Belden IBDN System 10GX

Enabling Technologies

by

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Introduction

The IEEE 802.3an standard for the 10 Gigabit Ethernet over high performance twisted-pair copper was published in September 2006. In a span of 15 years the speed of data networks has 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 has evolved from Category 3 to a new level of performance called Category 6A (augmented Category 6), specifically designed to support 10 Gb/s transmission for distances up to 100 meters.

The speed of data networks is not only limited by the information carrying capacity of the cabling but also 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 is a need for a low cost 10 Gb/s solution over twisted pair copper. The initial demand for 10GBASE-T is for data center networks (between 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 high definition video, high resolution imaging, digital animation, CAD/CAM, storage and cluster computing.

In order to support 10GBASE-T operation for a full implementation up to 100 meters, Category 6A cabling (ISO Class E_A) is recommended for new installations. Category 6A cabling is specifically designed to meet stringent alien crosstalk requirements in worst case (six-around-one) bundled cabling configurations with up to 4 connectors. Power Sum Alien Near-End Crosstalk (PS ANEXT) and Power Sum Attenuation-to-Alien Crosstalk Ratio Far-End (PS AACRF) is specified for channels, permanent links and components. In addition, the internal transmission parameters such as Insertion Loss, Return Loss, PSNEXT, and PSACRF are specified over a frequency range from 1 MHz to 500 MHz.

Category 6A (ISO Class E_A) cabling is the minimum performance that is needed to support the short reach mode option in the standard. Short reach mode is designed to run 10 Gb/s with less power than the full version of 10GBASE-T for link segments up to 30 meters. Short reach mode is particularly advantageous for data center applications because of the high concentration of equipment that operates over much shorter distances than typically found for horizontal distribution is a commercial building.

10GBASE-T operation can also be supported over installed base Category 6 cabling for distances of up to 55 meters and possibly longer provided that the cabling meets the additional guidelines of TIA TSB-155. The capability to meet these guidelines for the installed base Category 6 cabling depends on the alien crosstalk environment (bundling conditions, patch panel design). TSB-155 discusses strategies for alien crosstalk testing in the field and provides mitigation techniques in the event that alien crosstalk coupling parameters are not met.

Belden IBDN System 10GX Enabling Technologies

Belden Networking has invested considerable resources in the development of a complete end-to-end solution for 10 Gigabit Ethernet over Category 6A 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 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.

Figure 1 – Belden 10GX Cabling Components

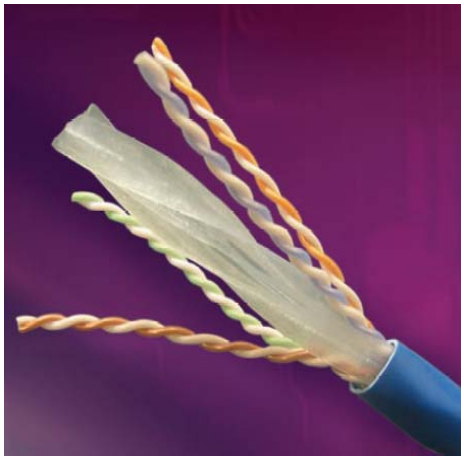
RoundFlex Technology

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 in these cables have the same twisting lay and cabling lay, and therefore have the same resonance frequencies where the crosstalk adds in phase.

The RoundFlex Technology is illustrated in Figure 2. There are two main elements in the patent-pending cable design. The first is a unique cross-web design, shaped like a double H, which separates the pairs and keeps them close to the axis of the cable and away from the jacket as indicated by the air space. The second feature of the cross web design is the asymmetry, which positions the long lay pairs (orange and brown) closer to the center of the cable than the short lay pairs (green and orange). The combination of these two elements increases the physical separation between pairs in neighboring cables and reduces ANEXT coupling between like pairs, by virtue of the fact that the long lay pairs, which are more susceptible to alien crosstalk, are further separated from each other than the short lay pairs.

An additional benefit of the RoundFlex design is a much improved pair balance (TCL) performance and a lower Insertion Loss because of the airspace in the core. The TCL performance of the 10GX RoundFlex cable is about 15 dB better than specified in the TIA 568 B.2-10 (Category 6A) standard.

By redesigning our earlier 10GX cable's internal cross-web construction and removing the filler, Belden's engineers have attained smaller diameter cable (only .295 in.) than could previously be made. The use of this RoundFleX Technology means higher density connections in the rack. What's more, the smaller diameter and greater flexibility provides for easier handling during installation.



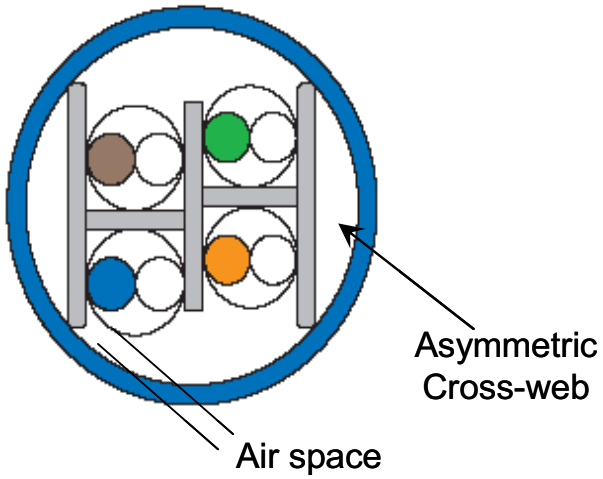
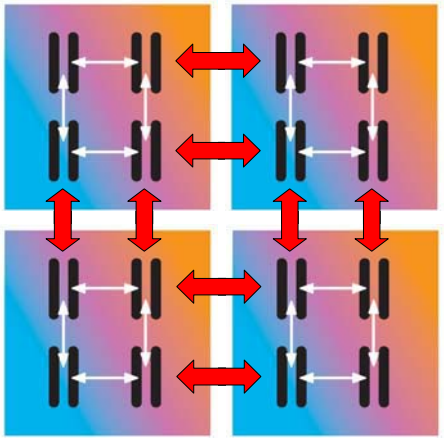


Figure 2 – RoundFlex Technology reduces ANEXT coupling between cable pairs

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.



Near field electromagnetic interference + The two contacts with unequal coupling = Poor Alien NEXT performance

Figure 3 – Typical IDC Modular alignment

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.

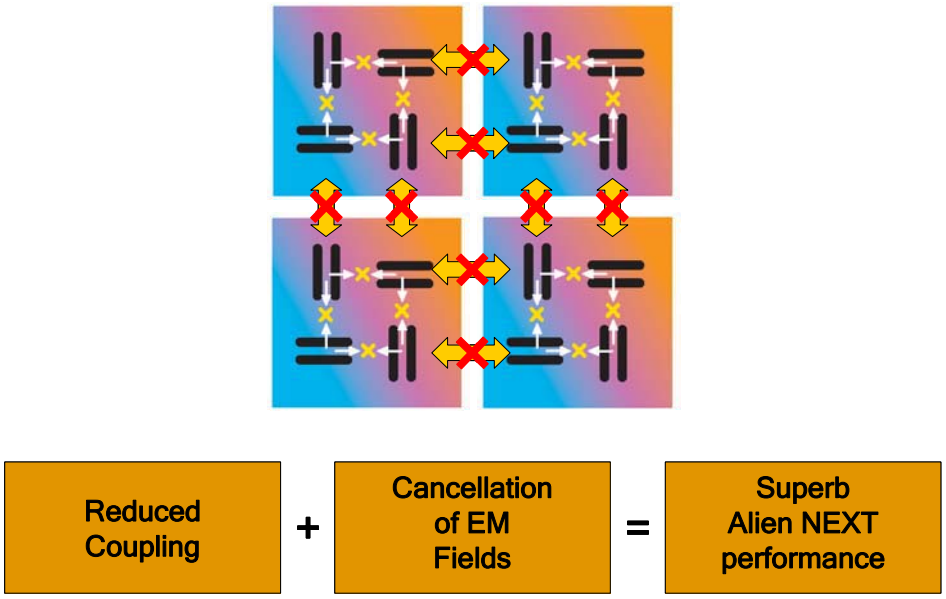


Figure 4 – MatriX IDC Modular alignment

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.

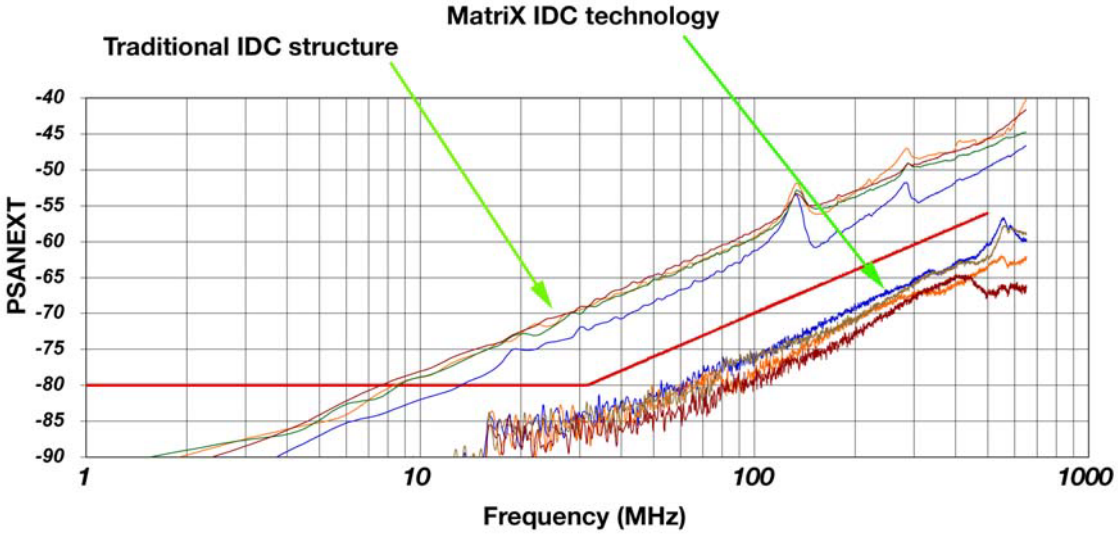


Figure 5 – PSANEXT of Patch Panel Typical IDC vs. MatriX IDC

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.

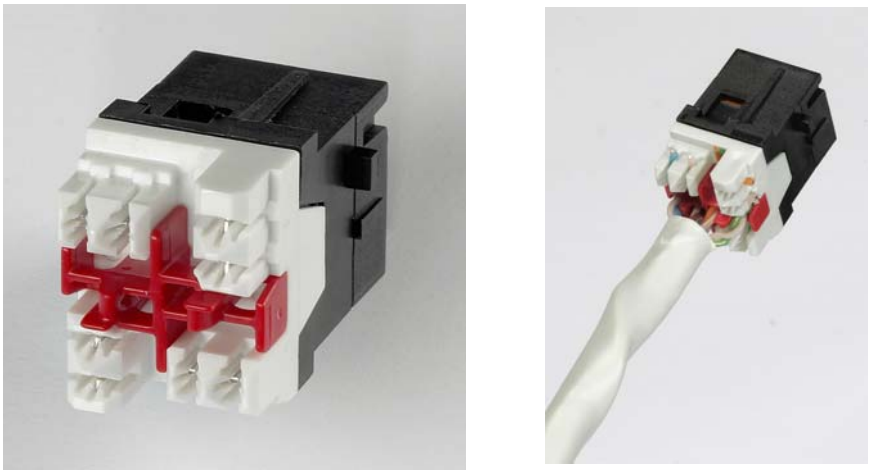


Figure 6 – X-Bar Insert and termination

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.

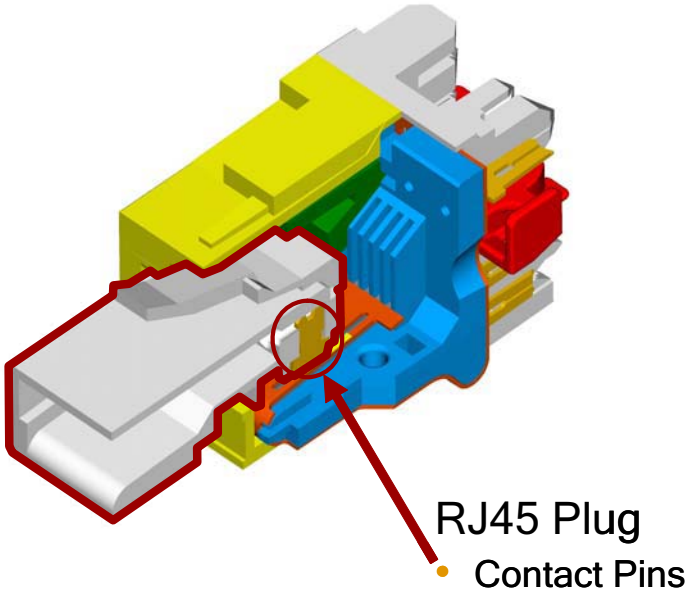


Figure 7 – FleXPoint PCB Design

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.

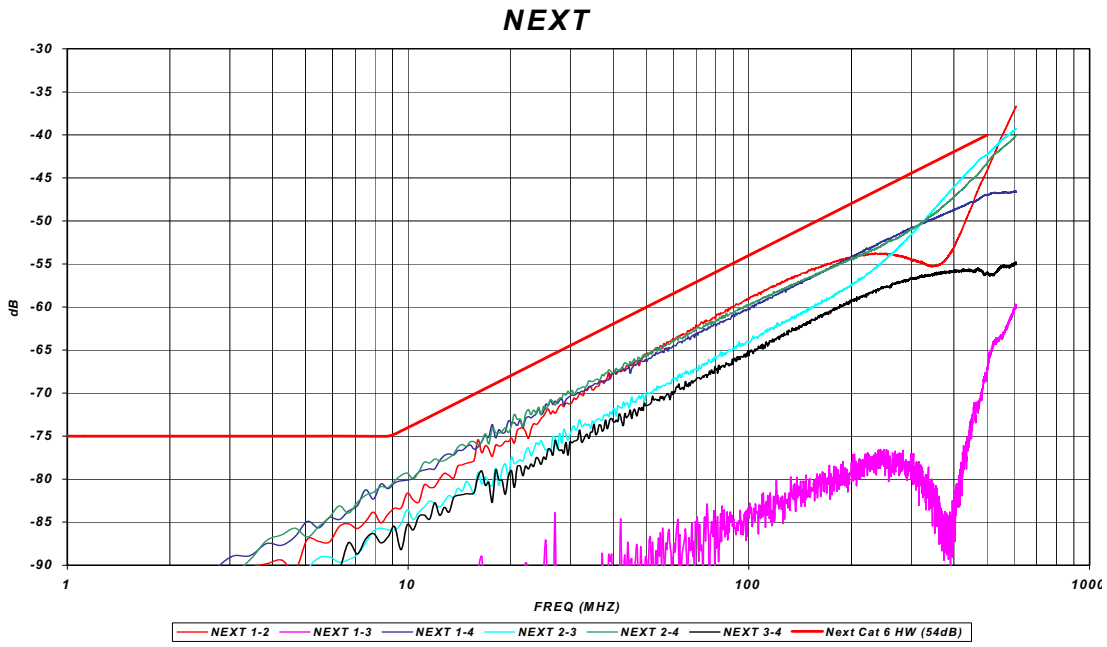


Figure 8 – FleXPoint PCB Mated NEXT Connector Performance

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 plug NEXT performance. The tolerance on plug NEXT is within half the range specified in Annex G of the TIA 568-B.2-10 (Category 6A) 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 providing 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 performance? We conducted comparative EMI tests at a local research facility using 10GX cords with a floating screen and Category 6A UTP cords without a screen. The electromagnetic interference was measured in an anechoic chamber over a frequency range from 30 MHz to 800 MHz and compared with Class A radiated emissions requirements. The test configuration and the test results are described in a companion paper. Belden 10GX cords incorporating the internal screen provides far superior Alien Crosstalk performance while maintaining radiated EMI and conversely noise immunity performance comparable to Category 6A UTP 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 8 inch 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.

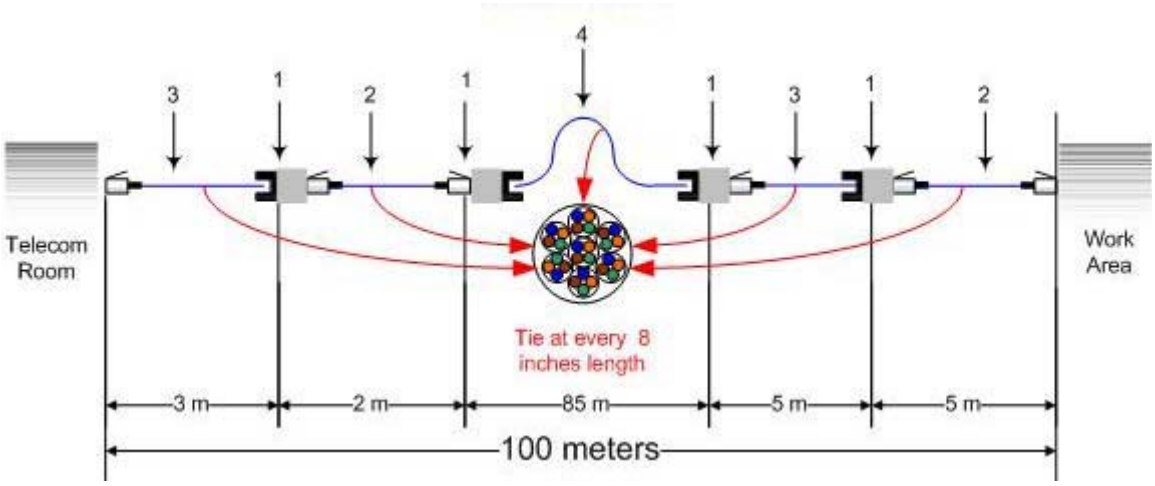


Figure 8 – Test configuration for channel measurements

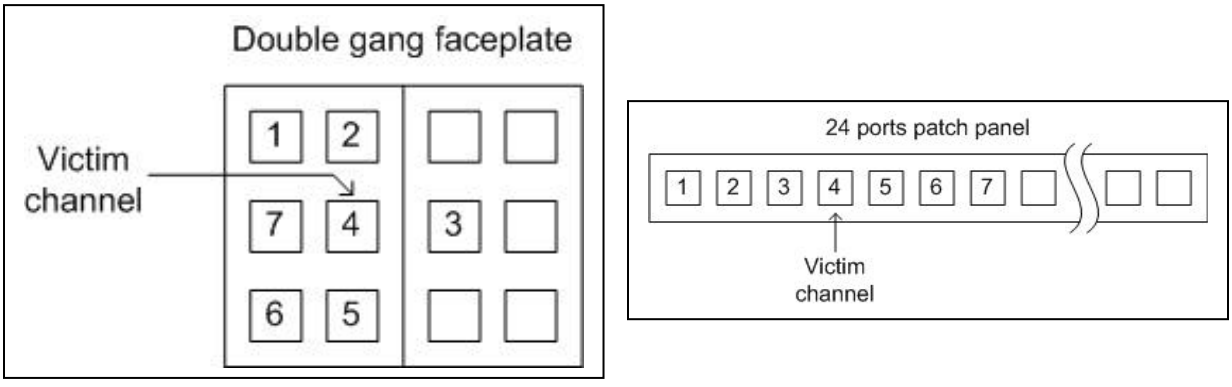
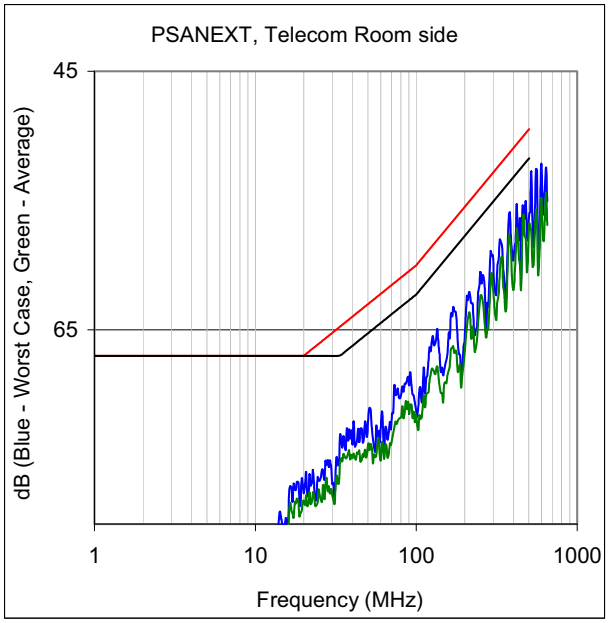


Figure 9 – Connector placement on patch panel and wall outlet

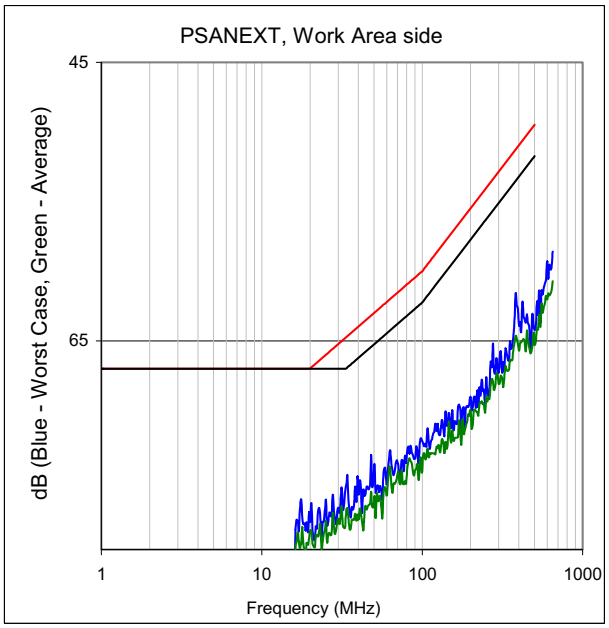
The power sum alien near end crosstalk (PS ANEXT) and power sum alien far end crosstalk (PS AACRF) from all the surrounding cables and connectors were measured using a network analyzer and an 8-port switch, tested at both ends in the forward

direction and in the reverse direction. The alien crosstalk results for a 100m 10GX32 channel with 4 connectors are shown in Figure 10a, 10b and Figure 11a, 11b. The two traces on the graph are the worst case (blue trace) and average (green trace) measurements for the victim channel. The red line and the black line are the corresponding individual pair and average requirements in the TIA 568 B.2-10 standard for augmented Category 6 (Category 6A) cabling.



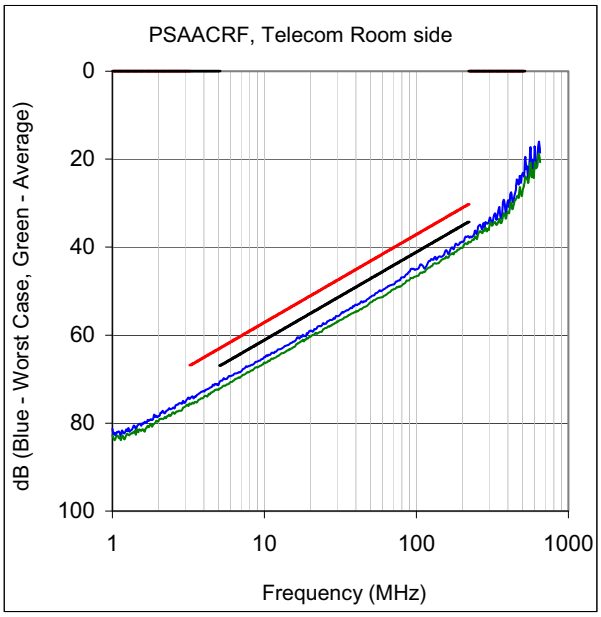
PSANEXT, Telecom Room side			Spec. TIA	
Freq.	Worst Case	Average	ind	Average
1	86.6	88.6	67.0	67.0
4	83.1	85.5	67.0	67.0
8	83.6	85.3	67.0	67.0
10	81.9	84.0	67.0	67.0
16	79.7	81.2	67.0	67.0
20	77.6	78.2	67.0	67.0
25	76.6	77.8	66.0	67.0
31	75.9	77.1	65.0	67.0
62	72.8	73.9	62.1	64.3
100	71.1	71.6	60.0	62.3
160	67.3	69.1	57.2	59.4
200	65.9	67.0	55.5	57.7
250	60.5	62.3	54.0	56.3
300	59.2	61.7	52.9	55.1
350	61.0	62.1	51.8	54.1
400	59.6	61.9	51.0	53.2
450	61.0	61.9	50.2	52.5
500	56.0	56.8	49.5	51.7
550	52.5	55.7		
600	52.2	54.8		
625	54.8	58.1		

Figure 10a – Power Sum Alien Near End Crosstalk (TR)



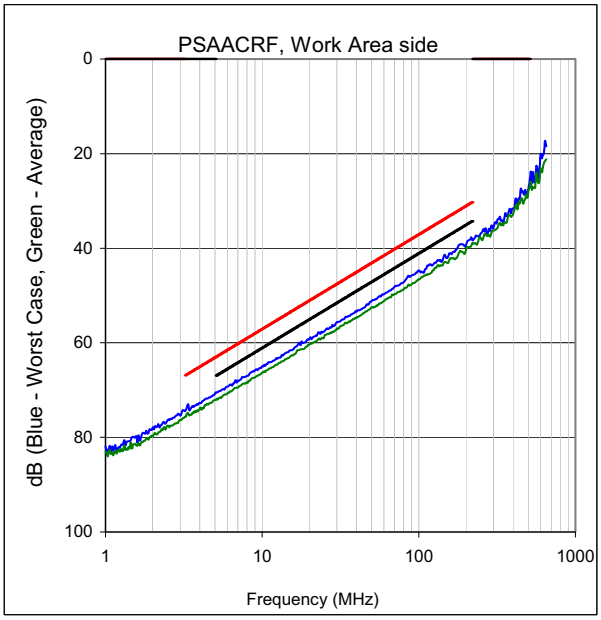
PSANEXT, Work Area side			Spec. TIA	
Freq.	Worst Case	Average	ind	Average
1	87.3	88.5	67.0	67.0
4	84.8	85.5	67.0	67.0
8	84.0	85.3	67.0	67.0
10	82.7	83.2	67.0	67.0
16	81.6	83.0	67.0	67.0
20	78.0	78.6	67.0	67.0
25	76.5	78.0	66.0	67.0
31	75.6	76.9	65.0	67.0
62	73.4	74.0	62.1	64.3
100	72.2	74.5	60.0	62.3
160	70.0	71.4	57.2	59.4
200	69.0	70.0	55.5	57.7
250	67.6	69.0	54.0	56.3
300	67.3	68.1	52.9	55.1
350	65.0	66.4	51.8	54.1
400	63.9	65.7	51.0	53.2
450	63.1	64.3	50.2	52.5
500	64.2	65.3	49.5	51.7
550	61.4	62.3		
600	59.3	62.0		
625	59.5	61.8		

Figure 10a – Power Sum Alien Near End Crosstalk (WA)



PSAACRF, Telecom Room side			Spec. TIA	
Freq.	Worst Case	Average	ind	Average
1	81.3	82.7	info	info
4	71.4	72.5	63.1	info
8	67.0	68.4	59.0	63.0
10	65.0	66.2	57.0	61.0
16	61.2	62.5	52.9	56.9
20	59.1	60.4	51.0	55.0
25	57.4	58.4	49.0	53.0
31	55.4	56.6	47.0	51.0
62	49.5	50.9	41.1	45.1
100	45.0	46.7	37.0	41.0
160	41.0	42.6	33.2	37.2
200	38.7	40.2	31.0	35.0
250	37.1	38.2	info	info
300	34.3	36.1	info	info
350	30.9	33.5	info	info
400	29.4	32.0	info	info
450	27.3	29.2	info	info
500	23.1	26.7	info	info
550	20.5	23.0		
600	17.2	20.7		
625	21.3	21.8		

Figure 11a – Power Sum Alien Equal Level Far End Crosstalk (TR)



PSAACRF, Work Area side			Spec. TIA	
Freq.	Worst Case	Average	ind	Average
1	81.9	83.0	info	info
4	71.0	72.1	63.1	info
8	67.1	68.4	59.0	63.0
10	65.0	66.3	57.0	61.0
16	61.3	62.5	52.9	56.9
20	59.3	60.4	51.0	55.0
25	57.5	58.4	49.0	53.0
31	55.4	56.5	47.0	51.0
62	49.4	50.7	41.1	45.1
100	44.7	46.6	37.0	41.0
160	41.8	43.1	33.2	37.2
200	39.7	40.6	31.0	35.0
250	36.8	38.1	info	info
300	35.9	36.3	info	info
350	33.7	34.5	info	info
400	31.6	32.8	info	info
450	27.4	29.6	info	info
500	27.3	27.8	info	info
550	25.8	27.2		
600	20.1	23.2		
625	20.1	22.8		

Figure 11b – Power Sum Alien Equal Level Far End Crosstalk (WA)

The test results for all other transmission parameters are reported in Figure 12 to Figure 17 respectively.

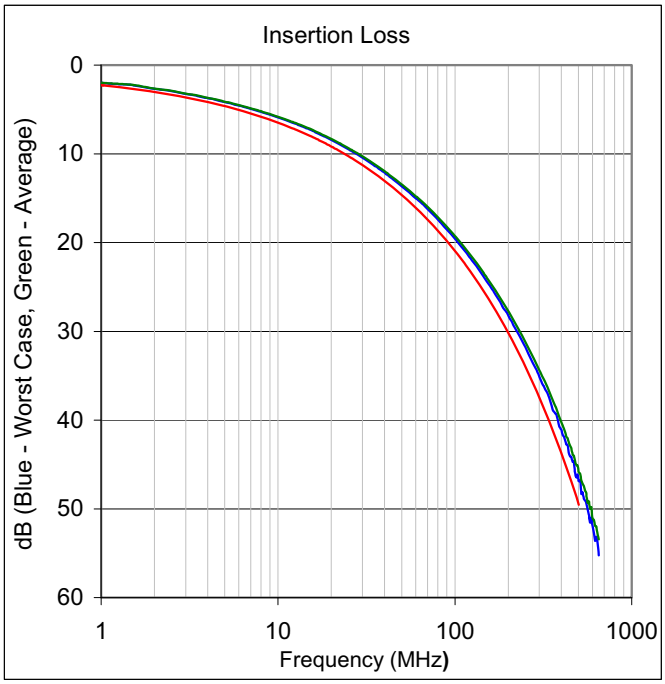


Figure 12

Insertion Loss			
Freq.	Worst Case	Average	Spec. TIA
1	2.0	2.0	2.3
4	4.2	4.1	4.6
8	5.2	5.2	5.8
10	5.9	5.8	6.5
16	7.5	7.4	8.2
20	8.4	8.3	9.2
25	9.5	9.4	10.3
31	10.7	10.5	11.5
62	15.2	15.0	16.4
100	19.5	19.2	20.9
155	24.6	24.2	26.3
200	28.2	27.7	30.1
250	31.8	31.2	34.0
300	35.0	34.3	37.4
350	38.3	37.4	40.8
400	41.2	40.3	43.8
450	44.1	42.9	46.5
500	46.9	45.9	49.5
550	49.3	48.2	
600	51.9	51.1	
625	53.6	51.9	

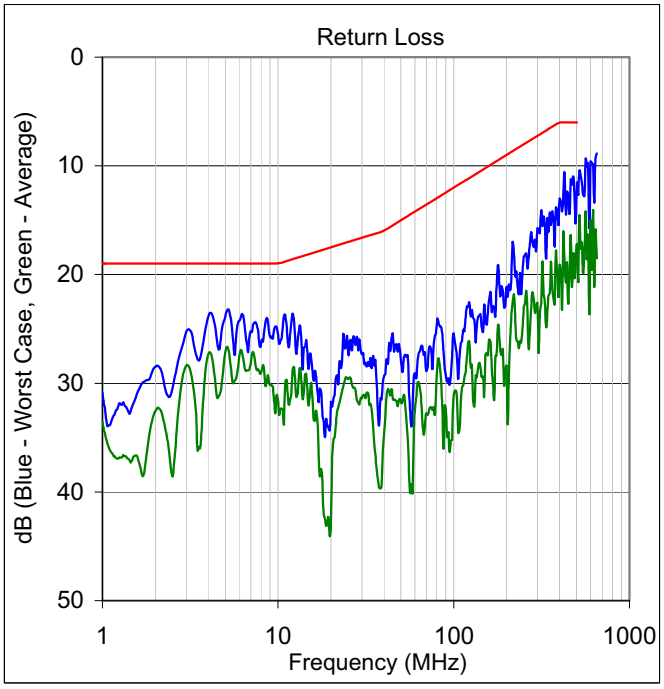


Figure 13

Return Loss			
Freq.	Worst Case	Average	Spec. TIA
1	30.8	33.5	19.0
4	24.1	27.5	19.0
8	26.7	29.1	19.0
10	25.5	31.6	19.0
16	29.8	33.4	18.0
20	31.7	43.0	17.5
25	27.4	29.6	17.0
31	28.1	31.4	16.5
62	28.0	30.0	14.1
100	25.5	31.5	12.0
155	24.6	27.2	10.1
200	21.1	28.4	9.0
250	18.3	23.0	8.0
300	15.8	22.6	7.2
350	14.3	21.7	6.5
400	13.0	19.1	6.0
450	12.7	22.7	6.0
500	11.6	17.2	6.0
550	12.8	17.7	
600	9.6	15.1	
625	9.9	14.1	

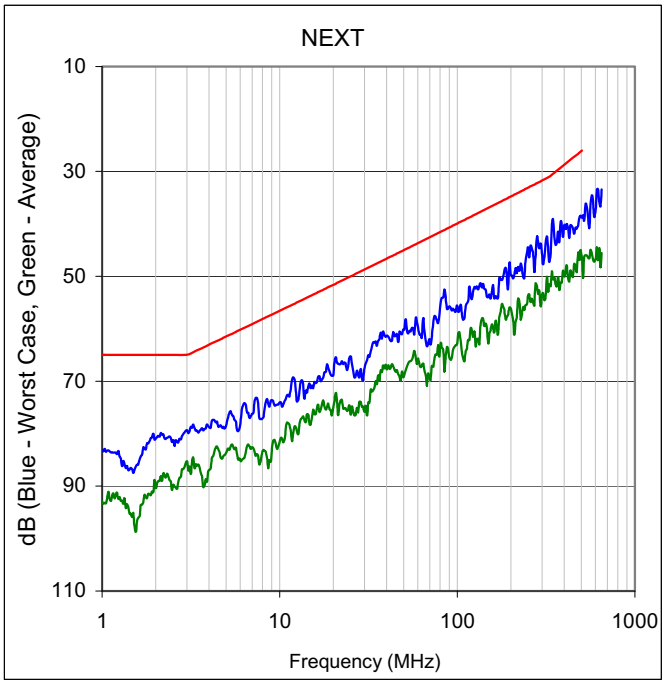


Figure 14

NEXT			
Freq.	Worst Case	Average	Spec. TIA
1	83.1	92.9	65.0
4	78.7	83.8	61.5
8	77.2	83.9	58.2
10	74.1	81.7	56.6
16	70.4	76.3	53.3
20	68.9	75.1	51.6
25	65.2	76.4	50.0
31	65.0	74.0	48.4
62	61.2	67.3	43.4
100	55.6	62.9	40.0
155	54.2	60.4	36.7
200	49.7	56.1	34.8
250	44.4	53.6	33.1
300	45.2	53.7	31.8
350	42.5	50.2	30.2
400	40.2	50.1	28.7
450	40.9	50.1	27.4
500	38.8	46.6	26.0
550	40.8	46.6	
600	37.2	46.6	
625	33.4	46.9	

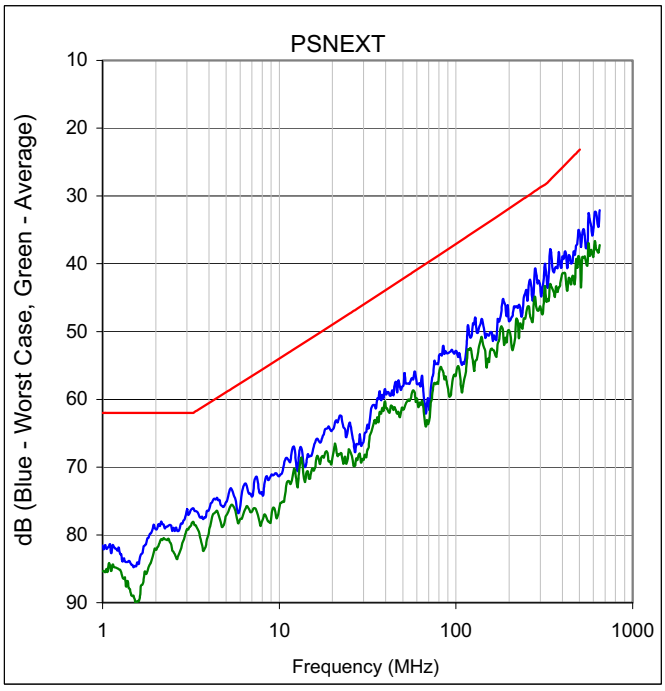


Figure 15

PSNEXT			
Freq.	Worst Case	Average	Spec. TIA
1	81.6	85.4	62.0
4	75.3	77.4	59.0
8	73.7	78.1	55.6
10	71.4	76.3	54.0
16	66.3	70.0	50.6
20	64.5	68.7	49.0
25	63.4	67.6	47.3
31	63.7	67.4	45.7
62	57.6	60.5	40.6
100	52.9	56.6	37.1
155	50.6	54.4	33.8
200	48.5	49.8	31.9
250	43.9	47.2	30.1
300	43.2	46.3	28.8
350	40.6	43.7	27.3
400	38.9	41.4	25.8
450	40.0	43.0	24.5
500	35.7	39.5	23.2
550	37.6	40.2	
600	34.9	39.0	
625	32.4	37.8	

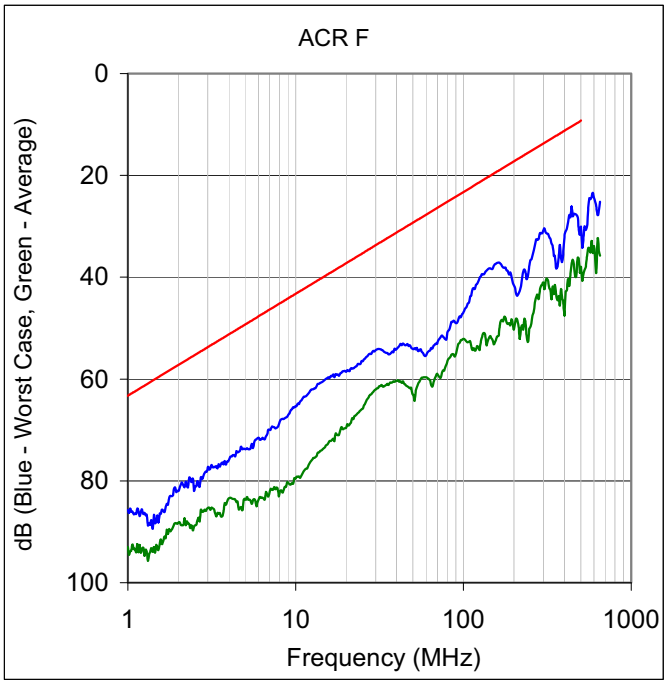


Figure 16

ACR F			
Freq.	Worst Case	Average	Spec. TIA
1	85.7	93.0	63.3
4	73.7	83.5	49.3
8	69.0	83.1	45.2
10	65.3	79.6	43.3
16	59.8	72.1	39.2
20	58.6	69.6	37.2
25	56.5	65.8	35.3
31	54.1	61.4	33.3
62	54.5	60.0	27.4
100	47.1	52.1	23.3
155	37.5	52.8	19.5
200	41.6	50.3	17.3
250	36.7	49.8	15.3
300	30.8	41.0	13.7
350	35.8	41.5	12.3
400	31.8	47.4	11.2
450	28.0	36.6	10.2
500	30.1	38.0	9.2
550	26.3	34.3	
600	24.4	33.9	
625	26.0	39.1	

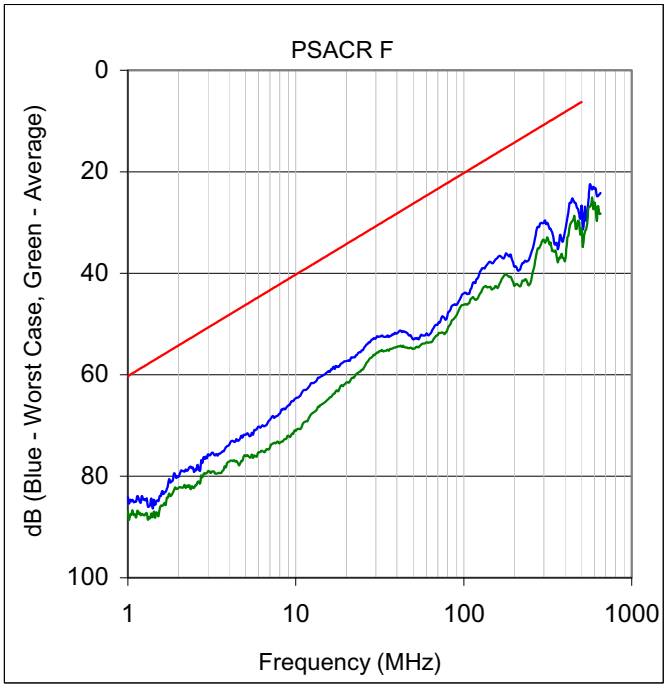


Figure 17

PSACR F			
Freq.	Worst Case	Average	Spec. TIA
1	84.1	87.0	60.3
4	71.9	75.8	46.3
8	67.7	73.5	42.2
10	64.6	71.0	40.3
16	59.4	64.5	36.2
20	57.3	61.5	34.2
25	55.1	58.9	32.3
31	52.5	55.3	30.3
62	52.1	53.7	24.4
100	44.0	46.2	20.3
155	37.3	42.5	16.5
200	38.7	42.5	14.3
250	36.3	41.8	12.3
300	30.0	33.4	10.7
350	34.4	35.6	9.3
400	31.7	37.6	8.2
450	25.6	29.5	7.2
500	26.7	31.2	6.2
550	25.4	27.1	
600	23.4	26.0	
625	24.8	29.6	

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 Category 6 standard" for a worst case channel and components.

Belden 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 IEEE 10GBASE-T standard, the TIA Category 6A standard as well as the ISO Class E_A 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 an optimal arrangement of pairs, inter-cable pair separation, and amazing flexibility