Lab Demo #1
TECH 3812
Transmission Lines

Part 1: Velocity of Propagation

As we discussed in class, propagation through a transmission line is NOT the speed of light but is some fraction of that speed based on the Velocity Factor (V_f) of the cable.

The Velocity Factor (aka Propagation Velocity) of a cable can be calculated by the formula:

$$V_p = \frac{1}{\sqrt{\epsilon}}$$

Where ϵ is the dielectric constant of the material used in the cable.

Here is a list of common dielectric material used in coax cables along with the ϵ and V_p:

Dielectric Material	Dielectric Constant	Velocity Factor	Velocity of Propagation
Polyethylene (PE)	2.3	0.659	65.9%
Foam Polyethylene	1.3 - 1.6	0.79 - 0.88	79% to 88%
Air Spaced Polyethylene		0.84 - 0.88	84% to 88%
Solid PTFE	2.07	0.695	69.5%
Air Spaced PTFE		0.85-0.90	85% to 90%

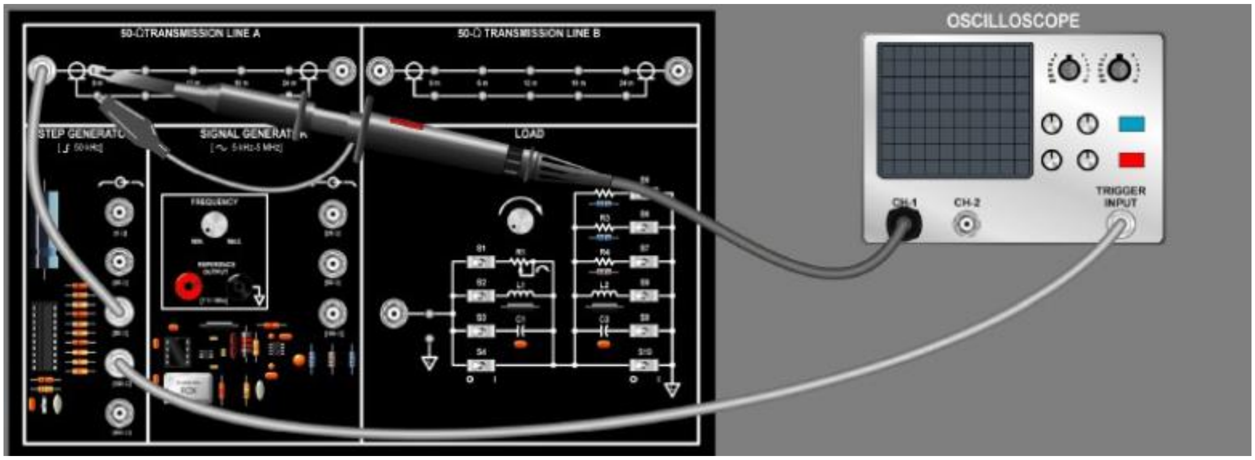
Figure 1- Dielectric Material and Velocity of Propagation[1]

The velocity of propagation can be used to calculate the length of the transmission media (coax) by measuring the time between the incident (start of signal) and reflected wave at the point where an exponential increase is seen.

[1] https://www.everythingrf.com/community/what-is-propagation-velocity-in-a-cable

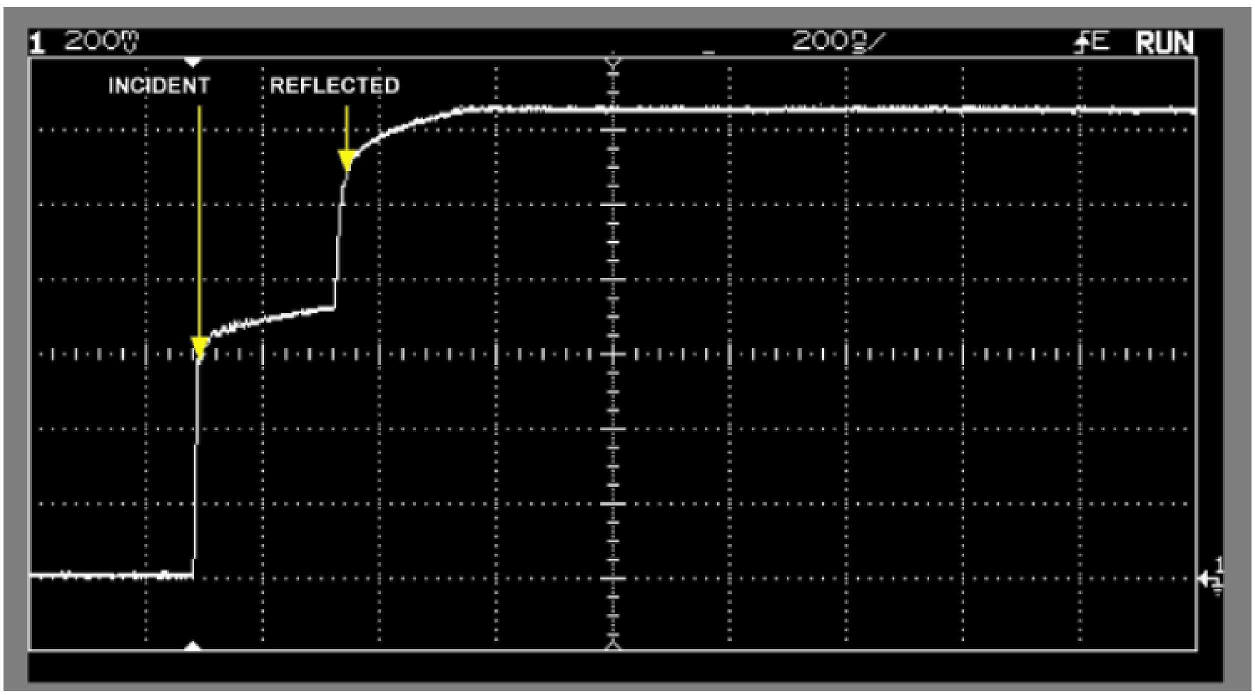
Procedure:

Connect the LabVolt Transmission Line Module as shown[2]:



Note transmission line A is NOT terminated (and cannot be terminated to see the reflected signal).

You should get a waveform similar to:



If you measure the time of incident (signal introduced in the wire) to the time of reflection, this time can be used to calculate the length of the wire using the following formula:

[2] Thanks to Sam Achikian, (ECU) Lab 1 – Characteristics of Transmission lines for posting his lab report on-line.

$$L = \frac{t}{2} * c * v_p$$

Since t, measure from the oscope, is the time it takes to travel to the end of the wire and return, we need to divide by 2 to get the travel time in one direction. *c* is the speed of light ($3*10^8$ m/s) and v_p is the velocity of propagation of the coax cable (in the case of the transmission line module, the dielectric is polyethylene (PE) with a v_p of 65.9%.

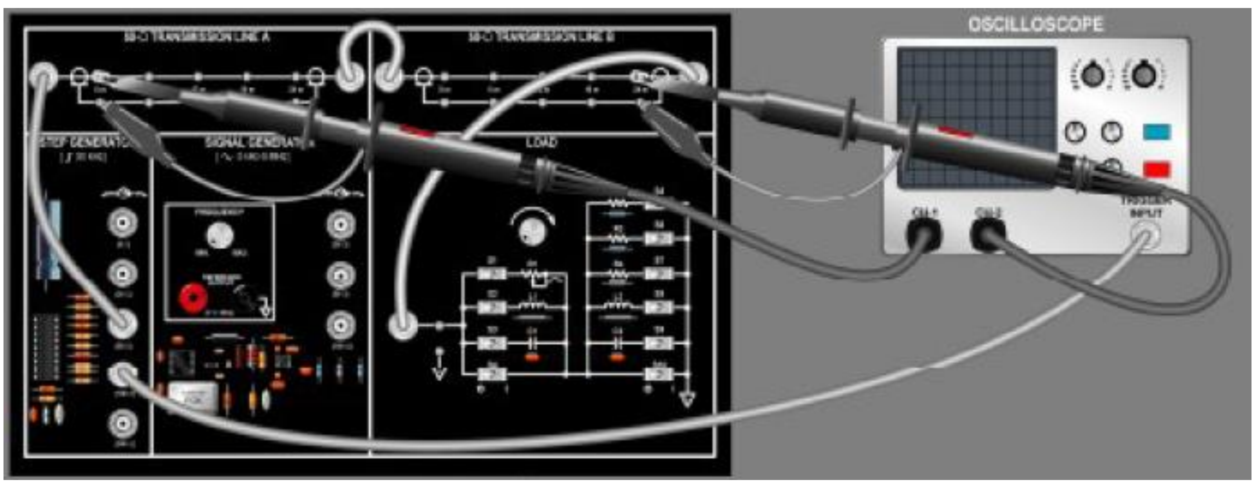
In the case of the demo, 2T was measured at $250x10^{-9}$sec (250nS) so the calculated distance is 24.71m (it should be approx. 24m)

Now add a coax jumper between transmission line A and B. Repeat the measurement (the “cable” is still unterminated, but now at the end of transmission line B).

You should get an approximate distance of 48m.

<u>Part II: Attenuation and Distortion</u>

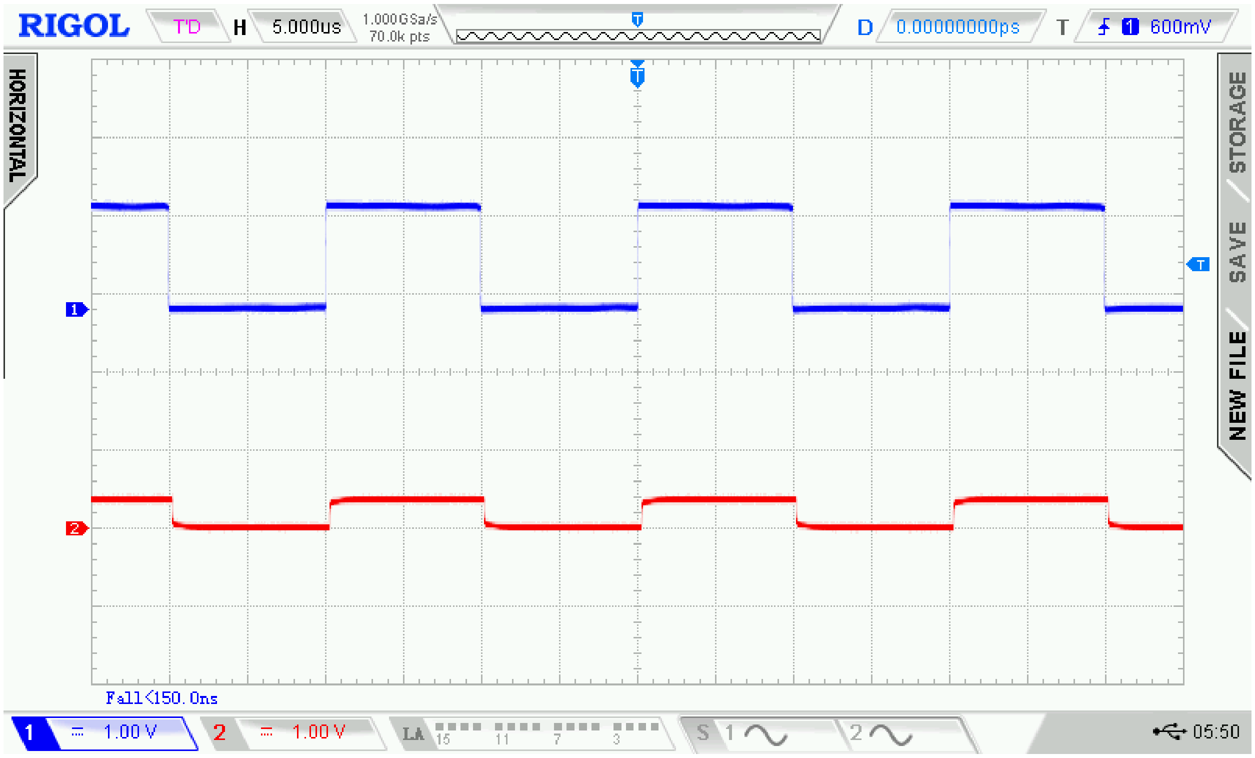
Hook up the module as shown below:



Now with the transmission line terminated we can look at the effects of various loads on the transmission line (although I found it is better to connect the 100Ω output from the step generator directly to ch1 and trigger off of that).

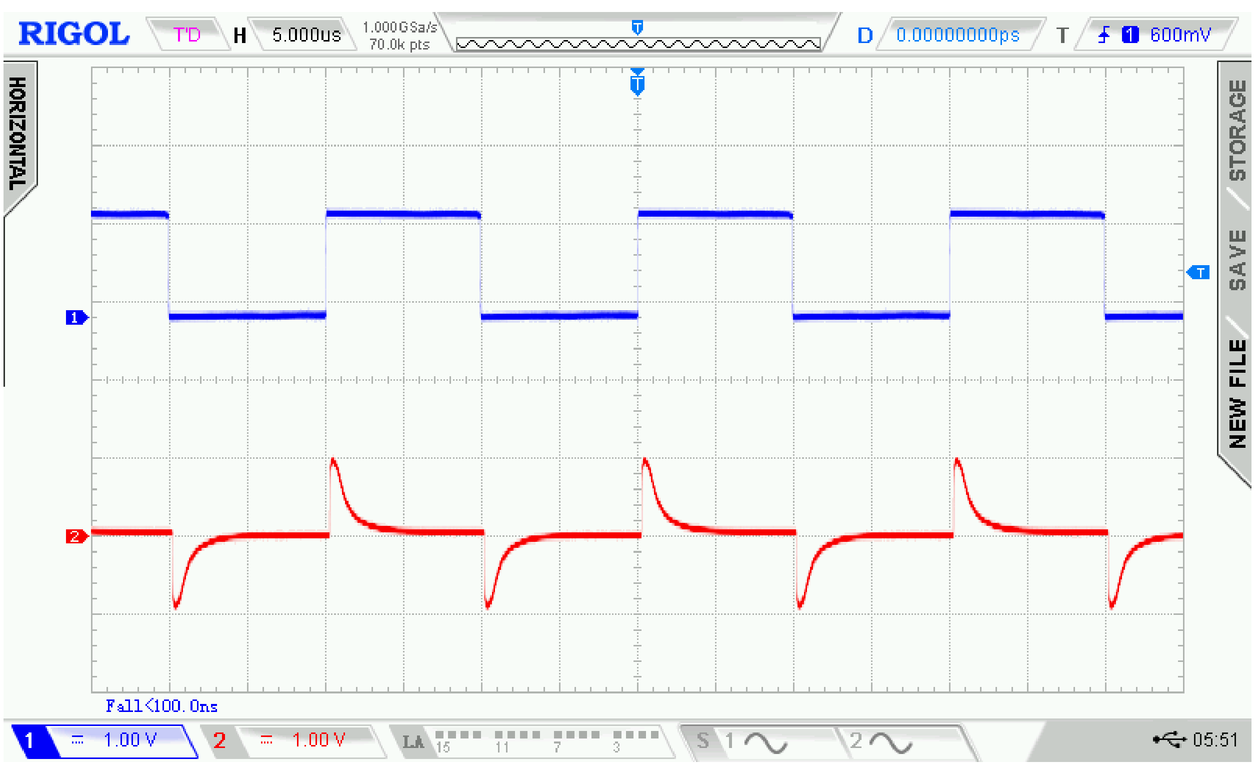
Now we can independently add various loads (Resistive, Capacitive and Inductive) or any combination via the switches. Note that SW 10 must be on for the left column of loads and SW 4 must be on for the right column of loads to be active).

If we turn on SW 4 and 5, we are adding a resistive load to the transmission line. This should result in a waveform like:

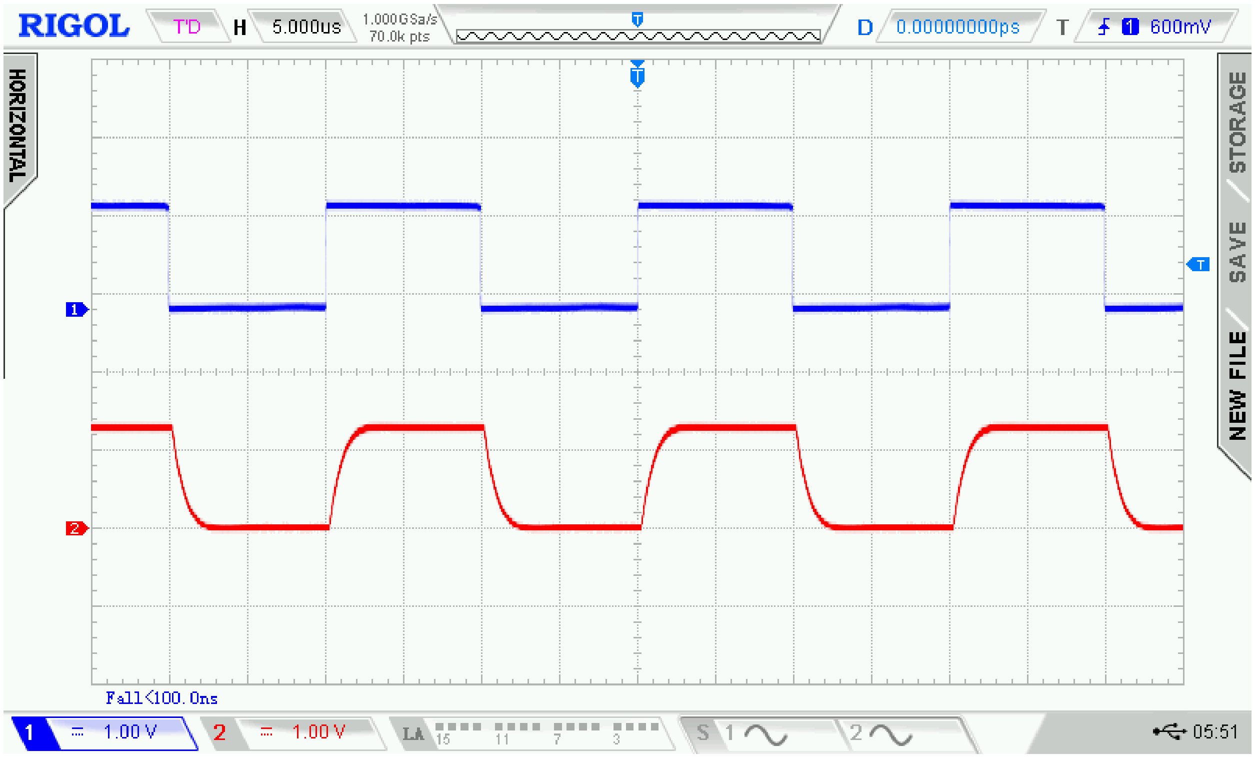


Note that, with the same vertical scale of 1v/div, the input to the transmission line (blue) is attenuated (reduced) by the time it has traveled the 48 meter transmission line (red)

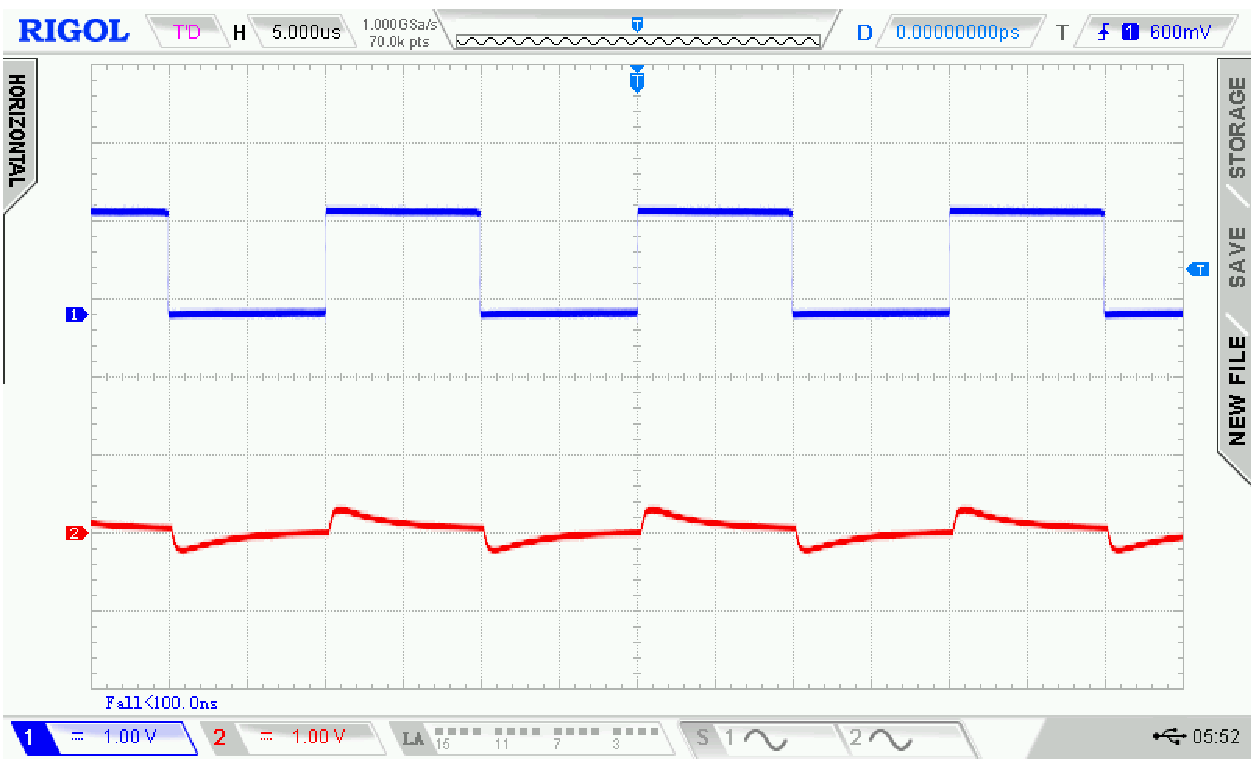
If we turn on SW 4 and 8, now we have an inductive load on the transmission line and the results will be as shown:



With SW 4 and 9 turned on, we now have a capacitive load:



And with SW 4, 5, 8, and 9 turned on, we see the effects of all loads at once:



Note how each has changed the shape and amplitude of the signal at the end of the transmission line. If data were being sent (instead of just a simple square wave), much of the information would be lost or distorted by the end of the transmission line.

Most communications methods used in data communications today, have limits on transmission medium lengths before the signal goes through equipment to reshape the wave to avoid these issues and this demo shows why that is needed in modern digital communications.