Abstract

This note describes the basic principles behind the operation of Time Domain Reflectometers, explains some common events that can be seen on coaxial and twisted pair cables and lists some common terms used with all TDRs.

General

All Time-Domain-Reflectometer (TDR) devices are built on the same general principle. Radio Frequency waves travel at a speed that can be measured. The speed of the RF signal varies depending on the material it is traveling through. RF travels fastest through a vacuum (at speed of light or 100%) and slower through twisted wire pair (50% to 75% speed of light). When RF encounters an obstacle or impedance shift in twisted wire pair (TWP) or Coaxial cable, some or all of the energy bounces back towards the origin end. The time it takes for this bounced energy or reflection to arrive back at the source is measured and divided by two to account for the round trip. If the Velocity Factor (VF) or Velocity of Propagation (VoP) of the medium is known, the time can be translated into an accurate distance measurement. The following equation expresses the TDR's basic principle of operation:

$$\frac{\text{Time}}{2} \times \text{Velocity} = \text{Distance}$$

What will a TDR Measure

The 20/20 TDR will characterize the Z (impedance) of any "paired" type of cable, including pulp TWP, PIC TWP, Drop Wire, coax, triax, Interior Wire (IW) Cat 3 through Cat 7, paired power lines, zip cord, and speaker wires. Actually, any single wire with a near parallel ground reference can be characterized. The characteristic impedance of a cable is also known as the Z_0. Using the pair of individually controllable cursors, the 20/20 will display the distance from the start point at the TDR's connector or end of the test leads to any two "events" and the distance and impedance between the two events.

Common Cable Failures

Short or Open.

A short is a low impedance event and will show as a curved trace to the bottom of the screen. An open is a high impedance event and the curved trace rises to the top of the screen. Normally, the cable will end in one of these two conditions. If the short or open occurs at the expected distance, it is not a fault but merely the end of the cable. Detailed explanations are contained in App Notes AN210 – AN219 and AN220 – AN229

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Water Damage.

Water incursion shows as an area of low Impedance. Detailed explanations are contained in App Notes AN213 and AN223.

Pinched Coax.

A pinched coax brings the shield closer to the center conductor adding capacitance and lowering the impedance for the area that is pinched. Detailed explanations are contained in App Note AN212.

Splits/Re-Splits.

In a Telco twisted pair bundle there will be an occasional crossing of the Tip or Ring wires from two separate pairs. After the initial correct impedance is displayed from the TDR to the start of the split, there will be a rise in impedance to some arbitrary number that is solely dependant on the distance between the two now interconnected pairs. If the split is detected and fixed at a point beyond the original split site (aka “Resplit”), the impedance measurement will return back to the standard Z_0 from that point onward. Detailed explanations are contained in App Note AN225.

Taps/Stubs.

Anytime a cable taps into another, the Impedances will act the same as parallel resistances and the overall values will be cut in half. Two 50 Ohm coaxes will exhibit approximately 25 Ohms for as long as both coaxes are being measured. Detailed explanations are contained in App Notes AN216 and AN226.

Poor/Contaminated Connection or Splice/ Sub-Standard Repair.

A contaminated connection can exhibit any number of possible deviations from normal. A repaired cable will usually have a short distance where the two conductors are separated further than normal, creating an impedance bump. Detailed explanations are contained in App Notes AN211 and AN221.

Low Quality Cable.

Cables that use steel instead of copper will show higher losses. The dielectric used will also affect the bandwidth and the losses of the coax. RG6 coaxial cable for instance can range from premium grade down to very low grade depending on the materials used to manufacture it. Detailed explanations are contained in App Notes AN210 and AN220.

Wrong Cable Type Used.

Incompatible cables have different impedances. Detailed explanations are contained in App Note AN215.

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Limitations of the 20/20 TDR.

Pulse Barriers

As with all TDR designs, the 20/20 cannot see beyond an inline amplifier, a repeater, a major fault (open or short), or a well matched load coil.

Accuracy

Distance readings will be no more accurate than the Velocity Factor (VF) accuracy. If the VF is off by 3%, the distance reading will also be off by 3% (plus the inherent TDR accuracy). It is important to understand that the cable manufacturer is permitted a generous margin for VF difference between their published VF and the cable's actual VF. Additionally, once a cable has been spooled, unspooled, pulled, cut, pairs untwisted and connectorized it is not likely the VF will match the factory specification. This creates a given uncertainty in TDR measurements that must be taken into account by the user when locating events, even on a good cable. A cable with damage, water intrusion, or a split pair will have serious VF issues, making distances less accurate beyond the fault.

Step Rise Time

Although the 20/20 exhibits no Dead Zone, the actual impedance readings in the first 2 feet (.6 meters) are indicative rather than absolute. Faults can be seen, but the impedance will not be completely accurate over this soft range.

Complex Cable Networks

Cables with many taps or bridges can be difficult to interpret. They can however, be recorded for historical purposes, so changes over long periods of time can be noted. A Detailed explanation about a Bridge Tap is contained in App Note AN226.

Common TDR Terminology

The following terms and abbreviations are used throughout the application notes and are important to understand. In some cases dissimilar terms have the same meaning. To reduce confusion only one common term will be used throughout the manual, displays and software. It may not be the most common one for your industry, but it does not alter the basic meaning or application of the term.

Dead Zone (DZ) aka Blind Zone or Blind Spot – Refers to a length of the cable from the connection on the TDR outward that does not display impedance reflections. Typical in Pulse TDRs, the Dead Zone increases as the pulse width is increased to see further along the cable. Since the 20/20 is a "Step" TDR designed to avoid this problem, it has no Dead Zone on any range scale.

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Dribble Up – Slow rise in the impedance over the length of the cable. This effect is due to the increase in wire resistance over that same length. This causes the horizontal trace to display a slow rise on longer cables. Twisted pair cables display more dribble up than coax due to the higher amount of loop resistance. In power cables, where the resistance is very low, users often observe "Dribble Down."

Horizontal Scale (H Span) or Range Scale– Represents the displayed distance of returned reflections over the length of the cable. The TDR measures the reflections in time/2 and multiplies by the VF to obtain the distance.

Impedance (Z_0 or Z) – Z_0 refers to the manufacturers specified value of impedance for a specific cable and Z refers to the measured value of impedance (the amount of resistance a cable pair or coaxial cable offers to the flow of an AC signal). The Z or Z_0 depends on both the conductor's properties and the dielectric properties of the insulation. Deviations from the normal or expected impedance create RF reflections which are displayed as upward or downward deviation in the Vertical Scale along the time/distance domain on a TDR trace or plot.

Velocity Factor (VF or VF) aka Velocity of Propagation (VoP or VP) or Nominal Velocity of Propagation (NVP) – Refers to the speed at which an RF signal will travel on twisted pair cable conductors or coaxial cable. It is expressed as a fraction of the speed of light in vacuum. (e.g. .66c). See the cable tables stored in the 20/20 TDR for a list of common cable types and their velocities.

Plot or Trace – refers to the display presentation on the 20/20 TDR's LCD or AEA Technology's TDR PC Vision Software for storing and displaying uploaded information. In some cases the reference "plot" refers only to the cable's reflections trace and in other cases it may refer to the entire chart on which it is presented.

Vertical Scale (V Scale) – Represents the impedance range displayed on the plot. For optimum presentation the full scale should be set to about twice the cable under test's normal impedance (Z_0).

VF Uncertainty – This is an important factor in judging the accuracy of any TDR's distance measurement. The cable manufacturer can only hold the tolerance of a cable's VF within certain limits to the published specification. Additionally, the stresses of spooling, unspooling, pulling, cutting, untwisting and connectorizing alter a cable's velocity factor over its length.

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