Project 1 - Impedance Plotting

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Fields Waves II - ECEN-3623

Contents

1 Introduction

Develop a MATLAB code that will calculate and plot the impedance (magnitude and phase) along the length of a lossless 50 cm coaxial TL (RG-58) with a 2.4 GHz source (50 ohms), 50 Ohm characteristic impedance for the load conditions and lengths as described below.
A. ZL = 25 Ohms
B. ZL = 100 Ohms
C. ZL = 0 Ohms
D. ZL = open circuit
E. Calculate the power delivered to the load from a 1 Vrms source for parts A and B.

2 Beginning Calculations

The formula of Input Impedance for a lossless transmission line is as follows:

$$Zin = Zo * \frac{Zl + j * Zo * tan(\beta * l)}{Zo + j * Zl * tan(\beta * l)}$$

(1)

Other equations utilized include:
Angular Frequency

$$\omega = 2 * \pi * f \tag{2}$$

Propagation Velocity (65.9% for RG-58 Transmission Line & c = 299792458 m/s)

$$\nu = c * .659 \tag{3}$$

Beta

$$\beta = \frac{\omega}{\nu} \tag{4}$$

3 25 Ohm Load Impedance

For Case A: 25 Ohm Load Impedance, calculations for the real part of amplitude and the phase were completed with resulting graphs.

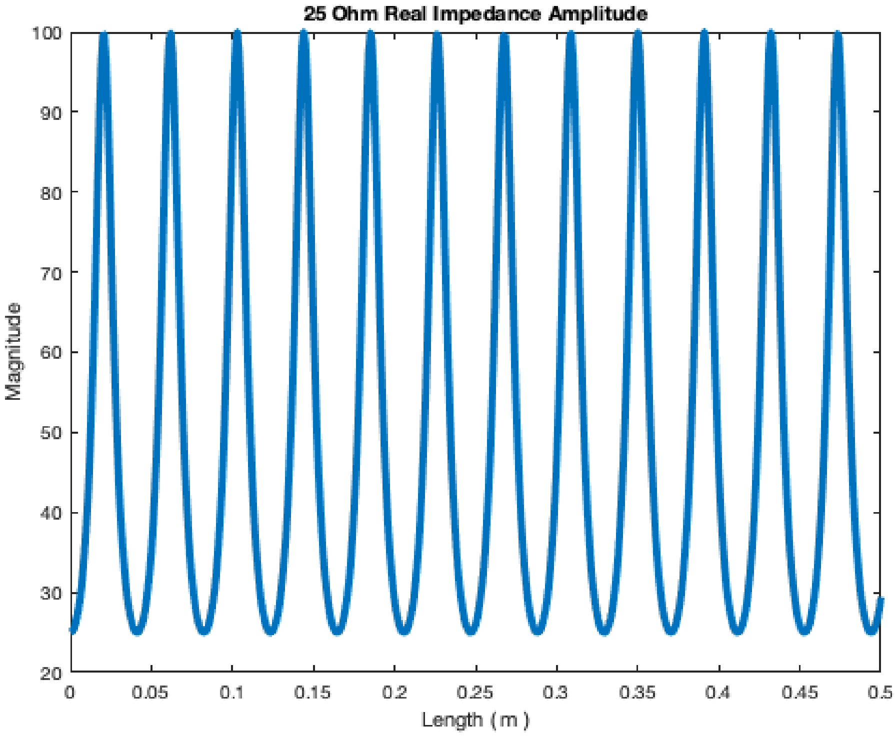

Figure 1: 25 Ohm Real Amplitude Plot

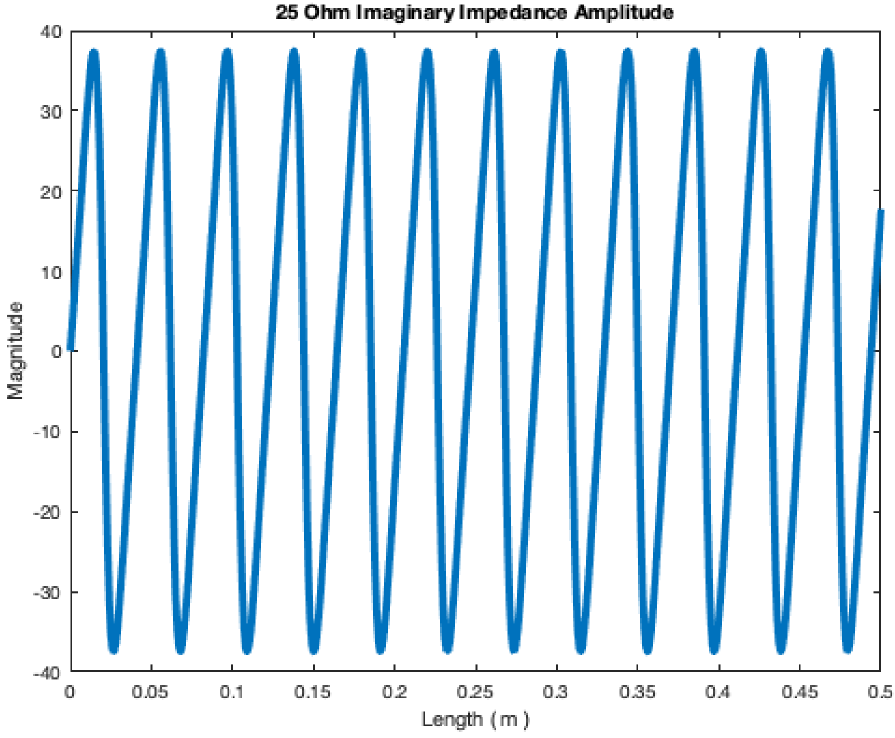

Figure 2: 25 Ohm Imaginary Amplitude Plot

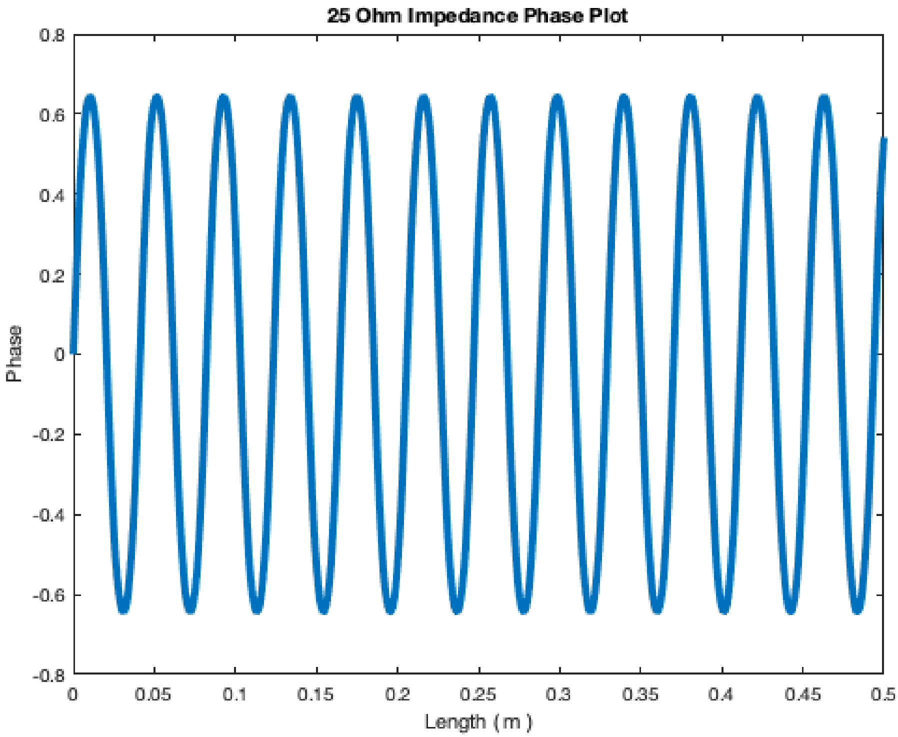

Figure 3: 25 Ohm Phase Plot

As can be seen above, the 25 Ohm load impedance reaches its maximum during the "peaks" of the phase. The wave is also shown in a sinusoidal pattern propagation which can be observed through the phase graph. The maximum magnitude of the input impedance is 100 Ohms and the minimum magnitude is 25 Ohms. The input line impedance is 25 at the beginning and ending of the length of the line, or 25 ohms at length of 0 and length of 0.5m.

4 100 Ohm Load Impedance

For Case B: 100 Ohm Load Impedance, calculations for the real part of amplitude and the phase were completed with resulting graphs.

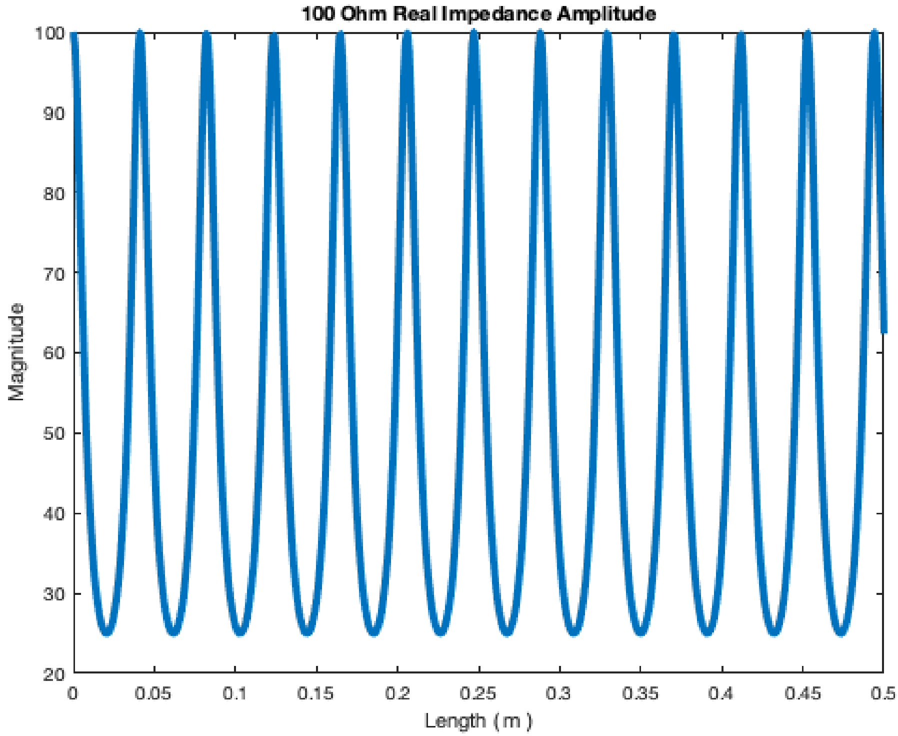

Figure 4: 100 Ohm Real Amplitude Plot

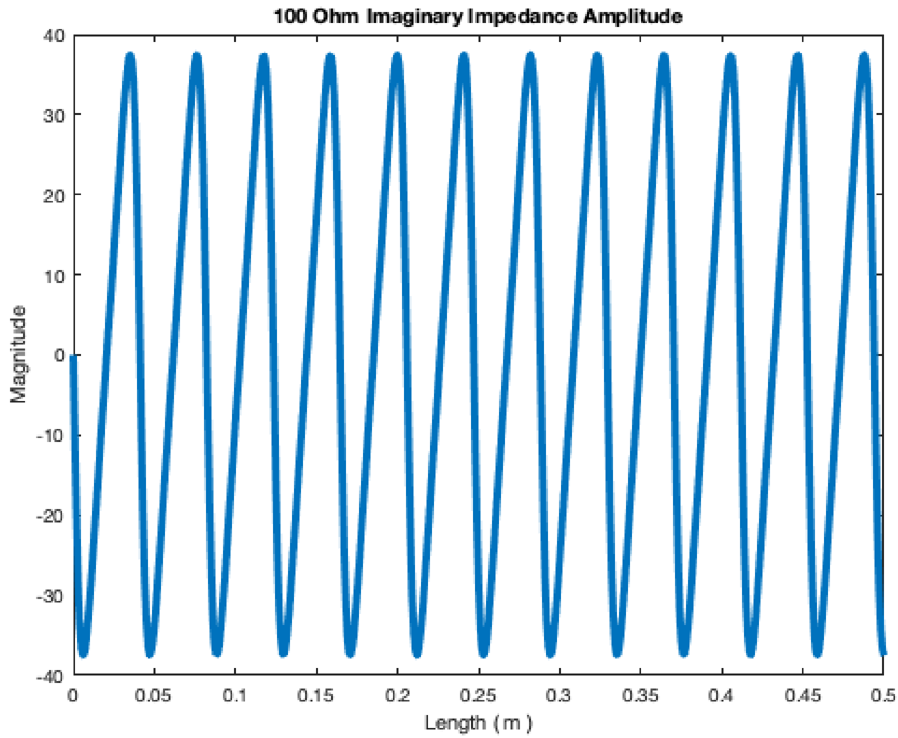

Figure 5: 100 Ohm Imaginary Amplitude Plot

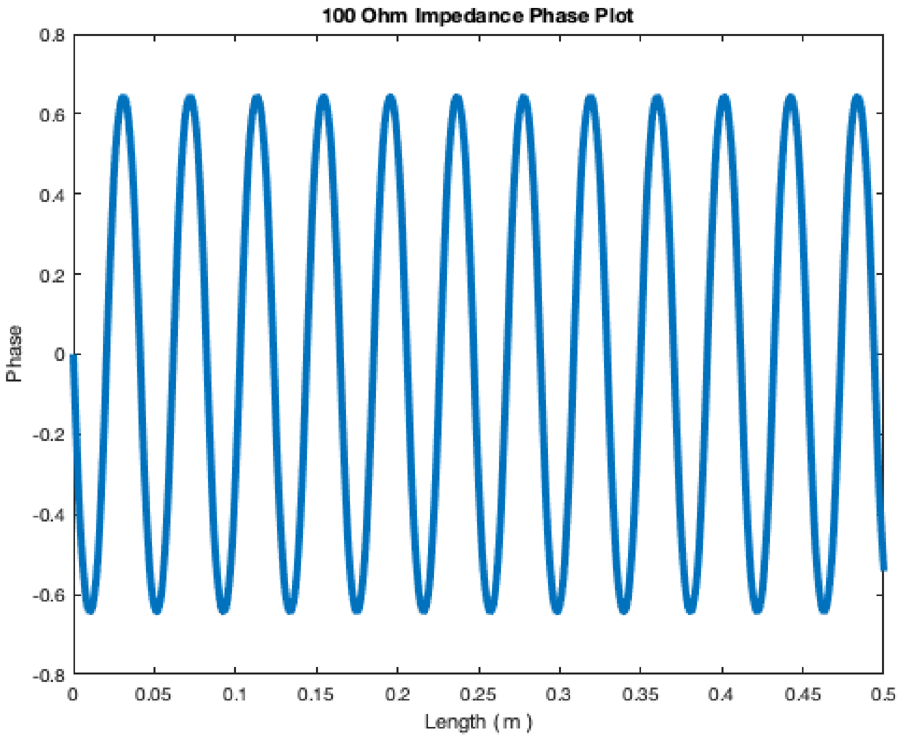

Figure 6: 100 Ohm Phase Plot

As can be seen above, the impedance reaches its maximum during the "peaks" of the phase. The wave is also shown propagating which can be observed through the phase graph. It is important to note the impedance has a different phase than the 25 Ohm case. The maximum magnitude is 100 Ohm when the phase equals 0 and the minimum magnitude is 25 Ohm. Along the length, the impedance should be 100 Ohms at the beginning and ending of the line (ie. 0m and 0.50m)

5 0 Ohm (Short Circuit) Load Impedance

For Case C: 0 Ohm Load Impedance, calculations for the real part of amplitude and the phase were completed with resulting graphs.

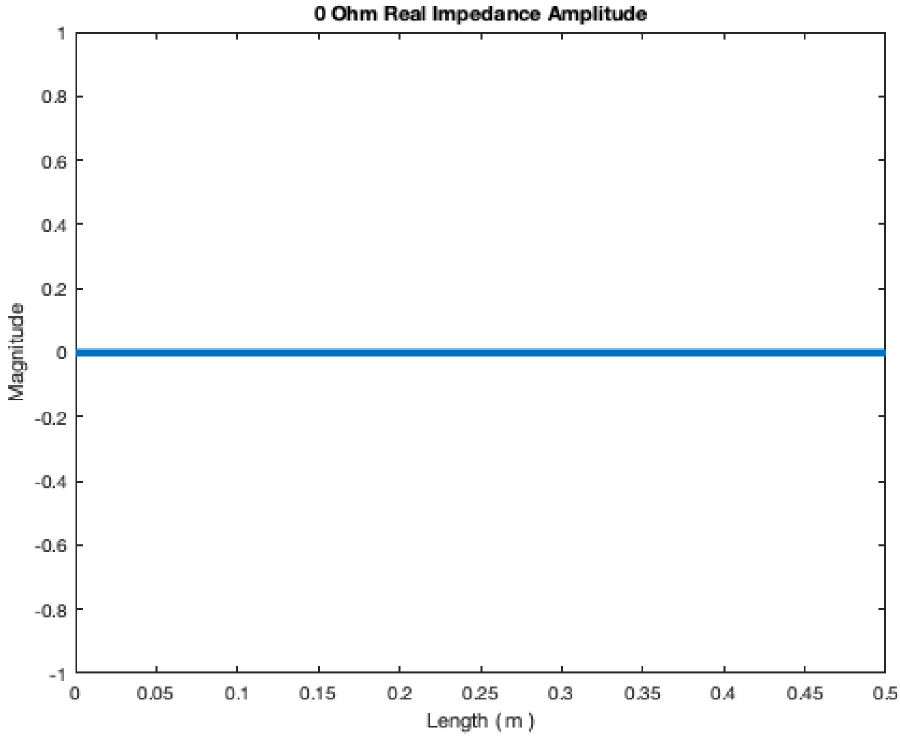

Figure 7: 0 Ohm Real Amplitude Plot

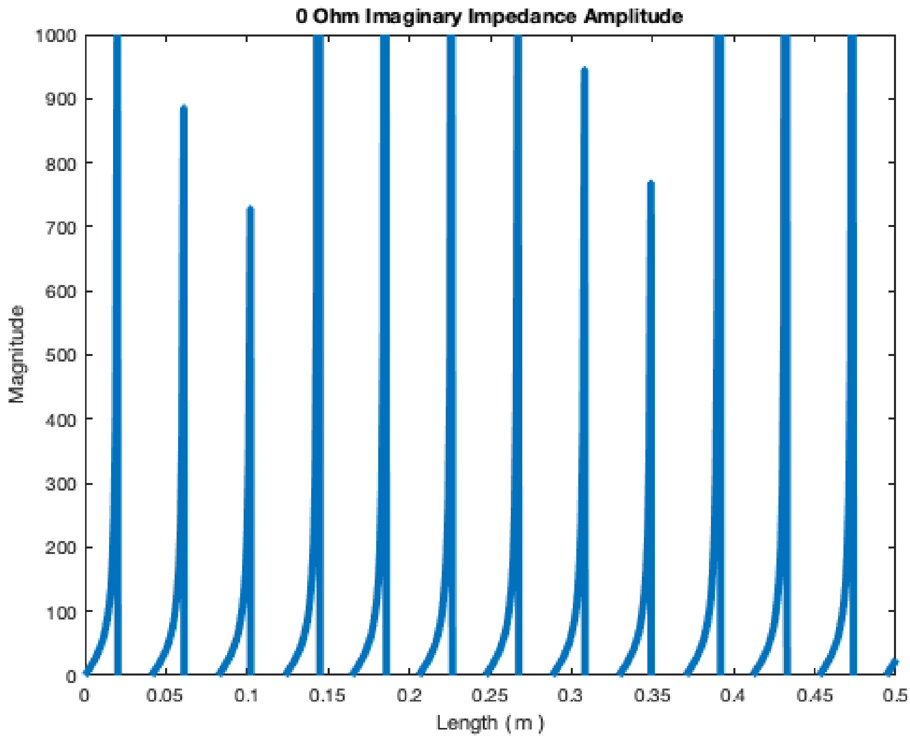

Figure 8: 0 Ohm Imaginary Amplitude Plot

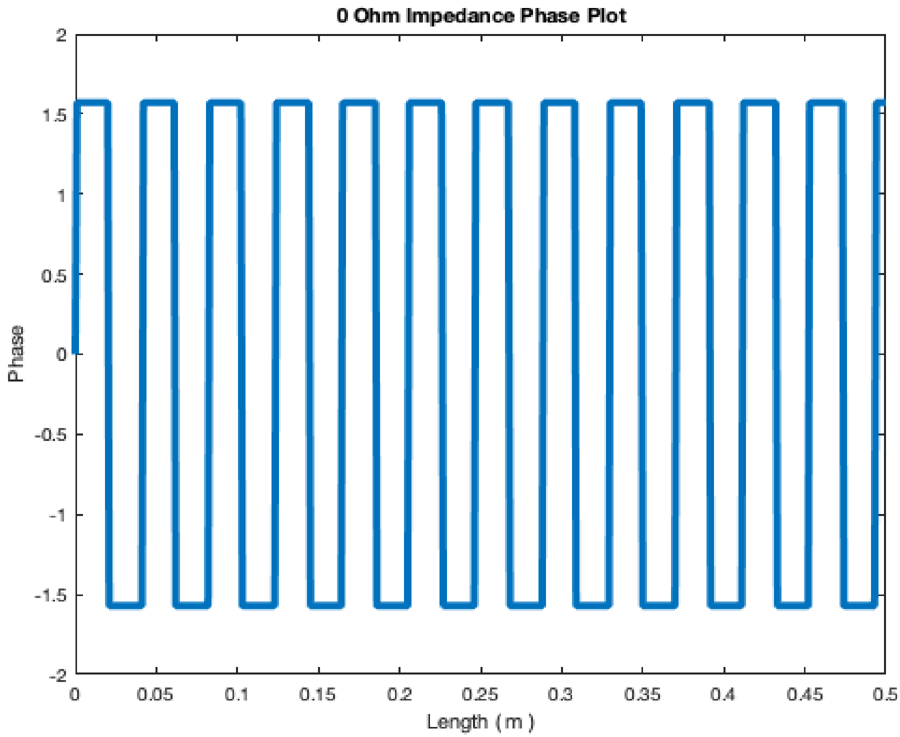

Figure 9: 0 Ohm Phase Plot

These graphs demonstrate the complete the wave propagation. This is shown by the constant amplitude of 0 for the input impedance and the square wave. Due to the short circuit, the amplitude is entirely imaginary and is representative of tangential asymptotic behavior. The impedance should begin and end along the line at an amplitude of 0.

6 Infinite Ohm (Open Circuit) Load Impedance

For Case D: Infinite Ohm Load Impedance, calculations for the real part of amplitude and the phase were completed with resulting graphs.

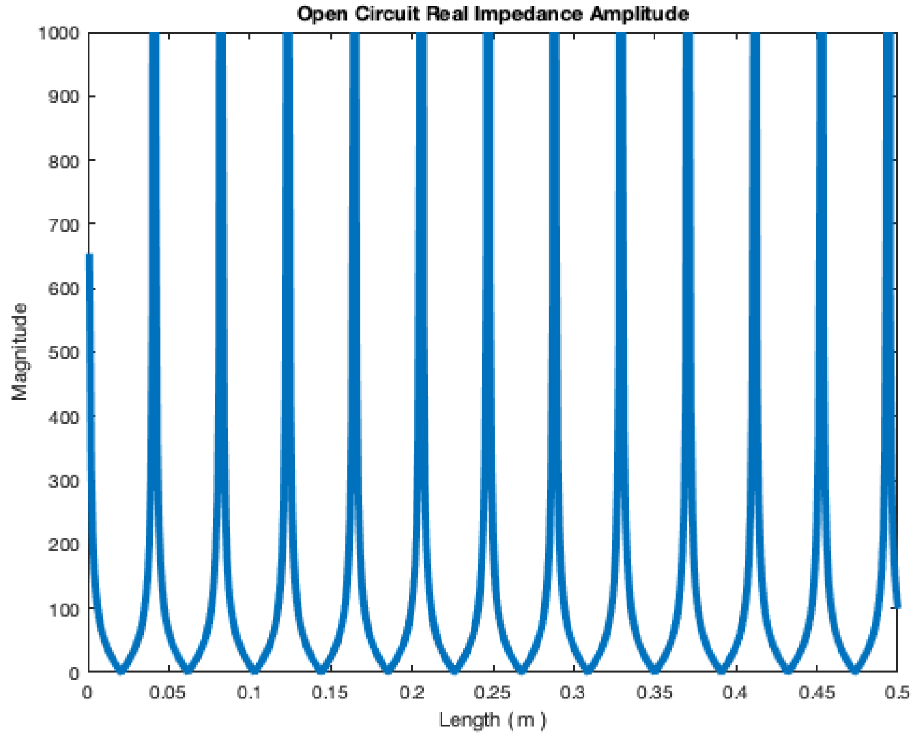

Figure 10: Infinite Ohm Real Amplitude Plot

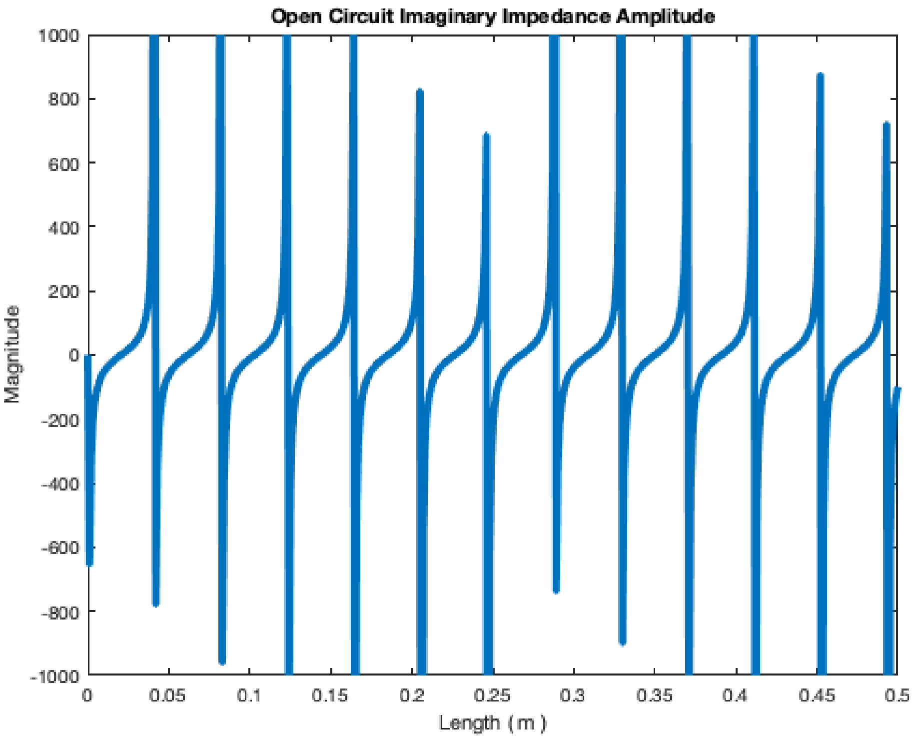

Figure 11: Infinite Ohm Imaginary Amplitude Plot

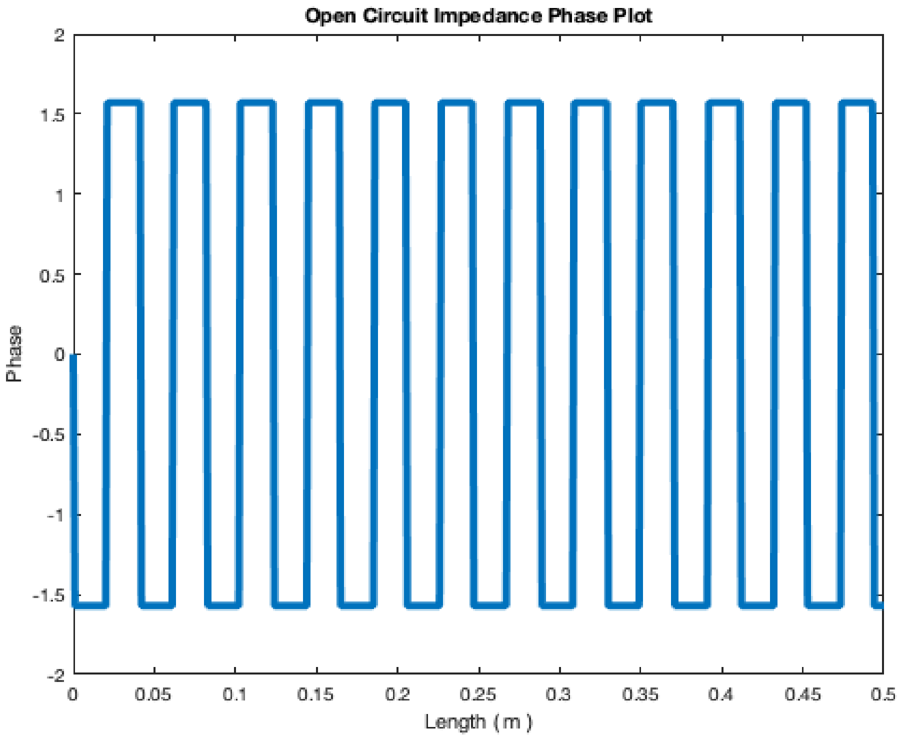

Figure 12: Infinite Ohm Phase Plot

The load impedance demonstrated for an open circuit is close to infinity, but not infinity. Using a large value such as

$$50 * 10^{20} \tag{5}$$

the graph is displayed. The impedance should begin and end at infinity.

7 Power for Case A & B

For the Cases A & B the power the equations were utilized:

$$I = \frac{Vrms}{Rs + Zin} \tag{6}$$

$$P = I^2 * \Re(Zin) \tag{7}$$

Using these equations resulted in power output to load as:
Case A (25 Ohm Load): Power = 0.044
Case B (100 Ohm Load): Power = 0.044

8 Appendix

8.1 Case A

```
clear all
clc
%Aaron Rosen - Fields & Waves II - Project 1
%CASE A - 25 Ohm Amplitude & Phase of Impedance

length = 0:0.001:0.5;
%Zo: Characteristic Impedance
Zo = 50;
%Zl: Load Impedance
Zl1 = 25;

%Frequency f = 2.4e9;
%w == angular frequency
w = 2.*pi.*f;
%l in m l = 0.5;
%c == speed of light in m/s
c = 299792458;
%up == propagation velocity
%up of RG58 is 65.9%up = c/sqrt(er) up = 0.659*c;
B = w./up;
t = tan(B.*length);
num1 = Zl1 + 1j.*Zo.*t;
dem1 = Zo + 1j.*Zl1.*t;
Zin1 = (Zo.*num1)./dem1;

figure, plot(length, abs(Zin1), 'LineWidth', 4), title('25 Ohm Real Impedance Amplitude'), xlabel('Length ( m )'), ylabel('Magnitude');
figure, plot(length, imag(Zin1), 'LineWidth', 4), title('25 Ohm Imaginary Impedance Amplitude'), xlabel('Length ( m )'), ylabel('Magnitude');

figure, plot(length, angle(Zin1), 'LineWidth', 4), title('25 Ohm Impedance Phase Plot'), xlabel('Length ( m )'), ylabel('Phase');
```

8.2 Case B

```
clear all
clc
%Aaron Rosen - Fields & Waves II - Project 1
```

%CASE B - 100 Ohm Amplitude & Phase of Impedance

length = 0:0.001:0.5;
%Zo: Characteristic Impedance
Zo = 50;
%Zl: Load Impedance
Zl1 = 100;

%Frequency
f = 2.4e9;
%w == angular frequency
w = 2.*pi.*f;
%l in m
l = 0.5;
%c == speed of light in m/s
c = 299792458;
%up == propagation velocity
%up of RG58 is 65.9%up = c/sqrt(er)
%I am going to use the 65.9% to calculate up
%source: http://www.idc-online.com/technical$_{r}eferences/pdfs/data_{c}ommunications/RG_{5}8.pdf$
$up = 0.659 * c$;
$\%B = up/w$
$B = w./up$;
$t = tan(B. * length)$;
$\%100ohmnum1 = Zl1 + 1j. * Zo. * t$;
$dem1 = Zo + 1j. * Zl1. * t$;
$Zin1 = (Zo. * num1)./dem1$;

figure, plot(length, real(Zin1), 'LineWidth', 4), title('100 Ohm Real Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');
figure, plot(length, imag(Zin1), 'LineWidth', 4), title('100 Ohm Imaginary Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');

figure, plot(length, angle(Zin1), 'LineWidth', 4), title('100 Ohm Impedance Phase Plot'), xlabel('Length (m)'), ylabel('Phase');

8.3 Case C

clear all
clc
%Aaron Rosen - Fields & Waves II - Project 1

%CASE C - 0 Ohm Amplitude & Phase of Impedance

length = 0:0.001:0.5;
Zo = 50;
Zl1 = 0;

f = 2.4e9;
w = 2.*pi.*f;
l = 0.5;
c = 299792458;
up = 0.659*c;
B = w./up;
t = tan(B.*length);
num1 = Zl1 + 1j.*Zo.*t;
dem1 = Zo + 1j.*Zl1.*t;
Zin1 = (Zo.*num1)./dem1;

figure, plot(length, abs(Zin1), 'LineWidth', 4), title('0 Ohm Real Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');
figure, plot(length, imag(Zin1), 'LineWidth', 4), ylim([0 1000]), title('0 Ohm Imaginary Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');

figure, plot(length, angle(Zin1), 'LineWidth', 4), title('0 Ohm Impedance Phase Plot'), xlabel('Length (m)'), ylabel('Phase');

8.4 Case D

clear all clc
length = 0:0.001:0.5;
Zo = 50;
Zl1 = 50*10e20;

f = 2.4e9;
w = 2.*pi.*f;
l = 0.5;
c = 299792458;
up = 0.659*c;
B = w./up;
t = tan(B.*length);
num1 = Zl1 + (1j.*Zo.*t);
dem1 = Zo + (1j.*Zl1.*t);
Zin1 = Zo.*(num1./dem1);

figure, plot(length, abs(Zin1), 'LineWidth', 4), ylim([0 1000]), title('Open Circuit Real Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');
figure, plot(length, imag(Zin1), 'LineWidth', 4), ylim([0 1000]), title('Open Circuit Imaginary Impedance Amplitude'), xlabel('Length (m)'), ylabel('Magnitude');

figure, plot(length, angle(Zin1), 'LineWidth', 4), title('Open Circuit Impedance Phase Plot'), xlabel('Length (m)'), ylabel('Phase');

8.5 Case A - Power

clear all clc %Aaron Rosen - Fields & Waves II - Project 1
%CASE AP - 25 Ohm Power

Zo = 50;
Zl1 = 25;

f = 2.4e9;
w = 2.*pi.*f;
l = 0.5;
c = 299792458;
up = 0.659*c;
B = w./up;
t = tan(B.*0);
num1 = Zl1 + 1j.*Zo.*t;
dem1 = Zo + 1j.*Zl1.*t;
Zin1 = (Zo.*num1)./dem1;
Rs = 50;
Vs = 1; totalresistance = Rs + Zin1;
I = Vs./totalresistance;
P = I.$^2. * abs(Zin1);$
P

8.6 Case B - Power

clear all clc %Aaron Rosen - Fields & Waves II - Project 1
%CASE BP - 100 Ohm Power

Zo = 50;
Zl1 = 100;

f = 2.4e9;
w = 2.*pi.*f;
l = 0.5;
c = 299792458;
up = 0.659*c;
B = w./up;
t = tan(B.*0);
num1 = Zl1 + 1j.*Zo.*t;
dem1 = Zo + 1j.*Zl1.*t;
Zin1 = (Zo.*num1)./dem1;
Rs = 50;
Vs = 1; totalresistance = Rs + Zin1;
I = Vs./totalresistance;
P = I.$^2 . * abs(Zin1);$
P