Transmission Lines

A transmission line is a guide for electromagnetic waves in the sense that the waves propagate along the transmission line even though the line may have curves or corners. Coaxial cables, TV twinleads, and microwave waveguides are examples of transmission lines. A transmission line has a characteristic impedance Z just as a string does; consequently, when an EM wave traveling along the line encounters a change in Z, part of the wave will be transmitted and part will be reflected. In particular, reflection will occur if the line is terminated with an impedance that is not equal to Z.

Before You Come to Lab:

Read HL 9.3 and 9.6. Be sure you understand the analogy between voltage and current on a transmission line, and amplitude and velocity on a string. Review how boundary conditions affect mechanical waves on a string (HL Chapter 6).

I) Nature of the Reflections

The transmission line used in this lab is a long piece of coaxial cable. One end of the line is connected to a pulser, which generates *very short* electrical pulses, and to an oscilloscope. The other end of the line is terminated by a box with an adjustible termination impedance. This termination impedance can be measured with the available digital multimeter, *but the meter should be disconnected before measurements are made on the cable.* The oscilloscope trace will show the original pulse (from the pulser) as well as any reflections returning from the other end of the line.

Investigate the behavior of the reflected pulses when the terminating impedance is changed. Sketch the resulting waveforms in your notebook, describe your observations, and interpret these observations in terms of the boundary conditions at the terminated end. Draw an analogy between the behavior of the wave on the cable and the behavior of a pulse on a string. In particular, pay attention to the role of impedance. (In class, we argued that electrical impedance plays exactly the same role in this situation that mechanical impedance played for waves on a string. You should find this to be the case.)

II) Determination of the Characteristic Impedance

Determine experimentally the characteristic impedance of the cable. (This is the terminating impedance for which there is no reflection.) Electromagnetic theory predicts the characteristic impedance for a coaxial cable is given by:

$$Z = \frac{60}{\sqrt{K}} \ln \frac{R_{outer}}{R_{inner}}$$

(OVER)

where R_{outer} and R_{inner} are the radii of the outer conductor (shield) and the central wire, and K is the dielectric constant of the material. A micrometer and sample of the cable are available for measuring these dimensions. (The outer conductor has a thickness; you will have to think about whether you want the inner, outer, or average radius.) The value of K is about 2.3 +/- 0.05.

III) Determination of the Wave Velocity

Determine the velocity of propagation of the waves on the cable and compare with the theoretical prediction:

$$c = \frac{c_{vacuum}}{\sqrt{K}} .$$

IV) Delay Line Clipping

The time delay associated with the propagation of a pulse on a cable is frequently used to make very short duration pulses out of longer pulses. This technique is called delay line clipping. See if you can figure out how to make it work. You may find that the 50-ohm terminator included with your apparatus is helpful. How would you make a pulse of arbitrary length, given this technique and a long pulse?

R.R.C.	4/11/83
S.J.H. rev.	1/14/91
R.R.C. rev.	2/18/93
C.E.C. rev.	1/19/96