Positioning Paper

10 Gigabit Ethernet

R&M

Convincing cabling solutions

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Convincing cabling solutions

Application:	Enterprise Cabling
Technology:	Ethernet – Copper and Fiber
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Topics:	10 Gigabit Ethernet, R&M support for fiber and copper
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1. Introduction

Ethernet has proven itself over the years to be a robust protocol, constantly expanding the number of applications it serves while increasing performance. Today 10 Gigabit Ethernet is reality and already talk of 40 Gigabit or even 100 Gigabit Ethernet has been in the news – clearly Ethernet will continue to be a significant force in networking for the foreseeable future.

However, whilst optical fiber transmission provides a problem-free yet expensive solution, copper cabling – especially unshielded or unscreened (UTP) cabling – seems to be reaching its limits in attaining 10 Gigabit performance, likely resulting in some restrictions or in specially designed products to extend the functionality. The release of some of these products may be premature considering that the 10 Gigabit Ethernet over copper standard is still under development and will not be finally approved before summer 2006.

Enterprises cannot wait when it comes to necessary investments in networks and equipment. R&M understands that IT managers and planners have to make decisions now. This paper explains R&M's position regarding 10 Gigabit Ethernet and provides planners with information and arguments to enable them to find the best future-proof solution.

2. Ethernet is Everywhere

Last year Ethernet celebrated its 30th birthday. From its beginnings as a 3 Mbit/s shared bus technology it has grown to become the ubiquitous standard for private networks. It is now present in 80 to 90% of LANs and is the most widely adopted networking technology in the world. Nearly all traffic on the internet originates or ends with an Ethernet connection.

2.1. Raison d'être

Many reasons can be given for the success of Ethernet. The fact that it is based on standards ensures a high level of quality and reliability. It also ensures interoperability between multiple vendors which reduces component costs. Overall, the costs of implementing an Ethernet solution are low. The implementation, configuration and maintenance of an Ethernet solution are relatively simple, minimizing time needed for these activities. Finally, Ethernet is backward compatible, allowing one system to switch from Gigabit down to 10 Mbit/s shared.

2.2. Continuous Development

Another aspect of the success of Ethernet is the continuous performance improvements which have been implemented over the years.

Some may think that the technology has finally reached its limitations with 10 Gigabit Ethernet. People who said that about Ethernet in the past were proven wrong. Already talk of 40 Gigabit or even 100 Gigabit Ethernet has been in the news, with some companies releasing proprietary products. It's a good bet that Ethernet is here to stay.

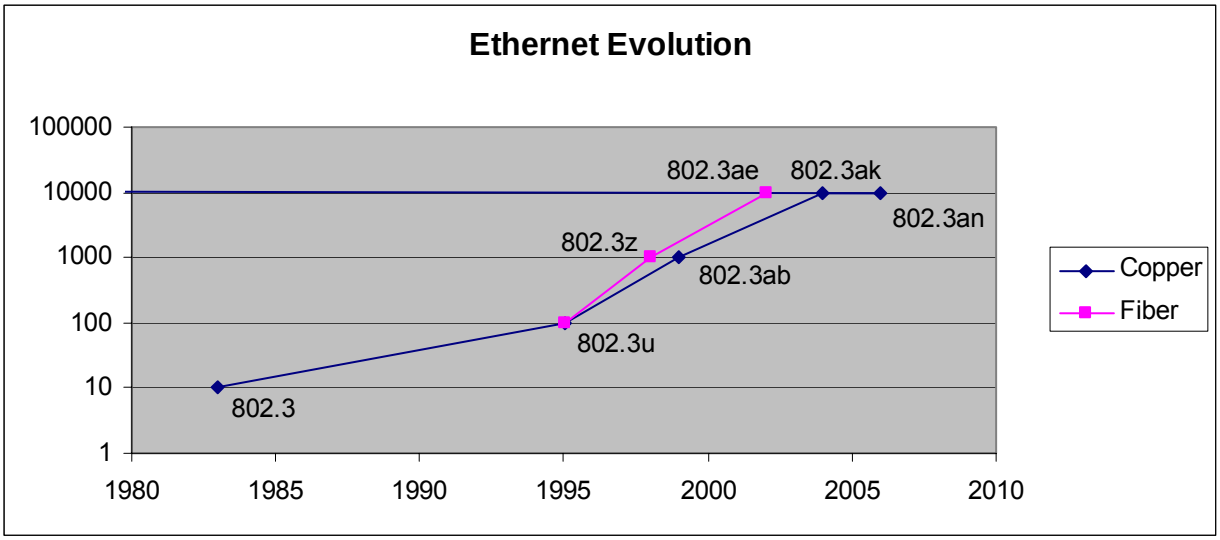

Fig. 1: Continuous growth of bandwidth, with copper techniques reaching the mark of 10 Gigabit which was a domain of fiber optics transmission for only a short time. 10 / 100 Mbit/s and 1 Gbit/s standards:
IEEE 802.3 – 10BASE-5;
IEEE 802.3u – 100BASE-TX (copper) and 100Base-FX (fiber);
IEEE 802.3z – 1000BASE-CX,-LX, -SX (fiber);
IEEE 802.3ab – 1000BASE-T (copper)
Latest 10 Gigabit standards are explained below.

3. 10 Gigabit Ethernet

As Gigabit Ethernet is being deployed more and more to the desktop, the need for 10 Gigabit Ethernet is also growing. A number of standards have already been released for 10 Gigabit Ethernet performance and others are in progress. An overview of all standards status and activity is given below.

3.1. IEEE 802.3ae – 10GBASE-xx Fiber Interfaces

Released in 2002, this was the first 10 Gigabit standard. It specifies fiber only in full duplex mode. A number of interfaces are provided for use in various applications. They include support for multimode fiber, singlemode fiber and SONET compatibility. The 10GBASE-xR standards have gained the broadest market acceptance to date, while the 10GBASE-LX4 interface has not been a success due to its high cost.

The 10GBASE-xW interfaces added a WAN physical layer to provide compatibility with SONET, and enable Ethernet to be used in the service provider market as well.

	10GBASE		
Coding	**LAN 8B/10B**	**LAN 64B/66B**	**WAN SONET**
Short 850 nm		**10GBASE-SR** OM1 62.5 µm 33 m OM2 50 µm 82 m OM3 50 µm 300 m	**10GBASE-SW** OM1 62.5 µm 33 m OM2 50 µm 82 m OM3 50 µm 300 m
Long 1300/1310 nm	**10GBASE-LX4** MM 62.5 µm 300 m MM 50 µm 300 m OS1 9 µm 10 km	**10GBASE-LR** OS1 9 µm 10 km	**10GBASE-LW** OS1 9 µm 10 km
Extra long 1550 nm		**10GBASE-ER** OS1 9 µm 40 km	**10GBASE-EW** OS1 9 µm 40 km

Table 1: 10 GBASE interfaces and maximum distances for short haul (850 nm wavelength), long haul (1300/1310 nm) and extra long haul (1550 nm) connections. MM = multimode, OM and OS signify the fiber type for multimode and singlemode transmission. The core diameter of the fiber is given in µm, the maximum distance in m or km.

The wide array of interfaces provided in the standard enable 10 Gigabit Ethernet to support a wide range of applications, from the enterprise network to the metro and on to the WAN.

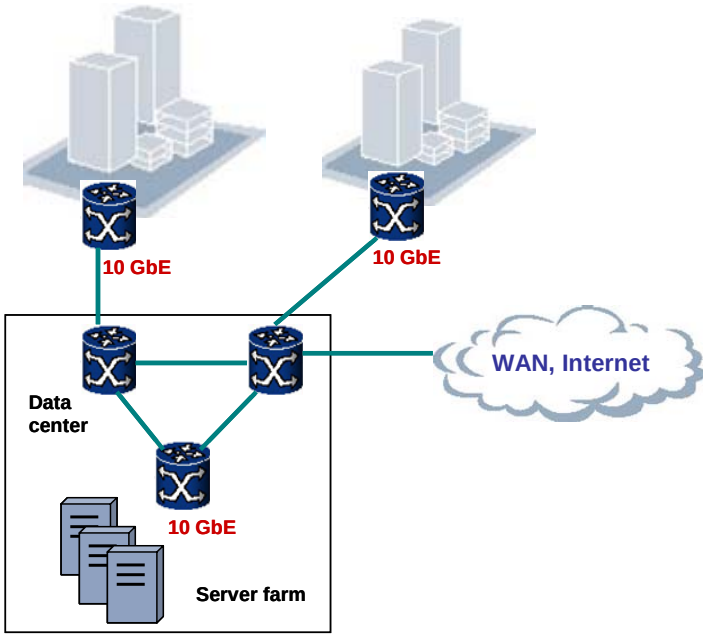

Fig. 2: Typical 10 Gigabit Ethernet (10 GbE) application in enterprise networks.

Figure 2 shows 10 Gigabit Ethernet being used in the enterprise backbone, intra- and inter-campus and to connect the server farm in the data center. Another up-and-coming application for 10 Gigabit Ethernet is in the Storage Area Network (SAN) because of the potential cost savings compared to Fiber Channel and the possibility to collapse the storage and corporate networks into one.

With the recent drop in prices, the markets for both Gigabit and 10 Gigabit Ethernet have grown significantly. According to the Dell'Oro Group, a market research firm specialized in the networking and telecommunications industries, in 4Q03 the number of 10 Gigabit Ethernet port shipments increased by a factor of 4. The Yankee Group reported that the equipment market grew from $42M in 2002 to $90M in 2003. During the past two years, the price per gigabit of bandwidth dropped to about 20%. Nevertheless, fiber will probably not be cost effective for in-building horizontal cabling in the near future.

3.2. IEEE 802.3ak – 10GBASE-CX Twinax Copper Interface

This standard runs over copper, but uses a 4-pair twinaxial cable instead of the more common twisted-pair structured cabling. This cable is more rigid than twisted pair but costs significantly more. In addition, the standard specifies a maximum of 15 meters, limiting it to small data center applications. IT managers and planners should be aware that investing in a 10GBASE-CX installation means adopting a standard with the character of a proprietary solution because it does not follow the standards for structured cabling. R&M has thus chosen not to support it.

3.3. IEEE 802.2aq – 10GBASE-LRM Fiber Interface

A task force was recently formed with the objective of developing a standard to support 10 Gigabit Ethernet over 220 meters of OM1 and OM2 50 and 62.5 µm multimode fiber rated at a bandwidth-distance product of 500 MHz x km. These fibers were widely used for fiber optic applications all over the world. The goals of the new IEEE standard are to achieve a lower component price than 10GBASE-LR and to leverage the existing cabling infrastructure as much as possible.

Current plans are to have the first draft by the fall of 2004, with a final version in 2006.

3.4. IEEE 802.3an – 10GBASE-T Twisted-Pair Copper Interface

This standard will support 10 Gigabit Ethernet over 4-pair twisted copper cabling. The main driver for this interface is cost, as copper interfaces are typically three times cheaper to produce than optical interfaces. In addition, the aim is to leverage the very large installed base of structured copper cabling, as well as the vast knowledge base associated with it.

The following goals have been agreed upon by the task force:

1. Support full duplex operation only
2. Support star-wired LANs using point to point links and structured cabling topologies
3. Support a speed of 10 Gbit/s at the MAC/PLS service interface
4. Select copper media from ISO 11801:2002, with any appropriate augmentation to be developed through the work of IEEE 802.3 in conjunction with ISO/IEC JTC 1/SC 25 working group (WG) 3.
5. Support coexistence with 802.3af – DTE (Data Terminal Equipment) Power via MDI (Media Dependent Interface)
6. Support operation over 4-connector structured, 4-pair, twisted pair copper cabling for all supported distances and classes
7. Define a single 10 Gbit/s physical layer that would support links of:
   a. At least 100 meters on 4-pair Class E & F screened balanced copper cabling
   b. At least 55 to 100 meters on 4-pair Class E unscreened balanced copper cabling
8. Support a BER (Bit Error Ratio) of 10exp-12 on all supported distances and classes

4. Status of 10GBASE-T

The first draft of the 10GBASE-T specification is expected by the end of 2004. The second and third drafts should follow in 2005 and the final version should be ratified in the summer of 2006. The task force is working closely with both TIA TR-42 and ISO/IEC JTC 1/SC 25 groups to develop the cabling specification.

R&M is a working member of the ISO/IEC group and through them is actively contributing to the definition of the cabling specifications.

4.1. Technical overview

According to Shannon's Law the maximum capacity of a channel is a function of the bandwidth and the signal to noise ratio on the transmission channel. Basically it shows that the number of bits of information which can be sent on a channel increases with the strength of the signal and decreases with the amount of noise. Noise can be generated by external sources or within the cabling itself. The noise generated within the cable can be cancelled using advanced digital signal processing techniques in the active components.

The work of the IEEE task force thus far has shown that the Alien NEXT (Near-End Crosstalk) parameter, which is the interfering noise from neighboring cables, will be the most critical factor in reaching 10 Gbit/s of data, or 2.5 Gbit/s of data on each pair. Unfortunately, the effects of Alien NEXT cannot be compensated for in the active components and thus must be addressed in the cabling. Of course, this is only an issue with unscreened systems since screened systems have sufficient immunity against Alien NEXT.

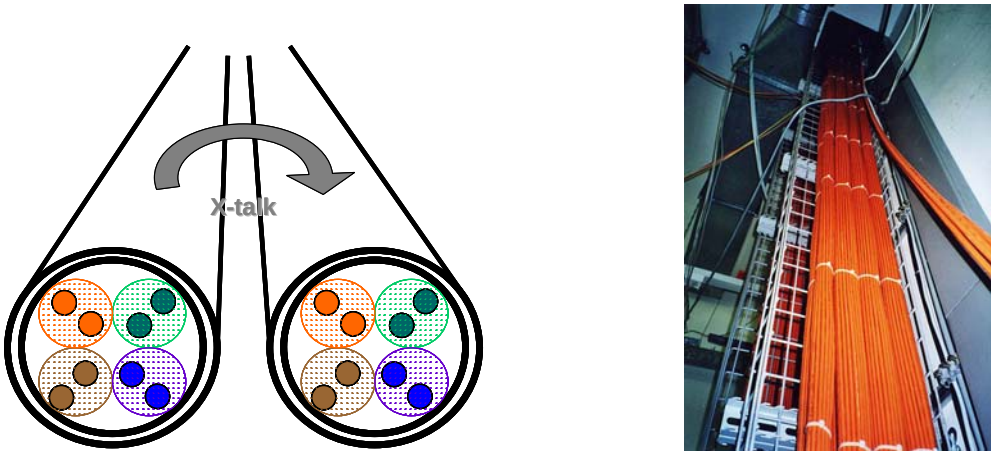

Fig. 3: Crosstalk between two 4-pair cables. Alien NEXT is an issue in enterprise cabling especially with bundles of cables in parallel.

The graphs below, based on testing done in R&M labs, show the significant effects of Alien NEXT with only 3 cables in a bundle.

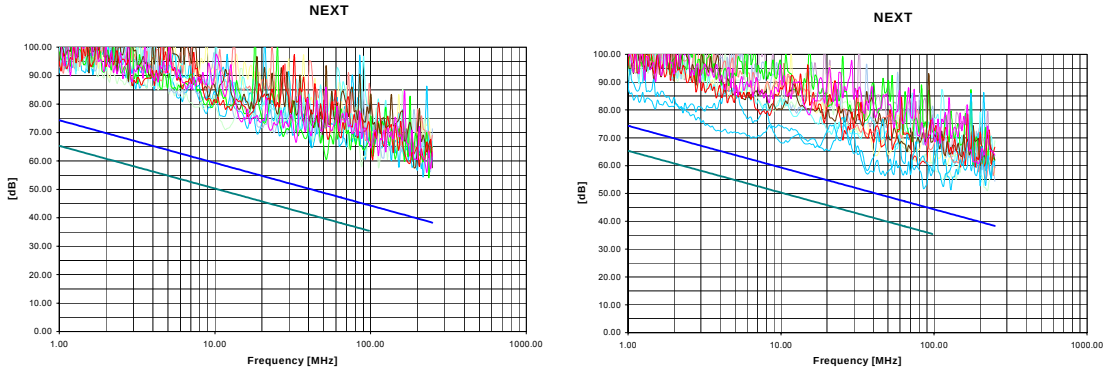

Fig. 4: Alien NEXT (Near-End Crosstalk) for a single cable (left) and 3 bundled cables. Test length: 5 m.

Reaching the 2.5 Gbit/s of data transfer rate per pair will also require complex coding schemes. IEEE has not finalized yet which one will be used, but it is clear that even with sophisticated coding the minimum bandwidth will need to be increased beyond 250 MHz. Until recently IEEE was looking at 625 MHz with PAM 5 (5-level Pulse Amplitude Modulation). As of today IEEE is looking at either PAM 8 or 12 and has lowered the bandwidth upper limit to 500 MHz.

4.2. Models being considered

This spring, the IEEE task force came to the realization that the goal of supporting 10 Gigabit operation over Cat. 5 cabling was not feasible. Their current goal is to support the following four models:

Channel Model	Cable	Distance
1	Class F	100 m
2	Class E UTP	55 m
3	Class E screened	100 m
4	Class E, improved for Alien NEXT	55 m < L ≤ 100 m

As a starting point they have extrapolated the Cat. 6 parameters out to 500 MHz (Fig. 5). Models for Alien NEXT are being developed in cooperation with the TIA and ISO cabling standard groups. Initial limits were established by the task force based on cabling measurements which are representative of a “reasonable” worst case. Because models 1 and 3 are based on screened cables, they are immune to the effects of Alien NEXT and will not require field validation.

Insertion loss directly influences the signal strength at the receiver. IEEE therefore would like as low an insertion loss as possible. Since this would mean increasing the copper diameter in the cables and thus increasing the cable price, discussions for a compromise are still ongoing.

The very important signal to noise ratio (SNR) parameter then is basically a function of the maximum insertion loss of the cabling in relation to the amount of Alien NEXT at the receiver. The 55 m length limitation of model 2 was determined by calculating the maximum insertion loss, Alien NEXT limits and the needed SNR to ensure a low data error rate. In order to increase the length, as in model 4, either the insertion loss of the cable must be improved, the Alien NEXT must be mitigated, or both.

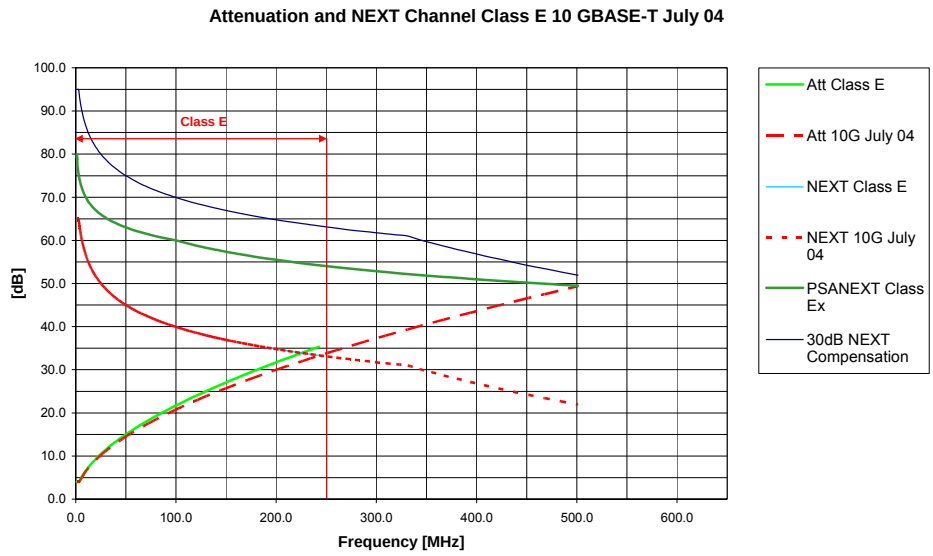

Fig. 5: Extrapolating Cat. 6 parameters out to 500 MHz.

Some Alien NEXT mitigation strategies being considered are separating cables and patch cords to reduce the amount of coupling between adjacent cables, separating ports on the patch panel or limiting the number of channels in conduits and bundled cables. In addition, cabling vendors are developing cable and other components that decrease the effect of alien crosstalk, although they cannot reduce it by 100%.

5. R&M Solutions

R&M is committed to supporting 10 Gigabit Ethernet in its most practical forms.

5.1. VISIONsystem

The R&M VISIONsystem provides a full range of high-quality solutions including cable, connectors and patch cords, to support the wide range of 10 Gigabit Ethernet interfaces specified. All fibers are Gigabit and 10 Gigabit Ethernet compliant and can be used for a variety of applications, from campus cabling to the backbone or to horizontal. They also comply with the latest specification of international standards, guaranteeing future-proof, risk-free installations.

Fig. 6: R&M VISIONsystem cables and components comply with Gigabit and 10 Gigabit Ethernet specifications. Examples: Splice tray, SC connector patchcord, outlet with E2000™ Compact connectors and fiber optic loose tube cable.

Our qualified personnel are able to advise customers every step of the way to ensure that they make the right choices for their needs.

5.2. 10GBASE-T

R&M is working closely with the various standards groups to make sure that we provide a comprehensive solution for supporting 10GBASE-T. As the standard is two years away from being ratified, it is too early for any reputable vendor to give a definitive statement since many things can change in that timeframe. However, based on current information we will provide the following support.

Model 1, Class F, 100 m: The market acceptance of this cabling standard to date is very low. This may be due in part to the fact that two different connectors are standardized, resulting in confusion about which connector to choose and concern about compatibility issues. Therefore, R&M has chosen not to support this model.

Model 2, Class E UTP, 55 m: Due to our high quality components and based on third-party (3P) test results up to 600 MHz, we expect that our Cat. 6 UTP (Unshielded Twisted Pair) solutions will meet the requirements of the standard. Various studies have shown that up to 70% of installed links are 55 m or less, so this solution should meet the needs of many customers that already have Class E UTP installations.

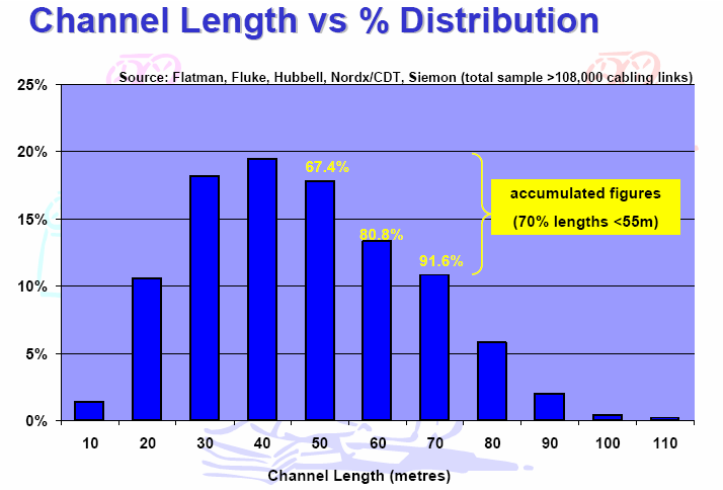

Fig. 7: Distribution of installed channel lengths.

Model 3, Class E, screened, 100 m: Based on 3P results of testing up to 600 MHz, we are confident that our standard Cat. 6 shielded solution will meet the requirements of the 10GBase-T standard. This model offers the most robust solution with the lowest risk. Customers with Class E screened installations can be secure that 10 Gigabit Ethernet will run on their system.

Model 4, Class E, UTP, 55 m to 100 m: As mentioned earlier, this will be the most challenging model to support and will depend greatly on what the final specification looks like. We are investigating various mitigation techniques to lower the susceptibility of the cabling to Alien NEXT. In addition, we are studying installation methods which help to alleviate the effects of noise. Already our modules and patch panels have an advantage in that the distance between ports is larger than that of most other vendors. Our 24-port panel's staggered design is optimal for 10 Gigabit Ethernet use.

6. Recommendation – Take Another Look at Screened Systems

R&M will support both screened and unscreened models for 10 Gigabit Ethernet, especially to enable customers with Class E installations to run this application. However, for new installations R&M strongly recommends our screened system as the most future-proof solution.

Clearly, UTP is the cabling of choice for most of the world and the topic to switch to screened systems has been debated for years. But with ever-increasing bandwidth requirements demonstrating a need for 10 Gigabit Ethernet over copper in the not so distant future, it is worthwhile to take another look at the common arguments.

6.1. Space

One argument against screened cables is that they are larger than unscreened cable and thus require more space, increasing costs. However, it should also be noted that according to installation standards such as EN50174 unscreened cables have to be physically separated from power cables by a minimum specified amount. If the system as a whole is considered, unscreened systems will require more space for all of the cabling, increasing costs.

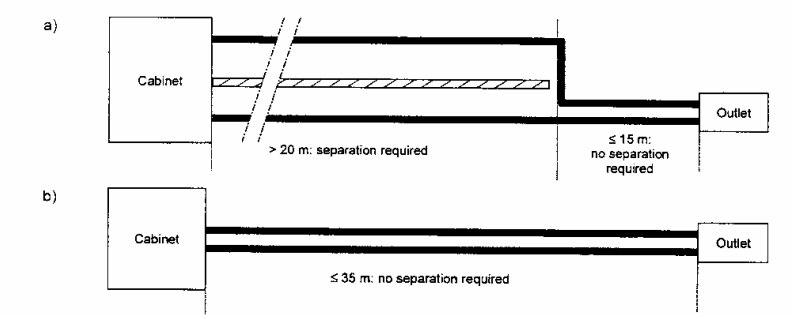

Fig. 8: Separation of unscreened (above) and screened cables (below).

Some vendors are introducing new cables which are optimized to reduce Alien NEXT effects. It is likely that this will result in a larger cable. For example, one Alien NEXT optimized cable already introduced in the market has a diameter of 10 mm. Compared to typical unscreened cable diameters of 5.5 to 7 mm or even screened cable diameters of 7 to 8 mm this is a significant increase. In fact, Alien NEXT optimized cables will likely require more space than screened cables.

Today's installation standards (EN50174) specify a maximum fill limit of 40 to 50% in conduits. One of the recommendations for mitigating Alien NEXT is to limit the number of cables in a conduit, and this, coupled with the other factors already mentioned, likely means that an unscreened system optimized for Alien NEXT will require much more space than a screened system.

6.2. Termination

The time it takes to connect a cable to the module is usually longer with screened components than with unscreened, increasing labor costs. However, R&M compared the termination times with our components and discovered that screened components only require 13% more time (85 s vs. 75 s) to remove the screening. Considering the increased data security of screened systems, this cost is negligible.

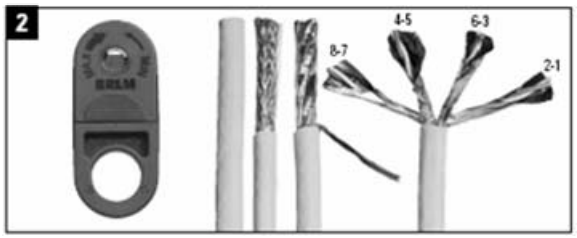

Fig. 9: Screened cables can be terminated nearly as quickly and easily as unscreened cables.

Also, some find the larger screened cables more difficult than unscreened cables to work with. The bayonet of R&M's screened module keeps the cable in place while working, thus optimizing the termination process, increasing speed, and reducing labor costs. Again, the Alien NEXT optimized cables will likely be as large or larger than screened cables so termination will be more of an issue with them.

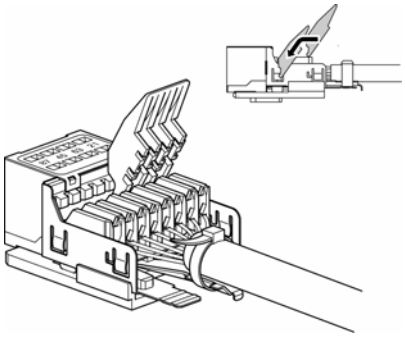

Fig. 10: The bayonet of R&M's screened RJ45 module enables easy handling of installation cable during termination.

6.3. Grounding

Many cabling vendors claim that installers and planners find grounding concepts too complicated. It is interesting to note that all RJ45 ports on active equipment such as switches are screened and must be somehow grounded. Every building or house must have a grounding system installed, so clearly this type of expertise exists in the market. The standards offer detailed information on planning grounding systems specifically for cabling. Admittedly, care must be taken when designing and installing screened systems, but the same is also true of unscreened systems, if to a slightly lesser degree. Considering the benefits, the small upfront investment is well worth it.

R&M has designed its products for ease of installation. This is especially seen with the screened components, as the grounding aspect is practically automatic. Each module is individually screened and snaps into the module holder and patch panel as the unscreened components do. All the installer needs to do is to ground the panel using the supplied bonding cable. The termination is also quite easy as the bayonet simply needs to be slipped into the cable to make contact with the shielding.

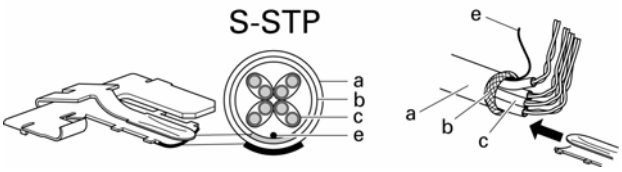

Fig. 11: The bayonet automatically makes contact with the shielding.

7. Summary

Of all the options for supporting 10 Gigabit Ethernet discussed, the fiber optic solutions are the most robust. This is due to the fact that the standards are ratified, products are available and prices are dropping. However, there are legitimate reasons to stay with twisted-pair copper solutions, including cost and leveraging knowledge base and existing equipment. In this case, both screened and unscreened solutions can be considered.

When comparing screened components with Alien NEXT optimized unscreened components, it seems clear that today screened is the better choice. Many of the cost differences are eliminated or even fall in favor of screened components as described above. It is also conceivable that vendors will charge more for their 10 Gigabit Ethernet solutions to recoup their development costs.

R&M's screened components are proven in the market and have been installed in thousands of projects, making them the lowest risk copper solution for 10 Gigabit Ethernet transmission available today.

8. Additional Information

For additional information on R&M products and solutions visit our website at www.rdm.com