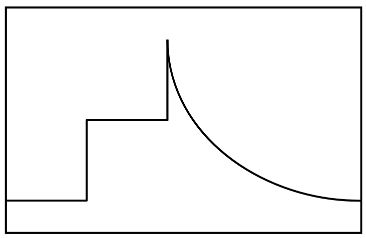
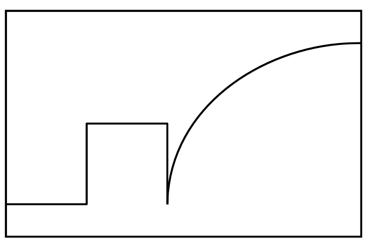
Kennesaw State University	ECET 3410 Laboratory Exercise No. 1
Electrical Engineering Technology	TIME DOMAIN REFLECTOMETRY

This exercise investigates the concepts of time domain reflectometry. A TDR is the instrument used to observe wave phenomena from a connection point on a transmission line. This connection point is typically one end of a line section. Instruments that are available commercially provide internal sources for line excitation and offer a variety of features that aid in determining locations and characteristics of faults, mis-terminations, line loss, propagation velocity, and line length. These instruments are available for both metallic and non-metallic (fiber-optic) lines.

Typical TDRs employ a 150-ps rise-time step voltage and can locate faults within a distance of a few centimeters. A reflection occurs each time the step encounters a discontinuity. The reflection is added to the incident wave and is displayed on the scope output screen. The time required for the reflection to return to the oscilloscope locates the discontinuity, indicating the two-way propagation time. The shape and magnitude of the reflected wave indicate the nature and value of the mismatch. The mismatch can be resistive, inductive, or capacitive. An inductive discontinuity reflects a voltage spike having the same polarity as the incident step and appears as shown below.



A capacitive discontinuity reflects a voltage spike of opposite polarity, producing the display below.



In the lab you will investigate the effect various resistive mismatches produce when measured using a TDR. The sign and magnitude of the signal reflected from the end of the cable back to the TDR is dependent on the impedance of the line and the terminating impedance. The ratio of the reverse traveling signal to forward traveling signal at the "load" end of the cable defines the ***reflection coefficient*** of the terminating impedance. The following equations can be used to determine the reflection coefficient:

$$\Gamma_L = V^- / V^+ = I^- / I^+ = (Z_L - Z_0) / (Z_L + Z_0)$$

The reflected signal (V^-) is equal to the reflection coefficient (Γ_L) times the forward signal (V^+). A resistive discontinuity having a value greater than the line impedance results in a positive reflection coefficient such that a step of the same polarity is displayed after the signal travels twice the length of the cable. A resistive discontinuity having a value less than the line impedance results in a negative reflection coefficient and a step of the opposite polarity. The magnitude of the step is determined by the degree of impedance mismatch.

Coaxial Cables											
RG #	AWG Material	Insulation	# Shields	Jacket	Nom. O.D. (inch)	Nom. Imp. (Ohms)	Nom. Vel. Of Prop.	Nom. Cap. (pF/ft.)	Nom. Attenuation per 100' MHz	dB	Standard Spool Lengths
58/U **JAN-C-17A**	20 Bare Copper	Poly-ethylene	1	Black Vinyl	0.195	53.5	66%	28.5	100 200 400 900	4.1 6.2 9.5 14.5	100,500 1000
58A/U **JAN-C-17A**	20 Tinned Copper	Cellular Poly-ethylene	1	Black Vinyl	0.195	50	66%	30.8	100 200 400 900	5.3 8.2 12.6 20.0	100,500 1000
58A/U Type	20 Tinned Copper	Cellular Poly-ethylene	1	Black Vinyl	0.195	50	78%	26.0	100 200 400 900	4.8 6.9 10.1 15.5	100,500 1000
62/U	22 Bare Copper	Semi-Solid Polyethylene	1	Black Vinyl	0.242	93	84%	13.5	100 200 400	3.1 4.4 6.3	100,500

Data from textbook: **Table 1-3 Characteristics of Coaxial Lines Used in Communication Systems**

TEST PROCEDURE

Instrumentation

TEK 11801 Digital Sampling Oscilloscope with SD-24 TDR/Sampling Head

Device(s) Under Test [DUT]

3.6m section of **RG-58/U Type** coaxial cable (known length)
5.0m section of **RG-58A/U Type** coaxial cable (known length)
Spool of **RG-58A/U Type** coaxial cable (112ft estimated length)
Spool of **RG-62/U Type** coaxial cable (400ft estimated length)
Coaxial terminations (**short circuit**, **50Ω**, **100Ω**, and **200Ω**) and **6dB attenuator**

CAUTION: DO NOT REMOVE SAMPLING HEAD. If TDR does not appear to function properly, see your lab instructor.

1. Remove SMA **short circuit termination** from Channel 1 of the TDR Sampling Head.

2. Using an SMA-to-BNC adaptor, connect the **3.6m** section **RG-58/U Type** cable to Channel 1 of the TDR Sampling Head and leave the other end of the cable unterminated.

3. Switch **ON** the TDR and allow it to perform its self-test.

4. Select the "**Waveform**" function (button to the right of the display).

5. Using the touch-screen menu, select "**Graticule**". Set up the ***vertical display for*** **voltage** and the ***horizontal display for*** **time** measurements (I.e. - choose "**Seconds**" for the horizontal units). Then press "**Exit**" to leave this menu.

6. Press the "↔" symbol at the top of the screen to adjust the horizontal magnification. Use the upper vernier to adjust the magnification so that both the incident and reflected waveforms are displayed. You can adjust the horizontal position of the trace using the lower vernier.

7. Press the vertical "↔" symbol at the left side of the screen to adjust the vertical magnification. Use the upper vernier to adjust the vertical magnification to maximize the size of the vertical displacement of the trace. You can adjust the vertical position of the trace using the lower vernier.

8. Select the "**Cursor**" function and use vernier controls to determine **time delay** between the application of the incident waveform and the return of the reflected waveform. The time appears as **Δt** in the bottom center of the screen.

9. Based on the measured time delay and the known cable length, calculate velocity at which a wave travels on the section of RG-58/U Type cable and express the result as a percentage of the speed of light in a vacuum, **c**.

10. ***Accurately sketch*** the **TDR display** for the **unterminated**, **3.6m** section of **RG-58/U Type** cable. Be sure to label the time measurement on the sketch.

11. Replace the cable with the **5m** section **RG-58A/U Type** cable and repeat steps 6 through 9 in order to determine the velocity at which a wave travels on the section of RG-58A/U Type cable.

12. Select "**Graticule**" on the touch-screen menu and set up the ***horizontal display for*** **length** measurements. Choose "**Feet**" for measurement units and adjust either vernier control for the ***appropriate velocity factor*** as determined in the previous step for RG-58A/U Type cable. Then press "**Exit**" to leave this menu.

13. Select the "**Cursor**" function and use vernier controls to determine **cable length** in **feet**. The length appears as **Δf/2** (half the total distance traveled by the pulse) in the bottom center of the screen. Also use the cursors to determine the magnitude of the incident and the reflected voltages.

14. ***Accurately sketch*** the **TDR display** for the **unterminated**, **5m** section of **RG-58A/U Type** cable. Be sure to label the length and the relevant voltage levels on the sketch.

15. Place a **200Ω load** on the end of the cable and use the cursors to determine the magnitude of the incident and the reflected voltages.

16. ***Accurately sketch*** the **TDR display** for the **5m** section of **RG-58A/U Type** cable with a **200Ω load**. Be sure to label the relevant voltage levels on the sketch.

17. Replace the 200Ω load with a **100Ω load** and use the cursors to determine the magnitude of the incident and the reflected voltages.

18. ***Accurately sketch*** the **TDR display** for the **5m** section of **RG-58A/U Type** cable with a **100Ω load**. Be sure to label the relevant voltage levels on the sketch.

19. Replace the 100Ω load with a **50Ω load** and use the cursors to determine the magnitude of the incident and the reflected voltages.

20. ***Accurately sketch*** the **TDR display** for the **5m** section of **RG-58A/U Type** cable with a **50Ω load**. Be sure to label the relevant voltage levels on the sketch.

21. Replace the 50Ω load with a **short circuit terminator** and use the cursors to determine the magnitude of the incident and the reflected voltages.

22. ***Accurately sketch*** the **TDR display** for the **5m** section of **RG-58A/U Type** cable with a **short circuit terminator**. Be sure to label the relevant voltage levels on the sketch.

23. Replace the short circuit terminator with a **6dB (open-circuited) attenuator** and use the cursors to determine the magnitude of the incident and the reflected voltages.

24. ***Accurately sketch*** the **TDR display** for the **5m** section of **RG-58A/U Type** cable with a **6dB (OC) attenuator**. Be sure to label the relevant voltage levels on the sketch.

25. Disconnect the 5m cable from the TDR head and replace it with the **spool of RG-58A/U Type** cable. Leave the end of the spool unterminated. Repeat the steps required in order to measure the **length** of the **Spool** of **RG-58A/U Type** cable.

26. Replace the spool of RG-58A/U Type cable with the Spool of **RG-62/U Type** cable and repeat the steps required in order to measure the **length** of the **Spool** of **RG-62/U Type** cable.

27. When cables with different velocity factors are used together, the TDR can still be used to verify cable lengths. This is done by setting the TDR velocity factor setting to 1.0 and multiplying the measured length of each section of cable by its velocity factor. Connect the spool of **RG-58A/U Type** cable directly to the TDR and then connect the **RG-62/U** spool to the end of the RG-58A/U Type cable.

28. Use the cursors to measure the length of each cable section and then use the cable velocity factors to calculate the actual cable lengths. ***Accurately sketch*** the **TDR display** for the combination of both cables. Be sure to label the lengths on the sketch.

29. When you have concluded your testing, disconnect the SMA-to-BNC adaptor. Replace the SMA short circuit on the Sampling Head and turn the TDR off.

TEST EVALUATIONS

1. Compare the velocity factors calculated in steps 9 and 11 to those provided in Table 1-3.

   In terms of velocity factor, **which cable** listed in Table 1-3 does the 5m section of cable in the lab labeled RG-58A/U Type best resemble?

2. Based on the data provided in Table 1-3 and the theoretical impedance values of the different loads, determine a set of "**theoretical**" **reflection coefficients** for the OC (unterminated), 200Ω, 100Ω, 50Ω, and SC loads connected to the end of the 5m section of RG-58A/U Type cable.

3. The 6dB attenuator will cause a 6dB loss in the power of any waveform that passes through the attenuator ($dB_{loss} = -10 \cdot log\frac{Pout}{Pin}$). Assuming $P^{+} = (V^{+})^2$ and $P^{-} = (V^{-})^2$ along with the fact that the 6dB attenuator was unterminated, determine a "**theoretical**" **reflection coefficient** for the **6dB attenuator** connected to the end of the 5m section of RG-58A/U Type cable.

4. Using the incident and reflected voltages magnitudes recorded in the TDR plot sketches form steps 14, 16, 18, 20, 22 and 24, determine a set of "**measured**" **reflection coefficients** for the **OC** (unterminated), **200Ω**, **100Ω**, **50Ω**, and **SC** loads and the **6dB attenuator** connected to the end of the 5m section of RG-58A/U Type cable.

5. Tabulate the sets of "theoretical" and "measured" reflection coefficients and compare the corresponding values by means of a set of relative difference calculations. Include the results within the table.

6. Compare the **measured lengths** for the spools of **RG-58A/U** and **RG-62/U** to those listed on the spools.

7. Calculate the **lengths** of the spools of **RG-58A/U** and **RG-62/U** using the lengths recorded in the combination sketch from step 28 and the appropriate velocity factors, and then compare the results to those measured in the steps 25 and 26.

Kennesaw State University | **ECET 3410** Laboratory Exercise **No. 1**
Electrical Engineering Technology | **TDR Lab Data Sheet**

Name: ______________________________ **Section (Day/Time):** __________________
(Print Name – Last Name First)

Step 9: Nom. Vel. Of Prop. (RG-58/U Type cable) = _______ % of **c**

Step 10: Sketch of TDR display for **unterminated 3.6m** section of **RG-58/U Type** cable

Step 11: Nom. Vel. Of Prop. (RG-58A/U Type cable) = _______ % of **c**

Sketches of TDR display for **5m** section of **RG-58A/U Type** cable

Step 14: **Unterminated** cable

Step 16: Cable with **200Ω load**

Step 18: Cable with **100Ω load**

Step 20: Cable with **50Ω load**

Step 22: Cable with **short-circuit** terminator

Step 24: Cable with **6dB (OC) Attenuator**

Step 25: Length of **Spool** of **RG-58A/U Type** cable = _______ feet

Step 26: Length of **Spool** of **RG-62/U Type** cable = _______ feet

Step 18: Sketch of TDR display for **combined spools** of **RG-58A/U** and **RG-62/U Type** cables