EXPERIMENT 8

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PHY 115L

INTRODUCTION

In this experiment I sought to learn about the wave behavior of voltage through radio-frequency transmission lines. Using an oscilloscope, I desired to determine the capacitance of RG-58 coaxial cable. I then set out to measure the speed of electromagnetic waves in the cable. I then set out to observe and measure the reflected waves produced from various terminations of the cable, namely an impedance-matched resistance, a mismatched resistance, a short circuit, and an open circuit. Finally, I sought to observe and measure the reflected and transmitted waves produced from an incident wave striking an impedance discontinuity between transmission lines.

RESULTS

Capacitance of RG-58 Coaxial Cable:

In this section, I set up the oscilloscope to observe a pulse sent from an Avalanche pulse generator through a 10-ft length of RG-58 to the oscilloscope. I used the oscilloscope to measure the time constant τ of the decaying pulse, which I measured as . Using this time constant and the RC-circuit nature of the setup, I determined the capacitance per length of the RG-58 cable to be

. This is very close to the specified value .

Additionally, when substituting a longer 40-ft cable for the 10-ft RG-58, I noticed the frequency of the transient response was lower with the longer cable. This is because it's total capacitance C is greater even though it’s per-length capacitance is identical, so it takes longer to accumulate charge and respond to the changes in signal.

Propagation Speed of Signal in RG-58 Cable:

The first thing I did in this section was measure the effect of the directional coupler on signals passed through it. I measured the attenuation of the output signal to be a fraction of the input signal, or essentially a 2% attenuation, which is relatively modest. I then measured the ratio of the coupled signal to the input signal as . This is within experimental error of the reported coupling ratio.

Next, I set out to measure the round-trip time for a signal travelling to and from the end of a 40-ft length of RG-58 cable. I determined this time to be . From this, I deduced that the speed at which signals propagate in the cable was , or approximately 2/3 the speed of light. Based on this result, I concluded that the insulator in the cable is solid polyethylene with . Based on the reported dielectric constant and the known speed of light, the speed of signals in the cable is theoretically , which is extremely close to that which I measured.

Reflected Signals from Termination:

In this section, I used an incident pulse of amplitude through the cable with 50 Ω impedance. When corrected for the attenuation of the directional coupler output signal, this incident pulse is equivalent to about 2.156 V through the output port. I measured the output signal in 4 different termination setups, and the measurements are as follows.

Table 1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Termination | 50-Ohm resistor | | Open circuit | | Short circuit | | 93-Ohm resistor | |
| Z of Termination | 50 |  | infinite |  | 0 |  | 93 |  |
| Amplitude of reflection (V) and δ | 0 | 0 | 2.0 | 0.1 | -2.0 | 0.1 | 0.6 | 0.1 |

By comparing these measured reflected amplitudes to the incident amplitude, I determined the reflection coefficients in each case and compared them to the theoretically predicted ones as follows.

Table 2

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Termination | 50-Ohm resistor | | Open circuit | | Short circuit | | 93-Ohm resistor | |
| Z of Termination | 50 |  | infinite |  | 0 |  | 93 |  |
| Observed Reflection coefficient and δ | 0 | 0 | 0.94 | 0.06 | -0.94 | 0.06 | 0.27 | 0.05 |
| Theoretical Reflection coefficient and δ | 0 |  | 1 |  | -1 |  | 0.30 |  |

It is evident from table 2 that my results for the reflection coefficients (the fraction of incident amplitude that is reflected) match the theoretical predictions to a great degree, within experimental uncertainty, thus validating the theory of reflected waves.

Signals from Impedance Discontinuity:

Finally, in this section, I connected the cable of 50 Ω impedance to a cable of 93 Ω impedance and observed the transmitted and reflected waves from this discontinuity in the cable through the oscilloscope. Again, I compared the amplitudes I observed to an attenuated incident amplitude of 2.156 V instead of the full 2.2 V I measured. These were the amplitudes I measured.

Table 3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Reflected pulse | | Transmitted pulse | |
| Amplitude (V) and δ | 0.6 | 0.1 | 2.7 | 0.1 |

From these measurements, I determined the reflection and transmitted coefficients as follow. I also compared them to those predicted by the theory of impedance discontinuity in the medium of travelling waves.

Table 4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Reflected pulse | | Transmitted pulse | |
| Observed coefficient and δ | 0.27 | 0.05 | 1.2 | 0.1 |
| Theoretical coefficient and δ | 0.30 |  | 1.3 |  |

From table 4, I again see that the theory does a good job of predicting what I observed in the oscilloscope since the coefficients I observed are well within experimental uncertainty of the predicted values.

SUMMARY

I successfully measured the capacitance-per-length of RG-58 coaxial cable while studying the properties of waves in transmission lines in this experiment. I also succeeded in investigating the propagation speed of signals in the cable, confirming the theory predicting the wave speed inside a transmission line. I then was able to verify the theoretical predictions for reflection coefficients at various cable terminations, namely an impedance matched resistance, a mismatched resistance, a short circuit, and an open circuit, by observing the reflected waves. Additionally, I was able to confirm the theoretical predictions for reflection and transmitted coefficients at a cable impedance discontinuity by observing the signals that were transmitted across the discontinuity and those that were reflected. In doing so, I was able to fulfill each of the objectives outlined in the introduction. A question for a future experiment could be how fiber optic lines compare to radio-frequency lines in terms of their wave behavior, signal speeds, and fidelity.