ECEN 3400, Fall 2013, Zoya Popovic

<u>Project 3</u> (covers transmission lines and plane waves)

Assigned: December 2, 2013

Due: December 13th (last class), but you can turn it in earlier if you wish. You have plenty of time, but start soon so you can ask me for help if needed.

For this first project, you are asked to

I. Learn how to use a free Smith chart CAD tool to solve simple impedance matching problems.
II. Apply transmission line theory to plane wave analysis.
III. Perform a simple experiment on plane waves using a laser pointer and jello.

PART I.

In this part of the project, you will download a simple Smith chart analysis program, the link is: http://www.ae6ty.com/Smith_Charts.html . Scroll down to find the executable file for your operating system. The web page and "help" in the program itself contains all you need to learn how to use it (very simple).

I.1. Choose a frequency in the UHF or microwave range based on some application (give reference, come talk to me if you want some ideas). Pick some complex impedance that you would need to deliver power to from a 50-ohm or 75-ohm coaxial cable, e.g. real part is the day of your birth date, and the imaginary part is the month. State your choice. Plot the impedance on the Smith chart and read off the reflection coefficient and SWR.

II.2. Examine the effects of adding a capacitor in series and parallel, and an inductor in series and parallel (one at a time) and sweep the values L and C to see what happens. Draw some conclusions and show sample plots.

II.3. Next, you will match this impedance using lumped elements (capacitors and inductors). This means that after adding some Ls and Cs you need to end at the center of the Smith chart. When you obtain the values of the Ls and Cs, comment on whether this is practical (can you buy these values?). How sensitive is your design to the exact values of the inductance and capacitance?

II.4. Next you will do a transmission line match. Add a section of line that makes the input impedance purely real. Then, add a quarter-wave section of line to finish the matching.

Include screen dumps of all relevant results.

PART II

In this part of the project, we learn how to apply transmission-line theory to plane wave propagation.
A plane wave radiated from a radar is incident normally onto a flat part of a large metal object (e.g. plane or ship). If you know the frequency of the radar is 10GHz, design a "stealth" dielectric layer that will make this part of the ship invisible to the radar.

II.1. Can you design the anti-reflection coating if you assume that the metal is a perfect conductor AND that the dielectric is lossless?

- Can you design the anti-reflection coating if the dielectric is lossless, but the metal is not a perfect conductor (most ships are made of steel)?
- Can you design the anti-reflection coating if the metal is assumed to be perfect, but the dielectric is not lossless?

II.2. Pick one of the three cases above and design the coating to work at 10GHz at normal incidence.

II.3. Where does the power that the radar wave is carrying go? Discuss.

(You can try to do the problem using the Smith chart tool from Part I.)

PART III

In this project we examine basic properties of plane waves using waves in the optical region of the spectrum (green or red light, so 500 to700-nm wavelengths). The source of the plane wave is a laser pointer, and the wave power is detected using your own sensors (eyes), but could also be detected with a photodetector.
The contents of your project 2 package are:

- Red laser pointer
- 1 optical polarizer (about 1.5cm x 1.5cm)
- 2 packets of gelatin
- A protractor printed on mylar

Preparation

Use a large glass or plastic container (~ 6" x 6"), and fill it with gelatin to at least 1cm thickness. To prepare the gelatin, follow the following recipe:
Add 1/3 cup of cold water to 2 bags of jello, stir and then add 1 cup of hot water and stir until jello is completely dissolved. Pour into tray and refrigerate until firm. Get jello out of container and position so that a straight edge is aligned with the middle of the protractor (Fig.1).

III.1. Snell's Law and Total Internal Reflection

In this part of the project you will use Snell's law to find the unknown permittivity of a material. Use a rectangular piece of gelatin as the medium with a permittivity different than air. Align a sharply cut edge of the gelatin piece with the protractor main axis (see below). Measure the angle of refraction as a function of the angle of incidence using the laser pointer and scales and fill out a table like the one below. The laser pointer beam is polarized, but it is hard to control the polarization, so in this part of the project we will not consider the wave polarization.

Incident θ_i	15 degrees	30 degrees	45 degrees	60 degrees	Any other
Reflected θ_r					
Relative Permittivity					
Index of refraction					

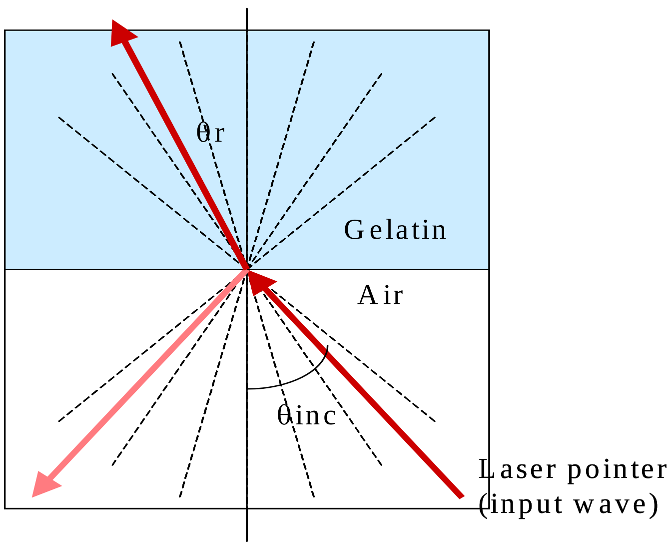

Fig.1. Sketch of setup for measuring the dielectric constant of gelatin.

III.1.1. Based on the angle measurements, find the relative permittivity and index of refraction of the gelatin and fill in the two last rows of the table.

III.1.2. Calculate the accuracy of your measurement from the permittivity data obtained for different angles. [Explain how you define the measure of accuracy.]

III.1.3. Calculate the angle of total internal reflection (TIR) from the mean value of the permittivity from your measurement. Think of a way to measure the TIR angle of the gelatin and sketch your method. How close is the measured angle to the calculation?

III.2. Brewster Angle

In this part of the project, you will examine how light reflection and refraction depends on polarization. First use the polarizer to check if your laser pointer is polarized. Explain your conclusion.

III.2.1. Bounce the laser beam off a reflector (any metal surface will work, e.g. aluminum foil) and observe the reflected beam intensity as you change the (a) incidence angle and (b) for each incidence angle you rotate the laser pointer to change polarization. You might need to figure out how to hold things so you know the angle. You can do this part with someone else, just make sure you write down who your partner was.
Record your observations and discuss. Then think about what would be different if instead of the metal surface you had a dielectric and explain in a few sentences or bullets.

III.2.2. Define the Brewster angle. Measure the Brewster angle for gelatin, and from that estimate the dielectric constant. How does it agree with the method in part III.1?

III.2.3. Colored glass has a different permittivity in the optical part of the spectrum than glass that is not colored. Find a piece of colored glass (e.g. beer bottle). Using the measurement of the Brewster angle, find the dielectric constant of a sample of colored glass and explain.

You should work on these problems independently and challenge yourself. Do not work in groups, and do not copy from anyone. I will not be kind if you copy, I want everyone to do this at their level, the best they can. This is how you will learn the material. I will definitely give extra credit to those who do an exceptionally good job, but you will get full credit even for the simplest but fully correct assignment.