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Assignment 6: Voltage and Current Traveling Waves in Transmission Line Equivalent Circuits

Exercise 1: Low-Loss Transmission Line

Matlab Code:

```
%exercise 3 - Gurleen Dhillon - dhillg25 - 400301955
clear all; close all %#ok<CLALL> reset everything

%parameters
R = 1.8;
L = 286;
G = 0.65;
C = 115;
F = 1,000,000,000;
W = F*(2*pi);

%plot equations
Z = sqrt((R + i*W*L)/(G + i*W*C));
y = sqrt((R + i*W*L)*(G + i*W*C));
a = real(y); %a
b = imag(y); %b
c = W/b;     %c
d = real(Z); %d
e = imag(Z); %e


%a
subplot(5, 1, 1)
fplot(a, [1*F 10*F], 'red')
title("attenuation constant") %title
xlabel('frequency (GHz)');

%b
subplot(5, 1, 2)
fplot(b, [1*F 10*F], 'blue')
title("phase constant")
xlabel('frequency (GHz)');

%c
subplot(5, 1, 3)
fplot(c, [1*F 10*F], 'green')
```

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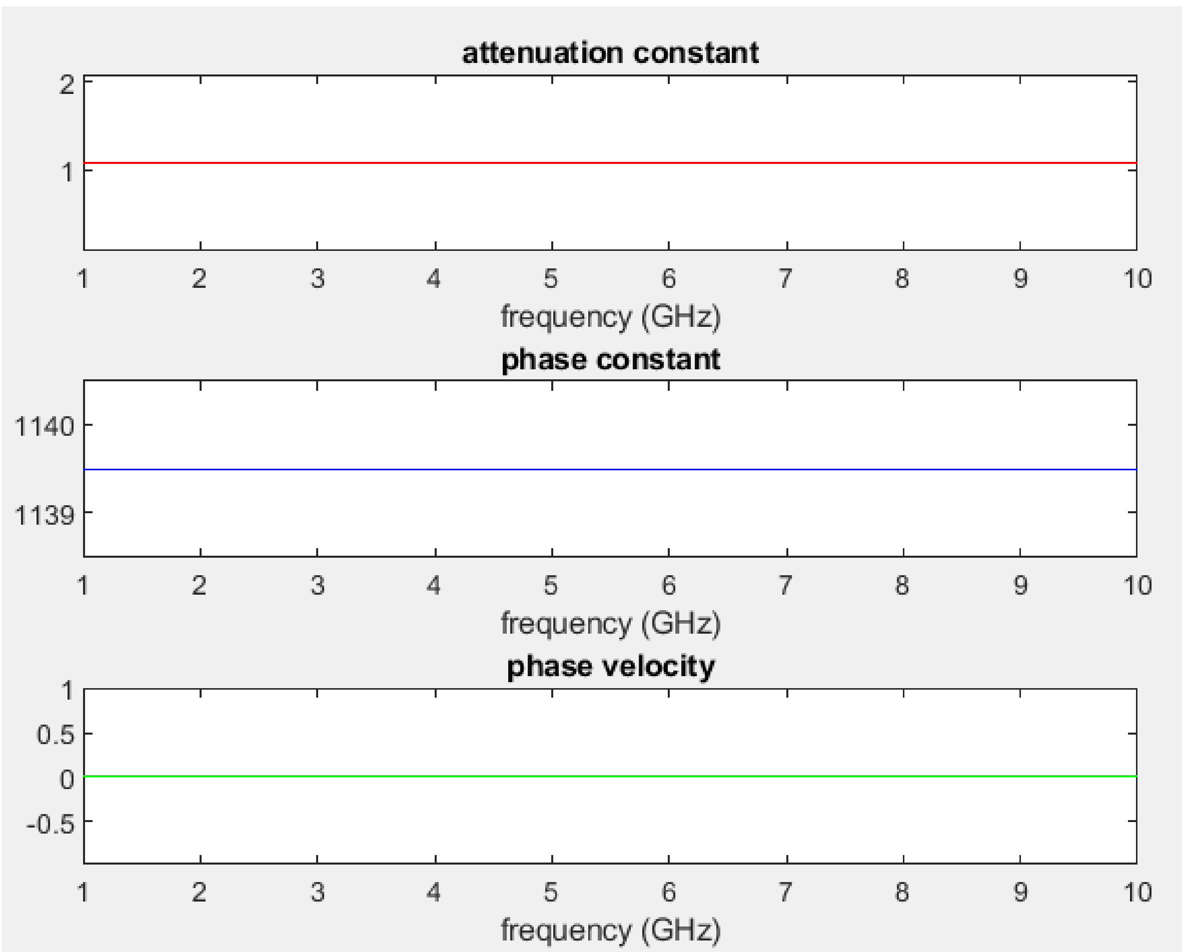
```
title("phase velocity")
xlabel('frequency (GHz)');

%d
subplot(5, 1, 4)
fplot(d, [1*F 10*F], 'magenta')
title("real part of characteristic impedance")
xlabel('frequency (GHz)');

%e
subplot(5, 1, 5)
fplot(e, [1*F 10*F], 'black')
title("imaginary part of characteristic impedance")
xlabel('frequency (GHz)');
```

Matlab Plots:



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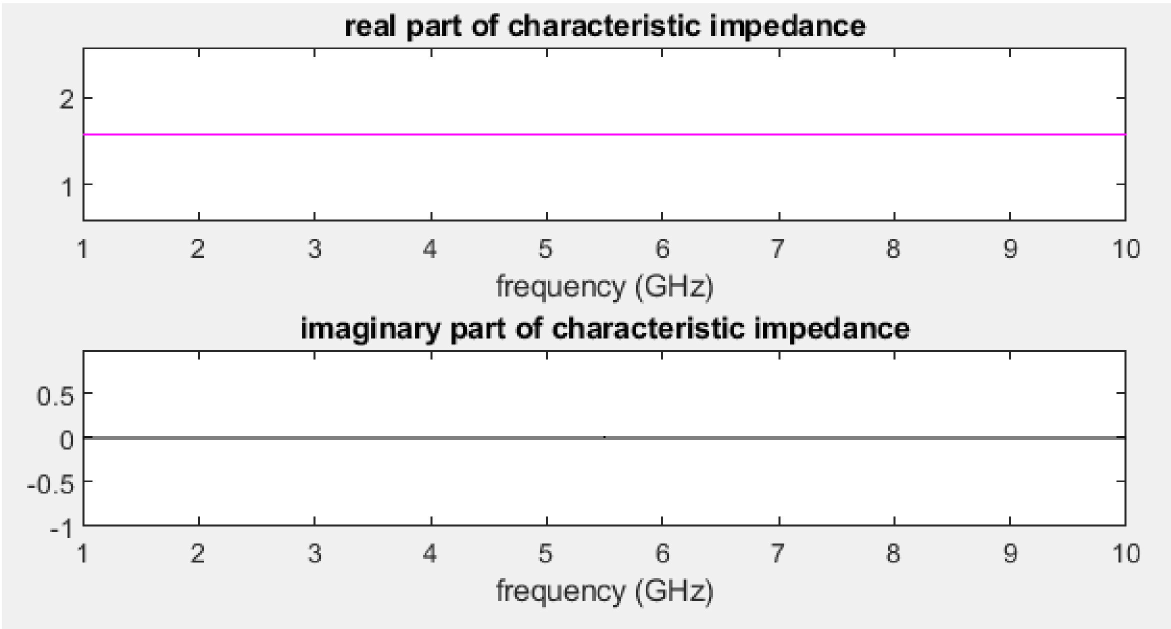
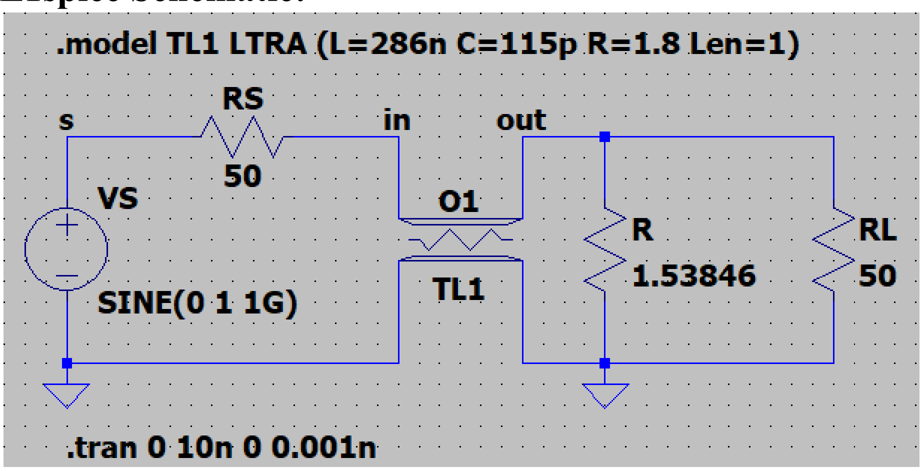


LTspice Schematic:



LTspice Netlist:

```
* C:\Users\gurle\Documents\LTspiceXVII\eleceng 2cf3
assignements\assignment 6\assig6_q1.asc
VS s 0 SINE(0 1 1G)
RS in s 50
RL out 0 50
R out 0 1.53846
O1 in 0 out 0 TL1
.tran 0 10n 0 0.001n
.model TL1 LTRA (L=286n C=115p R=1.8 Len=1)
.backanno
.end
```

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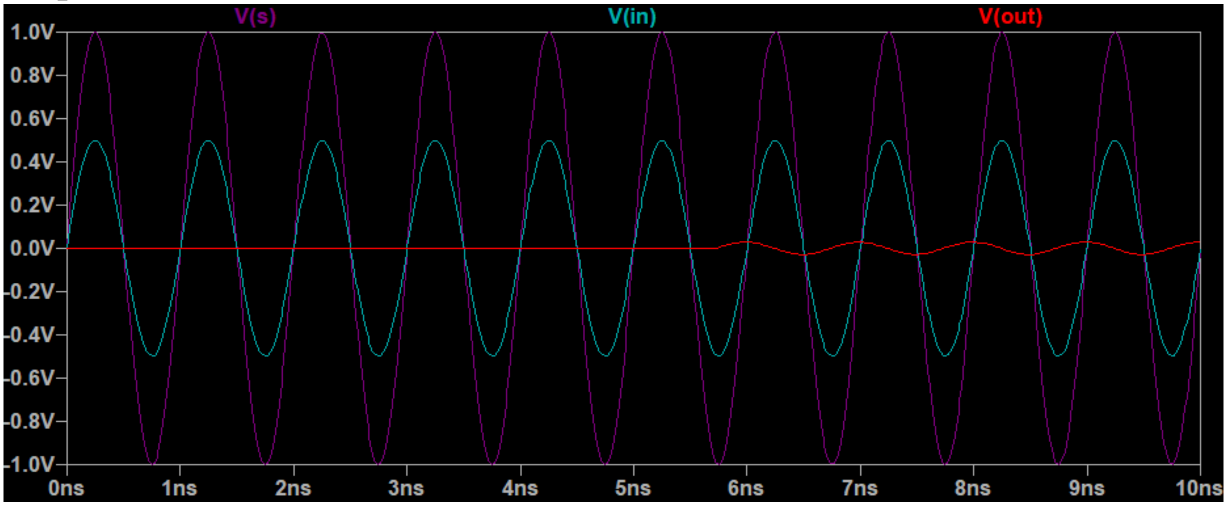
LTspice Simulation Plot:



How does the magnitude of v_{in}(t) compare to the magnitude of v_s(t)? Explain your observation.

The magnitude of V_in is almost half of the magnitude of V_s at any point on the plot, as V_in reads to be almost 500mV when V_s is about 1V.

How does the magnitude of v_{out}(t) compare to the magnitude of v_{in}(t)? Explain your observation.

Most of the time, the magnitude of V_out is almost 0, but at around 6ns, V_out starts acting like a sinusoidal function that reaches a maximum of about 28.5mV, while V_in reaches a maximum of about 0.5V. V_out tends to reach its maximum (or minimum) when the magnitude of V_in is 0V (at its roots) and the same can be true the other way around as V_in reaches its maximum (or minimum) when V_out is 0V. This shows that the waves have a phase difference of about pi/2.

Calculate the attenuation constant α (in Np/m) of the TL using the peak values of v_{in}(t) and v_{out}(t) that you determined in Questions 7 and 8. Does this value agree with the value obtained with your MATLAB code?

$\alpha \ = \ ln(\frac{V_{in}}{V_{out}}) \ = \ ln(\frac{498.5}{28.5}) \ = \ 2.862$

This value of the attenuation constant does not agree with the values from the MATLAB code, as the value that the MATLAB code outputted about 1.1 which was more than double the calculated value.

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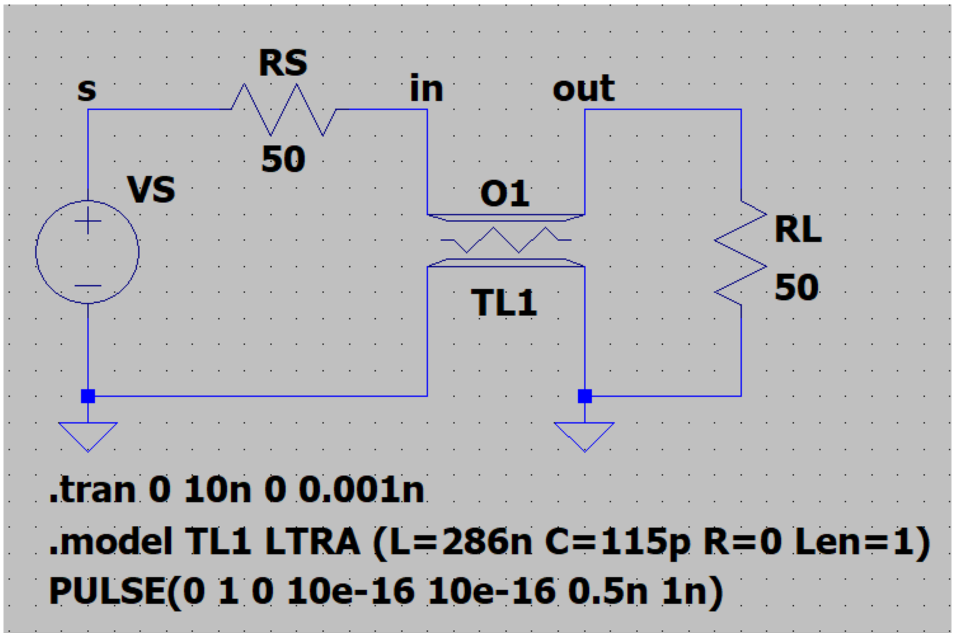
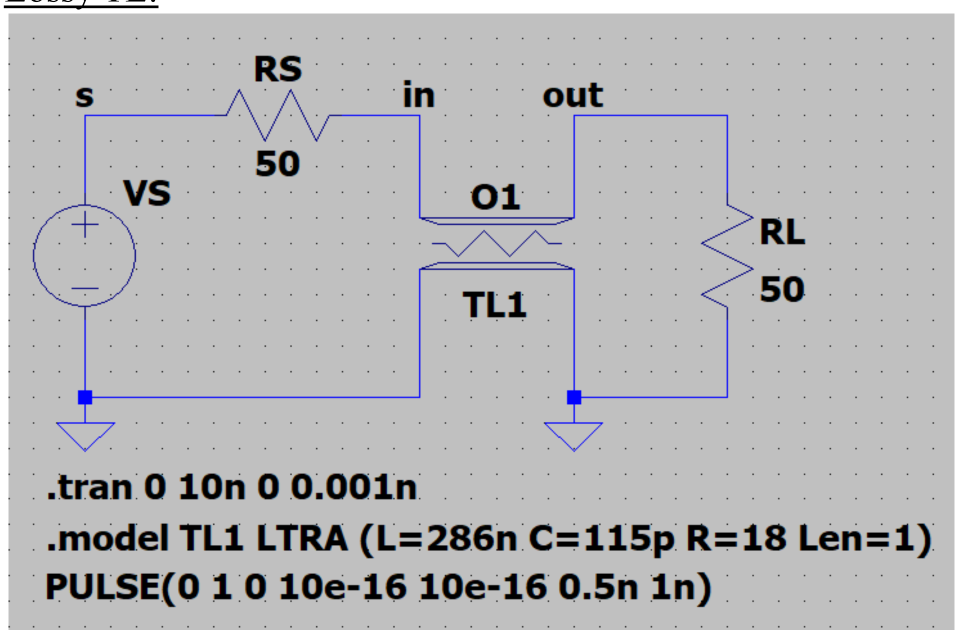
Exercise 2: Lossy Transmission Line

LTspice Schematic:

Loss-Free TL:



Lossy TL:



LTspice Netlist:

Loss-Free TL:

```
* C:\Users\gurle\Documents\LTspiceXVII\eleceng 2cf3
```

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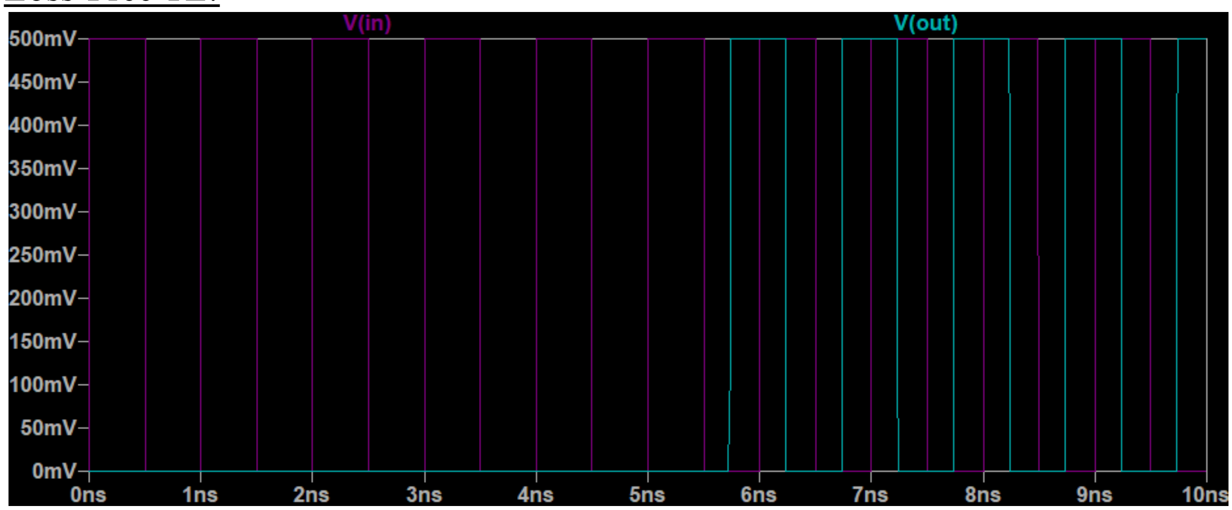
```
assignements\assignment 6\assig6_exercise2_lossfreeTL.asc
VS s 0 PULSE(0 1 0 10e-16 10e-16 0.5n 1n)
RS in s 50
RL out 0 50
O1 in 0 out 0 TL1
.tran 0 10n 0 0.001n
.model TL1 LTRA (L=286n C=115p R=0 Len=1)
.backanno
.end
```

Lossy TL:

```
* C:\Users\gurle\Documents\LTspiceXVII\eleceng 2cf3
assignements\assignment 6\assig6_exercise2_lossyTL.asc
VS s 0 PULSE(0 1 0 10e-16 10e-16 0.5n 1n)
RS in s 50
RL out 0 50
O1 in 0 out 0 TL1
.tran 0 10n 0 0.001n
.model TL1 LTRA (L=286n C=115p R=18 Len=1)
.backanno
.end
```

LTspice Simulation Plot:

Loss-Free TL:



Lossy TL:

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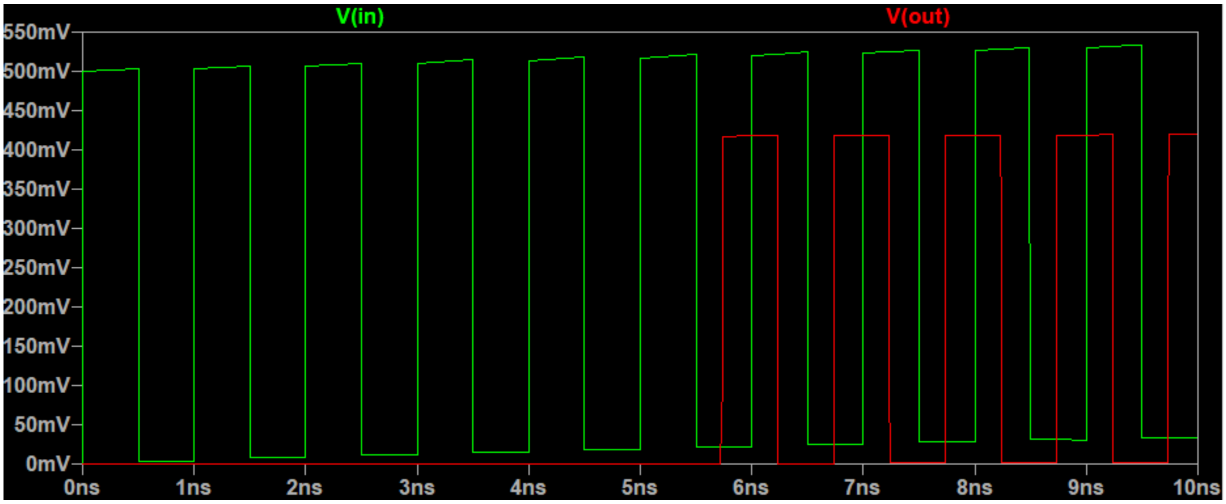

Compare the magnitude of $v_{out}(t)$ in the loss-free TL compared to the magnitude of $v_{out}(t)$ in the lossy TL. Based on these two values, calculate the attenuation of the lossy TL in dB/m. You do not need to compare this calculation with analytical calculations.

The magnitude of the V_out in the loss-free TL is about 500mV, while the magnitude of V_out in the lossy TL is about 419mV.

$\alpha\ =$

What is the time delay t_d between $v_{in}(t)$ and $v_{out}(t)$ in the lossy TL?

In the lossy TL, the time delay between V_in and V_out is about 0.73ns.

Calculate the phase velocity v_p in the lossy TL using the time delay t_d found in Question 7. The length of the TL is 1m.

0.73

$v_p\ =\ 1/sqrt(L * C)$

Compare the so obtained phase velocity v_p with the analytical value, which you can compute using your MATLAB code at the repetition frequency 1/T where T = 1ns. The analytical calculation of v_p must take the losses into account, i.e., you cannot use the low-loss approximation. Include your analytical value of v_p in the report. Is there good agreement? Please, state clearly the values of the simulation based and the analytical phase velocities.