Belden IBDN System 10GX
The next level of cabling performance

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Introduction

There is a new standard under development in the IEEE 802.3an task force that will usher in the next level of networking performance, 10 Gigabit Ethernet over high performance twisted-pair copper. It is anticipated that the standard will be ratified by July 2006. In a span of 15 years the speed of data networks will have increased by a factor of one thousand from 10 Mb/s (10BASE-T) to 10 Gb/s (10GBASE-T). In this same timeframe, the performance of network cabling will have evolved from Category 3 to a new level of performance called augmented Category 6, specifically designed to support 10 Gb/s transmission for distances up to 100 meters.

The speed of data networks is limited to more than the information carrying capacity of the cabling. It is also limited by the access speed of storage devices, network traffic, interface protocols, and the speed of the data bus. It is clear that as computing power increases and applications place greater demands on the network, there will be a need for a low cost 10 Gb/s solution over twisted pair copper. Initially, the demand for 10GBASE-T will be for data centers with a high density of computer devices (servers, switches, routers and storage modules) and at data aggregation points for enterprise networks. Later, 10 Gb/s Ethernet will migrate to the desktop to support bandwidth intensive applications such as CAD/CAM, digital animation, storage and cluster computing.

It is the objective of the IEEE 802.3an task force to develop a single PHY (Physical Layer specification) that will support a minimum distance of 55 meters over installed base Category 6 cabling and 100 meters over augmented Category 6 (augmented Class E) or Category 7 (Class F) cabling. The specifications for augmented Category 6 are currently under development in TIA TR 42.7 subcommittee and in ISO/IEC JTC1 WG3. The key transmission parameters are the alien Near End Crosstalk (ANEXT) and alien Equal Level Far End Crosstalk (AELFEXT) performance, which are new parameters. In addition, the established parameters such as Insertion Loss, Return Loss, PSNEXT, and PSELFEXT need to be specified over an extended frequency range from 1 to 500 MHz.

Belden IBDN System 10GX Enabling Technologies

Belden CDT Networking has invested considerable resources in the development of a complete end-to-end solution for 10 Gigabit Ethernet over augmented Category 6 cabling. The 10GX solution incorporates several innovative enabling technologies that go way beyond the state of the art of Category 6 cable and connectivity designs in the market. The design concepts will be described in this paper as well as the performance capabilities compared with conventional designs. It takes something dramatically different in order to achieve the performance requirements for augmented Category 6 cabling in a worst case environment, including bundled cables and 4-connector, 100 meter channel topologies.
The interaction between one channel and its neighbors is called alien Crosstalk. It is one of the most difficult requirements to meet for an augmented Category 6 channel. Every single component of the channel must not only be improved, but redesigned, in order to achieve this objective:

- The modular jack must be designed for extended high frequency performance and very low ANEXT when inserted side by side in faceplates or patch panels
- The patch cord must be flexible, and designed to provide the highest level of crosstalk isolation because of its proximity to strong signals near equipment.
- The horizontal cable must be designed for crosstalk isolation, when installed in a tray or conduit or when bundled together in a rack or cabinet

The Belden IBDN System 10GX is a whole new system developed around a series of dynamic enabling technologies to ensure the highest level of alien crosstalk isolation and the best performance margins for a channel extending up to 625 MHz. What differentiates our 10GX system from other 10 Gigabit Ethernet offerings? There are three main aspects that differentiate the System 10GX offering: technological leadership, performance headroom and testing done under the most stringent conditions (6-around-1 bundled configuration including patch cord). The components that comprise the 10GX solution are illustrated in Figure 1.
**SpiralFlex Technology**

The alien crosstalk requirements for 10GBASE-T impose a major technical challenge for conventional UTP cable designs. This is because of the electromagnetic coupling between pairs of a cable and the neighboring cables surrounding it. This electromagnetic coupling is enhanced by the fact that all the pairs these cables have the same twisting lay and cabling lay, and therefore have the same resonance frequencies where the crosstalk adds in phase.

The patent-pending SpiralFlex Technology creates randomization in the cross-section of the cable and along the axis of the cable, improving the ANEXT coupling by increasing and randomizing the distance between a cable and the neighboring cables surrounding it. There are two main elements in the core design. The first is a unique cross-web which separates the pairs, and the second is a dielectric filler that spirals around the core. The combination of the two elements breaks up the pattern of like pairs between adjacent cables coming together in a consistent manner along the length of cable and increases the physical separation between pairs. The core design is illustrated in Figure 2. An additional benefit of the SpiralFlex design is an amazing mechanical flexibility and low surface friction, which facilitates installation.

![Figure 2 – SpiralFlex Technology creates asymmetry](image-url)
**MatriX IDC Technology**

The IDC is that part of the jack where the horizontal cables are connected to the module and is one of the most critical sources of alien crosstalk coupling. If all the IDC contacts are aligned horizontally or vertically, the electromagnetic field coupling due to capacitive unbalance and mutual inductance between adjacent IDCs is very high. This is the case with modules of conventional design as illustrated in Figure 3.

![Figure 3 – Typical IDC Modular alignment](image)

There are two approaches to reduce this effect. One approach is to use shielding or physical separation, while a better approach is to use a novel design where crosstalk coupling between adjacent IDCs cancels itself. The patent pending MatriX IDC Technology is a design of the IDC where each pair of IDCs is positioned at 90 degrees to its neighbors. The impact of the MatriX IDC Technology is just astonishing, reducing the ANEXT between pairs of adjacent modules by 15dB.

The MatriX IDC Technology is illustrated in Figure 4. The orthogonal alignment of adjacent IDCs orients the electric and magnetic fields to cancel out differential mode coupling, effectively canceling the alien crosstalk at the point of connection.
The improvement in alien crosstalk performance is remarkable. This is illustrated in Figure 5, which shows the Power Sum Alien NEXT for a patch panel of conventional design compared with a patch panel using MatriX IDC Technology.
**X-Bar Technology**

The X-Bar is a plastic device allowing each pair to be perfectly positioned at right angles to one another for termination on the 10GX Module’s IDC pins. This device optimizes the termination process and allows a 10GX Module terminated in real life field conditions to have similar performance to a module that is terminated in ideal conditions in a laboratory environment. Performance variations due to termination are practically eliminated.

The X-Bar facilitates installation by positioning and aligning the pairs. It holds the pairs in place to prevent untwisting of pairs into the cable and locks them into position to provide strain relief and to maintain pair integrity when handling the cable. Use of the X-Bar also maintains the optimal amount of unjacketed cable at the module. The installation process is simplified and performance is assured with consistent results each and every time.

What is the gain for installers? The installers will appreciate the ease of installation using the X-Bar to guide the pairs into position and to achieve consistent termination performance, not requiring any re-terminations. This will translate in reduction of the craftsmanship required.

What is the gain for end-customers? The overall system performance has been improved and will provide end-customers with greater headroom. The X-Bar technology is illustrated in Figure 6.

![Figure 6 – X-Bar Insert and termination](image-url)
**FleXPoint PCB Technology**

Current connectivity designs are severely limited in performance at high frequencies, above 250 MHz, because of the inherent crosstalk in the plug that cannot be fully compensated for by the jack. This is because the compensation circuitry is located at some physical distance from the source of crosstalk, which is at the plug interface. The patent-pending FleXPoint PCB connector design uses a flexible printed circuit board to bring the compensation circuitry as close as possible to the plug interface. This “minimum delay” compensation provides a frequency response beyond 500 MHz and meets the extrapolated Category 6 component limits for a mated connection, which is unique today.

The FleXPoint PCB connector design uses a flexible printed circuit board where the gold plated traces on the PCB make direct contact with the plug interface (see Figure 7). The PCB is a multi layer design where the compensation circuitry occurs right at the point of contact of the plug, you can’t get any closer. The effective time delay of the compensation circuitry is reduced in half compared to conventional compensation techniques for Category 6 modular connectors.

![Figure 7 – FleXPoint PCB Design](image)

The FleXPoint PCB connector design meets the extrapolated Category 6 component limits for a mated connection from 250 MHz to 500 MHz for a full set of qualified plugs (see Figure 8). This is an extraordinary feat in the industry. The built in NEXT margin for the 10GX connectivity using FleXPoint PCB technology is 12 dB better at 500 MHz as compared to the worst case performance of installed base Category 6 connectivity, which rolls off at 60 dB per decade above 250 MHz.
Figure 8 – FleXPoint PCB Mated NEXT Connector Performance

**Modular Cord - Management Bar Technology**

The management bar technology is a patented technology which allows the 10GX Modular Cord to be perfectly optimized with the 10GX Module and have tightly controlled and centered de-embedded NEXT (dNEXT) performance. The tolerance on dNEXT is within half the range specified in the TIA 568-B.2-1 standard.

The 10GX Modular Cord also incorporates a plug with a small footprint and shorter boot allowing for better compatibility with cable management accessories for high density switch ports and equipment connections in tight spaces. The patch cables are a flexible dual jacketed construction with an internal screen to provide the highest alien crosstalk isolation while maintaining high noise immunity due to the balanced pair construction.

What is the effect of using a patch cord incorporating an internal screen on the EMI and noise immunity performance? We conducted comparative noise immunity tests using 10GX cords and conventional PS6LX cords at a local research facility. The noise induced into the cable, including connectors, from an electromagnetic field of 10 V/m was measured in an anechoic chamber over a frequency range from 30 MHz to 800 MHz. The test configuration and the test results are described in a companion paper. Incorporating the internal screen provides for superior Alien Crosstalk performance while maintaining noise immunity and conversely radiated EMI performance comparable to conventional PS6LX cords.
10GX Channel Performance

For the purposes of evaluating the performance for a 10GX channel, we used a worst case configuration as illustrated in Figure 8. The cable under test is the center cable in an arrangement with 6 additional cables surrounding the cable under test. The center cable touches each of the surrounding cables and all cables are parallel to each other. The relative positions of the cables are maintained throughout the length of the bundle using Mile-Tie brand flexible tie wraps installed at 1 foot intervals. The connecting hardware at the wall outlet and at the patch panel were also arranged in a 6 around 1 configuration as shown in Figure 9.

Figure 8 – Test configuration for channel measurements

Figure 9 – Connector placement on patch panel and wall outlet
The power sum alien near end crosstalk (PSANEXT) and power sum alien far end crosstalk (PSAELFEXT) from all the surrounding cables and connectors were measured using a network analyzer and an 8-port switch, tested at both ends, and from end to end, forward and reverse. The results are shown in Figure 10 and Figure 11 for the worst case pair in the victim cable compared with the requirements of the TIA working document SP-3-4426-A10, draft 1.3, for augmented Category 6 cabling. At the time of writing, there were no proposed requirements for alien far end crosstalk in the TIA TR 42.7 committee. It is a parameter that is required for 10GBASE-T but is still under study in the standards committees.

Figure 10 – Power Sum Alien Near End Crosstalk

Figure 11 – Power Sum Alien Equal Level Far End Crosstalk
The test results for all other transmission parameters are reported in Figure 12 to Figure 17 respectively.
Conclusions

Belden IBDN System 10GX is one of the only UTP solutions available on the market today that complies with all the requirements currently defined in the TIA “Augmented Cat 6 standard” under development for a worst case channel and components.

The synergies of the merger of Belden and CDT can be seen in the creativity and performance of the 10GX solution. Belden CDT Networking has put together a dedicated team of engineers and researchers to come up with innovative, robust cabling technologies that deliver performance beyond the minimum requirements of the proposed 10GBASE-T standard. The solutions are ahead of the curve in the industry and incorporate several key patent-pending technologies in connectivity and cable design.

Connectivity:

- Innovative module design with minimum delay compensation ensuring extended NEXT and PSNEXT performance up to 625 MHz
- MatriX IDC design and circuit layout to virtually eliminate alien crosstalk at the cable termination point, reducing APSNEXT by 15dB
- Unique X-Bar to ensure consistent termination and reliable NEXT and ANEXT performance after installation
- Module technologies that allow for high density patch panels with in-line ports, large simplified labeling areas and proper cable management
- Small footprint that is 100% compatible with existing Belden IBDN Patch Panels and Faceplates
- Precision, impedance-matched plug / jack design exceeding channel return loss of better than 8 dB at 500 MHz

Cable:

- Innovative unique cross-web design with optimum twist and cabling lays
- Additional integrated filler to provide increased randomization and inter-cable pair separation, and amazing flexibility