

## Homework 2

Due 31 January 2007 at 6:00 pm

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 125meters. The excitation frequency is  $f = 600kHz$ .

### 1. Transmission Line Characteristics

Since you will need them later, write down the following characteristics of the line and waves on the line.

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

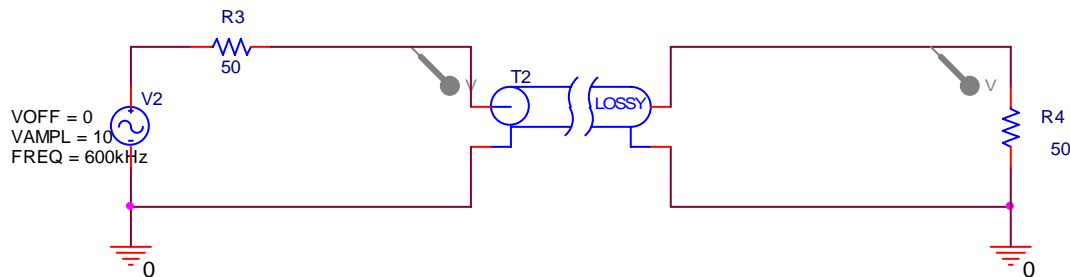
The delay time for the line  $T = 625 ns$

The angular frequency  $\omega = 1.2 \times 10^6 \pi = 3.77 \times 10^6$

The propagation constant  $\beta = 6 \times 10^{-3} \pi = 0.0188$

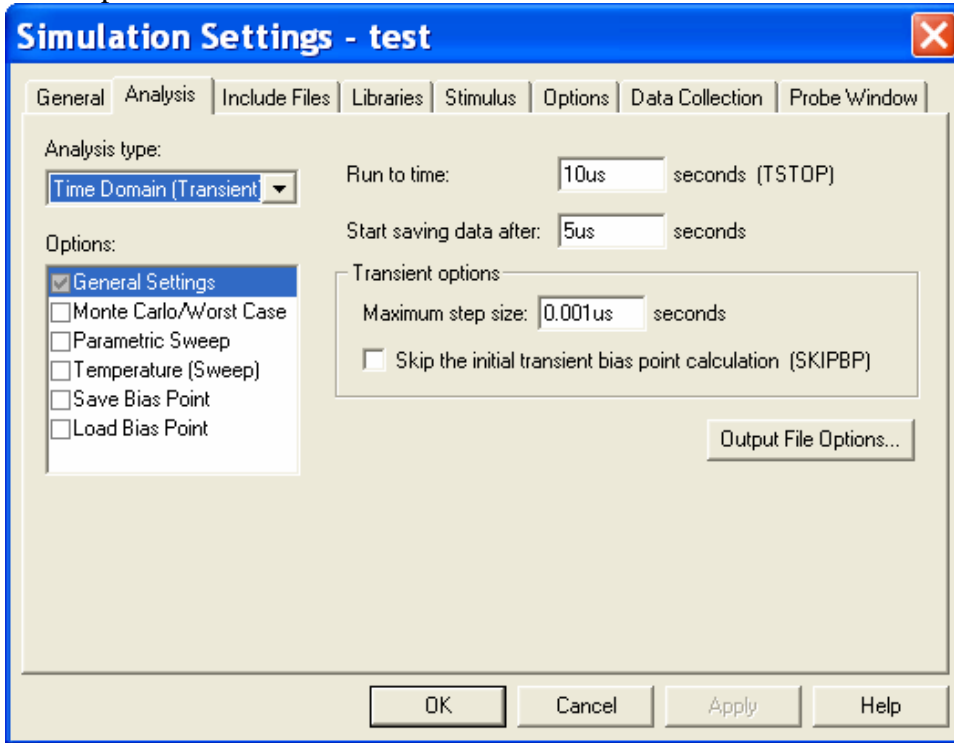
### 2. PSpice Simulation of the Transmission Line with Sinusoidal Input Voltage

First we will consider how the line behaves with the sinusoidal input voltage  $V(t) = 10 \cos \omega t$  where the frequency  $f = 600kHz$ . The voltage source and the load are both matched to the line. Set up the following representation.

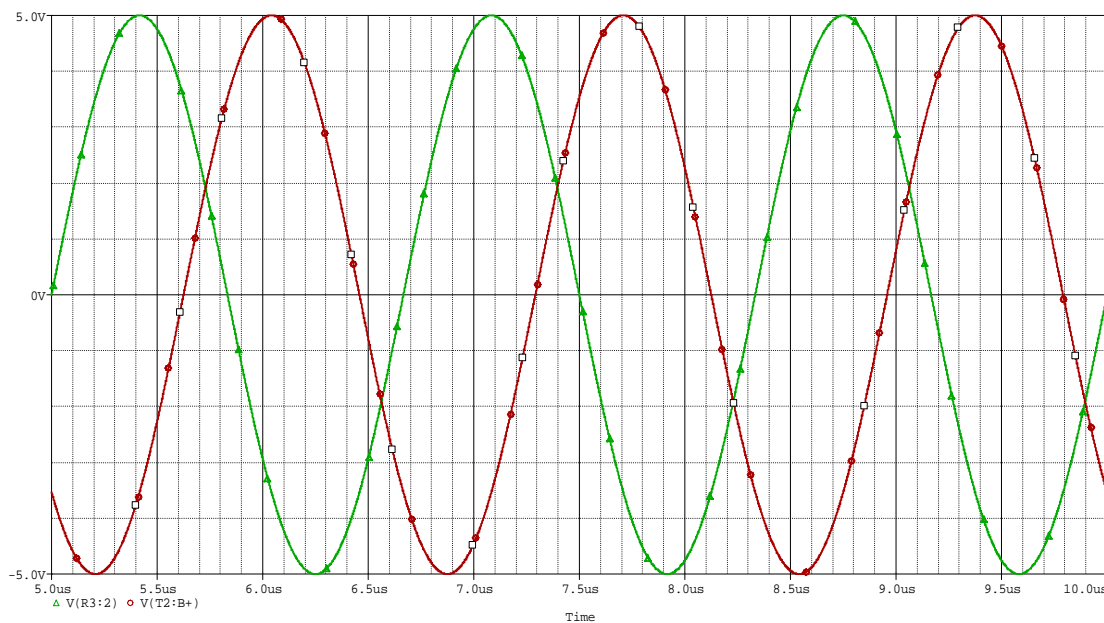


Homework 2

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 load resistances of  $32.5\Omega$  and  $93\Omega$

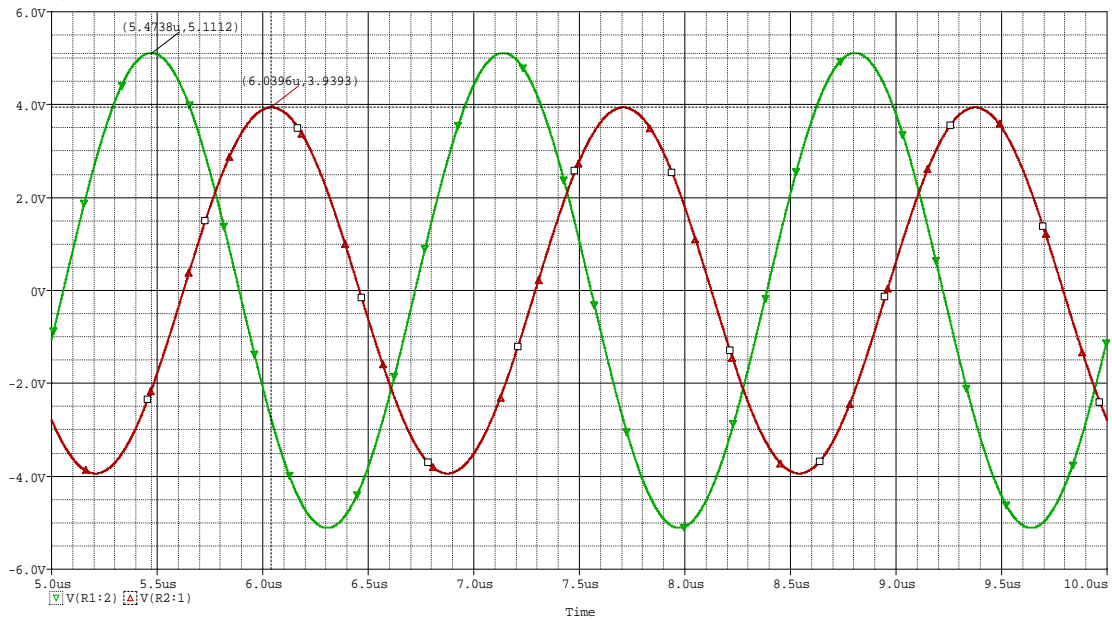


For  $Z_l = 50\Omega$

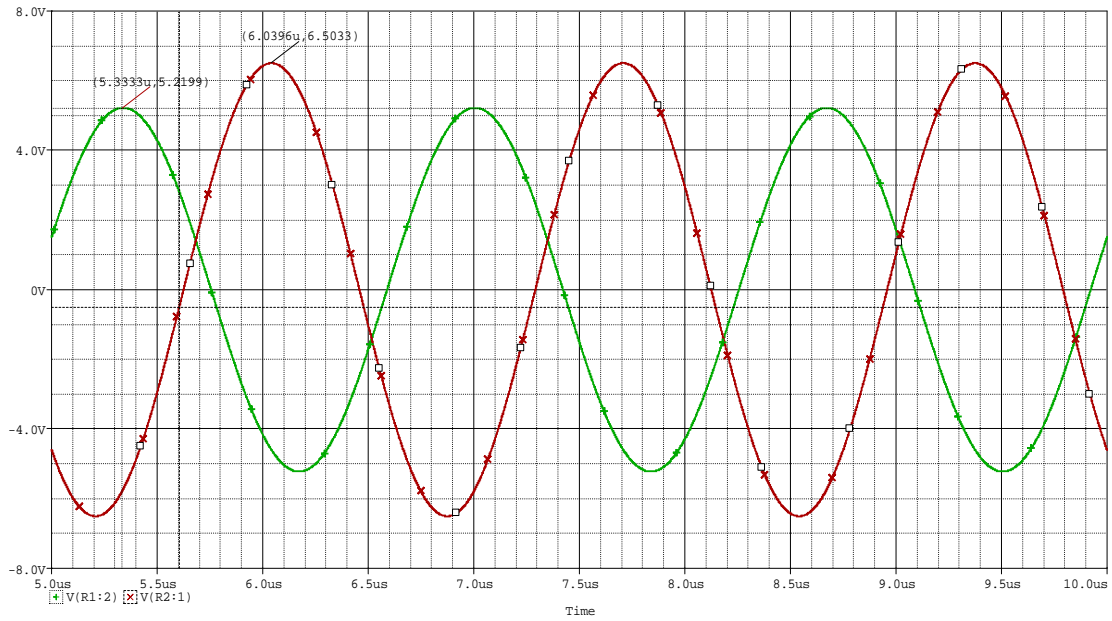


Homework 2

For  $Z_l = 32.5\Omega$



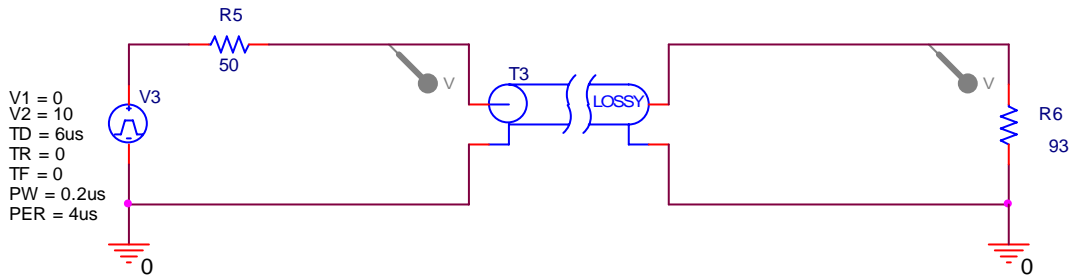
For  $Z_l = 93\Omega$



Homework 2

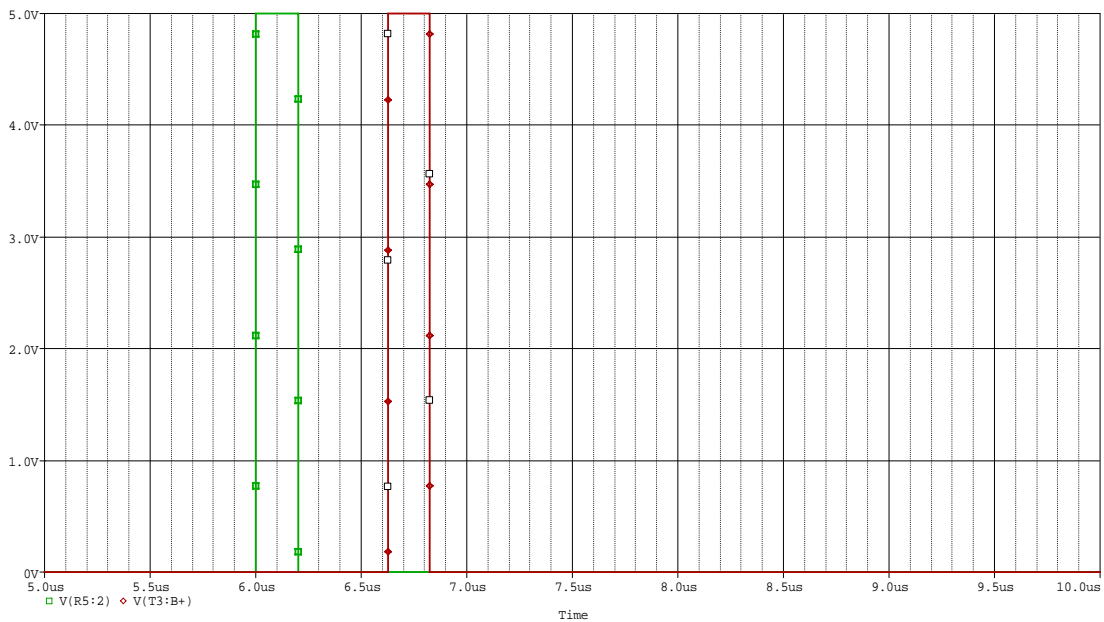
**3. PSpice Simulation of the Transmission Line with a Pulsed Source**

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.



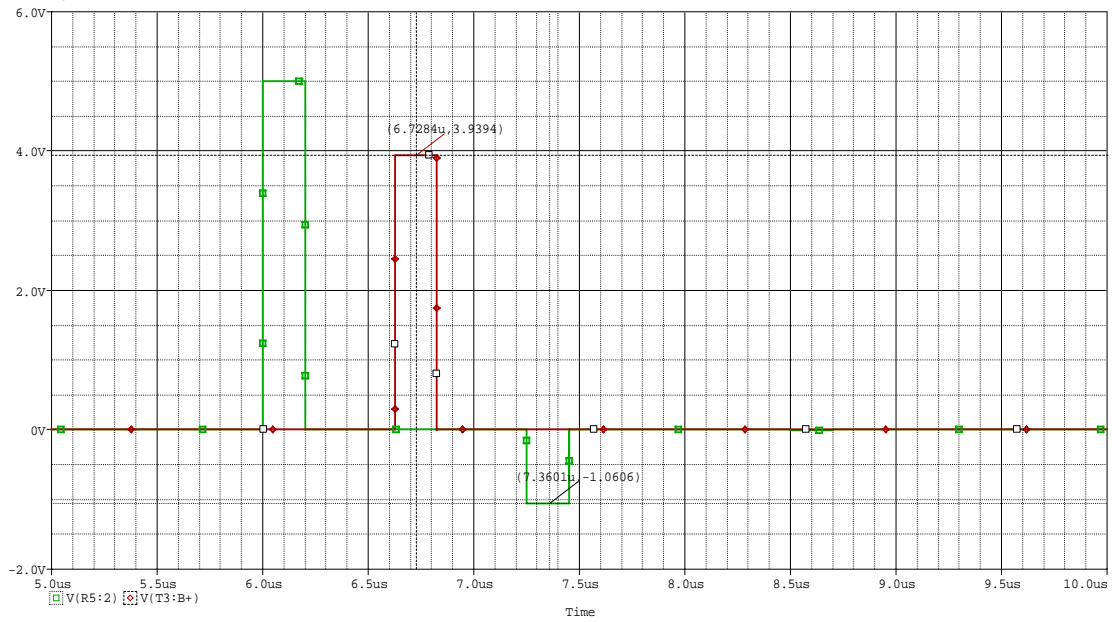
Now run your simulation again, which should simulate both the sinusoidal and pulsed cases simultaneously. You should observe pulses at the input and output ends of the line, for all three loads. It might be helpful to show the sinusoidal and pulsed cases on two separate plots, which PSpice will allow you to do. Now, if necessary, adjust the simulation profile until your plot demonstrates that you are observing all pulses whose voltages exceed 0.5V. Change the simulation conditions only enough to show this. Your plot or plots should show both the sinusoidal case and the pulsed case. Carefully label all waves and pulses, noting where they are observed (input or output end) and their amplitude (since this is not always easy to read from the plots).

For  $Z_l = 50\Omega$

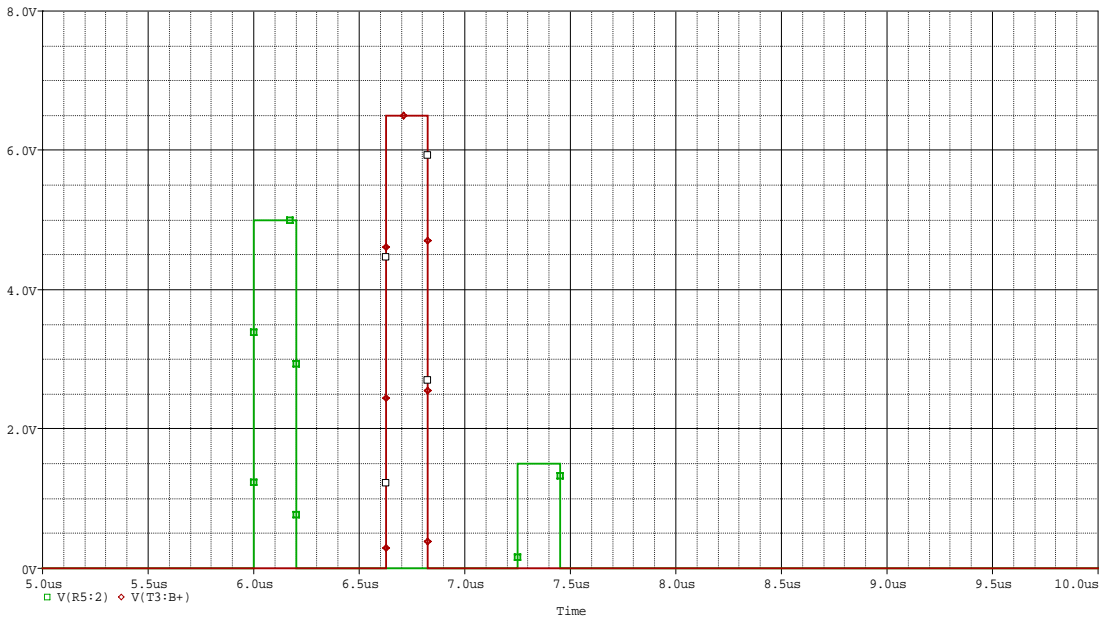


Homework 2

For  $Z_l = 32.5\Omega$



For  $Z_l = 93\Omega$



## Homework 2

**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.

*To provide the answers to these questions, a Matlab m-file was written as follows:*

```
%HW 2 Spring 2007 Fields and Waves I
% K. A. Connor

% Parameters for RG58 cable -- Have to Specify Zl before running this
d=125; l=0.25e-6; c=100e-12;
Zo=sqrt(l/c);u=1/sqrt(l*c); f=6e5; 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));

% Input Voltage
vin=10*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 ,  $Z_{in} = 50\Omega$  ,  $V_{in} = |V_{in}| = 5V$  ,  $P_{in} = P_{out} = 0.25W$  ,  $|V_{out}| = 5V$

For  $Z_l = 32.5\Omega$  ,  $Z_{in} = (45.6942 - j20.2988)\Omega$  ,  $V_{in} = (5.0000 - j1.0606)V$  ,  
 $|V_{in}| = 5.11V$  ,  $P_{in} = P_{out} = 0.24W$  ,  $|V_{out}| = 3.94V$

## Homework 2

For  $Z_l = 93\Omega$ ,  $Z_{in} = (41.7078 + j27.5765)\Omega$ ,  $V_{in} = (5.0000 + j1.5035)V$ ,  $|V_{in}| = 5.22V$ ,  
 $P_{in} = P_{out} = 0.227W$ ,  $|V_{out}| = 6.5V$

*Checking for each case against the PSpice plots:*

*For  $Z_l = 50\Omega$  all voltages are 5V as predicted.*

*For  $Z_l = 32.5\Omega$  the voltage magnitudes are as predicted. To see the values on the plots, it is helpful to zoom in and expand the page to at least double its normal size.*

*For  $Z_l = 93\Omega$ , all voltage magnitudes are as predicted.*

*The time delay between the various input and output terms is approximately the time delay predicted of 625ns. There is an additional phase shift from the input impedance, but we are only looking for qualitative agreement here.*

## Homework 2

**5. Pulses on a Transmission Line**

This question relates to the pulsed voltage.

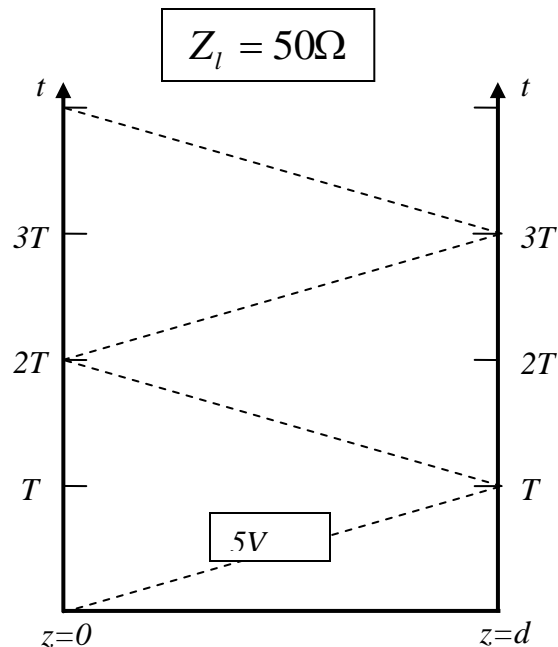
- Determine the voltage input to the line from the voltage divider relationship that characterizes the initial line voltage.
- Determine the reflection coefficients at the load and source end for both lines.
- Generate the bounce diagram for both lines, showing the voltages observed until the level reaches less than 0.5V.
- Sketch the voltages observed at the input and output ends of the line.

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

$$V_{in} = 10 \frac{50}{50 + 50} = 5V$$

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

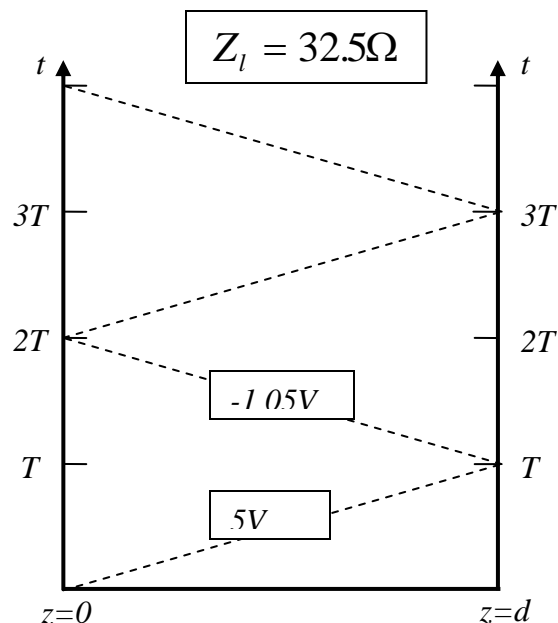
$$\Gamma_g = \frac{50 - 50}{50 + 50} = 0$$



$$V_{in} = 10 \frac{50}{50 + 50} = 5V$$

$$\Gamma_l = \frac{32.5 - 50}{32.5 + 50} = -0.21$$

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



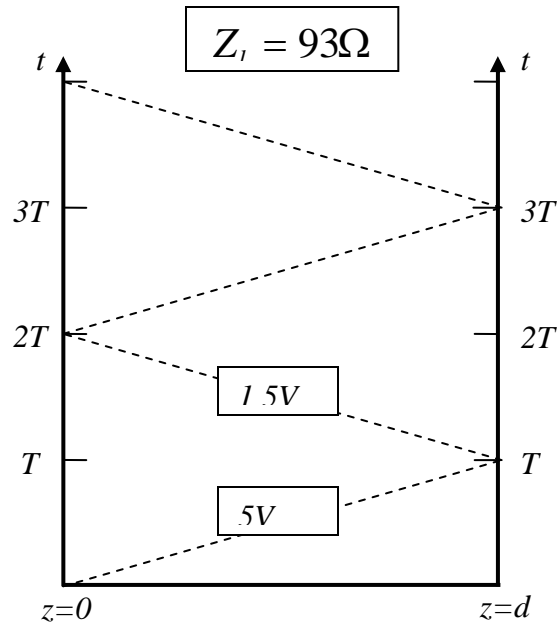


## Homework 2

$$V_{in} = 10 \frac{50}{50 + 50} = 5V$$

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

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



For the matched load  $Z_{in} = 50\Omega$ , the input and output pulses should both be 5V and be separated by the delay time, which they are.

For the load  $Z_l = 32.5\Omega$ , the input pulse is still 5V since the input impedance remains the same. For the voltage at the load, we should have  $5 - 1.05$  or  $3.95V$ , which is approximately 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 no reflection, so only the pulse traveling toward the source is seen, which is  $-1.05V$ .

For the load  $Z_l = 93\Omega$ , the input pulse is still 5V since the input impedance remains the same. For the voltage at the load, we should have  $5 + 1.5$  or  $6.5V$ , which is approximately 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 no reflection, so only the pulse traveling toward the source is seen, which is  $1.5V$ . 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.

## Homework 2

**6. Comparison Between Modeling and Theory**

- a. Use your results for problem 2 to explain the voltages observed for the sinusoidal source. *Done above*
- b. Use your results for problem 3 to explain the voltages observed for the pulsed source. *Done above*

**7. Experimental Verification**

Set up both configurations using one of the reels of coaxial cable in the studio classroom. Be sure to terminate your cable at the scope, in turn, with each of the three loads. There are no 32.5 Ohm terminators, but this can easily be done. Capture your results using the Agilent Intuilink software. Compare your experimental results with those from your analysis. That is, identify what is the same and what is different. For the pulses, you probably should terminate the short cable from the function generator to one of the scope channels. 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.