ESE 4330, Fall 2025

ADS Project 1 Branch-Line & Rat-Race Couplers

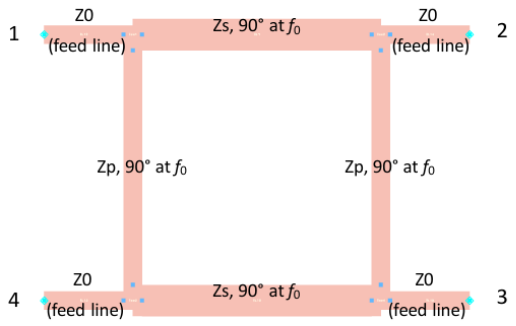
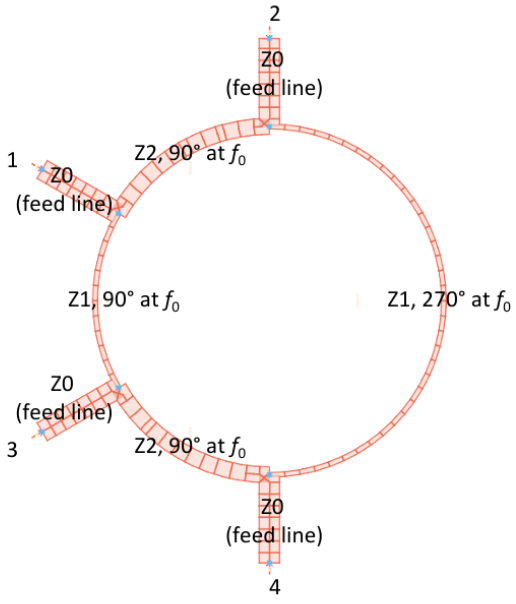
Due 10/27 (11:59 pm CT)

The goal of this project is to successfully design a 50ohm Branch-line coupler and a rat-race coupler using EM simulation in ADS.

1. Design the branch-line coupler depending on your group number, shown below. Describe your step-by-step design procedure in detail. You can use the design formulas provided here. Note that a "x dB" coupler means dB(S31) is "– x dB".

   Group 1 and 2: 3dB branch-line fo = 2GHz. 6dB rat-race, fo = 3GHz

   Group 3 – 5: 6dB branch-line fo = 2GHz. 3dB rat-race, fo = 3GHz

Branch-Line Coupler for arbitrary coupling (3 dB case is shown in Fig. 7.21 of the textbook)	Rat-Race Coupler for arbitrary coupling (3 dB case is shown in Fig. 7.42(a) of the textbook)
	
$S_{21} = -j\frac{Z_S}{Z_0}, S_{31} = -\frac{Z_S}{Z_p}, S_{11} = S_{41} = 0$	$S_{21} = -j\frac{Z_0}{Z_2}, S_{31} = -j\frac{Z_0}{Z_1}, S_{11} = S_{41} = 0$

2. Perform ADS ideal circuit simulations for your coupler using ideal transmission lines (TLIN).
   a. Include all schematics for the branch line coupler and rat-race coupler. Plot magnitude of S-parameters (S11, S21, S31, and S41) in dB on the same rectangular plot. Frequency range is 1 GHz to 4 GHz. Repeat the same procedure for the rat-

race coupler. (Note: Use a Line Marker to display the values of all curves at a single frequency)

b. Plot the phase difference between the two outputs (S21 and S31) for the branch-line coupler in degrees. Repeat for the rat-race coupler (S21 and S31 as well as S24 and S34), as it is an antisymmetric coupler. Compare two couplers based on the phase difference of the signals at their output ports.

3. Perform ADS microstrip circuit simulations for your couplers in Part 2 by replacing ideal transmission lines with corresponding microstrip transmission lines (MLIN) and by including 50-Ω feed lines and junction discontinuities. Use the following substrate information (RO4003C).
   - Thickness (H)= 32 mil
   - Permittivity (εr)= 3.55
   - Loss tangent (TanD)= 0.0021
   - Copper thickness (T) = 35 um
   - Copper Conductivity (Cond)=5.8e7 (S/m)

   a. Include all schematics for the branch line and rat-race coupler. Plot the magnitude of S-parameters (S11, S21, S31, and S41) in dB on the same rectangular plot. Frequency range is from 1 GHz to 4 GHz.

   b. Plot the phase difference between two outputs (S21 and S31) for the branch-line coupler in degrees. Also, plot the phase difference of the microstrip rat-race coupler (S21 and S31 as well as S24 and S34). Compare two couplers based on the phase difference of the signals.

   c. Compare the microstrip simulation result for the branch-line coupler in this part with the corresponding ideal simulation result in Part 2 and comment on any discrepancy. If required, optimize your microstrip coupler. Repeat steps for the rat-race coupler.

4. Perform ADS Momentum simulations for the two microstrip couplers in Part 3. For the layout of rat-race coupler which includes meander lines, use "MCURVE" components and use "Edit->Advanced Rotate- >Rotate Relative" to rotate a component with an arbitrary angle. In this way, you can draw a meandered line. For the proper mesh, you may need to change "arc resolution" (EM Setup → Options → Preprocessor) from 45 degrees (default value) to 5 degrees.

   a. Provide the dimensions on the momentum layouts for the branch-line coupler. Plot magnitude of S- parameters (S11, S21, S31, and S41) in dB on the same rectangular plot. Frequency range is 1 GHz to 4 GHz. Do the same things for the rat-race coupler.

   b. Plot phase difference between two outputs (S21 and S31) for the branch-line coupler in degrees. Compare two couplers based on the phase difference.

   c. Compare the momentum simulation result for the branch-line coupler in this part with the corresponding microstrip simulation result in Part 4 and comment on any discrepancy. If required, optimize your layout. Do the same things for the rat-race coupler.

Report:

Number your answers according to your task. Use markers at important points of the graphs.
Make sure that your graphs and markers are readable. Comment on what you are doing and explain your work precisely and concisely. Should be submitted in 2-column IEEE format (https://www.ieee.org/conferences/publishing/templates.html)
One PDF per group. Save your group's ADS project workspace in a shareable link. List **each member's** contributions (design, schematic, layout, sims, write-up).