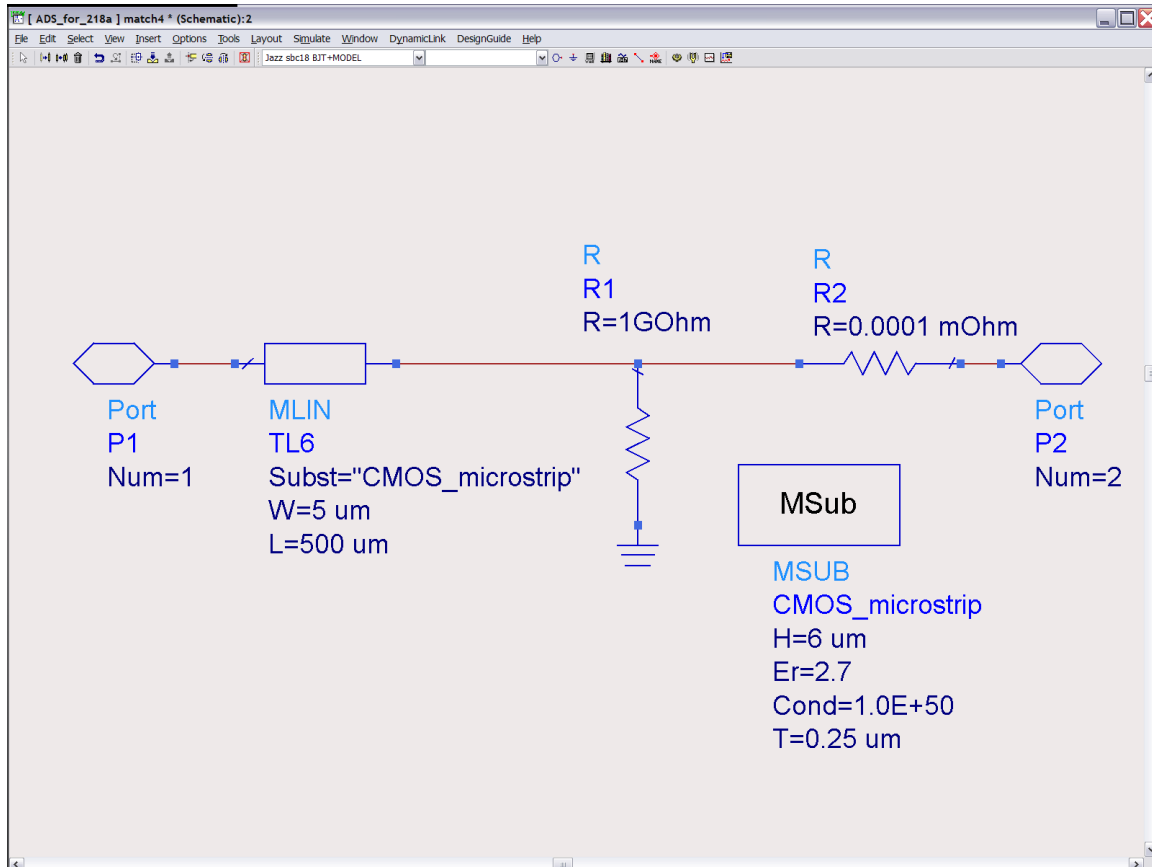# ECE 145A and 218A.

Transmission-line properties, impedance-matching exercises

Problem #1

This is a circuit file to study a transmission line. The 2 resistors are included to allow easy disconnection of port 2 without causing numerical problems in the simulator. MSUB defines the microstrip substrate; H is the dielectric thickness, Er its constant, and T the metal thickness. I've cheated and made the metal conductivity very high, so as to minimize skin loss.

Please simulate S11, plot on a Smith chart, and from the frequencies at which the line is multiples of a quarter-wavelength, determine the line Zo.

Make R1 zero, and R2 1GOhm (open ckt line), simulate S11, and plot Z11 vs frequency. From the frequenies of the poles (singularities) and zeros, determine the wave velocity.

Problem 2

We want to design a bypass capacitor, either to AC ground a power supply or an internal node in a transistor amplifier. We wish this impedance to be small over a wide range of frequencies. A large capacitor gives a low impedance $1/j\omega C$, but its large dimesions will give standing-wave resonances at a low frequency.

While our WiFi circuit is designed to work at only 60 GHz, the transistor bandwidth is almost 300 GHz, so we must ensure that the capacitor impedance remains small from a few GHz to 300 GHz

We will use substrate parameters as below:
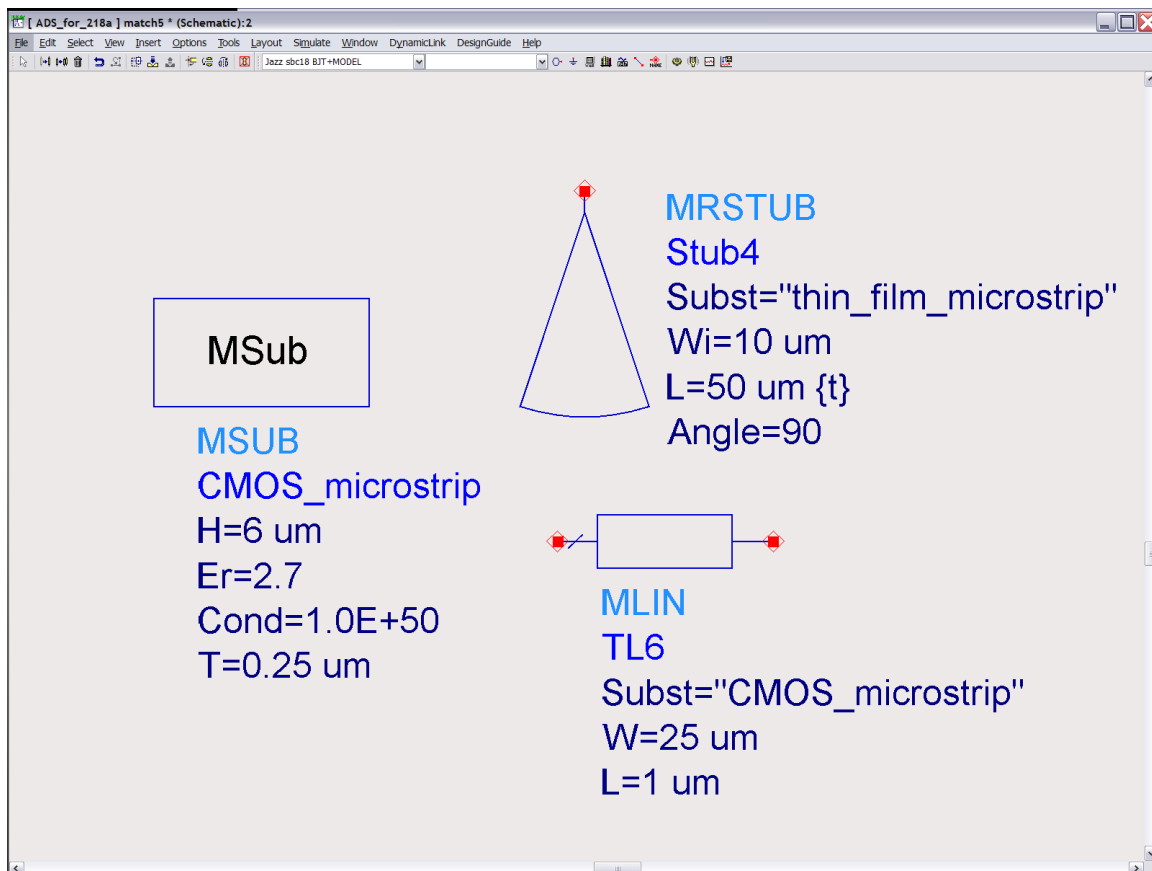
a) Hand calculations: Approximate a capacitor as a transmission line of length L and Width W. First, constrain W so that the line is less than a half-wavelength in the dielectic ($\lambda_d = \lambda_0 / \sqrt{\varepsilon_r}$). What is the maximum length if the line input impedance is not to go to infinity at 300 GHz ? What is the low-frequency capacitance of this line ?

b) simulations: make ADS plots of Z11 and Y11 vs frequency.

c) Hand calculations: Approximate a capacitor as a sector of a circle of flare angle 60 degrees and radius L. This is a microstrip radial stub. What is the maximum radius if the line input impedance is not to go to infinity at 300 GHz ? What is the low-frequency capacitance of this stub? Compare to (a)

d) simuations: make ADS plots of Z11 and Y11 vs frequency.

Problem 3

Here is a simple small-signal MOSFET model, except that C3 (Cgd) is unrealistically small. Making it exactly zero again causes some numerical problems.
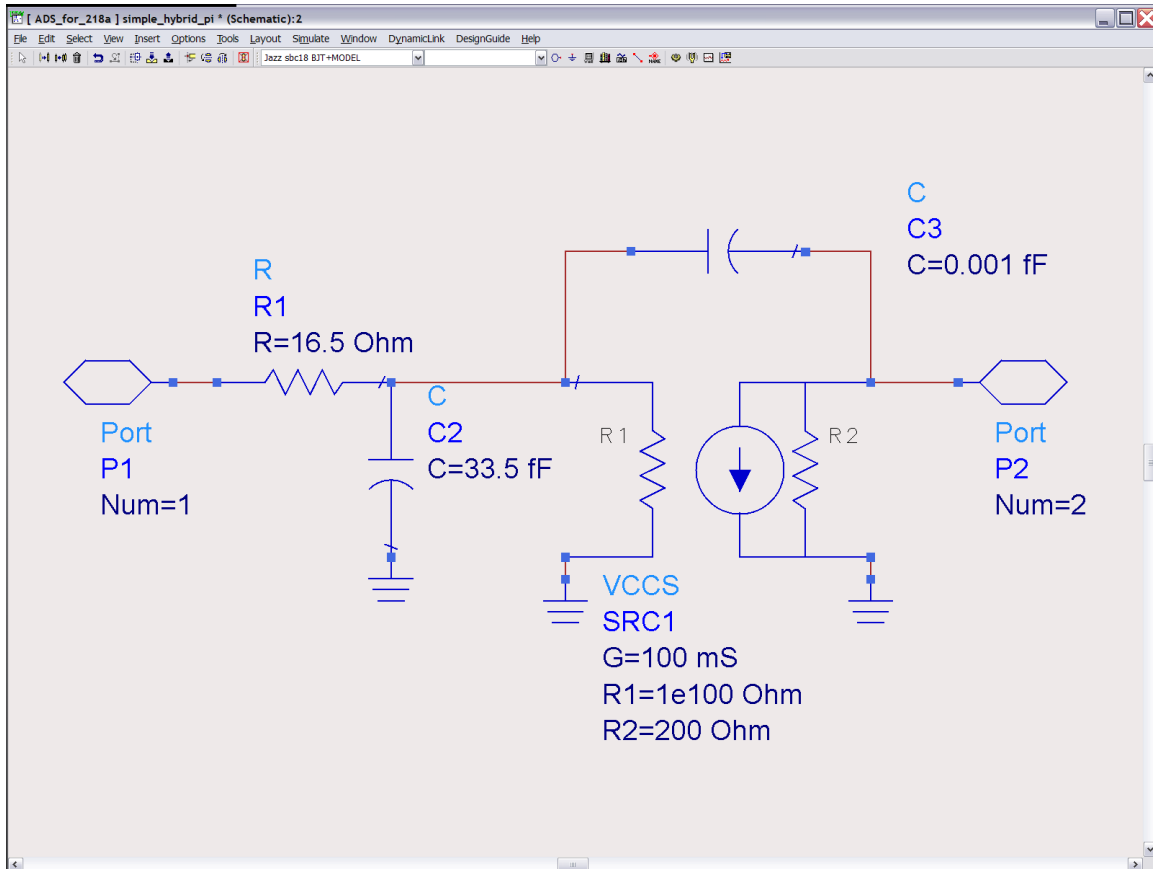
1) Design series-stub, shunt-stub matching networks for the input and output. Using high-Z lines of 5 microns width and low-Z lines of 50 microns width, design matching networks on input and output at 94 GHz signal frequency.

2) Determine the line impedances and velocities using the methods of problem 1, and then compute the Pi-section models. Ignoring the capacitance of the high-Z lines and the inductance of the low-Z lines, draw the resulting lumped LC matching network.

3) Design lumped LC matching networks and compare to (2).

Problem 4

Using this MOSFET model:
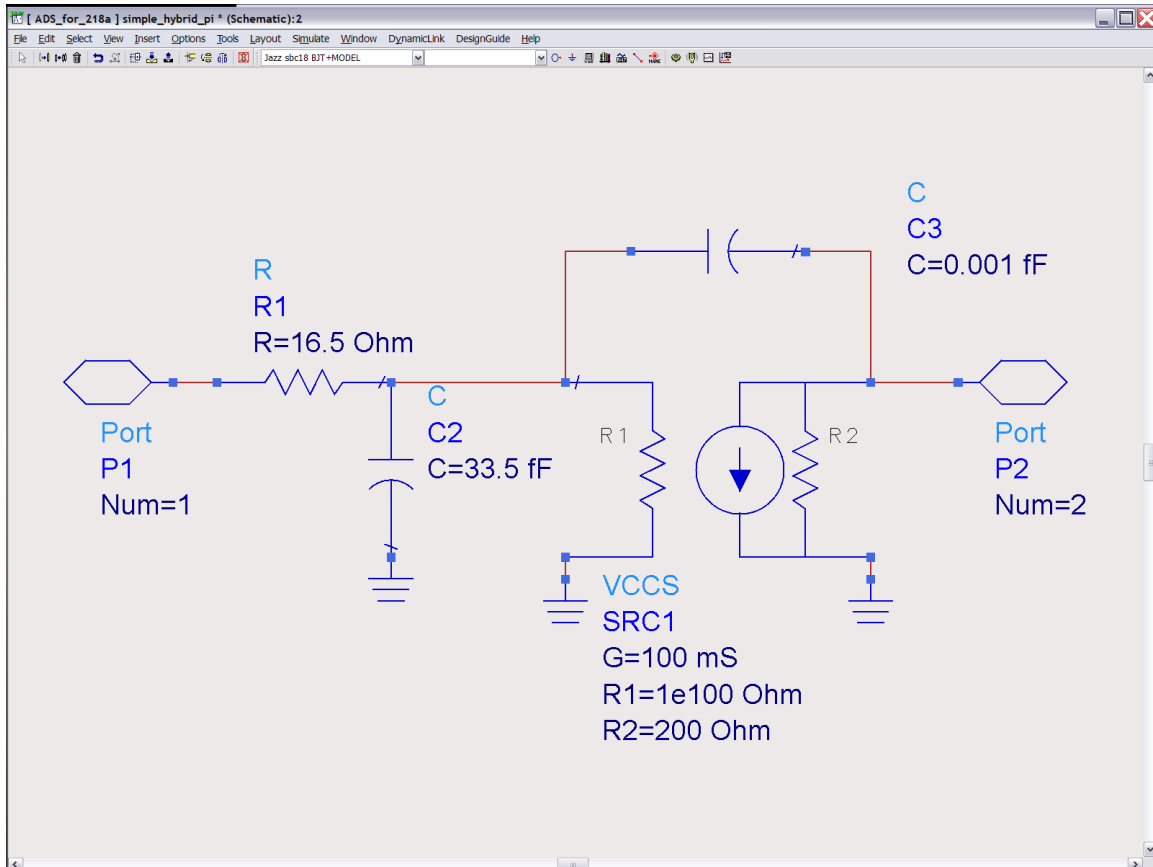
a) Simulate S21, S11, S22 in dB magnitude vs. Frequency

b) Design and place a 100 GHz lumped LC matcing networks at the input, and again Simulate S21, S11, S22 in dB magnitude vs. Frequency

c) Keeping the input matching network in place, design and place a 94 GHz lumped LC matcing network at the output, and again Simulate S21, S11, S22 in dB magnitude vs. Frequency.

d) We now increase C3 (Cgd) to 0.5 fF. Re-adjust the matching networks to obtain matched S11 and S22 at 100 GHz. What do you observe ?

e) Increase Cgd to 5 fF and reduce Rg to 5 Ohms. Try to re-adjust the matching networks to obtain matched S11 and S22 at 94 GHz. Now what do you observe ?

Problem 5
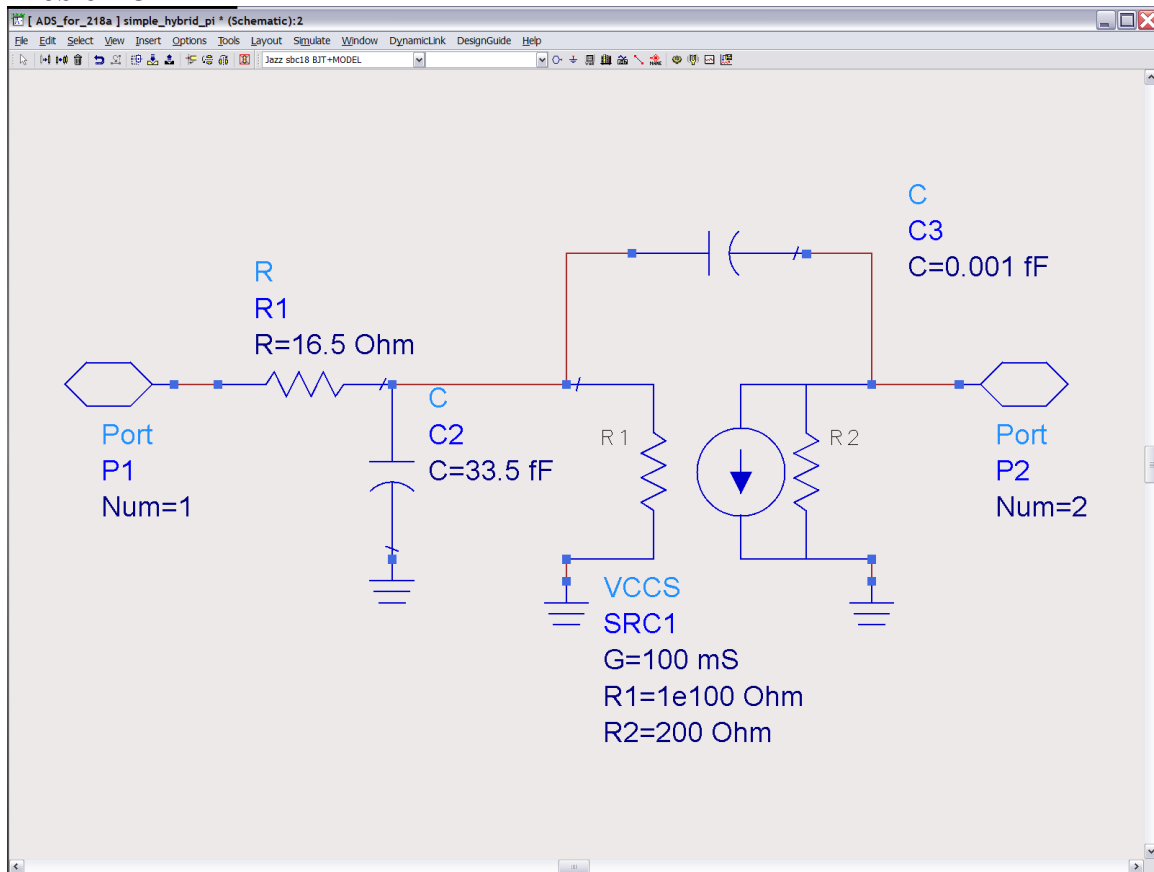
Using the MSUB parameters of problems(1,2), design a quarter-wave line output matching network at 94 GHz. At the input, use a short-circuited high-impedance shunt line of 5 microns width to make the input impedance pure real, and then a quarter-wave series line to complete the input match.

The problems below use the ADS directory ADS_for_218a; this is on the class web site.

Problem 6: a) Design matching networks to match the input and output to 50 Ohms at 94 GHz. Give values of all 4 elements. b) Simulate using the provided gain_testbench, and make plots of dB magnitude of all 4 S-parameters vs frequency (DC-300 GHz) on a *linear frequency* scale.	 Also make ADS Smith chart plots of S11 and S22 Ri= 3.3 Ohms, gm=300 mS, Rds=60 Ohms, Cgs=200 fF, Cgd=0 fF
Problem 7: The series lines are 75 Ohms impedance, and the shunt lines are 25 Ohms impedance. a) Design matching networks to match the input and output to 50 Ohms at 94 GHz. Give values of all 4 elements. b) Simulate using the provided gain_testbench, and make plots of dB magnitude of all 4 S-parameters vs frequency (DC-300 GHz) on a *linear frequency* scale.	 Ri= 3.3 Ohms, gm=300mS, Rds=60 Ohms, Cgs=200 fF, Cgd=0 fF
Problem 8: (218a only) (a) Using the same line lengths and impedances as problem 7, replace the series lines with Pi-sections and the shunt lines with T-sections. Draw the resulting equivalent circuit, drawing element values, and compare to problem 6. (b) Simulate using the provided gain_testbench, and make plots of dB magnitude of all 4 S-parameters vs frequency (DC-300 GHz) on a *linear frequency* scale.	 Ri= 3.3 Ohms, gm=300mS, Rds=60 Ohms, Cgs=200 fF, Cgd=0 fF
Problem 9: (218a only) Please do the following a) generate a hand-drawn mask layout assuming --microstrip wiring. --normal (right side up) thin-film wiring in an IC technology. --4 microns dielectric between the ground plane and the signal line --a dielectric constant of 3.8	 Please use *linecalc* in ADS to compute the necessary line widths and lenghts. Represent the FET on the layout as a blank square