CopperTen™ Cabling Solution

Making the Impossible Possible

For years, copper UTP solutions have been the preferred medium over which most Local Area Networks communicate. And in this same period, a debate has raged as to when fiber would displace copper as the preferred infrastructure. Several years ago Gigabit Ethernet seemed like a pipe dream, yet today Gigabit Switch port sales have overtaken 10/100BaseT of old.

Fiber has for years lead the Ethernet industry forward in port speed progression. So why, if fiber is one step ahead, doesn't it replace copper? The answer is quite simple. To convert Electrons to Photons and then back to Electrons adds cost (from an active hardware prospective)! This makes the cost of fiber optic active hardware as much as six times more expensive per port today than the equivalent speed copper UTP solution on gigabit Ethernet switch ports.

With Ethernet now the winner of the horizontal desktop LAN protocol war, a pattern has arisen with regards to transportation speed. Migration from 10BaseT to 100BaseT and now Gigabit Ethernet (1000BaseT), the transportation speed has always progressed tenfold. Where we are today, with regards to protocol advancement, is no different.

Ten Gigabit Ethernet is alive and breathing today in the form of fiber optics. The year 2003, particularly the last quarter, was pivotal in the old question of "when will copper reach its limit"? By the title of this paper you might surmise, yet once again, someone has figured out a way to produce a copper networking solution to support 10Gig.

The cabling industry (Telecommunication Industry Association (TIA)/Electronic Industries Alliance (EIA)) doesn't drive the electrical parameters needed to run transmission protocols. It is the IEEE who develops proposed protocols, understands what is needed from an electrical standpoint and then gives the TIA responsibility of developing measurable parameters for cable (with the possible exception of Category 6 – See "The Evolution of UTP" for a better understanding.). This was no exception for 10Gig Ethernet. An IEEE 802.3 Study Group was formed to discuss how best to approach running 10Gigabit transmission over a copper infrastructure. This group is composed of representatives from several different aspects of the networking community, such as chip manufacturers, hardware manufacturers and cabling/connectivity manufacturers.

The 10GBaseT working group discussions include which protocol encoding will be used, how it relates to the needed bandwidth from the cabling infrastructure (what the frequency range is) and what Shannon's Capacity is needed to support them. A definition of Shannon's law is given below. The value for the capacity is measured in bits per second. To achieve 10Gbps of transmission, a Shannon's capacity of >18Gbps is required from the cabling solution. The additional capacity over the desired data rate is due to the amount of bandwidth used within the active hardware noise parameters i.e. Jitter, Quantization, etc.

Shannon's law (Capacity)

It is one thing to understand how this law works, but another to meet the much needed channel capacities required to run protocols. That being said, the following is the basic formula for understanding how efficiently a cable can transmit data at different rates.

Concerning a communications channel: the formula that relates bandwidth in Hertz, to information carrying capacity in bits per second. Formally:

$$Q = B \log_2 (1 + S)$$

Where Q is the information carrying capacity (ICC), B is the bandwidth and S is the signal-to-noise ratio. This expression shows that the ICC is proportional to the bandwidth, but is not identical to it.
The frequencies needed to support the different proposed encoding schemes, to achieve a full 10Gig were now extending out as far as 625MHz. It quickly became evident that the signal to noise ratio within a cabling solution could be predicted, and therefore, cancelled out within the active electronics. A random noise source, Alien Crosstalk, now existed from outside the cable. This noise source would need to be measured and reduced to achieve the Shannon's Capacity requirements of the cabling solution.

You may be aware of how the industry currently prevents the effects of crosstalk within cables. The pairs within a single cable are twisted at different rates (as the different colors in the cable would indicate). These different rates are used in an effort to minimize the crosstalk between pairs along parallel runs. While this works well within the cable, it doesn't do much for cable-to-cable crosstalk (Alien Crosstalk).

Alien Crosstalk is quite simply the amount of noise measured on a pair within a cable induced from an adjacent cable. This isn't a concern for different twist lay pairs between cables. Where this has the highest impact is between same twist lay pairs between adjacent cables.

Initial testing on existing Cat 6 UTP cable designs quickly showed that the rationale behind reducing the impact of crosstalk between pairs, within a cable, could not support Alien Crosstalk requirements. Twist lay variation and controlled distance between the pairs have been standard design practice for achieving Category 6 compliance. While the distance between pairs can be controlled within a cable jacket, it could not be controlled between same lay length pairs on adjacent cables.

Testing to Shannon's Capacity on existing Category 6 UTP solutions only yielded results in the 9Gbps range. The results achieved previously did not provide the needed additional throughput to allow for active electronic anomalies. This was a far cry from the desired 19Gbps. Therefore the question to be asked: Is there a UTP solution capable of achieving the needed Alien Crosstalk requirements or would fiber finally rule the day? The August 2003 meeting of the working group would yield three main proposals as a result.

1. Lower the data rates to 2.5Gbps for Cat 6 UTP. This would be the first time fiber would not be matched in speed and that a tenfold increase in speed would not be achieved.
2. Reduce the length of the supported channel to 55m from the industry standard 100m for Cat 6 UTP. This would greatly impact the flexibility of the cabling plant, considering most facilities are designed with the 100m distance incorporated into the floor plans.

Figure 1. Example of a center cable being impacted by the adjacent 6 cables in the bundle.

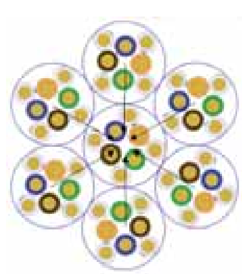


Figure 2. Example of how cables with same twist lays impact one another.

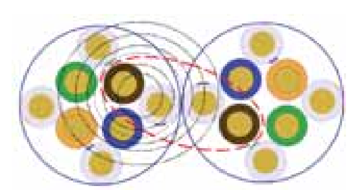


Figure 3. The star filler used within several Cat 6 cable designs increases and controls the distance between pairs.

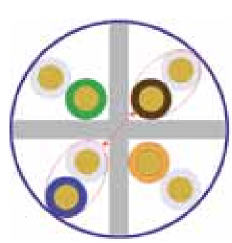
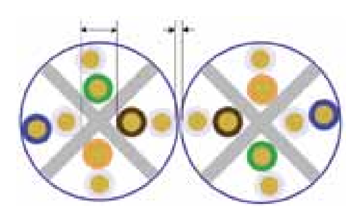


Figure 4. While the distance between pairs within the same cable is maintained, the distance between same lay lengths on adjacent cables is still compromised.



3. Use shielded solutions and abandon UTP as a transport medium for 10Gig. This would mean returning to ScTP/FTP type solutions, requiring additional labor, product cost and grounding, as well as space.

Category 5e would also be dropped as a proposed transport medium entirely. The active hardware and chip manufacturers would now be faced with a lesser solution than the already available Fiber Optic solution. And, questions would now be raised concerning the value of producing such active hardware to support transmission rates that only increased by 2.5 times, or if distance limitations of 55m were really worthwhile? Would the additional cost of installing a shielded solution outweigh the benefits in cost for the active components?

The next meeting of the working group would be pivotal in addressing the above questions. UTP could very well have reached its limit.

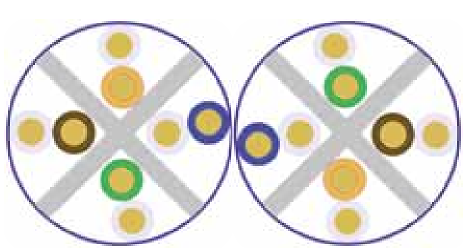
KRONE INNOVATION CopperTen™

A momentous challenge was now presented. How could a UTP cable achieve the desired capacity of >18Gbps, maintain the 100m distances to which the industry has become accustomed while remaining within normal size constraints?

In response to the challenge, KRONE's research and development team quickly went to work. Working within a very short developmental timeframe several innovative ideas were presented, tested and then put into production. Almost overnight, the KRONE R&D team presented a solution to the 10Gig, 100m UTP problem.

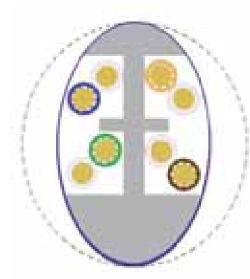
Addressing Pair Separation

With standard Cat 6 cable construction the pair separation within the cable is counter productive for pair separation between cables. The often-used star filler pushed the pairs within the cable as close to the jacket as possible leaving same pair combinations between cables susceptible to high levels of crosstalk.



With KRONE's new design of CopperTentm Cat 6 cable the pairs are now kept apart by creating a higher degree of separation through a unique oblique star filler design. Crowned high points are designed into the filler push the cables away from one another within the bundle. This is very similar to a rotating cam lobe.

Due to the oblique shape of the star, the pairs remain close to the center, while remaining off-center as the cable rotates, creating a random oscillating separation effect.



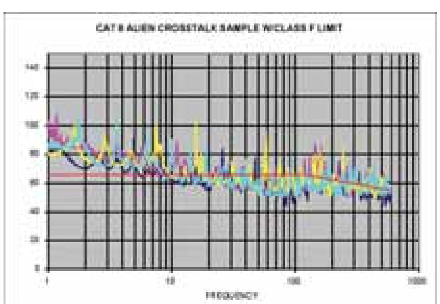
Oblique, elliptical, offset filler, which rotates along its length to create an air gap between the cables within a bundle.

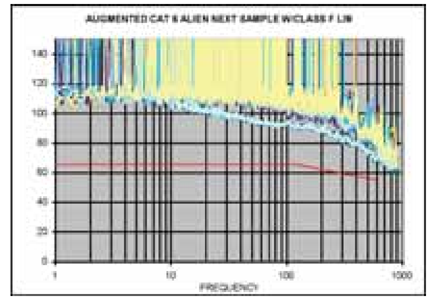
The bundled cables now have sufficient separation between same lay length (same color) pairs to prevent Alien Crosstalk.

This separation can be better understood through the actual cross section below. KRONE's unique design keeps cable pairs of the same twist rate within different cables at a greater distance from one another than in the past. Similar to KRONE's patented AirES® technology cable design, air is used between these pairs.

This effect is even more dramatic when viewed from the side of a cable bundle. The peaks of the oblique, elliptical filler (red arrows) are used as the contact points along the length of the run. These provide the greatest distance between the actual pairs by vaulting the sides of the ellipse (yellow arrows) where the pairs are housed.

The reduction of Alien Crosstalk is now greatly improved over the standard design Cat 6 cables we use today. The chart below compares measurements made on standard Cat 6 cable and the new CopperTentm Cat 6. The improvements are approximately 23dB better on CopperTentm than the standard Cat 6. To put this in prospective: for every 3dB of extra noise there's a doubling effect resulting in standard Cat 6 cable being more than six times noisier than KRONE CopperTentm Cat 6.





For the purpose of comparison, the Cat 7 limit line was used to show the dramatic improvement in preventing Alien Crosstalk.

This ability to create a future-proofing cable in CopperTentm Cat 6 brings up a question as to the need for Standard Cat 6 cable, a cable sold and purchased (for the most part) in an effort to support the next technology leap.

The industry now has taken that next leap. Copper UTP has been given another lease on life to support the next future proofing step in a 10Gig transport protocol. The cost of active hardware will remain in check and be cost effective for future advancements in data transfer rate speeds.

Could this mean Standard Cat 6 is now in the same category as its Cat 2 and Cat 4 predecessors?

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