White Paper

Testing Challenges for 10 Gb/s Ethernet over Twisted-Pair Cabling

New installation and testing guidelines help combat Alien Crosstalk (AXTalk)

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Introduction to 10GBASE-T field testing and certification

The transmission capabilities of a cabling link cannot be defined in isolation. The transmitter encodes the digital information, generates the electrical signals to be transmitted and sends these signals on the cabling link. The physical link must be able to transmit the signal from the transmitter to the receiver over the desired distance and deliver the signal quality at its end, the input of the receiver. The receiver must also meet a set of performance parameters such that a signal arriving over the link meets the specs, the receiver can successfully perform its task. Transmitter requirements, signal encoding, receiver capabilities and link transmission characteristics must be studied and considered as an integrated system.

The Institute of Electrical and Electronics Engineers (IEEE) develops and maintains the IEEE 802.3 Ethernet standard. The 10 Gb/s Ethernet work group will create the 802.3an standard. The IEEE harnesses the expertise to design and specify the active electronics subsystems and engages the cabling standards bodies such as the Telecommunication Industry Association (TIA) and the International Standards Organization (ISO) to develop the performance specifications for the cabling channel.

Fluke Networks has been actively involved in the TIA and ISO study committees since their beginnings. Fluke Networks' contributions have led to the development of a practical and efficient methodology to measure *Alien Crosstalk (AXTalk)*. Alien Crosstalk has emerged as a critical performance parameter to allow a twisted-pair cabling link to transmit the 10 Gb/s Ethernet (10GbE) signaling. We will explain the nature of these parameters, as well as the test methodology.

The field certification of installed twisted-pair cabling for 10GBASE-T includes all the test parameters currently specified in the TIA/EIA-568-B document for Cat 6. They are Insertion Loss, Return Loss, Pair-to-pair NEXT, Power Sum NEXT, Pair-to-pair ELFEXT, Power Sum ELFEXT, Propagation Delay, Length and Delay Skew. The 10GBASE-T test limits are identical to the limits for Cat 6 up to 250 MHz, but the frequency range and performance requirements for these tests is extended to 500 MHz to support the much higher data rates of the 10 Gb/s Ethernet technology. In addition, the Alien Crosstalk test parameters discussed in this paper must be included with the field certification effort for 10 Gb/s Ethernet.

Understanding Alien Crosstalk and how it impacts 10 Gb/s performance

10GBASE-T signaling requires cabling bandwidth up to 500 MHz, which is much higher than the 100 MHz bandwidth required for 1000BASE-T (1Gigabit/sec Ethernet). Because of these very high frequencies, one significant new disturbance must be added to the cabling test parameters. This new set of test parameters is called Alien Crosstalk.

Crosstalk measures signal coupling from one wire-pair to another within a twisted-pair cabling link. This kind of coupling is undesirable since it creates a noise disturbance in a wire pair. The effect of crosstalk is very similar to a noisy transmission line. A receiver may not be able to distinguish the signal sent by the transmitter at the other end of the link from the noise induced by crosstalk. In data communications, crosstalk is a critical performance parameter. The amount of crosstalk increases with the frequency of the transmitted signal while the higher frequency signals are subject to greater attenuation (become weaker as they travel along the link). The combination of these two effects is the reason that we will find a frequency at which the noise created by crosstalk equals the signal received from the transmitter. This frequency is typically around 120 MHz for 100 m Cat 5e channels and around 240 MHz for full length Cat 6 channels.

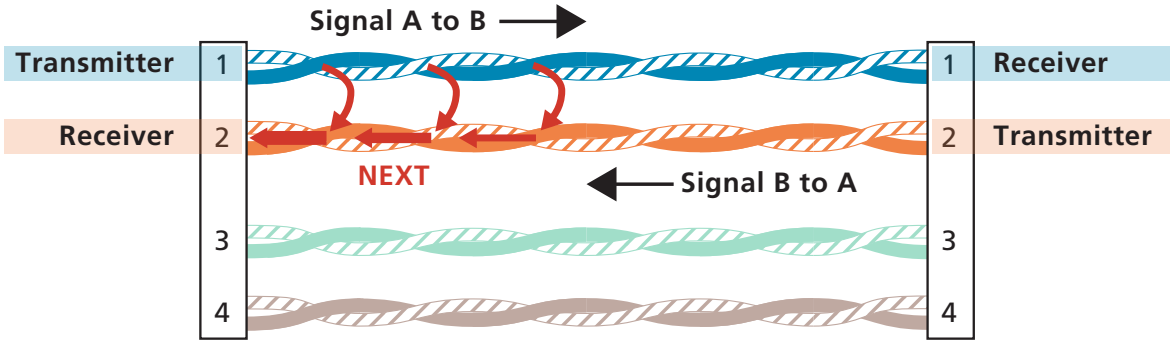

Figure 1 – Near-End Crosstalk (NEXT) measures the crosstalk induced by "signal A to B" in pair 2 that returns to the receiver side and competes with "Signal B to A" arriving at the same receiver over pair 2.

Without sophisticated digital signal processing techniques in the electronics, reliable transmission is no longer possible around that frequency and for higher frequencies. This phenomenon sets a limit in bandwidth for twisted-pair cabling.

Near-End Crosstalk or NEXT measures the crosstalk signal that appears at the same end of the cabling link from which the test or disturbing signal is launched. Figure 1 illustrates Near-End Crosstalk in a two wire-pair system. If transmission simultaneously takes place over multiple wire-pairs as is the case in 1000BASE-T and 10GBASE-T, Far-End Crosstalk (FEXT) must be considered and tested as well (see Figure 2).

The crosstalk depicted in figures 1 and 2 takes place between wire-pairs in one cable (wire-pairs wrapped in the same sheath). Alien Crosstalk is the exact same phenomenon, but the crosstalk coupling now occurs between wire-pairs in different, adjacent cabling links.

Alien Crosstalk is a challenge for unshielded twisted-pair cabling (UTP) as it is the most significant disturbance or noise source for the 10GbE application when using UTP cabling. Figure 3 shows the Alien Crosstalk in a wire pair induced by wire pairs in adjacent cables.

Alien Crosstalk will be measured as Alien NEXT between wire pairs, as well as Alien FEXT. Since the combined impact of many wire-pairs in the bundle upon the wire-pair under test (usually referred to as the *victim* wire-pair) must be assessed, Power Sum Alien NEXT (PSANEXT) and Power Sum Alien FEXT (PSAFEXT) should be computed and evaluated for wire-pairs in a cabling bundle.

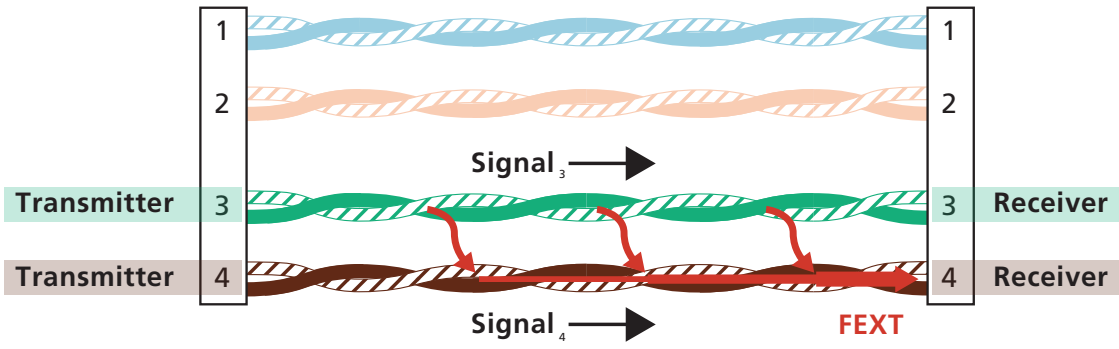

Figure 2 – Far-End Crosstalk (FEXT) measures the crosstalk induced in wire-pair 4 that travels the length of the cable in the direction of the transmitted signal and competes with the clarity of "Signal 4" arriving at Receiver 4.

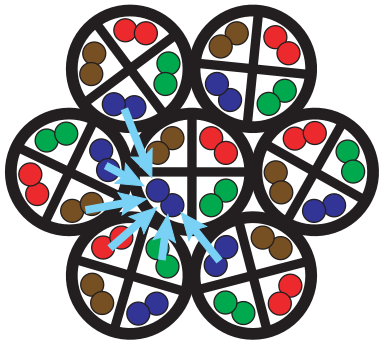

Figure 3 – Alien Crosstalk measures the crosstalk signal induced in a wire-pair in the "victim" cable by wire-pairs in adjacent cables in the bundle or pathway. Alien Crosstalk is also defined and measured as Alien NEXT and Alien FEXT.

Testing Alien Crosstalk

This section describes a method to measure Alien Crosstalk as well as a test strategy. The measurement method describes the hardware and software configuration of the test tools to measure the crosstalk between wire pairs in adjacent cables. The test strategy discusses the way in which the test of a cabling installation may be approached. In most cases, it is not economically feasible or affordable to test the Alien Crosstalk between all possible wire-pair combinations.

Fluke Networks developed experimental measurement tools and techniques based on the DTX-1800 CableAnayzer™ tester which offers the bandwidth to test Alien Crosstalk parameters. The measurement techniques have evolved and are currently used by many cabling manufacturers to characterize Alien Crosstalk parameters in the laboratory as well as in field trials. Alien Crosstalk Modules will be offered with the DTX-1800 when the development cycle is completed.

Measurement method

When certification testers are used to test the NEXT performance of a cable, the main and remote are connected at either end of the same cable and the two units use the link-under-test to synchronize their measurement processes. To measure Alien NEXT, the main and remote DTX-1800 units are to be connected to different cables using the DTX Permanent Link Adapters as depicted in Figure 4. A method needs to be provided between the main and remote units to allow these two units to synchronize the measurement process. A special Alien Crosstalk Module plugs into the back of the DTX-1800 units in the same place where a fiber optic loss test module such as the DTX-MFM can be inserted. After each unit has been equipped with an Alien Crosstalk Module, a standard patch cord may be used to connect these two modules and complete the linkage required for the synchronization. The far ends of the cabling links-under-test are now not connected to a tester unit. An open circuit at the end of a link creates a very significant reflection of the test signals. A special termination

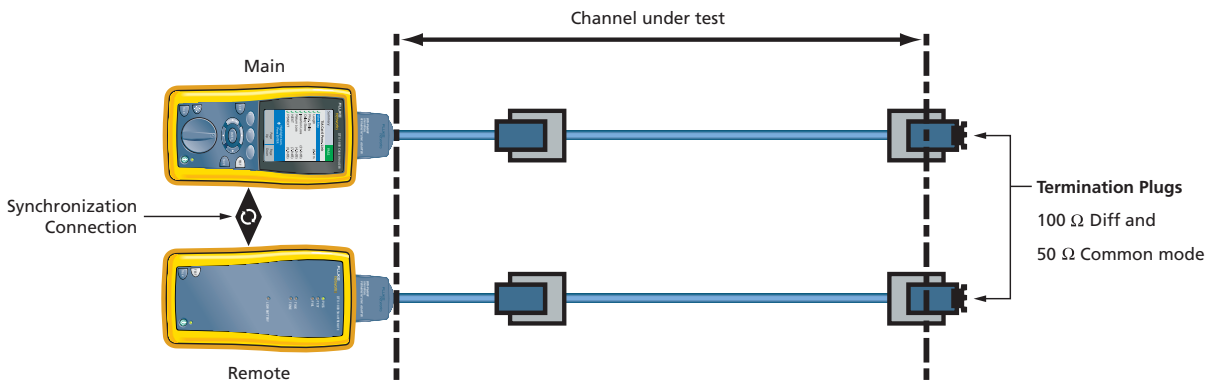

Figure 4 – Pair-to-pair Alien NEXT measurements. The main and remote units are sitting side-by-side at one end of the cabling bundle under test. These units are plugged into different cables. A standard patch cord connects the synchronization of the Alien Crosstalk Modules plugged into each of the testers to allow the testers to perform all of the pair-to-pair NEXT measurements between the wire pairs of two selected cabling links.

plug must be installed at the end of these two links to avoid reflections from the far end which would interfere with the measurement process and jeopardize its accuracy. Figure 4 depicts the connections of the main and remote units of a DTX-1800 tester configured to test the pair-to-pair Alien NEXT between two cables in a bundle. All the possible wire-pair combinations for NEXT between two cabling links count 16 combinations. Configured as depicted in Figure 4, the DTX-1800 measures the 16 pair-to-pair Alien NEXT combinations over the frequency range from 1 through 500 MHz in approximately 30 seconds.

Figure 5 shows the connections of the DTX testers to measure the pair-to-pair Alien FEXT between cables in a bundle. The two tester units are now connected at different ends of the bundle. The tester units must be configured with the same Alien Crosstalk Modules we described above for the Alien NEXT measurements. A spare cabling link or a link that is not used in the measurements can be used to provide the synchronization path between the main and remote DTX-1800 units. The open ends of the links involved in the test must be terminated by the same type of plug as used for Alien NEXT testing. This method has been used in the field with very good results. A very significant performance parameter of the tester is the noise floor which allows the tester to measure the small pair-to-pair Alien Crosstalk signals very accurately.

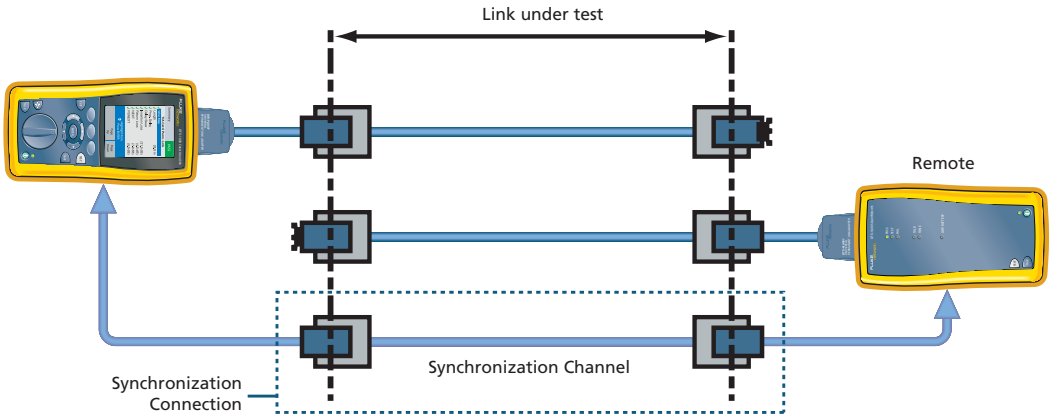

Figure 5 – Pair-to-pair Alien FEXT measurements. The main and remote units are plugged into different cabling links at opposite ends of bundle under test. A spare channel in this bundle connects the synchronization modules plugged into each of the testers to allow the testers to perform all of the pair-to-pair FEXT measurements between the wire pairs of two selected cabling links.

Power Sum measurements

As we mentioned above, the Alien Crosstalk evaluation of a cabling bundle does not stop with the measurement of the Alien Crosstalk coupling between individual wire pairs. During full network operation all wire-pairs in a cabling bundle simultaneously transmit in full duplex (signals flow in both directions on each wire pair). Therefore, any one wire-pair will be affected by transmissions on numerous wire-pairs surrounding it in the bundle. This combined affect of the surrounding cables is captured by calculating the Power Sum Alien NEXT (PSANEXT) and Power Sum Alien FEXT (PSAFEXT) parameters.

The DTX-1800 main unit must be connected to a laptop computer using the USB connection. The software running in the computer will import the pair-to-pair NEXT or FEXT measurement results data and calculate the Power Sum test results as more cables in the bundle are included in the test.

Alien Crosstalk test strategy

The effort to obtain the Power Sum test results for each wire pair in a bundle can very quickly mushroom into a time- and resource-consuming task. As mentioned above, each additional cabling link to be added to the Power Sum calculations requires 16 pair-to-pair measurements.

If the cables shown in Figure 3 remain in the same relative position for the total length of the link, they form the six-around-one configuration which is considered a worst case configuration for studying Alien Crosstalk. This configuration is considered a worst case configuration because it is very unlikely that seven cables in a bundle will stay in such a tight configuration over the full length of a cabling bundle. The cabling link in the center of this configuration is defined as the *victim* cable. In order to calculate the Power Sum Alien NEXT for the four wire-pairs in this victim cable, we need to measure 96 (6 times 16) pair-to-pair Alien NEXT combinations. The total test time using the method described above is about 180 seconds or three minutes plus, of course some time to (re)connect test leads and to upload test results to the PC. That part is great but we have only considered one victim cable in a very small bundle. Most bundles in a typical installation contain many more than seven cabling links.

On the one hand, the standards recognize that Alien Crosstalk is going to be a very significant performance parameter in the 10GBE transmission over twisted-pair cabling. Therefore, some field testing of these performance parameters must be required to provide assurance that the cabling installation will be able to support this high-speed network application. On the other hand, a reasonable test time is very desirable.

Alien Crosstalk sampling guidelines

A practical test strategy of Alien Crosstalk consists of selecting samples of representative links including the most "suspect" cabling links. The overall test strategy contains the following elements:

1. Only test the longer links that must be qualified for 10GBASE-T operation; shorter links (less than 50 m) will most likely not pose a problem. Note that the insertion loss of a link increases with length and with signal frequency. This means that the signals arriving at the end of a longer link are weaker, which lowers the ratio of the signal to the strength of the Alien Crosstalk disturbance. The standard will define the insertion loss value above which Alien Crosstalk becomes a suspect disturbance factor.
2. When a large number of links within a cable bundle need to be qualified for 10GBASE-T operation, choose a few of the longer links as victim cables and observe whether similar PSAXtalk performance is obtained for each of them. When the cable bundles contain a large number of cables, some averaging of all Alien Crosstalk occurs. As a result, PSAXtalk properties of different victim cables tend to be somewhat similar. When the PSAXTalk results for the chosen victim cables show consistency and pass the test limit values, no additional testing will be needed.
3. PSANEXT needs to be measured for longer links (over 50 m or 160 ft). This is certainly the case for category 6 cabling "as currently installed." Start testing using disturber links next to the victim link where a large number of cables join (i.e., at a patch panel). Add disturber links as long as it appears that the PSANEXT result appears to be affected or changing.
4. PSAFEXT needs to be measured for longer links that are bundled with shorter links. Select the shorter disturber links next to the victim link where a large number of cables join (i.e., at a patch panel). Add disturber links to the result as long as it appears that the PSAFEXT result appears to be affected. Since the frequency response for this test parameter is very predictable, a single value at 100 MHz may be observed to make the decision.

Currently Installed Cabling	Channel Length (m)	Comments
Class F	100	Supported (IEEE Objective) - Will meet AXTalk with limited sample testing in the field for patch panel compliance
Class E/Cat 6 UTP	55	Supported (IEEE Objective) - AXTalk sample testing required using the recommended test strategy rules
Class E/Class 6 ScTP	100	Will meet AXTalk with limited sample testing in the field for patch panel compliance
Class E/Cat 6 UTP	55 to 100	All the links longer than 55 m must be included in the field test AXTalk test
Future Cabling		
Augmented Class E/Cat 6	100	AXTalk sample testing required using the recommended test strategy rules

Table 1 - Cable types expected to support 10 GBASE-T

Applicable cable types

The IEEE considered the cabling types listed in Table 1 for 10GBASE-T. The comment phrase "Supported (IEEE Objective)" for some cable types in Table 1 means that the requirements for the electronics (transmitters and receivers) have been specified in such a way that they properly operate with the specified cabling channel in a six-around-one configuration. As you can see, a 55 m Cat 6 channel is one of the cabling links that "by design" should meet the requirements for 10GBASE-T.

In other words, if you are designing the cabling infrastructure for a data center in which all links are 55 m or less, existing Cat 6 UTP cabling may be satisfactory. The installation will need to be executed with meticulous attention to installation and termination quality. And, although the Augmented Cat 6 or Cat 6A component specifications have not yet been finalized or published, it would be advisable to specify and use the newest patch panels and connecting hardware that is advertised as Cat 6A in order to minimize Alien Crosstalk at the patch panels. Last but not least, the cabling performance of such mission critical installations should be certified in the field using the Alien Crosstalk test strategies outlined above. The Fluke DTX-1800 CableAnalyzer™ supports the two draft cabling standards for 10GBASET. Check the Fluke Networks website to ensure your tester runs the latest software and contains the latest test standard specifications (test database).

Two draft standard documents address the cabling performance requirements for 10GBASE-T. The first document is a "Telecommunication Systems Bulletin" (TSB) developed by the Telecommunication Industry Association (TIA) referred to as TIA TSB-155. The second document is Appendix 10 to the TIA/EIA-568-B.2 standard (TIA/EIA-568-B.2-10). Why do we have two documents to address this need? The first document, TSB-155, addresses the requirements for a cabling link to support the transmission requirements of 10 Gb/s Ethernet possibly with a link length restriction. You may view this document as specifying how Cat 6 links can be certified for the10GBASE-T application. The second TIA document (Appendix 10) defines a new cabling category, called Augmented Cat 6 or Cat 6A, that offers more performance than Cat 6, and is designed to support a 100 m 10GBASE-T channel. Augmented Cat 6 provides a higher margin above the minimum requirements of 10 Gb/s Ethernet both for the Alien Crosstalk parameters as well as for the performance of the in-channel test parameters above 250 MHz.

Recommendations

When using Cat 6 or Cat 6A cable, special attention must be applied to design the cabling system to minimize Alien Crosstalk. The recommendations to mitigate Alien Crosstalk disturbance focus on bundling and wire management. Recall that the test requirements for 10GBASE-T extend to 500 MHz and all the established installation procedures to deliver a quality cabling link must be meticulously observed.

Only cabling links in the same bundle are expected to contribute in a measurable way to Power Sum Alien Crosstalk (PSAXtalk). Therefore, PSAXtalk will be smaller when the number of cabling links in a bundle is smaller. The test strategy we discussed above will be more effective when the number of links per bundle is kept smaller. The optimum number of links per bundle especially of Cat 6 cabling channels may be 12 links, but preferably no more than 24 links.

Tighten the cables in a bundle only loosely; place the tie-wraps 2 or more feet apart.

Most of the Alien NEXT occurs within the first 20 m of the link measured from the end from which you are testing. Modeling and verification of the models has shown that Alien NEXT generated further away from the end from which you are testing has virtually no impact on overall PSANEXT unless the cables run in parallel the full length of bundle. Therefore, the patch cords and patch panel arrangement of links and the resulting wire management in the rack can have a significant influence on the amount of alien crosstalk coupling between the links. Tight proximity increases Alien Crosstalk coupling.

As becomes obvious from many of the sampling or test strategy recommendations we discussed above, it is beneficial to have knowledge of the cabling topology when testing Alien Crosstalk performance at a patch panel. It helps to know which of the cables run in the same bundles. A cable naming scheme can be designed and adopted that includes the identification of the bundle in which the cabling link is routed.

Conclusion

10 Gb/s Ethernet is going to be a demanding network technology for twisted-pair cabling. It will require a very good Cat 6 cabling system that in addition has implemented all of the mitigating measures to limit the impact of Alien Crosstalk disturbance. Alternatively, it will require the newly proposed Augmented Cat 6 cabling plant. In either case, the workmanship of installation is going to play a very significant role in assuring that the cabling installation will support this super fast new network technology flawlessly. Field certification of the in-channel requirements and of the Alien Crosstalk (between-channel) requirements will be the only way to assure that the cabling system will support 10 Gb/s Ethernet.

For the latest developments on the 10GBASE-T Standard, new technical papers, webcasts as well as new product releases, visit **www.flukenetworks.com/10Gig**

NETWORKSUPERVISION

Fluke Networks
P.O. Box 777, Everett, WA USA 98206-0777

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