Introduction

The unit of capacitance is the farad and is equivalent to one coulomb per volt. Capacitance is a function of the materials and its geometry. Given a fixed impedance transmission line, the capacitance is a function of its length and can be used to determine the length of the transmission line.

Time domain reflectometry (TDR) is a method of evaluating a transmission line and its terminated load. A step generator transmits a series of pulses down the line. An oscilloscope reads the incident and reflected voltage waves at a particular point. TDR is used to measure the impedance of the line and the nature of discontinuities in the line (inductive, capacitive, or resistive).

In a cardiac device, a broken wire will disrupt communication. The disrupted circuit will fail to operate and this could be fatal. At a minimum, the circuit will cease communication with the reader, and any information obtained will be useless.

TDR is a method which can be used to determine the internal capacitances, inductances, and resistances of the wires in the cardiac device. This understanding of the electrical characteristics of a wire will allow discontinuities to be found efficiently, allowing the cardiac device to be repaired and to resume normal operation.

Method

A capacitance meter was used to measure the capacitance the following cables: 50Ω coaxial, 75Ω coaxial, and a twin-lead. In order for the meter to effectively measure the capacitance of the coaxial cables, two inputs of the meter were shorted. Conversely, the inputs were not shorted for the twin-lead. Using the meter, measurements were made on various lengths of coaxial cable, open-air twin-lead, and twin-lead buried in a box of sand.

An AEA 20/20 TDR device was used for all the TDR measurements. A computer program was used to capture all of the measurements and import them to a spreadsheet where they could be graphed.

Possible sources for error in these results include the amount of cord buried. Burying different lengths of a cable varies the capacitance by different amounts. Different groups running the same experiment will measure different capacitances. The increasing or decreasing trend should remain.

Results

Table 1.1 shows the capacitance measured for various lengths of transmission lines.

Table 1.1 T-line Measurements

	Lamp Cords (Twin-Lead)				RG-58 Coax		RG-59 Coax		
Capacitance (pF)	10.7	22.6	76.7	156.6	643	735	67.8	130.4	195
Length (ft)	0.0425	0.194	2.917	6.883	21.583	24.583	3.083	6.125	9.167
Length (m)	0.013	0.059	0.889	2.098	6.578	7.493	0.940	1.867	2.794
C' (pF/m)		65.183	66.097		100.612		67.515	69.672	
Average C' (pF/m)		65.640			100.612		68.593		
Prelab C' (pF/m)		64.94			90.72		N/A		
% Error of C'		1.07%			9.83%		N/A		

As shown in the table, the longer the cable, the higher the capacitance thereof. It is inferred that the longer cables had more transmission line effects than the smaller cables.

Table 1.2 shows a comparison of the capacitance of open-air twin-lead versus buried twin-lead.

Table 1.2 T-line Measurements (Unburied Coax vs. Buried Coax in Sand)

		Lamp Cords (Twin-Lead)		
Capacitance (pF)	no sand	22.6	76.7	156.6
	sand	25.4	96.9	206
% Difference of C		12.39%	26.34%	31.55%

It was observed that the capacitance of the cables buried in sand was higher than the capacitance of the cables prior to being buried in the sand. Further, the capacitance increased by a higher percentage with increasing length of the cables. This may be attributed to the dielectric constant of sand ~~is~~ being higher than the dielectric constant of ~~sand.~~ air ?

The figure below depicts graph of normalized voltage of an electromagnetic wave at a point in a short-circuited transmission line. The maximum voltage amplitude of 1.5 V varied slightly from the predicted value of approximately 2.0 V. This variation may have been caused by the internal impedance of the TDR itself, as its reflection coefficient is not matched (Γ = 0) with the transmission line.

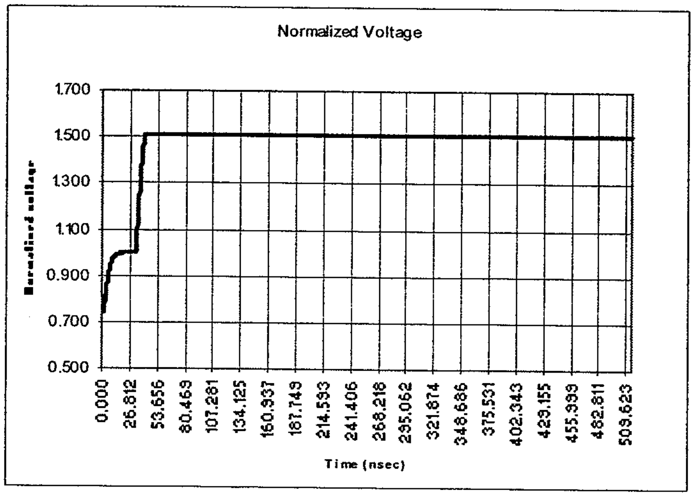

Figure – Plot of Normalized Voltage vs. Time

number

The TDR plot in the figure is for an open termination. Graphs for other terminations were recorded in the lab notebook. A graph for a capacitive load charges up to what looks like an open and an inductor gradually decays into what looks like a short. A resistive load settles into place after a finite number of bounces to a constant voltage. Tandem lines may introduce other bounces from other lines. All these graphs can help to locate a fault in a wire in a cardiac pacemaker for repair.

let the report stand alone. Don't reference book.

Conclusion

In this lab, various transmission line terminations were measured using time domain reflectometry (TDR). The capacitance of different lengths of transmission lines was measured using a capacitance meter; the capacitance of an open-air transmission line was compared to that of a buried transmission line with the same characteristic geometry.

As the length of a line increases, the capacitance of the line increases as well. For the RG-59 coaxial cable: the lengths of 3.083 ft, 6.125 ft, and 9.167 ft correspond to 67.8 pF, 130.4 pF, and 195 pF respectively. For the twin-lead cable: 0.194 ft, 2.917 ft, and 6.883 ft correspond to 22.6 pF, 76.7 pF, and 156.6 pF respectively.

way too much data listed in text

Burying the twin-lead cable increased the capacitance. Special care was taken to ensure that the entire length of line except about two inches was buried and this resulted in an increasing percentage difference for each length. The 0.194 ft, 2.917 ft, and 6.883 ft cables increased by 12.39%, 26.34%, and 31.55% respectively after burial. More experimentation is needed, but this appears to be an exponential growth. Capacitance is a good general measure, but it lacks precision for locating faults since it depends on its environment for a numerical value.

The effects of reflections on a discontinuity in a transmission line can be very useful for locating faults and determining the impedance of the load termination of a system. Using TDR to determine the load termination of a system can locate precisely where a fault lies in a wire. If the fault is completely open, it will look capacitive, otherwise tandem lines will be present in the line. TDR is a superior method for locating faults in a line.

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