Riser Bond

Application Guide

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AN INTRODUCTION TO TIME DOMAIN REFLECTOMETERS

CHANGES IN THE INDUSTRY

Years after its invention, the Time Domain Reflectometer (TDR) remains the fastest, most accurate way to pinpoint cabling problems. For years, however, TDRs complexity and high cost meant only large companies and high level engineers had access to them.

That all changed when Riser Bond developed the world's first easy-to-use, non-waveform, numeric TDR Cable Fault Locator in the early 1980s. Simple, accurate, user-friendly, rugged and cost effective, Riser Bond TDRs have now become a standard tool in many industries worldwide, such as the communications and power industries.

RISER BOND TDRS FIND FAULTS

The speed and accuracy of the TDR make it the preferred method of cable fault location. Due to the advances in technology, the operation and interpretation of a TDR has been greatly simplified.

If a cable is metallic and has at least two conductors insulated from each other, it can be tested by a TDR. You can even use a TDR to troubleshoot and measure all types of twisted pair, coaxial and power cables, both aerial and underground.

TDRs can locate major or minor cabling problems including: opens, shorts, splices, splits and re-splits, bridged taps, water damage, crimps, cuts, smashed cables, shorted conductors, system components, and a variety of other fault conditions. In addition, TDRs can be used to test reels of cable for length, shipping damage, cable shortages, cable usage, inventory management and documenting cable systems.

Although today's instruments are user-friendly, a solid understanding of the basic principles and applications of a TDR is essential to successful troubleshooting, and making your TDR a more valuable and effective tool.

RISER BOND TDRS…A NECESSITY, NOT A LUXURY

TDRs are used in all phases of a cabling system's life, from construction and maintenance, to fault finding and restoration.

The TDR can be used to:

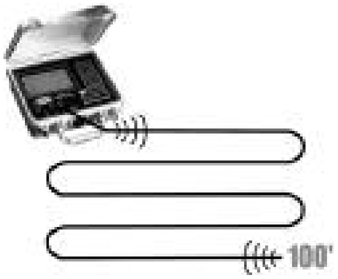
✓Locate wet/corroded splices
✓Locate bridged taps
✓Locate unknown splices
✓Clear lines for ISDN, HDSL, ADSL
✓Find in-line components
✓Locate water in the cable
✓Locate load coils
✓Find splits and re-splits
✓Aid in measuring and verifying new or partial cable reels
✓Locate crushed, pinched or kinked cables
✓Locate opens, shorts, and partials in the cable
✓Locate bullet holes in the cable
✓Capture intermittent faults
✓Measure dBRL (decibels of return loss) of the fault
✓Locate problems caused by construction
✓Document or map cable networks and conditions
✓Locate problems causing excessive loss of either AC or RF
✓Verify cable installations prior to acceptance
✓Detect theft of service
✓Help pinpoint ingress and egress problems
...and a variety of other cabling problems.

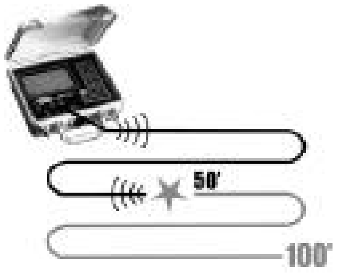
PRINCIPLES OF OPERATION

Converting Time Into Distance

A TDR works on the same principle as radar. The TDR transmits a pulse of energy down a cable. When that pulse reaches the end of the cable, or a fault along the cable, it (or a part of it) is reflected back to the instrument.

The TDR measures the time it takes for the signal to travel down the cable, locate the problem, and reflect back. The TDR then converts this time into distance and displays the information as a waveform and/or distance reading, so a fault can be located and repaired.





Selecting A TDR Display Method

TDRs can display the information they receive in two ways. The most traditional method is to display the actual waveform or “signature” of the cable. The display, which is either a CRT or an LCD, will display the outgoing (transmitted) pulse generated by the TDR and any reflections which are caused by impedance changes along the length of the cable.

The second type of display is a digital, numeric readout that indicates the distance in feet (or meters) to the first major reflection caused by a fault along the cable. Some instruments also indicate if the fault is an open or short, indicating a high impedance change or a low impedance change respectively, or if power is detected on the cable.

Traditional waveform TDRs supply more information than do the simplified, digital, numeric versions. However, the numeric models are less expensive and easier to operate. Costing only a fraction of traditional TDRs, many digital numeric TDRs are just as accurate and will locate most major cable faults. Traditional waveform units are better at detecting smaller faults and for testing over longer distances.

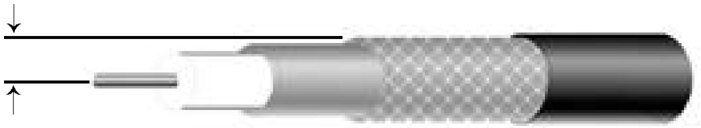
Model 1000
Digital Numeric TDR

Model 1270A
Waveform TDR

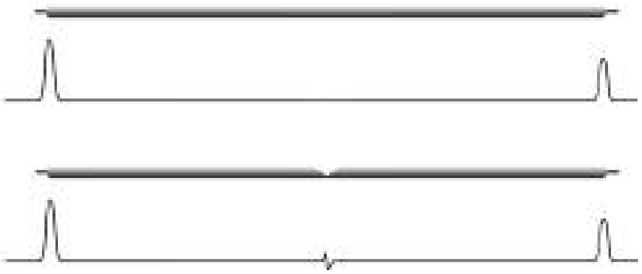
Changes In Impedance = Key To Detection

Any time two metallic conductors are placed close together, they form a transmission line which has a characteristic impedance. A TDR looks for the changes in impedance that can be caused by a variety of circumstances, including cable damage, water ingress, change in cable type, improper installation, and even manufacturing flaws.

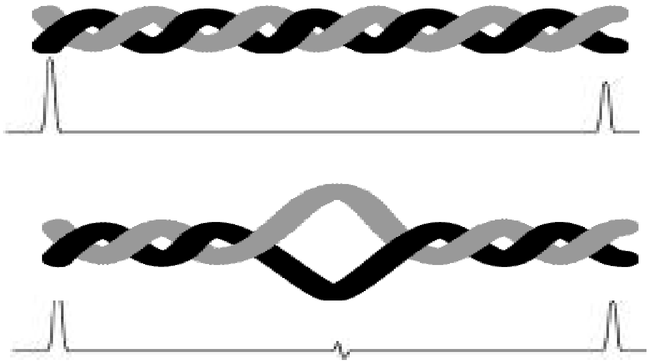
The insulating material that keeps the conductors separated is called the cable dielectric. The impedance of the cable is determined by the conductor diameter, the spacing of the conductors from each other and the type of dielectric or insulation used.



If the conductors are manufactured with exact spacing and the dielectric is exactly constant, then the impedance will be constant. If the conductors are randomly spaced or the dielectric changes along the cable, then the impedance will also vary along the cable.



A TDR sends electrical pulses down the cable and samples the reflected energy. Any impedance change will cause some energy to reflect back toward the TDR and will be displayed. The amount of impedance change determines how much energy is reflected.



Selecting The Right Pulse Width

Many TDRs have selectable pulse width settings. The pulse width allows the TDR signal to travel down a cable at different levels of energy and distances. The larger the pulse width, the more energy is transmitted and the farther the signal will travel down the cable. The size of the pulse is expressed in time and may range from less than 1 nanosecond (sub-nsec) for short distance/high resolution testing to greater than 330 microseconds for long distance telephone cable applications.

NOTE: Even when testing very long lengths of cable, always start the fault finding procedure in the shortest pulse width available, as the fault may be only a short distance away. Use the Zoom and Gain controls to help locate the fault. If you don't locate the fault immediately, switch to the next larger pulse width and retest. Keep switching to the next larger pulse until the fault is located. All reflections will be the same width as that of the output (incident) pulse.

Sometimes, larger pulse widths are helpful even for locating faults that are relatively close. If the fault is very small, the signal strength of a small pulse may not be enough to travel down the cable, "see" the fault, and travel back. The attenuation of the cable combined with the small reflection of a partial fault can make it difficult to detect. A larger pulse width transmits more energy down the cable, making it easier for the TDR to detect a small fault.

Sample Pulse Widths and Ranges
(Twisted Pair cable at .60 VOP)

Pulse Width	Maximum Range
sub-nsec	800 ft (243.8 m)
2 nsec	1,700 ft (518.1 m)
10 nsec	1,700 ft (518.1 m)
100 nsec	3,400 ft (1,036.3 m)
1 usec	13,600 ft (4,145.3 m)

Blind Spots

The pulse that the TDR generates takes a certain amount of time and distance to launch. This distance is known as the blind spot. The size of the blind spot varies with the pulse width. ***The larger the pulse width, the larger the blind spot.***

It is difficult to locate a fault contained within the blind spot. If a fault is suspected within the first few feet or meters of cable, it is advisable to start at the lowest pulse width or add a length of cable between the TDR and the cable being tested. Any faults that may have been hidden in the blind spot can now easily be located. If you decide to add a length of cable to eliminate the blind spot, remember that the TDR will also measure the length of the jumper cable; the length of the jumper must be considered in the distance reading. Riser Bond Instruments' exclusive dual independent cursors can subtract the length of the jumper automatically by placing the first cursor at the point of connection of the jumper.

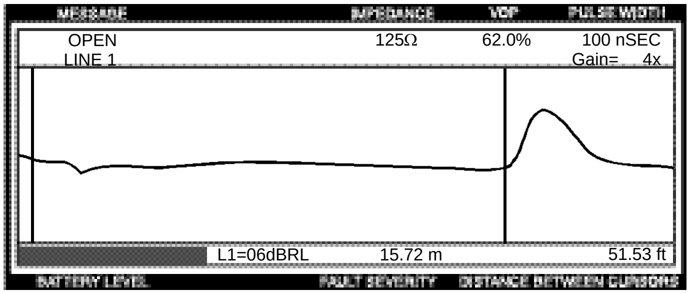
To ensure accurate readings, use the same type and impedance for the jumper cable as the cable under test. The quality of the connection, however, is the most important factor regardless of the type of jumper being used.

	Blind Spot			
Pulse width	Tw. Pair		Coaxial	
sub-nsec	1ft	0.1m	1ft	0.1m
2nsec	3ft	1m	3ft	1m
10nsec	12ft	4m	14ft	4m
100nsec	50ft	16m	55ft	17m
1usec	350ft	105m	430ft	133m
2usec	650ft	200m	810ft	246m
4usec	1300ft	390m	1600ft	487m
6usec	1970ft	600m	——	——

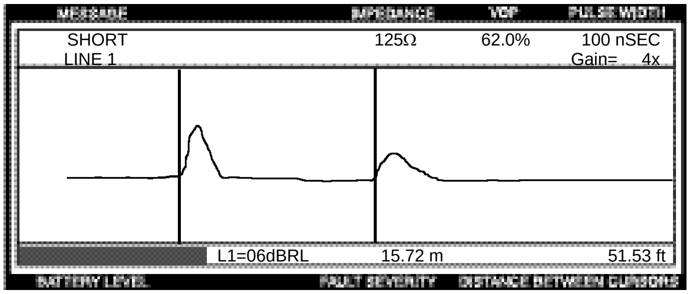
Minimizing Blind Spots — The Balance Control

Some TDRs incorporate a balance or compensation control, sometimes called a balance network. The balance control cancels or "compensates" the TDR transmit pulse out of the waveform display. This effectively reduces the blind spot, because a fault can still be located during the transmit pulse. A balance control can also compensate for DC or low frequency distortion that occurs when a pulse is transmitted on a capacitive cable such as telephone twisted pair.

NOTE: A balance network will cancel most of the pulse from the pulse area of the waveform display, but not all. Some pulse signal will still be visible, but all major and most minor faults in this area can be located.



OPEN 125Ω 62.0% 100 nSEC
LINE 1 Gain= 4x
L1=06dBRL 15.72 m 51.53 ft



SHORT 125Ω 62.0% 100 nSEC
LINE 1 Gain= 4x
L1=06dBRL 15.72 m 51.53 ft

Increase Your Accuracy - Using the Correct VOP

TDRs are extremely accurate instruments. However, variables in the cable itself can cause errors in distance measurements. One way to minimize error is to use the correct Velocity of Propagation (VOP) of the cable being tested. The VOP is a specification of the speed at which a signal travels through the cable. Different cables have different VOPs, and knowing the VOP of a cable is the most important factor when fault finding. By entering the correct VOP, you've calibrated your TDR to the particular cable. Typically, the VOP of the cable being tested will be listed in the cable manufacturer's catalog or specification sheet.

VOP Defined: The speed of light in a vacuum is 186,400 miles/300,000 kilometers per second. This speed is represented by the number 1 (100%). All other signals are slower. A coaxial cable with a VOP of .85 would transmit a signal at 85% of the speed of light. A twisted pair cable, which typically has a lower VOP (such as .65), would transmit a signal at 65% of the speed of light. VOP may also be expressed as distance per unit of time, such as 100 meters per microsecond and will commonly be abbreviated as 100 m/us. The expression is often called "V/2."

Using Your TDR To Determine VOP

The dielectric material that separates the two conductors determines the VOP number of a cable. In a coaxial cable, the foam separating the center conductor and the outer sheath is the material determining the VOP. In twisted pair, the VOP number is determined by the spacing between conductors and the insulation that separates them.

Temperature, age, humidity and other factors can affect a cable's VOP. It can also vary from one manufacturing run to another. Even new cable can vary as much as +/- 3%.

There are several ways to determine the correct VOP. The first is to simply refer to the VOP card provided with the instrument. Second, consult the manufacturer for the correct VOP of that specific cable. A third way is to actually determine the VOP from a known cable length. Measure a known cable length - the longer the cable, the more accurate the VOP will be. Correctly place the cursors of the TDR on the output pulse and the reflected pulse (end) of the cable. Change the VOP setting until the "Distance Between Cursors" displays the known length. You have now determined the VOP of the cable.

Increasing VOP Measurement Accuracy

When pinpointing a fault with a waveform instrument, the most common technique used to reduce VOP error is as follows:

Determine the path of the cable. With a measuring wheel or tape, measure the exact length of the cable being tested. Set the VOP according to the manufacturer's specifications, test the cable, and record the distance to the end of the cable. If the reading is the exact length of the cable that was measured, the VOP is correct and the fault has been accurately located.

However, if the reading is more than the measured distance, reduce the VOP setting and retest. If the reading is less than the measured distance, increase the VOP setting and retest. Keep changing the VOP settings until the distance to the end of cable reading is the same as the known length. This will provide an accurate distance to fault reading.

The same result can be obtained mathematically. Take the actual cable length and divide by the TDR reading of distance to the end of the cable. This produces an adjustment factor. Next, multiply the distance to fault reading by the adjustment factor. The result will be the corrected distance to fault.

Example: TDR readings equal 500 feet (152 m) to the fault and 1200 feet (366 m) to the end of the cable. Actual cable cable length equals 1000 feet (305 m).

> 1000 ft./1200 ft. = Adjustment Factor = 0.833
> (305 m/366 m = 0.833)
> 500 ft. x 0.833 = 416 ft. actual distance to fault
> (152 m x 0.833 = 127 m)

In the case of a complete open or a complete short in the cable or when using a digital numeric TDR, it is necessary to modify the precedure. As before, determine the path of the cable, neasure its exact length, and set the VOP according to manufacturer's specifications. Then, test the cable from one end and record the fault distance reading. Next, using the same VOP setting, test from the opposite end of the cable and again record the fault distance reading. If the sum of the readings equals the exact length of the cable that was measured, the VOP is correct and the fault has been located. If there is a discrepancy, adjust the VOP settings as previously described until the total of the two readings equals the known cable length or calculate the adjustment factor, as shown above, and correct the two distance to fault measurements mathematically.

If the sum of the two distance to fault readings is still less than the known cable length, even after the VOP setting has been adjusted to its maximum level, it is likely that the cable has more than one fault and the TDR is not measuring the distance between the faults.

> *NOTE:*
> *When measuring cable reels, cable coiled on the reel can cause an error in the length reading by as much as 5%.*

Examples of Cable Types and Their VOP

Telephone	PIC 19AWG	0.69	Pulp/Paper 22AWG	0.69
	PIC 22AWG	0.68	Pulp/Paper 24AWG	0.68
	PIC 24AWG	0.66	Pulp/Paper 26AWG	0.66
	PIC 26AWG	0.65		
	Jel Filled 19AWG	0.68		
	Jel Filled 22AWG	0.65		
	Jel Filled 24AWG	0.64		
	Jel Filled 26AWG	0.63		

CATV	Belden (foam)	.78 - .82	Trunk/Dist foam	.87
	(solid)	.66	Drop foam	.82
	Comm/Scope (F)	.82	Capscan (foam)	.82
	Trunk/Dist PII	.87	CC	.88
	Series 6	.85	CZ Labs (foam)	.82
	Series 7	.85	General Cable	
	Para I	.82	RG-59	.82
	Para III	.87	MC^2	.93
	QR	.88	Scientific Atlanta	
	Times Fiber RG-59	.93	RG-59	.81
	T4, 6, 10, TR+	.87	Trunk	.87
	TX, TX10	.89	Cableflex	.87
	Dynafoam	.90		
	Trilogy (F)	.83		
	6 Series	.85		
	7 Series	.85		

Power (International)	Impregnated paper	150-171 m/us (.50 - .57)	PVC	152-175 m/us (.51 - .58)
	Dry paper	216-264 m/us (.72 - .88)	PTFE	approx. 213 m/us (.71)
	PE	approx. 200 m/us (.66)	Air	approx. 282 m/us (.94)
	XLPE	156-174 m/us (.52 - .58)		

Power (U.S.)	XLPE	345	35	1/O	.57	XLPE		15	#4 CU	.52
	XLPE		35	750 MCM	.51	XLPE		15	500 MCM	.53
	PILC		35	750 MCM	.52	XLPE		15	750 MCM	.56
	XLPE		25	1/O	.56	XLPE	260	15	750 MCM & AL	.53
	XLPE	260	25	1/O	.51	EPR	220	15	1/O	.52
	XLPE		25	#1CU	.49	EPR	220	15	4/O	.58
	PILC		25	4/O	.54	EPR		15	#2 AL	.55
	XLPE	175	15	1/O AL	.55	PILC		15	4/O	.49
	XLPE	175	15	1/O	.51	EPR		5	#2	.45
	XLPE		15	2/O	.49	EPR		5	#6	.57
	XLPE		15	4/O	.49	XLPE		.6	1/O	.62
	XLPE		15	#1 CU	.56	XLPE		.6	4/O	.62
	XLPE		15	#2 CU & AL	.52	XLPE		.6	#2	.61
	XLPE		15	#2 AL	.53	XLPE		.6	#8	.61
	XLPE		15	#2 AL	.48	XLPE		.6	#12-6PR	.62

LAN	UTP 26	.64	Poly core dielectric		.66
	Thinnet	.66 - .70	Polyethylene		.66
	no pelenum	.66	Polyvinyl chloride		.45
	pelenum	.70	Beldon 53 ohm		.70
	dec	.78	73 ohm		.70
	Ethernet	.77	93 ohm		.85
	Token Ring	.78	9907		.80
	Arcnet	.84			
	Twinaxial Air	.80	IBM	1	.64
	Twinaxial	.71		2	.66
	Appletalk	.68		3	.70
	Thicknet	.77		4	.72
	RG58	.78		5	.76
	RG58/U	.66		6	.78
	Cellular ply foam	.78		7	.82
	Paired computer	.66		8	.84
	Twisted Pair 26	.64		9	.82
	Twinaxial	.71		Type 1	.64
	Appletalk	.68		Type 2	.66

Land/ Mobile	Andrew Radiax	All	.79
	Heliax		
	FHJ 1-50	1/4”	.79
	FSJ 1-50	1/4”	.78
	FSJ 4-50B	1/2”	.81
	LDF 2-50	3/8”	.88
	LDF 4-50A	1/2”	.80
	LDF 4-75	1/2”	.88
	LDF 5-50A	7/8”	.89
	LDF 7-50	1 5/8”	.88
	FT 4-50	1/2”	.85
	FT 5-50	7/8”	.89
	HJ 4-50	1/2”	.91
	HJ 5-50	7/8”	.92
	HJ 5-75	7/8”	.90
	HJ 7-50A	1 5/8”	.92
	HJ 8-50B	3”	.93
	HJ 11-50	4”	.92
	HJ 9-50	5”	.93
	Cablewave		
	FLC 12-50J	1/2”	.88
	FLC 78-50J	7/8”	.88
	Cellflex FoamFCC + FLC		
	FCC 38-50J	3/8”	.81
	FLC 12-50J	1/2”	.88
	FLC 78-50J	7/8”	.88
	FLC 158-50J	1 5/8”	.88
	Celwave	All	.88
	Coax Transmission Line		
	920213	7/8”	.99
	920214	1 5/8”	.99
	Flexwell HCC		
	HCC 12-50J	1/2”	.91
	HCC 78-50J	7/8”	.91
	HCC 58-50J	1 5/8”	.95
	HCC 300-50J	3”	.96
	HCC 312-50J	3 1/2”	.96
	HF 4 1/2 CU24 4	1/2”	.97

Quickly Locating Multiple Faults

It’s not uncommon for a cable to contain more than one fault. Multiple faults can be caused by many factors, including rodent damage, improper or faulty installation, construction, ground shift, or even structural flaws from the manufacturing process.

If a fault is a complete open or a dead short, the TDR will read only to that point and not beyond. If the fault is not a complete open or dead short, the TDR may indicate the first fault as well as other faults farther down the cable.

Multiple faults affect waveform and digital numeric TDRs differently.

In the case of a waveform TDR, the waveform signature of the cable will show most faults, both large and small, along the length of the cable.

In the case of a digital, numeric TDR, only the distance to the first major fault will be indicated, and not smaller faults beyond the larger fault, because the first fault hides the others. You must test from the opposite end of the cable for signs of other possible faults.

Termination

When testing cables, it is best if the cable is not terminated. A termination can absorb the pulse and no signal will return to the instrument. The TDR’s output pulse must be reflected back to the instrument by a fault or the end of the cable in order to indicate a distance. It is best if all equipment and components are disconnected from the cable being tested.

Sometimes it is not practical to disconnect the far end of the cable. However, it is still possible to test a cable that is terminated. If the cable is damaged, the signal will reflect at the damaged point prior to being absorbed by a termination.

If a reflection is created at the point of termination, it is possible the TDR has found a faulty terminator.

Cable Loss

As signal energy travels down a cable, some of the signal energy is lost due to the resistance of the cable. This is known as attenuation, or cable loss. Cable loss is measured in decibels (dB). If the transmitted signal energy reaches an impedance discontinuity (fault), some, or all of the energy is reflected back to the instrument. The ratio of signal energy, transmitted to reflected, is known as return loss. Return loss is measured in decibels of return loss (dBRL).

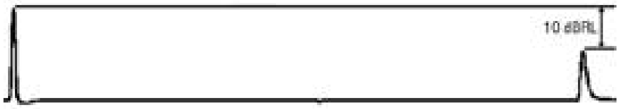
Return loss is a way of measuring impedance changes in a cable. Understanding dBRL is sometimes confusing. This is due to the fact that a large dBRL number means the reflection or fault is small, and vice versa. A dBRL reading indicates the difference between the amplitude of the output pulse versus the reflected pulse.

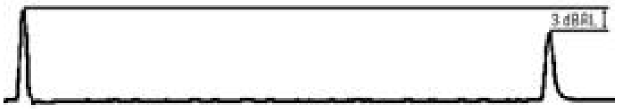
A large return loss means that most of the transmitted pulse was not reflected. The signal simply continued down the cable or was absorbed by a termination or load on the cable. A small return loss means that most of the transmitted pulse was reflected or returned due to an impedance change caused by a fault or the end of the cable. A complete open or a dead short would reflect all of the signal energy. Therefore, the return loss would be zero.

Mathematically, the formula for finding return loss is:

$$\text{dBRL} = 20\ \text{LOG}_{10}\ V_O/V_R$$

- Where dBRL is the decibels of return loss
- V_O is the voltage of the output signal
- V_R is the voltage of the reflected signal





Automatically Calculate Return Loss

Return loss can be difficult to calculate, but many Riser Bond TDRs calculate it automatically. The main point to remember is that the closer to zero a dBRL reading is, the worse the fault is. The larger the fault, the larger the reflected pulse will be, and therefore, the smaller the ratio. The dBRL value displayed on the instrument is this ratio.

Another important point to remember is that the reflection is a cable length away from the instrument. This means the fault is really more severe than the instrument reading. This is caused by cable loss. As an example, if you are 100 feet away from a fault that is 20 dB, the TDR would read 25 dB. But if you were 500 feet away, the same fault of 20 dB might make the TDR read 35 dB. This is another reason to get as close to the fault as you can.

The auto-calculation of dBRL on the instrument is a quick way to see if a fault is severe enough to need immediate attention. The automatic dBRL display can be used to set a standard for repairs within a cable system. Your company may set a numeric standard, for example, of 30 dBRL and instruct technicians to repair all faults of 30 dBRL or less within a certain distance and to ignore all faults greater than 30 dBRL.

The operator may also track splices and in-line components going bad on a cable. If a splice has a dBRL reading of 40 and one month later has a reading of 33 dBRL, the user knows that the splice is going bad.

Get The Best Connection Possible

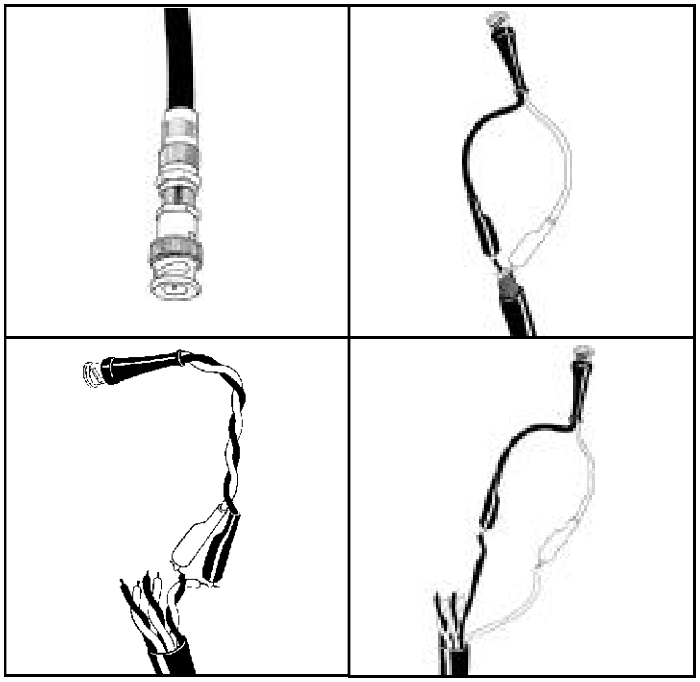
Make a quality connection between the instrument and the cable under test. The importance of a quality connection cannot be overstated. It is best if the cable is adapted to connect directly to the front panel of the instrument. Use adapters and connectors with the same impedance as the cable under test. A poor connection can result in a distorted waveform that can mask a fault. Do not use the test leads found in the door of telephone cross-connect boxes. They are inherently a bad connection for TDRs.

Test From Both Ends For Accuracy

It is always best to test a cable from both ends. It can help reduce error in VOP and uncover hidden faults.

A reduction in the TDR pulse energy, caused by attenuation or cable loss, can make a small fault difficult to see if the fault is a long distance away. By going to the end of the cable and testing in the opposite direction, you place yourself and the TDR much closer to the fault, making it easier for the TDR to locate.

As mentioned previously, a digital, numeric TDR cannot “see” a small fault beyond a larger fault. Again, by testing from the opposite end, a second fault may be located which might otherwise remain hidden. Testing a cable from both ends assures that no fault is being hidden by a blind spot or dead zone caused by the pulse width. Always retest after fixing a fault.



Correct Connection **Incorrect Connection**

TESTING TIPS

1. Read the Operator's Manual

More often than not, the operator's manual is read only as a last resort. There are important basic instructions in the manual that can make troubleshooting easier and more accurate. Take the time to thoroughly read the operator's manual and review any additional instructional materials.

2. Know your TDR

Experiment with the TDR on known cable lengths and conditions. Learn to identify waveform signatures and the function of each key. Become familiar with the instrument prior to actual field applications.

3. Get as close to the fault as possible

Isolate the trouble to the smallest cable section possible. Positioning the TDR close to the fault increases your chances of accurate fault location. Use cable plant maps whenever possible.

4. Make a quality connection

The importance of a quality connection cannot be overstated. Whenever possible, connect directly to the front panel of the instrument. A poor connection can result in a distorted waveform that can mask a fault and reduce the amount of pulse energy transmitted to the cable.

5. Enter the correct VOP of the cable

Because a TDR will test almost any type of metallic, paired cable, entering the correct VOP of the cable being tested is important for achieving accurate test results. By entering the correct VOP, you are matching the instrument to that particular cable, providing optimum accuracy.

6. Start with the shortest pulse width

Always start your troubleshooting test procedure in the shortest pulse width, range, or mode that is available on your TDR. Even if you are testing a very long length of cable, it is possible that the fault is contained in the first section of cable. If a fault is not located, switch to the next larger pulse width. If you suspect a fault is contained so close that it is hidden within the blind spot, add a jumper cable to "expose" the fault.

7. Test from both ends of the cable

Testing a cable from both ends can help reduce error in VOP and uncover hidden faults. Attenuation, or cable loss, can make it difficult to locate a small fault that is a long distance away. By going to the other end of the cable, the TDR is much closer to the fault, making it easier to locate. When testing with a digital, numeric (non-waveform) unit, the TDR cannot locate a small fault beyond a larger fault. By testing from the opposite end, a second fault may be located which might otherwise remain hidden.

8. Determine the cable path and depth

A TDR will indicate a distance reading to the fault. However, obtaining an accurate measurement can sometimes be difficult due to cable "snaking" and cable depth. Use a cable locator to determine the path and depth of the cable for more accurate distance measurements.

9. Retest the cable

Always retest the cable after making a repair. This is an easy way to verify the cable was repaired properly and you may be able to locate a second fault beyond the first.

10. Use common sense

Although a complete understanding of the TDR is vital to successful troubleshooting, there is never a substitute for good common sense.

If your TDR indicates a fault at 500 feet (152.2 meters) and you notice a new fence post at 490 feet (149.4 meters), there is a good chance that the fault was caused by the fence post.

If your TDR indicates a minor fault far away, adjust the horizontal and vertical controls to enhance the fault, use various pulse widths, move closer to the fault and test from the other end of the cable. These procedures will help establish a more accurate distance reading.

When using a digital, numeric TDR, common sense is imperative. Although waveform information is not supplied, it is more difficult to know what the numeric TDR is indicating. Many digital, numeric TDRs can be interfaced with an oscilloscope making the instrument more versatile.

The more you use a TDR, the more confident and comfortable you will become. You soon discover that the TDR is one of the most valuable tools available for locating faults quickly and accurately.

FEATURES UNIQUE TO RISER BOND TDRs

SUPER-STORE WAVEFORM STORAGE

SUPER-STORE will store all of the vertical and horizontal waveform information, as well as all the instrument settings. This allows the operator to move and adjust the waveform as though it was “live”. SUPER-STORE far surpasses any other type or brand of waveform storage.

The operator can utilize manpower more efficiently by storing a waveform in the field and later recalling the same waveform back at the office. This allows a more experienced person to interpret the waveform, or get a second opinion from coworkers.

The user also has the ability to recall and display the waveform at any time. The waveform can still be fully adjusted. The only changes that cannot be made are in the pulse width, the impedance settings, balance or engaging the filters. WAVE-VIEW software (see the next section) allows the stored waveforms to be transferred to a personal computer where the same benefits can be utilized.

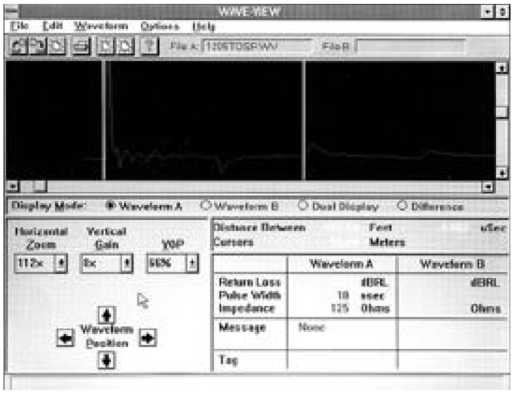
In two-way cable systems, downtime is more of a concern than ever. SUPER-STORE allows the user to disconnect the cable, take the necessary TDR readings, store the information, and restore the customer’s service, all within a matter of seconds. There is no need to leave the customer disconnected while analyzing waveforms.

The combination of SUPER-STORE and WAVE-VIEW make a good tool for TDR training. Students or new employees can use the computer as though it was a TDR, which keeps the TDR in the field. In addition, a variety of sample waveforms can be stored. Various cable spans and types, faults, system components and samples of known cable conditions can all be recalled and studied.

Contractors can use SUPER-STORE and WAVE-VIEW to document their work or to use as proof-of-completion and/or performance. SUPER-STORE can also be used to show the need for cable replacement or repair. Documenting a cable section when newly installed makes a convenient and easy comparison when problems arise at a later date. Cables can be periodically monitored for signs of deterioration. Stored information can also be sent to remote locations via modem. Riser Bond’s SUPER-STORE and WAVE-VIEW provide a variety of opportunities and applications not found with any other TDR.

WAVE-VIEW SOFTWARE

Use a computer and WAVE-VIEW software as an extension of your Riser Bond TDR. WAVE-VIEW allows for information stored in the instrument to be transferred to a computer. Waveform information can be archived, adjusted, compared, or analyzed from the convenience of your computer. Using the software in combination with the appropriate equipment allows the user to e-mail stored waveforms. Updates to WAVE-VIEW software can be downloaded from the Riser Bond Instruments website at www.riserbond.com.



Display Mode: ● Waveform A ○ Waveform B ○ Dual Display ○ Difference

	Waveform A	Waveform B
Return Loss	dBRL	dBRL
Pulse Width	10 nsec	
Impedance	125 Ohms	Ohms
Message	None	
Tag		

All of the information about the waveform can be stored and downloaded to a computer, allowing the operator to zoom in, zoom out, adjust the vertical gain, change the VOP, and move the cursors. With WAVE-VIEW software, you can view the waveform just as if you were still in the field.

Your computer can be used for TDR training because it is similar to testing with an actual instrument. In addition, the user has the ability to export waveform data and graphics to other applications.

Document your cable system by storing a waveform of each cable section within the system. When a problem is suspected, retest the questionable cable with the TDR and make a direct comparison to the stored cable waveform on the computer to find irregularities.

A technician with little or no TDR experience can use WAVE-VIEW to look at the stored waveforms, identify different faults and become familiar with what components look like prior to going in the field. Contractors can upload waveforms and make copies on disk for their employing companies. Users can e-mail waveforms to one another for comparison and information transfer.

INTERMITTENT FAULT DETECTION

The Intermittent Fault Detection (IFD) feature is designed to find intermittent problems, such as intermittent series resistance or "noisy static" causing problems. The IFD Mode will continuously monitor a cable under test and memorize the irregularities that occur, even if they occur for only a moment. Riser Bond's IFD retains the waveform trace. The waveform can be adjusted, repositioned, zoomed in or out, and the cursors moved, without affecting the IFD function. The user is then able to examine the waveform and find any changes that have taken place along the cable.

Other TDRs with an intermittent fault function allow a fault to be detected only if that section of cable is on screen. If the fault occurs off screen, the intermittent fault test must be restarted and the area where the fault occurs must be located on the display for it to be detected. This can be a problem. For example, when you have an intermittent fault that only shows up once every hour, you do not want to wait another hour after resetting to be able to detect the fault that is occurring. With other TDRs, the user must have an accurate idea of where the intermittent fault is located before using this type of intermittent fault test. This is not a problem, because the Intermittent Fault Detection mode will monitor the entire cable under test and detect a fault whether the section of cable is on or off screen. The auto-off feature is deactivated when the instrument is in the IFD mode. For additional information, refer to the CATV Applications section.

AUTO-SEARCH/AUTO TEST

AUTO-SEARCH is a feature found in some Riser Bond TDR models. This function will quickly scan the cable for faults or the end of the cable. It is not designed to replace manual operation of the instrument, but it is a quick and easy way to locate major faults, the end of the cable, or for bringing the waveform back on screen. When a fault or the end of the cable is found, the cursors are automatically placed on the leading edge of the transmitted and reflected pulses. You may have to increase the horizontal zoom and slightly adjust the cursor position, because making manual adjustments may result in a more accurate reading and/or the discovery of hidden faults. Remember that AUTO-SEARCH does not adjust the VOP or the cable impedance/balance automatically; the user must correctly input this information.

To activate AUTO-SEARCH, press the asterisk (*) key to view the pop-up menu. Use the unlabeled icon keys to select the "Search" function from the menu. The instrument will AUTO-SEARCH to multiple faults with each activation of the AUTO-SEARCH function.

The AUTO-SEARCH feature will have better results testing coaxial cable than twisted pair cable. Twisted pair cable is noisier, which can cause the AUTO-SEARCH feature to trigger falsely or misplace the cursors.

AUTO-SEARCH can be a fast and helpful feature when initiating a test. If a major fault exists, AUTO-SEARCH will generally find it. However, know and understand both the benefits and limitations of the AUTO-SEARCH feature and do not rely on it for all of your tests.

Riser Bond multi-function instruments feature an Auto Test function. This function allows you to press a single button and perform a series of diagnostic test on twisted pair. These tests include DCV, ACV, Foreign Battery, Resistance, Loop Current, and Noise and Balance. The results of the tests are displayed on a comprehensive table on the screen. Like the AUTO-SEARCH function, Auto Test provides a convenient starting point for conducting tests, but is not intended to be a substitute for manual operation of the instrument.

RANGE-PLUS

RANGE-PLUS allows the operator to quickly and easily step through preset distance range, vertical gain, and pulse width settings. However, unlike other range functions, Riser Bond Instruments' TDRs' waveform can still be adjusted by all keypad functions. You are not "locked out" of manual operation.

In some models, by using the setup menu, the AUTO-SEARCH key can be configured as a preset range control or as a standard AUTO-SEARCH key. The range function automatically combines the horizontal zoom and pulse width settings enabling the operator to select preset distance ranges. Other instruments come standard with separate range keys.

DUAL, INDEPENDENT CURSORS

Dual, independent cursors enable the user to place either cursor anywhere along the waveform and the instrument will always measure the distance between the cursors. This feature allows the operator to measure the distance between any two points along the cable. Measure from the beginning of the cable to any fault along the cable, from the fault to the end of the cable, or measure the distance between any two points on the waveform.

To find the distance from the beginning of the cable to a fault, place the first cursor on the leading edge of the launch pulse, and the second cursor on the leading edge of the fault.

Dual Cursors For Multi-Spliced Cables

The operator may use this feature when testing a cable that is made up of several different cables spliced together, each with a different VOP. In this case, the user would place the first cursor at the leading edge of the output pulse and the second cursor at the leading edge of the first splice and input the correct VOP for that section of the cable. Take note of the distance displayed on the screen. Then place the first cursor on the leading edge of the first splice point and the second cursor at the leading edge of the second splice point, and/or end of the cable, and input the correct VOP for that section of cable. Document the distance displayed on the LCD for this section of cable. You would continue to test from splice point to splice point until all of the sections of cable have been measured. This helps the user maintain the accuracy of the test.

When used correctly, the independent cursors can improve the distance accuracy of the test. Increase the horizontal zoom and place the cursors at the same relative position on the leading edges of the reflections. The distance accuracy is increased significantly. For example, the user can determine where a specific pedestal is located on the waveform and place the first cursor at that point along the waveform. Measure from that point along the waveform to a fault located at some point beyond the pedestal. This will not only save the user from having to walk to the pedestal and reconnect the TDR, but will also be a more accurate reading as you have decreased the distance from the first cursor to the fault.

MULTILEVEL/MULTIFUNCTION NOISE FILTERING

This feature provides a unique system for filtering out various types of interference on the cable. The operator has the option to try many types and levels of filtering until the appropriate filter is located for each test. The AUTO FILTER will automatically engage if power is present on a cable being tested. Testing cable with power present may cause instrument damage if the instrument is not protected for live power cable testing. When not required, the auto-filter option may be disengaged to speed up the test process.

Riser Bond's TDRs offer a wide range of filtering options. This is extremely beneficial when RF, or any other type of interference, is present on a cable. If this should occur, the waveform may become extremely noisy and difficult to interpret. The user would then engage the filters to remove the "noise" on the waveform. The waveform will become smoother and easier to interpret.

Multilevel/Multifunction filtering allows the user to test antennas or cellular sites that may be receiving signals.

It is not always possible to completely disconnect the cable being tested from all other equipment. Examples of this are tower cables that go into an antenna, or a local area network that needs to stay operational during the test. If the cable is left attached to equipment at the far end, the energy on the cable may present a danger to the operator or TDR. If so, do not proceed with the test until danger is removed.

There are many different types of signals that can be present on the cable. They range from 50/60 Hz power to audio frequency, to data in the 1 to 100 MHz range, to RF. No single filter will eliminate all of these signals. Riser Bond Instruments' waveform TDRs have multiple types and levels of software filters which can eliminate almost any type of problem. In a filtering application, it is necessary for the operator to step through the various filters to see which one will work best.

Because of the inherent nature of the filters, some operate so fast they do not seem to affect the speed of the instrument display, while others seem to slow the display making adjustment almost impossible. An example of this is filtering power line noise. A 50 Hz power line cycle takes 20 milliseconds to complete and, therefore, 20 ms for the TDR to create one screen display dot. The update rate of a 256 dot display would then be over two seconds. This is a long time when trying to reposition a waveform. One way around these long delays is to engage the filter that will be the most effective, then store the filtered waveform. Waveform storage may take a long time, but the post-storage waveform analysis will be as fast as having the filter turned off.

The TDR noise filters are extremely useful when testing noisy cable, but experience will enhance success. Practice with different noise sources using different filters.

UPLOAD STORED DATA TO YOUR PC

Some of Riser Bond's TDRs feature an RS-232 Serial Port. The serial port allows the operator to upload stored waveform information to a computer for additional storage, archiving and for later analysis and comparison. The RS-232 port can also be used to print waveforms directly to a serial printer.

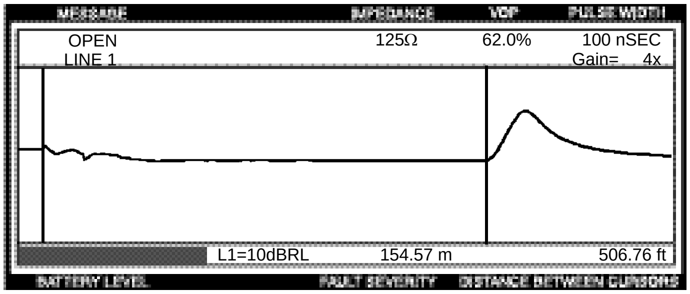
Analyzing Waveforms

A variety of waveforms may be encountered during testing. This variety is due to the different applications, electrical, and environmental characteristic variations found in the cables that exist today. Various industries, cable types, and components produce thousands of different waveforms. The TDR's pulse width, horizontal zoom, and vertical gain settings also affect how a waveform will appear.

Practice testing on multiple types of known cable segments, with and without components. Become familiar with how each segment looks prior to any problems. Use a printer or WAVE-VIEW to document the cable without problems, then compare the "good" waveforms with the "problem" waveforms.

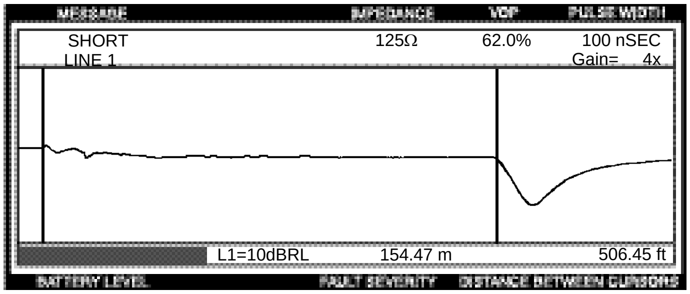
Following are examples of some waveforms that you may encounter. Some of the example sections use an instrument with a balanced transmit pulse and some use a non-balanced instrument.

TWISTED PAIR CABLE WAVEFORM EXAMPLES



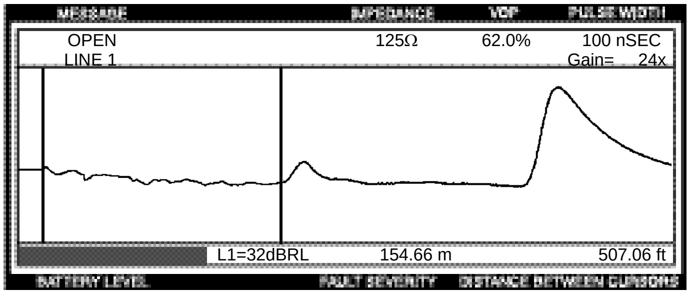
OPEN
LINE 1
125Ω
62.0%
100 nSEC
Gain= 4x
L1=10dBRL
154.57 m
506.76 ft

A positive or upward reflection indicates a fault with OPEN (high impedance) tendencies. The reflection shown at the 2nd cursor is a COMPLETE OPEN.



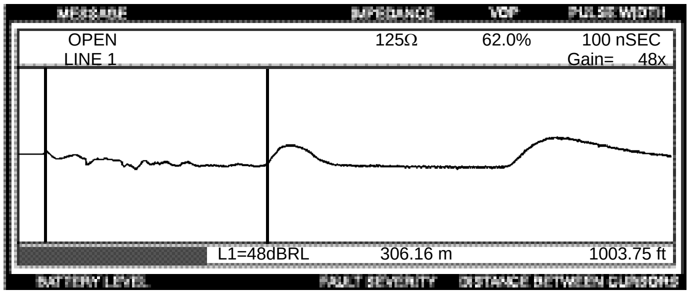
SHORT
LINE 1
125Ω
62.0%
100 nSEC
Gain= 4x
L1=10dBRL
154.47 m
506.45 ft

A negative or downward reflection indicates a fault with SHORT (low impedance) tendencies. The reflection shown at the 2nd cursor is a COMPLETE SHORT.



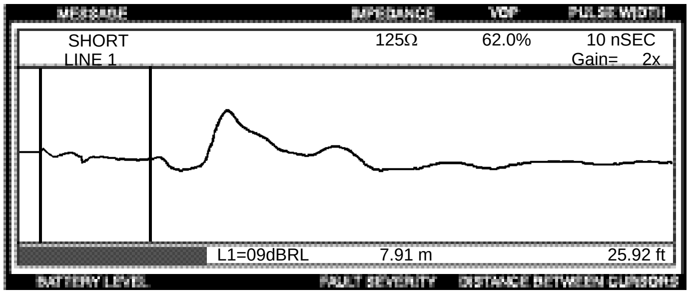
OPEN
LINE 1
125Ω
62.0%
100 nSEC
Gain= 24x
L1=32dBRL
154.66 m
507.06 ft

The middle reflection at the 2nd cursor is a partially open pair followed by a COMPLETE OPEN (end of the cable). The more severe the fault, the larger the reflection will be.



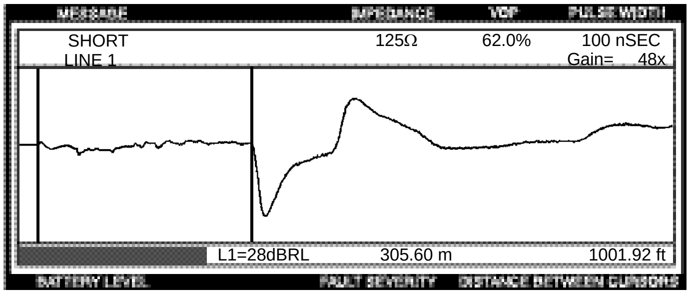
OPEN
LINE 1
125Ω
62.0%
100 nSEC
Gain= 48x
L1=48dBRL
306.16 m
1003.75 ft

A 10 ohm SERIES RESISTANCE FAULT at the 2nd cursor (1000 feet/305 m) followed by a COMPLETE OPEN at 2000 feet (610 meters).



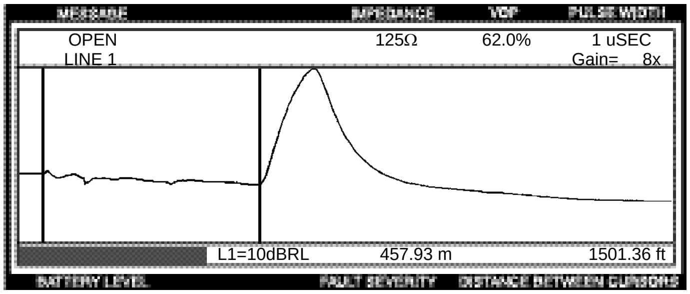
SHORT 125Ω 62.0% 10 nSEC
LINE 1 Gain= 2x
L1=09dBRL 7.91 m 25.92 ft

A WET SPLICE at the 2nd cursor is the first splice out from the cross-connect box.



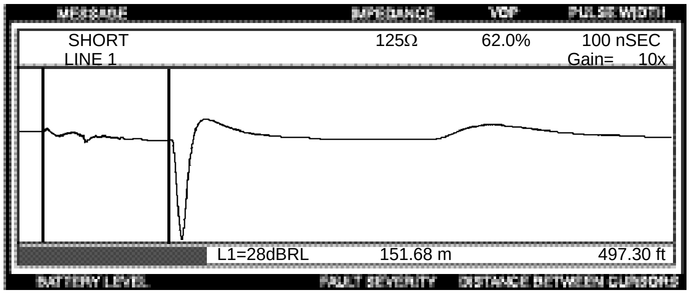
SHORT 125Ω 62.0% 100 nSEC
LINE 1 Gain= 48x
L1=28dBRL 305.60 m 1001.92 ft

A BRIDGED TAP will appear as a negative or downward reflection followed by a positive reflection (end of the cable).



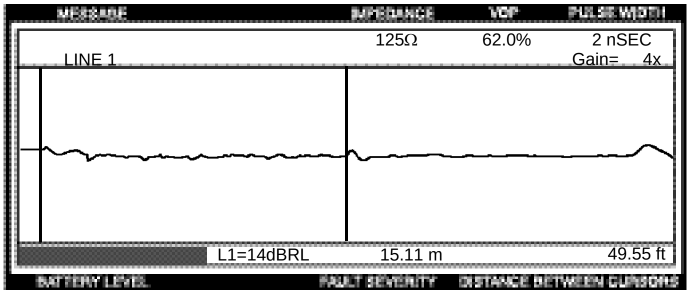
OPEN 125Ω 62.0% 1 uSEC
LINE 1 Gain= 8x
L1=10dBRL 457.93 m 1501.36 ft

A telephone LOAD COIL will cause a high impedance upward reflection similar to a COMPLETE OPEN. Some TDRs have the ability to test through load coils.



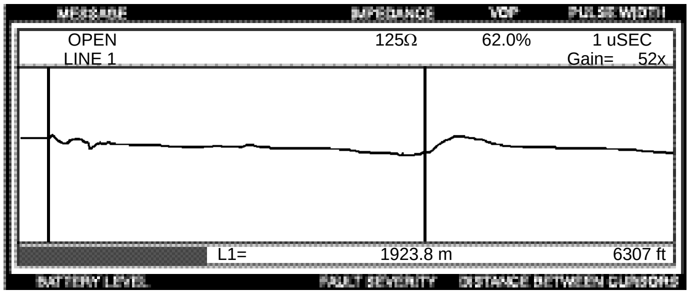
SHORT 125Ω 62.0% 100 nSEC
LINE 1 Gain= 10x
L1=28dBRL 151.68 m 497.30 ft

A telephone BUILD OUT CAPACITOR causes a low impedance DOWNWARD reflection (similar to a SHORT) followed by a smaller positive reflection.



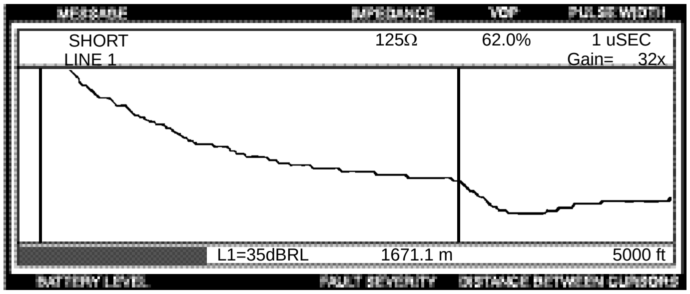
125Ω 62.0% 2 nSEC
LINE 1 Gain= 4x
L1=14dBRL 15.11 m 49.55 ft

A JOINT or SPLICE is shown at the 2nd cursor. The visibility of a splice will depend on the quality of the splice and the distance away from the TDR.

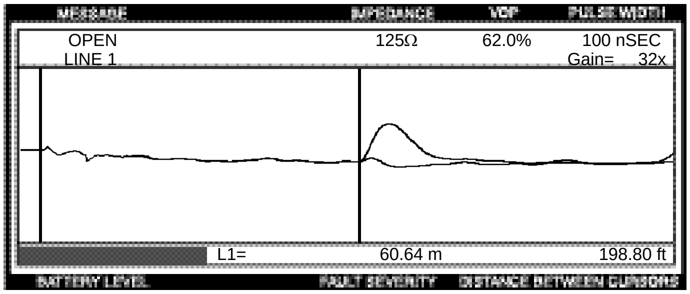


OPEN 125Ω 62.0% 1 uSEC
LINE 1 Gain= 52x
L1= 1923.8 m 6307 ft

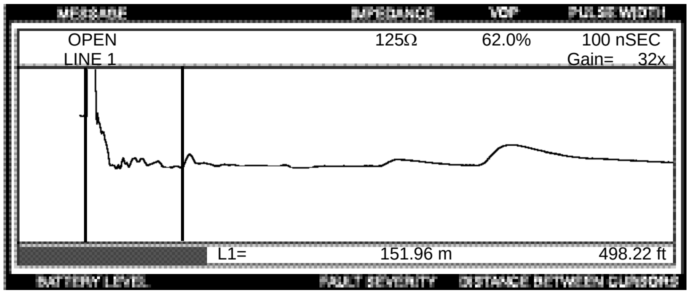
An OPEN is shown at 6307 feet (1922 meters) on twisted pair cable. Increasing the pulse width and vertical gain is necessary to see a distant fault.


MESSAGE: SHORT, LINE 1
IMPEDANCE: 125Ω
VOP: 62.0%
PULSE WIDTH: 1 uSEC
Gain= 32x
FAULT SEVERITY: L1=35dBRL
DISTANCE BETWEEN CURSORS: 1671.1 m 5000 ft

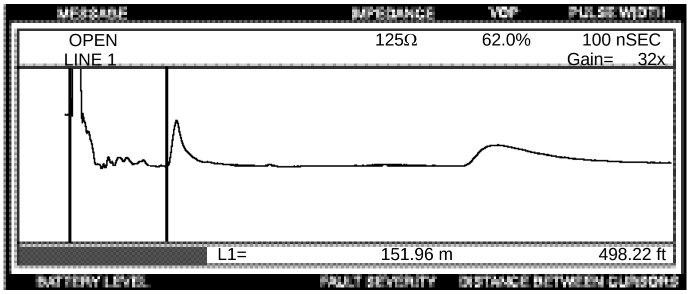
A SHORT is located at 5000 feet (1524 meters) on twisted pair cable. A reflection from a distant fault will be smaller and distorted.


MESSAGE: OPEN, LINE 1
IMPEDANCE: 125Ω
VOP: 62.0%
PULSE WIDTH: 100 nSEC
Gain= 32x
FAULT SEVERITY: L1=
DISTANCE BETWEEN CURSORS: 60.64 m 198.80 ft

An INTERMITTENT OPEN at the 2nd cursor is trapped by the Intermittent Fault Detection (IFD) Mode.

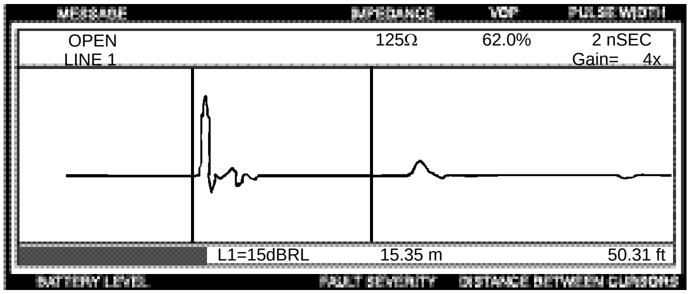

MESSAGE: OPEN, LINE 1
IMPEDANCE: 125Ω
VOP: 62.0%
PULSE WIDTH: 100 nSEC
Gain= 32x
FAULT SEVERITY: L1=
DISTANCE BETWEEN CURSORS: 151.96 m 498.22 ft

After the first major reflection, the second event could be a more severe fault. It appears smaller due to absorption of signal at the first fault. Always test the cable from both ends to help eliminate this problem.

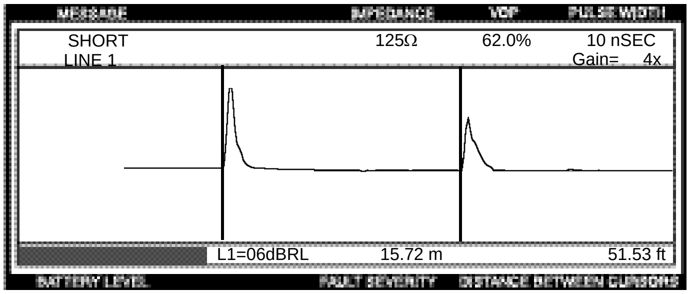

MESSAGE: OPEN, LINE 1
IMPEDANCE: 125Ω
VOP: 62.0%
PULSE WIDTH: 100 nSEC
Gain= 32x
FAULT SEVERITY: L1=
DISTANCE BETWEEN CURSORS: 151.96 m 498.22 ft

This waveform illustrates the importance of testing a cable from both ends. This is the same cable shown in the previous wavefrom. The severity of the second fault is now more obvious.

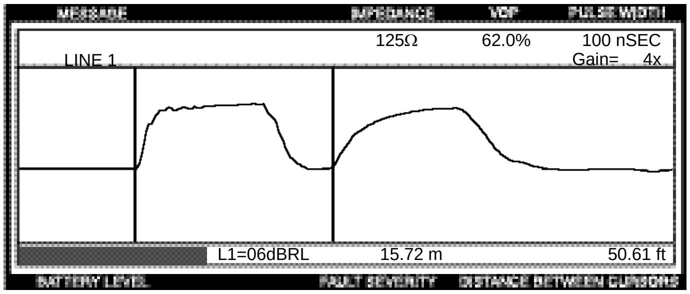
These three waveforms illustrate how changing the pulse width can affect the way a waveform appears. All three waveforms are of the same cable, using only different pulse widths.



OPEN 125Ω 62.0% 2 nSEC
LINE 1 Gain= 4x
L1=15dBRL 15.35 m 50.31 ft

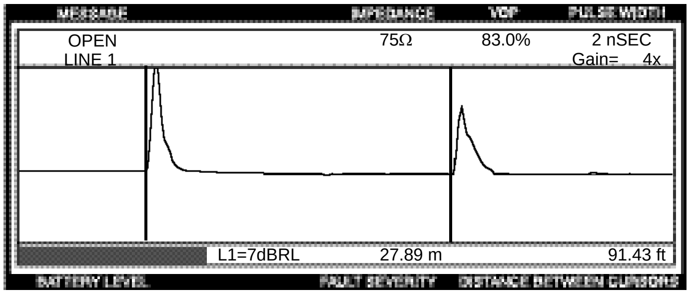


SHORT 125Ω 62.0% 10 nSEC
LINE 1 Gain= 4x
L1=06dBRL 15.72 m 51.53 ft



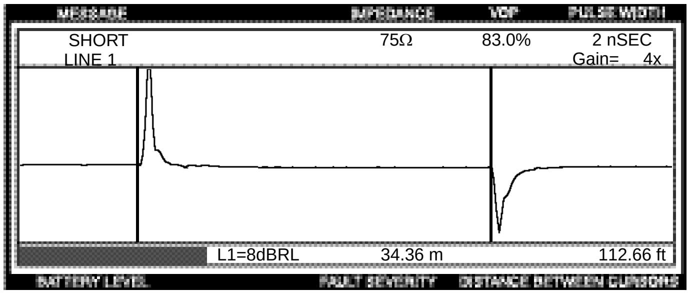
125Ω 62.0% 100 nSEC
LINE 1 Gain= 4x
L1=06dBRL 15.72 m 50.61 ft

COAXIAL CABLE WAVEFORM EXAMPLES



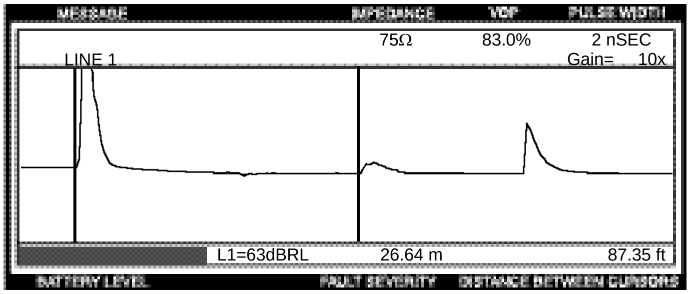
OPEN 75Ω 83.0% 2 nSEC
LINE 1 Gain= 4x
L1=7dBRL 27.89 m 91.43 ft

A reflection with the same polarity as the output pulse indicates a fault with OPEN (high impedance) tendencies. The reflection shown at the 2nd cursor is a COMPLETE OPEN.

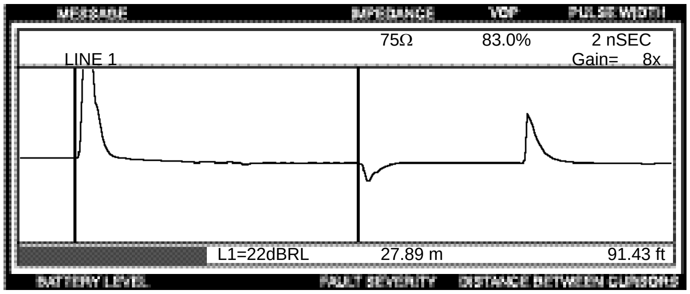


SHORT 75Ω 83.0% 2 nSEC
LINE 1 Gain= 4x
L1=8dBRL 34.36 m 112.66 ft

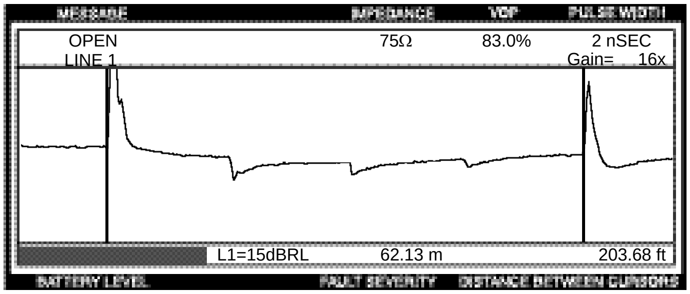
A reflection with the opposite polarity as the output pulse indicates a fault with SHORT (low impedance) tendencies. The reflection shown at the 2nd cursor is a DEAD SHORT.



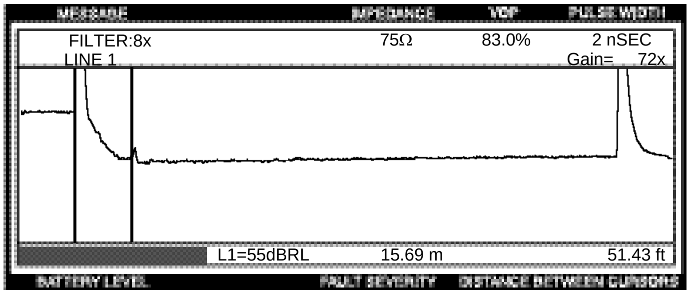
The middle reflection at the 2nd cursor is a PARTIAL OPEN followed by a COMPLETE OPEN (end of the cable). The more severe the fault, the larger the reflection will be.



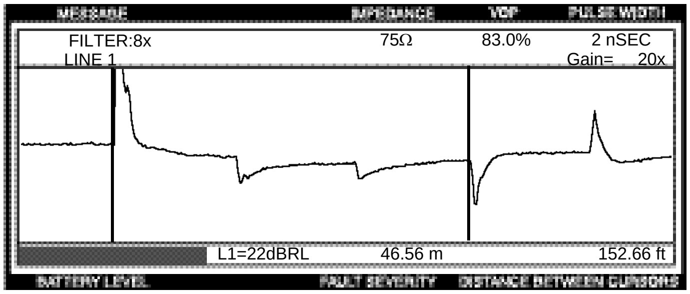
The middle reflection at the 2nd cursor is a PARTIAL SHORT followed by a COMPLETE OPEN (end of the cable). The more severe the fault, the larger the reflection will be.



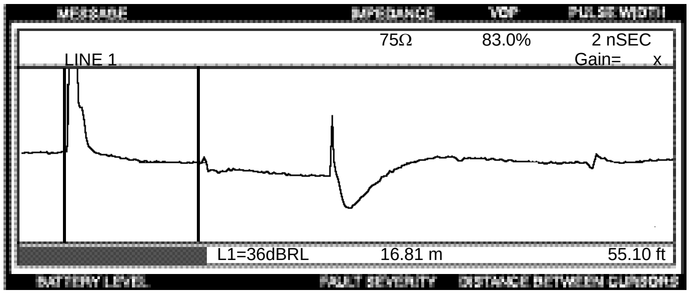
Due to attenuation, the reflections caused by each equally spaced tap are progressively smaller. The larger reflection (2nd cursor) beyond the smaller reflection may indicate an unterminated or faulty tap, or may be the end of the cable.



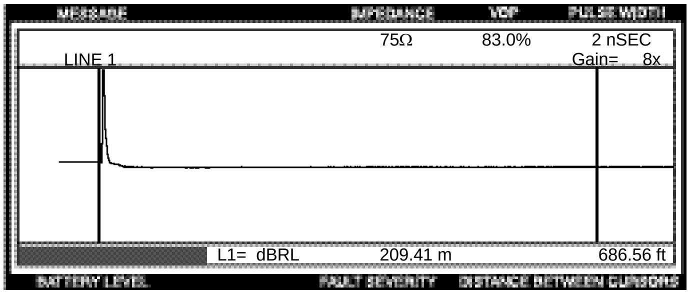
Two sections of cable with a splice shown at the 2nd cursor showing the amount of reflection caused by the splice is directly proportional to the quality of the splice. A good splice equals a small reflection; a bad splice equals a large reflection.



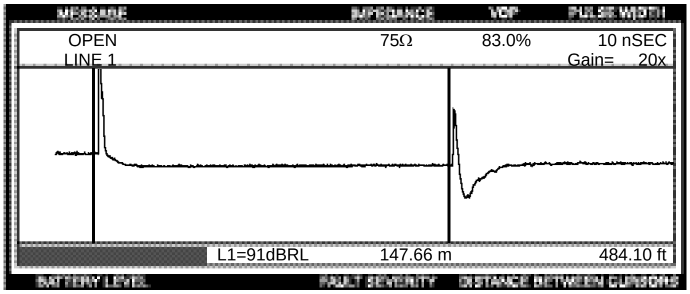
Coaxial taps (both indoor and outdoor) will cause reflections along the waveform. The quality and value of each tap determines the amount of reflection.



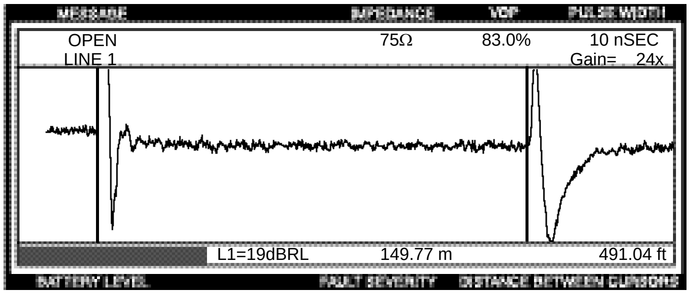
A splitter or directional coupler can be identified, although accurate measurements are difficult due to multiple reflections. The 2nd cursor identifies the splitter. The two reflections following are the ends of each of the segments.



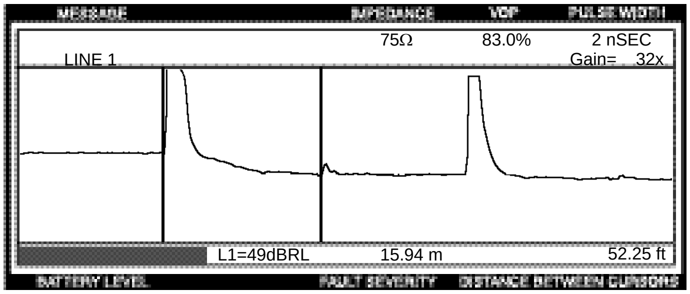
A properly terminated cable will absorb the TDR signal, resulting in no reflection. Faults prior to the termination may appear as reflections along the waveform.



Testing through to an antenna usually results in an “S” shaped reflection, although reflections can vary greatly depending on the antenna.

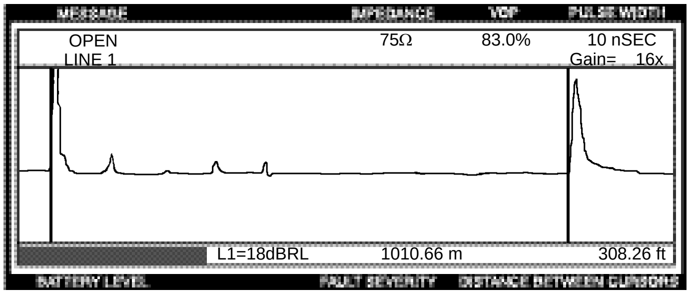


Testing tower cables with antennas can be challenging due to energy induction from high RF areas as shown in this waveform. Stepping through various noise filter settings will result in a “clearer” waveform.

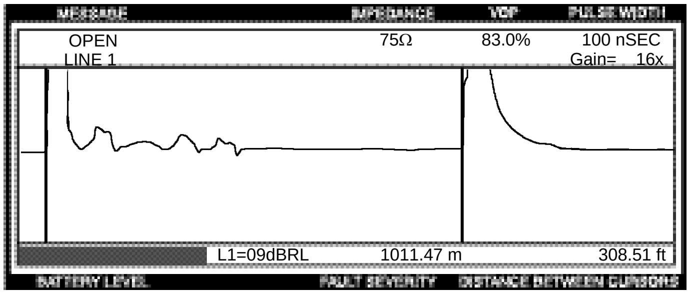


Mechanical inner-connectors (known as bullets) connecting sections of broadcast transmission line sometimes burn open causing power outages. These bullets can be detected and monitored for deterioration by a TDR.

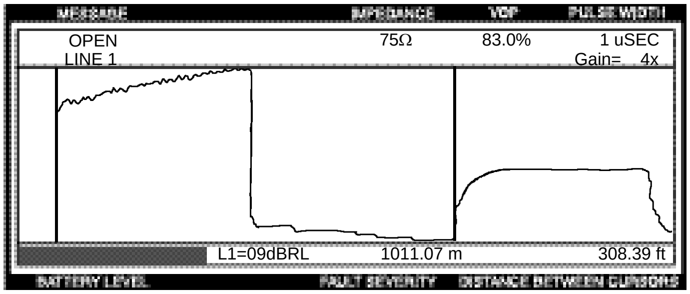
These three waveforms illustrate how only one setting can change the way a waveform appears. All three waveforms are of the same cable. Only the pulse width setting of the instrument has been changed.



OPEN
LINE 1
75Ω 83.0% 10 nSEC
Gain= 16x
L1=18dBRL 1010.66 m 308.26 ft

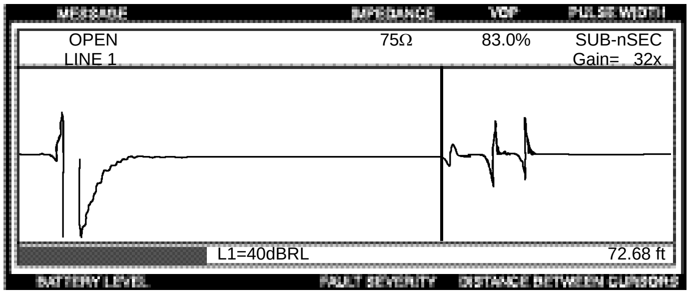


OPEN
LINE 1
75Ω 83.0% 100 nSEC
Gain= 16x
L1=09dBRL 1011.47 m 308.51 ft



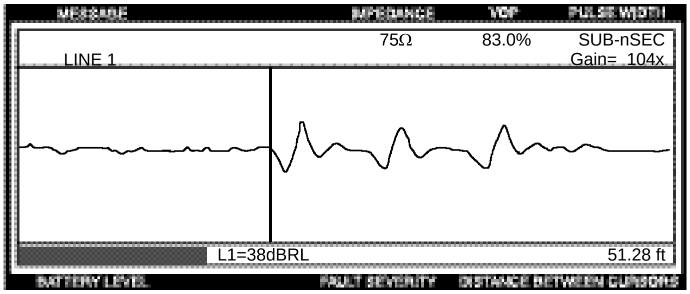
OPEN
LINE 1
75Ω 83.0% 1 uSEC
Gain= 4x
L1=09dBRL 1011.07 m 308.39 ft

The three elements seen in this section of 750 CATV hard line are a minor dent, a major dent, and a questionable splice.



OPEN
LINE 1
75Ω 83.0% SUB-nSEC
Gain= 32x
L1=40dBRL 72.68 ft

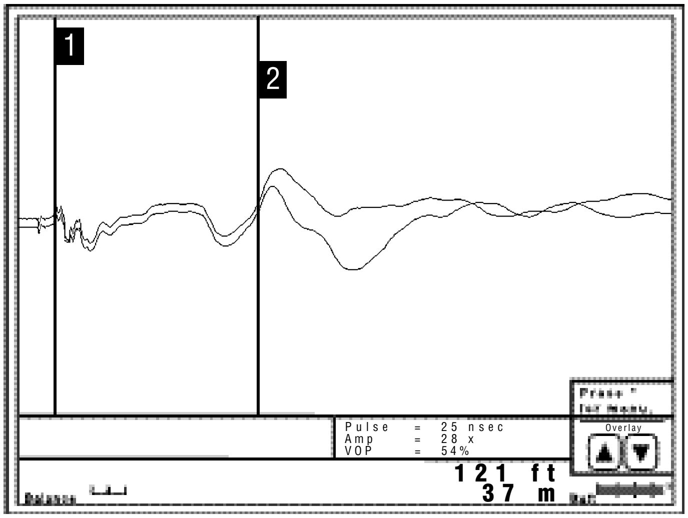
The horizontal zoom and vertical gain keys allow the operator to view these three crimps more closely.



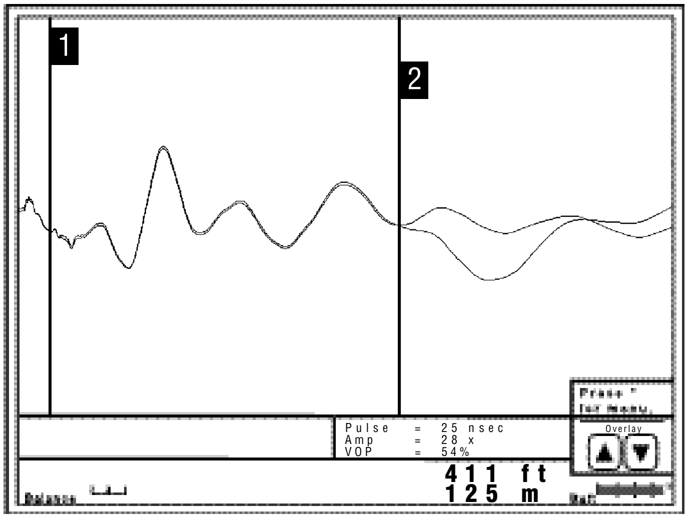
LINE 1
75Ω 83.0% SUB-nSEC
Gain= 104x
L1=38dBRL 51.28 ft

POWER CABLE WAVEFORM EXAMPLES

There are two 25 nanosecond pulse waveforms on a low voltage network simulation cable. One waveform is of a "good" phase and the other shows the same run of cable with a SHORT CIRCUIT at 121 feet (37 meters). The two are displayed together with the default overlay setting.

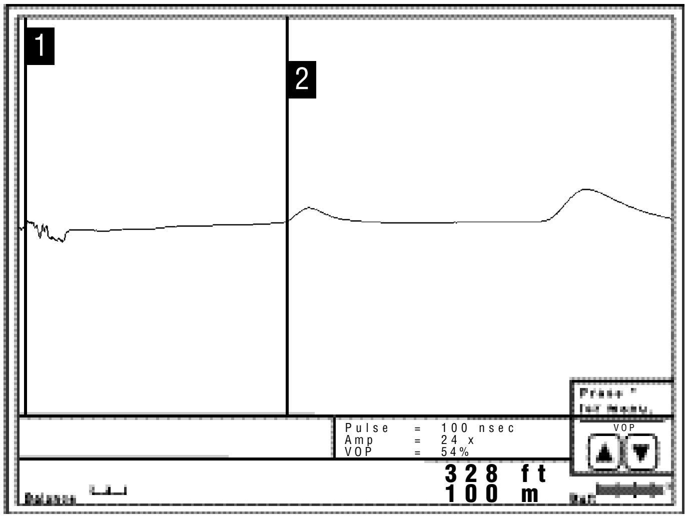

Pulse = 25 nsec
Amp = 28 x
VOP = 54%
121 ft
37 m

Two 25 nanosecond pulse waveforms on a low-voltage net work simulation cable. One waveform is of a "good" phase and the other shows the same run of cable with a SHORT CIRCUIT at 411 feet (125 meters). The two are displayed together with the overlay adjusted to zero offset.


Pulse = 25 nsec
Amp = 28 x
VOP = 54%
411 ft
125 m

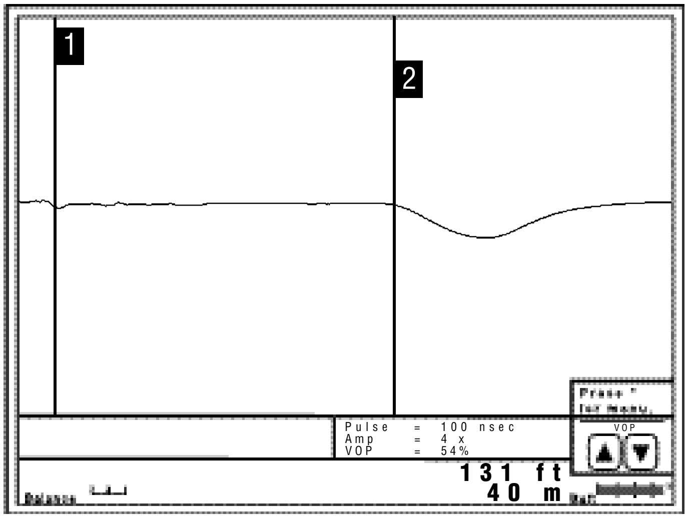
This is a waveform in the difference mode, using the 1 microsecond pulse, taken on a low-voltage network simulation cable. It shows the difference between a "good" phase and a PARTIAL OPEN CIRCUIT at 411 feet (125 meters).


Pulse = 100 nsec
Amp = 72 x
VOP = 54%
411 ft
125 m



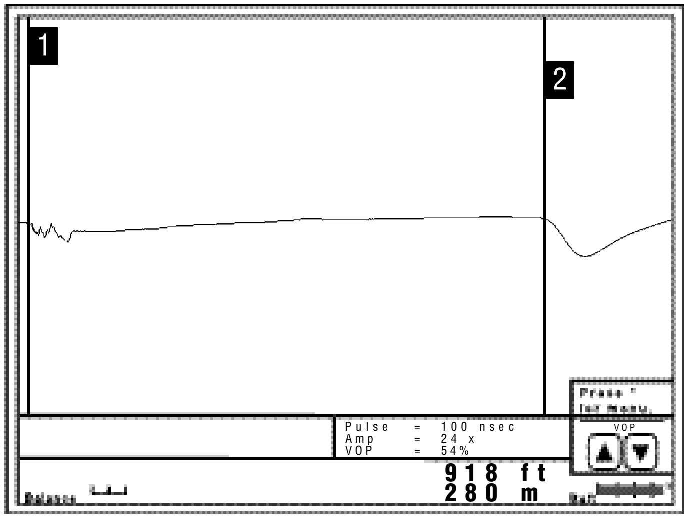
Pulse = 100 nsec
Amp = 24 x
VOP = 54%
328 ft
100 m

A 100 nanosecond pulse waveform, with a PARTIAL OPEN CIRCUIT at 328 feet (100 meters), followed by a COMPLETE OPEN CIRCUIT at 918 feet (280 meters).



Pulse = 100 nsec
Amp = 4 x
VOP = 54%
131 ft
40 m

A 100 nanosecond pulse waveform on a straight run of street lighting cable. There is a COMPLETE SHORT CIRCUIT at 131 feet (40 meters).



Pulse = 100 nsec
Amp = 24 x
VOP = 54%
918 ft
280 m

A 100 nanosecond pulse waveform on a straight run of street lighting cable. There is a COMPLETE SHORT CIRCUIT at 918 feet (280 meters).

APPLICATION NOTES

GENERAL APPLICATIONS

Fault Location

Troubleshooting cables is the primary function of the TDR. In most cases, there will be a single-point problem in the cable which can easily be identified. Other problem areas, such as water, structural problems and minor damage, may be harder to locate. The more time and experience gained, the more proficient the user becomes in utilizing the equipment.

TDR Tape Measure

Another benefit of the TDR is its measuring capability. If a cable contains no damage, the TDR will read to the end of the cable, thus indicating the entire length of the cable. New reels of cable can be checked for shortages or damage prior to installation. Partial reels of cable can also be tested for length and hidden damage.

Cable Identification

A TDR can also be used for identifying cables by length. Test each unmarked or mismarked cable in a pedestal and note the length. By comparing these cable length measurements to cable plant maps or records, the proper identification or location can be made.

Determining Cable Attenuation

Every signal will lose some of its energy or signal strength as it propagates down the cable. This loss is frequency sensitive. As the frequency of a signal goes up, the loss becomes greater. With any given set of frequencies, some cables will have more loss and some will have less.

Over a given cable length and within a span of frequencies, the user needs to know the signal attenuation. This specification will be in the cable manufacturer's catalog.

Normally, in order to find this attenuation, the cable is tested with a sine wave signal source (or sweep generator) attached to one end of the cable and a signal receiver (or AC power meter) with terminator attached to the other end. As the signal source is scanned through the frequencies of interest, the cable can be tested for attenuation versus frequency at a particular cable length.

A TDR transmits signals at various frequencies. The different pulse widths have different fundamental frequencies. Examples of fundamental frequencies for various pulse widths are:

Pulse width	Significant spectral power up to
sub-nsec	600 MHz
2 nsec	250 MHz
10 nsec	50 MHz
100 nsec	5 MHz
1 usec	500 KHz
2 usec	250 KHz
4 usec	125 KHz
6 usec	83 KHz
330 usec	1.5 KHz

It is possible to use a TDR to find an approximate value of cable attenuation. Simply connect the TDR to the cable under test. Set the first cursor to the output pulse and the second cursor to the reflected pulse. Note the cable length, the pulse width setting, and the return loss reading. Make sure the far end of the cable under test is not connected to a terminator or any other piece of equipment.

Since the TDR has both the signal source and the receiver located at the same end, the signal will have twice the attenuation because the signal has traveled down and back along the cable.

Therefore, if you simply divide the dBRL value by 2, you will have the approximate value of the cable attenuation at that frequency and cable length.

Structural Return Loss

Structural Return Loss (SRL) in a cable is caused by small imperfections distributed along the length of the cable. These imperfections cause signal distortion and/or micro-reflections. SRL can be caused by manufacturing flaws, installation damage, or by some other means of cable disturbance or degradation.

A TDR is generally used to locate "point" problems rather than "distributed" problems which cause SRL. Therefore, if you want to use a TDR for checking SRL, it can be used as a quick, cursory check or evaluation of SRL and not for absolute SRL measurements. For true SRL measurements, a sweep generator should be used.

Structural return loss can be viewed on a TDR by looking at the base line of the waveform. A perfectly flat baseline indicates a high quality cable with no damage or structural return loss. A bumpy baseline would indicate a low-quality cable, damage, and/or structural return loss.

In order to analyze SRL with a TDR, some basic information must first be determined:

> What is the cable attenuation vs. distance at different frequencies? You can find this either from the cable manufacturer's catalog or from previous application notes.
>
> What is the frequency content of the various pulse widths of the TDR being used? You will find this discussed in the previous application note.
>
> What is an acceptable/unacceptable level of dBRL at specific frequencies for the cable being tested? This is a value determined by your particular application.

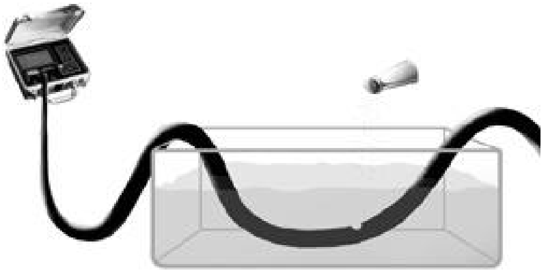
Remember, each pulse width has a specific fundamental frequency and cable attenuation is frequency sensitive. Therefore, identical readings at two different distances can indicate a different severity of cable problem. Cable attenuation, signal frequency, and distance to the fault must all be taken into consideration when analyzing dBRL.

To evaluate the SRL of a cable, first select the shortest pulse width and position the first cursor on the leading edge of the output pulse. To scan the cable in short lengths, zoom-in and increase the vertical gain. Move the second cursor along the baseline of the waveform, noting the distances at which the dBRL number drops below the acceptable value determined by your graph. When the maximum distance at one pulse width has been reached, switch to the next larger pulse width. Inspect the cable at any point where an unacceptable dBRL reading is indicated.

Learning With Realistic Problems

As with any test equipment, it is best to learn about the equipment in a controlled environment by creating faults on the cable while in the work center. A word of caution: make sure the problems are realistic! Physical problems such as opens, shorts, load coils and bridged taps are easy to duplicate. Water soaked cable is harder to duplicate. What does a water problem really look like?

In the real world, when water causes a problem in the cable, it takes place over a long period of time. Also, the water by itself is not the problem. It is the contamination (salt or minerals from the ground and air) that the water is carrying. To simulate wet cable, make a hole in the cable and immerse the cable in water. To simulate contamination from the ground and to speed up the cable deterioration process, add some common table salt to the water. Now, using the TDR, it is possible to see what wet cable really looks like.



Another example of modeling a field problem in the shop or work center is to test across the pair with an Ohmmeter. A reading of less than 100 K Ohms indicates a bad pair. A TDR connected to this pair will usually find the problem. However, if you try to simulate this problem in the shop by simply connecting a 100 K Ohm resistor across a pair, the TDR will not find the 100 K Ohm resistor. Why not?

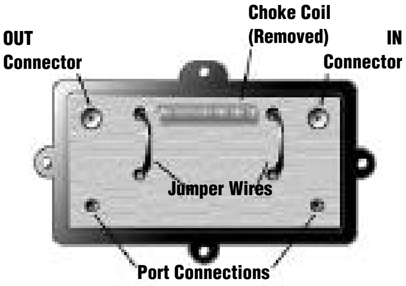
A field pair with low insulation resistance will also have a change in impedance caused by moisture. The Ohmmeter is looking only at the DC resistance; the TDR is looking at the AC cable impedance. The total cable impedance includes the resistance, the capacitance, and the inductance. Simulating the fault with just a resistor is not simulating the true fault. It is an unfair and unrealistic simulation. When simulating a field problem, make certain the true problem (or model) is simulated properly.

It is wise to do some testing in the shop with some known faults before going into the field and having to interpret the information under pressure. As with any equipment, familiarity and experience will build confidence in yourself and the test equipment.

CATV APPLICATIONS

Try A Tap Plate Connector

It can be tiresome breaking down installed taps and installing an adapter in order to test the cable with a TDR. A solution is to modify a tap plate of the same type in your system to connect the TDR to each leg of the cable. The modified tap plate can be installed instead of the original tap plate to gain quick and easy access to the cable.



Remove the circuit board from a two port tap. Desolder and remove all the components from the circuit board. Next, make two wire jumpers which connect the input and output ports to housing connectors at the respective tap ports on the plate. Connect the input connector to one tap port and the output connector to the other tap port. This makes the two tap ports independent from each other and used to test in either direction from the tap.

To find a location for the wire jumper, look for a coil connection from the IN to the OUT port which passes any power signal on the cable through the tap. Solder one end of a wire jumper to one side of the removed coil location. To connect the jumper to the tap port, look for a hole in the circuit board that is connected to the tap port center conductor. Solder the other end of the jumper. Do this for both tap ports.

Use an Ohmmeter to check for continuity when trying to locate which holes in the board to use, and to check to see if the plate is properly wired.

Remove the existing faceplate of the tap, either overhead or underground, and replace it with the modified tap plate. Connect the lead from the TDR to the input tap port and test the cable back to the upstream tap. Alternatively, connect the lead to the output tap port and read to the downstream tap. Removing faceplates is a lot easier and quicker than working with connectors.

Warning: **Make sure you do not test cable with AC on the line.**

Save Time Down The Road - Create A Reference Guide

When installing new cable plant, ideally a company will map their system. Using a waveform TDR and either storing or printing the TDR reading, they can document and archive each new build and add it to their plant map or existing database. This can provide specific information regarding the cable plant and its condition for future references. This information can be used for reference and comparison if and when problems occur.

Stop Theft of Service With Your TDR

A TDR is an excellent tool to determine if a device, such as a television, VCR or Converter, is connected to the end of a drop cable inside a residence. A TDR test of a cable with an open end has a very defined signature (waveform), which is easily recognizable. A waveform with an open end (upward reflection) simply indicates there are no devices connected and, most likely, no provable theft of service.

To determine theft of service, the following guidelines are recommended:

1. Once an illegal tap is located, the technician will disconnect it from service, document the time and date and possibly confiscate the coaxial cable.
2. Test and store the line connected to the house with the TDR every time you see an illegal tap. For safety reasons, it is usually necessary to test the cable and store the information as quickly as possible. Once connected, SUPER-STORE allows the technician to store the waveform in different settings in a matter of seconds. Later, the information can be recalled and adjusted as if the TDR were still connected to the cable under test. When testing into multiple unit dwellings, it is a good idea to use at least two different pulse widths: the smallest pulse width available and another to give you more distance.
3. Leave a note on the customer’s door explaining what was found and how they can call to get service installed.
4. If the problem repeats itself, it may be necessary to inform the customer that legal action may be taken if the problem persists.
5. Documentation may include photographs, affidavits, and any evidence found on the scene (i.e. homemade connections and waveforms from a TDR).
6. If a cable is illegally connected and running directly to a dwelling, that resident may still claim they had no knowledge and was not using the service. Many systems have found that if they can prove that the

cable is connected to a device inside the residence, they can prove it is being used.

7. Storing the waveform into the TDR allows the technician to gather evidence for that particular line. The waveform will show if the cable has been connected to a device or not. If it is connected to a television, VCR or cable box, it will display a lowering of impedance characteristic, or downward reflection. If the cable is not connected to a device and just lying on the ground, it will be displayed on the screen as a complete open or upward reflection.
8. All stored waveforms can be uploaded to WAVE-VIEW for Windows software. It provides the same flexibility as the SUPER-STORE feature. Not only can you adjust the waveform as if the TDR were still connected, you can print or e-mail the results and use them as evidence.

CATV Case Studies

The following applications are real life examples from Riser Bond Instruments' customers.

The Missing Signal

Sometimes, a perfectly good cable goes bad for no apparent reason. Take the case of the missing signal. A local church broadcasts services on cable. One Sunday, the church called to report their signal was not getting out. After verifying the problem was not within the transmitting equipment, the cable was then checked.

A 2,100 foot (640 m) cable ties the church into the cable system. Checking from the church out, the TDR indicated an open at 2,000 feet. Checking from the other end back toward the church, the TDR indicated an open at 108 feet (33 m). With the aid of a measuring wheel, the problem was quickly found; a new school-crossing sign placed along the road the week before had been driven right through the cable. The time to repair was less than 30 minutes.

The Splice Of Life

Within many systems, there are many cable splices in the ground. Many are old and their locations are unknown. With every splice, it is just a matter of time before they can go bad. Customers started calling one afternoon to report that their televisions were snowy. The technician tested the cable and found a 300 foot (91 m) length of distribution cable had 24 dB of excessive loss. With the aid of a TDR, a corroded underground splice was easily located and repaired.

Whose Cable Is This?

A construction crew was burying new cable. Each pedestal had at least two cables in it, with some having as many as five. The crew placed the pedestal, buried the cable, and cut it off in the pedestal. They were not consistent or accurate about identifying and marking the various cables. With the aid of a TDR and the plant map which showed cable lengths between each pedestal, the cable technician was able to identify the various cables by their length. The time it took to identify and activate the cable was decreased significantly by using a TDR.

TDRs Excel At "Snow" Removal

Customers started calling, complaining of snowy reception on their cable. But, when the technician went out on the service call, everything checked out fine, including the reception. Several hours later, the calls started again and the process started over.

After several hours of this cycle, it was discovered that every time the wind gusted, a nearby tree's roots moved just enough to cause the buried cable to move, thus creating a short. With the aid of a TDR in the Intermittent Fault Detection (IFD) mode, the problem was located and easily fixed.

TELEPHONE APPLICATIONS

Use Your TDR To Find The Water

A large percentage of twisted pair problems fall in the moisture-in-the-cable category. How to locate the problem, why one pair may be affected but not another, and how much of the cable is affected are all problems you have to address.

A TDR will find water in the cable. It is displayed as a decrease in the cable impedance. Most times, it is difficult to accurately determine the length of the water problem. In filled cable, moisture cannot migrate inside the cable, so it is always a point problem. In air-core or pulp cable, moisture can migrate anywhere along the cable.

By testing the cable from both ends and recording the distance to fault in all pairs, it is possible to determine how much cable is wet.

When testing through water, measurements up to the water are very accurate. After the water, distance readings may be erroneous due to a change in the VOP caused by the water. Even though the moisture may be 20 to 30 feet (6 to 9 m) wide, each pair usually becomes penetrated at different points. The range of these points will indicate the length of the problem.

Water can seep into the conductors through pinholes in the plastic insulator around the conductors. Water in a multi-paired, air-core cable may be several feet wide. When testing each pair, the distance to the problem may read different for each pair. This is because the water has penetrated through the conductor insulation at different points and shorted out the conductors at different distances.

The location and the length of the water damage is now known, but it is still necessary to locate where the water actually entered the cable. The break in the sheath will not necessarily be within the span of where the water is and might not show up in the testing. If the break in the sheath is not fixed, the problem will show up again in the future.

If the hole in the sheath is at a high point in the cable, the water will enter through the hole then migrate to a lower point. If the water entry point is not found, it may be necessary to visually inspect the cable. It is also necessary to check the integrity of the sheath.

Learn to Correctly Identify Bridged Taps

A bridged tap is a component within a telephone system that can be one of the easiest to locate with a TDR, but it is also the most misidentified. The definition of a bridged tap itself can often times cause confusion. Some people refer to a bridged tap as the lateral that extends off of a main cable circuit. However, the true definition of a bridged tap is the point on the cable where a lateral connects to the main cable. A bridged tap is not a section of cable.

Therefore, we will refer to the point of connection of the lateral to the main cable as the bridged tap. The cable extending from the bridged tap to the subscriber will be referred to as the lateral.

Figure 1 is a common waveform which results from testing a section of cable with a bridged tap. A lateral extends to the subscriber.

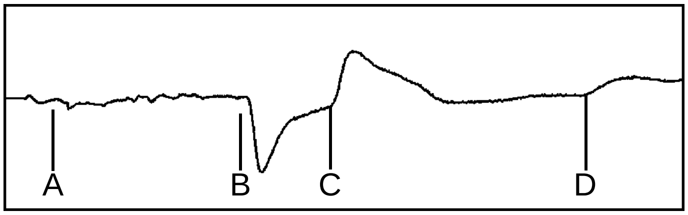


Figure 1

Referring to Figure 1, you might assume the following:
Point A: The TDR's pulse from the point of connection
Point B: (Downward reflection) The point of a bridged tap on the main cable
Point C: The end of the lateral
Point D: The end of the main cable circuit

The waveform shown in Figure 1 and the conclusions that were made could be correct. However, Figure 1 could also be the result of a somewhat different cable layout.

A common mistake that is made when testing through bridged taps is to misidentify the end of the lateral for the end of the main cable circuit. As shown below, Figures 1a and 1b show two slightly different cable plant layouts. However, notice that the resulting waveforms are identical.

LESSON: DO NOT ASSUME THE FIRST UPWARD REFLECTION AFTER A BRIDGED TAP IS ALWAYS THE END OF THE LATERAL; IT MAY BE THE END OF THE CABLE.

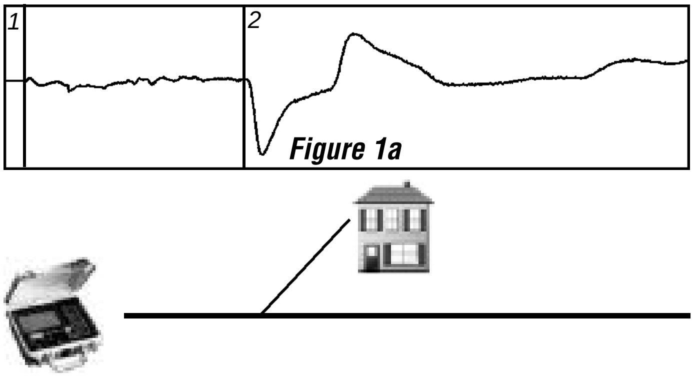


Figure 1a

It is always a good idea to refer to plant maps whenever possible to help minimize confusion or errors when testing cable plant, especially when testing through bridged taps. Remember, a TDR will test through a bridged tap and display a waveform interpretation of the cable under test, including any bridged taps and their corresponding laterals. A lot of information is displayed in the waveform. Therefore, a thorough study of the waveform and correct cursor placement becomes very important.

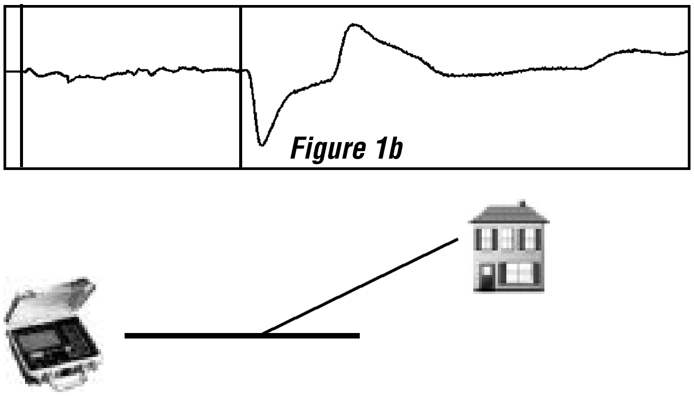
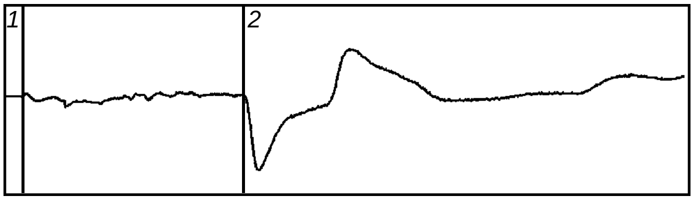
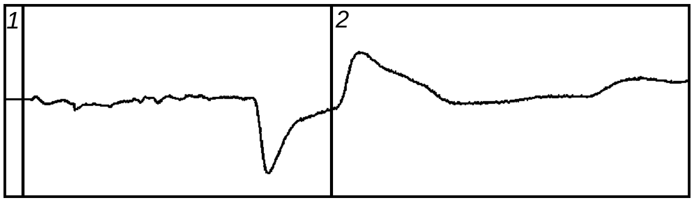


Figure 1b

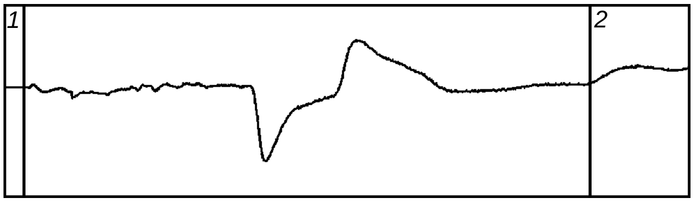
In the following examples, we will use the cable layout as shown in Figure 1a where the first downward reflection is the bridged tap, the next upward reflection is the end of the lateral, and the last upward reflection is the end of the main cable circuit.



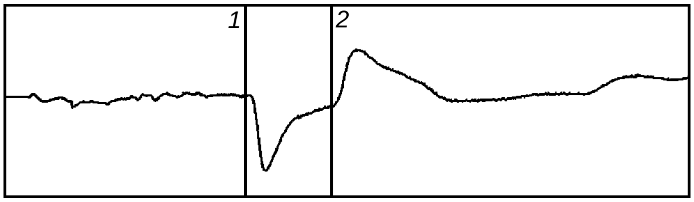
The distance between the two cursors is the distance from the TDR to the point of the bridged tap.



The distance between the two cursors is the distance from the TDR to the end of the lateral.



The distance between the two cursors is the distance from the TDR to the end of the main cable. There is no need to subtract the length of the lateral. This is an advantage of a TDR over an open locator.



The distance between the two cursors is the length of the lateral.

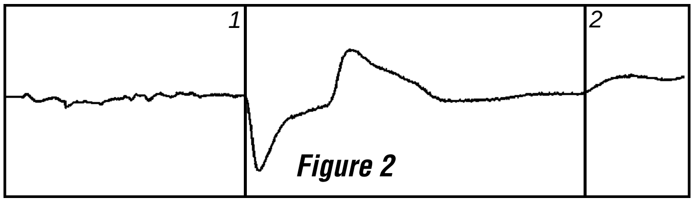


Figure 2

The distance between the two cursors is the distance from the bridged tap to the end of the main cable in Figure 2.

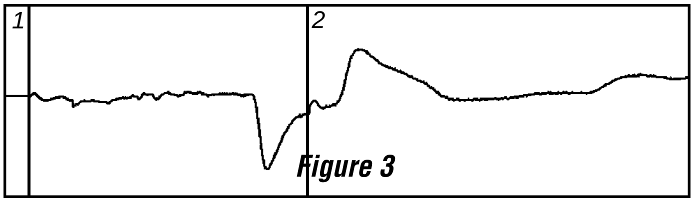


Figure 3

When testing through a bridged tap, it can be difficult to determine if the reflection caused by a fault is located in the lateral or in the main cable section beyond the bridged tap point, as illustrated in Figure 3. (Compare to Figure 1a)

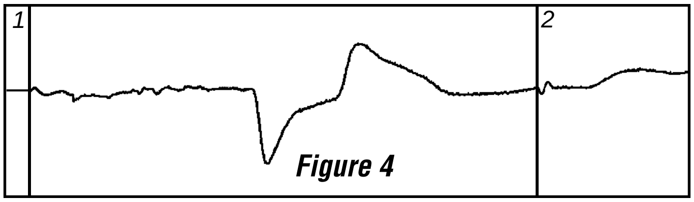


Figure 4

Figure 4 is a waveform from the cable plant layout in Figure 1a. The reflection caused by a fault is obviously located in the main cable beyond the point of the bridged tap and not the lateral. It is always a good idea to go to the bridged tap point and test both the lateral and the main cable beyond the point of bridged tap.

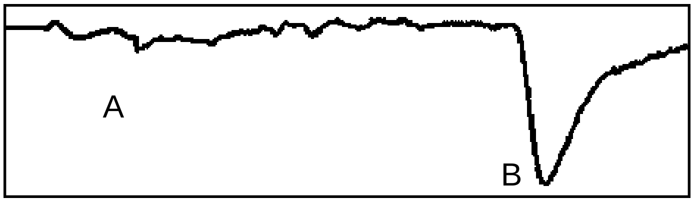


Figure 5

In Figure 5, there appears to be a short at Point B on the waveform. However, the waveform shown in Figure 5 is actually the same waveform shown in Figure 6. The only difference is the operator has used the zoom function to show only the cable section from points A to B. The amount of cable shown on the display is not enough to see the end of the lateral.

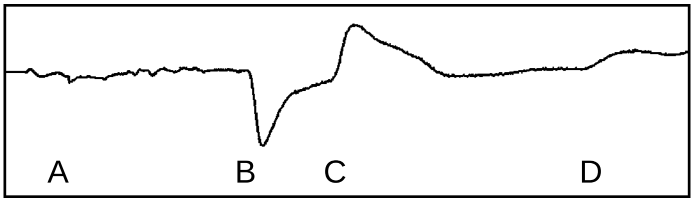


Figure 6

Remember, when testing with a TDR, always start the test in the shortest pulse width or range possible. Continue to increase the pulse width or range until the entire waveform has been viewed. This procedure will ensure that no faults are accidentally missed or misinterpreted.

Ghost reflections can appear when testing through bridged taps. Referring to Figure 7a, it appears as though there is a partial open at Point E. This cannot be true as the cable physically ends at Point D. Referring to the cable plant layout in Figure 7b, the ghost is caused when the signal returning from Point D passes Point B. The signal splits, some energy returning straight to the TDR (Point D) and some energy traveling down the lateral, reflecting from the end and returning to the TDR (Point E) after the reflection of the end of the cable.

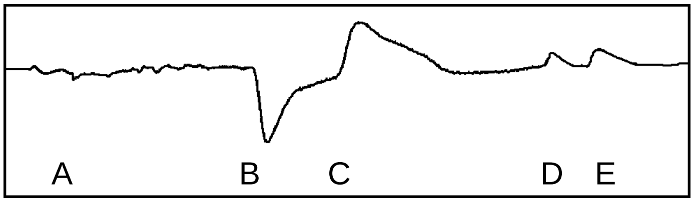


Figure 7A

A good clue that a reflection is actually a ghost from a bridged tap, is that the distance from the end of the cable to the ghost is the same length as the lateral itself (the distance from Points D to E in Figure 7a is the same as Points B to C in Figure 7a). A way to test whether or not Point E is a ghost is to have someone short the end of the cable. If Point D reflects downward along with Point E when the cable is shorted, then Point E is a ghost reflection of the bridged tap.

Remember, when testing through bridged taps, the signal strength is cut in half. Because you can see through a bridged tap, a lateral provides a second path for the signal to take. Point B in Figure 7b is where the signal splits. Because the signal splits, the maximum distance readability of the signal is cut in half from that point outward. If you can normally see 6,000 feet (1830 m) in a pulse width or range in Figure 7b, you may only be able to see 3,000 feet (915 m) beyond Point B due to the bridged tap.

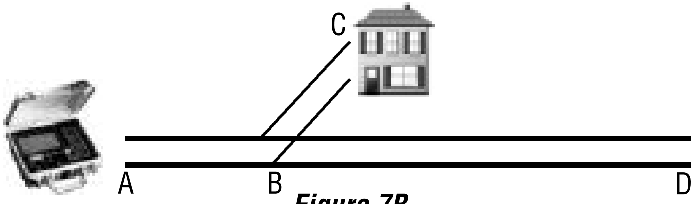
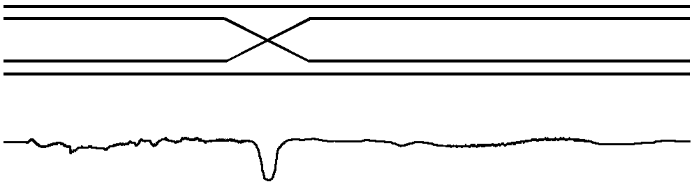


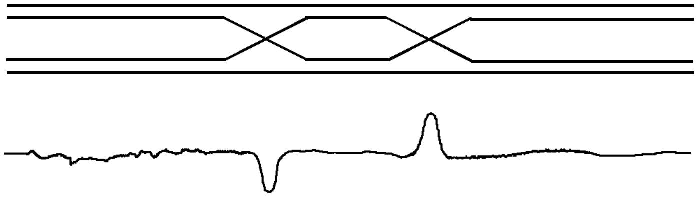
Figure 7B

Easily Locating Splits and Resplits

A split or re-split pair is when one of the conductors from two different pairs are switched somewhere along the cable length. A TDR used in the traditional mode of simply looking for the impedance discontinuity can, many times, find this split. The problem with the traditional method is the discontinuity is relatively small and, therefore, the TDR's reflection will be small. If the split is close, it can be identified. If, on the other hand, the split is some distance away, the small reflection is attenuated by cable length and the split can be difficult to locate. Using Riser Bond's exclusive Crosstalk mode greatly enhances the reflection and makes finding splits that are far away much easier to find.

This is an example of a split and split/re-split and their corresponding TDR waveforms using the Crosstalk mode.





Connect one pair of the split pair to Line 1 and the other pair of the split pair to Line 2. Set the TDR to display Line 1 and adjust the 1st cursor to the "0" distance marker. Cycle the instrument to the Crosstalk display mode. The crosstalk mode transmits the TDR pulse on Line 1 and receives on Line 2. If any energy is coupled from pair 1 to pair 2 (split or re-splits), it will return to the instrument and be displayed on the waveform trace. Use the Range, horizontal zoom, waveform position and vertical gain keys to find the discontinuity. Set the 2nd cursor to this point. Now you have found the locations of the split and re-splits.

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Upgrading Cable Plants For High Speed Digital Services

There are two components found in outside plants that can affect service while upgrading for digital circuits such as ISDN, HDSL, and ADSL. These components are bridged taps (or laterals), and load coils. Removing bridged taps and load coils is necessary for upgrading, so finding them becomes a challenge.

Locating And Removing Laterals

With the main circuit being the primary path for a digital signal, a lateral creates a second path. Laterals are normally short in length. The digital signal travels down the lateral and is reflected by the open end back toward the main circuit. This signal is mixed with “good” digital signals. The reflected signal renders the data relatively useless. The result is the digital circuit crashes. For a digital circuit to operate properly, the laterals must be removed. A TDR is the most useful tool for identifying the presence and length of a lateral in a circuit.

It may be difficult to identify the open at the end of the lateral, but you should not need to know where the end of the lateral is, only the location of the bridged tap. The end of the cable may not be clearly defined because some of the TDR’s pulse energy will be lost going through the tap and lateral.

A bridged tap on a TDR will look similar to a short, or downward reflection. Keep in mind that the TDR does not distinguish between the lateral and the continuing length of cable. After finding and removing a lateral, make sure you retest the cable for any laterals that may have been missed.

Locating And Removing Load Coils

Next, find all of the load coils in the system because loaded analog systems and digital systems such as ISDN and ADSL are not compatible. Identifying a load coil from what appears to be an open at the end of the cable may not be easy unless you know exactly what you are looking for.

There are two basic rules in identifying a load coil from an open. First, a load coil generally displays a more rounded appearance than an open. Second, load coil spacing is very particular - at 3,000 feet (915 m) or 6,000 feet (1830 m) intervals, depending on the location in the section. While not all load coils look the same, if you see an open-like reflection on the waveform at approximately 6,000 feet (1830 m) from the TDR, suspect a load coil.

Remember that because not every TDR’s signal can pass through a load coil, the first load coil is all that you will see. Once you have found the first, remove it and retest the cable.

Appearance varies on how far away you are from the load coil. If you are less than 500 feet (152 m) from a load coil and using a medium sized pulse width, the load coil may appear as a double open. Normally, a load coil reflection will look like a rounded open reflection. A sure signthat the reflection is a load coil and not an open will be the baseline after the open will be lower than the baseline approaching the open.

Cut Down On Repeat Trouble

One of the more frustrating problems found in outside plant today is “noisy static” repeat trouble. Many times, the customer calls with complaints of sizzling on the line. However, by the time the trouble ticket is received, there is no trouble found. This is because this type of trouble usually comes and goes as does the loop current on the line. When there is no loop current, the fault heals itself. When the customer uses the line again, inducing the loop current, they report the same type of trouble again.

Solid cases of trouble are very easy to locate with the help of a TDR. If the trouble is intermittent, the technician will have a difficult time getting a distance reading with a TDR. Many times, when this type of trouble is located very close to the subscriber end of the line, the trouble is usually a high resistance open (series resistance fault).

Below is a quick and easy guide on how to locate “noisy static” trouble with Riser Bond’s waveform TDRs:

1. Disconnect at the protector on the subscriber end.

2. Confirm the trouble. Connect a butt set, turn the speaker on and listen to the line. Confirm that the trouble you hear (if any) is what the customer reported, and not a separate case of trouble.

3. Turn the butt set to mute and dial a silent termination. This is done to prevent any noise picked up by the microphone of the butt set to be put on the line. It may affect the TDR waveform.

4. Connect the TDR. Connect the test probe leads to the pair under test. Continue to keep the butt set connected to the pair with the silent termination.

5. Switch on the TDR by touching the POWER key.

6. Initiate the IFD mode.

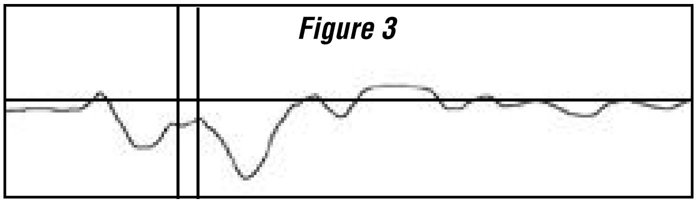
7. Wait for the fault to occur. With the loop current on-line, the trouble will normally appear within 5 to 10 minutes. Adjustment of the waveform on the screen, either vertically or horizontally, will not affect the test.

Toughest Faults To Find May Be Closest

A fault located at the pedestal or pillar, very close to the instrument, is a common problem. In order to make the test an easy process, it is important to utilize the dual independent cursors. Move the waveform to the center of the screen and zoom in on the first 32 feet (10 meters) of cable. Short the test leads together and place the first cursor at the end of the leads. Carefully note the exact location of the end of the alligator clips. Connect to the cable under test. Examine the area of the waveform right after the alligator clips connection for faults.

Utilizing this technique, a short circuit was located very close to the TDR. In Figure 3, the first cursor was placed at the end of the leads and the second cursor was placed at the point of the fault, a short circuit 0.5 feet (.14 m) into the pedestal.

Figure 3



Telephone Case Studies

Keep Customers Connected to the Web

A customer called in reporting trouble with his Internet connection. A technician was sent to solve the problem. Starting at the exchange, the technician analyzed the cable with the Model 1205TX, a TDR designed specifically to test through load coils, and found no obvious problems. He then tested the internal wiring in the customer's home.

In Figure 1, the first cursor is placed at the alligator clips connection to the cable under test and the second cursor is placed at the reflection of the telephone, 43 feet (13m) away.

The telephone was unplugged and the technician tested again. Figure 2 shows the waveform with the telephone disconnected. The technician now noticed a small downward reflection 6 feet (2m) from the instrument. Suspecting a bridged tap, the cable was visually inspected. The technician found a homemade tap wired into the cable just inside the house. Once the tap was removed and the cable repaired, the problems connecting the Internet disappeared.

Figure 1

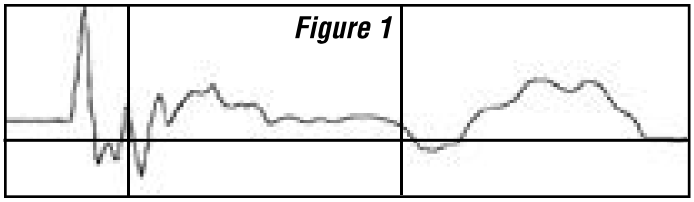
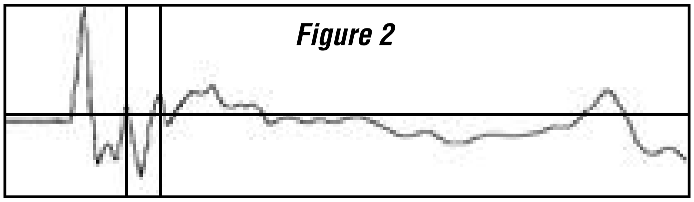


Figure 2



The Repeat Trouble Ticket

The technician began testing the line with the Model 1205TX. Starting in the central office, he connected to the main distribution frame. Next, he tested the loaded line, through all the load coils, out to the customer's house.

A rural telephone subscriber complained of a noisy telephone connection. The line was a lengthy, loaded cable. The lineman spent a lot of time trying the usual tests to find the customer's problem. Finally, in the interest of saving time, he switched the customer to an unused quieter pair. This solved the problem for a few months.The customer called again to report the same problem. When the technician went back and retested the pairs, he found the original pair was now quieter.

Noisy pairs going quiet and quiet pairs becoming noisy led to the suspicion of water in the cable. Since it had been a wet winter, it made sense that water could be causing the problem. The plant records showed the cable was not spliced, so it was unknown how and where water could be getting into the cable.

The technician began testing the line with the Model

1205TX. Starting in the central office, he connected to the main distribution frame. Next, he tested the loaded line, through all the load coils, out to the customer's house. A traditional TDR would only have tested out 3,000 feet (914 m) to the first load coil. The technician would have driven to the point where the first load coil was connected, unhooked it and retested to the next load coil. This process would have to be repeated at each load coil until the section containing the fault was located. The old process worked, but it was inefficient, complicated, and time consuming.

After doing the test from the central office, the full length of cable was visible on the TDR. The problem was located in between the fourth and fifth load coil. It appeared to be an undocumented splice. In order to pinpoint the exact location, the technician only had to do one more test. He drove out to the point of the fourth load coil and tested just that section of cable, using the unloaded testing mode of the TDR. Sure enough, there was a splice midway through this section, and a reflection that indicated a bad splice.

After digging up the splice, the technician found it was totally saturated with water. The cable was re-spliced and the lines were quiet again. The customer was happy and the repeat problem was fixed.

BROADCAST APPLICATIONS

Broadcast Transmission Line Bullets

A waveform TDR designed for coaxial cable testing is a good preventive maintenance tool for broadcast tower transmission lines.

A high power broadcast transmission line that is made of rigid elements bolted together needs periodic maintenance. The point where the sections are bolted together wears and deteriorates with time. The hollow center conductors are spliced together with a small solid copper section, commonly known as a bullet.

As the transmission line warms and cools from day to night and from summer to winter, the sections expand and contract. This expansion and contraction causes the hollow center conductor to rub and wear against the solid connection sleeve. This wearing can generate small filings that will drop onto the nylon spacer directly below the connection. Eventually, these filings will create an RF power path to the transmission cable sleeve and ground.

This path to ground will cause a momentary short to ground and momentary loss of output power. A waveform TDR can monitor deterioration and help the tower maintenance crews to identify any faulty bullets. When compared to the trauma of an instantaneous outage, the cost of refurbishing a bad bullet is low. The TDR is instrumental in the location and evaluation of transmission line bullet connectors.

No Match For A TDR

Engineers that work with transmitters, transmission lines and antennas are familiar with Standing Wave Ratio (SWR or VSWR). SWR is caused by an impedance mismatch. In the transmitter/transmission line/antenna system, the mismatch usually takes place at the transmission line/antenna connection. Usually the mismatch is caused by an antenna that is not tuned to the frequency of the outgoing signal. The mismatch can also be caused by other problems such as bad cable, moisture in the cable, or bad connections.

Other transmission line technicians, such as cable TV technicians, are more familiar with the term Return Loss, or dBRL. There is a definite relationship between SWR and dBRL. Both SWR and dBRL should be read at the point of the mismatch. But, in reality, they both tend to be read at the most convenient point, usually the point of the transmitter. The error in the measurement is the cable loss. An additional error in the SWR reading is the actual phase of the voltage with respect to where the meter is actually placed.

SWR is a passive reading using the transmitted signal as the signal source. This is because an SWR meter can always stay on the line. Monitoring the reflected signal and the transmitted signal is the most accurate example of a signal that creates the SWR. The dBRL is normally measured using its own signal source.

SWR is usually thought of as a narrow band frequency problem and dBRL as a broadband problem. SWR is thought of in terms of the mismatch between the transmitted signal frequency and the antenna frequency. If the transmission line goes bad from moisture in the cable, the SWR will increase and the engineer's first reaction is that the antenna has gone bad.

$\mathrm{SWR} = (V_O + V_R)/(V_O - V_R)$
$\mathrm{dBRL} = 20\ \mathrm{LOG}_{10}\ (V_O/V_R)$
Where V_O is the voltage of the outgoing signal,
V_R is the voltage of the reflected signal.

For SWR, a value of one means a perfect impedance match. An SWR value of infinity means a total mismatch, such as a complete open or dead short. For return loss, a value of infinity is a perfect match and a value of zero is a total mismatch, such as a complete open or dead short.

The following tables show the SWR and return loss for the span of all possible mismatches. NOTE: The first line is a perfect match, the last line is a complete open or dead short.

V_O	V_R	SWR	dBRL
1	0.00	1.00	infinite
1	0.02	1.04	34
1	0.05	1.11	26
1	0.07	1.15	23
1	0.10	1.22	20
1	0.20	1.20	14
1	0.30	1.86	10

V_O	V_R	SWR	dBRL
1	0.40	2.33	8
1	0.50	3.00	6
1	0.60	4.00	4
1	0.70	5.67	3
1	0.80	9.00	2
1	0.90	19.00	1
1	1.00	infinite	0

CELLULAR

The TDR can be a very useful tool when turning on a new cell site. Within a single cell there may be as many as six antenna cables with multiple transmit antenna cables and multiple receive antenna cables.

Generally, cables are not labeled, making identification difficult. Installers are usually more intent on safely making all the right mechanical connections, rather than making sure the cables are connected to the proper antennas. On the other hand, the site operator is very concerned with matching cables to antennas.

A waveform TDR can easily distinguish between receiver antenna cables and transmitter antenna cables. With the noise filter turned off, connect the TDR to the transmission cable with an antenna in place, zoom-in and study the waveform. A very noisy waveform will be seen. The RF signal from the antenna will show up on the TDR baseline as noise. A relatively high gain antenna, such as the receive antenna, will have more signal amplitude than a relatively low gain transmit antenna. This difference in amplitude allows distinction between receive antennas and transmit antennas and ensures they are not mislabeled or switched.

If it is necessary to see the actual waveform of the cable being tested even with the antenna connected, simply turn the instrument on and step through the TDR's noise filters. The TDR's noise filters will remove most of the RF signal even in a relatively high RF energy level environment.

2-WAY RADIO APPLICATIONS

Many 2-way radio companies provide communications service for clients in radio and television, local, state and federal government agencies, fire departments, small businesses, and individuals.

2-Way Radio Case Study

A 2-way radio company had a 900 foot (274 m) tower containing two 1 5/8" (4.13 cm) cables, two 7/8" (2.22 cm) cables, and a commercial radio station's 3 1/8" (7.94 cm) cable. The company was receiving complaints from customers who were connected to one of the 1 5/8" (4.13 cm) cables. They were reporting noisy and intermittent signals.

A tower climber inspected the entire length of the cable, the antenna connections and the antenna. Believing the cable itself might be the culprit, the climber paid particular attention to it. His visual inspection indicated no apparent damage.

A spring rainstorm further deteriorated the signal, which brought more customers complaints.

A lower-cost, non-waveform, digital, numeric TDR was connected to the transmission line. In the least sensitive mode, the TDR read the full length of the cable, indicating no major breaks or discontinuities. Increasing the sensitivity, the instrument indicated an open at 27 feet (8.2 m); the distance to the drip loop at the base of the tower. Inspection of the cable for several feet around the drip loop resulted in no obvious damage.

A small hole was drilled in the cable at the base of the drip loop and a steady stream of water from the cable yielded almost two gallons (7.5 l). The cable was cut open at the drip loop exposing the fact that the hollow center conductor had been split out. Water had entered the hollow center conductor, traveled down the cable, froze in the drip loop, and split out the center conductor.

A view of the cable was gained by looking at the TDR's waveform with an oscilloscope connected to the digital, numeric TDR. A very small fault was found in the cable at 150 feet (46 m). Climbing the tower to this point, the technician found a small hole in the cable. The original tower climber had missed the 150 foot point damage because a tower painter had seen the damage and put electrical tape around it thinking that would fix any problems. The water was running down the cable, under the tape, and into the hollow center conductor.

Water in the cable was absorbing almost all of the RF signal resulting in poor operation. Both the hole and the split center conductor were repaired and the cable was placed back into operation.

POWER APPLICATIONS

Safely Dealing With High Voltage Power Cable

Working with high voltage power cable can be dangerous and even fatal. Exercise extreme caution. Be sure that all power is removed from the cable before testing.

Working with high voltage power cable presents two major challenges when finding faults: correct VOP and a quality connection. High voltage power cable is seldom required to carry high frequency signals; therefore, VOP is not required to be specified. The VOP between two power conductors and the VOP between conductor and concentric neutral may be different. Therefore, determine VOP using the techniques that are outlined in the section titled "Using Your TDR to Determine VOP."

Obtaining a quality connection can be difficult, because the conductors of power cable tend to be very large. Making a good connection requires the technician to pay close attention to detail. It is best to keep the conductors as close together as possible to ensure a quality test. Ingenuity can also help in obtaining a quality connection.

Power conductors can be tested two different ways: one power conductor against another (3-phase concept) or power conductor and concentric neutral. The latter technique allows the testing of the quality and integrity of the concentric neutral.

Why You Need A Riser Bond TDR

A great deal of time and energy can be saved by testing high voltage power cable with a TDR over the more traditional high voltage breakdown test sets. The breakdown test sets are time consuming, expensive, can damage the cable plant and can be dangerous for the operator. Many times, simply testing with a TDR will find most faults on power cable. The TDR is a simple, fast and inexpensive way for finding many faults.

Low Voltage Network Can Be Complex

In many countries, the 220 VAC residential power distribution system consists of a central local substation transformer which distributes power via three phase cables. A service connection is hard wired into the feed cable as a tee joint which is fed to each consumer. The number of consumers supplied from a particular substation depends on system design and could be as few as ten and as many as several hundred consumers.

To apply the TDR to the low voltage network, the user must be aware of the network they are testing. The tee joints on this type of power network increase the complexity of the waveform trace. The service connection tee joints reflect and split the TDR pulse. The net effect is a complex TDR waveform trace and attenuation that reduces the testable length. The TDR can be useful on the low voltage network, but the user must be wary.

Get Closer To A Fault - Isolate It

Isolating a fault to a section or particular run of cable will prove valuable by allowing the operator to get closer to the fault. Although the TDR traces produced by the low voltage network are complex, a short or open circuit can be easily visible if the TDR is connected close to the fault.

Be aware of how the fault manifests itself and make logical conclusions based on this information. If a group of customers are off-supply after a certain point, it suggests a break in the cable. Testing from a point close to the break will yield better results because of the potential for a more conclusive trace.

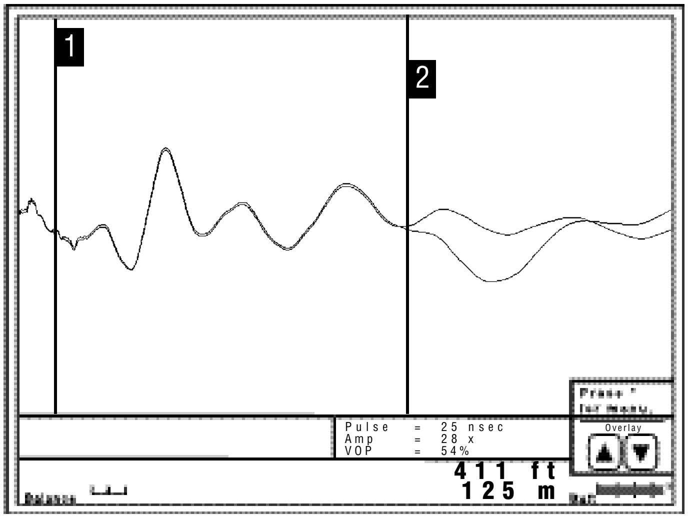
Coping With Old Cable

In many places around the world, there is an increasing number of low voltage faults due to the widespread use of concentric neutral, solid aluminum conductor cable which was installed in the 1970s and 1980s. This type of cable is susceptible to faults due to the fact that only minor damage to the outer PVC insulation allows moisture to enter the cable and cause rapid degradation to the aluminum neutral.

The Model 1000P, a digital, numeric TDR, was recently used on a low voltage burn-off where a number of business customers were completely without supply. The cable was three phase, and the only access points were at the customer cutouts. The problem was further complicated as the electric company's headquarters were only a few hundred yards away. All three phases were open circuit. When the Model 1000P was connected at the various customer cutouts between the end of the cable and the fault position, the unit consis-tently and simply indicated the correct position of the open circuit.

Locating Faults On Complex Networks

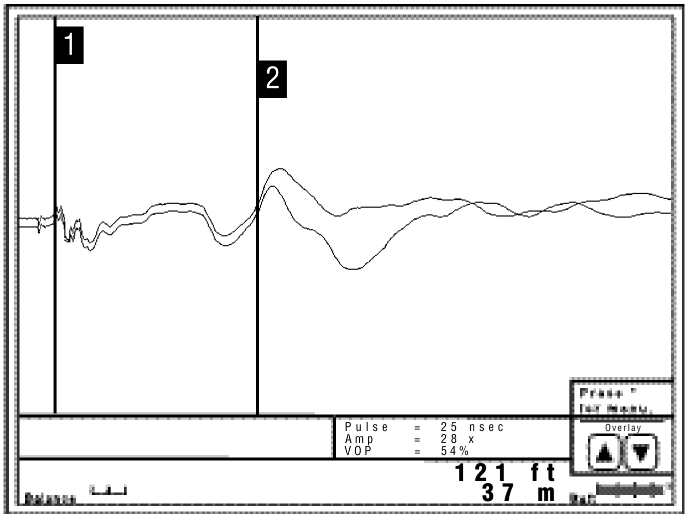
The best methods for fault locating on a complex network involve a "before and after" or "good vs. bad" comparison. A healthy TDR trace produced by the complex network shows many reflections caused by the service connection taps and the ends of these cables. Even a gross fault down the network will be masked by the other features of the network. In many cases, comparison and differential techniques are the only option.



Pulse = 25 nsec
Amp = 28 x
VOP = 54%
411 ft
125 m

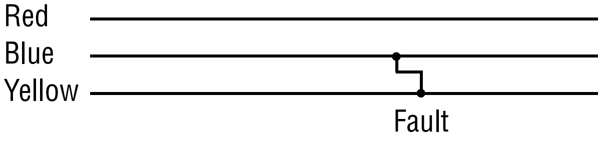
A good practice is to store a TDR waveform trace at the beginning of the troubleshooting process for a particular fault. This creates a reference to compare subsequent traces, after the fault has been modified by actions such as replacing fuses, or installing a fault re-energization device. Once the fault has changed characteristics, before and after traces are compared either by displaying both traces simultaneously on screen or in a difference mode. The point of significant difference on the trace is most likely the fault location.

Although not quite as definitive as a before and after trace in which the fault has changed because of an action, comparison to a healthy phase can also indicate a fault location. Again, the process is to store a healthy trace of another phase in the cable as a reference in which to compare the faulty trace.



Pulse = 25 nsec
Amp = 28 x
VOP = 54%
121 ft
37 m

A good example is where a short circuit fault is located between blue and yellow phases. The blue phase is chosen arbitrarily as common. A TDR trace is stored between the red and blue phases (good) and compared to a TDR trace between the blue and yellow phase (bad). A point of significant difference is most likely the fault location. With this procedure, keep in mind the two traces will not necessarily be identical as will be the case with a before and after test of the same cable. Differences in service connection joint locations and lengths may add minor different features on the TDR trace which are not the fault.

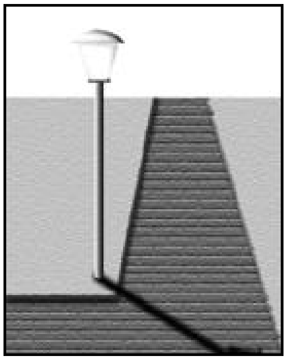


Service Connections Tip

If a fault is suspected in the joint of a service connection because only one customer is off-supply, test from the end of the service cable, rather than some point on the network. The length of the service connection cable is typically short, so the TDR signal does not suffer extreme attenuation of a long length of cable. Also, there are no tee joints on a service connection cable between the feeder cable and the meter to split the pulse energy down multiple paths.

Power Case Studies

Keeping The Lights On



A street lighting cable was causing local residents and the power company concern. The lack of streetlights at night was obviously a potential safety and security hazard. The problem facing the company was that the road had been constructed out of brick paving, which meant the fault must be located accurately to minimize the difficult street repair. The short circuit had been sporadically blowing fuses.

The Model 4200 was attached to one end of the cable and AUTO-SEARCH located the open circuit at the next column. Further use of AUTO-SEARCH indicated a fault approximately midway between the two columns. The Model 4200 was then attached at the opposite end of the cable and the same result confirmed the location of the fault. After originally stating that the company did not need a TDR, the very pleased lighting department contacted Riser Bond Instruments a few days later to confirm that the fault was exactly where the Model 1205T had indicated.

Track Down Illegal Electrical Taps

Illegal taps are a huge problem for many electric companies throughout the world because millions of dollars are lost due to theft of service.

An illegal tap occurs when an individual connects to the power cable before it reaches the meter. When a customer connects before the meter, they bypass the meter that measures power consumption. Normally, the individual will connect their air conditioning, heater, or any other heavy load device to the illegal tap for “free” power.

In the United States, and other similar networks, power is distributed using high voltage lines to the neighborhood. The high voltage is reduced by a transformer near the customer’s home. The smaller low voltage is the 110 Volts that runs most of our appliances. Most homes receive two phases of 110 Volts in order to power larger appliances that run on 220 Volts. These two phases are run with a neutral.

Normally, the drop line will run directly from the transformer to the house. However, the power company may run a feeder cable of 110 Volts to connect a strip of houses or businesses. Either way, the cable runs to a meter box that registers power usage for the billing process. After the meter, the cable runs to a breaker box and then is distributed throughout the subscriber’s home or office.

When looking for an illegal tap, focus on the drop line from the meter to the transformer. In the case of aerial cables, focus only on the section of cable that is not visible. This may be the cable inside the conduit, which can be 1-4 meters (4-12 feet) of cable.

In the case of buried cable, lengths are often much longer; however, the focus is still on the cable running between the meter and the manhole. To steal power, the customer only needs to tap one phase and use the neutral already in the house. However many connect to both, if not all three phases.

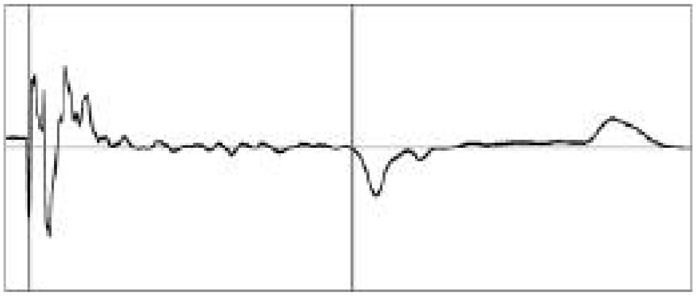
Theft of service often occurs at the meter. It is necessary to pull the meter in order to gain access to the cables. Power to the customers will be disconnected when the meter is removed. However, the lines being tested are still live. Testing should be done as quickly as possible, to restore power to the customer.

Connect the leads to the phases, using the Model 4200 with fused leads, such as Model 40 Mains Blocking Filter with fused lead probes, to protect the operator and instrument. Connect to the phases first because these are the cables that the customer would tap to steal power. Next, test between the neutral on each of the phases. By testing all the cables, one may discover a difference in waveforms that could prove to be a tap. It is important to save each test for comparison analysis. The stored waveform can then be used to document whether or not a tap was discovered. Documentation of a tap is also important because of possible legal problems between the customer and the power company.

If done incorrectly, testing live power cable can be dangerous. Before testing electrical power distribution cables, please consult a Riser Bond Instruments representative or distributor.

Irrigation Examples
Center pivot irrigation equipment is used extensively in the United States and other countries. Pinpointing a fault between phases and/or phase-to-neutral on the power cable can be difficult. Most irrigation power cables are laid in conduit making it difficult to trace the path of the cable. The use of tracer tape, a cable locator, and a TDR can make fault finding much easier. A distance measurement for splices, water, or glassed (oxidized) problems can easily be determined with the use of a TDR.

Following are two actual waveform examples documented with WAVE-VIEW of a splice and glassing (oxidation/open) on Power Irrigation Cable.



Horizontal Gain:	44x
Vertical Gain:	56x
VOP:	58.1%
Distance Between Cursors:	800.87 feet (244.11 m)
Return Loss:	dBRL
Pulse Width:	25 nsec
Impedance:	0 Ohms
Location:	Madison, NE (Elkhorn Power)

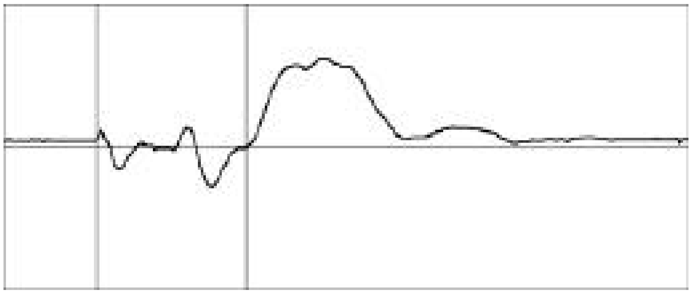
Notes: Phase to neutral from pivot. Suspected splice (sleeve) at 800’ (cable gauge change). End of cable at 1385’.

Horizontal Gain:	384x
Vertical Gain:	44x
VOP:	58.1%
Distance Between Cursors:	9.83 feet (3.0 m)
Return Loss:	dBRL
Pulse Width:	2 nsec
Impedance:	0 Ohms
Location:	Madison, NE (Elkhorn Power)

Notes: Phase to neutral from meter. Phase is open at 9’. Excavated and found the conduit broken, full of water, and the conductor completely glassed (oxidized) creating an OPEN.

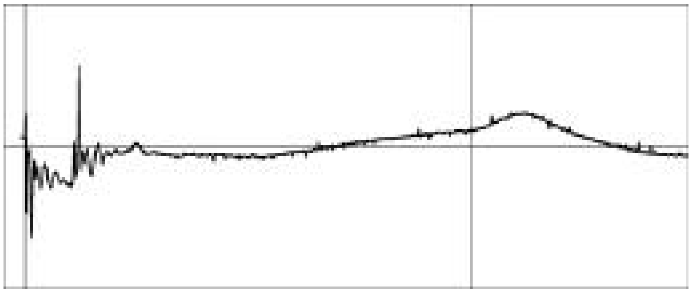
Railroad Examples
Various railway systems use twisted pair cables to operate cross arms and light signals. A TDR and cable locator can help sectionalize a fault within these cables and greatly reduce troubleshooting time. Pinpointing a broken or pinched cable in a fraction of the time it would normally take saves time, money, and possibly lives.

Another unique application with Railroads is to locate disconnects between railroad cars. Railroad car sections can consist of 100 or more cars. Finding a loose connection with a TDR can save time and money by helping to determine an approximate distance to an open (faulted) cable, versus the traditional method of manually inspecting each connection between cars.



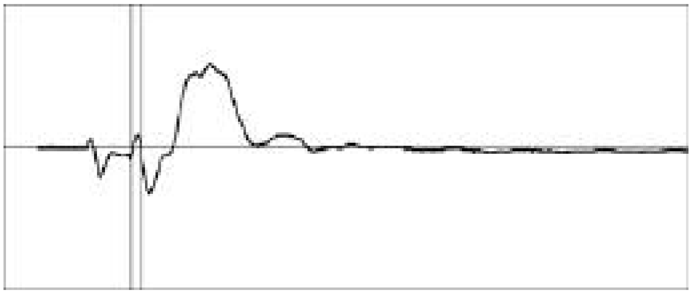
Location: St Joseph, MO
Notes: Testing a new railroad car system (computerized ballast distribution). This waveform example shows a single car with a junction box located mid-span (between cursors) and the end of the cable (end of car approx. 64' long) shown by the second cursor.

Horizontal Gain: 224x
Vertical Gain: 4x
VOP: 51.0%
Distance Between Cursors: 64.43 feet (19.64 m)
Return Loss: dBRL
Pulse Width: 100 nsec
Impedance: 0 Ohms



Location: St Joseph, MO
Notes: Testing through 50 railroad cars. Open at end of run 3080' out. Problem detected with one side open at bad connection point approximately 350' (vertical spike).

Horizontal Gain: 12x
Vertical Gain: 10x
VOP: 44.0%
Distance Between Cursors: 3080 feet (938.8 m)
Return Loss: dBRL
Pulse Width: 1 usec
Impedance: 0 Ohms



Location: St Joseph, MO
Notes: The cursors mark the beginning and end of the controller box in the rail car. Approximately 9' of cable in the box.

Horizontal Gain: 120x
Vertical Gain: 4x
VOP: 51.0%
Distance Between Cursors: 9.83 feet (3.0 m)
Return Loss: dBRL
Pulse Width: 100 nsec
Impedance: 0 Ohms

NOTES

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