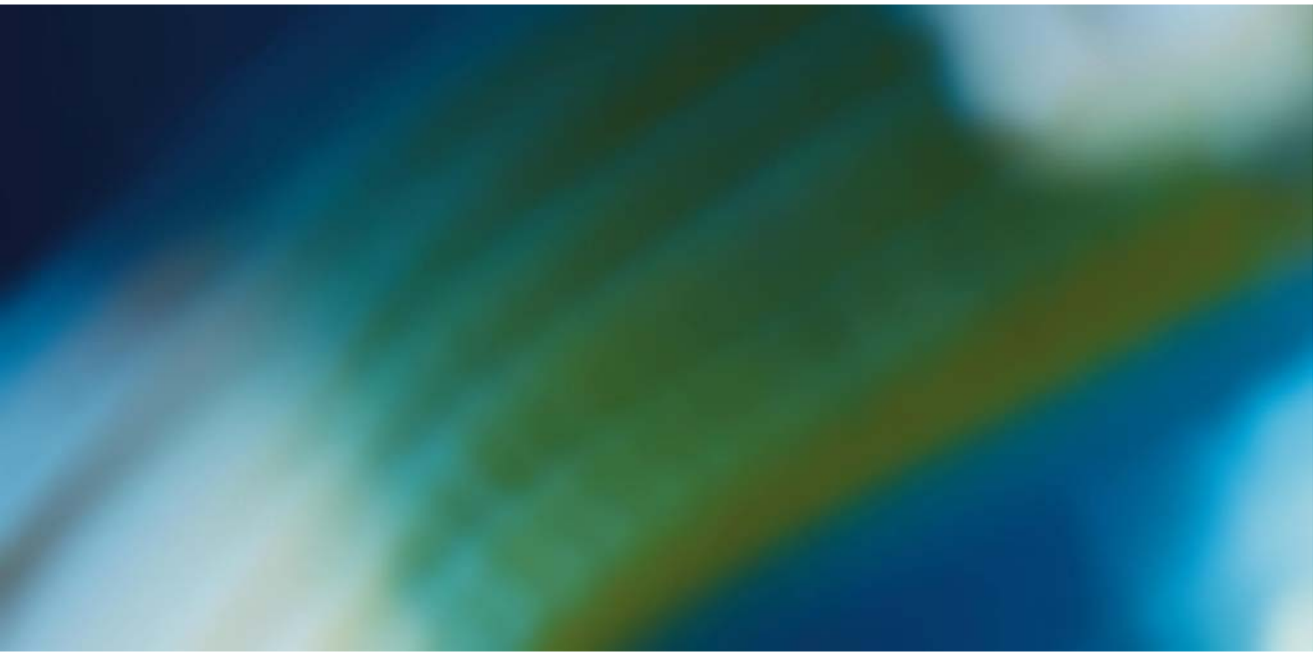
White Paper



Alien Crosstalk

Crosstalk effects and cable shielding

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1. Introduction

The world of information technology cabling is divided. While the U.S. is the stronghold of unshielded cabling, shielded cabling is almost mandatory in Europe, particularly in Germany. The differences gain in significance due to the ever increasing data rates that should run through cabling systems – shielded or unshielded – without interfering and without being interfered. The mutual effects of pairs inside a cable are known and can be kept in check as long as a uniform technology LAN, like Ethernet, is operated over it.

Yet, in addition, there can be ATM and Token Ring, and there is always a power supply. The EN 50174-2 was quite right to give special attention to installation and operation of information technology cabling within the environment of a premise building operating a low-voltage electricity distribution system (less than AC 1000 V rms), taking into account the interaction effects of information technology cabling and other cabling systems. This white paper focuses on the effects, which can be summarised as "alien crosstalk".

Application:	Enterprise Cabling, Industrial Cabling
Technology:	All LAN technologies concerned with transmission over copper cables
Format:	White Paper
Topics:	Information technology cabling systems with unshielded (UTP) and shielded (STP) lines; little considered crosstalk effects from other cables (alien crosstalk); practical measurement results; recommendations for installations
Objectives:	Investment protection, points to consider when making investment decisions
Target groups:	Planners, decision makers, installers, R&M Sales
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2. UTP versus STP: how effective is shielding really?

2.1 EMC and related installation uncertainties

Electromagnetic compliance, EMC for short, consists of two parts: electromagnetic interference and interference immunity. Respective parameters exist for some individual components, allowing the comparison between components, but of the same type only. An information technology cabling, however, is composed of many different components and it is moreover situated between other installations. These factors are quite often confusing for planners and installers. What are the relevant criteria for an interference-free, future-proof installation of local networks?

The most important component is the cable itself. Authoritative standards specify test situations that yield comparable parameters. The key EMC parameter for shielded (STP) cables is the transfer impedance of the cable shield. The lower it is, the better the shield performance. Transfer impedance of unshielded (UTP) cables cannot be measured – since there is no shield. Maybe it doesn't need one after all?

What actually makes a UTP cable work is the sufficiently balanced design of the conductor pairs. It means that both conductors of a pair are affected in equal measures by noise so that ideally they cancel it out.

In practice this ideal is only partly accomplished, with a peak noise rejection of 40 dB. **An additional shield improves this value by up to 60 dB, i.e. by factor thousand.** In real data networks this difference can be measured at the relevant frequency range between 1 MHz and 100 MHz. Relevant because it is the crucial range for data transmission protocols.

The effects between adjacent conductor pairs inside a cable are known and clearly defined. Little consideration though is given to crosstalk of pairs between adjacent UTP cables – an aspect that has been largely neglected in the discussion about UTP technologies so far. Great efforts went into testing and documenting installed transmission links, in the firm belief that they were describing a stable situation. But the link parameters alter with each subsequent installation because the UTP cable is not a closed system like the shielded cable, and significant crosstalk can occur between adjacent UTP cables. In the U.S., the largest UTP market in the world, a term was coined for this effect: alien crosstalk. The problem it presents in real installations has no registered link test value since a link is only measured on its own. Yet, alien crosstalk does reduce the ACR (attenuation crosstalk ratio) just like "ordinary" NEXT (near-end crosstalk) does.

2.2 Alien crosstalk: origin and counter measures

For UTP cables that are closely bundled together for a distance of more than 15 metres, alien crosstalk can be a concern. It is difficult to measure because it requires synchronising two sets of test instruments, and even then, the result is only a lab measurement. There are no pass/fail limits proposed or set for alien crosstalk.

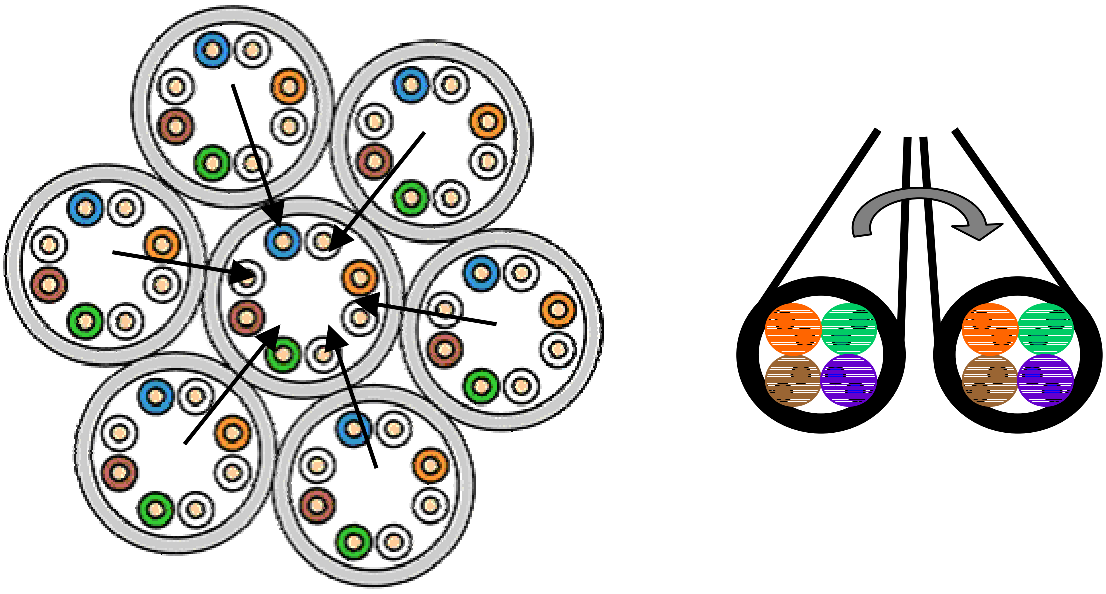

Figure 1: Alien crosstalk between conductor pairs of unshielded cables (left). Shielding helps (right).

The origin is explained in figure 1. In unshielded cables each conductor pair induces crosstalk in the adjacent pairs in its own *and* in the neighbour cable. The reason is the capacitive and inductive coupling between the current carrying conductors.

Crosstalk as the sum of partial capacitances can be reduced with constructive measures. One is to twist the pairs of balanced cables by using different twist lengths. Further decoupling is achieved by shielding the individual pairs and the four pairs together, as shown in figure 1 on the right.

Crosstalk between two pairs that are not separated by a metal shield basically depends on the pairs' twist length. By choosing appropriate twist length a very high crosstalk attenuation can be achieved. Since there aren't that many twist length combinations possible on a certain length while still reasonable with regards to manufacturing and costs, the crosstalk level of multi-pair phone cables is usually worse than that of data cables. Moreover, the high number of pairs alone already increases crosstalk. The referred to unit usually is the power sum (PS).

In the case of unshielded data cables similar considerations need to be made, even beyond the jacket of the individual cable, since a bundle of unshielded data cables of four pairs each is nothing else than a multi-pair cable in this respect. In the following some practical research is presented with examples to clarify the problem.

2.3 Alien NEXT and FEXT – the critical parameters

In crosstalk we differentiate between near-end crosstalk (NEXT) occurring at the near end of the cable and far-end crosstalk (FEXT) at the far end of the cable. These two parameters concern the effects inside a cable. They became more important with the increasing transmission speed and with more frequent use of the pairs in both directions, i.e. to send and to receive.

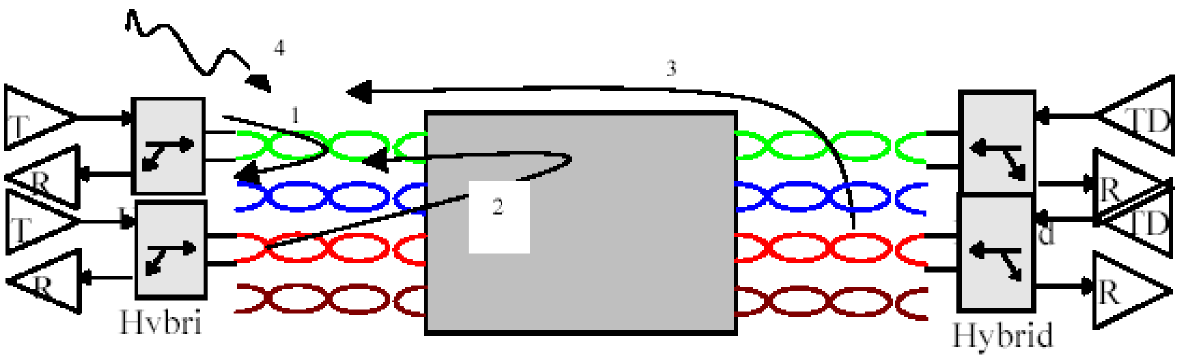

Figure 2: direct crosstalk from output to input port of the same pair (1), NEXT (2) and FEXT (3) from the adjacent pair, and Alien crosstalk (4)

Figure 2 shows a typical situation as it occurs with the Fast Ethernet protocol 100Base-TX. 100Base-TX uses two pairs in both directions each. All in all, there are four parameters to interfere with the transmission (figure 2): direct crosstalk from output to input port of the same pair (1), e.g. caused by mismatched impedances. Digital signal processing (DSP) can easily compensate this crosstalk because it knows the signal. The same goes for near-end crosstalk of the adjacent pair (2) because DSP also generates that signal, distributing the original information between the two pairs. It is far more difficult to identify and compensate the crosstalk from the far end (3), and as good as impossible to do so with alien crosstalk (4).

With the Ethernet protocol 100Base-T2, designed for Class C cabling with a specified frequency range of up to 16 MHz, external high-frequency noise was reduced by means of a fifth-order filter, triggered at 20 MHz. It achieved good attenuation results with signals of 30 MHz onwards. The model was not successful on the market though since it cannot be applied to cabling classes after Class D and Class E, specified to up to 100 MHz and 250 MHz. This makes alien NEXT and FEXT the deciding factors for fast local networks.

2.4 Conclusion

Due to high spatial cable densities, use of larger bandwidths and extension of radio networks, increasing EMC problems have to be expected. A further factor is the increasing complexity and smallness of electronic components, which makes them even more susceptible to electrostatic discharge. Full protection of data networks can only be provided by shielded cabling systems. And the shielding must also include components.

The terms shielding and earthing are quite often incorrectly applied and implemented. This can have fatal consequences on function and effectiveness of an earthing concept. The term shielding refers to the electrically conductive shell that surrounds a conductor or an electrical component, protecting it against external electrical inference and at the same time shielding the exterior from the internally generated electromagnetic fields. Depending on the system the shielding can also function as signal return path, e.g. in coax cable systems. In order for a shielding to work properly it needs to be electrically closed.

A good shielding is only effective with a good earthing. The earthing needs to be carefully planned and inserted so that no current loops can occur, which would cause other interferences.

3. Practical measurements

3.1 Unshielded cables (U/UTP)

Efficient test methods and fault diagnosis are the foundations of an optimal network, and significant lab measurements do not necessarily mean costly preparations. To measure the interaction effects between two unshielded Cat. 5 data cables for example, they can be laid on the floor in a straight line, next to each other, for 20 metres, their twist length would be about 20 mm. By separating the two cables to about 9.5 cm max., at 5-mm steps, you get a series of measurements that can be considered representative for the practical situations in real installations.

Another possibility is to simulate the effects of the bundling in the lab, just as they occur in "clean" installations. Figure 3 shows such a bundle as it was used by the R&M research and test lab for measurements. The results correspond to those of other companies.

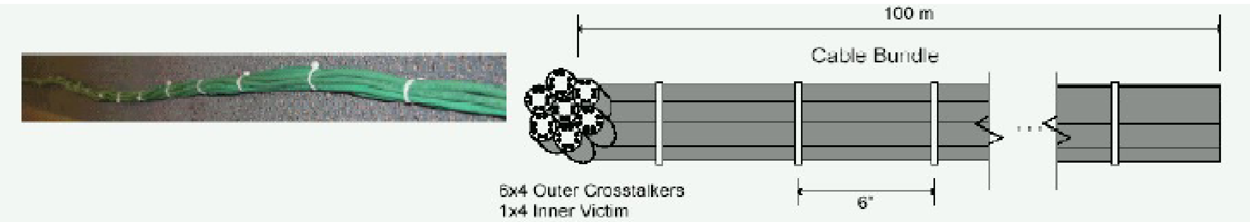

Figure 3: Bundle of six U/UTP Cat. 5 cables

At frequencies below 50 MHz alien NEXT attenuation is worse than NEXT attenuation inside the cable itself. Above this frequency alien NEXT is about 10 dB better than the NEXT attenuation inside the cable. NEXT compensation largely happens inside the cable itself and is therefore quite easy to do. It is much more difficult with alien NEXT. Moreover, alien NEXT occurs on very short links of bundled cables already. Tests show that 3 metres are all it takes, and 3 metres is a very common length in rack cabling. With a NEXT attenuation of 40 dB inside the cable, an alien NEXT from one single pair in the adjacent cable is already noticeable. And it gets worse if we calculate the alien NEXT power sum (alien PS NEXT) of all five cables of four pairs each.

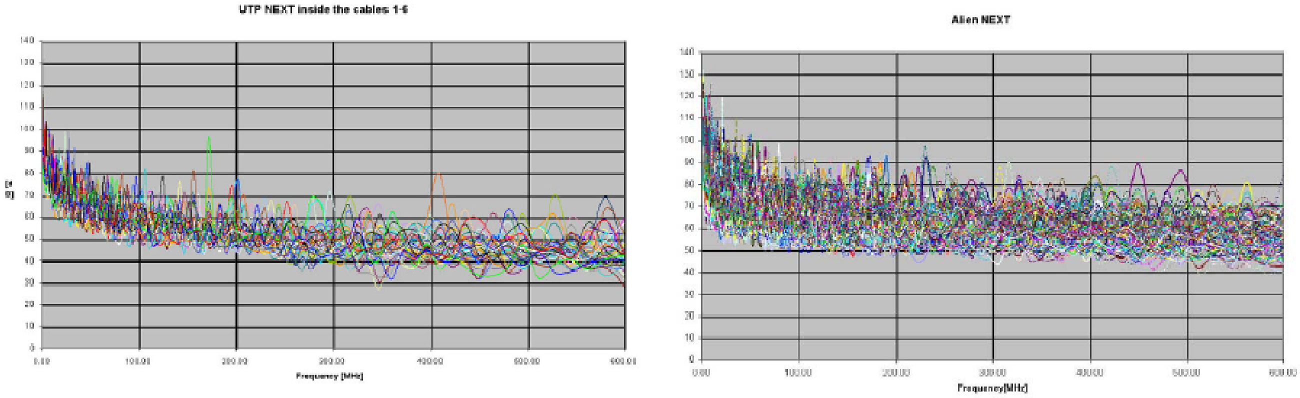

Figure 4: On the left, near-end crosstalk (NEXT) inside the U/UTP cable. On the right, alien crosstalk (alien NEXT) between the pairs of adjacent cables.

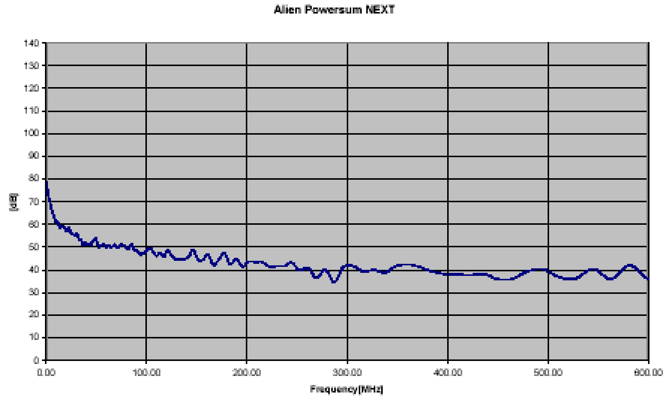

Figure 5: Alien power sum NEXT (Alien PS NEXT). Its attenuation is lower than the NEXT attenuation inside the cable.

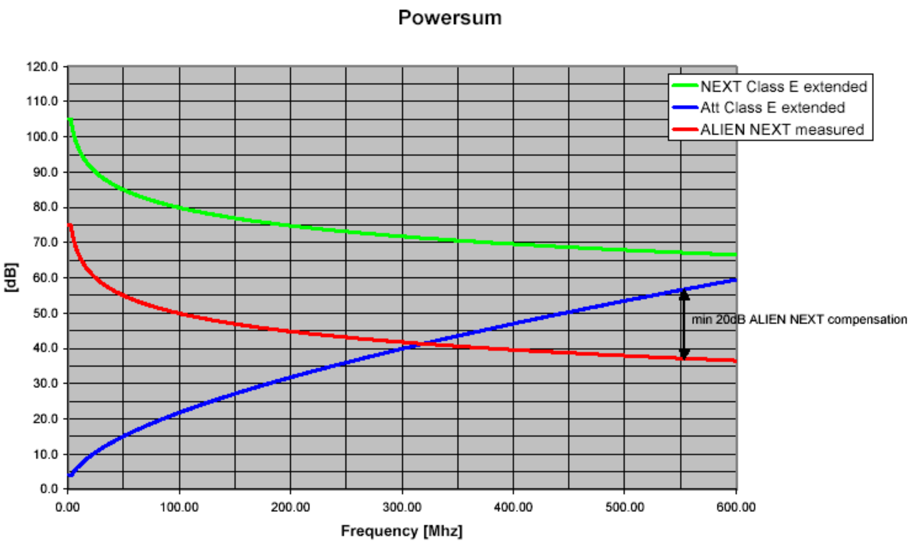

Figure 6: Showing the NEXT attenuation of a Class E cable (green), the measured and calculated attenuation of Alien PS NEXT (red) and the attenuation of the signal (blue).

Figure 6 summarises the measured and calculated Alien PS NEXT values and the attenuation values of a Cat. 6 cable. The difference between the alien NEXT of a Cat. 5 and a Cat. 6 cable is so small that we use the results for the alien PS NEXT of both cable types.

The figure makes one thing immediately clear: the ratio (Alien PS ACR) of cable attenuation to the Alien Power Sum NEXT is not big enough to allow usage of the cable up to 250 MHz (e.g. for 10 Gigabit Ethernet), because cable attenuation at 250 MHz is higher than 30 dB. Alien PS NEXT needs to be compensated with at least 15 to 20 dB. Depending on the position of the cable alien NEXT, its power sum can vary as much as 10 dB. That makes it even more difficult to find a solution. The IEEE is investigating an alien NEXT compensation of 0 to 15 dB. If there is no such improvement of alien NEXT, it will not be possible to transmit 10 Gigabit Ethernet over bundled cables.

The fact that this kind of interference is not known with other cables and that other protocols can also run on these cables, let us take a look at the following ways to tackle alien NEXT:

- Increasing the cable jacket thickness of UTP cables. The resulting cable diameter of 8 to 10 mm would impact the filling factor of a line. And it is not easy to connect a cable of 10 mm in diameter to a module.
- So-called spaghetti cable laying instead of parallel cable runs. Installation takes a lot of time, however, and the results are uncertain.
- Cables inducing a reduced alien NEXT. These cables are specifically designed with a reduced alien NEXT. We cannot present their specific details here but an alien NEXT improvement of 20 dB does not seem likely. The last way out is to use to shielded cables.

3.2 Shielded cables (SF/UTP)

The fact that central Europe works with shielded cables could be of advantage for 10 Gigabit Ethernet. The IBM cable type 1 always was and still is a shielded cable, and the new Ethernet standard 10GBase-CX4 also specifies a shielded cable to transmit the signal over 25 m.

The NEXT and alien NEXT values of an SF/UTP cable of Cat. 5e (cable with braided screen and foil shield) are the following:

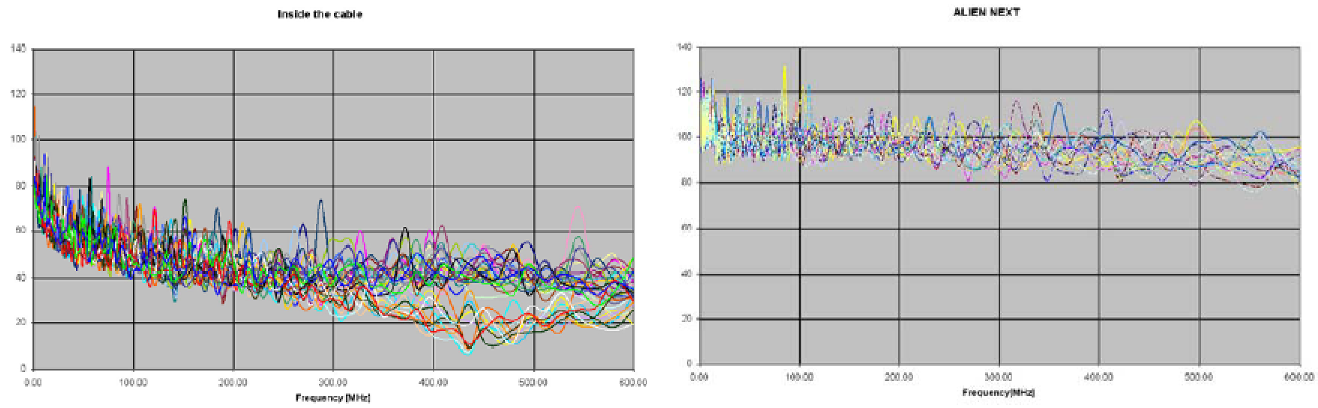

Figure 7: NEXT and Alien NEXT values of an SF/UTP cable of Cat. 5e.

Two aspects become evident:

- First, the NEXT attenuation value is very good for a regular Cat. 5e cable but it is not optimised for frequencies above 250 MHz. In this case not even a NEXT attenuation of 40 dB would lead to the required ACR value.
- Second, the cable's Alien NEXT attenuation lies on a level above 80 dB. Compared to the 35 dB of a UTP cable, the shielding obviously causes an improvement of 45 dB.

Consequently, there is no need with well shielded cables to resort to either special alien NEXT components nor to any particular way of laying the cables.

3.3 Migration to faster networks

New and faster transmission technologies place higher demands on cables. The same dynamics apply to cabling infrastructure.

The optical fiber is mainly taking over backbone cabling in enterprise cabling systems. Within the walls of new industrial estates more and more frequently copper cables of categories 6 and 7 are used for "horizontal" cabling. The whole thing is combined with existing Cat. 5 cabling, which adds to the sources of failure.

So now it is not enough to just check for possible NEXT of a new jack after installation. Gigabit Ethernet uses all four pairs of the Cat. 5 cable, potentially interfering with the data flow in adjacent cables. Also low-level hardware is increasingly likely to act as an interference factor. Some switches just cannot cope with high bandwidths. It is not only of interest to the customer to detect such sources of failures.

Initial measurement and fault analysis of the network infrastructure is mostly performed by specialised companies. Cable testers and analysers today need to be able to carry out much more complex tasks than in the days when ISO class D was predominant in almost every LAN. This means that measuring technology has become more costly, and an administrator usually does not need such specialised equipment.

Having the testing carried out by specialists gives the customer the certainty of a professional installation and valuable arguments in case of deficiencies.

4. The UTP markets' reaction to the crosstalk problem

4.1 Active compensation

It makes economic sense to use the large number of installed unshielded cables up to the highest possible transmission speed. For that purpose the UTP markets came up with active crosstalk compensation, where an electronic switch reacts to the phase relation of signal and noise (performance indicator in the complex plane). These solutions, however, are mostly of proprietary nature (closed architectures), limiting the customer's option to one sole manufacturer.

4.2 Compensation through twisting

A kind of simple "shielding" is achieved by the twisting of the pairs and cable construction. This only works to a certain extent and is only effective in an absolutely uncritical environment. And it does not compensate alien NEXT.

4.3 The obvious trend towards shielding

It is of fundamental interest to the IEEE and their members to work with the latest and best technologies and further develop them. Consequently, the experience gained from Fast and Gigabit Ethernet is now incorporated into the 10 Gigabit Ethernet standard. The latest measurements and discussions at IEEE and ISO indicate that specifications and applications of Cat. 6 cables will be extended to 600 MHz.

The first choice for the transmission of 10 Gigabit Ethernet will be an end-to-end installation of Cat. 6 cables. With other solutions part of the transmission capacity would be taken up by transmission repetitions due to errors on the line. Particularly to transmit 10 Gigabit Ethernet UTP cabling is not reliable enough anymore.

With the R&Mfreenet Cat. 6 cabling system the customer is assured of future-proof solution for the transmission of at least 10 Gigabit Ethernet.

5. Annex

5.1 Standards

EN 50174-2	Information technology - Cabling installation Part 2: Installation planning and practices inside buildings; August 2000, English version

5.2 Glossary

ACR – Attenuation Crosstalk Ratio
The ratio of attenuation to crosstalk, or the difference between NEXT and the attenuation

EMC
Electromagnetic compatibility

FEXT – Far-End Crosstalk
Crosstalk between pairs within a cable, measured at the far end

NEXT – Near-end Crosstalk
Crosstalk between pairs within a cable, measured at the near end

PS ACR – Power Sum ACR
Algebraic summation of the individual ACR effects (calculated)

PS FEXT – Power Sum FEXT
The sum of all far-end crosstalk signals (calculated)

PS NEXT – Power Sum NEXT
The sum of all near-end crosstalk effects on each pair by the other three pairs (calculated)

SF/UTP – Unshielded twisted pair with an overall single foil and braided screen

S/FTP – Shielded twisted pair with an overall braided screen

U/UTP – Unshielded twisted pair

For further information also go to www.rdm.com.