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Rejuvenation Instructions Power Cables Electronic Cable Diagnosis & Pinpointing

Version 20120125

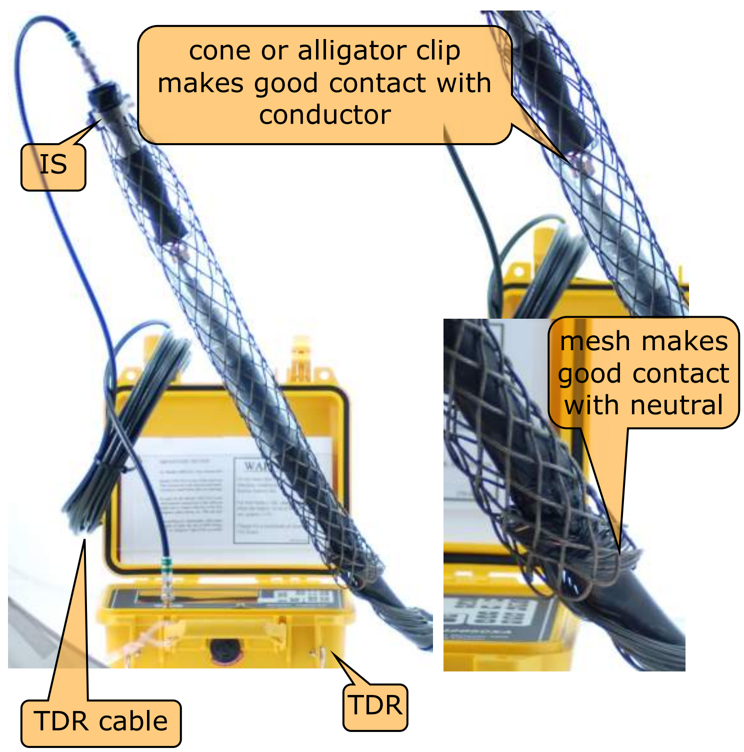
Electronic Cable Diagnosis & Pinpointing

All cables must be de-energized, tested dead, and grounded before any of these Diagnosis & Pinpointing procedures may be executed. All switching operations must cease. 100% of the personnel on the site must verbally concur that it is safe to handle the cable. The ground must be connected to the termination to be handled, or in the case of a spiking operation at a cable midpoint (e.g. a splice or fault), the ground must be immediately adjacent (i.e. the connection can be confirmed by an unobstructed view of the cable between the spike and the work area) to the portion of the cable to be worked. The individual who executes these Diagnose & Pinpoint instructions must be present when the ground is put in place and must witness and concur with the temporary removal of any ground connections. The ground connections should be left in place until their removal is required and put back in place as soon as possible. All test instruments and equipment and accessories must be of the appropriate type and rating for the application for which they will be used; proper functionality must be verified before and after an absence of voltage test, per the individual equipment instructions.

Caution: Working around energized high-voltage systems may cause serious injury or death. The procedures in these instructions should be performed by personnel familiar with good safety practice in handling high-voltage electrical equipment. De-energize and ground all electrical systems before proceeding.

1. Wire brush all connectors or exposed wires to ensure a good electrical connection is made.

2. Install an impedance streamliner (IS) (npn: 0-el-tdrlis for small diameter cables or npn: 0-el-tdris2 for large diameter cables) on the exposed cable termination. The first termination connected to will be termination 1 (term 1).
   a. The conductor cone or alligator clip must make good electrical contact with the conductor.
   b. The mesh must …
      - make good electrical contact with the aluminum body of the impedance streamliner
      - make good electrical contact with the cable neutrals (electrical connection can be improved by cinching with a tie wrap)
      - **not** make electrical contact with the conductor or portions of the electrical connection which do



3. Connect the IS to the TDR (time domain reflectometer, (npn: 0-el-tdr) using the 25' lead. Consult the documentation that comes with the TDR for operating instructions. The VOP should be set based upon past experience with cable of the same type. Supplemental information for Riserbond™ TDRs may be found at http://www.radiodetection.com/menu_map_level_3.asp?sec_id=2845

VOP (Velocity of Propagation) for power cables generally ranges from 48% to 55% of the speed of light. EPR cables will tend towards the lower end of the range, while cables which do not have a full neutral will tend towards the higher end.

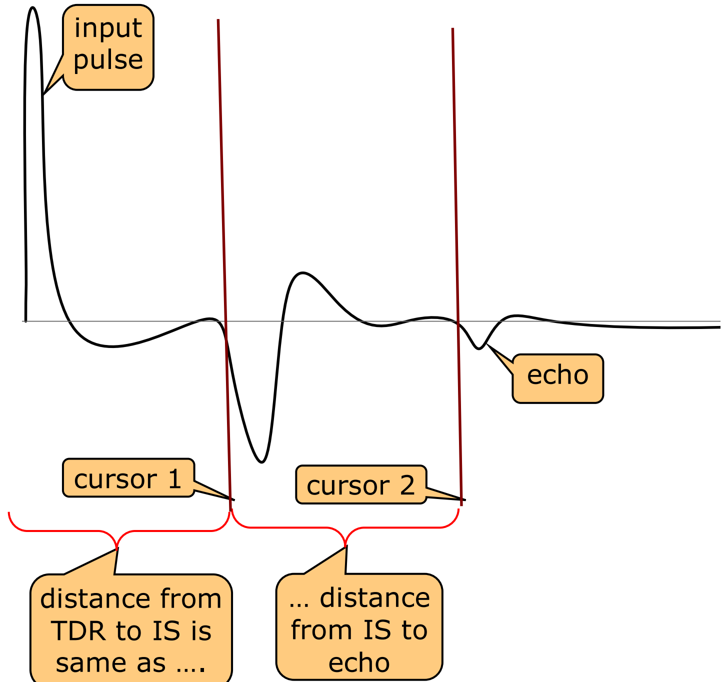
a. Confirm the VOP value by making a wheeled measurement (or equivalent) of the cable path at least once each day, each time a new loop is started, and each time a splice is to be pinpointed. It is not necessary to re-confirm VOP for each and every cable in other cases.

Note: If a VOP changes significantly for the same cable on adjacent runs suspect a deviated cable path and confirm with the RF locator as described in step 6.

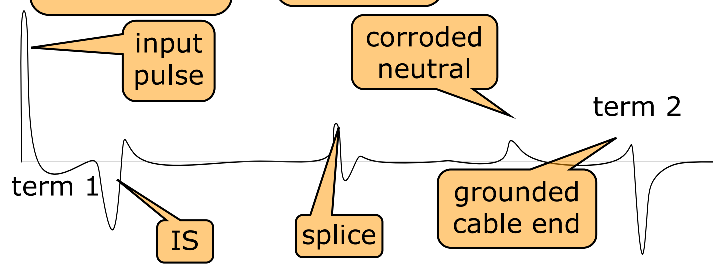
b. Turn on the TDR; Adjust the pulse width to 2ns, the vertical gain to between 8X and 10X, and the VOP (Velocity of Propagation) to appropriate setting for the type of cable to be examined.

c. Place the first cursor on the cable start at the IS near the TDR (term 1). There is often an echo of the IS/cable connection which can be ignored. The echo can be recognized because it …

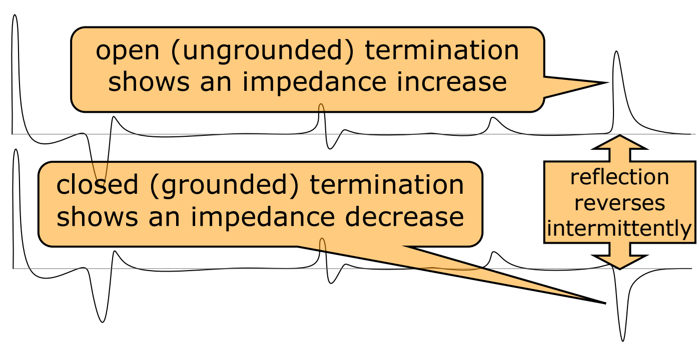
- appears precisely the same distance from the IS as the coaxial cable lead length – either 6′ or 30′;
- is dominated by a negative deviation preceding the positive deviation, attenuated and smeared by the reflection – just the opposite of a splice;
- moves if the coaxial cable lead length is swapped;
- is not visible from the other cable end.



d. Zoom out until the grounded far cable end (term 2) is clearly visible. Increase the pulse width to 25ns or 100ns if far end of the cable is not visible. The pulse width should be the lowest value for which it is possible to detect the grounded cable end.

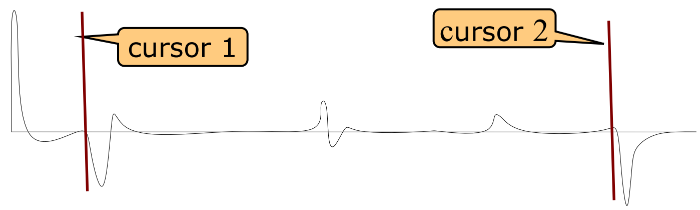


e. Intermittently disconnect and reconnect the ground (bump ground) on the end of the cable away from the TDR (term 2) to positively identify the cable and end point. Ignore reflections at multiples of the actual cable length. If the TDR image does not respond appropriately, the cause must be investigated before proceeding further.

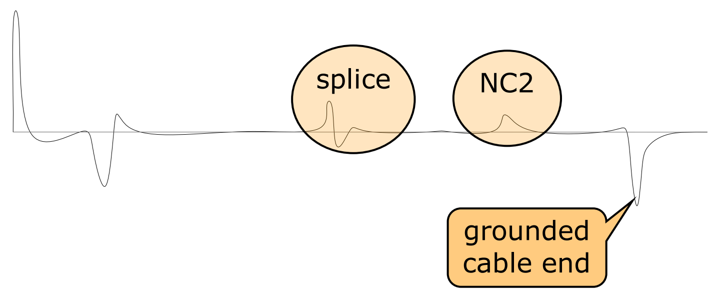


If the TDR image does not respond to ground connection / disconnection, this may indicate that the wrong cable is being intermittently disconnected. Confirm the cable is correct before proceeding. Improper cable indentification can lead to severe injury and or death.

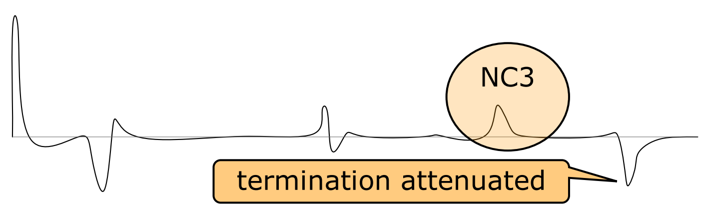
f. Zoom in, and place the second cursor on the far cable end. Record the provisional cable length and VOP (velocity of propagation).



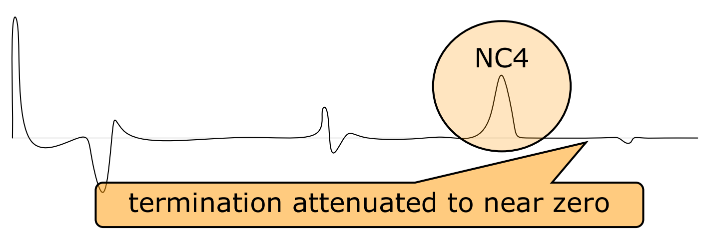
- **Identify each impedance anomaly in the cable run as:**
- **splice:** impedance increase followed by any decrease.



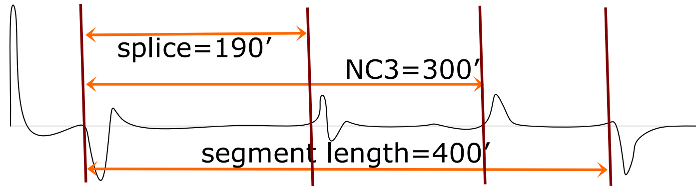
- **neutral corrosion level 1: NC1** represents 0-25% neutral damage and is not visible on the TDR.
- **neutral corrosion level 2: NC2** represents 25-50% neutral damage and is indicated by an impedance increase smaller than magnitude of the decrease at the grounded cable end.
- **neutral corrosion level 3: NC3** represents 50-75% neutral damage and is indicated when the impedance increase is equal to or larger than the grounded cable end, but the grounded cable end is still clearly visible.



- **neutral corrosion level 4: NC4** represents 75-100% neutral damage and is indicated when the grounded cable end is barely visible or not visible.



g. Determine the distance from the TDR cable end by moving cursor 2 to each anomaly identified in step 3e; record the distance and anomaly type. **If any anomalies are present, conduct a level 2 flow test to rule out the presence of a splice. See NRI 50.**



h. Repeat the TDR measurements (steps 3b-f) from the second termination if …
- the far end of the cable is not visible,
- there is doubt about an anomaly, or
- it is not possible to use an RF locator to pinpoint an anomaly

term 1	anomoly 1	anomoly 2	term 2
from 1	190	300	400
400	210	100	from 2
400	400	400	400

Enter the values in a table as shown. All columns should add to approximately the same value. **The existance or absence of a splice must be confirmed by executing step 2b in NRI 50, "Flow & Pressure Testing" for all cases where there is any doubt.**

i. If there is any uncertainty about what an anomaly is, upload to a PC and use WaveView™ to get a clearer picture of the TDR output before digging or injecting.

WaveView software is available from www.riserbond.com.

j. For long runs, cables with high losses such as aged cables with copper taped shields, partial neutrals, or cables with many splices or neutral corrosion sites, the signal may be attenuated and dispersed such that some length of the segment is not visible even with wider pulse widths (See step 3b) and application of the TDR at both terminations (See step 3g). For the cases where a portion of the cable is not visible, either (1) excavate the first anomalies and repeat steps 1 through 3h from each new excavation, (2) execute a warranty waiver (code NI-Neutral Indeterminate), or (3) abandon the run to replacement.

term 1	SP1	SP2	SP3	SP4	term 2
from 1	100	300			
			400	250	from 2
	from SP1	100 + 200	100 + 400		
		250 + 350	250 + 150	from SP4	
		900	900		
0	**100**	**300**	**500**	**650**	**900**

Assemble a table to map impedance anomalies.

k. If practical, short the conductor on the far end of the cable to ground before saving a TDR wave form. The conductor to ground connection may be removed if necessary to get a good signal, but should be used whenever possible. Note any instances where the far end of the cable is not shorted to ground.

l. Store all waveforms required to document all impedance anomalies. The maximum length that can be stored is related to the pulse width and user selected memory option (16 or 32 waveforms). Choose the 16 waveform memory option in the TDR Setup menu.

Pulse Width	16 waveforms	32 waveforms
sub nsec	1,800 ft (550m)	900 ft (225m)
2 nsec	6,000 ft (1.8km)	3,000 ft (900m)
25 nsec	18,000 ft (5.5km)	9,000 ft (3km)
100 nsec	36,000 ft (10km)	18,000 ft (5km)

Utilize the TDR's tagging function to mark each stored wave-form using at least the last 3 digits of the Novinium warranty tag. If there is more than one waveform for a segment, add a, b, c, etc. to the tag to distinguish between waveforms.

m. Upload waveforms to PC using WaveView™, then from PC to NITS / FDE.

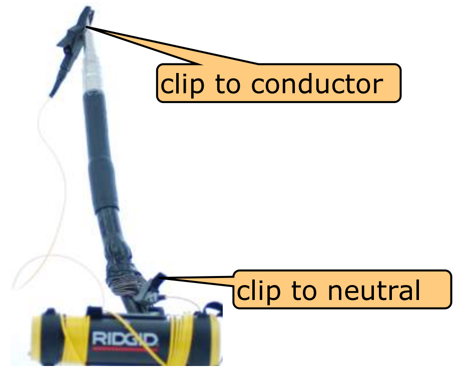
4. Pinpoint the splice or corroded neutral using a radio frequency (RF) transmitter & locator. The 5W RF transmitter is suitable for many URD applications, but the 10W RF transmitter may be beneficial on longer runs or where signal attenuation is high.

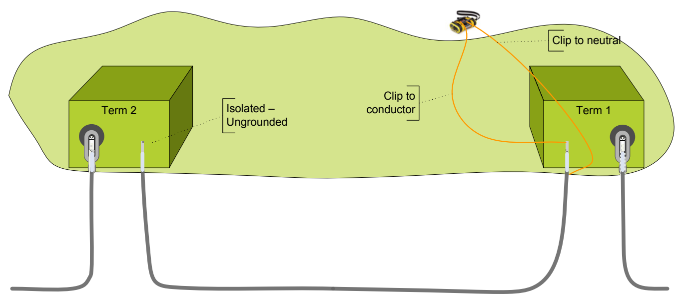
ST-305
5W RF
transmitter
(NPN: 0-EL-RF-ST305)

ST-510
10W RF
transmitter
(npn: 0-el-rf-st510)

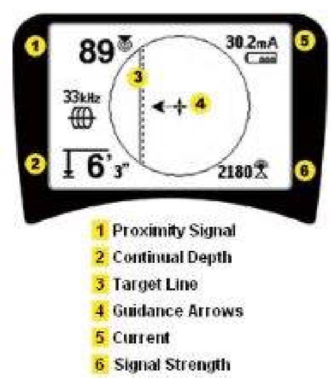
SR-20/SR-60
RF locator
(npn: 0-el-rf-sr20)/
(npn: 0-el-rf-sr60)

a. Connect one transmitter lead to the conductor and the second transmitter lead to the neutral. To minimize RF signals emanating from the transmitter and its leads, the transmitter should be placed as far away from the suspected cable path as possible and the leads from the transmitter should be twisted. The cable should be grounded at the end away from the transmitter.



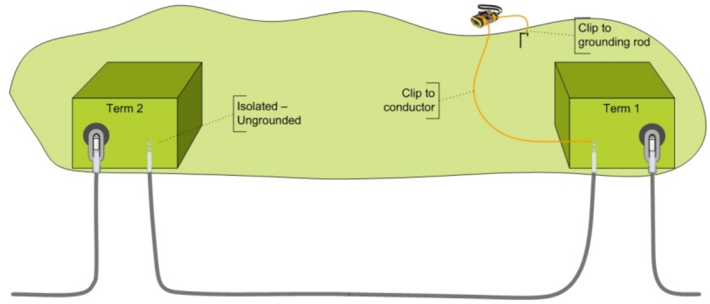


b. The cable path is visible on the locator screen. Walk along the entire cable path to verify the length and the provisional VOP and mark as necessary with paint or the spot markers (attached to the locator). If the VOP differs by more than 2 percentage points from what is typical for the type of cable being located, search carefully for cable loops or jogs which might confound your measurements.



c. If there is any difficulty finding the cable path:

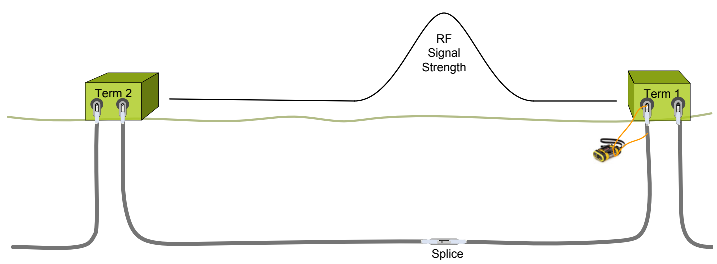
- use the maximum transmission strength available
- disconnect the alligator clip lead from the neutrals and connect to a grounding stake placed as far from the cable as possible; remove the ground from the cable end away from the transmitter.



This configuration boosts the signal for locating the cable path, but lowers the sensitivity to pinpoint individual impedance anomalies. After locating the cable path, restore the connections to those called for in step 4a.

d. Utilizing the TDR measurements from step 3 identify the approximate physical locations of the impedance anomalies (e.g. splices or corrosion) with a wheel.

e. Starting about 30 feet (10 m) from the approximate splice location move directly over the cable path toward an anomaly which requires pinpointing. Note when the signal strength begins to increase, where it reaches a maximum, and where it returns to a baseline signal strength. The splice or neutral is generally under the signal maximum. Mark an "X" and note the cable depth.



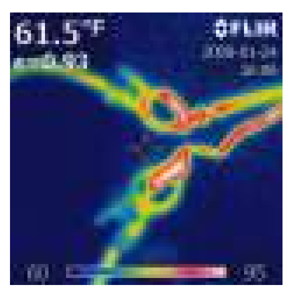
The RF signal typically begins to increase about 6' (2 m) from the splice or corrosion. Make a mark every 6" (15 cm). The cable path often appears to make a jog (right or left) out of the trench line near a splice. The depth reading directly over the anomaly may not be accurate. Note the cable depth several feet away from the anomaly.

5. For maximum circuit reliability splices must be excavated and replaced with new connectors and IAs as described in NRI-32, “IA Installation – Dead-front splice.” All excavations must be executed with the “2 measurement rule” in the *Tips and Troubleshooting* section of this NRI-12.

6. Neutral corrosion greater than level 2 (See step 3e) must be repaired as described in NRI-80, “Neutral Corrosion Repair” if …

   a. The circuit owner requires it, or

   b. N-Ter™ technology, described by NRI-25 is to be utilized.



Tips and Troubleshooting:

Two Measurement Rule

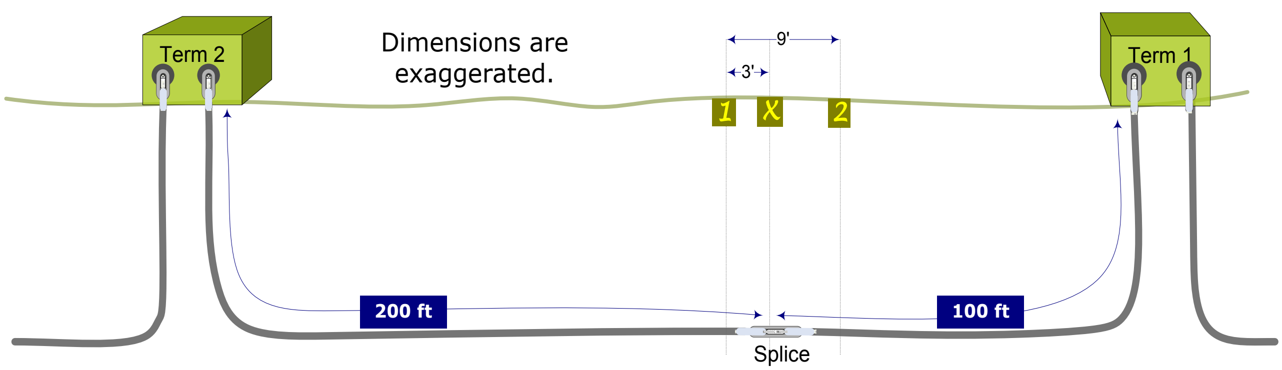
Two measurement rule: Before any excavation may begin and to avoid digging holes at the wrong location there must be two independent measurements indicating where to dig.

1. Most commonly there is a TDR and wheeled measurement from a single termination and an RF measurement directly above the splice or corrosion.

2. If it is not possible to use an RF measurement, 2 TDR measurements from opposite ends of the cable should be utilized. With paint mark a "1" for the measurement from Term 1 and a "2" for the measurement from Term 2. Multiply the distance between the "1" and the "2" by the ratio of the distance from Term 1 to the splice and the cable length. For example, if the cable were 300 feet long, and the distance to the splice from Term 1 was 100 feet, and the distance between the marks "1" and "2" was 9 feet compute the location of the "X" that most accurately marks the splice as follows:

$$9 \text{ ft} \times \frac{100 \text{ ft}}{300 \text{ ft}} = 3 \text{ ft}$$

Mark the "X" three feet from the "1" mark toward the "2" mark. Note that half of the time, the "1" mark will be closer to Term 1 and half the time "2" will be closer to Term 1. The formula above works the same in either case.



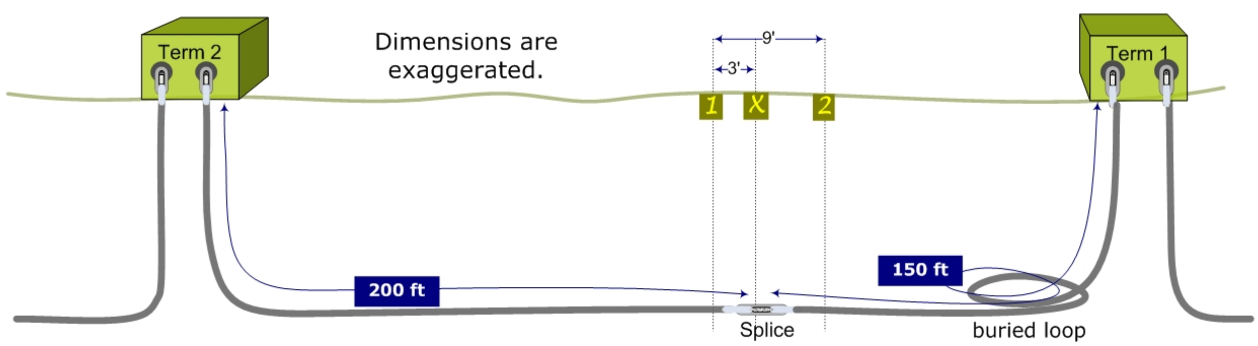
If the distance between the "1" mark and the "2" mark is greater than 4% of the cable length (e.g. 12' for a 300' run, 16' for a 400' run, etc.), either the assumed VOP is wrong, or there are loops or jogs in the cable run which have not been recognized. Execute Steps 6a-c to re-confirm the cable path and review the "Cable Loop" troubleshooting rule on the next page. Adjust the VOP as appropriate and repeat these instructions. Also note that the VOP as established by the distance from Term 1 to Term 2 must be precisely the same when measured from Term 1 as it is when measured from Term 2.

Cable Loop

Dealing with a loop of cable: Occasionally cable installers may leave a loop of cable as shown in the illustration below. The loop is typically under or near a transformer, but not always. The existence of such a loop should be suspected when either or both of the following is true:

1. The wheeled measurement of an RF identified cable path is significantly shorter than the TDR indicated length, where the TDR indicated length was determined with a propagation velocity that was validated on another run of apparently identical cable..

2. The RF signal is strong, wide, and confusing at a location along the cable path. Where a cable loop exists, …
   a. **Strong**: … the signal strength is stronger, because more than a single piece of cable is broadcasting to the receiver.
   b. **Wide**: … signal will extend away from the cable path for a greater distance than where there is a single cable laid in a straight line.
   c. **Confusing**: … the software in the receiver will have difficulty determining the lay and sometimes the depth of the cable.

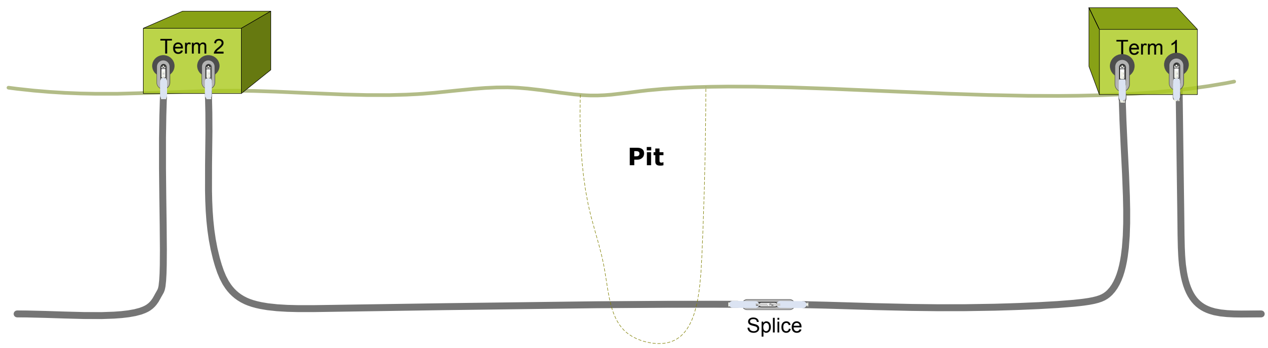


After locating where a loop lies, it is possible to use the two measurements rule to locate a splice. Use the TDR to measure the Probable Cable Length (PCL). Use the RF locator to measure the Apparent Cable Length (ACL). Measure the Apparent Cable Length through the middle of the loop. Subtract the Apparent Cable Length from the Probable Cable Length to estimate the length of cable in the loop or Loop Length (LL).

$$LL = PCL - ACL$$

For example, if the probable cable length in the illustration below is 350 feet and the apparent cable length is 300 feet, the loop length is 50 feet. Now follow the instructions on the previous page under the "two measurement rule," but whenever wheeling over the loop, manually advance the wheel by LL. In the illustrated example, LL is 50 feet.

Dry Hole



Despite best intentions occasionally a dry hole may be encountered. A dry hole of the first kind is when the cable cannot be found. This is easily remedied by running the RF locator in cable locate mode again. Climb down into the dry hole to determine a direction and distance to the cable path. A dry hole of the second kind is when the cable is located, but no splice is found within three feet of the designated location. When a dry hole of the second kind occurs, review all previous steps for errors. Use the RF locator to re-pinpoint the splice.

If the splice still cannot be located, …

- attach an equipotential grounding mat to the neutrals using a hot stick,
- attach the TDR as indicated in steps 4-5, and
- while an operator watches the TDR, change the local cable impedance from the grounding mat with one of the following two methods until the location is visible to the TDR operator:
    - Utilize slack in the neutrals to deflect the neutrals away from the cable.
    - If there is insufficient slack, apply a neutral jumper from the exposed neutrals at one end of the pit to the exposed neutrals at the other end of the pit from the equipotential grounding mat or with a hot stick, then snip the neutrals one at a time.

The location of the deflected or snipped neutrals will appear as though it were a new splice. Moving the deflected neutrals or the neutral jumper alternately toward and then away from the conductor will cause the neutral anomaly to dynamically move on the TDR display. This is helpful if the real splice is very close to the snipped neutral. The distance between the snipped neutrals and the splice can be visualized and measured. Place cursor 1 on the TDR screen on the beginning of the splice and cursor 2 on the beginning of the deflected or snipped neutrals. The distance between the cursors will display on the TDR. Instructions can be provided to the excavation team to proceed. If the snipped neutral location is reasonably close to the splice, spike the cable to confirm that it is grounded, cut the cable, and add a Dutchman and new cable length from the old splice(s) to the snipped neutral location. If the distance is too great, repair the neutral. Repair the neutral by completing the neutral cut and wrapping the two neutral ends into a pigtail and crimping on a new piece of copper between the two pigtails. The new piece of copper should have more ampacity than the original neutral wires and should be tie wrapped into intimate helictical contact with the insulation shield. If the cable is jacketed use a Raychem© wrap-around heat-shrink re-jacketing sleeve or equivalent.

TDR Recommended Settings:

Access the setup option through the TDR's menu

Horizontal scale units: FEET (set to Meters if preferred)

Distance display format: FEET (Set to Meters if preferred)

Horizontal Reference: ON

Backlight at startup: OFF (set to ON for nighttime work)

Velocity format: VOP (%)

VOP precision: 3 DIGIT

Cancel test lead length: NO

Serial printer type: CITIZEN

Memory Options: 16 WAVEFORMS

Autofilter: DISABLED

dBRL type: TOTAL

Language: ENGLISH

Chose the option to EXIT after setup is complete

TDR Quick Tips (Basic Operation):

Use a streamliner whenever possible

Set the Pulsewidth to 2ns.

Set vertical gain at 8-10X.

Check that VOP is correct (typically 48-55%)

Set first cursor at the beginning of the cable.

Zoom out – Center the picture.

Zoom in at the end of the cable – place 2nd the cursor at the far end of the cable.

Avoid Radio and Cell Phone Use while examining the cable
Use filters to reduce noise if needed.

Set contrast only as high as needed.

Use clips supplied with TDR if streamliner is not possible

Use 25ns or 100ns pulse width for long cables where the far end cannot be seen.