

Structured Cable Certification Tests

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INTRODUCTION

Structured cabling or data cabling (also known Local Area Network or LAN Cabling) is increasing in its deployment for business, commercial and residential use to carry signaling for networks which use a data format to transmit information around the infrastructure of the building. This data network is normally installed to meet industry performance criteria identified under IEEE, TIA or ISO standards. These standards identify transmission rates to be achieved, allowing the network designer to ensure performance meets requirements. To determine these transmission rates, it is necessary to identify potential restricting conditions which are usually the result of inadequate installation material or techniques.

PARAMETERS

The following is a brief overview of the key parameters which need to be evaluated to certify low voltage structured cable installations. These parameters result in a fixed range of tests necessary to certify the installation to relevant standards. This paper will cover the following:

- Wiremap
- Length
- DC Loop Resistance
- Signal (Propagation) Delay
- Attenuation - Insertion Loss
- Near End Cross Talk - NEXT
- Attenuation to Crosstalk Ratio (ACR)
- Power Sum NEXT (PSNEXT)
- Return Loss
- Far End Crosstalk (FEXT)
- Equal Level Far End Crosstalk (ELFEXT)
- Power Sum Equal Level Crosstalk (PSELFEXT)
- Alien Crosstalk – AXT

Wiremap

Wiremap is used to identify installation wiring errors.

For each of the 8 conductors in the link, wire map should indicate:

- Proper pin termination at each end
- Continuity to the remote end
- Shorts between any two or more conductors
- Transposed pairs:
 - Crossed pairs.
 - Reversed pairs
- Shorted pairs
- Any other miswires

Figure 1 represents examples of correct and incorrect wiring.

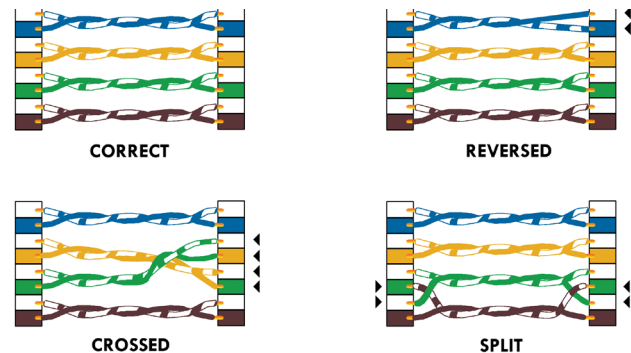


Figure 1: Typical Wiring Possibilities

In most cases you will expect to see straight through connections. With simple tools, such as LED display testers, a lamp will light up indicating a short or open. Advanced tests, such as reversed or split pairs, are often not available in such equipment. While these simple tools are usually adequate, it must be noted that a passing result does not necessarily guarantee a correct wiring installation. For example, split pair detection requires the measurement of NEXT or Impedance, which is beyond the capability of low-end testers. Split pairs will cause a high degree of NEXT (typically over 22 dB) which will severely limit available bandwidth on the installed cabling.

In the case of Screened Twisted Pair cabling you will need to verify screen continuity. This is usually only available on more advanced certification tools.

Wire map is a fundamental test, but it is important to note that correct wiring does not verify bandwidth performance. Frequency-dependent tests such as

NEXT, attenuation, and return loss are keys to ensuring that the cabling is capable of supporting high-speed applications.

Length

Length is defined as the physical or sheath length of the cable. It should correspond to the length derived from the length markings commonly found on the outside jacket of the cable. Physical length is in contrast to electrical or helical length, which is the length of the copper conductors. Physical length will always be slightly less than electrical length, due to the twisting of the conductors.

To measure length, a test set first measures delay, then uses the cable's nominal velocity of propagation to calculate length. Nominal Velocity of Propagation (NVP) refers to the inherent speed of signal travel relative to the speed of light in a vacuum (designated as a lower case c). NVP is expressed as a percentage of c , for example, 72%, or 0.72 c . Typical structured wiring cables will have NVP values in the range of 0.6 c to 0.9 c . Similarly, if you know the physical length and the delay of a cable you can calculate the NVP.

In most instances, length is derived from the shortest electrical length pair in the cable. Because of delay skew, the length of the four pairs often appears slightly different. This is normal and no cause for concern with the exception of significant (over 10%) variances. Provided the variance is within the 10% allowance, the electrical length of the shortest pair is taken to be specification for the cable.

DC Loop Resistance

DC Loop Resistance is the total resistance through two conductors looped at one end of the link. This is usually a function of the conductor diameter and varies only with distance. This measurement is sometimes done to ensure there are no gross misconnections which can add significant resistance to the link. Note that the wire map test automatically isolates breaks but not high resistance connections.

DC resistance is often confused with impedance, a term describing the dynamic resistance to signal flow, usually at a specified frequency. DC loop resistance should not be confused with electrical impedance. Although both are measured in ohms, and both reflect a hindrance or restriction to the signal, DC resistance increases proportionately with the length of the cable tested while

impedance remains fairly constant regardless of length.

From a signal perspective, attenuation (sometimes called insertion loss) is now a more useful measurement, and DC resistance has become less important.

Signal (Propagation) Delay

Propagation delay, or delay, is a measure of the time required for a signal to travel from one end of the circuit to the other. Delay is measured in nanoseconds (nS). Typical delay for category 5e UTP is a bit less than 5 nS per meter (worst case allowed is 5.7 nS/m). A 100 meter cable might have delay as Figure 2.

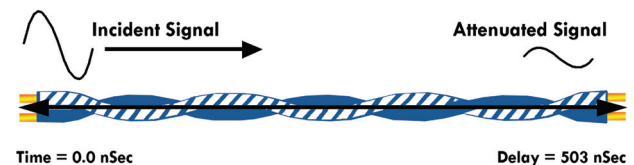


Figure 2: Signal (Propagation) Delay

Delay is the principle reason for a length limitation in LAN cabling. In the majority of networking applications, such as those employing CSMA/CD, there is a maximum delay that can be supported without losing control of communications.

Nominal Velocity of Propagation (NVP), on the other hand, is different. NVP refers to the inherent speed of signal travel relative to the speed of light in a vacuum (designated as a lower case c). NVP is expressed as a percentage of c , for example, 72%, or 0.72 c . All structured wiring cables will have NVP values in the range of 0.6 c to 0.9 c .

Propagation Delay Skew (skew) is the difference between the propagation delay on the fastest and slowest pairs in a UTP cable. Some cable constructions employ different types of insulation materials on different pairs. This effect contributes to unique twist ratios per pair and to skew.

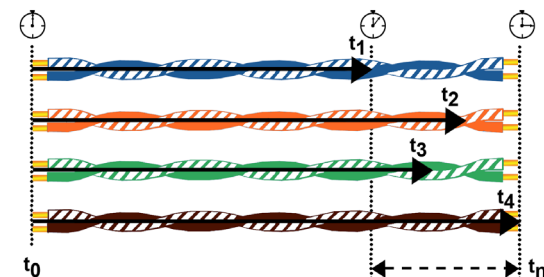


Figure 3: Result of Propagation Factor

Delay measurements are relatively straightforward. Most structured wiring standards expect a maximum horizontal delay of 570 nS. If design specifications allow, higher delay can be acceptable.

Since each pair in the cable has its own unique twist ratio, the delay will vary in each pair. This variance (delay skew, discussed in the next section) should not exceed 50 nS on any link segment up to 100 meters. Standards require all pairs to meet the requirement. It is possible to report just the worst case pair. This will be the pair with the highest propagation delay.

Attenuation - Insertion Loss

Recent changes in the standards now use the term “insertion loss” and not attenuation. Given that test equipment manufacturers have used the term attenuation since 1993, attenuation will continue to be seen on test reports.

Electrical signals transmitted by a link lose some of their energy as they travel along the link. Insertion loss measures the amount of energy that is lost as the signal arrives at the receiving end of the cabling link. The insertion loss measurement quantifies the effect of the resistance the cabling link offers to the transmission of the electrical signals.

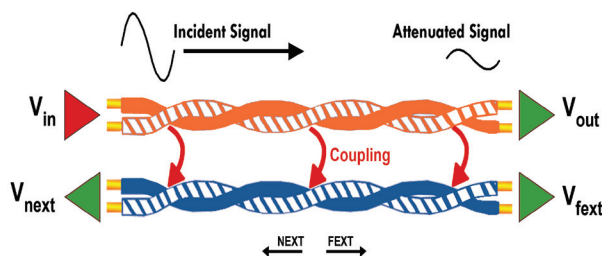


Figure 4: Insertion Loss

Insertion loss characteristics of a link change with the frequency of the signal to be transmitted; e.g. higher frequency signals experience much more resistance. Stated a different way, the links show more insertion loss for higher frequency signals. Insertion loss is therefore to be measured over the applicable frequency range. If you test the insertion loss of a Category 5e channel, for instance, the insertion loss needs to be verified for signals ranging from 1 MHz to 100 MHz. For Cat 3 links the frequency range is 1 through 16 MHz. Insertion loss also increases fairly linearly with the length of the link. In other words, if link “A” is twice as long as link “B”, and all other characteristics are the same, the insertion loss of link “A” will turn out twice

as high as the insertion loss of link “B.”

Insertion loss is expressed in decibels or dB. The decibel is a logarithmic expression of the ratio of output power (power of the signal received at the end of the link) divided by input power (the power launched into the cable by the transmitter).

Near End Cross Talk - NEXT

When a current flows through a wire, an electromagnetic field is created that can interfere with signals on adjacent wires. As frequency increases, this effect becomes stronger. Each pair is twisted because this allows opposing fields in the wire pair to cancel each other. The tighter the twist, the more effective the cancellation and the higher the data rate supported by the cable. Maintaining this twist ratio is the single most important factor for a successful installation.

If wires are not tightly twisted, the result is Near End Crosstalk (NEXT). Most of us have experienced a telephone call where we could hear another conversation faintly in the background. This is crosstalk. In fact, the name crosstalk derives from telephony applications where ‘talk’ came ‘across’. In LANs, NEXT occurs when a strong signal on one pair of wires is picked up by an adjacent pair of wires. NEXT is the portion of the transmitted signal that is electromagnetically coupled back into the received signal.

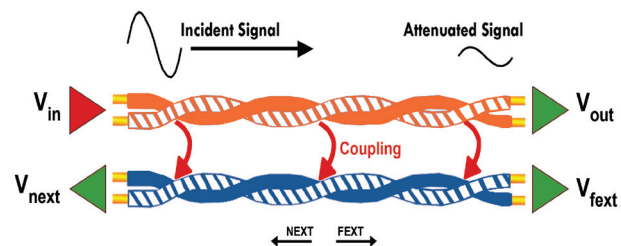


Figure 5: Near End Cross Talk - NEXT

Since NEXT is a measure of difference in signal strength between a disturbing pair and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because NEXT varies significantly with frequency, it is important to measure it across a range of frequencies, typically 1 – 100 MHz. If you look at the NEXT on a 50 meter segment of twisted pair cabling, it has a characteristic “roller coaster going uphill” shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because twisted pair coupling becomes less effective for higher frequencies.

The field tester should compare successive readings across the frequency range against a typical pass/fail line, such as the Class D specification. If the NEXT curve crosses the pass/fail line at any point, then the link does not meet the stated requirement. Since NEXT characteristics are unique to each end of the link, six NEXT results should be obtained at each end.

Attenuation to Crosstalk Ratio (ACR)

Attenuation to Crosstalk Ratio (ACR) is the difference between NEXT and the attenuation for the pair in the link under test. Due to the effects of attenuation, signals are at their weakest at the receiver end of the link. Signals that survive attenuation must not get lost due to the effects of NEXT.

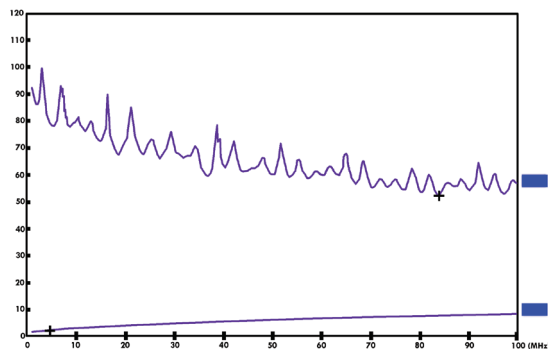


Figure 6: Attenuation to Crosstalk Ratio (ACR)

Using PSNEXT and attenuation, Power Sum ACR (PSACR) can also be calculated. PSACR is not required by TIA/EIA 568-B. Some field testers will report it anyway. However, if you desire PSACR you will need to specify its requirement in the statement of works document.

During signal transmission over twisted pair cable, both attenuation and crosstalk are active simultaneously. The combined effect of these two parameters is a very good indicator of the real transmission quality of the link. This combined effect is characterized by the Attenuation-to-Crosstalk Ratio (ACR). ACR is nearly analogous to the definition of signal-to-noise ratio. (ACR excludes the effect of external noise that may impact the signal transmission.)

Power Sum NEXT (PSNEXT)

Power Sum NEXT (PSNEXT) is a calculation, not a measurement. PSNEXT is derived from the summation of the individual NEXT effects on each pair by the other three pairs. PSNEXT is an important measurement

for qualifying cabling intended to support 4 pair transmission schemes such as Gigabit Ethernet, although IEE 8023.ab does not specifically require PSNEXT. If you run the specific Gigabit Ethernet test within the field tester, you will see that PSNEXT is not recorded.

There are four PSNEXT results at each end of the link per link tested.

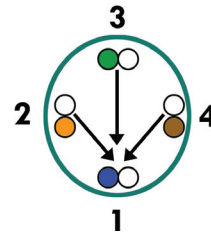


Figure 7: Power Sum NEXT

Since PSNEXT is a measure of difference in signal strength between disturbing pairs and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because PSNEXT varies significantly with frequency, it is important to measure it across a range of frequencies, which vary depending on the wiring standard used. If you look at the PSNEXT on a 50 meter segment of twisted pair cabling, it has a characteristic “roller coaster” shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because twisted pair coupling becomes less effective for higher frequencies. Typically, PSNEXT results are around 3 dB lower than the worst-case NEXT result at each end of the link.

Return Loss

The impact of incorrect characteristic impedance is more accurately measured and represented by the quantity return loss. Return Loss (RL) is a measure of all reflections that are caused by the impedance mismatches at all locations along the link and is expressed in decibels (dB). Return Loss is of particular concern in the implementation of Gigabit Ethernet.

All standards define the formulae to calculate the

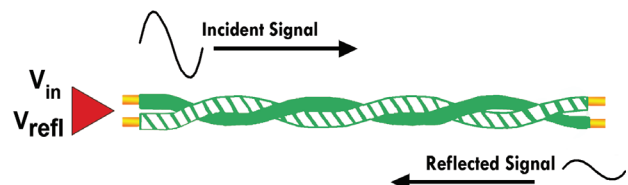


Figure 8: Return Loss

allowable return loss for each cabling link model (Channel and Permanent Link) over the frequency range. A field test instrument may report a passing return loss test result in one of two ways: (1) the worst case return loss margin or (2) the worst case return loss value.

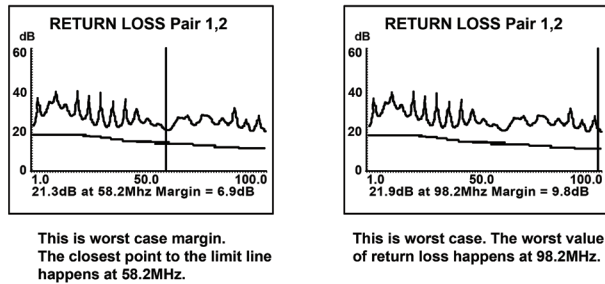


Figure 9: Loss margin / Loss Value

Far End Crosstalk (FEXT)

Far End Crosstalk is similar to Near End Cross Talk (NEXT), except that the signal is sent from the local end and crosstalk is measured at the far end.

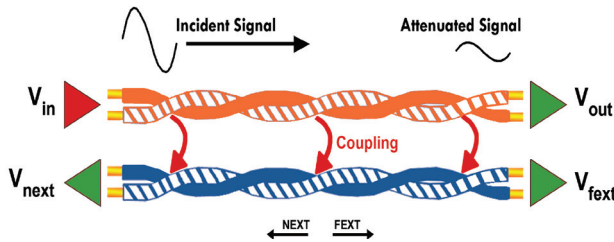


Figure 10: Far End Crosstalk (FEXT)

For this reason, FEXT results are not meaningful without an indication of the corresponding attenuation on the link. Thus, FEXT is measured but rarely reported. FEXT results are used to derive Equal Level Far End Crosstalk (ELFEXT).

Equal Level Far End Crosstalk (ELFEXT)

ELFEXT is a calculated result, rather than a measurement. It is derived by subtracting the attenuation of the disturbing pair from the Far End Crosstalk (FEXT) this pair induces in an adjacent pair. This normalizes the results for length. Consider the FEXT and attenuation measured on two links constructed of the same materials with the same workmanship, but different lengths. Another way to understand ELFEXT is to think of it as the same thing as far-end Attenuation Crosstalk Ratio (ACR). 50 m link example:

If ...

$$\text{FEXT} = 45 \text{ dB and}$$

$$\text{Attenuation} = 11 \text{ dB, then}$$

$$\text{ELFEXT} = 45 - 11 = 34 \text{ dB}$$

Compare the results of measurements made from both ends of the link to the appropriate ISO or TIA limits. There are 12 ELFEXT measurements made from each end, for a total of 24. This is because the attenuation can vary slightly depending upon which pair is energized. So as an example, the field tester will energize Pair 1 and listen on Pair 2 at the far end. Then it will energize Pair 2 and listen on Pair 1 at the far end.

ELFEXT that is too high is indicative of either excessive attenuation, higher than expected FEXT, or both.

Power Sum Equal Level Crosstalk (PSELFEXT)

Power Sum ELFEXT (PSELFEXT) is actually a calculation, not a measurement. PSELFEXT is derived from an algebraic summation of the individual ELFEXT effects on each pair by the other three pairs. There are four PSELFEXT results for each end. Typically, PSELFEXT results are around 3 dB lower than the worst-case ELFEXT result at each end of the link.

Alien Crosstalk - AXT

The introduction of 10GBASE-T signalling over twisted pair copper cabling has caused a previously low energy noise source to become significant due to the extended frequency range (1- 500 MHz) of 10GBASE-T. The noise source called alien crosstalk is defined as unwanted signals coupling from one balanced twisted-pair component, channel or permanent link to another. The link(s) that are the source of the unwanted alien crosstalk are referred to as the disturber or disturbing link(s). The link that is the recipient of the unwanted alien crosstalk is referred to as the disturbed or victim link. When deploying 10GBASE-T alien crosstalk must be tested and evaluated to ensure that the 10GBASE-T network will function as designed. Alien crosstalk measurements are specified as a power sum measurement in order to approximate the worst case coupled energy if all pairs of the disturbing cable were energized. The resulting measurements are Power Sum Alien Near End Crosstalk (PS ANEXT), Power Sum Alien Attenuation-to-Crosstalk Ratio-Far End (PSAACRF), PSANEXT average and PSAACRF average measured from both ends of the link designated to support 10GBASE-T.

Alien crosstalk occurs in a cable when a disturbed cable susceptible to stray signals and disturbing cables emitting potential interfering signals are in close proximity to each other for a given length. Alien crosstalk coupling typically increases with cable length.

Significant alien crosstalk may occur when cables are bundled together. In a cable bundle, the proximity of cables and the length of the cables create the potential for strong alien crosstalk coupling. Worst case coupling occurs when six disturbing links surround a disturbed or victim link.

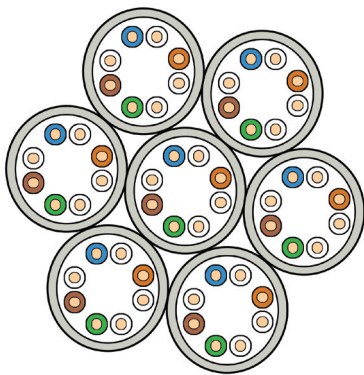


Figure 11: Alien Crosstalk

Alien crosstalk may also occur in patch panels when a disturbed link connection and disturbing link connections are in close proximity to each other. In a patch panel the proximity of the connectors creates the potential for strong alien crosstalk coupling.

Methods for mitigating alien crosstalk are found in the standards and guidelines.

Summary

With the series of test outlined above, transmission parameters for modern structured cabling systems can be evaluated and weak point identified by comparing the results to published industry standards. Worst case results highlighted by the latest test equipment allow rapid certification as well as enhancing diagnostic capabilities by pinpointing these measurements and detailing distance from either primary or secondary test source.

As can be seen, the tests detailed are complex and therefore it is vital that a true certification tester is used to determine the full capabilities of the installation under test. Diagnostic aids are also important to provide additional guidance where remedial work is required.

Structured Cable Testing Products from Megger include a range of high performance testers for certifying and evaluating copper and fiber cabling installations. Alien Crosstalk measurements are also available with the addition of a simple small kit.

For more information, please contact:

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