Matthew Spencer – Spring 2018

E190AK Lab 2: Transmission Line Reflection

In this lab you will use an oscilloscope to peer into the inner workings of a transmission line. A square wave driver is available which may help improve your measurements in the first three sections, feel free to attach it to Gen Out.

Observe Reflection in a Terminated Transmission Line

An oscilloscope with a built-in signal generator has been placed in the RF lab. Attach BNC tees (three-way connectors) to oscilloscope channels 1, 2, and 3. Attach a short BNC cable to the output of the signal generator and connect it to channel 1. Place a twelve-foot length of BNC cable between channel 1 and channel 2. Place another twelve-foot length between channel 2 and channel 3. Leave the other half of the channel 3 termination open. This configuration is pictured in Figure 1: the termination in the figure is an open circuit in this case. You must create the 12' cables by combining two 6' cables.

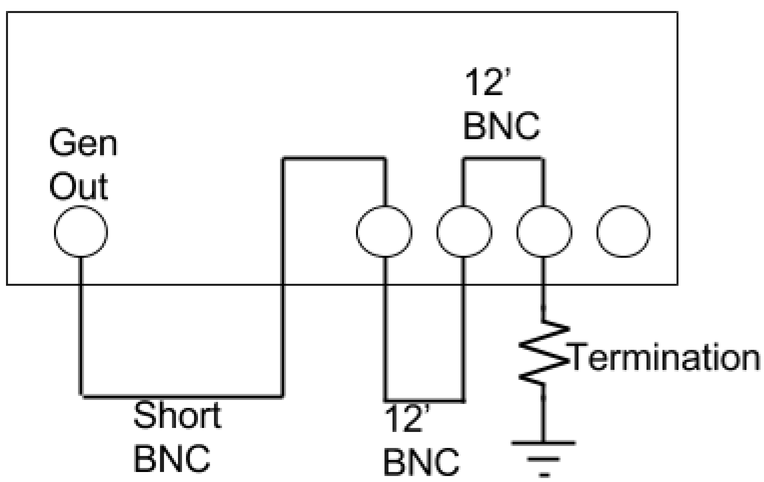

Figure 1

Set the signal generator to generate a 1kHz square wave. Set the oscilloscope to trigger on the signal generator clock and then zoom in on the edge of the square wave.

Use your observed trace to calculate your reflection coefficient. Report the times at which you observe a reflected wave on channel 1 and on channel 2. Report the amplitude of the reflected wave. Compare these times and reflection values to theory.

Repeat this when you attach the following to the open port of the channel 3 BNC tee: a 50 ohm termination, a 0 ohm termination, a 22 ohm termination and a 200 ohm termination. A potentiometer terminator is available if you'd like to see what a continuously varying load looks like.

Observe Reflection in a Transmission Line with a Discontinuity

Reconfigure the oscilloscope to match Figure 2: add a 50 ohm resistor in shunt across the transmission line at channel 2 of the oscilloscope, but keep the BNC cable connected from channel 2 to channel 3. This will require that you add an additional BNC tee to channel 2.

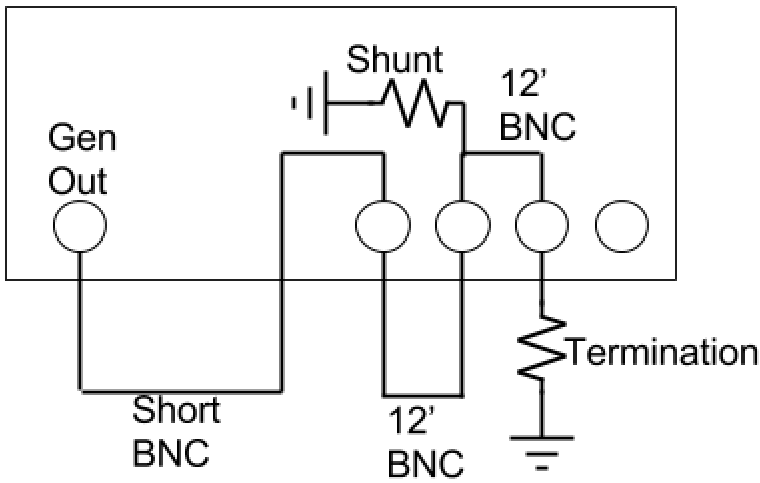

Figure 2

Calculate the reflection coefficients you expect in the line, sketch the expected waveform, and compare to measured data for the following combinations of shunt and termination:

Shunt	Termination
50 Ohm	50 Ohm
50 Ohm	200 Ohm
Short	Open

Measure the Velocity Factor of the Line and the Electrical Length of Line Components

Use the setup from Figure 1. Report the measured delay accrued by a wave propagating across your transmission line from the generator to the termination.

You're going to use this delay to calculate the velocity of waves in your line, but there are several confounding factors that make that calculation non-trivial. The fixtures you use to assemble your line (like the BNC T connectors) contribute additional delay. The delay of these fixtures is often surprisingly long because these connectors are not well impedance controlled. This delay is often reported as "electrical length," the amount of additional cable it would require to create the same delay as the fixture.

Design a series of experiment which allows you to estimate the electrical length of your line fixtures and the velocity of waves in your line. You may change the configuration of the oscilloscope as often as you'd like in these experiments, you're not bound to the configuration in Figure 1. Propagation speeds in transmission lines are often expressed as a velocity factor: the ratio of the velocity in the line to the speed of light. Report the velocity factor and propagation coefficient of your line in addition to the electrical length of your fixtures.

Observe VSWR in a Transmission Line

Reconfigure the oscilloscope to match the Configuration in Figure 3: replace the terminator on channel 3 with a BNC cable connected to channel 4, and terminate channel 4.

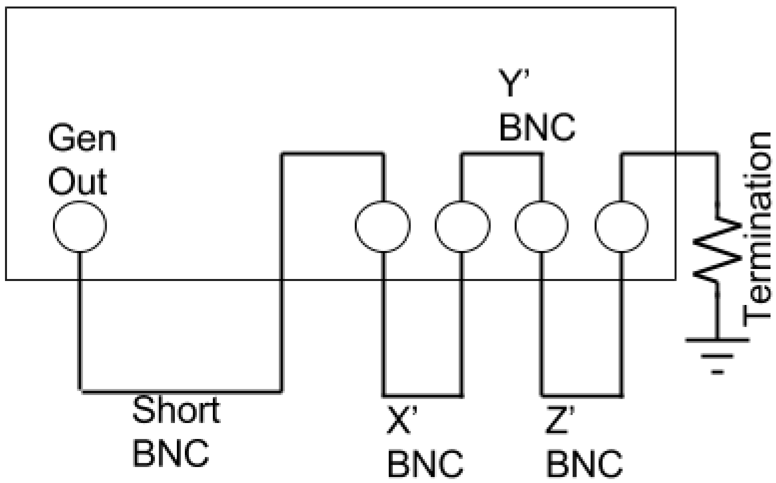

Figure 3

Set the function generator to produce a sine wave. In this configuration, you should be observing different parts of a voltage standing wave on your line. Vary the frequency of the sine generator, the value of the termination, and the (total electrical) lengths of cable X, Y and Z according to the table below. Record the amplitude of the wave observed at each channel, the driving point impedance seen by the signal generator, the phase difference between channels 2 and 3, and the VSWR. Compare these measurements to theory.

Termination	Frequency	X	Y	Z
50	20MHz	8	12	16
50	15MHz	8	12	16
22	20MHz	8	12	16
50	20MHz	16	8	12