ECE 3317
Fall 2023

Homework #3

Assigned: Thursday, Sep 7
Due: Thursday, Sep. 14

Assigned: Problems 2–7. (You may do the other problems for practice if you wish, but only turn in the assigned problems).

Note: In all plotting problems, you will be graded on both the *accuracy* and the *quality* of your plots. You plots should be drawn neatly and to scale. Please use graph paper.

1) Starting with the telegraphers equations for a lossy transmission line, derive the differential equation that the current $i\,(z, t)$ satisfies, and show that this is the same as the one that the voltage satisfies (as derived in class).

2) A coaxial cable is filled with lossless Teflon, having a relative permittivity of 2.1. (Teflon is nonmagnetic, so the relative permeability μ_r is unity.) How long with it take a signal to travel a one-meter length of the cable?

3) A coaxial cable for TV applications has an outer diameter of 3 [mm]. The coax is filled with lossless Teflon, having a relative permittivity of 2.1. What is the necessary diameter of the inner conductor (wire) in order for the characteristic impedance of the coax to be 75 [Ω]?

4) A twin-lead transmission line for TV applications is supposed to have a characteristic impedance of 300 [Ω]. If the spacing (center-to-center) between the two wires is 8 [mm], what should be the diameter of the wires, assuming that they are in air? Use both the approximate formula for the characteristic impedance (having the natural logarithm function) and the exact one (involving the inverse hyperbolic cosine function) and compare the results.

5) A microstrip line on a circuit board needs to have a characteristic impedance of 50 [Ω]. Assume that the thickness of the grounded substrate is 1.524 [mm], and the substrate is Teflon, with a relative permittivity of 2.1. What should the width of the line be? Use the approximate (parallel-plate) formula for the characteristic impedance, and then use the more accurate CAD formula given in the notes and compare the results. Assume that the thickness of the metal strip conductor is zero. (Note: As a suggestion, you can program the CAD formula for Z_0, and then use trial and error to numerically find the value of w that gives you the desired value of 50 [Ω].)

6) A coaxial cable is 10 meters long, and is filled with lossless Teflon, having a relative permittivity of 2.1. There is a matched load at the end of the line (this means that there is no reflection at the end, so there is only a signal traveling in the + z direction). At the input of the line, a sawtooth waveform is applied, having a peak voltage of 1.0 [V] and a duration of 1.0

[ns] (the time from the beginning of the waveform until the end). Make a plot (versus time) of what an oscilloscope would read if it were connected to the line at various locations, corresponding to the following values of z: 0.0 [m], 1.0 [m], 5 [m], 10 [m]. Plot out to 50 [ns] in your plot.

7) A coaxial cable is 10 meters long, and is filled with lossless Teflon, having a relative permittivity of 2.1. There is a matched load at the end of the line (this means that there is no reflection at the end, so there is only a signal traveling in the $+z$ direction). At the input of the line, a sawtooth waveform is applied, having a peak voltage of 1.0 [V] and a duration of 1.0 [ns] (the time from the beginning of the waveform until the end). Make a plot of the voltage as a function of distance z on the line, at the following times: 0.0 [ns], 0.5 [ns], 1.0 [ns], 10 [ns], 25 [ns], 40[ns], 49 [ns], 49.44 [ns], 50 [ns], 51 [ns]. For each time, choose appropriate limits on your horizontal axis (distance z) to make the plot easy to read.