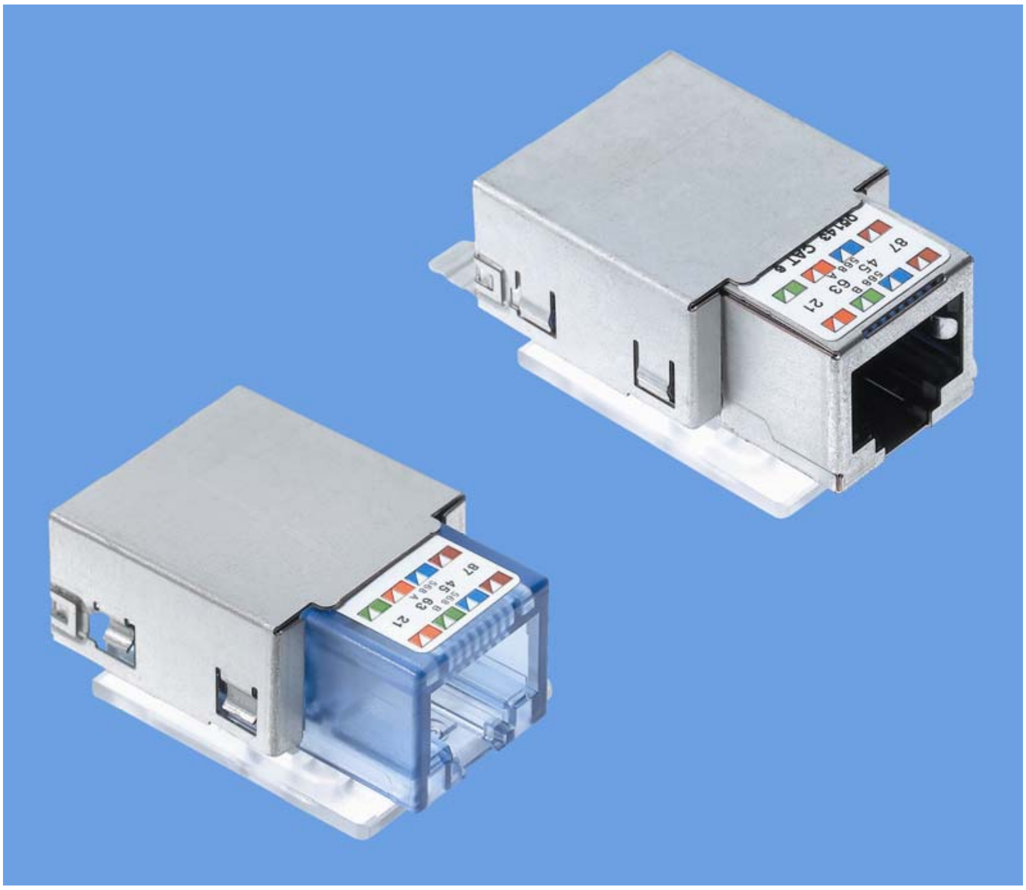
Technical Article



10 Gigabit Ethernet over copper: Unshielded, unprotected?

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Convincing cabling solutions

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Application:	Enterprise cabling
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Goal:	Introduction of the 10 GbE STAR Real10 range in the R&Mfreenet system with shielded and unshielded solutions, explanation of the current background conditions for 10 GbE
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10 Gigabit Ethernet over copper: Unshielded, unprotected?

10 Gigabit Ethernet over horizontal twisted pair copper cables right to the desktop – a dream for many users, a nightmare for some planners and IT managers. If you need to invest in your LAN infrastructure now, you can't wait until the relevant IEEE Standard has been finalized. You have to decide: Cat. 6 shielded or unshielded? Or Cat. 7?

IEEE 802.3ae, the standard for 10 Gigabit Ethernet over optical fiber, was passed in 2002. Since then, the most prolific LAN protocol has penetrated the WAN market. Complementing this, the optical fiber transmission medium has moved from wide area networks into MAN and campus networks and on through to backbone cabling in buildings. But, as far as price and handling are concerned, copper is still the winner when it comes to horizontal cabling. Planners and IT managers are therefore hoping for the final approval of the standard for 10 Gigabit Ethernet over copper, IEEE 802.3an (10GBASE-T), due in July 2006.

The application is clear. 10GBASE-T will be the most economical way of building server clusters in data centers, keeping fiber optic solutions out of the picture in the mid-term. The alternative protocol, 10GBASE-CX4, is unlikely to succeed because of the limitation of its 15 meter range.

10GBASE-T will also move into horizontal-structured building cabling. Future-oriented planners, who set a high priority on investment security, are convinced that higher bandwidths and bandwidth reserves are necessary. The need is there, without considering visible, highly demanding applications like multimedia streaming or real-time image processing. Those that are aware of the invisible applications working in the background, such as VoIP, virus scanning, and software updates, don't need convincing that the bandwidth requirement is increasing. Moreover, the installation of a cabling infrastructure is an investment that must last for several generations of computers and software.

A confusion of cables

If you have to decide on an installation now, you face a dilemma. As long as IEEE 802.3an has not been approved, the ISO/IEC and EIA/TIA workgroups concerned with the necessary cabling properties remain unable to issue any definitive recommendations. The confusion for planners is made complete by EIA/TIA discussions about an "augmented" or "extended" Cat. 6/Class E specification, and the "New Class E" from the ISO/IEC. Nevertheless, this confusion can be largely untangled by careful consideration.

The political solution

If the IEEE 802.3an standard is to be successful, it must work with as much existing cabling as possible. All the manufacturers of equipment, components and software involved are interested in this. As a result, even Cat. 5e / Class D was briefly considered as a possible medium by the IEEE. This idea had to be abandoned for technical reasons.

For the standard development IEEE assumed four cabling models with different ranges (Table 1).

Model	Cable type	Range
1	Class F	100 m
2	Class E UTP	55 m
3	Class E shielded	100 m
4	Class E UTP, NEXT optimized	55 m to 100 m

Table 1: Cabling models in IEEE 802.3an, as of July 2004

So, using Class E is feasible, and it does not have to be shielded. In fact, STP (shielded twisted pair) is only widespread in German-speaking countries, known for their thoroughness and high safety standards. Normally individually shielded S/FTP cabling is used, where the twisted pairs are shielded with foil (F) and the four pairs together are shielded again with a tin-coated copper braid (S). The French generally use U/FTP, dispensing with the common outer shielding. But the rest of the world, by far the majority, uses UTP (unshielded twisted pair) or, more precisely, U/UTP. In principle, this type of cabling should also be sufficient for 10GBASE-T.

The technical solution

Of course, a real effort has been made to squeeze the 10 Gbit/s into a 500 MHz bandwidth for 10GBASE-T. This is to be accomplished by distributing the data stream across all four wire pairs, using a clever encoding procedure (DSQ – Double Square – using 128 points from 16 x 16 / 2 bits) and multi-level pulse amplitude modulation (PAM16, i.e. 16 amplitude levels). Nevertheless, 500 MHz is difficult to realize in part because of the high attenuation of twisted pair data cables. The received signal becomes so small as to be virtually indistinguishable from noise. No wonder, then, that developers are doing all they can to reduce all likely sources of interference as much as possible.

Noise within the cable and, as such, within a 10GBASE-T link, can be suppressed using “intelligent” DSP circuits, which is a huge high-tech effort to enable copper cable to carry 10 Gbits of data. But, this system is powerless against disturbances from outside the cable. It can only compensate for noise it knows about.

This problem is particularly acute for Alien NEXT (ANEXT), crosstalk between neighboring cables and connector modules (figure 1). It is negligible for STP. In the case of UTP, however, it not only depends on the cable, but also on the way the cables are laid out. This additional complication is particularly unpleasant, because it means that the transmitted power level also depends on the way the components are installed, not just on the components themselves.

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ANEXT optimization by standardization?

For 10GBASE-T, the specification of cables and components needs to be extended from the current 250 MHz up to 500 MHz. This is where views start to differ. ISO/IEC envisages a linear extrapolation of NEXT for its “new Class E”. TIA’s “Cat. 6 augmented” requirement is more moderate, while the IEEE has a more relaxed limit for the values from 330 MHz upwards, which are seen as being adequate (figure 2).

Let’s be clear about this: It is the specifications that are “new” or “improved”, not necessarily the cables. Existing cabling can be quite capable of meeting the requirements for 10 Gigabit. Cables and modules that were good up to 250 MHz don’t have to be bad up to 500 MHz. That is particularly true of high-quality STP installations.

As stated, the biggest uncertainty is not NEXT but Alien NEXT. There are no compulsory, reproducible test procedures for measuring this. To determine suitable test scenarios, you need to know the distances over which the cables run parallel in the real installation, and how close they are together. Paradoxically, ANEXT is more of a problem with “neat” installations than with the much-maligned “spaghetti” style of cabling. An experiment with conventional UTP cables performed in the test laboratory at Reichle & De-Massari showed differences in ANEXT of 10 dB between cables laid strictly parallel to each other and those tied together only every 30 cm.

ANEXT optimization by design

Manufacturers of cables and components are therefore trying to build in reliability. The easiest way to reduce NEXT is to increase the spacing between the wire pairs within the cable. ANEXT and other spurious disturbances can be combated by a larger external cable diameter and a shorter twist length for the twisted pairs. This results in some “optimized” UTP cables having diameters of up to 10 mm! For these solutions new patch panels and outlets with greater distances between connectors are also needed.

A more sophisticated approach is to use the principles of shielding and apply them to unshielded components. Swiss cabling manufacturer Reichle & De-Massari and Norwegian cable manufacturer Draka have worked together on a solution which uses foil segments to protect the cable. These segments are completely isolated from one another and from the outside, and they are short enough not to carry loop currents or act as antennas (figure 4). The matching connector modules are equipped with a metal housing. This results in improved ANEXT values without the need to ground any shielding.

All about grounding

No shielding grounding, so no problem with grounding? Actually, the opposite is the case. If the cables are laid in metallic, grounded frames or trunking, the (common-mode) coupling becomes a significant factor. High-quality shielded cabling typically has a common-mode suppression ratio to ground of 40 dB, whereas unshielded cables barely achieve 10 dB. So while STP can tolerate spurious voltages of 2.5 V at 100 MHz in the surrounding ground system, UTP can tolerate just 0.05 V at 100 MHz! A good, consistent grounding concept conforming to EN 50174-2 and EN 50310 is therefore vital, particularly for UTP systems.

Cat. 6 shielded or unshielded?
If you already have a Cat. 6 UTP installation which you want to use for 10GBASE-T, you will need to make new measurements and improvements where necessary. ISO/IEC TR 24750 and TIA TSB 155 describe installation practice and improvement methods for ANEXT optimization. But, more often than not, these may not be feasible for certain installations or parts of them.

If you want 10GBASE-T capability on all links with 100% certainty, you will have to use a UTP solution that is specially designed for this, or better still, use a STP solution from the start. This will mean that you are not dependent on the installation factors described above. It is not just the material costs that have to be considered, but also the total cost – including risk analysis. Cabling using Cat. 6 STP components provides 10 Gigabit capability by its very nature, whereas channels with optimized UTP components will only have this capability if they have been installed perfectly.

Why not Cat. 7?
Without question, due to reduced attenuation and improved shielding characteristics Cat. 7 cables provide performance for the future, and the additional cost is minimal compared with the overall costs. The problem is with the Cat. 7 connectors. Two standardized but mutually incompatible systems are available: either IEC 60603-7-7 which is based on RJ45, or IEC 61076-3-104 based on a completely new design. This means that you have to decide on one system or the other, both of which are standardized but which also have all the disadvantages of a proprietary solution. And, as long as the terminal equipment is not fitted with the corresponding Cat. 7 connectors, hybrid cables will be needed. And at the very least, the end with the RJ45 plug will downgrade the channel back to Cat 6 again.

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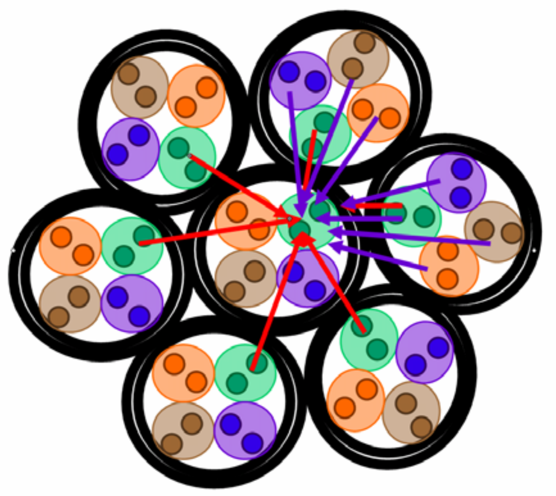

Figure 1. Alien NEXT, crosstalk from neighboring cables in a cable bundle. It is strongest between same colored pairs (shown in green with red arrows) because of their common twist length.

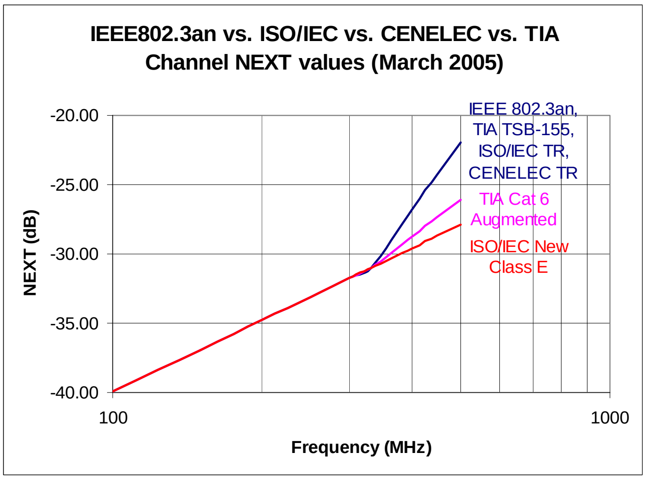

Figure 2. Channel NEXT limit values as envisaged by various standardization bodies (as of March 2005).

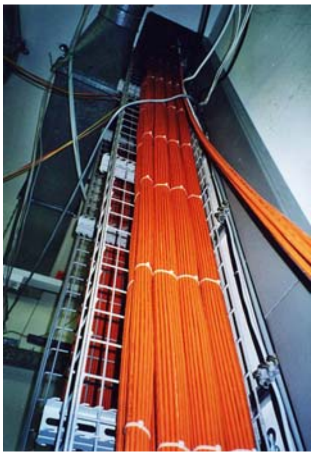

Figure 3. Alien NEXT becomes a critical factor when a lot of unshielded cables run parallel to each other over long distances, as in this riser zone.

Figure 4. A new solution: discontinuous shielding of UTP cables. (Photo: R&M)

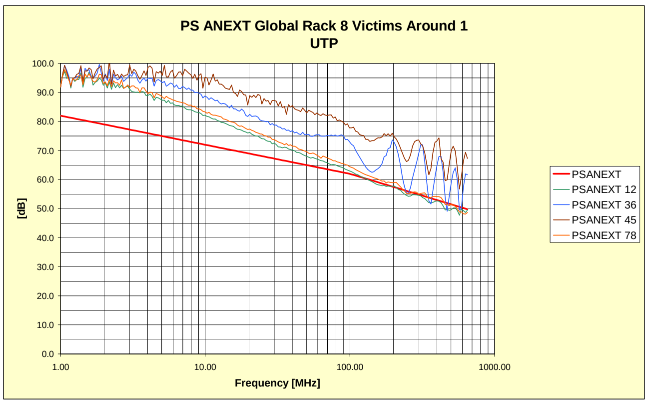

Figure 5. Conventional Cat. 6 UTP cables and UTP modules cannot cope with PS (power sum) ANEXT, the sum of crosstalk power levels from neighboring channels and modules.

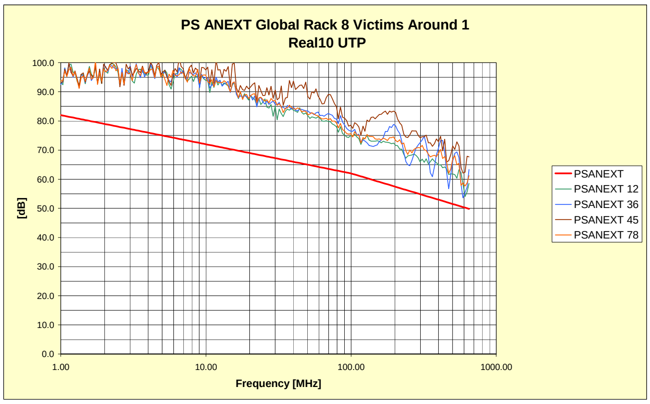

Figure 6. Cat. 6 UTP cables and modules optimized by means of innovative shielding keep within the limit values.

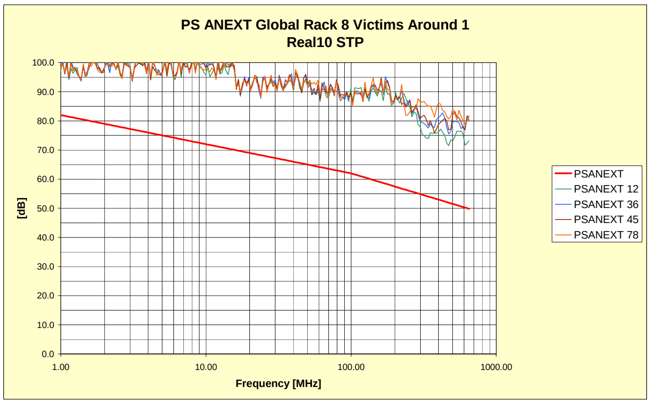

Figure 7. High-quality Cat. 6 S/FTP cables and modules have the most margin compared with all other solutions. All graphics: R&M

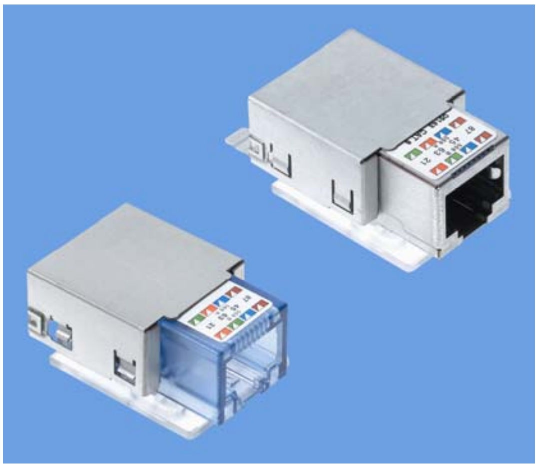

Figure 8. RJ45 connector modules: Cat. 6 Real10 UTP and Cat. 6 Real10 STP