10 Gb/s Over Copper: Horizontal Cabling Choices

Summary
This whitepaper describes the development of augmented category 6 cabling standards from the initial IEEE 802.3an project objectives published in 2002. This evolutionary process explains the equally evolutionary progression of Siemon's 10 Gb/s copper cabling systems. At each pre-standard benchmark, Siemon either had or developed a compliant product.

Throughout the changing 10GBASE-T landscape, Siemon has maintained a strong leadership position. With over one million 10G ip™ copper ports installed worldwide, Siemon has more experience developing 10 Gigabit ready copper cabling systems than any other manufacturer.

Desktop Planning:
With the IEEE 802.3an 10GBASE-T application standard nearing technical completion and the industry preparing for the document's final ratification in July of 2006, it's no surprise that many new buildings have already been cabled to support 10 Gb/s (Gigabits per second) data speeds at the work area. The knowledge that PC hard drive capacity doubles every 12 months (outpacing growth predicted by Moore's Law and leading experts to forecast the availability of 2.56 terabyte capacity by 2007[1]) and the increasing availability of 10 Gb/s chip technology are fueling the trend to support high bandwidth at the desktop. In fact, multiple chip manufacturers are already sampling their 10 Gb/s transceiver technology and a handful of manufacturers are committing to being able to supply full production volumes of chips to equipment manufacturers by Q3 of 2005!

In addition to applications equipment providers, telecommunications cabling manufacturers, bolstered by the balloting TIA and ISO augmented category 6A performance standards[2] , are now able to deliver copper cabling systems guaranteed to support operation of the 10GBASE-T application. The result is complete end-to-end availability of a powerful IT network solution capable of accurately and quickly moving large image, database, real time/on demand video and modeling files for the next decade to come.

Augmented category 6A and Beyond:
The key to robust 10GBASE-T application support is specifying copper media with the correct transmission characteristics and installing the system in accordance with proper guidelines. Fortunately, the pending TIA and ISO augmented category 6A cabling standards fully describe the minimum electrical requirements necessary to ensure proper network operation of the application over 100-meter horizontal cabling topologies containing up to four connectors (i.e. a full cross-connect,

consolidation/transition point, and work area outlet). Copper cabling systems that offer headroom to the pending augmented category 6A requirements, such as ISO category 7/class F solutions, will also support the 10GBASE-T application. The technical content in the current drafts of both the TIA and ISO standards has been officially liaised with engineering committees such as IEEE and BICSI and contain all of the transmission specifications proven to support the 10GBASE-T application. These documents are currently circulating for ballot comment review and the industry anticipates that they will publish before the 10GBASE-T application standard is ratified.

Supporting positive signal-to-noise (SNR) margin from 1 - 500 MHz and confirming channel capacity through Shannon capacity models were the most critical objectives in demonstrating technical feasibility for the 10GBASE-T application and developing augmented category 6A cabling requirements. For the first time, TIA and ISO standards bodies had to have a thorough understanding of how the new 10GBASE-T application functioned in order to be able to accurately specify performance requirements. Specifically, since the 10GBASE-T application is the first Ethernet solution to fully cancel the majority of near-end and far-end crosstalk within the channel, standards experts had to identify the most dominant noise source external to the channel in order to accurately assess SNR performance. The results of this evaluation led to a new noise parameter, alien crosstalk, being characterized in the augmented category 6A standard alongside new high-frequency limits for all of the currently recognized transmission parameters (e.g. insertion loss, return loss, NEXT loss, and ELFEXT).

Initial Shannon models developed by the IEEE 802.3an committee identified the channel capacity that was required to support the 10GBASE-T application. Shannon capacity simulation was an important benchmark used to confirm technical feasibility of emerging 10Gb/s cabling systems with future IEEE 802.3an compliant networking equipment. This same simulation approach was also used by experts serving on TIA and ISO standards committees to validate proposed augmented category 6A performance limits for all transmission parameters.

The characterization of alien crosstalk is the differentiator between augmented category 6A and all lower grades of cabling. Up until now, no cabling system, not even the industry de facto “category 6e” or “category 6E” products, had ever been qualified for alien crosstalk performance. Alien crosstalk is defined as undesired signal coupling from one cable to another or one channel to another most commonly affecting pairs with similar twist lays. Just like other crosstalk parameters, both pair-to-pair measurements and power sum calculations from both near-end and far-end test orientations are used to characterize alien crosstalk. It is interesting to note that the proposed augmented category 6A alien crosstalk limits are so stringent that they mandate almost 80% less alien crosstalk voltage than that exhibited by a typical installed category 6 channel! In addition, in order to support positive SNR margins up to 500 MHz, augmented category 6A cabling systems are specified to have an impressive 27% improvement in signal strength (insertion loss) overall.

Because of the extensive research that has been conducted into alien crosstalk, standards bodies are well equipped to pinpoint design and installation strategies that will yield robust alien crosstalk performance. By looking at the worst-case laboratory test configuration for cables shown in figure 1, it is apparent that good strategies for reducing/mitigating alien crosstalk include:

- Unbundling UTP cables through installation practices
- Maintaining separation by using UTP cables with an improved alien crosstalk design
- Shielding between cables with a metal foil or braid

For UTP Only — Installation Practices:

Sensible installation practices can improve alien crosstalk headroom for first-generation 10Gb/s UTP cabling systems without alien crosstalk compliant cable designs (i.e. 10G 6). These techniques may also be used to increase the channel capacity of legacy category 6 cabling to the level necessary to provide 10GBASE-T applications support for distances up to 55m (although these channels may not meet pending augmented category 6A alien crosstalk requirements). Examples of UTP installation practices that can positively impact alien crosstalk headroom include:

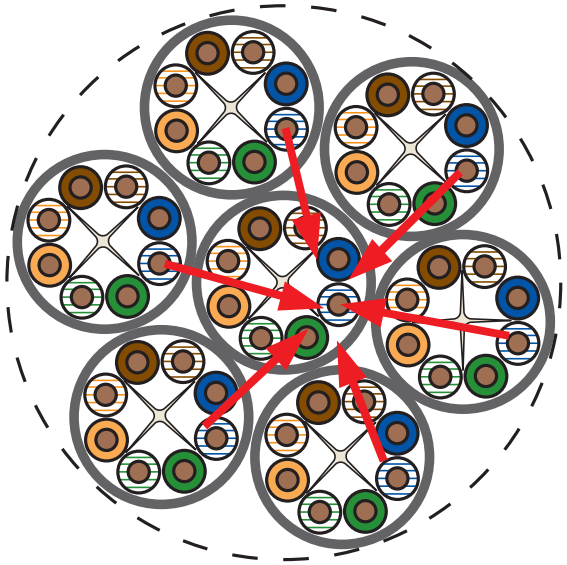


Figure 1: Worst-case alien crosstalk configuration — 6 outside cables coupling onto 1 inside

- Do not "comb" or "pinstripe" cables in the first 20 meters
- Separate patch and equipment cords in the first 20 meters
- Avoid tie-wraps
- Use loose Velcro™ wraps only when absolutely necessary
- Use horizontal wire management techniques (e.g. route odd ports to upper management and even ports to lower management)
- Loosely place cables in vertical wire management
- Avoid unusually high port density at the work area and distribution points.
- Reduce maximum conduit fill density to 40%

Implementation of these practices is not required for any augmented category 6A F/UTP (sometimes referred to as ScTP) or category 7 S/FTP (fully-shielded) cabling systems. In addition, these practices do not need to be applied when using augmented category 6A UTP systems, such as those with cable diameter design enhancements (see chart, page 5) that increase cable-to-cable separation.

Bigger UTP Cables, Less Alien Crosstalk:
The pending publication of a new TIA standard[3] that will allow the maximum overall diameter of twisted-pair cables (regardless of category or construction) to increase from 6.35mm (0.250 in.) to 9mm (0.354 in.) is dramatically and favorably impacting the industry's ability to control alien crosstalk in UTP cabling. By designing UTP cables with larger and thicker overall jackets, cabling experts can provide a means to physically isolate twisted-pairs from adjacent cables. As a result, new, albeit larger, augmented category 6A compliant UTP cables that exhibit significantly reduced alien crosstalk are available for consideration by system designers who prefer more flexibility and less restrictive cable management practices in the telecommunications closet as compared to UTP cables without improved, alien crosstalk designs.

Alien Crosstalk Conundrum:
Although the definition of alien crosstalk is straightforward, developing field test practices has been a challenge because of the number and complexity of measurements. Since the alien crosstalk characterization of all channels in an installation is entirely impractical, TIA has adopted a "sampling" approach for assessing the alien crosstalk present in a cabling installation. It is the intent that channels that are representative of worst-case alien crosstalk conditions be tested and if those results exhibit satisfactory performance, then the installation is deemed compliant to alien crosstalk specifications. This sampling method first appeared in the TIA augmented category 6A standard in June of 2005. Selection of the installed channels to be tested is based upon evaluating cable density (proximity and bundling), port adjacency at the patch panel, and channel length. It is important to note that specifying cabling systems with alien crosstalk headroom or virtually zero alien crosstalk (augmented category 6A F/UTP and category 7 S/FTP designs) will significantly reduce the need for alien crosstalk field test sampling of the installed cabling plant. See figure 2 for power sum alien near-end crosstalk (PSANEXT loss) data for various cabling types.

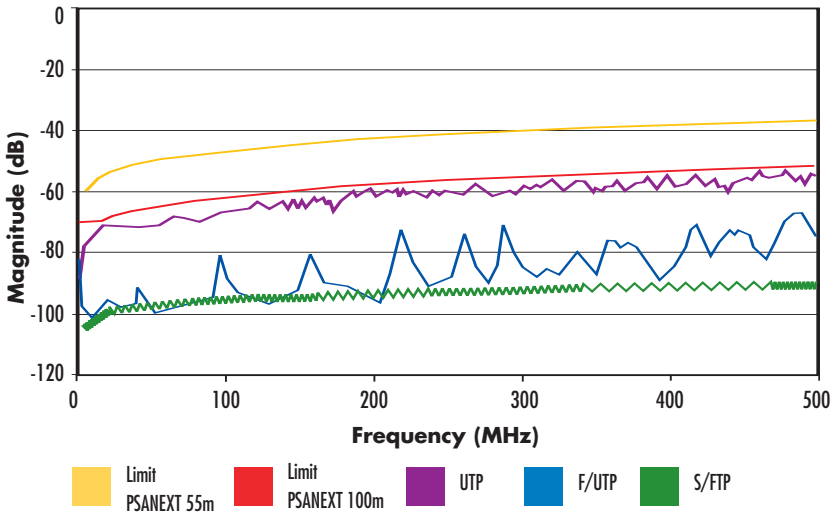
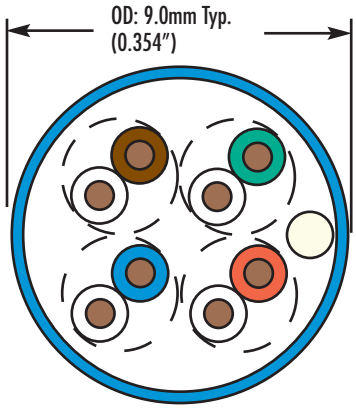
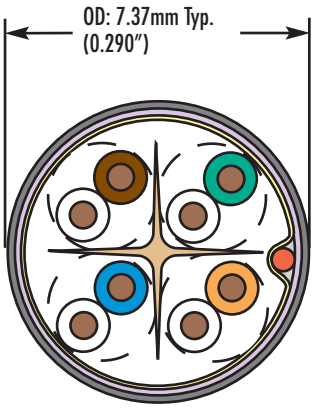
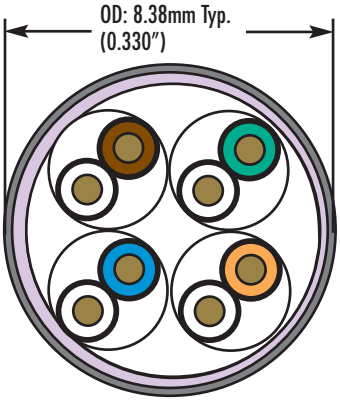


Figure 2: comparative PSANEXT loss per cabling type

Currently, TIA and ISO augmented category 6A standards only contain channel requirements for alien crosstalk and do not contain alien crosstalk requirements for cables and connecting hardware. Therefore, it is especially critical that channels are adequately characterized for 10GBASE-T capacity using simulation models and that they exhibit the minimum allowable performance levels of insertion loss, crosstalk, and return loss required to maintain appropriate signal-to-noise ratios.

Choices:

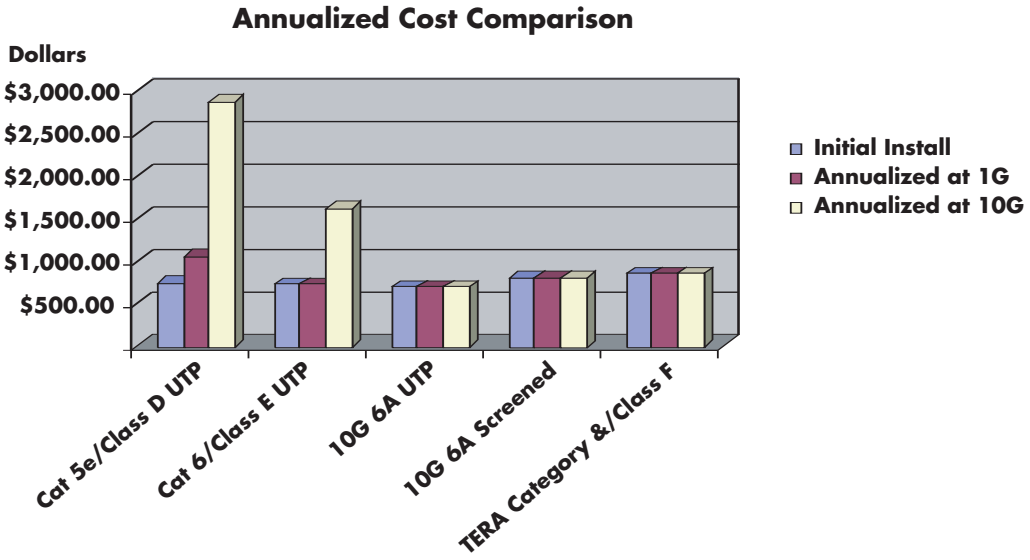
Now, more than ever, cabling media selection is all about evaluating options. The three cable types recommended to support the 10GBASE-T application, along with a summary of their associated features and benefits, are shown in figure 3. Common considerations when selecting media type are cost, ease of installation, and conduit fill. With more flexibility in cabling options than ever before, there is a 10 Gb/s solution for every budget and for every commercial building environment. Now is the time to get 10Gig ready!

Media	Augmented Category 6A UTP	Augmented Category 6A F/UTP	Category 7/Class F S/FTP
Cable Construction			
Alien crosstalk	Exhibits compliant alien crosstalk due to core separation design	Exhibits virtually zero alien crosstalk due to overall foil construction	Exhibits virtually zero alien crosstalk due to fully shielded construction
Installation Notes	Larger overall diameter must be taken into consideration when calculating conduit and pathway fill	Grounding of the foil in one location from the patch panel in the telecommunications closet to the TGB is required	Grounding of the shield in one location from the patch panel in the telecommunications closet to the TGB is required
Work Area Interface	Standard 8-position Modular (RJ-45 style)	Standard 8-position Modular (RJ-45 style)	Quadrant-Pair Isolated Connector (non RJ-45 style)
Maximum Recommended Conduit Fill	60%	60%	60%
Shannon Capacity	Exceeds IEEE 802.3an objectives	Approximately 18 Gb/s headroom (100% additional capacity based upon PSANEXT loss margin)	Approximately 22 Gb/s headroom (150% additional capacity based upon PSANEXT loss margin)
Recommended Installation	Compliant 10Gb/s performance in familiar UTP construction	Highest density 10Gb/s support when maximum density and conduit fill (e.g. data centers) is desired	Supports 10Gb/s applications when security is a concern or the need to support broadband video applications in the future is anticipated as well as a potential support of applications beyond 10GBASE-T

What about my installed category 6 cabling plant?

The good news for category 6-compliant cabling plant owners is that a large percentage of the installed base is anticipated to be able to support the 10GBASE-T application. Based upon IEEE objectives, 10GBASE-T is designed to operate over at least 55 meters of category 6 cabling within a "reasonable" worst-case alien crosstalk environment. Furthermore, data presented by IEEE members[4] during the 10GBASE-T objectives development phase illustrated that approximately 68% of today's installations fall below this minimum length requirement. Look to the guidance specified in the pending TIA TSB-155 document for a comprehensive overview of the minimum transmission performance (including alien crosstalk and extended frequency characterization) required to support the 10GBASE-T application over reduced lengths of category 6 cabling. The final channel length to be specified in TSB-155 is, at the time of writing, undetermined. Requirements for the level IIIe compliant field testers needed to verify the performance of the installed based and their associated test and sampling methods are provided. Since field evaluations have indicated that bundling practices may have resulted in excess alien crosstalk in some category 6 installations, TSB-155 also lists mitigation techniques that may be employed to improve alien crosstalk performance.[5]

The cabling industry universally recommends that it is not good practice to design new cabling plants to support 10GBASE-T with reduced-length category 6 cabling. Return-on-investment (ROI) modeling demonstrates that the additional testing and downtime costs to ensure that a category 6 cabling plant can support 10GBASE-T for distances up to 55 quickly surpasses the cost differential between category 6 and augmented category 6A media at installation time (see chart below).



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3. TIA increased overall cable diameter requirement to be published as TIA-568-B.2-11 ('568-B.2-11)

4. S. Abu Ghazaleh, V. Rybinski, S. Vaden, "10GBASE-T Market Potential & Technical Feasibility on Installed Cabling by 2005 Installed Cabling by 2005" (September 2003)

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Other reading:

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