



We want to consider an RG58U lossless transmission line used in different applications. We will also be using only the lossy transmission line model from PSpice but will input only lossless parameters. That is we will choose the resistance and conductance per unit length to be zero. Note that their default value is 1. The length of the line is 560 meters. The excitation frequency is $f = 20kHz$.

1. Transmission Line Characteristics

Since you will need them later, write down the following characteristics of the line and waves on the line. (The actual values of the real cables may be slightly different.)

The inductance per unit length $l = 0.25 \mu H/m$

The capacitance per unit length $c = 100 pF/m$

The characteristic impedance $Z_o = 50 \Omega$

The propagation velocity $u = 2 \times 10^8 m/s$

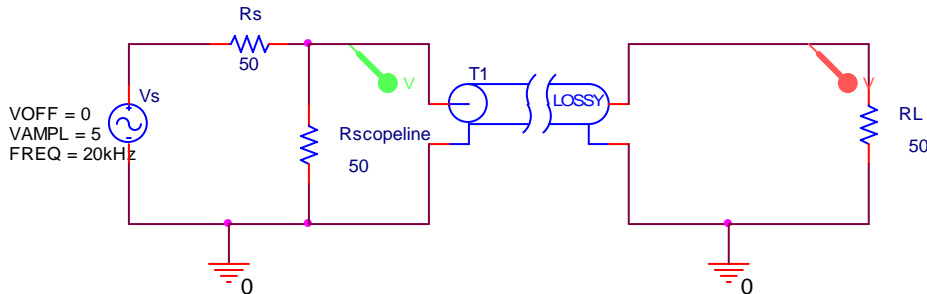
The delay time for the line $T = 2800 ns$

The angular frequency $\omega = 2\pi(2 \times 10^4) = 4\pi \times 10^4 = 1.26 \times 10^5$

The propagation constant $\beta = \frac{4\pi \times 10^4}{2 \times 10^8} = 2\pi \times 10^{-4} = 6.28 \times 10^{-4}$

2. PSpice Simulation of the Transmission Line with Sinusoidal Input Voltage

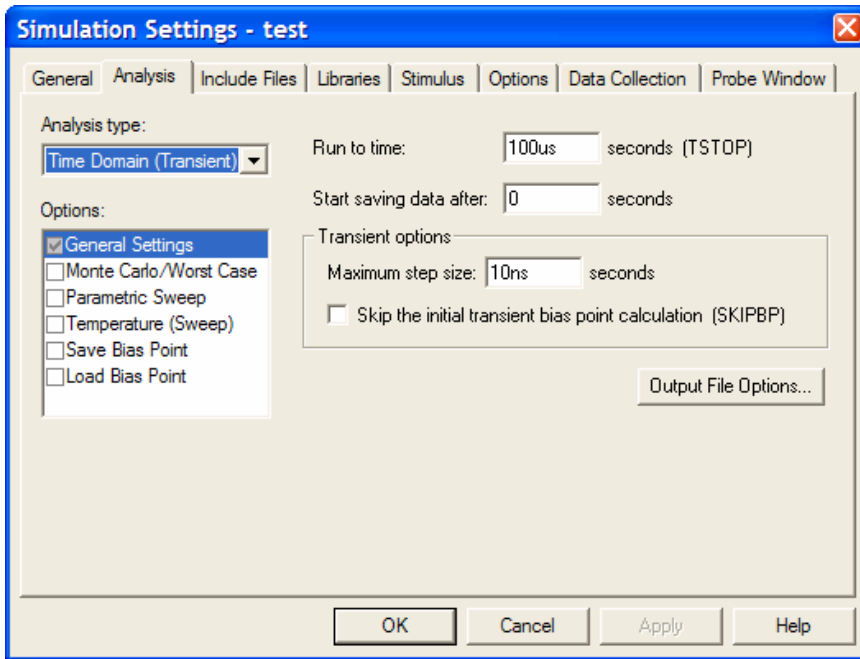
First we will consider how the line behaves with the sinusoidal input voltage $V(t) = 5 \cos \omega t$ where the frequency $f = 20kHz$. The voltage source and the load are both matched to the line. Set up the following representation.



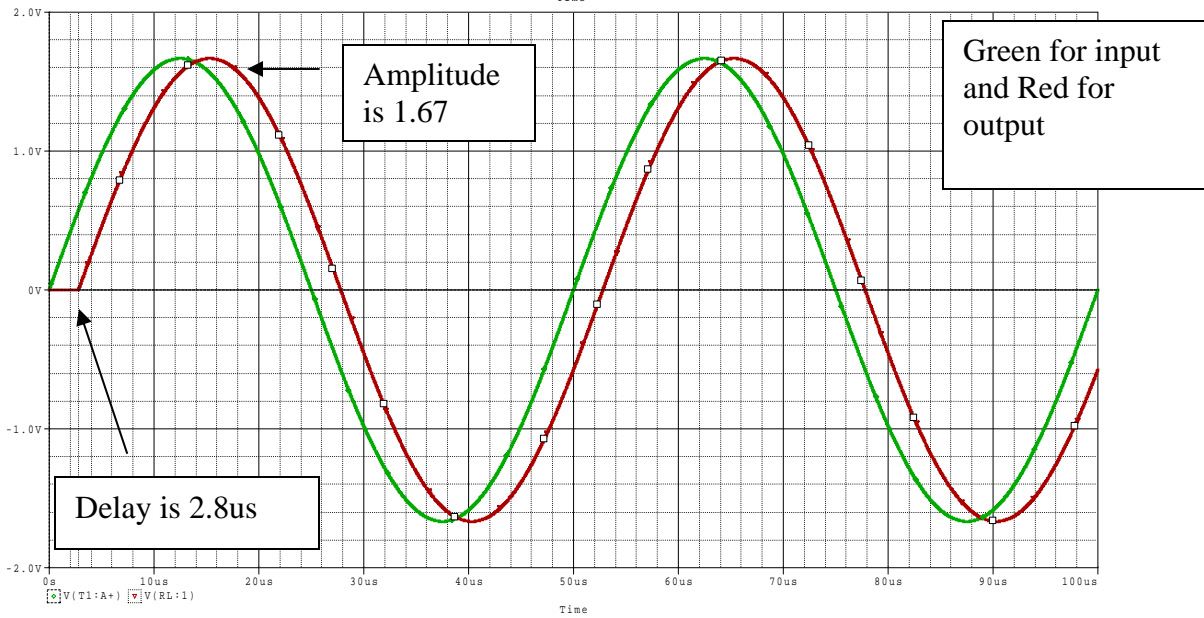
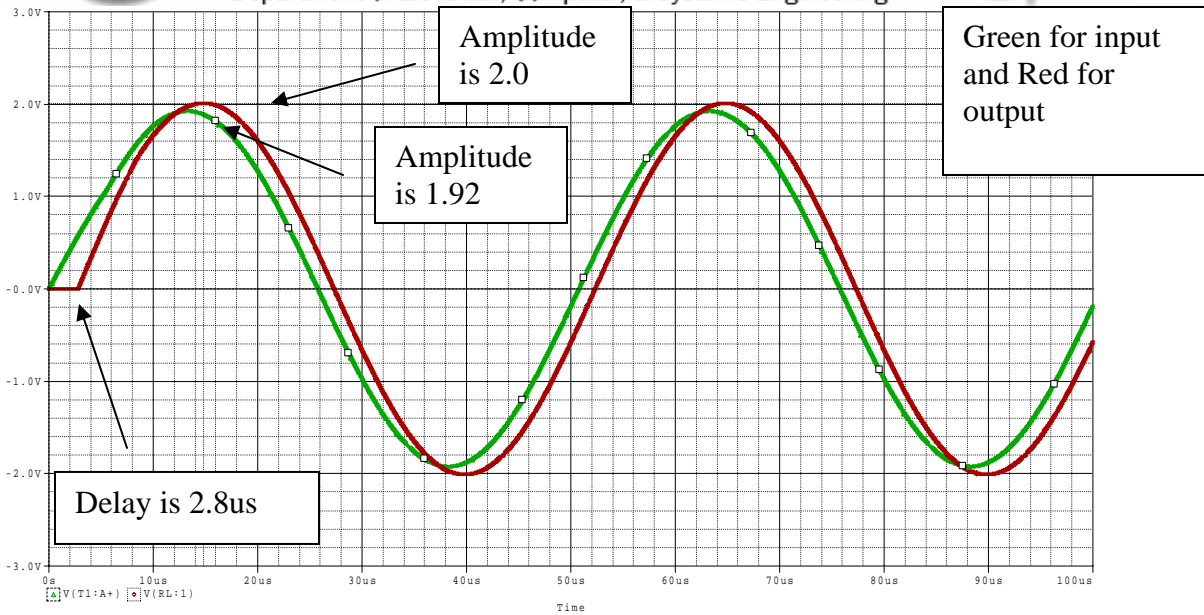


Note that there is a 50 Ohm resistor across the input of the line. This represents a connection to the 'scope that is terminated in 50 Ohms. You will do your measurements this way, so it is good to include it from the beginning.

When setting up your simulation profile, use the following as your first guess. You will be asked to possibly adjust it when you address pulsed sources. Run this simulation and save the output plots for your report. Be sure to include the voltage probes at the input and output of the line. Also run this for the cases where the load resistance is 93Ω



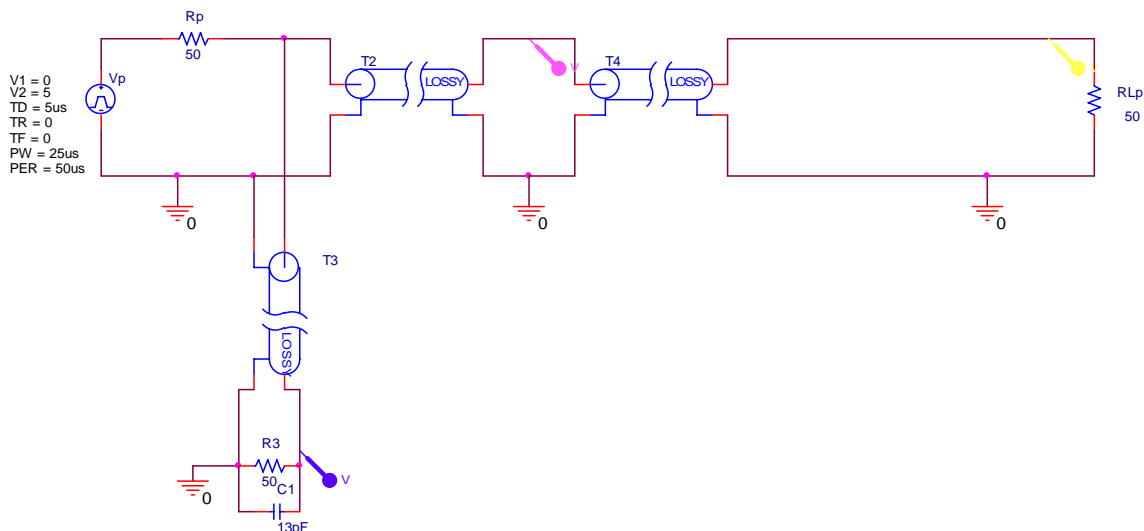
On the following page, the first plot is for 93 Ohms and the second is for 50 Ohms.





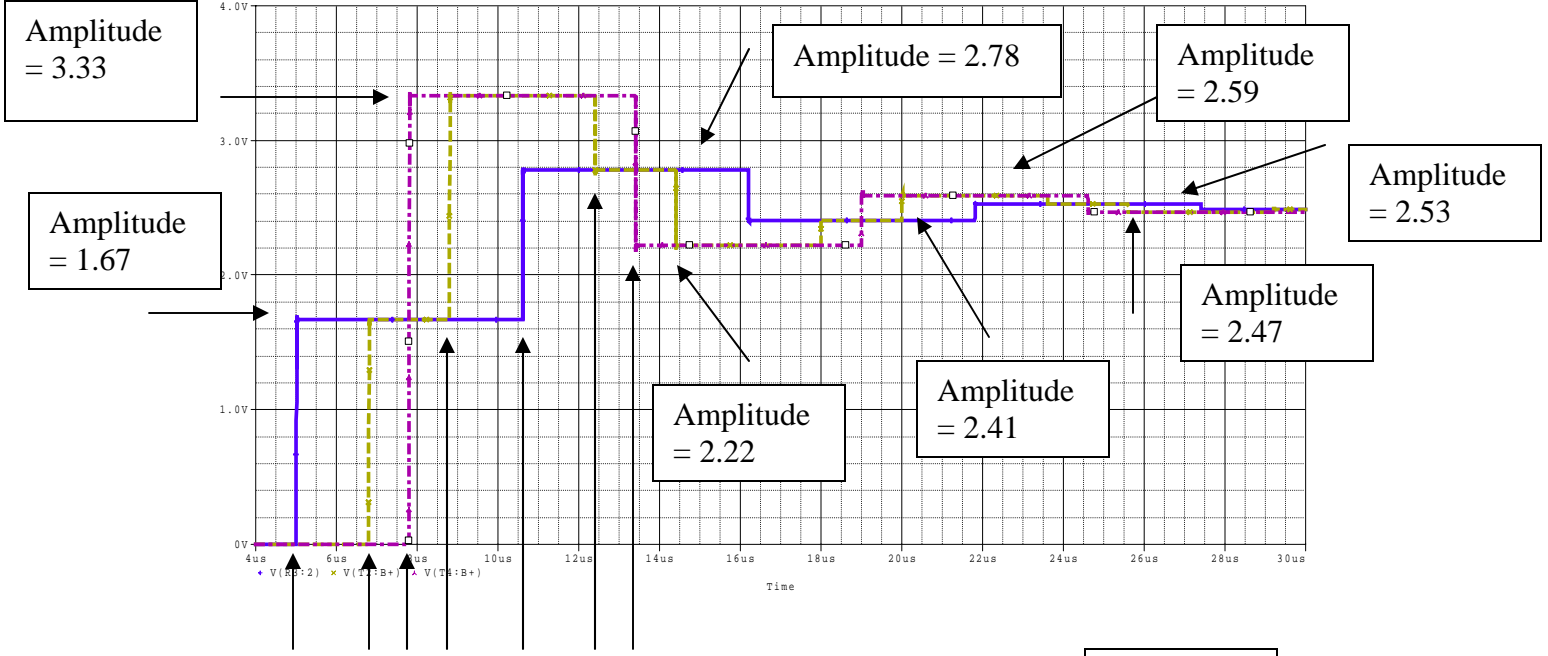
3. PSpice Simulation of the Transmission Line with a Pulsed Source

Set up the following configuration on the same page as your sinusoidal simulation. You can have more than one circuit analyzed by PSpice as long as you don't exceed the limitations of the student version. Again, use the lossy line model. The delay used is not necessary for this case, because there are no capacitors or inductors in the circuit. However, we will use it to be better prepared for more general problems and it will also keep things separate when you run both the sinusoidal and pulsed cases. Note that in this case, we have actually added a 1 meter long line to the 'scope and terminated it in 50 Ohms. Note also that we have replaced the transmission line connected to the load with two transmission lines. We have done this to obtain information at an intermediate point in the line in addition to at the input and output ends of the line. PSpice does not give us any information at the interior of lines, just like we cannot obtain such information from real transmission lines. However, we are able to create a long transmission line by stringing together several shorter lines. For this case, set the length of the first line to be 360 meters and that of the second line to be 200 meters. For the pulsed source case, you should analyze and obtain the information at all three locations.

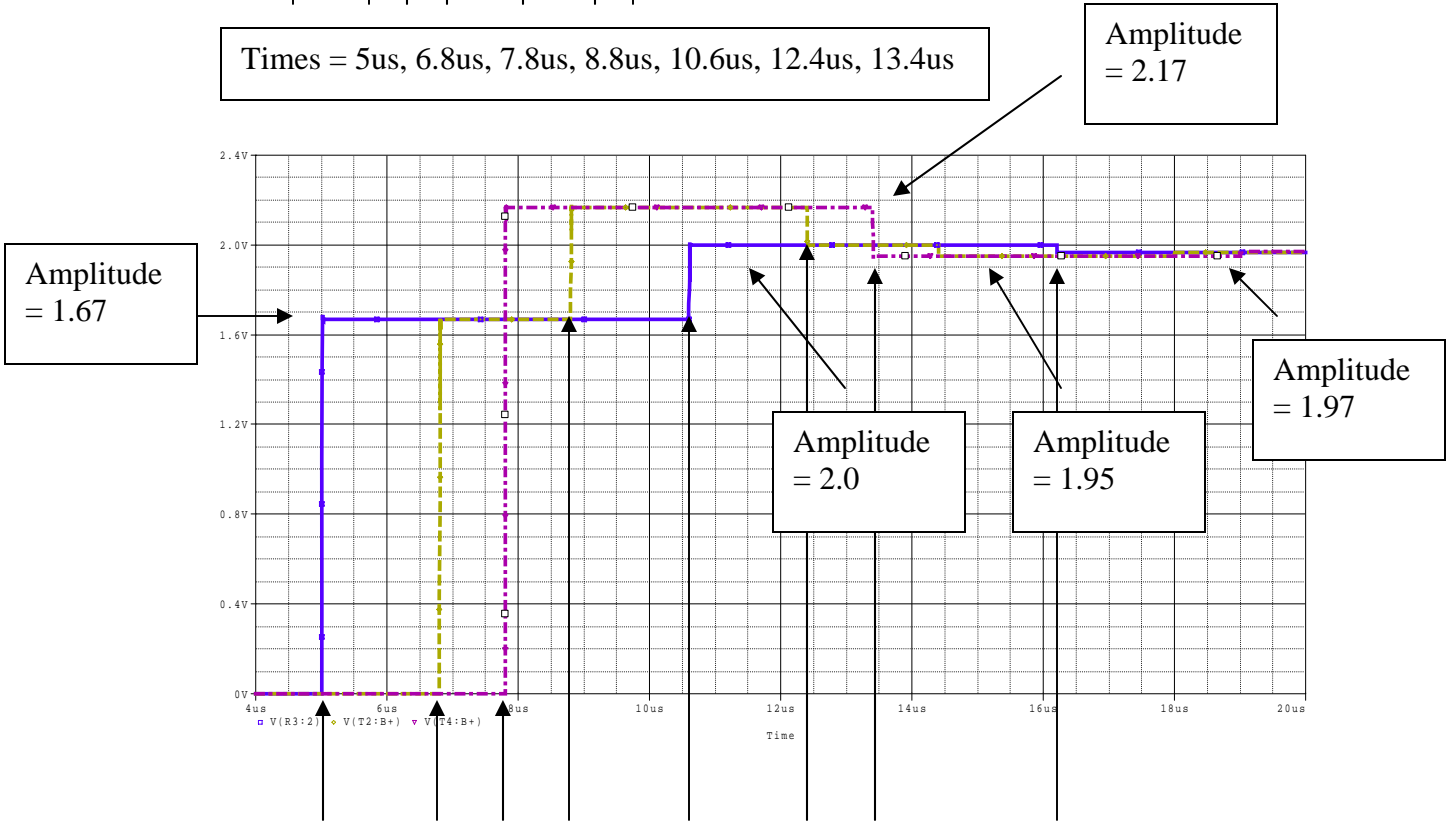


Now, if necessary, adjust the simulation profile until your plot demonstrates that you are observing the full signal while it settles into its steady state conditions. Change the simulation conditions only enough to show this. If you have included both the sinusoidal and pulsed cases in the same simulation, your plot or plots will show both the sinusoidal case and the pulsed case. You will find it easier if you separate the two cases. Carefully label all waves and pulses, noting where they are observed (input or output end or at the connection between the two lines) and their amplitude (since this is not always easy to read from the plots).

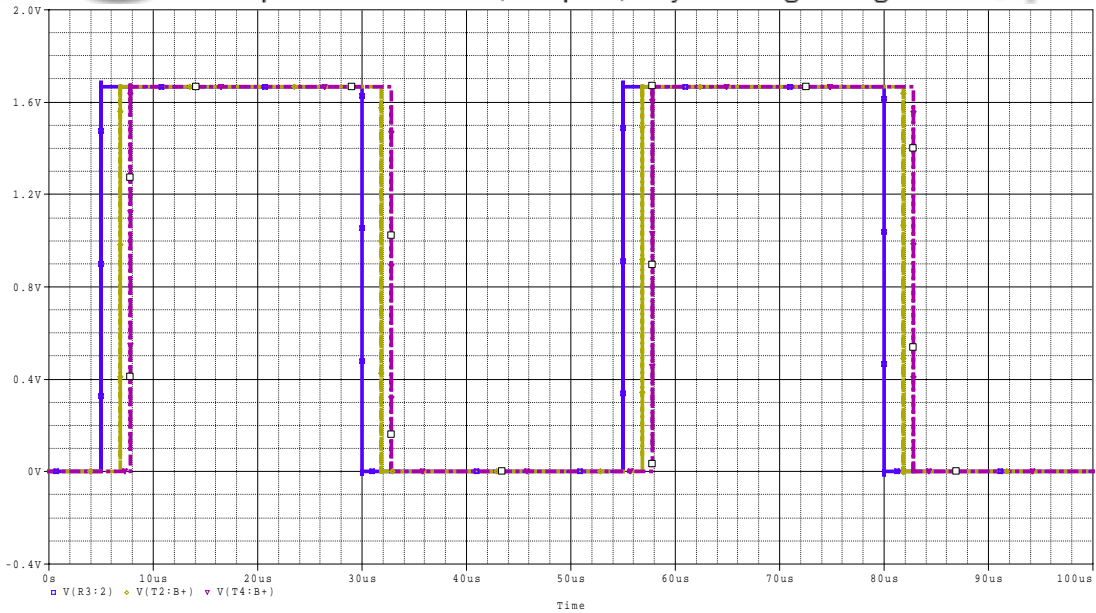
The first plot is for 1 Meg Ohm, the second for 93 Ohms and the third set of plots is for 50 Ohms. The first one is extra and not required for this assignment. The two plots are shown for 50 Ohms to demonstrate how things repeat.



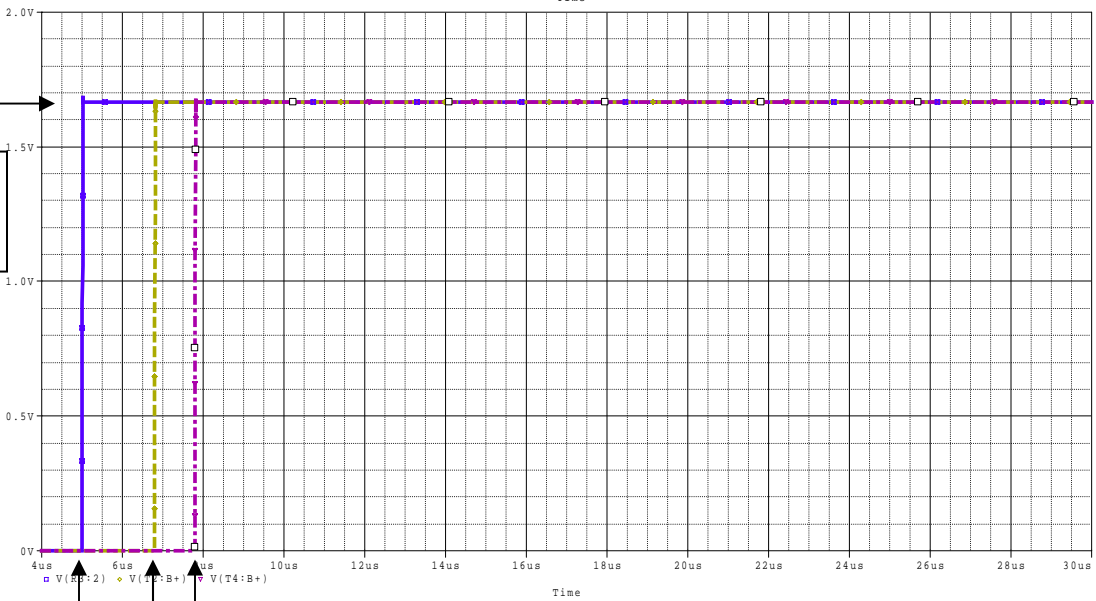
Times = 5us, 6.8us, 7.8us, 8.8us, 10.6us, 12.4us, 13.4us



Times = 5us, 6.8us, 7.8us, 8.8us, 10.6us, 12.4us, 13.4us, 16.2us



Amplitude = 1.67



Times = 5us, 6.8us, 7.8us



4. Input Impedance of a Line

This question relates to the sinusoidal voltage.

- Determine the input impedance of the line.
- From the input impedance, determine the input power to the line.
- From the input power to the line, determine the power delivered to the load.
- From the power delivered to the load, determine the voltage observed at the load.
This should allow you to explain the magnitude of the observed voltages.
- Qualitatively explain why the phase difference between the two voltages observed in your plots also makes sense. Only an approximate answer is necessary. **Extra credit:** Accounting for the exact phase difference is complicated. If you can explain the phase change in detail, you will receive extra points.

%HW 2 Spring 2008 Fields and Waves I
% K. A. Connor

% Parameters for RG58 cable -- Have to Specify Zl before running this
d=560; l=0.25e-6; c=100e-12;
Zo=sqrt(l/c);u=1/sqrt(l*c); f=2e4; w=2*pi*f; beta=w/u;

% Phase Shift
Td=d/u;

% Input Impedance
zin=Zo*(Zl+j*Zo*tan(beta*d))/(Zo+j*Zl*tan(beta*d));

% Include the additional 50 Ohms in parallel
Zin=zin;% This is the actual input impedance of the line
zin=(zin*50)/(zin+50);

% Input Voltage
vin=5*zin/(zin+50);% Phasor form

vin_mag=abs(vin);% Amplitude

% Input Power
pin=0.5*real((vin*conj(vin))/conj(zin));

% Output Power & Voltage
pout=pin;
vout=sqrt(2*Zl*pout);

For 50 Ohm Load $vin = 1.67$ $Zin = 50$ $pin = pout = 0.0278$ $vout = 1.67$

For 93 Ohm Load $vin = 1.92$ $Zin = 71.9732 - 30.7917i$ $pin = pout = 0.0217$ $vout = 2.01$



5. Pulses on a Transmission Line

This question relates to the pulsed voltage.

- a. Determine the voltage input to the line from the voltage divider relationship that characterizes the initial line voltage.
- b. Determine the reflection coefficients at the load and source end for both loads.
- c. Generate the bounce diagram for both loads, showing the voltages observed until the changes in level are under .1V.
- d. From the information in your bounce diagram, sketch the voltages observed at the input and output ends and the intermediate point of the line.

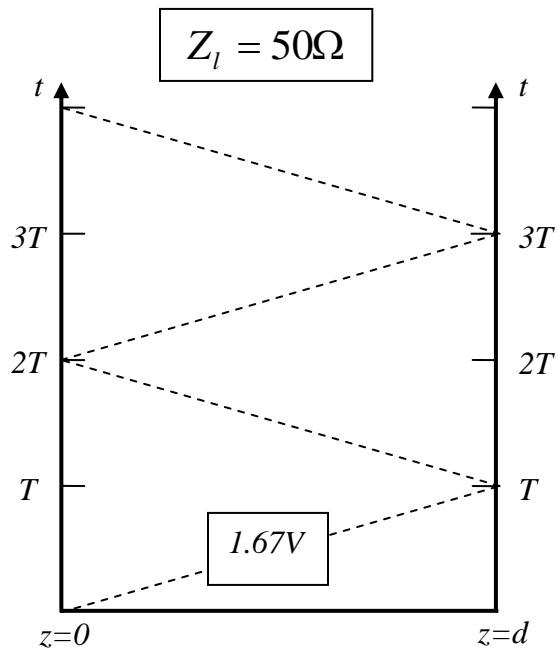
To answer the questions requires two bounce diagrams, one for each load.

$$V_{in} = 5 \frac{25}{25 + 50} = 1.67V$$

$$\Gamma_l = \frac{50 - 50}{50 + 50} = 0$$

$$\Gamma_s = \frac{25 - 50}{50 + 25} = -.333$$

The transit time T was evaluated on the first page

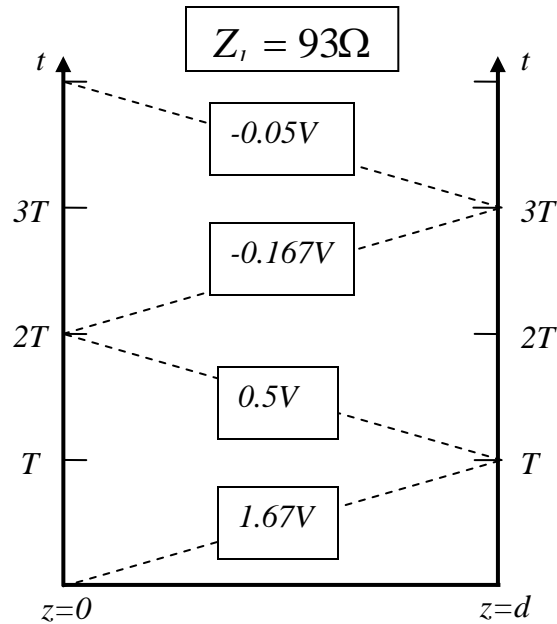




$$V_{in} = 5 \frac{25}{25 + 50} = 1.67V$$

$$\Gamma_l = \frac{93 - 50}{93 + 50} = 0.3$$

$$\Gamma_s = \frac{25 - 50}{50 + 25} = -.333$$



For the matched load $Z_{in} = 50\Omega$, the input and output pulses should both be 1.67V and be separated by the delay time, which they are. At the intermediate point (between the two lines), we see the signal at the source end appearing 1.8us later and the signal at the load end 1us later.

For the load $Z_l = 93\Omega$, the input pulse is still 1.67V since the input impedance remains the same. For the voltage at the load, we should have $1.67 + 0.5$ or 2.17V, which is what the plot indicates. We are not using the same number of significant digits as PSpice, so the agreement cannot generally be perfect. When the pulse returns to the source, there is another reflection, so we will see $2.17 - .167 = 2.0$. Back at the load, we see $2.0 - .05 = 1.95$. All are in agreement. At the intermediate point, we see the delays noted for the 50 Ohm case, where it takes the value of the end the signal just came from. In other words, it is first the same as the source end, then the load end, and so forth. Note that, in this case where the load resistance is higher than the line impedance, the voltage observed at the load is larger than the voltage observed at the source end. This is because the reflection coefficient is positive and we are simultaneously observing the incident and reflected pulses.

For both loads, this process repeats over and over each time the square wave takes a step. Also note that it takes much longer for the open circuit (1Meg) load to settle down since everything reflects from such a large mismatch.



6. Comparison Between Modeling and Theory

- Use your results for problem 4 to explain the voltages observed for the sinusoidal source.
- User your results for problem 5 to explain the voltages observed for the pulsed source.

This is done above.

7. Experimental Verification

The experiment to be done in the studio classroom requires the cooperation of all groups in each section. You are to select a group to provide the source voltage to their coil of wire. Then each group, in turn, is to connect their coil of wire in series with the others until the last group provides the terminated load of 50 or 93 Ohms. The load group must be sure to terminate its cable at its scope, in turn, with each of the two loads. The source group must remember to terminate the short cable from the function generator to one of the scope channels. However, at some point they should try it both ways to see the effect. Otherwise the setup is the same as the experiment that most of you did the first day of class.

Each group must also set up the pulsed experiment with their individual cable. However, the only measurement you each need to make is the transit time to go from one end of the cable to the other. You can do this any way you wish. From the transit time and your knowledge of the propagation velocity, determine the actual length of your cable. As an additional confirmation of the length, use the LCZ Bridge to measure the capacitance of the cable with no load (open circuit). Using the known capacitance per unit length of the cable, determine its length.

Email the following information to Prof. Connor by 6PM on Wednesday:

- The number on your cable spool.
- The measured delay time and resulting length of the cable.
- The measured capacitance and resulting length of the cable.

This information will be posted on the class announcement page, so that everyone will have the information necessary to do the following comparison. Obviously, the total length of the cable will not be 560 meters, but will be the sum of the cables used in each section.

Compare your experimental results with those from your analysis. That is, identify what is the same and what is different and why.