The Evolution of Copper Cabling Systems from Cat5 to Cat5e to Cat6

Copper Cabling Standards and Technical Aspects

White Paper – 2/27/04

Executive Summary

Now that the TIA/EIA-568-B.2-1 Category 6 Copper Cabling Standard has been ratified, it is an opportune time to discuss the evolution of this standard. The TIA/EIA-568-A Commercial Building Telecommunications Standard was published in 1995. This document was written for Category 5, 100-ohm copper cabling systems. At the time the IEEE 802.3 committee had just developed the standard for the 100 Base-T Ethernet transmission system. This transmission system was developed to replace the previous version of Ethernet, which was 10 Base-T. The 10 Base-T transmission standard provided signal transmission of up to 10 MHz of bandwidth over Category 3; usually Unshielded Twisted Pair (UTP) copper cabling. Category 3 cable was also available in Shielded Twisted Pair (STP) and Screened Twisted Pair (ScTP) cables as well, but UTP was the preference throughout the network communications cabling industry. 100 Base-T Ethernet systems require up to 100 MHz of bandwidth. Category 3 cabling systems could not support this bandwidth. Therefore, Category 5 cabling was developed and introduced to support 100 MHz bandwidth Ethernet transmission systems. When the TIA/EIA-568-A standard was introduced, it was projected that this cabling standard would support transmission systems for the next fifteen years. This paper will address the accuracy of that prediction.

TIA-EIA-568-A

The TIA-EIA-568-A standard defined the testing limits for the following parameters for testing Category 5 cabling installations: Length, Attenuation, Wiremap and Near End Crosstalk (NEXT). The length requirements defined that the maximum length a cable could be run from a Telecommunications Room to a work area outlet in a commercial building could not exceed 90 meters (295 feet). This 90-meter distance is defined as the horizontal link. When adding patch cables in the Telecommunications Rooms to either cross-connect or interconnect with electronic equipment and to connect devices at the work area outlet, the standard allows for a total of ten meters for these patch cables to be added to the horizontal link. This 100 meter maximum distance, the maximum 90-meter horizontal link plus 10 meters of patch cords, is defined as the horizontal channel.

Attenuation is the loss of signal strength as it is transmitted from the end of the cable which the signal is generated to the opposite end at which it is received. Attenuation, also referred to as Insertion Loss, is measured in decibels (dB). For attenuation, the lower the dB value, the better the performance, less signal is lost. This decrease is typically caused by absorption, reflection, diffusion, scattering, deflection, or dispersion from the original signal and usually not as a result of geometric spreading.

Wiremap is a continuity test. It assures that the conductors that make up the four twisted pairs in the cable are continuous from the termination point of one end of the link to the other. This test assures that the conductors are terminated correctly at each end and that none of the conductor pairs are crossed or short-circuited.

Near End Crosstalk (NEXT) measures the amount of signal coupled from one pair to another within the cable caused by radiation emission at the transmitting end, near end, of the cable. An example of crosstalk on voice channels is when extraneous conversations can be heard in the background over the phone line while on a telephone conversation. Those signals are being induced onto the voice channel from another channel. The same instance occurs in data signal transmission. If the crosstalk is great enough, it will interfere with signals received across the circuit. Crosstalk is measured in dB. The higher the dB value the better the performance, more of the signal is transmitted and less is lost due to coupling. (*Fig. 1)*

NEXT

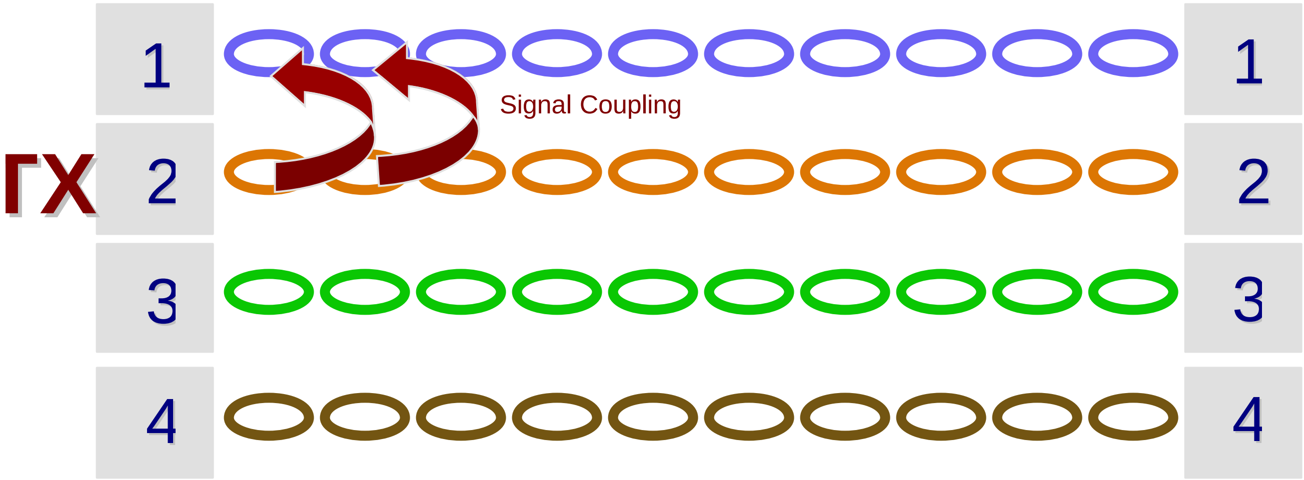

Figure 1

100 Base-T signals are transmitted across only two of the pairs in the cable. One pair is used to transmit signals and the second pair receives the signals. The other two pairs in the cable are not used at all in 100Base-T signal transmission. As technology advanced during the late 1990's, there was a demand generated by computer manufacturers and chip vendors to promote the use of more powerful computers and more powerful applications such as 3D graphics and full motion video. This demand would exceed the capabilities of 100 Base-T signal systems. Therefore the IEEE 802.3 committee went to work to develop the 1000 Base-T (Gigabit) Ethernet standard that would provide 1 billion cycles of bandwidth over Category 5 copper twisted pair cabling.

Although 1000 Base-T Ethernet was designed to function over Category 5 cabling systems, the margins were very slim. 100 Base-T signals utilize only two of the four pairs in the cable and the signals only run in one direction across the pairs. 1000 Base-T signals require all four pairs in the cable to be utilized to transmit up to 250 megabits of data per second (Mbps) in full duplex transmission across each pair. Full duplex transmission requires each of the pairs to be able to transmit and receive signals simultaneously. Therefore, the need for additional field test requirements such as ELFEXT and Return Loss was raised. These test parameters were defined for two connection points in TIA/EIA Technical Services Bulletin (TSB) 95.

Equal Level Far End Crosstalk (ELFEXT) measures the coupling of signals due to radiation emission measured at the end of the cable that is opposite from where the signal is generated, the far end. ELFEXT also takes into consideration the attenuation factor over the length of the cable. Return Loss measures the amount of signal that is reflected back to the source from which the signal was generated. Return Loss is created by impedance mismatches of the components in the link or channel and by distortion to the physical geometry of the cable, which may be caused by tight bends or cable ties being cinched too tightly. These additional tests are required to assure that an existing Cat 5 installation can support 1000 Base-T transmission. Due to the fact that the margins for running 1000-Base-T over Cat 5 cabling were so slim, a move was made to develop an enhanced cabling system that would support it with a wider margin. This was the birth of the Cat 5e cabling systems.

TIA/EIA-568-A-5

The standard that defined the requirements for Cat 5e was TIA/EIA-568-A-5 and was ratified in 1999. Category 5e, like Cat 5, is a 100 MHz transmission scheme. Required field test parameters for Category 5 link and channel performance, as well as those required for manufacturers lab tests, have been raised to a higher level to certify for Cat 5e transmission. ELFEXT and Return Loss minimum performance requirements are defined for worst case, four connector channels, utilizing full duplex transmission schemes such as Gigabit Ethernet. The four-connector scheme accommodates a Consolidation Point implemented in the horizontal cabling link. In May 2001 the TIA/EIA-568-B Standard was ratified and released for publication. The 568-B standard incorporates all of the previous 568-A addenda and TSBs into a document that is divided into three separate sections, 568-B.1, 568-B.2, and 568-B.3.

TIA/EIA-568-B

TIA/EIA-568-B.1 defines the general cabling requirements for copper and fiber cabling installations. 568-B.2 defines the specific requirements for copper cabling installations and component requirements for Cat 3 and Cat 5e systems. Category 5 cabling is not recommended in 568-B.2. Cat 5 has been placed in Annex N in the document and is only recognized for legacy installations where Cat 5 already exists. 568-B.3 defines the specific requirements for optical fiber systems.

The 568-B.1 standard defines that field testing shall be done according to the Permanent Link scheme. Permanent Link testing replaces the Basic Link testing scheme as was defined in previous standards. The Permanent Link test looks at the permanently installed cabling and components from the termination at the work area outlet to the termination point in the Telecommunications Room. It does not allow for any patch cords or test leads. The Basic Link test accounted for two meters at each end of the link, four meters total, to accommodate test leads. The Permanent Link test ignores the test leads. In addition to the field tests that have been outlined previously in this paper, additional tests are required in 568-B.2. These additional tests are: Power sum NEXT (PSNEXT), Power sum ELFEXT (PSELFEXT), Propagation Delay, and Delay Skew. Attenuation is now referred to as Insertion Loss.

Power sum NEXT measures the crosstalk in the cable at the near end. However rather than measuring the signal coupling from one pair to another pair within the cable, Power sum NEXT measures the effects of the coupling from the other three pairs in the cable against each of the individual pairs. Power sum ELFEXT measures the crosstalk at the far end of the cable, and again, considers the effects of the other three pairs on each individual pair while also considering the attenuation factor. (*Fig.2*).

ELFEXT

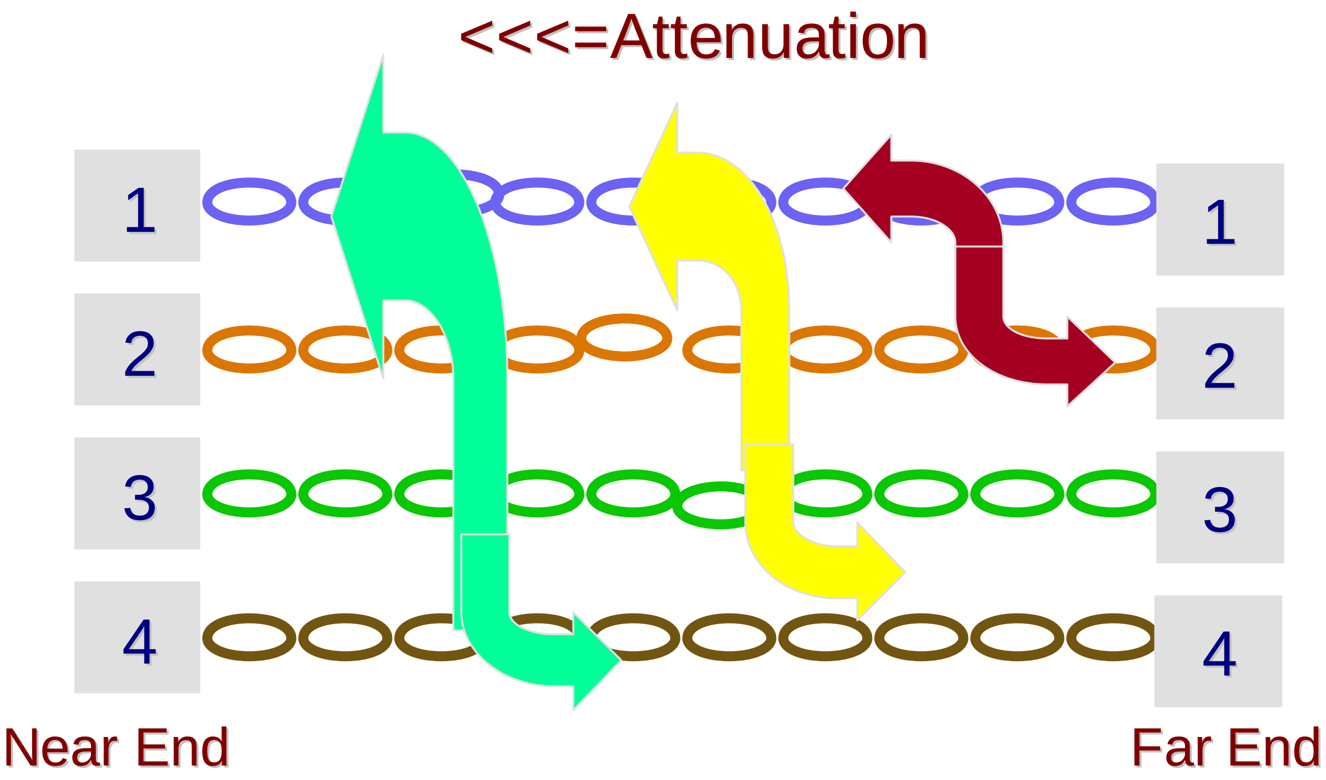

Figure 2

Propagation Delay is the time (measured in nanoseconds — ns) that it takes for the signal to be transmitted from one end of the cable to the other. Delay skew measures the difference of the speed of signal transmission between the fastest and slowest pairs in the cable. The Delay Skew must be less than 50 nanoseconds (ns) for a 100-meter channel.

The International Organization for Standardization (ISO) developed the ISO 11801 cabling standard. This standard is in harmony with the TIA/EIA-568-B standard. The ISO 11801 document defines 100 MHz cabling systems as Class D. The parameters and requirements for Class D cabling are similar to the TIA 568B requirements for Cat 5e. The ISO 11801 Class E requirements are parallel to the TIA/EIA 568B.2-1 Category 6 Standard that was ratified in May 2002.

TIA/EIA 568B.2-1 Category 6 Standard

Category 6 cabling was originally intended to yield 200 MHz of bandwidth. The IEEE requested that all testing be done to 250 MHz to assure that Cat 6 systems will operate with plenty of margin. All of the aforementioned field and manufacturer testing requirements also apply for Cat 6, except that the testing is done to 250MHz.

The Cat 6 standard provides the best performance specification for UTP and ScTP cabling systems. The requirements for Cat 6 cabling are much more stringent than they were for Cat 5 and Cat 5e. It is very important that installers maintain ½” or less of untwist at the termination, proper bend radius, and avoid short links, less than 15 meters. When properly installed, Cat 6 cabling systems will provide far better performance than Cat 5e. The frequency range is more than double than for 5e, at 250 MHz, where 5e is at 100 MHz. Cat 6 performance requirements are also significantly better than Cat 5e when compared at the same frequencies. (*Table 1*)

TIA/EIA 568B Channel Performance Comparison

Parameter	Cat 5e	Cat 6
Frequency Range	**1 – 100 MHz**	**1 – 250 MHz**
Propagation Delay	**548 ns @ 100 MHz**	**548 ns @ 100 MHz** **546 ns @ 250 MHz**
Delay Skew	**50 ns**	**50ns**
Insertion Loss	**24 dB**	**21.3 dB @ 100 MHz** **36 dB @ 250 MHz**
NEXT	**30.1 dB**	**39.9 dB @ 100 MHz** **33.1 dB @ 250 MHz**
PSNEXT	**27.1 dB**	**37.1 dB @ 100 MHz** **30.2 dB @ 250 MHz**
ELFEXT	**17.4 dB**	**23.2 dB @ 100 MHz** **15.3 dB @ 250 MHz**
PS-ELFEXT	**14.4 dB**	**20.2 dB @ 100 MHz** **12.3 dB @ 250 MHz**
Return Loss	**10 dB**	**18.6 dB @ 100 MHz** **8 dB @ 250 MHz**

Table 1

Category 6 cabling systems utilize RJ-45 connectors and are backward compatible to Cat 5e. This means that if Cat 6 and Cat 5e components are mixed in a channel, the channel will perform to Cat 5e limits. Cat 6 cabling will run Gigabit Ethernet more efficiently than Cat 5e because it is a better performing system. The Cat 6 standard also provides the requirements for manufacturers to test patch cords. Cat 6 is an interoperable standard, Cat 6 rated components from different manufacturers can be mixed in the channel and the channel should still perform to Cat 6 limits. This includes patch cords.

To assure interoperability for connectors, manufacturers are now required to conduct a de-embedded plug test for their components. The de-embedded plug test utilizes an industry standard common plug to be mated with the jacks under test to isolate the performance of the jack. With all manufacturers required to utilize the same plug design for this test, it assures interoperability and creates a level playing field for the manufacturers

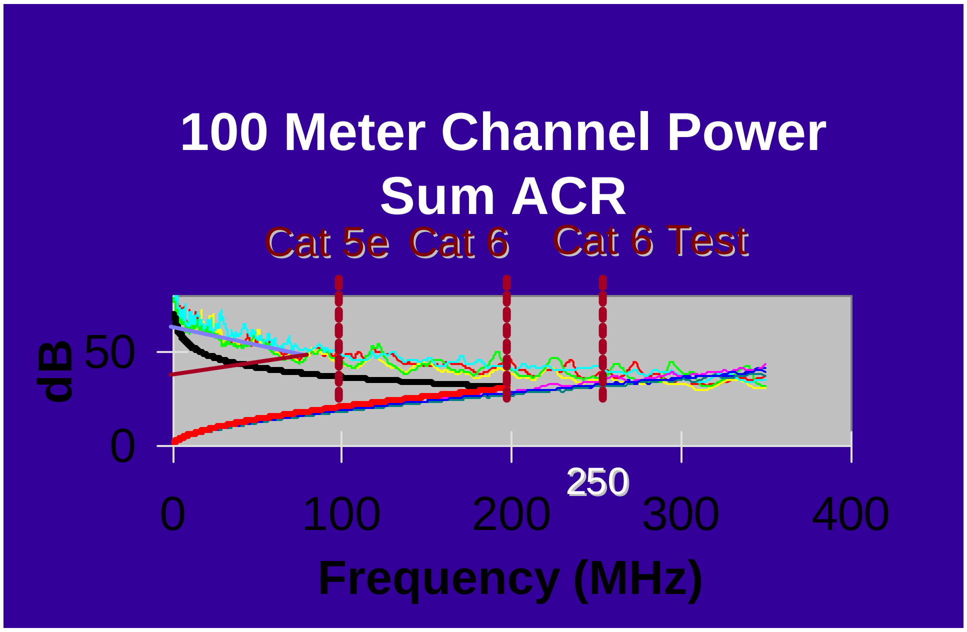

Figure 3

Bandwidth is determined by Attenuation to Crosstalk Ratio (ACR) or Attenuation to Power Sum Crosstalk Ratio (PSACR) (*Fig 3*). International standards require these tests, but they are not required in the TIA standards. Attenuation to Crosstalk Ratio is not a measurement; it is a calculation. It is determined by subtracting the Insertion Loss dB value from the NEXT dB value. This parameter defines how much greater the signal strength is than the noise, or unwanted signals, on the circuit. It defines the amount of "headroom" in the system. Headroom defines the difference between the available bandwidth and the bandwidth that is actually used. It is similar to filling 8 ounces of liquid in a 12-ounce glass, there are 4 ounces of headroom.

When the ACR equals zero, the noise is equal to the signal and there is no remaining bandwidth. Beyond that, it is running at a negative bandwidth, which means there is nothing but noise being transmitted. PSACR is determined by using the PSNEXT value in the calculation. The graph above indicates the PSACR limits for Cat 5e and Cat 6 channels as indicated in the standards with the solid lines. The erratic lines indicate the actual performance of the cabling showing how the link performs beyond the limits of the standard.

Conclusion

A structured cabling system to support Category 5e and Category 6 installations requires many different components. In the Telecommunications Room, racks, patch panels, connecting blocks, patch cords, RJ-45 jacks, and cable management devices are required. At the work area outlet, RJ-45 jacks, faceplates, patch cords, raceway and boxes are needed. The horizontal cable is run between these two spaces. A Consolidation Point or Zone Cabling box may be required as part of the horizontal cabling. All cabling and termination devices must be rated for the appropriate category as defined by the standards.

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