White Paper

How to Certify or Re-certify Twisted-Pair Cabling for 10 Gb/s Ethernet

And testing guidelines for Alien Crosstalk (AXTalk)

The standards review board of the Institute of Electrical and Electronics Engineers (IEEE) approved the standard for 10 Gigabit/sec Ethernet over twisted-pair copper cabling (10GBASE-T) on June 8, 2006. This paper provides an overview of the methods to measure and certify the performance of the installed cabling system for compliance with the requirements of 10GBASE-T, as well as with the draft specifications of Augmented Cat 6 (Cat 6A) or Augmented Class E (Class E_A).

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The applicable standards

The IEEE project 802.3an document addresses the cabling performance requirements for 10GBASE-T. The test methods described in this article fully implement and comply with the published 10GBASE-T testing requirements.

The cabling industry will create two different standards. The Telecommunications Industry Association (TIA) is currently preparing the release of a "Telecommunication Systems Bulletin" (TSB) referred to as TIA TSB-155. The International Organization for Standardization (ISO) is in the process of developing a "Technical Recommendation" (TR 24750) that parallels the content of TIA TSB-155. The channel specifications in these documents are identical to the requirements established in the IEEE standard. TIA TSB155 and TR 24750 will also include test specifications for the "permanent link" model. The latter documents are to be viewed as additional specification for Cat 6 links to certify compliance for the 10GBASE-T deployment. Length restriction will apply for Cat 6 links when transmitting 10GBASE-T. Although an initial channel limit of 55 m (180 feet) had been discussed, all Cat 6 bundles should be evaluated for compliance as discussed in this paper. Only after these tests pass – compliance has been verified – do you have the assurance that the installed cabling can support 10GBASE-T.

A new "augmented" cabling system

The TIA is currently studying and preparing the specifications for a new cabling type called "Augmented Cat 6," abbreviated as Cat 6A. This standard is planned to be published as Appendix 10 to the TIA/EIA-568-B.2 standard (TIA/EIA-568-B.2-10). As mentioned, this development is under way and it currently in draft 4. The ISO standards committees are undertaking a similar effort for the publication of the "Augmented Class E" standard (abbreviated as Class E_A).

These "augmented" cabling types (Cat 6A and Class E_A) are being defined and developed to deliver better AXTalk performance than Cat 6 or Class E with the goal that a well-installed horizontal channel of 100 m constructed with augmented cabling components meets the AXTalk specifications and supports 10GBASE-T traffic. Note that the specifications for a new cabling type like Cat 6A require that performance requirements be defined for cable, connecting hardware and patch cords. The performance limits (Pass/Fail conditions) for the "channel" are defined at this time and may only need some adjustments for special cases. Many more specifications need to be resolved and defined to complete this standard. We expect this effort may require several more months and is not expected to be "completed" until the middle of 2007.

Cabling certification procedure

First step – in-channel certification

The first step or test phase always requires that 100% of the links designated to transmit 10GBASE-T traffic must be tested against the *in-channel* test performance specifications and all links must pass. The in-channel parameters refer to the test parameters of and between wire pairs within a cabling link. Field certification up to the advent of 10GBASE-T only included in-channel test parameters. These parameters remain the same as currently specified in the TIA/EIA-568-B document for Cat 5e/Cat 6 or in the ISO 11801 standard for Class D, E and F. They are insertion loss, return loss, pair-to-pair NEXT, Power Sum NEXT, pair-to-pair ELFEXT, Power Sum ELFEXT, propagation delay, length, delay skew and wiremap. The 10GBASE-T test limits for these in-channel parameters are identical to the limits for Cat 6 up to 250 MHz. But, the frequency range and performance specifications for these tests is extended to 500 MHz in order to support the much higher bandwidth required for the 10 Gb/s Ethernet signaling rate.

The performance limits or Pass/Fail limits for Cat 6A or Class E_A are more demanding between 250 MHz and 500 MHz than the limits specified for 10GBASE-T.

You can perform the in-channel certification with your DTX-1800 as is. Be sure to update the tester to the latest software revision and select the proper test standard. If you are testing the cabling links as channels (end-to-end cabling with the network patch cables attached and in place), you can either choose the 10GBASE-T "application" standard or the TIA TSB-155 channel test. These two options are identical. You can also choose to perform the in-channel tests for the installed cabling using the permanent link model and select the TSB-155 permanent link test in your DTX1800.

The specifications for the current draft standards for Cat 6A and Class E_A are also included in the DTX-1800 standards library. Augmented cabling types may be tested as channels (with the network patch cords in place) or as permanent links.

The second phase – between-channel certification

In the second test phase, we will evaluate the Alien Crosstalk (AXTalk) performance of the installed Cat 6 cabling installation. First, we will review exactly what is Alien Crosstalk and how it is measured.

Definition of Alien Crosstalk

Crosstalk takes place between wire pairs in one cable (wire pairs wrapped in the same sheath) and is measured by the in-channel test parameters NEXT and FEXT. AXTalk is the exact same phenomenon, but the crosstalk coupling now occurs between wire pairs in different cabling links routed in proximity to each other for part or for all of their length.

AXTalk is a challenge for twisted-pair cabling as it is the most significant disturbance or noise source for the 10 GbE applications. Figure 1 shows how Crosstalk can be induced in a wire pair by wire pairs in adjacent cables.

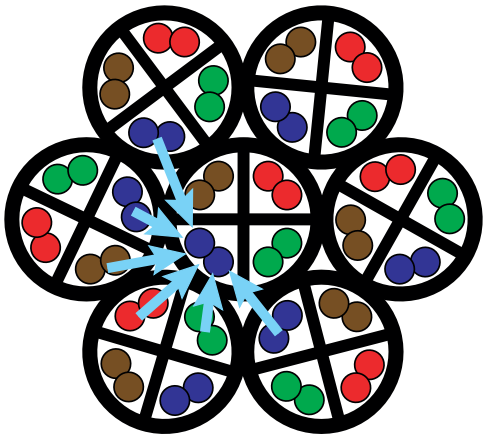

Figure 1.
Alien Crosstalk measures the crosstalk signal induced in a wire pair in the "victim" cable by wire pairs in adjacent cables in the bundle or pathway. Alien Crosstalk is also defined and measured as Alien NEXT and Alien FEXT.

AXTalk will be measured as Alien NEXT (ANEXT) between wire pairs as well as Alien FEXT (AFEXT). 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 a cabling bundle or pathway.

Since the combined impact of many wire pairs in the bundle upon the wire pair under test (referred to as the *disturbed* wire pair) must be assessed, Power Sum Alien NEXT (PSANEXT) and Power Sum Alien ELFEXT (PSAELFEXT) must be computed and evaluated for the wire pair under test. In the TIA and ISO standards the test parameter PSAELFEXT has been named PS AARC-F (Power Sum Alien Attenuation to Crosstalk Ratio – Far end). To simplify the standards terminology of disturbed link or disturbed wire pair and disturber link or wire pair, we will use the words *victim* and *disturber* rather than disturbed and disturber.

Alien Crosstalk measurement method

The measurement method describes the hardware and software configuration of the test tools to measure the crosstalk between wire pairs in adjacent cables.

To measure Alien NEXT, the main and remote tester units are to be connected to different cables as depicted in Figure 2. A special Communication Module plugs into the back of the Fluke Networks DTX-1800 units in the same place where a fiber optic loss test module such as the DTX-MFM2 can be inserted. After each unit has been equipped with an AXTalk Module, a standard patch cord may be used to connect these two modules and complete the linkage required for the measurement 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 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. All the possible wire pair combinations for NEXT between two cabling links count sixteen 16 combinations and are to be measured and evaluated over the frequency range from 1 through 500 MHz.

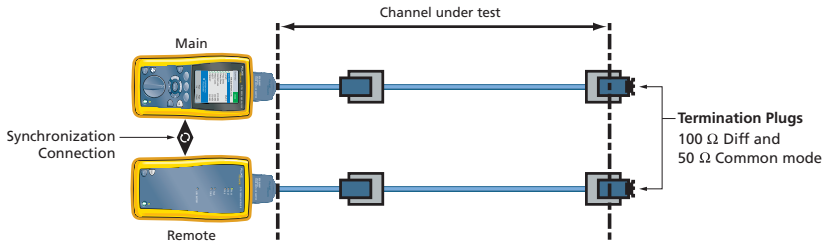

Figure 2. Pair-to-pair Alien NEXT measurements. The main and remote units are sitting side-by-side at one end of the cabling bundle under test. These units are plugged into different cables. A standard patch cord connects the synchronization modules plugged into each of the testers to allow the testers to perform all of the pair-to-pair NEXT measurements between the wire pairs of two selected cabling links.

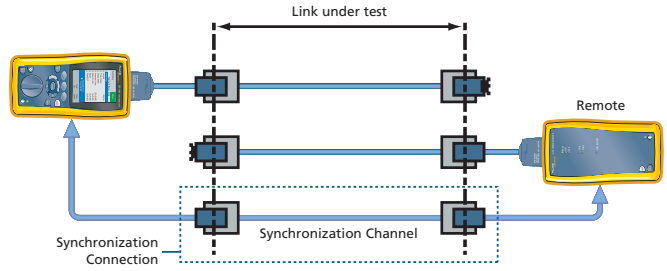

Figure 3. Pair-to-pair Alien FEXT measurements. The main and remote units are plugged into different cabling links at opposite ends of the bundle under test. A spare channel in this bundle connects the synchronization modules plugged into each of the testers to allow the testers to perform all of the pair-to-pair FEXT measurements between the wire pairs of two selected cabling links.

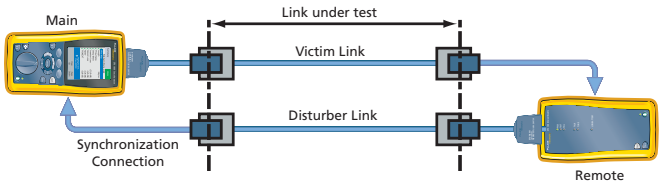

Figure 4. Alternate Pair-to-pair Alien FEXT Measurement. When no "third" or spare link is available to connect the two testers' Alien Crosstalk Communication Modules, these Connection Modules perform a dual role. They provide the test link termination and allow the two tester unit to synchronize the measurement actions. The testers always verify that a valid termination is present at each link. The latter verification requires more time in this alternative mode than in the setup shown in Figure 3.

Figure 3 shows the connections of the testers to measure the pair-to-pair Alien FEXT between cables in a bundle. The two tester units are now connected to the victim and disturber links, but at different ends of the bundle. The tester units must be configured with the same AXTalk Communication Modules we described above to make 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 tester 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. A "spare" link should be readily available when testing Alien FEXT between cables that run in one bundle from one rack to another. This is not the case when testing Alien FEXT between two horizontal links that are terminated in a face plate in a work area.

Figure 4 shows an alternate method to connect the testers for the Alien FEXT measurement. In this configuration, the Crosstalk Communication Modules provide the termination for the cabling links under tests. As the figure depicts, these modules use the victim link and the disturber to maintain communication and synchronization. The DTX test units always verify that each link is properly terminated before conducting the AXTalk tests. Using the configuration shown in Figure 4, this verification takes about 8 or 9 seconds longer than in the case a separate link is available.

Alien Crosstalk test equipment

To perform the AXTalk measurements, the DTX-1800 main unit must be connected to a (laptop) computer using the USB connection. The AxTALK Analyzer™ software running in the computer controls the DTX-1800 testers, imports the pair-to-pair ANEXT or pair-to-pair AFEXT measurement results data and calculates in real time the power sum test results for each wire pair in the disturbed link or the link-under-test. As the crosstalk effects of wire pairs in additional disturber links are measured, the AxTALK Analyzer software automatically adds and displays their effect by calculating the power sum AXTalk test result for all the disturbers included in the test so far on each victim wire pair.

The methods for Alien NEXT (ANEXT) and Alien FEXT (AFEXT) described above have been used in the field with very good results. A very significant performance parameter of the tester is the measurement (noise) floor which allows the tester to measure the small pair-to-pair AXTalk signals very accurately. Fluke Networks developed and markets an accessory kit called DTX-10GKIT that contains the special hardware accessories described in this section to perform the AXTalk measurements. This kit also contains the AxTALK Analyzer software that runs on a Windows-based personal computer.

Alien Crosstalk sampling guidelines

Practical field test results have proven that AXTalk between cables in different bundles or pathways is non-existent or negligible. The AXTalk test methods must be applied to cabling links that are bundled together. To properly test any one "disturbed" or victim link, all of the links that belong to the same bundle as the victim link must be included in the test procedure as disturber links.

A practical test strategy for AXTalk compliance consists of testing installed links that present a greater challenge to comply and therefore present the highest probability of failing. Compliance with 10GBASE-T requirements will be most difficult for the longest links. Compliance with the newly developed Augmented Cat 6 (Cat 6A) or Augmented Class E (Class E_A) cabling standard will be most challenging for the longer cabling links ***and*** for shorter links in which the distance between connectors is smallest. First select and test these most challenging links. All of the less challenging links will perform better and will very likely pass and pass with better margins. Recall that the workmanship of the links in the cabling plant has already been assured by the "in-channel" tests executed to 500 MHz.

Fluke Networks has developed a test strategy for two distinct scenarios.

1. **A limited number of links must be certified to support 10GBASE-T traffic**

   If only a few links in the data center are singled out to carry 10GBASE-T traffic, you can perform the AXTalk tests for those few links. The following cabling links should be included as disturbers in each of these tests:

   a. All the links in the same bundle as the selected link

   b. Links terminated in adjacent positions in the patch panel

   If you plan a limited number of links for 10GBASE-T deployment, testing and maintenance of the cabling plant can be simplified by bundling these links together. The longest link in the bundle must be selected as the victim link (the link you are thoroughly evaluating) and 10% of the cables in such a bundle should be selected as victim links. For example, in a bundle of 12 links, you should select one victim link; in a bundle of 48, you should select 5 victim links.

2. **Testing a complete cabling (sub)system**

   When you are planning to certify a cabling system for 10GBASE-T compliance or you are certifying a Cat 6A or Class E_A installation:

   a. The number of links to be tested as "victim" links is 1% of the total number of links in the cabling installation, or five links, whichever is greater.

   b. The victim links should be tested from the cross-connect (interconnect) patch panel location (telecom room). Testing from the remote end is performed when the cabling runs from patch panel to patch panel which is a more typical case in a data center. A measurement from the remote end counts as another test per Step a.

   c. Since the AXTalk requirements increase as the cable gets longer, the longest links in a cabling installation should be selected as "victim" links. If several links measure approximately the same length, select the victim links such that as many bundles as practical are covered. For every 10 meter reduction in link length, the overall AXTalk margin tends to improve between 1.5 dB and 2.5 dB. Therefore, if the AXTalk average margin has reached 5 dB, testing of shorter victim links should not be necessary, provided the link configurations and components used are of the same quality.

   d. Selection of the victim links in the installation. This is most easily done in advance when the test results from Phase 1 are imported and organized in the LinkWare test results management program on your computer. The LinkWare program has been structured to list cables by bundle or by rack. When the technicians open the LinkWare project file containing the test results data from Phase 1, they can select the subfolder with the tests results for cables that belong to a bundle or a panel. The process of identifying and selecting the right victim and disturbers in the AxTALK Analyzer™ software will be simple, save time and avoid meaningless tests (wasted time). Of course, if LinkWare contains tests results organized by rack or panel, the technicians must have the documentation on site that shows the bundling of the cabling links.

Evaluation of Alien Crosstalk results for 10GBASE-T

The IEEE802.3an standard on 10GBASE-T has three sets of requirements, all of which depend on the insertion loss of the disturbed and disturbing links.

1. Power Sum Alien NEXT (PS ANEXT) is measured over the full frequency range from 1 through 500 MHz. The results for each wire pair are evaluated against a Pass/Fail limit line. The average PS ANEXT of all four pairs in the disturbed link is calculated as well. The average result is compared to a separate limit line.

2. Power Sum Attenuation to Alien Crosstalk Ratio – Far End (PS AACR-F) is the difference between the measured Power Sum Alien FEXT and the insertion loss (attenuation) of the corresponding wire pair in the disturbed (victim) link. In the current IEEE 803.3an standard and in previous drafts of TR 24750 and TSB-155, PSAACR-F is called PSAELFEXT. This parameter must be measured/calculated for each wire pair in the disturbed (victim) link over the full frequency. The average value of the four pairs in the disturbed link is calculated and compared to the Pass/Fail limit line for the average.

3. AXTalk Margin Calculation (ACMC) is a combined PS ANEXT and PS AFEXT average margin. This average margin is a single number for each pair and, once more, a single number for the average of the four pairs; and each of the 5 ACMC results for one victim link must be greater than 0 dB.

All the computations from pair-to-pair Alien NEXT and Alien FEXT measurements, and previously obtained insertion loss (attenuation) measurements (phase 1 of the test procedure) are rather complex. The DTX AxTALK Analyzer software implements all these rules in full compliance with the standards. It is important to note that as a minimum, the requirement for ACMC (see point 3 above) must be met for 10GBASE-T compliance with AXTalk specifications. It is perfectly acceptable, as defined in the IEEE 802.3an standard, to have one or more failing results for PS ANEXT and/or for PS AACR-F as long as all 5 ACMC values are greater than 0 dB. In practice, ACMC will often pass when either PS ANEXT or PSAACR-F fail with a relatively small margin (a few dB).

The ACMC rule does not apply when testing a Cat 6A or a Class E_A cabling system. Only the Pass/Fail criteria described in 1 and 2 above apply for these new cabling systems and the Pass/Fail limit lines are more demanding than those defined in the IEEE 10GBASe-T standard.

Overall test time

Applying the test procedures outlined above, we can estimate a total test time to certify a few links or a cabling installation for compliance with the 10GBASE-T requirements.

The DTX-1800 is the fastest field test tool in the market. A Cat 6 Autotest executes in 9 seconds. When performing the in-channel test for the 10 GbE application to 500 MHz, the test time increases because of the extended frequency range; the Autotest over the full frequency range from 1 through 500 MHz executes in 22 seconds to fully conform to the 10GBASE-T, TIA and ISO standards. These standards specify the frequency range, as well as the maximum allowable frequency step size between consecutive measurements.

First, we estimate that the total time to certify (TTC) the in-channel parameters for each link is 40 seconds. This time includes the following components:

1. Autotest time for in-channel certification of a link: 22 sec
2. Time to save the test results data: 2 sec
3. Time to move from channel to channel in the data center: 16 sec

Let us now examine the total time to certify for Alien Crosstalk compliance (between-channel performance). The total test time for PS ANEXT per link combination (effect of one disturber on the victim link) is estimated to be 45 seconds. We arrive at this number by adding the actual test time per link combination (25 seconds), and 20 seconds to move connections to the next disturber cable in the bundle.

Table 1 – Total time to certification a limited number of selected cabling links

Number of links to be certfied for 10GBASE-T	Phase 1 "In-Channel" test time	Phase 2 "Between-Channel" test time			
	min:sec	*Bundle size (*)*	*min:sec*	*min:sec*	*hrs:min*
5	3:20	12	18:30	21:50	0:22
	3:20	24	73	76:20	1:16
12	8	12	18:30	26:30	0:27
	8	24	73	81	1:21
24	16	12	18:30	34:30	0:35
	16	24	73	89	1:29
48	32	12	66:40	98:40	1:39
	32	24	126:40	158:40	2:39

You will need the same amount of time to make the PS AFEXT measurements for the victim cable and the total time to certify one link for AXTalk performance includes some time to switch the measurement setup from Alien NEXT to Alien FEXT.

The test times in Table 1 reflect the assumption that in a bundle of 12 links, one victim needs to be tested; in a bundle of 24 links, two victim links are tested. From a testing perspective, if a limited number of links are to be re-certified for 10 GbE deployments, it is advantageous to keep those links bundled together. Furthermore, as the data in Table 1 shows, smaller bundles save time; smaller bundles typically provide better test results.

(*) Notes: One victim link is to be selected in each 12-link bundle. Two victim links are to be selected in each 24-link bundle. All "other" links in the bundle should be included as disturber links.

We also provided the sampling scenario in which a full cabling system or subsystem needs to be re-certified for compliance with the 10GBASE-T standard. We will use the same basic test time assumptions as stated above. Table 2 shows the total time to certify based on the sampling rules we proposed earlier. We assume, in this table, that as much as possible the victim links have been selected out of different bundles or pathways.

Table 2 – Total time to re-certify a cabling installation

Number of links in the installation	Phase 1 "In-Channel"		Phase 2 "Between-Channel"				Overall Time to Certify (hrs:min)	Phase 2 test time as percent of Overall
	(min:sec)	*(hrs:min)*	*Victim links*	*Bundle Size*	*Test Time min:sec*	*Test Time hrs:min*		
100	66:40	1:07	5	12	92:30	1:33	2:40	58.1%
	66:40	1:07	5	24	182:30	3:03	4:10	73.2%
500	333:20	5:34	5	12	92:30	1:33	7:06	21.7%
	333:20	5:34	5	24	182:30	3:04	8.36	35.4%
750	500	8:20	8	12	148	2.28	10:48	22.8%
	500	8:20	8	24	292	4.52	13.12	36.9%
1000	666:40	11:07	10	12	185	3.05	14.12	21.7%
	666:40	11:07	10	24	365	6.05	17.12	35.4%
5000	3,333:20	55:34	50	12	925	15.25	70.58	21.7%
	3,333:20	55:34	50	24	1,825	30.25	85.58	35.4%

Conclusion

The 10 Gb/s Ethernet standard (10GBASE-T) has been approved and is released. It is important to note that carefully installed Cat 6 or Class E cabling systems may well meet the transmission requirements to support 10GBASE-T with limitations for the channel length. Fluke Networks' DTX-1800 CableAnalyzer allows the user to verify the performance of the link parameters (in-channel test parameters). In addition, the 10GBASE-T standard specifies that the coupling between cables in the same bundle or pathway needs to be measured and evaluated (between-channel test parameters or AXTalk certification).

Fluke Networks introduced an accessory kit for the DTX-1800 – the DTX-10GKIT – that provides the test solution to measure and evaluate the AXTalk performance of installed cabling. AXTalk does not require a 100% test of all possible link interactions. The test procedure may be limited to links that are bundled together. This paper covers a recommended sampling procedure to select and test links such that a very high degree of confidence is established that the cabling plant complies with the AXTalk performance parameters.

The same equipment and sampling procedures cover the field certification of new cabling installations constructed with the augmented cabling types.

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