University of California, Berkeley
EECS 142/242A

Fall 2017
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Problem Set 4

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1. Calculate the scattering parameters of the following circuits:

   (a) Find the input S_{11} for a general two-port terminated at port 2 with a load reflection coefficient of Γ_L.

   (b) In the previous problem, what is the power that reaches the load in terms of the two-port scattering parameters and Γ_L? Suppose the input is driven with a matched source.

   (c) Derive the two-port scattering parameters of a three-port where port 3 is terminated in a load with reflection coefficient Γ_L.

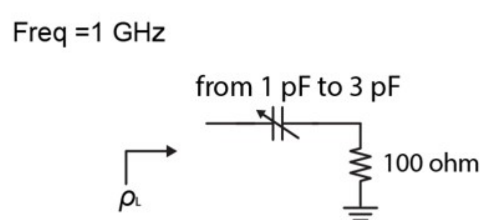
2. The Smith Chart is a graphical tool for convert between impedance and reflection coefficient. A blank Smith chart can be downloaded from
`http://www.acs.psu.edu/drussell/Demos/SWR/SmithChart.pdf`

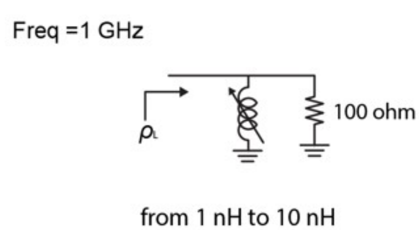
   (a) Assume $Z_0 = 50\Omega$. Using Smith Chart to find ρ_L for a load impedance $Z_L = 25 + 30j\Omega$.

   (b) Assume $Z_0 = 50\Omega$. Using Smith Chart to find the load impedance for $\rho_L = 0.5 + 0.1j$.

   (c) Repeat (a) and (b) with Z_0 changed to 10Ω.

   (d) For the following two circuits, trace ρ_L on a Smith Chart with $Z_0 = 50\Omega$.



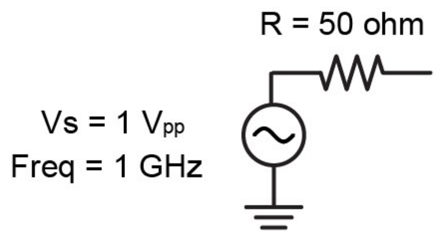


3. The Smith Chart you downloaded is called an Impedance Smith Chart. As we learned in class, we can also do an Admittance Smith Chart. A combined Impednace/Admittance chart can be found at
`http://www.eecircle.com/applets/006/imped_admit_smithchart.pdf`.

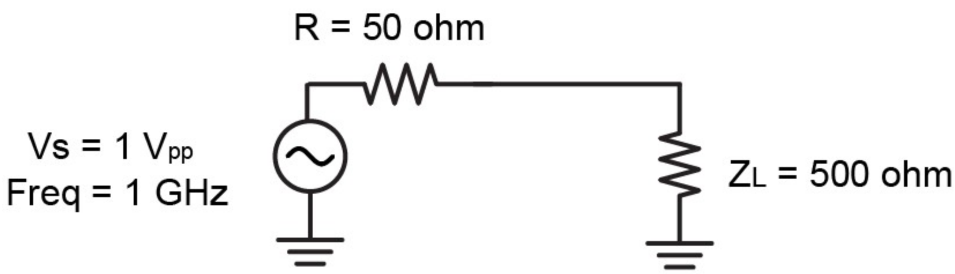
   (a) Assume $Y_0 = 0.02S$. Using the Admittance Smith Chart to find the ρ_L for a load impedance $Z_L = 25 + 30j\Omega$

   (b) Trace ρ_L for the second circuit shown above with the parallel inductor, but on the Admittance Smith Chart with $Y_0 = 0.02S$. Is using the Admittance Smith Chart helpful?

4. Impedance matching is an important technique to extract the highest power from the source.

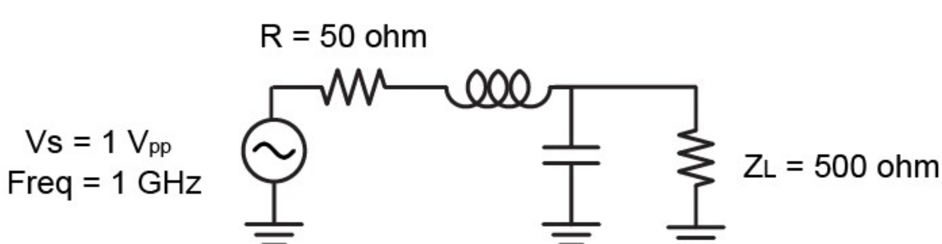


(a) What is the maximum power that can be extracted from the source shown above? What is the load impedance for the maximum power delivery to happen?



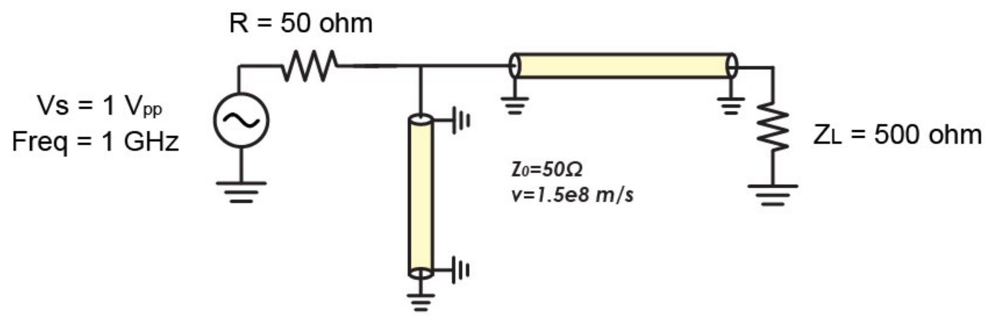
(b) Now we want to use this source to drive a 500Ω load and we connect it to the source directly, as illustrated above. What is the power delivered to the load and the load voltage?

(c) Let's try to achieve impedance matching by putting a resistor in parallel with our load. What should be the resistor value in order to extract the maximum power from the source? What is the actual power delivered to the load? Comment on this approach.



(d) You can see that the impedance matching network should not eat the precious power delivered from the source. Please use Smith Chart to design an impedance matching network using an ideal shunt capacitor and an ideal series inductor, as shown above. What are the capacitor and the inductor values?

(e) With the help of the matching network you designed in (d), what is the power delivered to the load? Calculate the load voltage and power by using KCL.

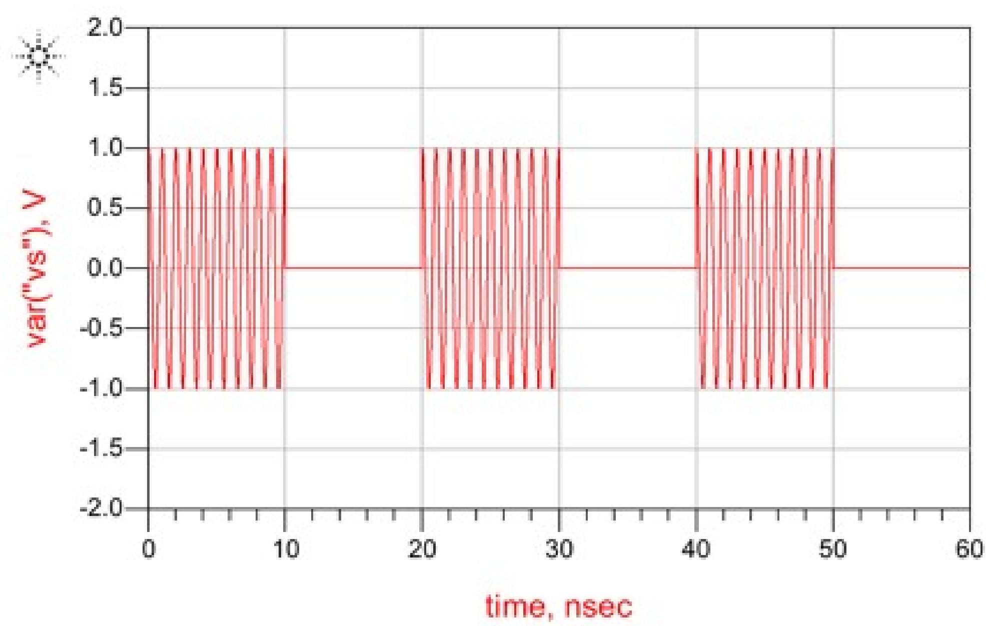


(f) (*242A only*) Alternatively, the impedance matching network can be designed by using transmission lines, as illustrated above. What are the length of the two lines?

(g) (*242A only*) Repeat (f) with Z_0 of the transmission lines changed to 100Ω.

(h) (*242A only*) Simulate the frequency response of the circuit you designed in (d) and (f). Plot the power delivered to the load versus the source frequency from 0.5 to 1.5 GHz.

(i) (*242A only*) Re-simulate (h) but now both the capacitor and the inductor have finite quality factor of 10 at 1 GHz.



(j) (*242A only*) Assume the input source is a RF pulse with RF carrier frequency of 1 GHz, pulse repetition period of 20 ns, and pulse width of 10 ns, as shown above. Simulate the load voltage with your designed impedance matching networks in (d) and (f) and the one without any matching network. Compare the three results.

(k) (*242A only*) Here are some follow-up questions for (j). Some of them might need to be answered by the aid of simulation tools.

i. What's the maximum power that can be extracted from the source?

ii. How much power is delivered to the load?

iii. Why is not all the power delivered to the load?