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Cabling Installation & Maintenance

EDITORIAL GUIDE

Connectivity in High-Speed Twisted-Pair Networks

For twisted-pair copper-based networks to fully support the throughput capacity demanded by today's leading-edge applications, performance of the networks' connectivity technology is crucial. The race toward 40-Gbit/sec twisted-pair solutions continues, while today's users also demand premier performance from current twisted-pair connectivity and cabling. This Cabling Installation & Maintenance editorial guide includes articles that look toward the twisted-pair requirements for 40G, as well as current technical issues with copper LAN cabling connectivity.

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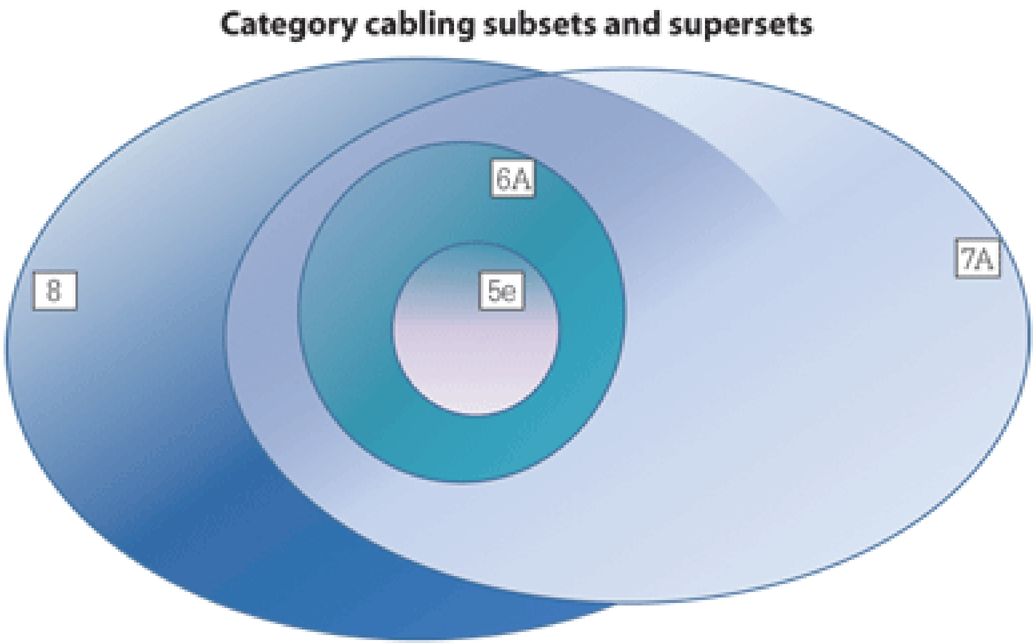
TIA's great Category 8 debate and ISO/IEC's cabling update

Unlike previous standards, Category 8 as proposed is not an electrical-performance superset of Category 7A.

by **VALERIE MAGUIRE,** The Siemon Company

AFTER DEBATING THE issue for three meeting cycles, the TIA TR-42.7 Copper Cabling Subcommittee adopted "Category 8" as the name of its next-generation balanced twisted-pair cabling system that is currently under development to support 40-Gbit/sec transmission in a two-connector channel over some distance up to at least 30 meters. The issue of what to call this new system was a subject close to the hearts of many subcommittee members; both proponents and opponents of the new name argued tenaciously for their positions. However, the real question is just how much confusion the name Category 8 is going to cause for the industry.

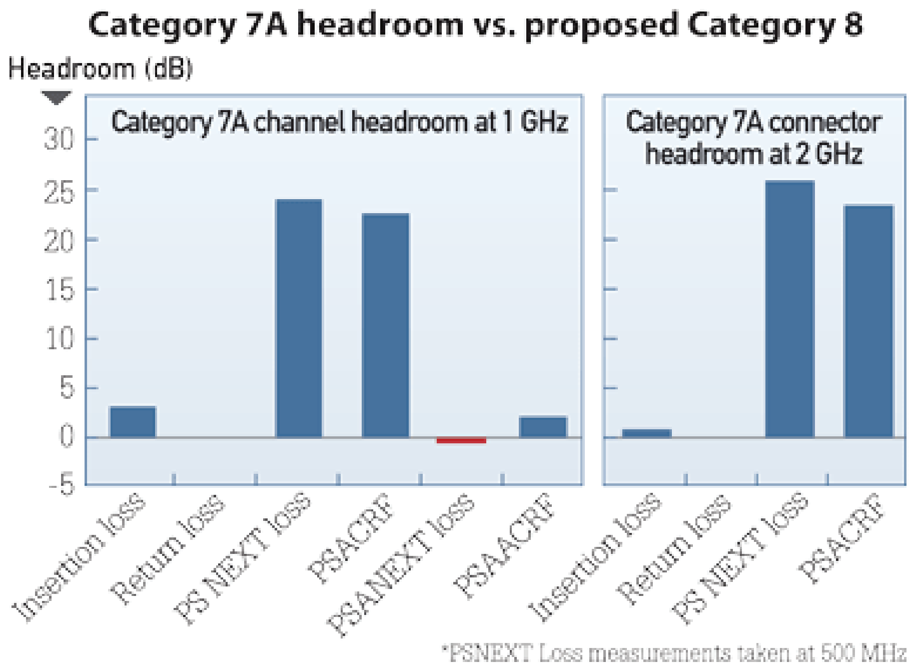
Traditionally cabling categories are supersets of each other, meaning that a higher category of cabling meets or exceeds all of the electrical and mechanical requirements of a lower category of cabling, and is also backward-compatible with the lower-performing category. While TIA specifies cabling systems up to Category 6A performance, TIA chose not to adopt Category 7 or 7A as published by ISO/IEC. TIA has now decided to call its next-generation cabling system "Category 8" to avoid confusion with published ISO/IEC Category 7 and Category 7A standards, which are indeed supersets of each other and of Category 6A. While it is true that the currently proposed Category 8 specifications tentatively describe transmission performance up to 2 GHz, whereas ISO/IEC specifies Category 7A requirements up to 1 GHz, the performance limits proposed for Category 8 as of March 2013 do not meet or exceed Category 7A requirements up to 1 GHz.



Traditionally, a new-generation category of cabling is a performance superset of the previous-generation category; therefore the previous generation is a subset of the next generation. For example, Category 5e is a subset of Category 6A, which is a subset of the ISO/IEC's Category 7A as well as the TIA's in-progress Category 8. However, the performance specifications originally proposed by TIA for Category 8 are not a superset of ISO/IEC's Category 7A for several electrical-performance parameters.

So herein lays the conundrum: Category 8 is expected to have a different deployed channel topology and will not be a performance superset of Category 7A. In fact, for every transmission parameter except return loss, ISO/IEC Category 7A channel and permanent link limits are more severe than those proposed by TR-42.7 for Category 8 up to 1 GHZ. In the case of internal crosstalk parameters, the differences are significant, with Category 7A beating out Category 8 performance by more than 20 dB.

While Category 7A is currently specified to 1 GHz, work items such as IEC 61076-3-104, 3rd edition standard for Category 7A connectors are extending Category 7A performance characterization out to 2 GHz. Having two cabling specifications specified to 2 GHZ, with Category 8 having lower performance than Category 7A, will create confusion.



Blue bars indicate the extent to which ISO/IEC Category 7A electrical-performance requirements surpass those of TIA's initial Category 8 at given frequencies. The PS NEXT loss figures shown in both charts reflect measurements taken at 500 MHz.

ISO/IEC faced the same "what-to-name-it" challenge with its new project to define two new grades of cabling (shielded and fully shielded) to support 40-Gbit/sec data transmission. ISO/IEC recently adopted Class I to describe cabling constructed from shielded modular RJ-45-style Category 8.1 components and Class II to describe cabling constructed from fully shielded Category 8.2 components.

Until the processing capabilities of a 40-Gbit/sec Ethernet (40GBase-T) application are finalized, it is too early to guarantee 40GBase-T application support distance for any media. However, Category 7A solutions remain the highest-performing commercially available twisted-pair cabling system. Not only do these solutions provide higher EMI/RFI immunity and more-flexible cable-sharing capabilities than RJ-45-style solutions, but ISO/IEC is actively working on a project to characterize the capability of existing Category 7A cabling to support 40-Gbit/sec data transmission.

VALERIE MAGUIRE is global sales engineer with The Siemon Company.

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40GBase-T promises excitement

by **PATRICK MCLAUGHLIN**

IN DECEMBER 2012 we reported on some of the initial efforts by the Telecommunications Industry Association (TIA) to produce a set of Category 8 twisted-pair cabling specifications for the support of 40GBase-T (see "TIA working on Category 8 standard," December 2012). The TIA group working on the Category 8 specifications has ambitious plans concerning the amount of progress it expects to make in 2013.

If you are inclined to read and/or contribute to industry-related discussion groups, you may already have seen some of the technopolitical debates taking shape around the Category 8 specifications. In large part these debates concern the TIA's decision to move ahead with a Category 8 specification independent of the ISO/IEC's Category 7 and 7A specifications, and the likelihood that the Category 8 requirements for some electrical-performance characteristics will be less-strict than those of Category 7A for the same characteristics. We mentioned this in our December reporting as well, but as you might imagine the topic has taken on a life of its own in the aforementioned discussion groups.

For me there is a bottom line to the discussion/debate. It's the bottom line for me because it's what I honestly believe matters the most to you as readers of this publication. And that is: Will a cabling system that complies with the specifications support the intended application? In this case, it's: Will a Category 8-compliant system support 40GBase-T?

The development of Category 8 is in keeping with the successful efforts through which a set of cabling-performance parameters is developed in tandem with an Ethernet transmission protocol. By contrast and for example, the TIA's development of Category 6 was not in sync with an IEEE effort to develop 1000Base-TX (i.e. Gigabit Ethernet over two copper pairs). The IEEE passed on a 1000Base-TX project and the TIA's own efforts to put forth 1000Base-TX fell flat.

Category 6A, on the other hand, aligned that cabling-performance level with 10GBase-T.

No one has ever told me that the TIA passed on opportunities to construct a Category 7 or 7A set of specifications because there was no direct alignment with an Ethernet protocol. But the TIA's actions, in the form of its decision to move forth with a 40GBase-T-aligned Category 8, make a statement.

PATRICK MCLAUGHLIN is chief editor of *Cabling Installation & Maintenance*.

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Patch cords can't afford to be a weak link

Solid performance of every segment in an end-to-end cabling system is growing more important than ever.

by **PATRICK MCLAUGHLIN**

AT A TIME when an increasing amount of precision is required to accurately install and terminate a structured cabling system in the field, the economic pressures of price and low-margin business are dangling the temptation for cabling-system stakeholders to use potentially underperforming patch cords in their networks. When one gives in to that temptation, and network performance eventually suffers as a result, the perception of patch cords as a cabling system's weak link is perpetuated. Such is the reputation of that portion of the cabling system that is most visible to the everyday user at a workstation, who knows or cares little about the cabling system that facilitates connectivity to a corporate network and to the outside world. By and large these users view patch cords only as nuisance speed bumps as they wheel their chairs around a workspace. A network cabling-system administrator, on the other hand, takes more serious and critical consideration of the cords used in the work area as well as equipment cords used in telecommunications rooms. At least, we hope these administrators take such consideration.

Bad press?

Typically patch cords make headlines, with us and with other cabling-related news and information sources, for unfortunate reasons. Every now and then Underwriters Laboratories issues a public notice about patch cables that use its (UL's) mark without authorization. It issued the most recent such notice a little more than a year ago, in March 2012, bringing the public's attention to Category 5e cables, as well as USB 2.0 cables, sold at Big Lots stores under the brand name TriQuest, that "bear an unauthorized UL Mark on the product packaging." As is typically the case when UL issues such a notice, it added, "The products have not been evaluated by UL to the applicable standard for safety and it is unknown if they comply with the UL safety requirements." In its notice, UL reported there were 95,120 units of the patch cable produced.

With UL not having issued a notice of this type in more than a year, is the circulation of this type of patch cable an anecdote, or an example of a more-widespread problem? Caution and prudence would suggest it being viewed as the latter. Two points of fact about these notices from UL are worth considering. First, the organization only issues a notice when its brand and markings are used incorrectly. A patch cord that does not perform at the level stated on its packaging, but does not use the UL mark, will not be on UL's radar. And second, UL exhausts multiple efforts to reach and work with a manufacturer before issuing a public notice. Before such a notice is issued, UL has been unable to satisfactorily resolve the issue with the manufacturer. In some cases, the manufacturer and UL have had no discourse at all, with UL's efforts to communicate being unsuccessful. With that in mind, it is plausible that some manufacturers are responsive to UL's inquiries and the issue is resolved without a public notice being issued. So the idea that anytime a rogue patch cord reaches the market, UL issues a notice about it, is false.

Keeping patch cords straight once they are installed is difficult. It's also easy to get tangled up and fall into one of the many pitfalls that exist when choosing cords in the first place.

Many-headed beast

The existence of substandard patch cords in the marketplace was addressed in an article we published in January 2012. Authored by comCables' Andy Work and Tom McAllister, the article was titled "The patch-cord conundrum: Corrosion versus conformity." In it, the authors explained, "Quality, as well as code- and standard-compliance, has a price tag. A high-priced patch cord does not mean it is standards-based and will pass the performance requirements; however, price is the first indicator to help guide your decision … Typically patch cords are not supplied by the structured cabling installer, nor are they found on the request-for-quote. Patch cords are usually supplied by the end-user's IT department after the installation is complete. Projects are not awarded for their patch-cord prowess; typically they are won on price and performance.

"It is ironic how a company will build a multi-million-dollar facility with new networking hardware, then the IT department will box up their old patch cords and reinstall them. If the cords are not reused, they are sourced off the Internet for the cheapest ones to be found, or worse, the cords are home-made."

In the field

That issue of field-made patch cords is debatable. Naturally, a company like comCables that factory-produces and tests patch cords will caution against the act of field-terminating two plugs on the end of a length of patch cable, pointing out the absence of quality-control measures in such an approach. Another viewpoint is put forth as well, though. For example, LANshack, which provides cable, connectors, installation tools and numerous other products, includes tutorials on its website about how to properly construct Category 5, 5e and 6 patch cords.

Within LANshack's tutorial is a caution about the potential for substandard performance. It reads, "If the completed assembly does not pass continuity, you may have a problem in one or both ends." The tutorial then advises to recrimp and examine the assembly and if necessary, to reterminate.

Whether they are constructed in the factory or the field, testing patch cords for continuity, or wiremap, alone has been regarded as insufficient by companies including comCables and Fluke Networks. In their article, Work and McAllister said, "The only way to really know that a patch cord has been manufactured to standards is to test it. Or you can choose to buy patch cords exclusively from manufacturers that performance-test 100 percent of their products using the correct test method before shipment is made."

The authors also call out a common myth—that users can test patch cords for standard performance using the channel adapters that come with Fluke Networks' DTX 1800 tester. "A channel test is a lenient test for patch cords because it includes significant leeway for all component parts of the end-to-end system."

Fluke Networks agrees with that sentiment—so much so that in spring 2011 it introduced a patch-cord test adapter for the DTX tester. The DTX Patch Cord Test Adapter series can certify twisted-pair patch cords, shielded or unshielded, to Category 5e, 6 and 6A component specifications established in TIA-568-C and ISO 11801 standards. With the adapters, a user can test patch cord parameters including wiremap, length, propagation delay, delay skew, near-end crosstalk, resistance and return loss. When announcing the adapters the company explained they are appropriate for field and factory use.

In a data sheet for the adapter series, Fluke Networks explained, "Most cords are only tested for wiremap, not performance—in spite of what may be indicated on the jacket. Channel certification shows the performance of the completed end-to-end link including equipment and work area patch cords. Permanent link certification shows the true performance of the installed link without the cords. This is very common because it's the most practical and accurate way to certify new cabling links, but it is dependent on compliant patch cords. Patch cord certification can quickly determine whether a patch cord meets industry performance specifications."

Some providers of factory-manufactured patch cords have taken steps not only to encourage the use of factory cords, but also to make it easier for users to acquire them. One example is Leviton Network Solutions' fall 2012 launch of an online copper patch cord customization tool, which allows customers to configure cords for their specific applications by selecting cord type, color and exact length. Specifically, nine cord types, eight jacket colors and 200 lengths are available to choose from. After selecting their options, customers each receive a part number for each unique cord, along with specific ordering details.

Leviton Network Solutions senior product manager Kirk Krahn said the tool was launched "to make it simpler for our customers to select the exact cords they need for their network. Our custom patch cords reduce installation costs and eliminate the waste and tangle of excess cord lengths by allowing customers to select the appropriate length for their application."

Being direct

Discussion about field-production of patch cords is an interesting topic, and when the topic is debated an issue frequently discussed is the precision workmanship required to produce a cord that complies with demanding standard-based electrical performance characteristics. Wherever the skill to achieve such performance does exist, it can be valuable in several ways, including a field-termination style that is gaining attention and use in the structured cabling industry.

The Single Connector Modified Permanent Link connection method frequently is referred to as direct-attach. Under this method, horizontal cable is terminated to a modular plug rather than to a jack. So it would be inaccurate to say direct-attach terminations are really just lengthy patch cords, because just one end of the horizontal cable is terminated to a plug. Even so, the skill required to effectively achieve that termination method is the same skill put to use when one attempts to field-construct a patch cord.

Graybar dedicates a page on its website to this connection method, including a white paper, video demonstration of the attachment method, and test results of direct-attach systems. Karl Griffith, director of emerging technology and author of the white paper, explained in it: "Direct attach was designed to help network architects and technicians leverage both their skill in communications wiring systems and UTP as the cable of choice for building facility-system networks… Many non-user administered IP devices are mounted in places high on walls, or on or in ceilings. In these locations the typical configuration isn't practical for installation and maintenance …The direct attach philosophy aims to decrease the safety hazards and configuration issues encountered with non-user administered IP devices by installing the modular plug directly on the end of the cable servicing the IP device, therefore eliminating the jack, faceplate and patch cord."

While the method may indeed eliminate the need for patch cords to connect some networked devices, it simultaneously can shine light on the need for sufficient skill in the installation environment, to successfully terminate twisted-pair cable to a plug.

PATRICK MCLAUGHLIN is chief editor of *Cabling Installation & Maintenance*.

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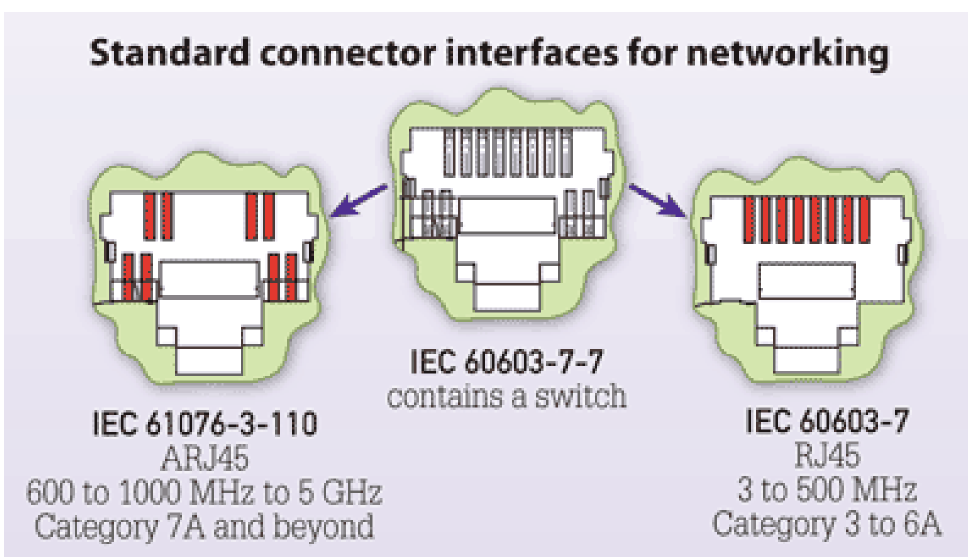
Why DCMC matters for high-frequency transmission

Differential- to common-mode conversion, transverse conversion loss and twisted-pair connector interfaces may be significant factors in transmission beyond 500 MHz.

by **YAKOV BELOPOLSKY** and **RICHARD MAROWSKY**

CLOSE TO ONE billion users are connected to the Internet today. Many of them are connected through copper-wire channels, either leading to a final user or as part of the infrastructure. The Internet is built upon the standardized Ethernet protocols described in the 802.3 standards put forth by the Institute of Electrical and Electronics Engineers (IEEE). The move toward 40- and 100-Gigabit Ethernet requires better and faster connectivity and lower noise within the transmission system.

The Ethernet signals use what is known as differential mode transmission. Each differential channel consists of two conductors, and requires balance within the transmitter or receiving pair. Or, in electrical terms, the characteristic impedance of each conductor within



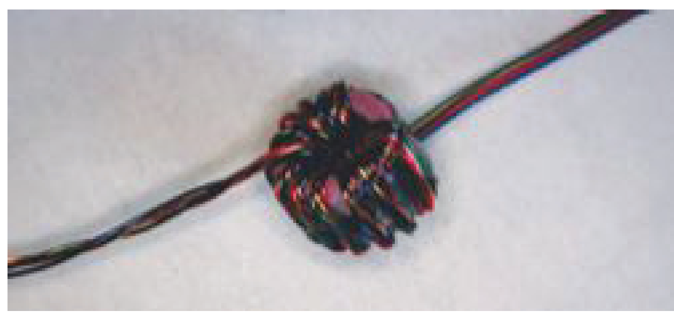
The IEC standard 60603-7-7 connector interface contains a switch and is a superset of the RJ45 and ARJ45 connector interfaces.

the channel shall be equal—typically 50 Ohm. If the balance is violated, the result is a transformation of a portion of the original signal energy into parasitic common-mode noise. This differential- to common-mode conversion (DCMC) worsens the transmission by reducing the signal strength and adding to the level of noise.

This article will discuss the relationship between DCMC and the interfaces used for twisted-pair copper cabling systems. The discussion will be limited to the application spectra above 500 MHz, for which there are no current Ethernet protocol specifications, but is a frequency range in which research and testing are taking place.

Interfaces and connectors

The interface between a network appliance and the premises wiring is an interface between the building cabling infrastructure and equipment such as a switch or computer. For the user it is simply a port into which a patch cord is plugged. In reality, the engineering behind the simple patch-cord plug-in is far from simple. In fact, there are two networking interfaces, which have rather complex electrical and mechanical characteristics, where the mechanical structures directly impact the transmission performance. The networking-equipment connectors are not covered by premises-wiring standards.



Shown here are the high-performance 10-GbE LAN transformer windings, which are made of twisted pairs.

The first interface is a connector, most often an RJ45 or ARJ45 (augmented RJ45). At the network-appliance side it is usually a receptacle (a jack). At the premises wiring side it is a plug. This interface is the interruption and disturbance of the twisted-pair media.

The second interface is a transformer that provides a safety barrier between cables and a networking appliance. Often transformers, other magnetic elements and other signal-conditioning components are incorporated into the connectors. Such connectors are referred to as integrated connector modules (ICMs).

As a result, the connectors specified in TIA-568 series and ISO/IEC standards for premises wiring have the same name as network equipment connectors, but they look and function differently. What they do have in common are the interfaces.

The interface is subject to mechanical stresses and abuses. It is subject to electrical discharges due to connection and disconnection under the electrical load, particularly in Power over Ethernet (PoE) applications. Yet the interfaces must be inexpensive and therefore not complex; they must be robust and easy to use for millions of people.

Transmission class ISO/IEC standards	Connector category	Frequency bandwidth	Typical application	Connecting hardware interface
Class C	3	16 MHz	IEEE 802.5 Token Ring	RJ45
Class D	5e	100 MHz	10 to 1000Base-T Ethernet	RJ45
Class E	6	250 MHz	100 to 1000Base-T	RJ45
Class EA	6A	500 MHz	To 10-GbE	RJ45
Class F	7	600 MHz	1-GbE over single pair, 10-GbE	GG45, ARJ45
Class FA	7A	1000 MHz	10-Gbit over 2 pairs, 10-GbE over 100 meters	ARJ45
NA	NA	2000 MHz	10- to 40-GbE	ARJ45

The basic connector, illustrated in the earlier figure, is a 12-contact, Category 7 connector that is described in ISO/IEC 60603-7-7. The dimensions of its openings and its contact positions were derived from the traditional RJ45 jack. The 8-contact RJ45 and ARJ45 connectors are its subsets. With an exception of the presence of bottom contacts, all the dimensions of the ARJ45 are identical to those of the RJ45.

The Category 7 connector has a mechanical switch inside of it that serves to redirect the signals from traditional split pairs, 3-6 and 4-5, to new pairs located on the opposite side of the cavity. A Category 7 jack can accept either Category 6A or lower RJ45 plugs, or Category 7 and 7A plugs. The same plug is used for Category 7 and Category 7A connectors. This plug has a keying feature that prevents it from mating with Category 5e, 6 and 6A jacks. A Category 7 and 7A plug has a protrusion in the front that activates a mechanical switch within the

Category 7 connector. A patch cord can have a Category 6A plug on one side and a Category 7A plug on the other.

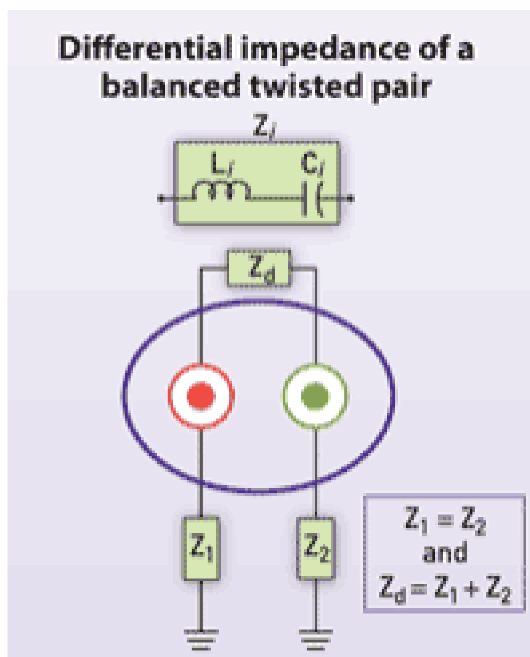
The Category 7A connector, ARJ45, does not have any split pairs. An alternative Category 7A connector that was not derived from the RJ45 interface is described in ISO 61076-3-114.

Compensation vs. isolation

The major difference between the RJ45 and ARJ45 connectors and interfaces is how the differential near-end crosstalk is attenuated. That issue was one of the primary reasons why the International Organization for Standardization (ISO) decided to change to a new interface for applications above 500 MHz in the ISO/IEC standard 60603-7-7.

The RJ45 connectors, Categories 5e to 6A, use compensation to cancel the differential near-end crosstalk. The compensation is a method of purposefully creating the crosstalk in the near vicinity of the interface that is equal in amplitude, but opposite in phase, to the near-end crosstalk "native" to the interface. In practice, it calls for adding capacitive and some inductive elements, and creating complex structures within the connectors. The compensation in the RJ45 connectors is used in both shielded and unshielded designs.

The Category 7A connectors rely on isolation to attenuate the near-end crosstalk. Category 7A connectors are always shielded. What is known as a Faraday cage is built around each differential pair; this cage isolates the pairs from each other, thus reducing near-end crosstalk. The ARJ45 interface design allows the isolation to be extended through a plug and a receptacle.



This electrical drawing illustrates that the impedance of a balanced twisted pair is derived from the impedances of two conductors.

An additional and valuable benefit of an isolation method design is a dramatic improvement in the transverse conversion loss (TCL) in comparison to lesser interfaces.

The measure of the balance and DCMC applicable to the interface is described in the connecting-hardware standards as the TCL, or Sdc11 as an S-parameter.

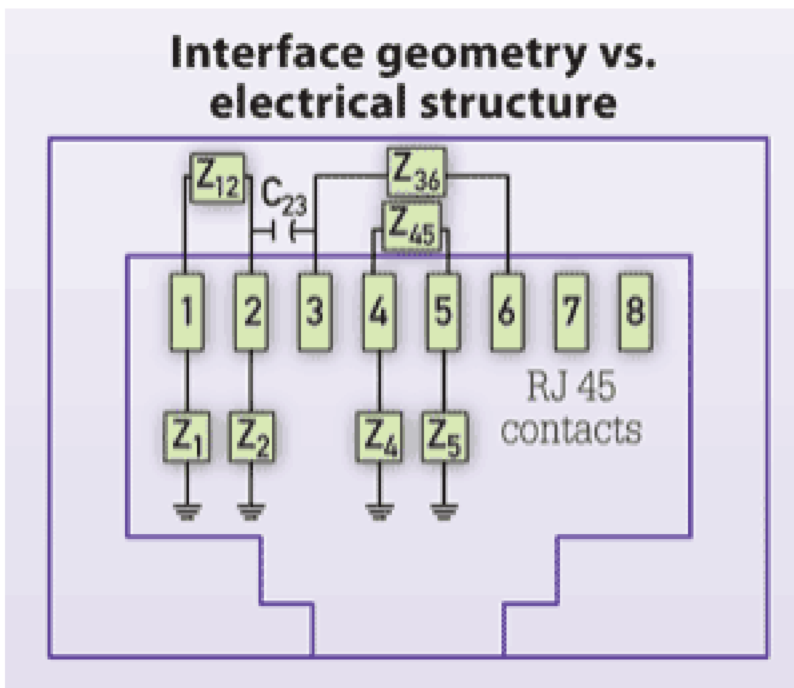
TCL (dB) = 20Log (Common Mode Voltage/Differential Mode Voltage) – measured at the same end

It is useful to keep in mind that TCL is the measure of the quality of the interface as a source of common mode. Both the TIA and ISO/IEC standard expressions yield the same values, as shown in the table on page 19.

Balanced twisted-pair environment

Outside the connector contacts proper, which form the mechanical interface, the regions directly adjacent to the interface are twisted pairs. On one side is a patch cord and on another side is a high-performance LAN transformer.

The differential pairs of the high-performance 10-Gbit Ethernet LAN transformer windings are twisted. In addition to reducing the inter-winding capacitance, which is always parasitic, the twisting directly improves the DCMC. Also, the highest-performing LAN magnetics (both chokes and transformers) tend to use a controlled media, such as ferrite, on all sides of the channels within the windings.



In an RJ45 connector, the intrapair balance of differential pairs 1-2 and 7-8 is affected by their positions. Diagrammed here is the effect of contact 2 capacitively coupling with contact 3. The result is skew and consequent degradation of the TCL.

The impedance of a balanced twisted pair is derived from the impedance of two conductors. The differential impedance in this case does not have a resistive component and consists of the inductance and capacitance.

The prime source of TCL is change in the geometry defining the characteristic impedance on the interface. Compare the figures entitled "Differential impedance of a balanced twisted pair" (page 17) and "Interface geometry vs. electrical structure" (page 18). The interface-geometry figure is an electrical structure of the RJ45—one of the most popular connectors in the world—where differential pairs are defined as contacts 1-2, 3-6, 4-5, 7-8.

The positions of the contacts in the RJ45 interface are such that there is explicit imbalance. The pair 4-5 is intrinsically better balanced, as is pair 3-6, though their impedance is hard to match to each other. The intrapair balance of differential pairs 1-2 and 7-8 are affected by their positions, where contacts 2 and 7 capacitively couple to adjacent contacts, and Z1≠Z2. The result is a skew and the degradation of the TCL.

	Expression	Frequency range, MHz
TIA	28-20Log(f/100)	1 to 500
ISO/IEC	68-20Log(f)	1 to 1000

Frequency (MHz)	TCL (dB)
1	68.0
10	48.0
50	34.0
100	28.0
150	24.5
200	22.0
250	20.0
300	18.5
400	16.0
500	14.0
600	12.4
700	11.1
800	9.9
900	8.9
1000	8.0

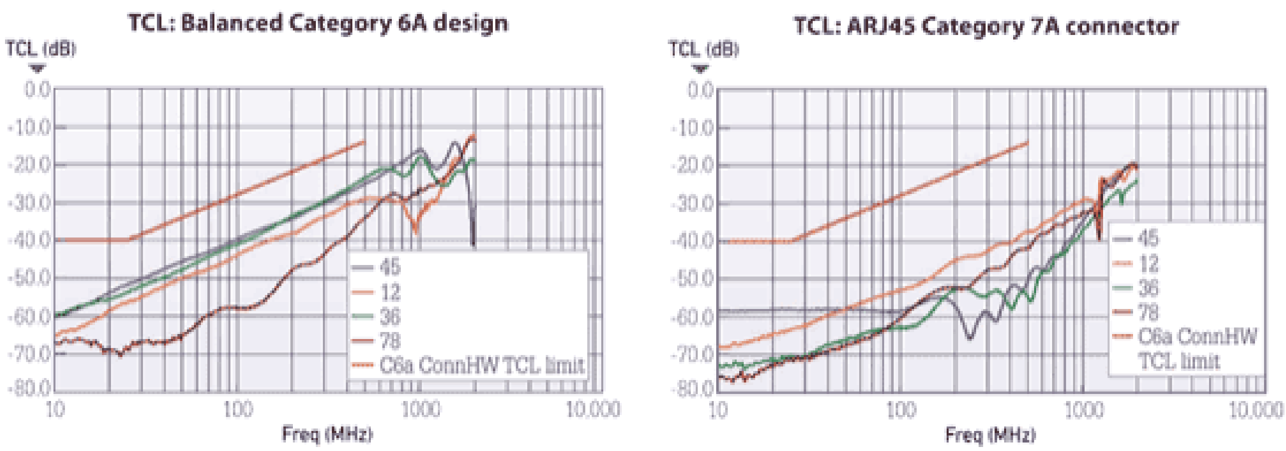
Other sources of imbalance also exist. All Category 6A connectors are supposed to meet minimum TCL requirements. Within the plug, the patch cord is changed from the twisted to the interface geometry. The balanced plug incorporates the design where at least a portion of the transmission channel within the plug is balanced or controlled. Technology, sometimes referred to as a wire guide filter, is used in which pairs are guided through the plug to mimic the balance of a twisted-pair cable.

Thus, within Category 6A connectivity there are subsets of balanced and unbalanced connectors. The

Category 7A connectors maintain the balance and low TCL to the spectra well above 1000 MHz.

Negative effects of high TCL

The high TCL causes greater common-mode noise. The common-mode noise reduces the signal energy. Generally the common-mode signal has a different propagation velocity from the differential signal. It also has an arbitrary phase. Two common noise signals can form an effectively parasitic differential signal superimposed on the original useful transmission. The common noise causes electromagnetic interference (EMI) and jitter. As a contributor to the alien near-end crosstalk, it may cause bit errors. The shorter the channel length, the greater the negative effects of the TCL.



Direct testing yielded these results for the transverse conversion loss of balanced Category 6A connectors with wire guide filters, and Category 7A ARJ45 connectors.

Reductions in TCL and corresponding DCMC translate to a lower noise, and potential increases in the useful channel length. The direct contribution of TCL to the channel length depends heavily upon the cable quality—specifically, the cable's insertion loss. Though the experimental evaluation is still in progress, the estimated increase in length that comes with a 10-dB TCL reduction can be as high as 10 meters for 500-MHz applications.

The computer modeling we conducted in Bel Stewart Connector's research-and-development facility used coaxial structures and established a theoretical

Frequency (MHz)	Unbalanced Category 6A	Balanced Category 6A	Category 7A
	RJ45	RJ45	ARJ45
50	34	45	58
100	28	40	53
250	20	32	56
500	14	26	42
1000	-	16	31
2000	-	14	19

limit for Sdc11 as 98 dB at 1000 MHz. The table above provides a comparison of the TCL values for balanced and unbalanced Category 6A connectors and Category 7A ARJ45 connectors. Numbers in the column "Unblanced RJ45" represent the TCL limit as opposed to actual data from unbalanced Category 6A connectors.

In summary, transverse conversion loss defines the interface as a source of differential- to common-mode conversion. The common-mode noise negatively affects network transmission. Internet traffic from 1-Gbit Ethernet to 10-Gbit Ethernet and, in particular, new 40-Gbit Ethernet systems should benefit from balanced Category 6A connectors. In the frequency spectra above 500 MHz, Category 7A connectors can provide improvement of more than 15 dB in comparison to Category 6A, and extend the channel bandwidth to 2000 MHz and above.

YAKOV BELOPOLSKY is manager of research-and-development and **RICHARD MAROWSKY** is principal electrical engineer with Bel Stewart Connector. If you have comments or questions about the technical detail provided in this article, please contact our editor at patrick@pennwell.com.

About Bel Stewart Connector

The Bel Stewart Connector portfolio of products comprises solutions for the broadest ranges of Ethernet connectivity. Our interconnect offering features passive modular jacks, shielded and unshielded plugs as well as cable assemblies that provide connectivity in a wide array of networking equipment. Modular plugs and cable assemblies are primarily used within structured cabling systems. All connectors are designed to meet current performance standards, including Category 6 specifications for Gigabit Ethernet and 10 Gigabit Ethernet (10GE) applications. Bel Stewart Connector's MagJack® products include a comprehensive line of single- and multi-port RJ-45 connectors with integrated magnetics solutions supporting for 10/100/1000BASE-T applications. To learn more about Bel Stewart Connector, visit www.belfuse.com/ethernet.

Bel Stewart Connector is a division of Bel Fuse Inc. (NASDAQ: BELFA and BELFB), a worldwide leader in the design, manufacture, and sale of products used in networking, telecommunications, high-speed data transmission, and consumer electronics. Partnered with the leaders in these markets, Bel develops new products for emerging technologies that enable high-speed communications.

For over 60 years, Bel has employed superior, high-volume manufacturing techniques and processes to deliver quality products to the global marketplace. Products include magnetics (discrete components, power transformers and MagJack® connectors with integrated magnetics), modules (DC-DC converters, integrated analog front-end modules, custom designs), circuit protection (miniature, micro and surface mount fuses) and interconnect devices (passive jacks, plugs and cable assemblies). The Company operates facilities around the world. To learn more about Bel Fuse Inc., visit www.belfuse.com.

LINKS:

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- Modular Plugs
- ARJ45® Connector Systems
- MRJ21 Cable Assemblies