CableScout and Twisted Pair…

Abstract

A twisted pair TDR can be used on coax and the opposite is also true. Whilst Tempo's CableScout™ TDRs are designed with F connectors and 75-ohm termination we will explain how this is not a problem if you need to test a twisted pair cable such as a telephone pair or Ethernet cable; or for that matter pretty much any cable.

By

Mark Govier, 12 June

Introduction

Many fables and half-truths have been written over the years about Time Domain Reflectometers and their applicability or not to alternate types of cables. Some of these did have some small level of truth that was more related to marketing needs and the limited capabilities of the earlier TDRs themselves. Examples may have been limited receive amplifier bandwidth, particularly as gains are increased or only having wider pulse widths available.

However, you can be assured that the new generation of CableScout TDRs from Tempo Communications are very applicable in all the following applications:

- Cable TV using 75-ohm coax
- Base station antenna cable testing, again using 75 or 50-ohm coax
- Ethernet cable testing using CAT5 or higher cables (approximately 100-ohm impedance)
- Telephone twisted pair checking (CAT3) of approximately 100-ohm impedance.

- Checking "de-energized" power cables; you will need to check carefully that they are "dead" and determine a suitable Vp as these cables are far less "controlled" when built for the "mains" frequencies they carry.
- If there is an electrical cable, whether copper, aluminium, coaxial, twisted pair or "twin and earth"; CableScout can probably check it for consistency and length.

Impedance Matching

Whenever two electrical devices are connected for the purposes of transferring energy, whether that is power or a signal of some type, you want to do so as efficiently as possible. This is done by utilising the techniques of "impedance matching" where the impedances of the source, connecting cable and destination are all carefully matched to minimise the losses.

Losses and "reflections" can be so bad in some applications that serious and permanent damage can occur almost instantly; a good example is operating a radio transmitter into a badly matched antenna system or with no antenna connected. As the power levels are relatively high this can result in damage to the output power amplifier. But for the application of TDR this does not apply.

Power Loss

If two devices are connected that "do not match", how much energy is reflected/lost from the system? Let us put things into perspective, let us examine in detail the case of connecting the CableScout which is 75-ohm to a twisted pair at approximately 100-ohm.

Now, if you remember, a Time Domain Reflectometer is all about measuring "coupling loss" or "return loss", the quantity of energy reflected from an "event" some distance from the launch point. So, what is the equation that relates the scale of the reflected (or lost) energy to the differences in impedance?

Sorry but it is going to get "all mathsy" here, but that is how the universe works, you do not need to know the details for the TDR to work…

$$Absolute\ Load\ Impedance\ Z_L = \sqrt{R^2 + j^2}$$

Where R is the "real" part of the load impedance and "j" is the imaginary part. For our purposes we will simply assume that Z_L is purely "real", i.e. just 100 ohms. It makes no difference at a practical level.

We will equally assume that the source impedance Z_0 is a simple 75-ohm real impedance.

The next bit we calculate is the "reflection co-efficient": The reflection coefficient measures the amplitude of the reflected wave versus the amplitude of the incident wave. The expression for calculating the reflection coefficient from the impedances is as follows…

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$$

As all the impedances being used to calculate here are "complex" the reflection coefficient is also a complex value. This is where the "phase" of reflected vs.

incident signal comes from (pulses shown up for open circuit and down for short circuit in the simple world of TDRs).

Any radio hams out there or even users of CB or marine radios would then have heard about SWR, or Voltage Standing Wave Ratio, VSWR, this is the "voltage" that can occur when an antenna system is mismatched and cause damage. This is calculated using the reflection co-efficient…

$$VSWR = \frac{1+\Gamma}{1-\Gamma}$$

As this has a term on the bottom that can quickly head towards zero, the VSWR can quickly become high causing the damaging voltages for high-power radio transmitters etc. Now forget VSWR, it is just a bit of background for you.

In the world of TDRs we concern ourselves more with "return loss". The return loss measurement describes the ratio of the power in the reflected wave to the power in the incident wave in units of decibels amplitude. The standard output for the return loss is a positive value, so a large return loss value actually means that the power in the reflected wave is small compared to the power in the incident wave and indicates a better impedance match. The return loss can be calculated from the reflection coefficient with the equation:

$$RL = -20 \times \log_{10} \Gamma$$

The mismatch loss measurement describes the amount of power that will not be available at the load (in the case of a TDR, going to the cable to continue testing further along the cable) due to the reflected wave, expressed in units of decibels power. It indicates the amount of power lost in the system due to the mismatched impedances. The mismatch loss can also be calculated from the reflection coefficient with the following equation:

$$Power\ Loss = -10 \times \log_{10}(1-\Gamma^2)$$

So How Bad is Connecting 75Ω to 100Ω

- Reflection co-efficient (Γ) is 0.14
- Return loss is 17 dB
- Power loss is just 0.1 dB

How bad is Connecting 75Ω to 50Ω

- Reflection co-efficient (Γ) is 0.20
- Return loss is 14 dB
- Power loss is just 0.2 dB

If you want to learn more of the theory behind this, please refer to your favourite electromagnetic engineering text-book.

Practical Use

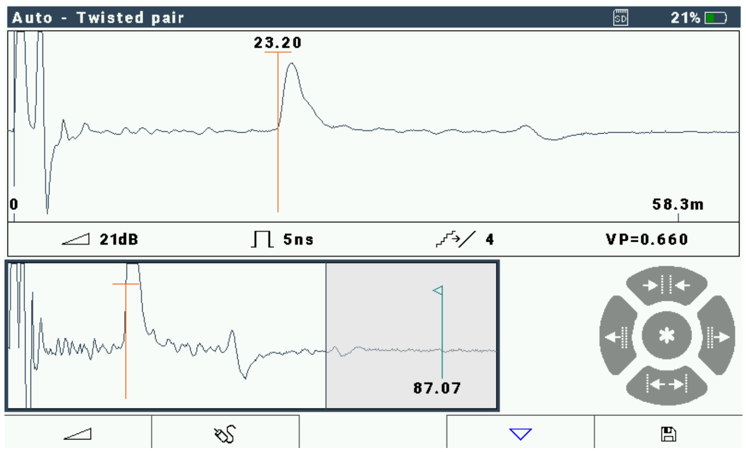
In the real world this means that once past the connection point where the 75-ohm system joins the other impedance cable, the TDR works as normal. There is really very little loss of signal for "normal" cables of between 50 and 120 ohms.

Ok that loss happens for both the outbound pulse and reflected “return” signal. But the typical loss due to mismatch is only equivalent to the loss over a few tens of metres of cable.

Yes, there will be a reflection visible, which in the past and with less capable TDRs meant that you could not see any event within the width of the launch pulse due to saturation of the receive amplifier. But with CableScout now having a 1 ns pulse and suitably rated receive amplifiers as standard the event dead-zone is less than a foot (0.3 m) in most cables.

Examples

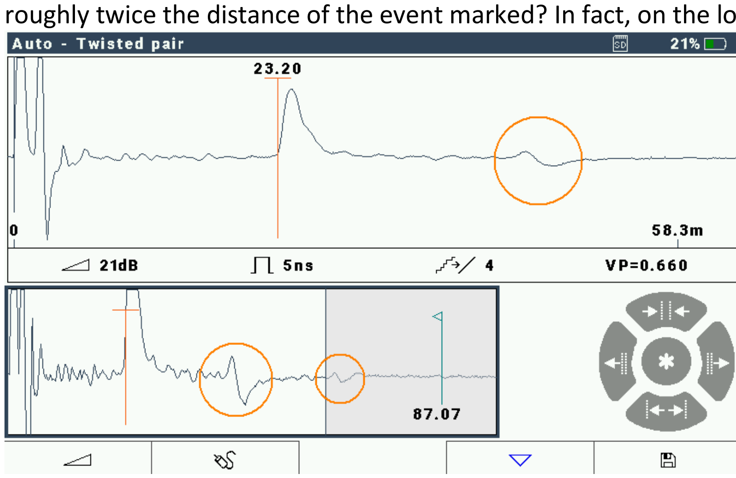
A short length of CAT3 – “telephone cable”…



This cable is 23 m long and apart from the open end shows no significant trouble.

The Ghost in the Machine

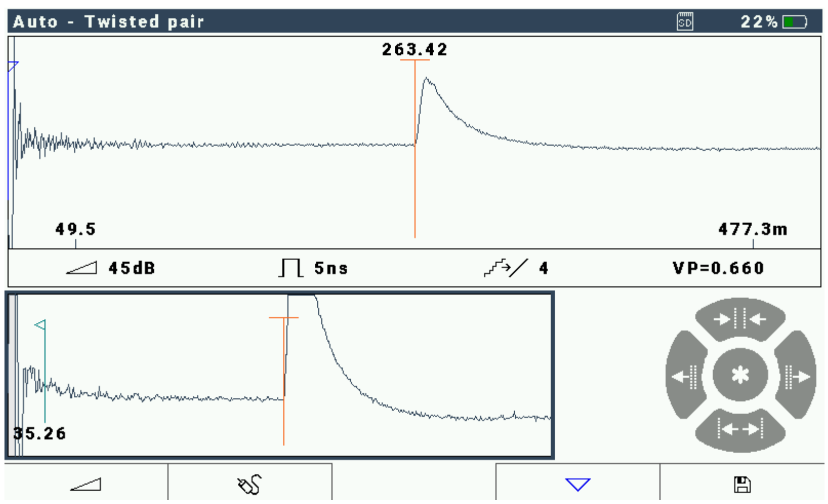
One thing to note and be aware of though… Can you see that wiggle on both the overview (lower) and main traces of the CableScout 90 (highlighted below) that is roughly twice the distance of the event marked? In fact, on the lower overview



trace you can see two of them. They are “Ghost reflections” where the part of the energy from the original reflection meets the mismatch near the transmitter and goes around the loop again (and again, attenuated by about 17 dB plus the cable losses each time).

How much is left on this drum of CAT5e?

So that's 264 m then… (a screen-shot):



Conclusions

Once you are aware that there may be an impedance mismatch as a signal is launched onto a cable, you can expect to get sensible results back for the rest of the connected cable.

A 75-ohm "coaxial" TDR like the Tempo Communications CableScout™ is perfectly useful when checking all other "common" cable types; whether 50-ohm coax, 100 to 120-ohm twisted pair or even a drum of "power" cable. This is particularly true in these days of FTTx networks where the lengths of the copper cables are reducing, and TDRs need shorter pulse widths to test with higher precision and extended bandwidth.

Just watch out for the "ghost" reflections that will be shown. If you have a good idea of the approximate length of the cable these are easy to eliminate. Our more advanced TDRs (e.g. TV220 CableScout Pro) can even tell these apart for you with their advanced "event detector" technology.