Understanding UTP Cabling

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Unshielded Twisted Pair (UTP) cabling has dramatically impacted network infrastructures. It has enabled end users to specify a singular type of cable independent of their LAN application. But lately, the "singular" solution of UTP has become unclear. There are now multiple grades of UTP cabling available, ranging from basic Category 3 to the proposed Category 6. As a result, understanding how to specify UTP Cabling is becoming more and more difficult for the end user.

There have been a great many articles written on this subject. Some view the insurgence of new, higher grades of UTP cabling as nothing more than hype. Others look at the enhancements as long overdue upgrades to inferior technology. So, which is right?

UTP Cabling Defined

During the last decade, UTP cabling has undergone many changes. As network needs have increased, so has the perceived need for higher-end UTP cabling. But before the merits of UTP cabling are discussed, we must first understand the terms that define it.

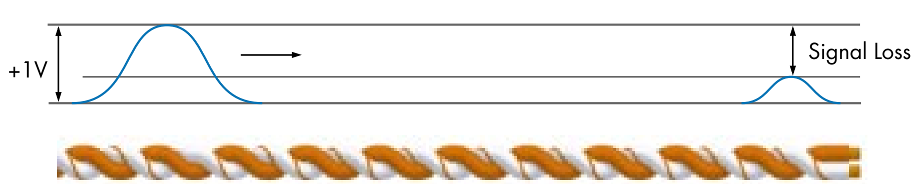
The purpose of any networking cable is to carry data from one device to another. Devices can include terminals, printers, and servers (just to name a few). There are many types of cabling media to which these devices hook up. Examples are fiber optic, coaxial, twinaxial, and both shielded and unshielded twisted pairs. Deciding which cabling type is best for a given application involves understanding many factors such as distance, life cycle, noise environment, security, cost, flexibility, and data rates. Many end users consider unshielded twisted-pair cabling a good medium for many of these concerns.

UTP has gained most of its success in the horizontal environment, specifically, cable runs from the desktop to the wiring closet. As its name suggests, UTP consists of multiple unshielded twisted pairs surrounded by an overall jacket. Although available in 2-, 4-, and 25-pair multiples, the most popular choice is 4-pair cabling. Although most LAN environments, such as 10/100 Base-T, only use two of the four pairs available, new protocols under investigation, such as Gigabit Ethernet, could require the use of all 4 pairs. Hence, the importance of choosing 4-pair cabling over the less-costly 2-pair operation.

Attenuation

One of the greatest concerns of any cabling infrastructure is signal loss. Unfortunately, anytime information is transmitted from device to device, signal degrades. In fact, for a 100 Base-T signal traversing 100 meters of a UTP cable, it is not uncommon for significant amounts of signal power to be lost. If too much signal is lost, the transmitted data will be unrecognizable by the receiving device. To make sure this doesn't happen, the standards committees have put limits on the amount of loss that is acceptable.

Attenuation



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A term which defines loss is “Attenuation.” For UTP cabling, attenuation defines the amount of loss that occurs as a signal traverses down a cable. The unit “dB” (**d**eci**B**els) is used to express this loss. Using decibels as a unit of measurement has its advantages. For instance, it is easy to remember that for every 3 dB increase in attenuation, an additional 50% signal loss will occur. The table below relates percentage of power loss to dB.

dB Vs. % Power Loss

dB	% Loss
3	50%
6	75%
10	90%
15	97%
20	99%

There are many factors in cable design which influence the amount of loss (or attenuation) that occurs. They include conductor size, conductor-material type, insulation and jacket material, frequency of operation, and distance. The first, **conductor size**, is fairly straightforward. Typically, the bigger the conductor, the lower the loss. This is why many higher-end UTP cables use 23 AWG instead of 24 AWG conductors. **Material type** is also critical. Copper, for instance, normally provides less loss than steel. There are materials better than copper (such as silver). However, many of these materials prove to be cost prohibitive. **Insulation materials** can also have an effect on signal loss. Higher-grade UTP cabling typically uses low-loss materials, such as FEP and Polyethylene, to insulate the conductors. These materials usually provide less loss over other compound types, such as PVC. **Jacket materials** will also have an effect on signal loss, which explains why many manufacturers distance the jacket from the insulated pairs by employing a “loose-tube” construction. Additionally, it is also known that attenuation in copper-based UTP cabling increases with **frequency**. For instance, attenuation is greater at 100 MHz than at 1 MHz (length remaining the same). And finally, signal loss is **length dependent**. All things remaining the same, longer lengths of cable will incur greater loss. In fact, attenuation is expressed in dB per unit length for this very reason.

Attenuation Summary

- As a signal traverses down a cable, it loses strength
- Attenuation defines the amount of loss incurred
- The unit “dB,” or decibels, is used to define the amount of attenuation
- Factors which influence a cable’s attenuation include conductor size, material type, frequency of operation, and distance

Crosstalk

When a signal is present on a twisted pair, it is referred to as “active.” When active, it naturally creates an electromagnetic field around it. This field can interfere with the operation of other “active pairs” in close proximity (see figure below).

One of the most difficult things to understand about crosstalk is the unit of measurement, namely dB. With attenuation, the higher the dB, the greater the loss of signal. With crosstalk, it is different: The higher the dB, the greater the loss of **noise**. The following table helps to better understand the situation.

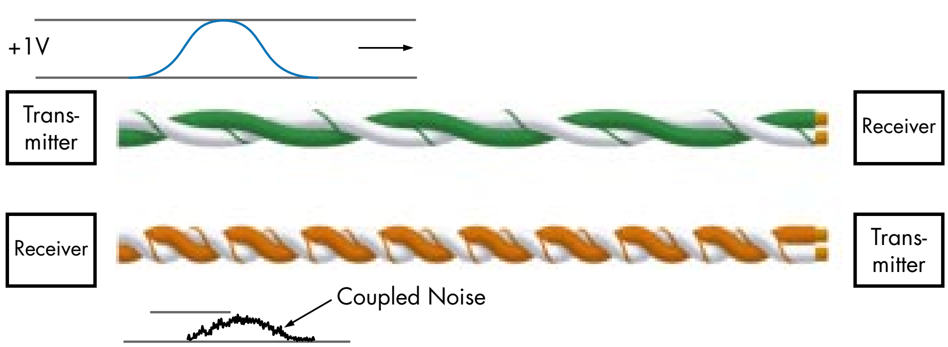
DB of Crosstalk	Voltage Level on Active Pair	Resultant or “Coupled” Voltage onto Adjacent Pair*
3 dB	1 V	.7 V
6 dB	1 V	.5 V
10 dB	1 V	.3 V
20 dB	1 V	.1 V

**Note that the higher the dB of Crosstalk, the lower the coupled voltage*

It should be noted that we do **not** want noise to couple onto adjacent pairs. The chart clearly shows that when the dB of crosstalk increase, **less** voltage (in the form of noise) will couple onto adjacent pairs.

Again, attenuation represents loss of signal. Consequently, higher dB represent higher signal loss. Crosstalk, however, represents loss of **noise**. In this case, higher dB represent higher **noise** loss. And, of course, lost noise is a **good thing**!

Crosstalk



Types of Crosstalk

Near-End Crosstalk

Systems such as 10 Base-T Ethernet use 2 pairs to transmit data: one to send the data and the other to receive it (see figure on next page). Signal strength is **strongest** right after the data is sent. Conversely, signal strength is **weakest** right before the receiving device picks up the data signal.

One of the terms often associated with crosstalk is “Near End.” The reason for this is as follows. At the near end, where the signal strength is strongest, there is the potential for strong EMI radiation to occur. Adjacent to the strong signal is the receiving signal which is shown to be at its weakest point. This combination can have severe consequences for the receiving signal, since it is being attacked by the strong field adjacent to it. This phenomenon, which happens at the “Near End,” is why we are so concerned with it.

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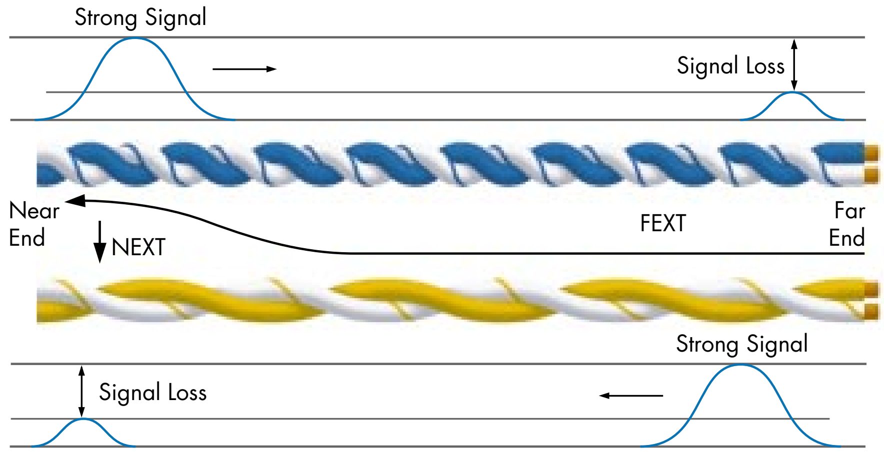


Powersum Crosstalk

As indicated earlier, there are systems that will require all 4 pairs being active. In the previous discussion of near-end crosstalk, we noted that only 2 of the pairs were being used. When all 4 pairs are activated, as with the proposed gigabit ethernet initiative, the noise generated will be substantially increased.

This is where "Powersum" crosstalk comes into play. With powersum, the effects of multiple active pairs are addressed (see figure below).

This example is of a 4-pair cabling system. The consequences become even more important with 25-pair backbone cabling, since up to 6 times more pairs are potentially active.

Powersum Crosstalk

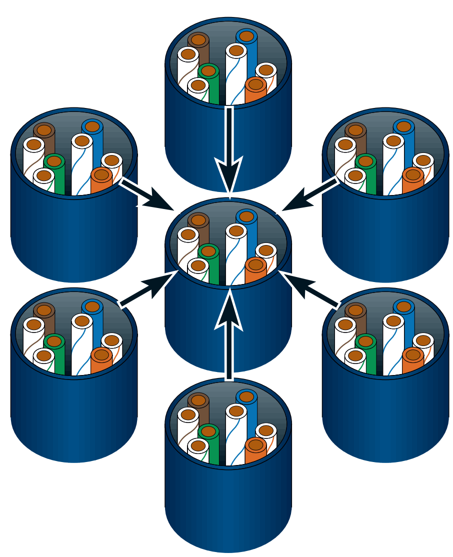
Far-End Crosstalk

Typical systems send data one direction, namely from transmitting devices to receiving devices. However, there are systems becoming available where data is sent bidirectionally. These systems are referred to as full duplex. In this case, data is being generated at **both** the near end **and** the **far** end simultaneously. Therefore, with full duplex, both near-end and far-end noise effects become important. Because of this, Far-End Crosstalk (FEXT) is being added to many specifications.

Noise occurring at the far end can be difficult to measure because much of the noise is lost or attenuated as it makes its way to the testing device. Therefore, it is common practice to "take out" the attenuation effects and look at the pure noise taking place. When looking at the noise minus the effects of attenuation, the term "Equal-Level Far-End Crosstalk," or EL-FEXT, is used.

Alien Crosstalk

"Alien Crosstalk" is a term used to describe cable-to-cable crosstalk effects. This is especially important when multiple pairs within a cable are active. In this situation, the energy radiated from a specific cable can become significant. Note the case shown below, namely 6 cables containing 4 active pairs surrounding a single 4-pair cable. There are now 24 active pairs, all with the potential of affecting the singular cable within. In this case, the importance of understanding alien crosstalk would be critical to successful network operation.



Crosstalk Summary

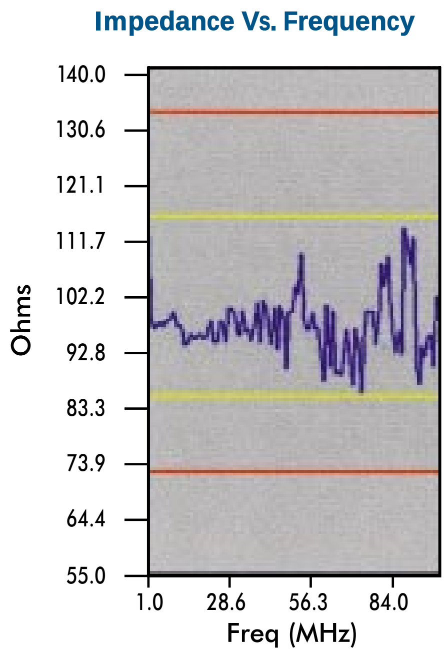
Near-End Crosstalk effects are important since the near end has the strongest transmitting signal and weakest receiving signal. This makes the receiving pair especially prone to noise from the transmitting pair.

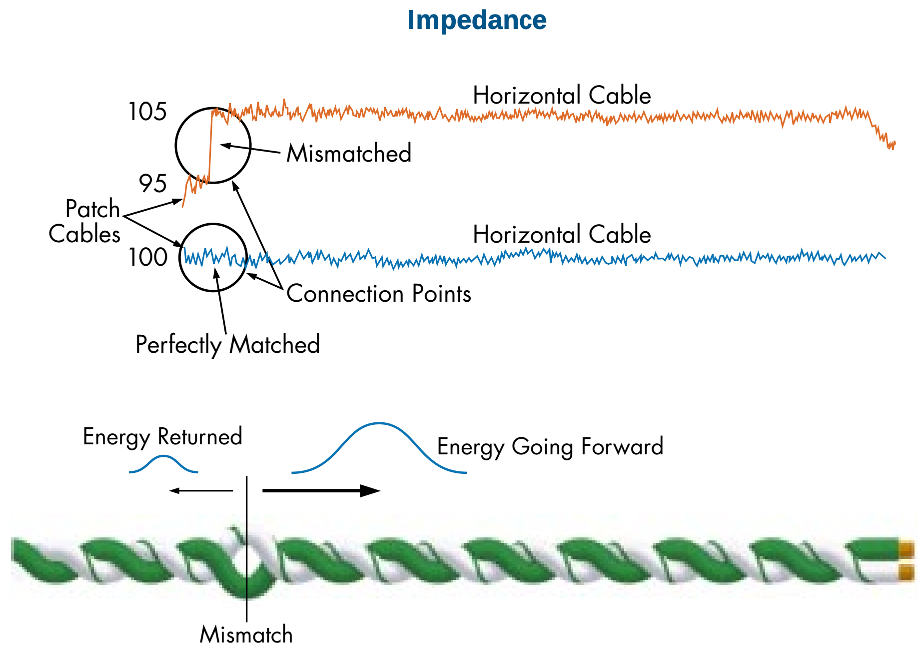
- Powersum Crosstalk looks at the effects that multiple active pairs have on a network.
- Far-End Crosstalk takes into account the consequences of full-duplex operation where both the near end and far end are generating signals simultaneously.
- Alien Crosstalk defines the effect of cable-to-cable crosstalk, especially important when multiple pairs are active within a cable.

Impedance and Return Loss

Impedance defines the best "path" for data to traverse. For instance, if your signal is transmitting at an impedance of 100 Ohms, it is important that your structured cabling also possess an impedance of 100 Ohms. Any deviation from this set point will result in part of the signal being reflected back towards the source of data. Impedance variations can occur for many reasons. One is from the manufacturing process itself. Any deviation of conductor-to-conductor spacing or insulation properties will cause impedance to vary. The two figures shown, "Impedance Vs. Frequency" and the picture of the twisted pair (see next page), are examples of this.

Another way in which impedances can vary is by mismatched components. For instance, when a patch cable of one impedance is connected to a horizontal cable of a differing impedance, mismatch will occur. (Refer to the side-by-side impedance traces, next page.)





This mismatch will cause energy to reflect back starting at the point of discontinuity. Where impedance defines the potential of mismatch, **return loss** quantifies the consequence. Measured in dB returned signal, return loss helps to indicate how much signal will be lost due to reflected energy.

Impedance and Return Loss Summary

- Impedance helps to define the best "path" for signals to traverse.

- Any deviation from this impedance will cause reflections to occur. These reflections mean energy which is supposed to go forward actually gets reflected back towards the transmitter. This ultimately reduces the strength of the forward propagating signal.

Delay Skew

Another parameter receiving much attention is "Delay Skew." Delay skew defines the timing of multipair signaling traversing down a cable (see figure at right).

When all four pairs are activated, it is typically important that the signals arrive within close proximity to another. Measured in nanoseconds, delay skew defines the timing difference in pairs within a cable. When the timing difference is too large, the receiving device is unable to reassemble the signal. This will ultimately cause errors and lost data.

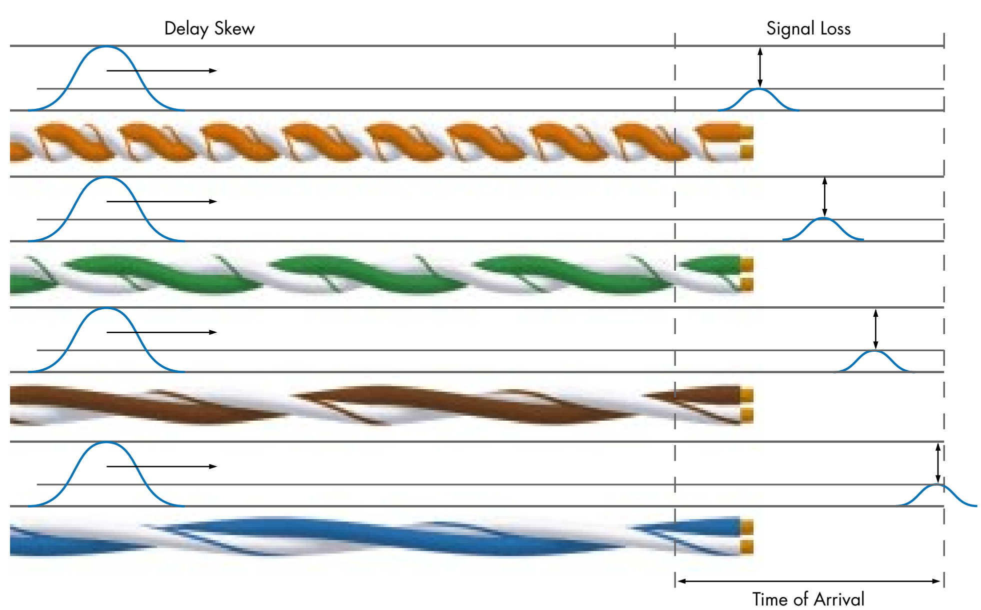
Why UTP is Being Enhanced

About five years ago, enhanced versions of Category 5 UTP became available. Many of the parameters discussed up to this point were improved by implementing unique designs, such as tight twisting, bonded pairs, and inner-filler technology. The purpose of these enhancements was to "ready the user" for upcoming changes in LAN technology.

When the original Category 5 first became available, there were few systems that actually required the bandwidth it could provide. In fact, 10 Megabit Ethernet and 4 Megabit Token Ring were actually designed to run on the lesser-grade Category 3 UTP cables. As new systems such as 100 Base-T and 155 ATM came out, the need for higher-grade Category 5 became evident. Lately, however, new protocols such as 622 ATM and 1000 Base-T are making many people wonder if even Category 5 will be enough. Hence, the drive for "enhanced" UTP. So what is it about the networks that are triggering this need?

Higher Data Rates

Systems such as 100 Base-T and 155 ATM are beginning to be commonly deployed in the network. Much more complex than their 10 Base-T/25 ATM counterparts, these systems require stronger signal strength, better protection from noise, and a higher level of consistency with regard to cabling.



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Complex Encoding Schemes

Systems such as 100 Base-T require multi-level encoding schemes to help "distribute" the signal energy across the frequency spectrum. This has many benefits, especially with regard to keeping radiated noise in check and the frequency at which radiation occurs low. Unfortunately, the more complex the encoding scheme, typically, the more sensitive the system. Therefore, the cable utilized must be consistent with regard to impedance stability and have good crosstalk isolation.

Full-Duplex Operation

On systems such as 10 Base-T, only one pair is active at one time. One pair sends the data, and the other pair receives. This is referred to as half duplex. New technologies and electronics have made it possible for systems to operate in full-duplex mode, allowing a signal to be sent and received on the **same pair simultaneously**. This is advantageous since it literally doubles the bandwidth capability of the UTP cable. However, the cable must have stable impedance performance with minimal reflections and good pair-to-pair near-end/far-end crosstalk isolation to operate properly.

Multipair Usage

Typical networks only utilize 2 of the 4 pairs available. Bandwidth can be significantly increased by utilizing **all** 4 pairs of a Category 5 cable. With the aid of some interesting electronics, data can be sent over multiple pairs and reassembled at the receiving points. To make this possible, the cable must also be capable of handling multiple active pairs with little pair-to-pair interference as the signal traverses the cable. This has been the main driver toward certifying Category 5 cables to powersum requirements.

Putting It All Together

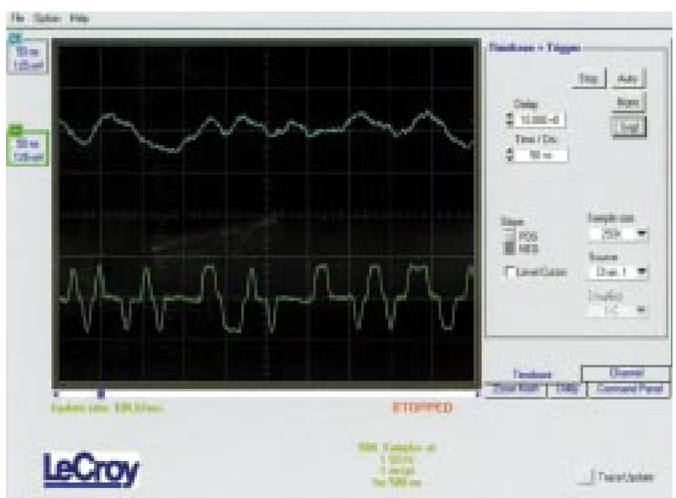
The whole argument on whether enhanced cable is needed can be summed up in two very simple questions:

1) **How will the claim of enhanced UTP help my existing network?**

2) **How will the claim of enhanced UTP help me to upgrade my network?**

If someone attempts to sell you an enhanced cabling solution, they had better be able to answer the above two questions. If they can't, their claim could be nothing more than hype. After all, your decision on cabling is not based on the enhancement itself – it is based on how that enhancement will benefit your network. And the key here is **your** network. Not all enhancements are applicable to your situation. It is also important to make sure the benefit realized is a benefit **you** will realize.

Therefore, simply putting in place an "enhanced" UTP cable is no guarantee of enhanced system performance. Instead, the user must be shown how those enhancements will improve their network capabilities and/or performance. Below is a trace gathered from an "active" 100 Base-T network testing device from LeCroy called "Newsline." The cable used was Category 5 compliant. The bottom trace shows the original signal; the top trace shows what happens to the signal after traversing 100 meters. The effects are startling.



The question remains, however, what is the overall effect on the network? The ability of UTP to achieve link light (successful connection) really isn't at issue here. More important is UTP's ability to traverse data through it consistently and error free.

The table which follows shows the throughput consequence for a 100 Base-T Ethernet Network. It has been shown that a 1% increase in data errors can result in an 80% decrease in throughput. Therefore, if enhancements in UTP cabling can help to prevent data errors, the move towards higher-end UTP could be justified. Improvements such as power-sum crosstalk, alien crosstalk, and signal strength enhancements are all ways which can lead to reduced error potential on existing and future networks. But these attributes must be proved and justified to the end users.

Percent of Retransmissions	Potential Throughput
0%	100 MB
1%	20 MB
2%	4 MB
3%	.8 MB
4%	.16 MB
5%	.032 MB

The notion of solid performing UTP cabling becomes more important as data rates increase. Systems such as 1000 Base-T have the potential of being 4 times more sensitive than 100 Base-T. Preventing errors in both is paramount to a successful network. By utilizing devices such as the LeCroy unit discussed earlier, end users are discovering that, in fact, UTP **can** impact network performance. And in some cases, the move towards enhanced cabling can maximize throughput by preventing data errors from occurring in the first place.

Bottom Line

Although the merits of enhanced UTP have the potential to maximize both your current and future network, the questions still remain: Will the enhancements be of benefit to the **system**, and will the enhancements help the **system** go the next step? With these two questions answered, only then will you have the ability to separate "actual" need from "perceived" need.

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