**ECEG 497 Wireless System Design Spring 2023**

**Homework Assignment #1 – due via Moodle at 11:59 pm on Wednesday, Feb. 1, 2023**
**[minor errors in Graded Prob. 4 corrected 1/31/23]**

***Instructions, notes, and hints***

You may make reasonable assumptions and approximations in order to compensate for missing information, if any. Some problem statements could contain extraneous information that is not needed to arrive at a solution. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Please note that it is your responsibility to review the solutions when they are posted and to understand and rectify any conceptual errors that you might have. You may contact me at any time for assistance with this task.

The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems. One or two graded problems will be randomly selected for detailed evaluation; the others will be evaluated using a coarse rubric.

***Graded Problems*:**

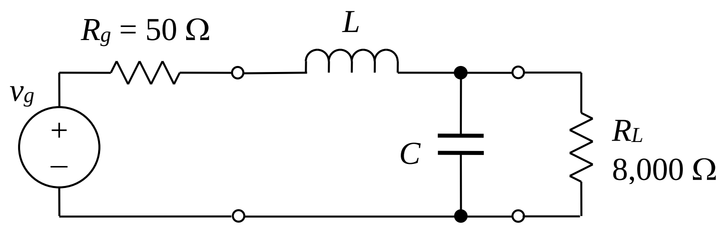
1. A load impedance of 250 Ω needs to be transformed to 50 Ω at a frequency of 1.9 MHz, which is the center of the "160-meter" amateur radio band. (The wavelength at 1.9 MHz is roughly 160 meters.) Design an L network using an inductor as the shunt element to accomplish the impedance transformation. A complete design includes specifications of the capacitor and inductor values using appropriate metric prefixes for the units (e.g., pF instead of F). You do not have to specify standard values.

2. Design an L network to match a 75 Ω source impedance to a load of 200 – *j*150 Ω at an operating frequency of 50 MHz. Use a capacitor as the shunt (parallel) element, if possible. This problem shows that matching networks can be designed to match complex impedances to real impedances.

3. This problem highlights an issue often encountered when trying to achieve a large impedance transformation ratio with nonideal components. Design an L network to match a load impedance of 0.5 Ω to 50 Ω at an operating frequency of 20 MHz. Use a capacitor as the shunt element, and initially assume that the matching components are ideal. After the $L$ and $C$ values are obtained, assume that the inductor has a winding resistance of $R_w$ = 0.4 Ω, and then calculate the actual input impedance of the nonideal matching network. *Hint*: The actual input impedance differs significantly from the ideal case ($R_w$ = 0).

(*continued on next page*)

4. **[1/31/23 corrections in bold face:]** Another issue commonly encountered in matching networks is power loss. Find the required $L$ and $C$ values in the matching network below, assuming that the operating frequency is 14 MHz (low end of the amateur radio "20-meter" band). Now assume that the inductor has a winding resistance of $R_w = 8.0\ \Omega$ at 14 MHz but that all of the other components are still ideal. The input resistance of the network will increase from 50 Ω to **58 Ω** (Do you know why?), which is an insignificant degradation of the impedance match. Suppose that the signal source is supplying 10 W to the input of the network, which means that the equivalent source voltage $v_g$ has a magnitude of **44.8 Vrms** or **63.4 Vpk**. Find the power delivered to the load $R_L$, and express the loss from source to load in dB. Note: The voltage source $v_g$ supplies about 20 W to the circuit, but only 10 W is supplied to the input of the network because half of the 20 W is dissipated in $R_g$. Remember, though, that power calculations in a Thévenin equivalent circuit (TEC) almost never reflects the actual delivery or absorption of power in the internal circuitry that the TEC represents. You can only draw conclusions from the circuit quantities that you calculate *outside* a TEC.




***Ungraded Problems*:**

The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. Try not to give up too quickly if you struggle to solve any of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. The input impedance of a certain small loop antenna can be modeled at its operating frequency as a 0.4 Ω resistance in series with 400 Ω of inductive reactance. Use the quality factor ($Q$) to find the parallel equivalent circuit representation of the input impedance. That is, find the values that a resistor and a reactive element ($L$ or $C$) in parallel would need to have if the combination were to have an equivalent impedance of $0.4 + j400\ \Omega$.

2. Use the results of the previous problem to show that the small loop antenna can be matched to a system impedance of 50 Ω using a matching network consisting of two capacitors (one in a shunt configuration and one in a series configuration) added between the antenna and the system. The equivalent parallel inductance of the antenna acts as the third element in the matching network. Find the required capacitor values, and draw a sketch of the matching network and the load, where the latter is represented by its parallel equivalent circuit. Capacitors and inductors should be labeled by their respective reactances. *Hint*: The $Q$ of the matching network is a very large two-digit value.

3. Show that the series equivalent impedance of a resistance $R_p$ and reactance $X_p$ in parallel is given by the expression below. Note that this result proves that $R_s < R_p$ and $|X_s| < |X_p|$ regardless of the resistance and reactance values in the parallel combination.

$$R_S + jX_s = \frac{R_p}{Q^2+1} + j\frac{X_pQ^2}{Q^2+1}, \quad \text{where } Q = \frac{R_p}{|X_p|}$$