Experiment # 2

CAPACITANCE AND INDUCTANCE OF TRANSMISSION LINES

OBJECTIVE

The capacitance and inductance per unit length of commonly used transmission lines are measured and compared to the theoretically calculated values and to manufacturer's supplied data.

EQUIPMENT

1. LCR meter (Digital).
2. A length of coaxial transmission line.
3. A length of twin-wire transmission line.
4. Caliper.
5. Meter stick.

INTRODUCTION

The two types of transmission lines to be studied in this experiment are the coaxial and the twin-wire transmission lines. The cross-section of these transmission lines are shown in Figures l-(a) and l-(b) respectively. The value of the capacitance *C* of any given structure can be analytically obtained by solving Laplace's equation. For the inductance *L*, analytical relations are obtained by calculating the magnetic flux linkage.
For the coaxial transmission line, the capacitance per unit length and the inductance per unit length are given, respectively, by:

$$C/l = \frac{2\pi\varepsilon}{\ln\left(\frac{b}{a}\right)} \quad \text{.......... (1)}$$

$$L/l = \frac{\mu}{2\pi}\ln\left(\frac{b}{a}\right) \quad \text{.......... (2)}$$

For the twin-wire transmission line:

$$C/l = \frac{\pi\varepsilon}{\ln\left(\frac{h}{a} + \sqrt{\frac{h^2}{a^2} - 1}\right)} \quad \text{.......... (3)}$$

$$L/l = \frac{\mu}{\pi}\ln\left(\frac{2h}{a}\right) \quad \text{.......... (4)}$$

where l is the total length of the line and a, b, and h are as shown in Figure 1. The constants ε and μ are the permittivity and the permeability of the material of the line respectively.
The characteristic impedance Z_o is related to L and C by

$$Z_o = \sqrt{\frac{L}{C}} \quad \text{.......... (5)}$$

EXPERIMENTAL SETUP AND PROCEDURE

The available transmission lines are the following:

Coaxial line:

Type	RG 59 B/U
Characteristic impedance	75 Ω
Capacitance/meter	68 *pF/m*
Maximum voltage	6 *kV*

Twin-wire line:

Characteristic impedance	300 Ω
Capacitance/meter	13.2 *pF/m*

In all of the measurements, make sure that the lines are fully extended (no loops). Also, avoid areas of electromagnetic interference inside the lab.

1. Measure the capacitance of the coaxial transmission line using the universal bridge. The far end of the line should be open-circuited.
2. Measure the length of the coaxial line, then find the capacitance per unit length (C/l) of the line.
3. Measure the relevant dimensions of the coaxial line using the caliper.
4. Repeat steps (1)-(3) for the inductance (L/l) of the coaxial transmission line. In this case, the far end of the line should be short-circuited.
5. Repeat all previous steps for the twin-wire line.

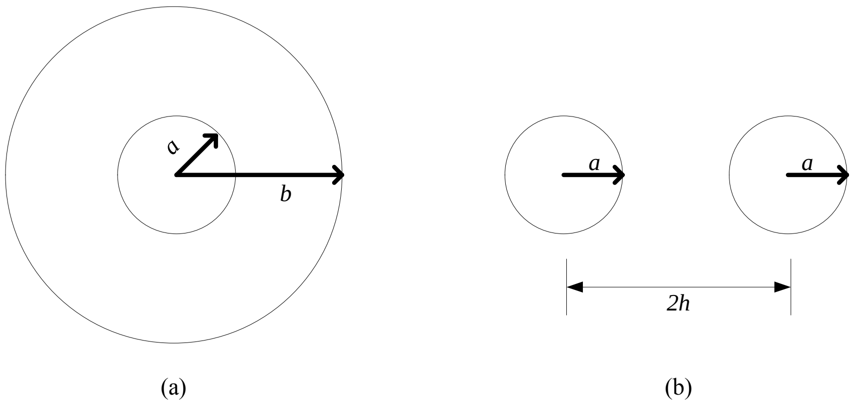

Figure 1. Cross sections of the transmission lines: (a) coaxial (b) twin wire

Table 1: Measured data of Coaxial and Twin-wire lines.

	Coaxial Line	Twin-Wire Line
Length 'l' (m)		
Inner radius 'a' (mm)		
Outer radius 'b' (mm)		-------
h (mm)	-------	
Measured Capacitance 'C' (pF)		
Measured Inductance 'L' (μH)		

Inductance per unit length '***L/l***' (μH/m)		
Capacitance per unit length '***C/l***' (pF/m) (Experimental)		
Z_0 (Ω) (Experimental)		
C/l (pF/m) (Theoretical)		
Z_0 (Ω) (Theoretical)		
C/l (pF/m) (Manufacturer)		
Z_0 (Ω) (Manufacturer)		

QUESTIONS FOR DISCUSSION

1. Calculate (*C/l*) using equation (1). The dielectric occupying the space between the conductors of the coaxial line is made of polyethylene (ε=2.3 ε_o, μ= μ_o).

2. Compare the theoretical, experimental and the manufacturer's data values of (*C/l*).

3. Calculate Z_o of the coaxial line from the experimental values of *L* and *C* and compare to the theoretical and manufacturer's values.

4. Repeat for the twin-wire line.

5. What is the effect on the characteristic impedance of the transmission line when it is not fully extended?

6. Explain the dependence of your measurements on frequency.