Transmission Line

1 Objectives

1. To study and understand transmission line theory.
2. To measure the characteristic impedance, the losses, and other characteristics of two-wire transmission lines.

2 Theory

2.1 Characteristics of Transmission Lines

In general, an equivalent circuit model for a transmission line can be obtained as shown in Figure 1.

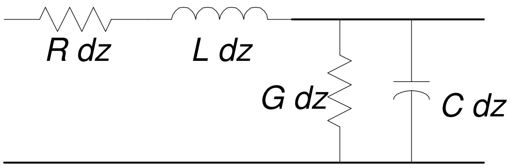

Figure 1 Equivalent circuit for a transmission line

where

R = resistance per unit length (Ω/m)

L = inductance per unit length (H/m)

G = conductance per unit length (S/m)

C = capacitance per unit length (F/m)

From the figure, one can obtain the parameters of the circuit as follows

Characteristic Impedance $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}}$ (1)

Propagation Constant $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$ (2)

Attenuation Constant α, Phase Constant β:

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \qquad (3)$$

2.2 Determining the losses and application of loading Coil

Consider the transmission-line system shown in figure 2, where the power from the source is supplied to the load Z_L via the transmission line.

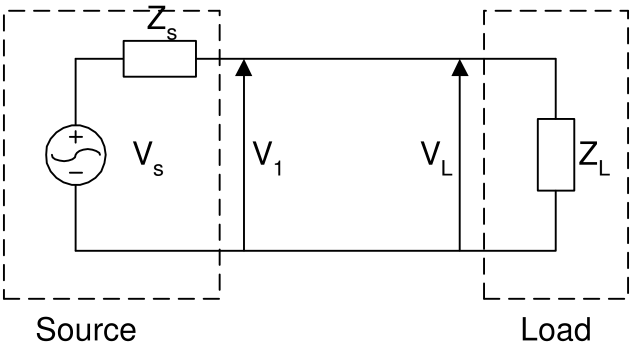

Figure 2 A transmission-line system

The voltage attenuation can be found from

$$a = 20\log\left(\frac{V_1}{V_L}\right). \qquad (4)$$

From (3) Attenuation Constant α can be given by

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} \tag{5}$$

In general transmission lines, since G is relatively small, α can be approximated as

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} \tag{6}$$

Thus, increasing L can lead to the reduction of α, i.e., lower attenuation. In transmission lines, one can increase L by inserting proper inductors into the transmission line every appropriate interval, which is called *loading coil*.

3 Prelab preparation

Read the transmission line note.

4 Equipment

1. Oscilloscope
2. Function Generator
3. Transmission Line Model I 73637 2 sets with the following characteristics

   R = 57.8 Ω/km   L = 0.7 mH/km

   C = 34 nF/km   G = 1 μS/km
4. Transmission Line Model II 73638

   R = 262 Ω/km   L = 0.7 mH/km

   C = 40 nF/km   G = 1 μS/km
5. Compensation Coil 73639
6. Resistor 300 Ω 57713
7. Resistor 600 Ω 57714
8. Connection Lead
9. Semi-Log graph

5 Experiments

Experiment 1 Characteristic impedance measurement

Aim: to study characteristic impedance measurement by measuring the input impedances when the line is open-circuited and short-circuited, respectively, then using them to obtain characteristic impedance. Note that the characteristic impedance generally has a complex value, and is frequency-dependent.

Procedure

1. Assemble the circuit according to figure 3.
2. With terminal 2-2’ open-circuited, supply the voltage V_G, with amplitude $4V_{pp}$, from the function generator, change the frequency between 100Hz and 100kHz then measure V_e and V_R. Here, measure both amplitude and phase of the voltages.
3. Repeat step 2 with terminal 2-2’ short-circuited.

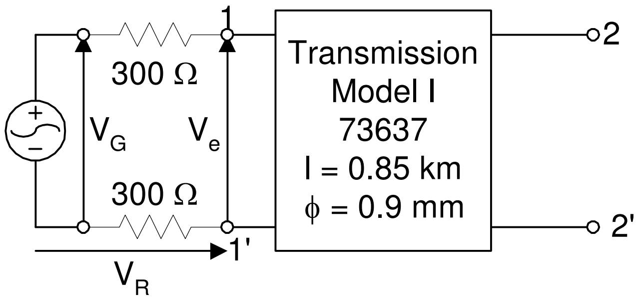

Figure 3 Characteristic impedance measurement (1)

4. Find Z_{OC}, Z_{SC} using the following equations:

$$Z_{OC,SC}=\frac{V_e}{I_e} \tag{7}$$

$$I_e = \frac{V_R}{300} \tag{8}$$

From (7),(8), one obtains

$$Z_{OC,SC}=300\frac{V_e}{V_R} \tag{9}$$

where V_e, V_R are the corresponding measured values to the open-circuit and short-circuit cases, respectively. It follows that the characteristic impedance can be found from

$$Z_0 = \sqrt{Z_{OC} \cdot Z_{SC}} \tag{10}$$

5. Replace the transmission line with transmission model I 1.7 km, then repeat steps 2-4.
6. Assemble the circuit according to figure 4, then repeat steps 2-4.
7. Replace the transmission line with transmission model II 5.0 km, then repeat steps 2-4.

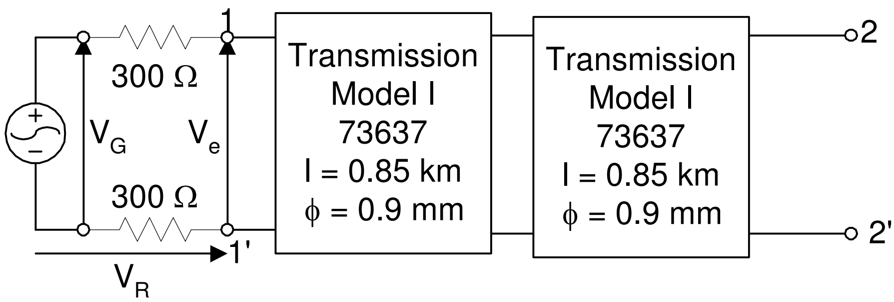

Figure 4 Characteristic impedance measurement (2)

8. Use semi-log graphs to plot the relationships between characteristic impedances and frequencies.

Experiment 2 Loss measurement

Aim: to learn how to measure losses in transmission lines and explore the frequency-dependent property of losses.

Procedure

1. Assemble the circuit according to figure 5.

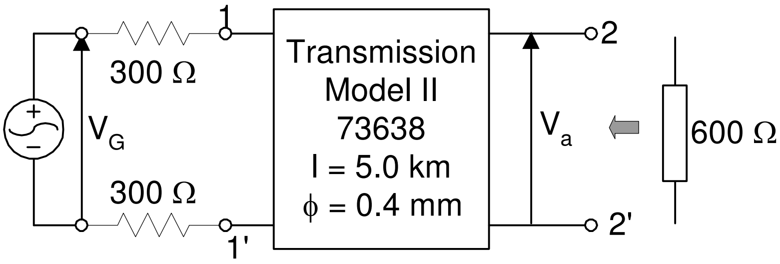

Figure 3 Loss measurement

2. With terminal 2-2' open-circuited (i.e., No-load case), supply the voltage V_G, with amplitude $4V_{pp}$, from the function generator, change the frequency between 100Hz and 10kHz then measure V_G and V_a.
3. Repeat step 2 with terminal 2-2' terminated by the 600Ω load.
4. Find the attenuation from

$$a = 20 \log (V_G / V_a) \tag{11}$$

5. Plot attenuation versus frequency using semi-log graph.

Experiment 3 Using loading coil

Aim: to study the effect of loading coil in reducing attenuation

Procedure

1. Assemble the circuit according to figure 6 with transmission system consisting of 73637 0.85 km , 73637 1.7 km , 73637 0.85 km in series.

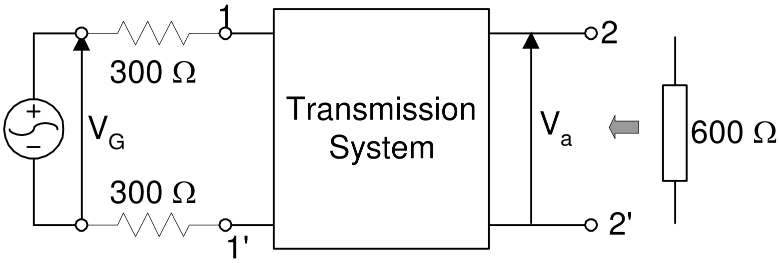

Figure 3 Effect of loading coil measurement

2. With terminal 2-2' open-circuited (i.e., No-load case), supply the voltage V_G, with amplitude $4V_{pp}$, from the function generator, change the frequency between 100Hz and 10kHz then measure V_G and V_a. Here, measure only amplitude.
3. Repeat step 2 with terminal 2-2' terminated by the 600Ω load.
4. Change the transmission system to the one consisting of 73637 0.85 km, 73639, 73637 1.7 km, 73639, 73637 0.85 km in series, then repeat steps 2-3.
5. Find the attenuation from equation (11).
6. Plot attenuation versus frequency using semi-log graph.

Experiment 1 Table ……

f[Hz]	Open-circuit			Short-circuit			$Z_0[\Omega]$
	V_e[V]	V_R[V]	$Z_{OC}[\Omega]$	V_e[V]	V_R[V]	$Z_{SC}[\Omega]$	
100							
140							
200							
270							
370							
520							
720							
1k							
1.4k							
2k							
2.7k							
3.7k							
5.2k							
7.2k							
10k							

Experiment 1 Table ……

f[Hz]	Open-circuit			Short-circuit			$Z_0[\Omega]$
	V_e[V]	V_R[V]	$Z_{OC}[\Omega]$	V_e[V]	V_R[V]	$Z_{SC}[\Omega]$	
100							
140							
200							
270							
370							
520							
720							
1k							
1.4k							
2k							
2.7k							
3.7k							
5.2k							
7.2k							
10k							

Experiment 1 Table ……

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100							
140							
200							
270							
370							
520							
720							
1k							
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2.7k							
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Experiment 1 Table ……

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	V_e[V]	V_R[V]	$Z_{OC}[\Omega]$	V_e[V]	V_R[V]	$Z_{SC}[\Omega]$	
100							
140							
200							
270							
370							
520							
720							
1k							
1.4k							
2k							
2.7k							
3.7k							
5.2k							
7.2k							
10k							

Experiment 2 Table ……

f[Hz]	No-load		600 Ω Load		f[Hz]	No-load		600 Ω Load	
	V_a[V]	a[dB]	V_a[V]	a[dB]		V_a[V]	a[dB]	V_a[V]	a[dB]
100					1.4k				
140					2k				
200					2.7k				
270					3.7k				
370					5.2k				
520					7.2k				
720					10k				
1k									

Experiment 3 Table ……

f[Hz]	No-load		600 Ω Load		f[Hz]	No-load		600 Ω Load	
	V_a[V]	a[dB]	V_a[V]	a[dB]		V_a[V]	a[dB]	V_a[V]	a[dB]
100					1.4k				
140					2k				
200					2.7k				
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370					5.2k				
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720					10k				
1k									

Experiment 3 Table ……

f[Hz]	No-load		600 Ω Load		f[Hz]	No-load		600 Ω Load	
	V_a[V]	a[dB]	V_a[V]	a[dB]		V_a[V]	a[dB]	V_a[V]	a[dB]
100					1.4k				
140					2k				
200					2.7k				
270					3.7k				
370					5.2k				
520					7.2k				
720					10k				
1k									