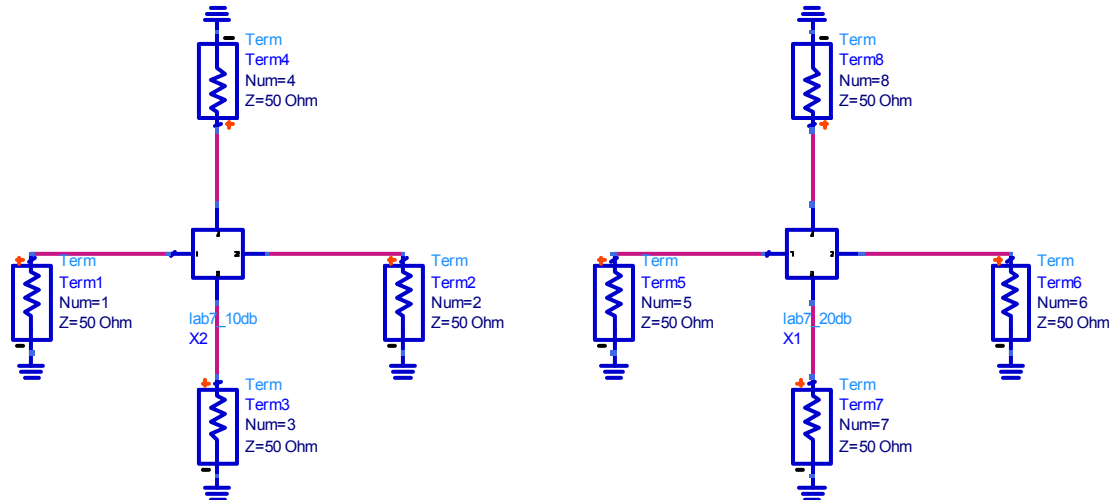
Figure 2: 20dB and 10dB coupled line coupler higher level schematic

11. Generate a plot for each coupler showing S11, S21, S31, and S41 (reflection, through, coupling and isolated) in dB.

B.   Increasing Simulation Complexity to Account for Discontinuities

In this section, additional elements will be added to the -20 dB coupler schematic to make the simulations more realistic. These elements will account for the discontinuities that occur at the four ports of the circuit, because the coupled lines must be separated at some point during practical implementation.

1. Using Linecalc, calculate the width of a 50 ohm microstrip line (MLIN) with the same substrate parameters that were used in the above section.

2. Open the "lab7_20db.dsn" file and save it as "lab7_20db2.dsn". Delete the four existing port elements. Go to the Tlines-Microstrip palette and select the MCORN (90 degree microstrip bend) element. Place a copy of the MCORN in the schematic and assign the width of the 50 ohm line to the W parameter for the MCORN. Set the MSUB parameter to MSUB1. Now select an MLIN element and place it in the schematic. Set the W parameter to represent a 50 ohm line and set L to 5 mm.

3. Arrange the lab7_20db2 schematic so that each port of the MCLIN element has an MCORN, a 5mm, 50-ohm MLIN, another MCORN element, and another 5 mm 50-ohm MLIN followed by a port as shown below in Figure 3. Assign ports 1 through 4 the same as in the previous section. Obtain a printout of the schematic for your report.
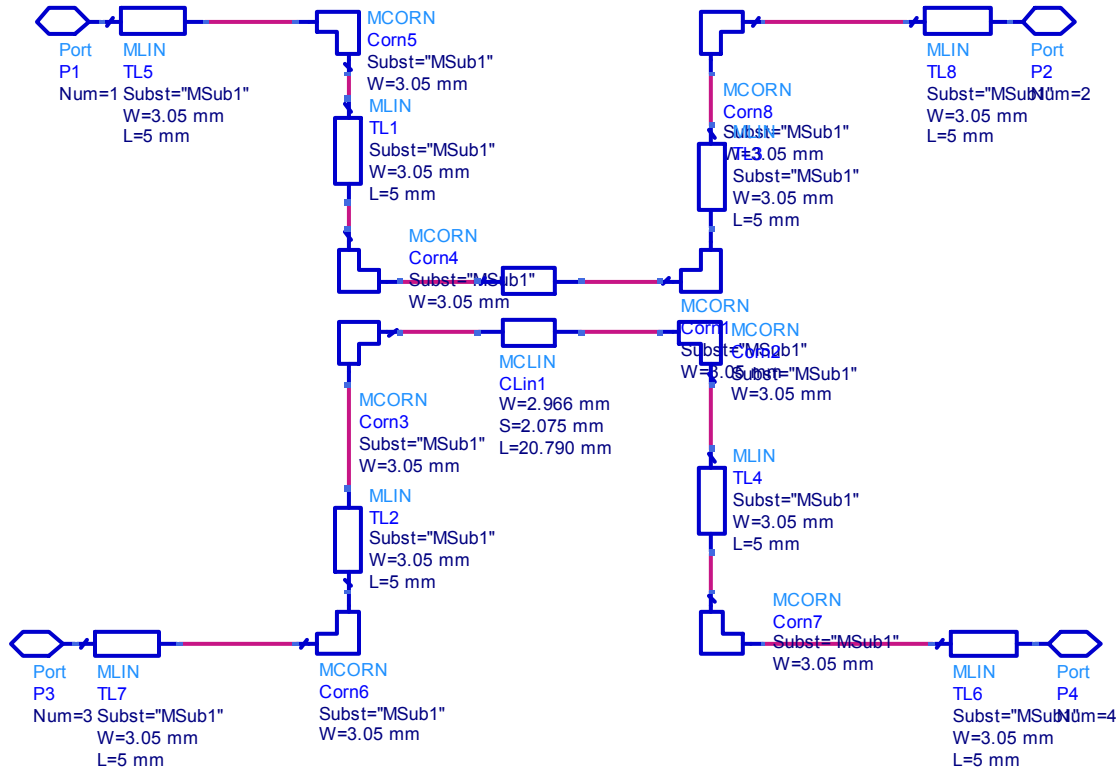
Figure 3: Complex coupled line coupler schematic

4. Reopen the lab7_lab schematic. Add a reference to the lab7_20db2 schematic and perform a simulation. Generate a plot that contains S11, S21, S31, and S41 for this design and obtain a copy of the plot for your report.

C. Microstrip Coupled-Line Coupler Coupler Measurements

A -20 dB coupler has been fabricated for measurement. In this section you will perform measurements to obtain the S-parameters of the coupler.

1. Calibrate the VNA from 100 kHz to 3 GHz. You should have one coaxial cable connected to each port of the VNA. <u>Also, place a 10 dB attenuator at the end of the cable that is connected to the transmission port of the VNA. Keep the attenuator in place during the transmission calibration and for your measurements.</u> This will minimize errors caused by reflections that occur due to the cable itself. Perform both a transmission calibration and a reflection calibration.

2. Connect 50 ohm terminations to Ports 2 and 4 of the coupler. Measure S11 and S31 using the VNA. Find the frequency range over which the coupling varies by less than +/- 1 dB about the nominal coupling value. Choose the "nominal coupling" value as the 2 GHz value. Enter these frequency values below:

F_low (GHz) = _____   F_mid (GHz) = 2 GHz

F_high (GHz) = _____

3. Connect 50 ohm terminations to Ports 2 and 4. This will allow you to measure S11 and S31. Fill in the appropriate entries. Use the values of F_low and F_high obtained in the previous step.

4. Connect 50 ohm terminations to Ports 1 and 4. Measure S22 and S32 using the VNA. Fill in the appropriate table entries. Use the values of F_low and F_high obtained in the previous step.

Note that Port 1 is the input port, Port 2 is the through port, Port 3 is the coupled port, and Port 4 is the isolated port. A diagram can be found in the Pozar text.

Ports 3 and 4 matched		F_low (GHz)	F_mid (GHz)	F_high (GHz)
	S11 (dB)			
	S21 (dB)			
Ports 2 and 4 matched				
	S11 (dB)			
	S31 (dB)			
Ports 2 and 3 Matched				
	S11 (dB)			
	S41 (dB)			

5. Save .s2p data for all 4 s-parameters for the -20dB coupler.

Report

Your report should contain the following:

1. A Summary of the laboratory assignment

2. Discussion of Results answering the following questions:

   A. Observing the trends in the Linecalc results, discuss changes in the microstrip coupled line geometry as the coupling value decreases from -10 to -20 dB.

   B. For the -10 and -20 dB microstrip coupled-line couplers, comment on the effect that increasing the coupling from -20 to -10 dB has on the input reflection coefficient (S11) and the isolation (S41) at 2 GHz.

   C. For the -20 dB coupler, what effect (in general) did including the MCORN and MLIN elements at the output ports have on the S-parameters? Specifically, which S-parameters were most affected?

    D. For your coupler measurements, what was the highest value of in-band S11 (worst-case reflection)? What was the highest value of mid-band S41?

3.   A copy of a plot containing the 4 S-parameters for the -10 dB and -20 dB coupler (1 plot for each coupler)

4.   A copy of the ADS schematic with MCORN and MLIN elements attached to each port

5.   The ADS plot with MCORN and MLIN elements attached to each port

6.   Data plots from the network analyzer (via .s2p files or other means)

7.   The laboratory write-up with all tables completed