

# AN203

## Getting the Most from Your TDR

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### Abstract

This application note is a collection of best practices and tips that help to enhance the performance of a TDR and optimize a user's view of a cable.

### General

#### Correct Setups

One of the most important factors in getting valid and accurate information from your TDR is to ensure the setups are correct. The two most important settings for any Step TDR, including the 20/20 TDR, are the cable's Velocity and Impedance. Using the correct velocity is crucial to obtaining accurate distances to events and determining distance to the end of the cable. The correct impedance is required to adjust the display for centering the measured impedance and for using the vertical scale settings. Most of the other setups discussed in this note will improve the usability of the TDR.

#### Velocity

Velocity of a cable is the speed at which injected pulses will travel along the length of the cable. Velocity Factors are expressed as a percentage of the speed of light (i.e. 0.66c or 0.85c, etc.) Since a TDR uses the Velocity Factor to determine distance from the TDR, it is important to have the correct Velocity Factor entered at the time of measurement. Manufacturer specifications have several terms for expressing the velocity that all mean the same factor. Velocity Factor (VF) or Velocity of Propagation (VP or VoP), or Nominal Velocity of Propagation (NVP).

The velocity of any cable is determined by the manufacturer at the time the cable is constructed. However, the manufacturer may have a margin of error that can be as much as 6% between what is specified for a cable and its actual velocity. Few quality manufacturers are off by more than 1 or 2 %. However, even this would mean a distance error of 10 – 20 feet at 1000 feet of cable or 3.3 – 6.6 meters at 330 meters of cable. Additionally, once a cable is spooled, unspooled, pulled, cut and connectorized it's nominal velocity will most likely be affected. For these reasons, AEA Technology recommends, whenever possible, to measure a known length of the cable to be tested and use the measured velocity for other measurements on that same cable.

## Examples of sampling velocity:

**New Installation** - Take a ten+ foot section of cable from a new spool or box and measure the jacket length accurately with a tape measure. Eye balling the length is NOT recommended. Connectorize one end and leave the other open. Attach the connectorized end to the 20/20 TDR and follow the instructions in the F5 menu for "Sample a Cable." *[Note: If a test lead is used rather than a direct connection to the TDR, be sure to use the "Cal Test Lead" feature in the F5 menu to remove it from the length calculation BEFORE selecting "Sample a Cable."]* When completed, the 20/20TDR will indicate "Unknown Cable Type VF xx.x". You may apply this measured Velocity Factor to a cable stored in memory:

1. In the F5 Menu, go to "View User List", and press any left-right key
2. Select the cable type being measured and press ENTER.
3. Now select F5's "Edit User List" and press any left-right key.
4. Move the cursor arrow down to VF and press any left-right key.
5. Enter the value obtained during the "Sample a Cable" process.
6. Define the "Save Location"; location 0 is for temporary storage as it gets accidentally overwritten more than the others.

NOTE: With multi-pair cables (i.e. Cat 5, 6, etc.) different pairs will have different velocity factors due to their different twist rates. If all planned testing occurs on one pair in the cable, be sure to sample that pair for its velocity. If testing will be with different pairs, you can set different VFs for each pair or sample all four pairs and average the velocities.

**Existing Installation** – Obtaining the "Nominal Velocity" for an existing installation can be more complex, but can help establish the velocity for an installed cable with an unknown velocity. Existing installations require that you find a good sample length between two access points. However, they have factors that affect the velocity between those points. The following are some of the factors to consider:

1. Do you have accurate cable diagrams or cable plats to find lengths between access points? "As Built" diagrams are generally the best source of information, but post building alterations could affect the measurement.
2. Measuring through splices will reduce a cable's velocity slightly depending on the percentage of the sampled length that has been untwisted and the quality of the splice. If there are splices over the length of the cable to be examined, it might be good to include a least one in the sample length to ensure these are factored into the velocity measurement.
3. Ensure the length being sampled is not wet. Velocity through any moist section of cable can reduce by 50% or more.
4. Are there maintenance loops in the sample section? If so, are the lengths of cable in the loop(s) included in the diagram measurement?
5. Multiple pair cables may have slightly different Velocity Factors on the different pairs. It might be good to sample more than one pair and average their Velocity Factors to improve the accuracy of other pair

measurements. This also gives you a good understanding of the variation and upper to lower VF of the pairs in that cable.

NOTE: Some Cat 5 cables manufactured between 1993 and 1996 contain one or two pairs made with polyvinylchloride insulation and not FEP Teflon. These PVC insulated pairs will be significantly slower than the FEP Teflon pairs inside the same 4-pair jacket.

6. Make sure you are not measuring to a break, short, load coil or bridged tap end. Always look at the sample to be measured for VF open at the far end and then shorted at the far end. If these two readings do not give the expected results, there may be an open or short before the far end.

Once the two access points have been located and the length known from the cable diagrams, they can be used to perform the "Sample a Cable" process in the same manner as the "New Installation" process above. Once you have the measured Velocity Factor compare it to manufacturer specified velocity for similar cable types. If it is too high or too low (more than 6-10% off) without a known reason, there may be a hidden cable fault or measurement error contributing to the difference.

## **Impedance**

Setting the correct cable type with the correct impedance will help center the vertical scale from the start of the measurement. For the most advantageous view of events on a cable, the cable's  $Z$  is set at the center of the screen plot with  $Z = 0$  at the bottom and twice the cable's  $Z_0$  set at the top. Hence when measuring a cable with a  $Z_0$  of 50 Ohms the top of the scale should read 100 Ohms.

## **Impedance on Long Cables**

On longer cables the resistance of the conductors or conductor and shield start to add to the impedance ( $Z$ ) measurement and this shows as an upward slope on the trace. This phenomenon in Step TDRs is known as "Dribble Up." To compensate for dribble up, the 20/20 TDR's "Scale" key can be used to raise the vertical scale or the vertical scale can be changed in the F3 menu. The conductor resistances cause dribble up because the further down a cable the step travels, the more conductor resistance it sees. The smaller the gauge of conductors the greater their resistance and hence the more dribble up will be seen. The following are some expected rates for twisted pair cables:

26 AWG cable adds 2 Ohms of resistance for every 25 feet of cable  
24 AWG cable adds 2 Ohms of resistance for every 40 feet of cable  
22 AWG cable adds 2 Ohms of resistance for every 62 feet of cable  
19 AWG cable adds 2 Ohms of resistance for every 125 feet of cable.

Dribble up is generally less prominent in coaxial cables since the shield adds very little resistance to the loop. Most of the loop resistance is due to the center conductor. If the dribble up measures much more than expected over a given length of cable, the cable is considered “Lossy.”

Very low resistance cables like power cables have large gauge conductors. They may exhibit “Dribble Down” over their lengths when the dielectric losses exceed the resistive losses. In either case the “Scale” key or F3, V Scale setting can be used to expand the scale and see events over a greater vertical range.

### Detecting Small Events

Since the 20/20 TDR will center the  $Z_0$  setting for the cable selected, the vertical scale can be reduced to see small events better on the LCD. How this works is best seen through the figures that follow:

In the first figure the vertical scale is set to twice the selected cable’s  $Z_0$  to get an overall view of the cable’s condition. A very small event, like the one at about 50 feet, might be overlooked with this setting.

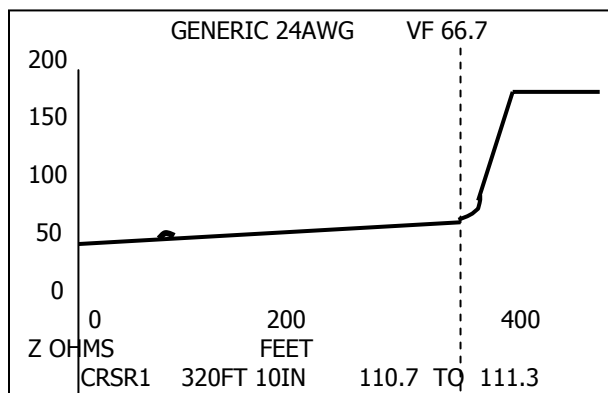


Figure 1

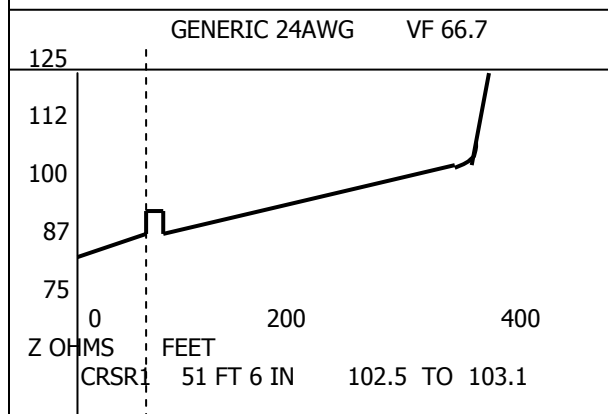


Figure 2

In figure 2, the vertical scale has been reduced from 200 Ohms to 50 Ohms greatly enhancing the resolution of the vertical scale. Note the range on the V Scale is now 75 – 125 Ohms. Now the small event at 50 feet can be seen much more clearly and located more precisely.

## Importance of Avoiding Connector Separation

Since the impedance ( $Z$ ) of a cable depends on the distance between the two conductors or the conductor and the shield, any separation between them dramatically changes the impedance at that point. Coaxial connectors, RJ11 and RJ45 connectors maintain correct distance between the conductors and avoid significant impedance change. However, when connecting with alligator clips, the impedance raises and a reflective event appears on the TDR trace.

The simple solution to reducing this type of reflection: keep as much twist as possible in both the test leads and in the cable under test. Figure 3 shows a good TDR test connection on a twisted pair cable.



Figure 3

Figure 4 is an Example of a poor connection that will cause an unnecessarily large reflection at the connection point.

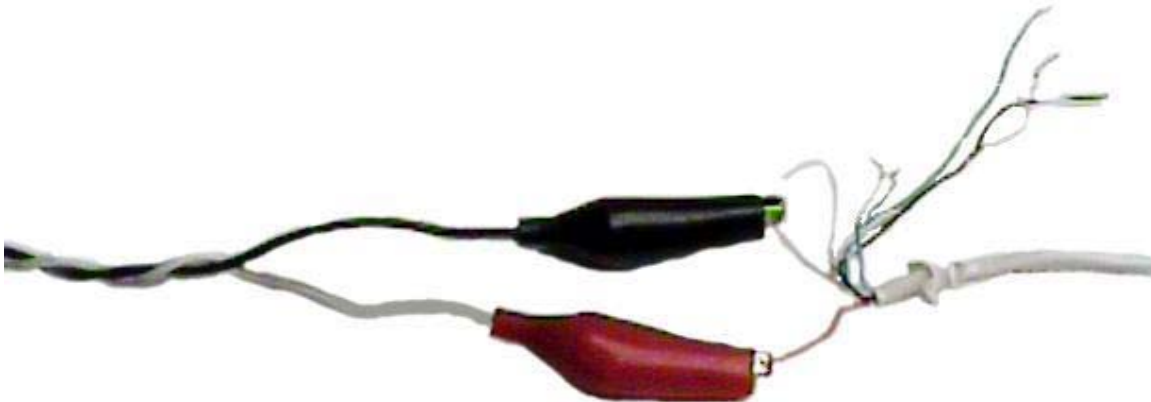


Figure 4

## Filter Application

Electromagnetic Interference or signal activity on a cable can disrupt the TDR's receiver and cause traces on the display to appear both thick and hairy or in some cases jump or present false temporary reflective events. Much of this interference can be removed through the application of the right filters. The 20/20 TDR has three types of filters; Noise, Averaging and Video.

The best way to apply filtering is to apply the least amount of filter required to obtain an acceptable trace display. More filtering causes the trace updates to slow down. Refer to the Operations Manual for detailed information about these filters. Below is a quick reference to filtering action:

**Noise Filter** – Receiver low band pass filter is best for suppressing high frequency noise. It is useful when measuring a cable with a signal on it.

**Averaging** – Software filter that accumulates sweep data in memory and averages the plot's trace. It acts like a low band pass filter, and is effective against medium to high frequency noise

**Video** – Compresses the thickness of the trace line, and is effective for high frequency noise that causes the trace to be thick and hairy. Video is useful for live CATV lines.

## Saving Instrument Setups

In most cases, there are a finite number of common cable measuring parameters that any particular user encounters in their field of testing. By taking the cable types normally encountered and saving them in the User List they will be readily available for use. However, the 20/20 TDR goes a step further in user convenience. A user can save the cable type with its impedance and velocity plus save all the instrument settings commonly used with that cable type. You may prestore your personal preferences for the types of measurements commonly made. The F4 Menu's Memory features permits up to 9 custom instrument settings that can be quickly recalled. Using this feature saves a great deal of time in resetting the 20/20 TDR to a previous measurement condition.

Using this feature is quite simple and saves all of the following setups in the menus shown below:

F2 – Backlight Timer, Brightness, Contrast, Audio Volume, Audio Mode, BAUD Rate and Battery Saver

F3 – Vertical Scale, Horizontal Scale, Plot Start, Units, Grid Lines, Big Numbers and Plot Type

F4 – Memory operations, Noise Filter, Averaging, Video Filter, Step or Pulse Mode and Input Channel

F5 – Cable Type and Test Lead Calibration



There are nine user memory slots numbered 1-9 for custom instrument settings. Memory slot zero is used by the instrument every time it goes through a normal power OFF it will save all the current settings in memory slot zero. When you are performing a common measurement and wish to save those setups, press F4, select “Memory Action” then “Save Inst” Enter the memory slot (1-9) and your custom setup will be saved. The next power ON will use memory slot zero’s stored settings. To use a custom stored setting simply go to F4, select “Memory Action” then select “Recall Inst” and enter the slot number of the setup you stored. See the Operator Manual for detailed steps. Instrument setups are also saved whenever you save plots.

Keywords: Tutorial on TDR practices and tips, Cable Velocity, Cable Impedance, How to set up the TDR, how to measure new installations, how to measure old installations, correct TDR test lead connection, applying TDR filters, Noise Filters, Video Filters, Averaging Filters, Saving instrument setups.