Agilent Technologies

# Near End Cable Measurements on Frequency Domain Field Tester WireScope 350

## Introduction

The last decade has seen a vast improvement in cabling systems driven by the growth in high-speed Ethernet communication over copper cables. New cabling standards such as the TIA Cat-6 and ISO Class-E define very stringent performance requirements. This means, the cabling systems now have narrower margins against the standard limits. This also imposes a significant challenge on the field test instruments for the accuracy of measurement. Near End Cross-talk (NEXT) and Return Loss are two of the most important measures of the quality of LAN cabling. This paper gives an overview of accurate near end measurements in WireScope 350. Although NEXT measurement is used to describe the technique throughout the document, all the description applies to Return Loss measurement as well.

## Cable Certification Testing

TIA and ISO standards specify frequency domain representation of cable certification test results. A typical standards compliant test result plot is shown in Fig 1.

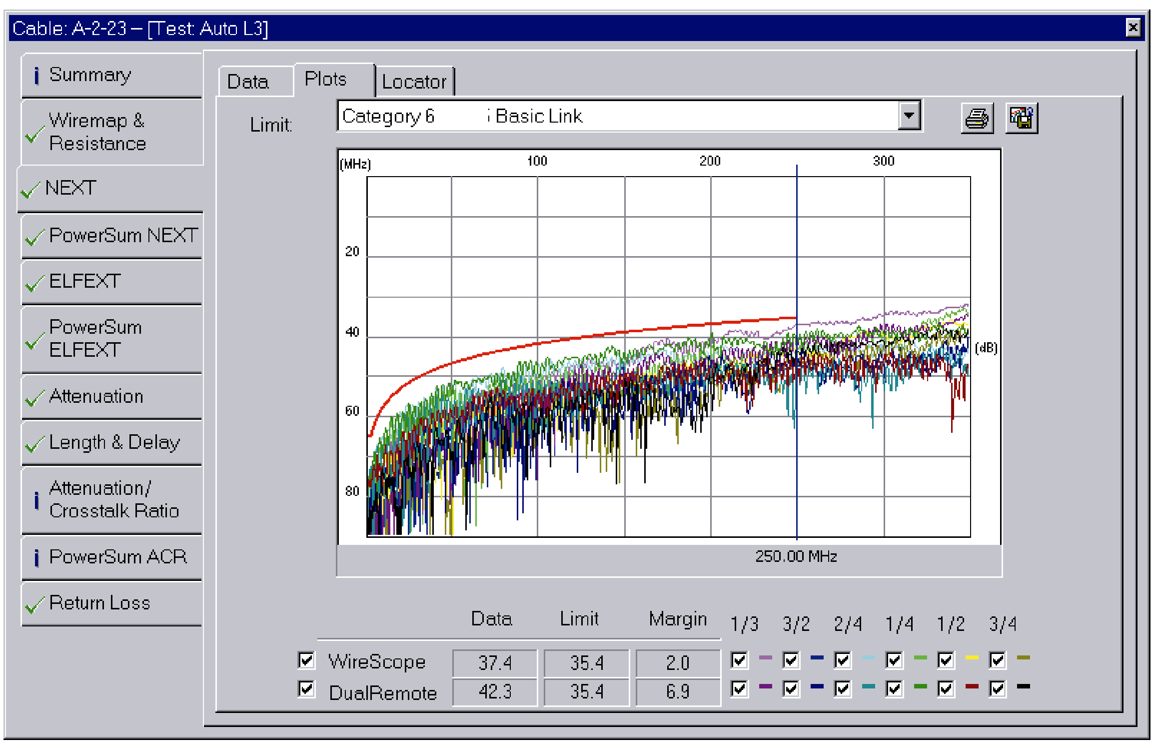


**Fig 1: Cat-6 NEXT test results**

## Frequency Domain Cable Testing

Frequency domain testers like the WireScope 350 have a variable frequency signal source, which can be programmed to generate all the frequencies in the measurement range. For example, CAT-6 or Class-E cable must be tested from 1 MHz to 250MHz. The step size or resolution of frequency change varies from 125kHz at the low end of the range to 500kHz at the high end of the range. Fig 2 shows a simplified block diagram of near end measurements in WireScope 350.

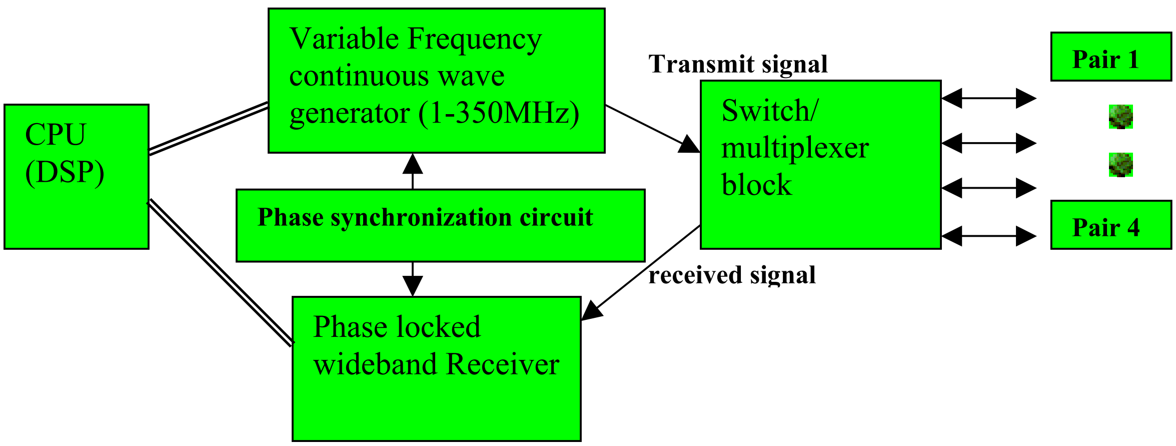


**Fig 2: Near end measurements block diagram**

The Digital Signal Processing (DSP) block of WireScope 350 main CPU analyses all the measured data from the RF and analog measurement block. The variable frequency source is the core of the transmit block. It can produce pure sinusoidal signals for all required frequencies in the range from 1MHz to 350MHz. In addition, it produces an internal signal for phase reference. The output frequency of the variable frequency source is under the CPU's control. The switch and multiplexer unit can connect one or more pairs of the LAN cable to the signal source or to the receiver. In addition, it provides necessary termination to the wire pairs. The receiver can be phase locked to the variable frequency source, producing accurate phase and magnitude measurements at each frequency step.

Each measurement requires the transmitter to sequentially produce all frequencies on transmit pair, and the receiver to measure the signal on specified receive pair. Such measurement is referred to as a *frequency sweep*.

The WireScope 350's remote unit, dual remote 350, contains the same measurement block to support testing at both ends of the cabling.

## Near-end Cross-talk (NEXT) Measurement

The WireScope 350 can be connected in link or channel configuration as shown in Fig 3.

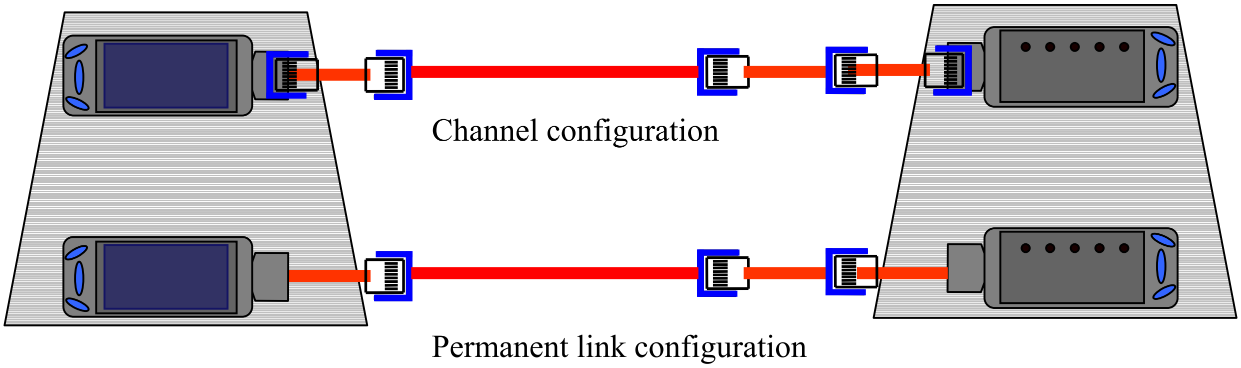


**Fig 3: Channel and Permenent Link Configurations**

When the main unit of WireScope 350 is performing the NEXT measurement, the remote unit terminates all four pairs into 100 Ω termination resistance. The transmitter of the main unit applies a frequency sweep to one of the wire pairs. The receiver of the main unit is configured (by the switch and multiplexer block) to receive signals on another wire pair. At each frequency step, the measured signal amplitude and phase represent the NEXT on the receive pair caused by the transmit pair.
The raw NEXT measurement obtained this way is a cumulative effect of the cable channel under measurement and the tester interfaces (shaded parts in Fig 3 above). The Digital Signal Processing unit in the WireScope 350 CPU needs to process this raw data to accurately remove the NEXT components due to the internal parts of the tester ($NEXT_{system}$) and external test interfaces ($NEXT_{interface}$).

$$NEXT = NEXT_{raw} - (NEXT_{NE\_system} + NEXT_{NE\_interface}) - (NEXT_{FE\_system} + NEXT_{FE\_interface})$$

The WireScope 350 unit undergoes a factory calibration process after manufacture. A similar calibration is performed on the unit during the annual calibration at the Agilent service centers. This calibration contains the information about the NEXT components (amplitude and phase) from cross-talk sources within the tester, or $NEXT_{system}$. Such components are very small and well within the level-3 accuracy standards specified by TIA and ISO. However, removing this small effect through calibration improves the tester's measurement accuracy significantly. Removing the effects of external test interfaces is a bigger challenge. In the case of channel configuration, the external test interfaces consist of universal channel adapter and the plug-jack mated connection at the near end of the tester. A tester can accurately remove the effects of the external interfaces only if it can accurately identify the exact location where a particular component of NEXT was introduced. In other words, the tester needs to make a very accurate 'distance profile' of the cross-talk measurement. This way, the raw NEXT measurement will be divided into NEXT components from different points along the cable length.

## Adapter and Interface Compensation in a Frequency Domain Tester

As explained in the previous section, the removal or compensation for the external interfaces requires a tester to do a 'distance profiling' of the raw NEXT measurement and selectively remove the unwanted components. Such distance profiling is intuitive in a time domain representation. This is because the time taken by an electrical pulse to propagate along a wire pair and return back is proportional to the distance.

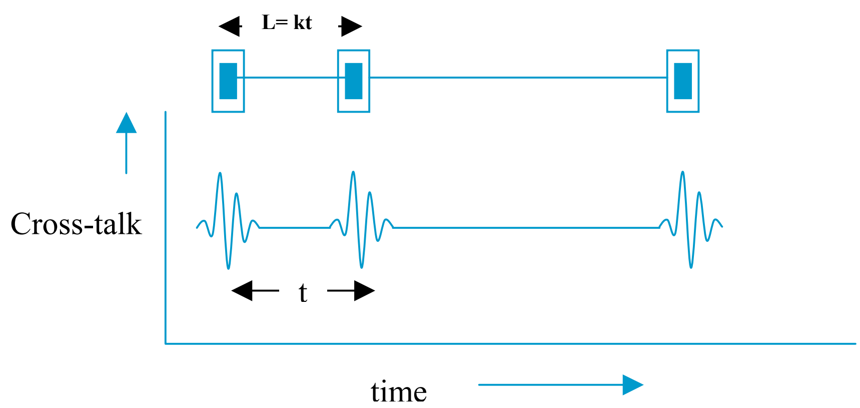


**Fig 4: Pulse response of cross-talk signal as a function of time and distance along the cable**

Fig 4 demonstrates a channel with three connecting points. As we can see from the plot, the distance between the first and the second connecting points is proportional to the time delay between their cross-talk pulse responses. The proportionality constant k is defined by the NVP (nominal velocity of propagation) of the cable.

A frequency domain tester can get a similar time v/s cross-talk characteristic by applying inverse Fourier Transform on the measurement data. This technique is used in the WireScope 350 to implement the fault locator utility (see Fig 5). The fault locator is a very useful tool that identifies the exact location on the cable corresponding to large or abnormal cross-talk source.

One possible way of applying interface compensation in the WireScope 350 is using a time domain technique similar to the one demonstrated in Fig 6:

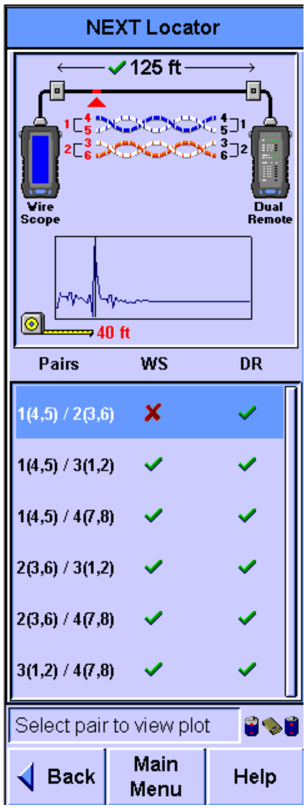


**Fig 5: NEXT Fault locator utility on WireScope 350**

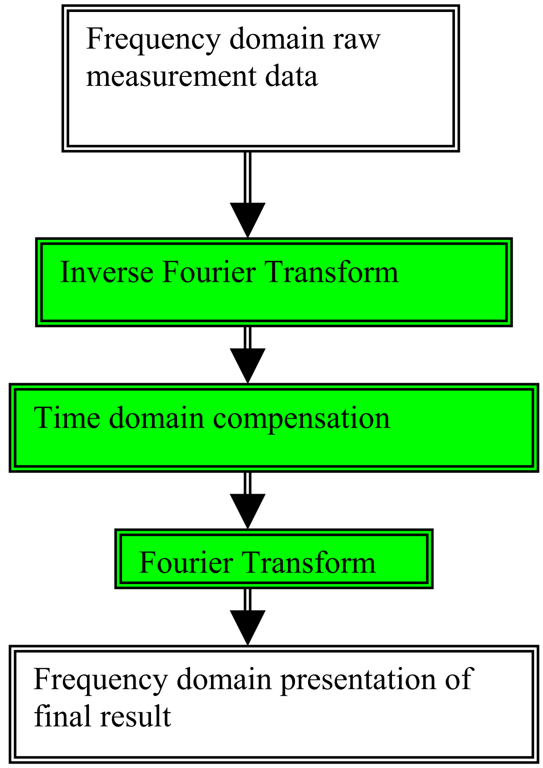


**Fig 6: Interface NEXT compensation using Fourier transform**

There are a few potential issues with this approach. First, the operations of Fourier transform and inverse Fourier transform can add some rounding errors. Second, performing interface compensation on the time domain data is not as simple as it initially sounds. Particularly when two connection points are very near, there can be significant overlap in the adjacent pulse responses (Fig 4 shows typical shape of the pulse response which extends over a period of time for each source).

## Enhanced Auto Cancellation Technique (eACT)

The WireScope 350 implements a novel technique to achieve interface NEXT compensation. This technique, eACT, is a digital filter within the Digital Signal Processing unit of the WireScope's main CPU.

As explained above, the distance of the cross-talk source is directly proportional to time delay of its pulse response. Is there any specific way that the distance of the cross-talk source influences its frequency domain presentation? Yes, but in a complex non-intuitive way. eACT exploits this complex relationship between the distance of the cross-talk source and raw frequency domain cross-talk measurement. Cross-talk originating from a specific location along the cable length has a unique frequency domain signature that corresponds to the distance of the cross-talk source. This signature cannot be extracted from measurement at one frequency point, but it can be completely extracted by processing the entire frequency sweep. The digital filter of eACT achieves the *distance profile* of NEXT measurement using this signature. Once the distance profiling of the cross-talk measurement is achieved, the rest is simple. It now selectively removes the effects of near end as well as the far end interfaces (the shaded sections in Fig 7) from the raw measurement.

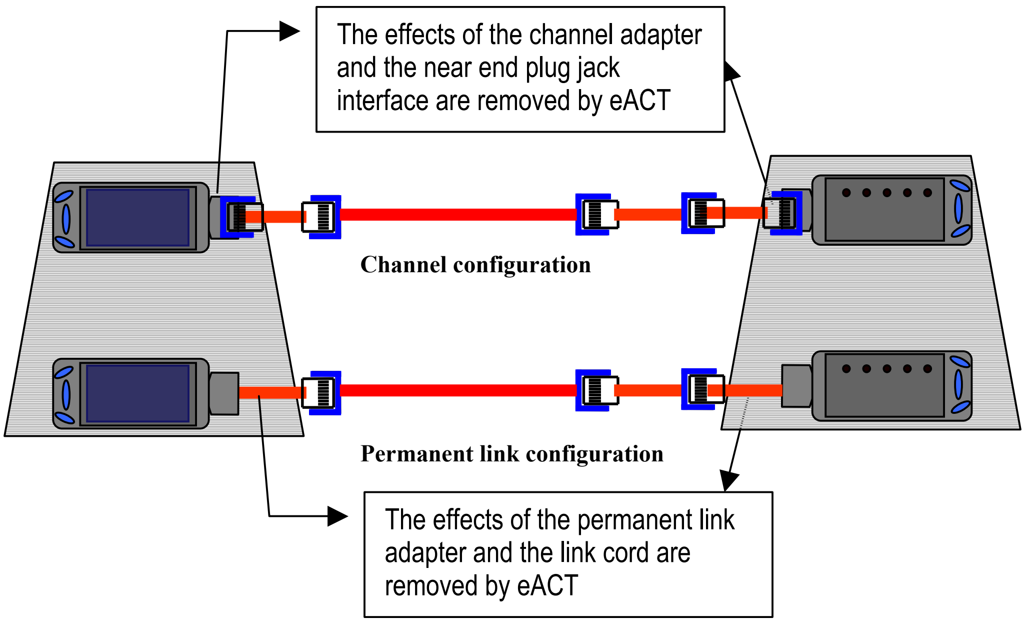


**Fig 7: eACT in action**

For the channel configuration, the contributions from the CAT-6 universal channel adapter and the plug-jack combination at both ends of the tester are eliminated from the raw measurement. For permanent link configuration, the contributions from the CAT-6 universal link adapter and the link cord are removed from the raw measurement.
There are several benefits of this approach. It overcomes the issues associated with computational inaccuracies because a Fourier transform is not required. The distance profiling in the frequency domain is more accurate in resolving the cross-talk sources that are placed very near to each other.

## Summary

Field testing of high quality copper cabling meeting or exceeding CAT-6 or Class-E standards requirements needs new levels of accuracy. One of the main factors affecting the accuracy of NEXT and Return Loss measurements is the effect of test interfaces.
To accomplish accurate removal of the effects of the test interfaces, a field tester needs to do a distance profiling of the raw measurement, and selectively remove the components of the measurement corresponding to the test interface.
The WireScope 350 implements novel technique, eACT, to remove the effects of test interfaces from the NEXT and Return Loss measurements in frequency domain. In the channel configuration, eACT removes the effects of channel adapters and plug-jack

mated connection at both local and remote test interfaces. In the permanent link mode, it removes the effects of permanent link adapters including the link cords from both ends of the tester. This results in significantly enhanced measurement accuracy for both link and channel mode testing of NEXT and Return Loss.

WireScope 350 software version 3.1.1 includes the eACT technology. This software version is available as a free upgrade from WireScope website [www.agilent.com/comms/wirescope](http://www.agilent.com/comms/wirescope).