TDR Testing

Application Note ANPRESTO 15

xDSL

TrendCommunications

UNDERSTANDING TDR SETTINGS FOR EFFECTIVE LOCAL LOOP MEASUREMENTS

Now Updated to Include Application Information on the NEW ADVANCED TDR/DMM Solution from Trend

Introduction

TDRs have gained a reputation as instruments that are both expensive and difficult to use. Due to advances in technology, the operation and interpretation of today's TDRs has been greatly simplified. This application note aims to provide a good understanding of the basic principles and applications of the Aurora Presto TDR to ensure simple and successful troubleshooting on copper pairs.

Basic Principles of Operation

Functional Overview

Fundamentally a TDR is a very simple instrument; a pulse is transmitted down a cable, which is then reflected back from any impedance mismatch that is encountered. The impedance mismatch may be caused by cable problems such as bad connections, a fault or simply by the end of the cable. The reflected pulse is sampled by the TDR and displayed as a waveform on the screen of the instrument. The Aurora Presto uses a graphical display to show the transmitted pulse and reflections that must then be interpreted by the user.

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 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. How much the impedance changes determine the amplitude of the reflection. Matching the impedance of the instrument to that of the cable under test will help reduce unwanted reflections, however, the distance accuracy of the instrument is not affected.

The Aurora Presto TDR is impedance matched for DSL lines to ensure that unwanted reflections are minimised.

Pulse Width

Increasing the width of a pulse transmitted by a TDR is equivalent to increasing the energy that the pulse is transmitted at. Greater energy allows the TDR pulse to travel further down a cable – therefore the wider the pulse, the more energy is transmitted and the further the signal will travel.

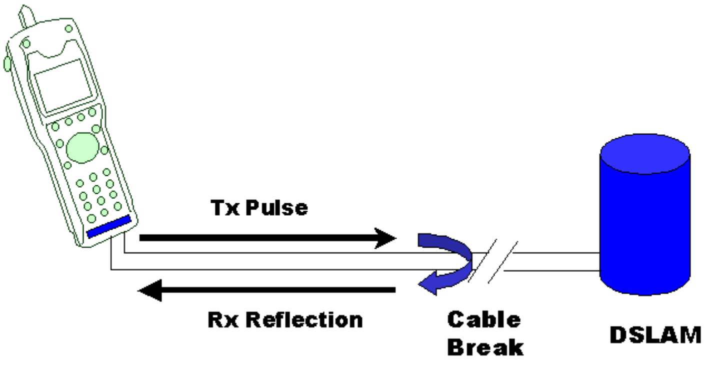

Figure 1 Pulse Width is critical for fault identification

Locating faults on a copper pair can be dependent on whether or not the user has selected an appropriate pulse width for the test – this is often difficult even for experienced users. The Aurora Presto TDR simplifies the process of selecting an appropriate pulse width by using measurement ranges based on cable length. Each measurement range uses a pulse width and receiver gain setting typical for fault finding on cable lengths in the selected range.

Larger pulse widths are helpful for locating either small faults that are relatively close to the tester or other faults that may be a significant distance away. For example, if the fault is very small, the signal strength of a small pulse may not be sufficient to travel down the cable, find the fault, and travel back – in this instance a larger pulse width may be useful.

The attenuation of the cable combined with the small reflection of a partial fault can also make the fault difficult to detect. A larger pulse width would transmit more energy down the cable, making it easier to see the reflection from a small fault.

Aurora Presto TDR allows the user to refine the pulse width, receiver gain and range to focus on specific fault conditions.

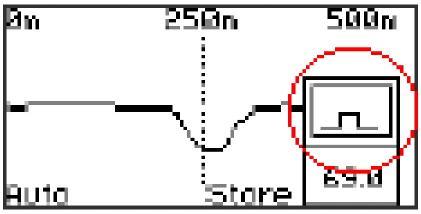

Figure 2 Changing Pulse Width on Aurora Presto

Receiver Gain

Any pulse that is transmitted from the TDR or any reflection that is generated as a result of an impedance mismatch will reduce in amplitude (energy) during propagation. This effect is known as signal attenuation. On long line lengths this can result in a very small signal being received back at the TDR, which makes the reflection difficult to resolve on the TDR display. Increasing the width of the transmitted pulse (as discussed previously) will assist in resolution of the received reflection, as will adjusting the receiver gain. The receiver gain determines the amplification of the received reflections; increasing the receiver gain can assist in the resolution of smaller reflections, however, adjusting the receiver gain higher than is necessary can result in faults being ‘masked’. The Aurora Presto TDR simplifies the process of selecting an appropriate receiver gain by using measurement ranges based on cable length. Each measurement range uses a receiver gain and pulse width setting typical for fault finding on cables lengths in the selected range. The user can then trim the receiver gain and pulse width settings to maximise the performance of the TDR.

Blind Spots

The pulse generated by a 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 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.

Using advanced hybrid technology, the Aurora Presto eliminates the blind spot in the TDR trace, allowing close in faults such as jumper faults on the MDF, to be isolated without the need of additional cabling.

Pulse Velocity Factor

The Aurora Presto TDR can accurately measure the length of a copper pair. More importantly it can also accurately measure the distance to an impedance mismatch caused by a fault on the pair. Aurora Presto makes this measurement by transmitting a pulse of known width and amplitude. It then measures the time between the pulse being transmitted (T=0) and a reflection being received. This time is then converted to a distance using a conversion known as the Propagation Velocity Factor (PVF). The PVF is the ratio between the velocity at which the pulses travel in the cable and the velocity of light in a vacuum (C = 300M/mS).

An example of the way in which Aurora Presto calculates the distance to fault is given below.

Using a PVF of 0.69 (entered by the user), the actual speed that the pulse is travelling down a known cable type is calculated as follows:.

PVF = 0.69 (or 69%)
Velocity of Light = 300 M/mS

Actual Velocity = 0.69 * 300
= 207 M/mS

In the example below, the time measured by Aurora Presto (T) between transmitting a pulse and receiving the reflection is 4.831 mS.

The value T = 4.831 mS is used by Aurora Presto to calculate the distance to fault as follows:

Actual Velocity (V) = 207 M/mS
Pulse Tx/Rx Time (T) = 4.831 mS

Distance to fault = V*T = 1000M

As an example of the importance of PVF in TDR measurements, assume that the user had specified a PVF of 0.65. Using the calculations above, this would give an actual velocity of 195 M/mS. Multiplying this value by the Pulse Tx/Rx Time (T) of 4.831 mS gives a distance to fault of 942 M (nearly 60 M away from the actual fault!).

Determining PVF

Since pulses travel at different speeds through different cable types (and through different cable gauges) it is often difficult to identify the correct PVF to make an accurate measurement. Accurate determination of the correct PVF relies heavily on at least some knowledge of the network topography.

Variations in the PVF of the same type of cable are not uncommon. The PVF 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 PVF changes and therefore the apparent length of the cable also changes.

There are a number of test methods that allow you to accurately determine the PVF for use on a particular cable type and gauge.

An identical length of cable is available, cable gauge is constant

If a short sample length of identical cable to the cable under test is available, the following steps can be taken to determine the PVF:

1. Accurately measure the length of the sample.
2. Connect Aurora Presto to the sample length of cable and obtain a waveform that shows the end of the cable.
3. Using Aurora Presto, measure the distance to the end of the cable if it is identical to the value measured in 1, then the PVF is correct.
4. If the length measured by Aurora Presto differs from the length measured in 1, then adjust the PVF until Aurora Presto measures the same cable length as measured in 1.

5. The PVF is now correctly determined and should be used to measure the cable under test.

Cable length is known

If the cable length is known, the following steps can be taken to determine the PVF:

1. Accurately measure the length of the sample.
2. Connect Aurora Presto to the sample length of cable and obtain a waveform that shows the end of the cable.
3. Using Aurora Presto, measure the distance to the end of the cable if it is identical to the value measured in 1, then the PVF is correct.
4. If the length measured by Aurora Presto differs from the length measured in 1, then adjust the PVF until Aurora Presto measures the same cable length as measured in 1.
5. The PVF is now correctly determined and should be used to measure the able under test.

Cable type and gauge known

If the cable type and gauge is known and is constant throughout the cable under test, tables of predetermined PVF values can be used to make accurate measurements. A table with typical cable type and gauges is shown in Table 1.

Table 1 *Typical PVF values*

Cable Gauge	Type	PVF
0.91 mm (19 AWG)	Gel Filled	68
0.64 mm (22 AWG)	Gel Filled	66
0.51 mm (24 AWG)	Gel Filled	62
0.4 mm (26 AWG)	Gel Filled	60
0.91 mm (19 AWG)	Air	72
0.64 mm (22 AWG)	Air	67
0.51 mm (24 AWG)	Air	66
0.4 mm (26 AWG)	Air	64

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 TDRs 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.

Interpreting TDR Traces

The following section gives a brief overview of some of the typical trace conditions that may be encountered by a user. Correct interpretation of TDR traces can rely heavily on the experience of the user. Generally, TDR measurements will be accompanied by measurements using a DMM (also included in the standard Aurora Presto TDR/DMM option).

Open

Open circuits are simply breaks in either one or both of the conductors in the copper pair.

Figure 3 Open

A reflection with the same polarity as the transmitted pulse may indicate an Open circuit (high impedance).

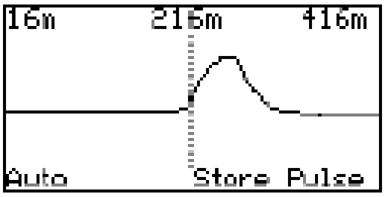

Figure 4 Open Circuit

Short

A short circuit occurs when the normally insulated metallic conductors come into contact with each other.

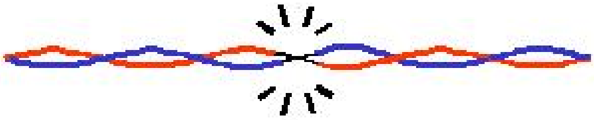

Figure 5 Short Circuit

A reflection with the opposite polarity may indicate a Short circuit (low impedance).

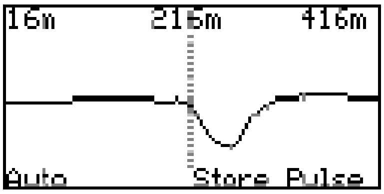

Figure 6 Short Circuit displayed on Aurora Presto

Split Pair

When jointing multiple pairs in a cable it is common for some mistakes to be made and for one conductor of a pair to become separated from the other conductor. So long as the stray conductor is matched up with its original twin before the end of the cable run, continuity is maintained and the line will be perfectly good for telephony application. But split pairs of this type result in serious degradation of xDSL service. Firstly the characteristic impedance of the section where the pair is split will be different from the rest of the line, resulting in mismatching, reflections and high insertion loss. Secondly the pair is no longer twisted which means that it will be susceptible to induced noise and will radiate and cause crosstalk into other pairs in the cable. Not only is the pair not twisted, but each conductor is twisted together with a conductor of another line, creating a high degree of coupling with that line and a high level of crosstalk with the service running in the other line. Split pairs result in noise, crosstalk, radiation and high insertion loss in xDSL applications and generally need to be located and rectified before a line can be used.

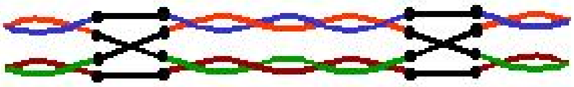

Figure 7 Split Pair

A split pair may cause either an upward or downward reflection depending on the way in which the pairs are connected. In both cases the reflection is sharp and characteristic.

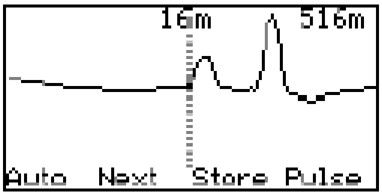

Figure 8 Split Pair displayed on Aurora Presto

Load Coil

Traditionally the reach of POTS lines was increased to over 6 Km by the addition of Load Coils onto the copper pair. A load coil is a simple inductor which increases the transmit power of voice frequencies (300 Hz to 3.1 kHz), therefore increasing the transmission range. Load coils are typically placed at regular intervals along the copper pair with the first being placed 1.5 km from the central office and subsequent load coils placed at 2.5 km intervals. Unfortunately at frequencies of greater than 3.5 kHz, the power transfer characteristics of the loads coil roll off considerably, with the result that little or no power transfer occurs at DSL frequencies. As a result load coils must be located and removed before the line can be used for DSL services.

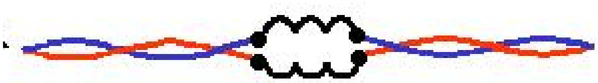

Figure 9 Load Coil

A telephone load coil will cause an upward reflection similar to a complete open (high impedance).

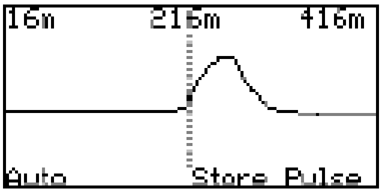

Figure 10 Load Coil displayed on Aurora Presto

Bridged Tap

As networks evolve, customer requirements change and modifications and repairs take place, parts of the line plant are often left connected but disused. For example, a particular pair may develop a fault and rather than locate and repair the fault it may be more economical to use a different pair to service the customer. The customer end connection would be changed over to the new pair, but at the street cabinet or distribution frame the new pair may be bridged to the old pair without the old pair being disconnected. The disused length of line is called a lateral, and is often left unterminated. Terminated and unterminated laterals create an impedance mismatch at the bridged tap, resulting in high return loss. Unterminated laterals also act as very efficient antennae, picking up noise from the environment and injecting it into the line. They also act as powerful transmitting antennae. Bridged taps result in noise, return loss and radiation which can disqualify the bridged pair from use for xDSL. Shorter bridged taps are more detrimental to DSL performance than longer ones. A DSL signal travelling down a short lateral is not attenuated as much as a signal travelling down a longer lateral. As a result, the amount of power that is reflected from the end of a short lateral is higher than a longer lateral. This causes the introduction of a greater amount of noise into the 'real' DSL pair, thus further reducing performance.

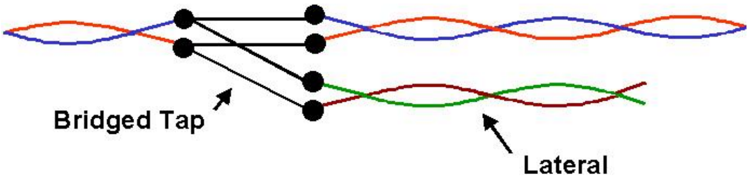

Figure 11 Bridged Tap

The impedance of the cable at the point of the bridged tap is one half that of the normal cable impedance. It will appear as a negative or downward reflection followed by a positive reflection that is caused by the end of the tap.

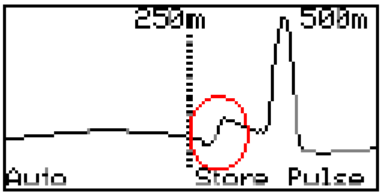

Figure 12 Bridged Tap displayed on Aurora Presto

Advanced TDR Features

The following features are included on the AuroraPresto Advanced TDR/DMM solution that also benefits from increased accuracy and greater resolution.

Auto Detect

The new Auto Detect feature on the AuroraPresto Advanced TDR allows for fast and effective TDR testing.

Note

Unlike other DSL testers that simply use a peak detector to indicate large deviations in amplitude, AuroraPresto uses a complex algorithm to detect the rising edge of the fault on the graph.

This has two significant benefits over peak detection:

- Firstly, the distance to fault is measured at the leading edge of the deflection, not at the eak of the deflection. Use of a peak detector to automatically find faults requires that the user scrolls backwards in the trace to highlight the leading edge and establish the distance to fault. This is time consuming and negates any benefit of having an autosearch feature.
- Secondly, a peak detector cannot easily discriminate between false negatives, leading to lost time attempting to identify faults that are not truly present.

When a fault has been located, AuroraPresto adjusts the scale and zoom to display the first fault. If more than one fault is found, AuroraPresto displays the most severe fault followed by the subsequent faults in descending order of severity.

Overlay

The Overlay option enables the copper pair under test, to be compared directly with a stored trace.

You can use Overlay to isolate difficult faults by comparing the ‘faulty’ pair with a stored trace of a known ‘good’ pair in the same bundle. Because both pairs will be subject to the same environmental conditions, for example noise, these effects are cancelled out when one trace is superimposed onto the other, making the fault easier to find.

TrendCommunications

Trend Communications Ltd
Knaves Beech Estate
Loudwater, High Wycombe
Buckinghamshire HP10 9QZ UK

International: .... +44 1628 524977
España:............ 93 300 3313
UK:................... 01628 524977
Deutschland: 089 32 30 09 11

France: 01 69 35 54 70
India:................. 22 8597 463/4
US: 256 461 0790