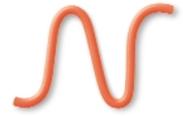


Cabling Challenges for 10GBase-T

White Paper
Nexans Cabling Solutions
October 2004



Introduction

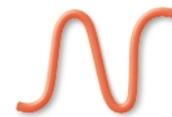
This paper looks at the technology challenges of designing and manufacturing copper LAN cabling to ensure support for modern communication systems including 10GBASE-T. The cabling requirements needed to ensure robust 10 Gigabit Ethernet operation over 100-meter, four-connector twisted pair cabling channels are neither specified nor known at this time and cannot be finalized without industry consensus on key decisions regarding signaling scheme, equalization, latency, DSP noise reduction and error correction within the IEEE 802.3an Task Group. Even when these decisions are made, the performance of a twisted pair solution will not be known until more investigation has been made regarding real-world variables and external noise sources such as alien crosstalk and installation imperfections.

History has shown that cabling technology has evolved at a rapid pace as has digital signal processing (DSP) and integrated circuit technology. However, until the issues listed above are resolved, it is premature to guarantee full 100-meter 10GBASE-T support over the most challenging media, UTP (Unshielded Twist Pair) cabling. Alien Crosstalk and external noise due to installation imperfections are the main issues that withhold the application to be supported over UTP cabling at this time.

Class F/Category 7 cabling is the only solution that can truly ensure 10Gbase-T support. It offers robust performance over the frequencies needed for 10Gbps operation without alien crosstalk as a burden.

Nexans is the first and only company to provide a full and explicit 10GBASE-T application guarantee without any restrictions as part of its LANmark-7 solution 20 years system warranty.

We also believe that Category 6 FTP will be able to support 10GBASE-T once industry testing and evaluations are complete. Nexans has been a leading, global manufacturer of Category 7 STP cabling products as well as of Category 6 UTP and FTP cable products for many years. The LANmark-7 and LANmark-6 solutions offer a large installed base offering a 20 years warranty worldwide.

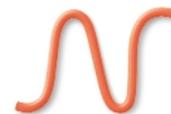


10GBASE-T Standardization Update

The following cabling objectives were among those agreed to by the 10GBASE-T study group for P802.3an during the September 2003 meeting:

- To support operation over 4-connector, 4-pair, twisted-pair copper cabling channels for all supported distances and cabling classes (categories).
- To define a single 10 Gb/s physical layer (PHY) that would support links of:
 - At least 100 m on four-pair, Class F (category 7) cabling
 - At least 55 m to 100 m on four-pair, Class E (category 6) cabling
- To support a bit-error-rate (BER) of 10^{-12} on all supported distances and cabling classes (categories).

To achieve the cabling objectives agreed to in September 2003, members of the working group negotiated basic requirements for electrical channel models to be used as a starting point. TIA TR42 and ISO/IEC JTC1/SC25/WG3 have been asked to refine these models and provide feedback to IEEE 802.3. Ultimately, the IEEE task group will use the completed models in the development of the 10GBASE-T standard. In July 2004 meeting of the P802.3an task force, the decision was made to focus on three baseline link segment models for alien near-end crosstalk based on different cabling categories and length objectives:



Model	Insertion Loss	Alien Near-end Crosstalk at 100 MHz
1	100-meters Class F Category 7 STP and/or augmented Category 6	60 dB
2	55-meters Class E or augmented Category 6 UTP	47 dB
3	100-meters Class E/Category 6 FTP	62 dB

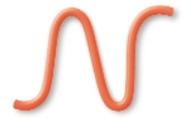
Table 1 : IEEE P802.3 Cabling Objectives for Baseline Link Model

As can be seen in Table 1, the Models 1 and 3 are the two applicable models designed to support 100-meter cabling channels as allowable in horizontal spaces by TIA or ISO structured cabling standards.

Model 1 is based on Class F/Category 7 cabling channels as defined in the ISO/IEC 11801:2002. They are specified to 600MHz and are alien crosstalk compliant thanks to the screening performance. The channels are available by Nexans as the LANmark-7 system. The LANmark-7 system is made up of the LANmark-7 1000MHz STP cable and the GG45 Category 7 connector. The GG45 is the IEC 60603-7-7 compliant connector as specified in the Category 7 standard. Belonging to the RJ45 family (IEC 60603-7) it is fully backward compatible to RJ45. The LANmark-7 system has been widely installed and installations can now be fully field-tested up to 600MHz. The system is specified to 625MHz and beyond and is fully alien crosstalk compliant thanks to the screening performance. It is fully covered by the Nexans LANmark-7 20 years system warranty.

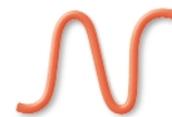
Model 2 is based on Class E/Category 6 UTP systems. It is anticipated that operating over 100-meters of UTP requires substantial augmentations to existing category 6 specifications. This will eventually result in a new enhanced category-6 cable standard specifically designed for 10GBASE-T transmission. Current performance specifications for category 6 only cover frequencies from one to 250 MHz.

Model 3 is based on a screened Class E/Category 6 system, as standardized by ISO/IEC 11801:2002 and TIA/EIA 568B.2-1. Nexans LANmark-6 cabling system meets the alien crosstalk requirements of Model 3 in Table 1, thanks to the screening performance which is necessary for the full 100m support. Still open awaiting further study within IEEE and cabling committees is the insertion loss and extended frequency requirements.



ISO and TIA cabling standardization committees have started working on cable and channel performance data at frequencies up to 500 MHz. Because the IEEE 802.3an standardization process is in the early stages of development, it is premature to specify exact frequency requirements although higher frequency ranges enable more signaling options. TIA has also initiated TSB-155 in an effort to define whether the installed cabling base would be capable of supporting 10GBase-T.

Because the IEEE 802.3an standardization process is in the early stages of development, it is premature to specify exact frequency requirements although higher frequency ranges enable more signaling options. The IEEE 802.3an hopes to have draft 1.0 of the 10GBASE-T shortly.

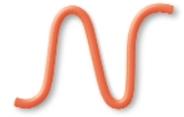


Cabling Challenges of 10GBASE-T

Channel capacity is very important because it tells us the maximum data rate (bits of information per second) that can be transmitted from the source to the destination without error. This remains true even when the transmission channel is noisy, provided the bandwidth and received signal-to-noise requirements are met.

The channel capacity as calculated using Shannon's Law (see Appendix A) and other variations, can be misleading if not carefully used and interpreted. When considering the system and cabling requirements for 10GBASE-T solutions, it is necessary to consider all significant signaling impairments that will reduce the signal to noise ratio of the system. Without adequate signal-to-noise across the required channel bandwidth, reliable or robust 10GBASE-T performance will not be achieved. Adequate signal-to-noise must be achievable in real-world installations where variables such as temperature, humidity, alien crosstalk and other external noise sources have to be taken into account.

Much of the 10 Gigabit discussion has focused on the uncertainty as to whether UTP has the capability to overcome the inherent problems of alien crosstalk when cables are installed in large bundles, but Nexans emphasized the fact the connector is an equally big issue. The RJ45 has been pushed to its limits with Cat 6 at 250MHz, but for 10 Gigabit we are looking at doubling these frequencies. The only connector available today which is standardized beyond 250MHz and is backwards compatible with RJ45 is the Nexans fully standardized GG45.



Alien Crosstalk

It has been determined that alien crosstalk is the dominant noise source that limits the received signal-to-noise ratio (SNR) of a 10GBASE-T transmission system. Alien crosstalk is extremely difficult to cancel using digital signal processing (DSP) techniques. Even if used, DSP cancellation of alien crosstalk would add significant cost and complexity to the transceiver. There are several methods that are available to mitigate alien crosstalk in a category 6 cabling system:

- **Shielding:** These cables are known as FTP cables for foil-shielded twisted-pairs, using a construction with one or more aluminium foils. FTP cables, when properly constructed, have very low alien crosstalk and greatly simplify the problem of operating 10GBASE-T over copper cabling. Incorporating the shielding within the cable design makes the immunity from neighbouring cables and external noise sources very controlled. Coupling attenuation is the standardized parameter that expresses this immunity by design. This parameter expresses the difference in noise immunity with a UTP cabling but also between good and bad shielding designs. Nexans has a great expertise in shielded cabling with many years of experience and a huge installed base worldwide.
- **Spacing:** Spacing could be an alternative if shielding is not possible or desirable. By employing clever cabling geometries and physical spacers, it may be possible to develop UTP cables that have improved alien crosstalk performance by pushing potential disturbing cables away. In this approach, alien crosstalk emissions are not eliminated. The cables are physically spaced far enough away from each other that alien crosstalk interference is reduced significantly. In addition, other cable design dimensions can be employed. As in cable designs being done to date, this has resulted in large cables with unusual shapes. These designs could be difficult to handle and install in tight pathway and racking installations however.
- **Balance:** A properly “balanced” cable has been manufactured in such a way that when noise is subjected to it, it is absorbed equally and oppositely on each wire pair and thus the contaminating effects can be cancelled at the receiver end. By improving the balance of the cable pairs, the alien crosstalk performance of the resultant cable can be improved.



Correlating Balance to Alien Crosstalk

Twisted-pair cabling uses differential transmission as a means to reduce radiated emissions and susceptibility to noise. Cabling balance when employed in differential cabling systems also plays an important role in controlling internal and alien crosstalk and other performance parameters.

Improvements to cable pair balance will result in more robust operation for today's network application such as 1000BASE-T and may be a critical component for 10GBASE-T and other emerging applications.

In a study performed by the Nexans Data Communications Competence Center (DCCC), various commercially available UTP cables were installed in a plastic raceway as two-connector channels and were exposed to a noise source called electrical fast transients (EFT) at increasing voltages (see Figure 1). The network performance (packet errors) when running 1000BASE-T in full duplex was measured and subsequently correlated to Longitudinal Conversion Loss (LCL), an indicator of cabling balance. Several samples of seven different brands of category 5e and category 6 cabling were tested. This testing duplicates difficult environments such as:

- Proximity to electrical motors and air conditioning units
- Elevators
- Factory environment

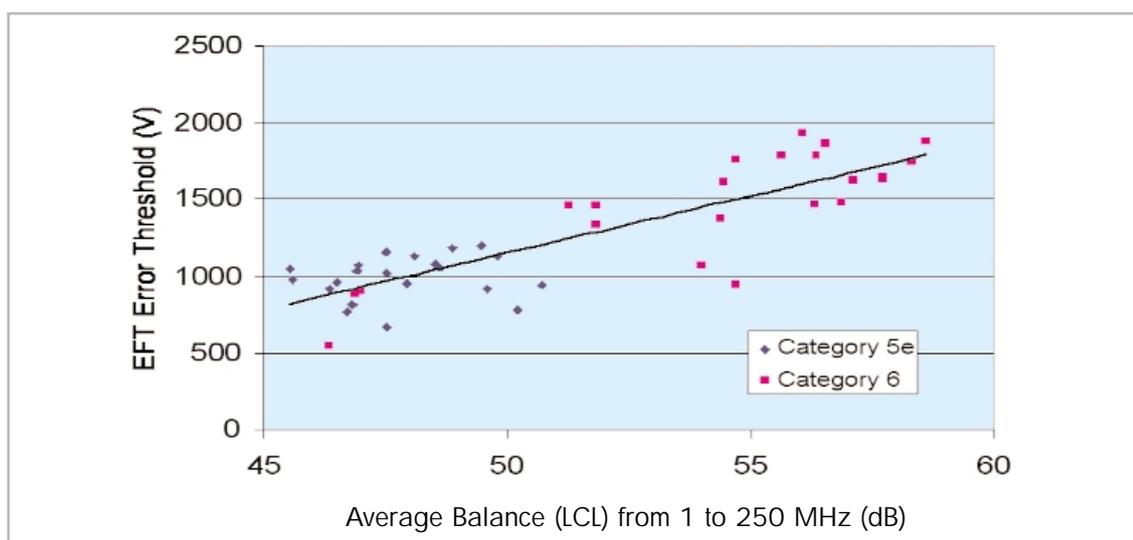


Figure 1

These results show that Category 6 solutions with better cabling balance cause fewer packet errors than Category 5e solutions in the presence of EFT interference.



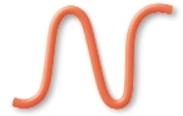
Nexans Efforts on 10Gbe over UTP

In support of this 10GbE development work, Nexans has been working with Pennsylvania State University's Center for Information & Communications Technology Research (CICTR) on a method and system for 10GBASE-T. This study, funded by the International Copper Association, was presented to the IEEE 10GBASE-T study group in November 2003 to help demonstrate the feasibility of running 10 Gb/s over copper cabling at 100-meters. The work by CICTR researchers has resulted in several exciting discoveries:

- Refinements are needed to the decision feedback equalizer (DFE) technology currently used in Ethernet applications over copper (e.g. 1000BASE-T).

- If the alien crosstalk is substantially worse than the IEEE link model, such as the one presented by Broadcom, Vativ and Marvell to the IEEE study group in May 2003, then no known code will achieve the target performance level over 100-meters of category 6 UTP cabling.

These conclusions regarding the ability of UTP cabling to support 10GBASE-T in the presence of various levels of alien crosstalk are at the center of the uncertainty and disagreement in the industry regarding cabling solutions to support this application in real-world installations. Accurate prediction of the noise environment in the field and the subsequent performance of the cabling are far from a certainty for UTP cables.



Conclusions

Modern Cabling Systems must be designed and manufactured to ensure robust network performance of modern LAN applications such as today's 1000BASE-T and tomorrow's 10GBASE-T. This includes:

- Stable, linear performance over a wide frequency range and ambient conditions (temperature, humidity, etc.). This should include frequencies up to at least 500 MHz.
- Better Insertion Loss (attenuation) is key for improving signal-to-noise and reducing power consumption. Improvements in balance (such as LCL) will improve the immunity of cabling to external noise including alien crosstalk. It is also an excellent metric for the quality and consistency of the manufacturing process for modern LAN cables and cabling components.
- Since the IEEE P802.3an project was just started in March 2004, consider a shielded cabling solution if you are preparing your network infrastructure for the eventual 10GBASE-T standard. Today, the alien crosstalk performance levels for UTP cables are not known. This applies to all existing announced UTP cable solutions as of the publication date of this document, including those supposedly intended to support 10GBASE-T.

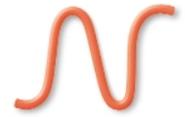
The cabling industry has a proven track record of innovation. In time, alien crosstalk and other issues will become clear and enhanced UTP solutions will probably emerge to support this application with the specifications, recommendation and procedures developed to ensure robust application support. But ...

- The ability of UTP cabling to support 10GBASE-T in the presence of various levels of alien crosstalk is far from a certainty for UTP cables.
- A new enhanced category-6 cable standard specifically designed for 10GBASE-T transmission is necessary. The creation of a new Class (Class 6 enhanced) represents a significant task and may take years to complete.
- The RJ45 has been pushed to its limits with Cat 6 at 250MHz, but for 10 Gigabit we are looking at doubling these frequencies.

However safe investments in cabling systems exist today that will support future 10 Gigabit Ethernet operations over 100m with a high level of performance and without any restrictions. It can be made with off-the-shelf available LANmark-7 Category 7 cabling systems using the GG45 connector.

This standardized GG45 connector also gives suppliers of passive and active equipment the chance to integrate into their new devices for the support of the upcoming new 10GBase-T protocol.

Thanks to its large bandwidth (600MHz) and its immunity to Alien Crosstalk, the Nexans LANmark-7 solution is already warranted for the support of the future 10Gbase-T protocol. For more information on the cabling challenges facing 10GBASE-T development contact your local Nexans Cabling Solutions sales representative.



Appendix A

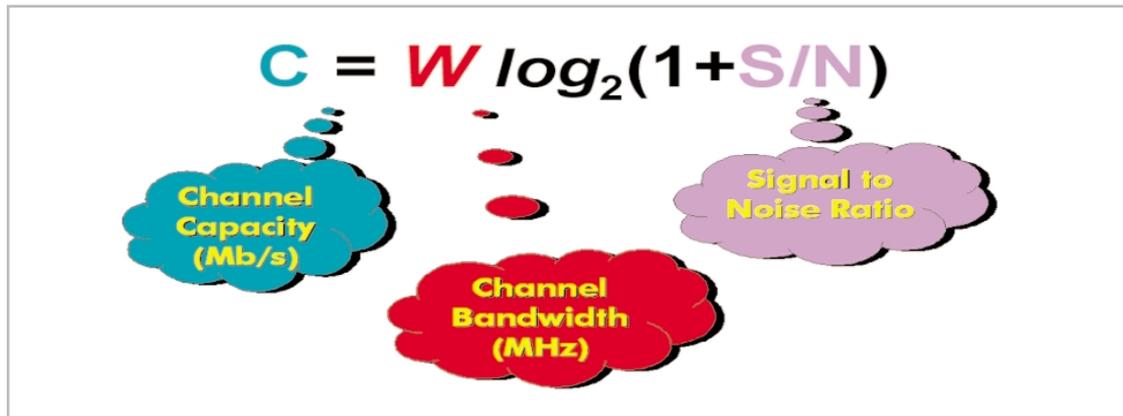


Figure A: Shannon's Law⁵ in Simplest Form

As shown in Figure A in its simplest form, Shannon's Law relates channel capacity to signal-to-noise across the usable bandwidth of the communication channel.

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Global expert in cables and cabling systems

Nexans Cabling Solutions

Alsembergsesteenweg, 2 b3 - B 1501 BUIZINGEN - Belgium

Tel: +32 (0)2 363 38 00 • Fax: +32 (0)2 365 09 99

E-Mail: info.ncs@nexans.com

www.nexans.com/ncs