RADIODETECTION®

The ABCs of TDRs

Application Note

90/ABC-TDR/01

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SPX®

Types of TDRs

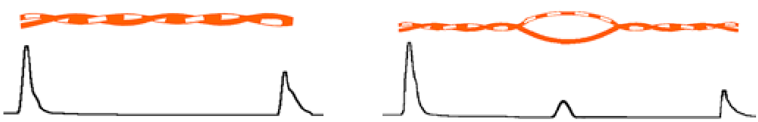
There are two ways a TDR can display the information it receives. The first and more traditional method is to display the actual waveform or "signature" of the cable. The screen displays the outgoing (transmitted) pulse generated by the TDR and any reflections which are caused by impedance changes along the length of the cable.

The second type of display is simply a numeric readout which 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.

Impedance

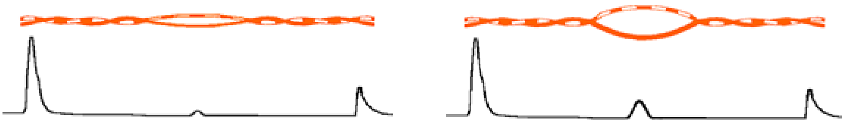
Any time two metallic conductors are placed close together, they form a transmission line which has a characteristic impedance. A TDR looks for a change in impedance which can be caused by a variety of circumstances, including cable damage, water ingress, change in cable type, improper installation, 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 material or insulation that is used to separate the conductors.



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

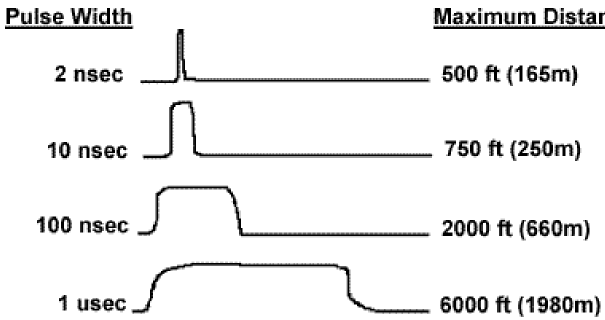
TDR sends electrical pulses down the cable and samples the reflected energy. Any impedance change will cause some energy to reflect back toward the TDR and will be displayed. How much the impedance changes determines the amplitude of the reflection. Matching the impedance of the instrument to that of the cable under test will help reduce unwanted reflections. If the operator forgets to match the impedance, the distance accuracy of the instrument is not affected.



Pulse Widths

The amount of energy sent down the cable can sometimes be controlled by the operator. Many TDRs have selectable pulse width settings which allows the TDR signal to travel down a cable at different levels of energy. The wider the pulse width, the more energy is transmitted, and therefore, the further the signal will travel down the cable. A TDR may contain one or more of the following pulse width settings: 2 nsec, 10 nsec, 100 nsec, 1000 nsec, 2000 nsec and 4000 nsec and 6000 nsec. Some TDRs offer pulse widths outside this typical range of values, a few even generating pulses of less than 1 nsec.

Note: Even when testing very long lengths of cable, always start the fault finding procedure with 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 the fault is not located, switch to the next longer range setting and retest. Then switch to the next larger pulse width and retest. Keep switching to the next longer range, then the next larger pulse, until the fault is located. All reflections will approximately 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 would transmit more energy down the cable, making it easier to see a small fault.

Blind Spots

The pulse generated by the TDR takes a certain amount of time and distance to launch. This distance is known as the blind spot. The length of the blind spot varies depending on the length of the pulse width. The larger the pulse width, the larger the blind spot.

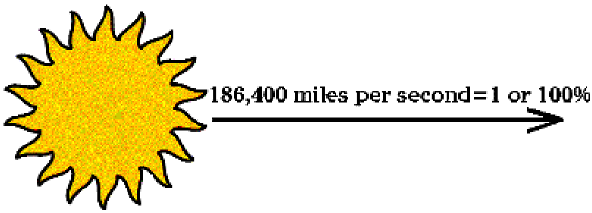
It is more difficult to locate a fault contained within the blind spot. If a fault is suspected within the first few feet of cable, it is advisable to add a length of cable between the TDR and the cable being tested. Any faults that may have been hidden in the blind spot can now easily be located. When adding length of cable to eliminate the blind spot, remember the TDR will also measure the length of the jumper cable. The length of the jumper must be considered in the distance reading. Many of Radiodetection's TDRs have dual cursors, meaning that the length of the jumper can be subtracted by placing the first cursor at the point of connection with the jumper.

Although not critical, it is best if the jumper cable is the same impedance as the cable under test. The quality of the connection is the most important factor regardless of the type of jumper being used. It is important to remember to subtract the length of the jumper from the cable when measuring from the point of connection because the TDR is also reading the length of this jumper. The distances below are based on one cable type, and results will vary.

Pulse width	Typical length of Blind Spot	
	Twisted Pair	**Coaxial**
2 nsec	6 ft / 2m	6 ft / 2m
10 nsec	12ft / 4m	14ft / 4m
100 nsec	50ft / 16m	55ft / 17m
1 usec	400ft / 120m	430ft / 135m
2 usec	630ft / 190m	850ft / 360m
4 usec	1250ft / 380m	1690ft / 515m
6 usec	1850ft / 560m	- / -

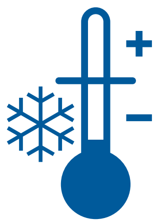
Velocity Of Propagation

The TDR is an extremely accurate instrument, however, variables in the cable itself can cause errors in the distance measurements. One way to minimize error is to use the correct Velocity of Propagation (VOP) of the cable under test. The VOP is a specification of the speed at which a signal travels through the cable. Different cables have different VOPs. Knowing the VOP of a cable is the most important factor when using a TDR for fault finding. By entering the correct VOP, the instrument is calibrated to that particular cable. Typically, the VOP of the cable under test will be listed in the cable manufacturer's catalog or specification sheet.



The speed of light in a vacuum is 186,400 miles per second. This speed is represented by the number 1 (100%). All other signals are slower. A coaxial cable with a VOP of 0.85 would transmit a signal at 85 percent the speed of light. A twisted pair cable, which typically has a lower VOP (such as 0.65), would transmit a signal at 65 percent the speed of light.

Variations in the VOP of the same type of cable are not uncommon. The VOP of a cable can change with temperature, age, and humidity. It can change approximately 1% for every ten degrees centigrade of change from room temperature. It can also vary from one manufacturing run to another. Every new cable can vary as much as ±3%. With this change in the dielectric constant, the VOP changes and therefore the apparent length of the cable also changes. When using a known length of cable to determine VOP, aim to use at least 100 feet (33 m). The longer the test cable the better.



Fortunately, there are ways to minimize error. When trying to pinpoint a fault, the most common technique used to reduce VOP error is to test the faulty cable from both ends. The procedure 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 from one end, and record the distance reading. Then test the cable from the other end and record that distance reading. If the sum of the readings is the exact length of the cable that was measured, the VOP is correct and the fault has been located.

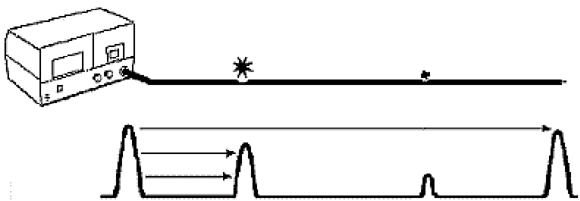
However, if the sum of the readings is more than the measured distance, reduce the VOP setting and retest. If the sum of the two readings is less than the measured distance, increase the VOP setting and re-test. If the two sums add up to less than the known length, the operator must also consider the possibility of two faults. Keep changing the VOP settings until the distance readings total the known length.

The same result can also be obtained mathematically. Take the actual cable length and divide by the sum of the two TDR readings obtained by the tests from each end. This produces an adjustment factor. Next, multiply each of the TDR readings by the adjustment factor. The result will be the corrected length readings.

Locating Multiple Faults

Sometimes a cable contains more than one fault. Multiple faults in a cable 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 an open or short, the TDR may indicate the first fault and other faults further down the cable. In the case of a waveform TDR, the waveform signature of the cable will show most of the discontinuities, both large and small, along the length of the cable.



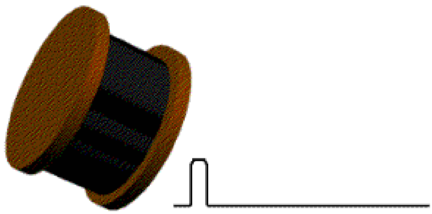
In the case of a digital numeric TDR, only the distance to the first major fault will be indicated, and not the smaller faults beyond the larger fault. You must test from the opposite end of the cable for signs of other possible faults. Remember also to retest the cable after any repair to ensure that you have found ALL the 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 transmitted 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 under test.

Sometimes it is not always 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 back 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.



In some cases, for example, when testing hard-line coax cable, we want to terminate the cable to eliminate ghosts and study the waveforms. It is always best to test using both methods. In order to minimize confusion and eliminate guesswork, it is best if all other equipment or hardware is disconnected from the cable under test.

Top 10 Rules For Cable Testing

1 Read the Operation Manual

2 Know your TDR

3 Get as close to the fault as possible

4 Make a quality connection between the TDR and the cable being tested

5 Enter the correct VOP of the cable being tested

6 Start with the shortest pulse width available

7 Test from both ends of the cable

8 Determine the cable path and depth for more accurate readings

9 Always re-test the cable after the fault has been fixed

10 Use common sense

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