

## Abstract

Knowing a cable's actual Velocity Factor (VF) makes all length measurements more accurate. Published VFs can be inaccurate for several reasons. This application note deals with understanding why measuring a cable's velocity is important and how to accomplish that task.

## General

### Velocity Factor (VF)

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

The VF of a 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 VF. 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 VF 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 VF:

**New Installation** - Take a ten+ foot section of cable from a new spool or box, and accurately measure the jacket length 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."]*

Step 1 – Select SAMPLE A CABLE and connect both the test leads and/or a sample length of cable. If twisted pair leads are used, ensure the leads are twisted together as much as possible at the connection point and that the sample cable is open at the opposite end.

NOTE: AEA Technology recommends sample cables be between 10 and 50 feet (3 to 15 meters) to get an accurate measurement.

Step 2 – Press ENTER to start the Sample A Cable operation and use the ZOOM, SPAN, SCALE and CRSR1 keys to position the cursor at the end of the leads. See Figure 2-32.

NOTE: The normal cursor information will NOT appear in the Sample A Cable procedure as it can be in error and misleading.

Step 3 – Press ENTER again to go to the Length Entry screen. First enter the sample's physical length in feet or meters (meters enters in nnnn.nnn format to include mm) and press ENTER. Then, if prompted to do so, enter the "inches" and press ENTER. The TDR now calculates the VF. The results screen will appear as shown in Figure 1 with both the Impedance and VF displayed.

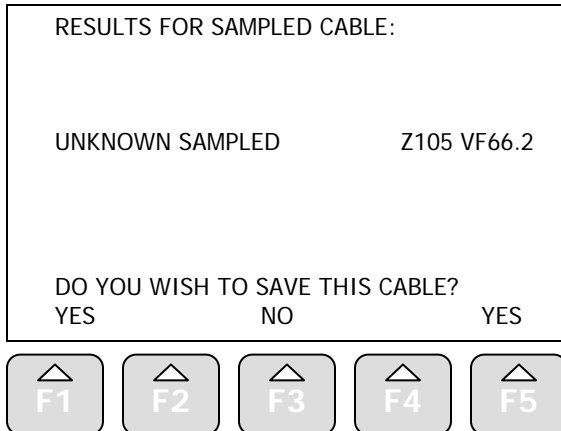


Figure 1

Step 4 - If the impedance and VF appear in the nominal range for the type of cable being sampled, accept the results and save it to User Cables List by pressing F1 or F5. When choosing to save the results, the next screen will ask for a memory slot in the User Cables list. Enter an available memory slot from 0 to 55.

Step 5 - Press ENTER to complete the save and return to the measurement screen.

If the velocity or impedance are outside the expected normal limits, Press F3 to erase the data and return to the F5 menu screen. Recheck the test setup and cable's physical measured length to ensure all is correct.

When completed, the 20/20TDR will indicate "Unknown Cable Type VF xx.x". You may apply this measured Velocity Factor to a cable type stored in memory using the following steps:

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 and manufacturing tolerances. If all planned testing occurs on one pair in the cable, be sure to sample that same 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. If averaging is used, note the slowest and fastest pairs. This difference becomes the tolerance range in length measurements for applying averaged velocity.

**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 and eliminate uncertainties from length measurements. 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 be reduced 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.

## **Conclusion**

A correctly sampled cable section’s velocity will produce far more accurate length measurements to end sections and events on the cable being measured.

Sampling for velocity reduces or eliminates the following velocity errors:

- A. Unknown tolerance variation from manufacturer’s specified velocity
- B. Velocity variations caused by cable handling and age
- C. Velocity anomalies induced from splicing and connectors