

Design criterias for high speed networks

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Introduction

If someone, some years ago were to say that copper systems will be able to transmit more than 100 Mbit/s, most of the people would have said: Impossible!! In the year 2000 the world was surprised that Class D (Category 5) systems were able to transmit 1000 Mbit/s. This was a major improvement for the active hardware manufacturers. The key tool is the DSP¹ technology, which is able to calculate some parameters and help to compensate for some weak physical layers, such as the cabling systems.

In 2006 the next milestone is under development -10 Gigabit Ethernet. 1 Gigabit is impressive even at this time and for some systems it is a big challenge- 10 Gigabit is a huge challenge to overcome.

Technical background

Bandwidth is a basic requirement for all communication transmission systems. Bandwidth is to the communication industry what “cylinder capacity” is to the automotive industry. “There is no substitute for cylinder capacity”. Bandwidth is a physical value and cannot be underestimated.

On the other hand, in practice the maximum theoretical speed (throughput) is of more interest. The maximum channel capacity is described by Shannon’s law.

$$Capacity = B * \log_2 \left(1 + \frac{S}{N} \right)$$

The formula describes in theory the maximum speed (throughput) for given values of bandwidth (B) and signal-to-noise ratio (S/N). The S/N ratio is a well known parameter in communication engineering to identify the quality of a communication system. Additionally the channel bandwidth (in Hz) influences the capacity as well.

Symbol Rate (MHz)	Shannon Capacity Channel (Gb/s) UTP system	Shannon Capacity Channel (Gb/s) Shielded system
833	9,9	24,2
833	9,9	22,5
1250	9,9	23,7

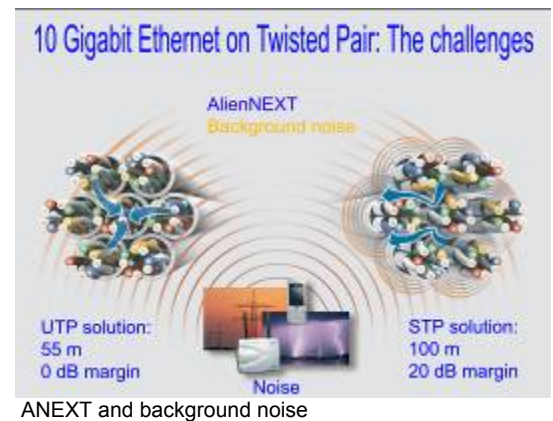
Because of the much higher bandwidth and better EMC performance, the potential capacity of a shielded system is more than 2 times that of any UTP system. In regards

to bandwidth the most important rule is

Megahertz ≠ Megabits

¹ DSP=Digital Signal Processor

The link between both megahertz and megabits is the coding mechanism. In simple terms, this is the ability of transmitting a given number of bits in one hertz. The goal is to transmit as many bits as possible within a certain bandwidth. In practice a limit is set by a given bandwidth and more significantly, background noise. Noise in modern systems is the critical factor, because of the very low signal amplitudes. In the past, the logical decision level was 5V; today the decision level is about 1V. If the noise is near or has the same amplitude, the receiver will be unable to distinguish between the signal and the noise.



With 10 Gigabit Ethernet this noise is the limiting factor, especially for UTP systems. To achieve the required transmission performance, the bandwidth has been defined up to 417 MHz (rounded up to 500 MHz). This is a big change compared to 62 MHz for 1 Gigabit Ethernet.

Alien (Exogeneous) crosstalk and background noise

Within this logical voltage range, cabling systems have to contend with two new parameters and their physical effects. First is Alien crosstalk, which means crosstalk between cables and components. The second factor is background noise which refers to any external electrical noise source in the environment. While NEXT is a noise effect within a cable, Alien crosstalk is an undesired effect between cables and components. Background noise is now critical because other equipment operates in the same frequency range as the IT system, e.g. TV, radio stations, railway systems, trams etc.

This raises the following problems:

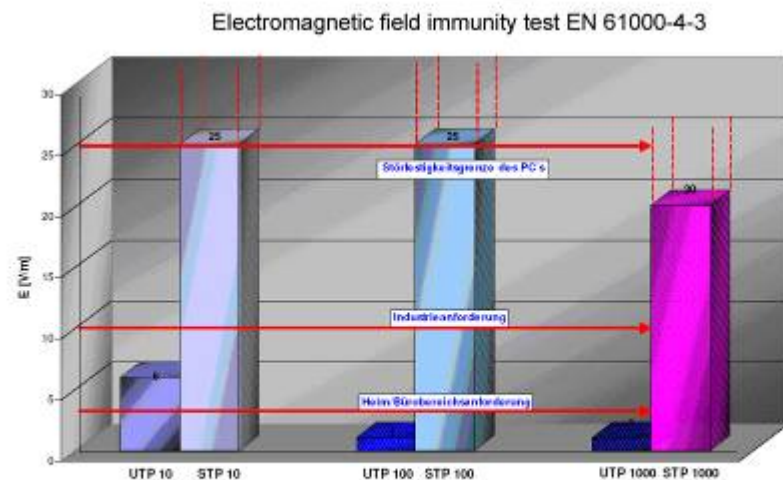
- Alien crosstalk and background noise can't be compensated by DSPs
- It can't be fully tested in the field
- It can't be mitigated just by the Twisting of the pairs
- Limits all UTP cabling systems up to 30m or less

The only way to mitigate Alien crosstalk is an electrical shield or a physical separation between cables and components. This explains the current situation on the market. All existing Class E (Category 6) UTP systems may just be able to support 10 Gigabit Ethernet up to 30 m.

Most of the Class E (Category 6) Shielded systems are expected to support 10 Gigabit up to 100m. More impressive (and this underlines the factor of bandwidth and shielded technology) are Class F systems. These systems are able to support directly 10 Gigabit Ethernet up to 100 m with a high performance margin.

The other parameter is background noise. This includes all electrical noise in the environment, like TV and broadcast stations, some radar systems, railway systems and in general all systems which work in the frequency range up to 500 MHz. This is again a major change from the past, where systems operated in the area of about 100 MHz. The industrial environment is where more critical disturbers are located. Examples are:

- Electrical machines
- Welding machines
- High power systems (cable)



Test with radiated radio frequencies/ electromagnetic field immunity



This explains the common use of fibre in this area.

In general EMC is now a subject which has to be considered seriously. EMC is divided into parts - immunity and susceptibility. In fact Alien NEXT is an EMC issue, because one system is disturbing another one.

In Europe the European directive describes the relation between electrical systems. For cabling systems and some other IT equipment the most applicable ones are:

EN 55022

EN 55024

EN 55022 (Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement) describes methods and characteristics for testing of electronic components and systems. The standard is divided into part A and B. Here the levels are the same, except that equipment for commercial use (Class A) is tested at 30 metres from the EMI source. Class B applies to domestic or residential environments. Class B equipment is used in close proximity to other Class A equipment and is tested at only 10 metres.

EN 55024 (Information technology equipment - Immunity characteristics - Limits and methods of measurement) will be more important in the very near future.

3rd party lab GHMT (an accredited test lab in Europe), made some comparisons between UTP and STP systems. As mentioned, Alien Next and background noise are an EMC issue. At this time a similar standard (EN 61000-4-3) has been used to simulate background noise.

The graphic above depicts the results of an immunity test in an electrical field, which simulates a typical environment for cabling systems.

For 10 Gigabit Ethernet, these results will be far worse because of the higher frequency range used by both applications. Tests have been made with Gigabit Ethernet and show a tremendous performance difference between UTP and STP. The test results are an indicator for radiated electric field like TV and radio stations. The UTP systems even failed for office and residential EMC requirements!



Shielded automotive connector

Shielded Technology

Shielded technology is commonly used in a wide range of industries. The main reason is the need to improve the EMC performance of electronic systems. Good examples are:

Automotive industry

- Railway systems
- Aviation industry
- Military systems
- IT industry

Some people may be surprised that the first and most famous twisted pair cabling system used in computer networks was a shielded system. It was the IBM Type 1 cable which has been on the market for more than 20 years. Even today that system provides a speed of 100 Mbit/s. In fact, many shielded IT cables are in use such as:



IBM Type 1 cable

USB cables

IEEE 1394 cables (FireWire)

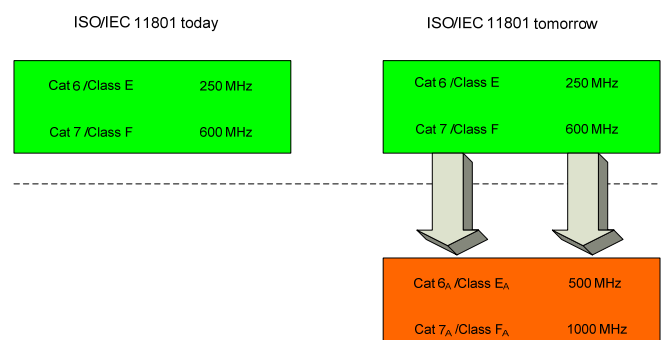
Printer cables

Serial cables

In reality shielding is a familiar technology. The reason is a well known fact. The amplitude of the logical signals in all modern digital devices and therefore cables are small and can be easily distorted if not protected. The only way is to shield the transmission system to avoid malfunction or unintended behaviour. All modern cars rely on networks of many electronic devices. All interface cables are either optical fibres or shielded types. Gone are the bad experiences of some years ago, when cars suddenly stopped under high power cables or experienced some other strange phenomena in their electrical operation.

Standards

The cabling standards recognised this issue and reworked the existing standards. Normally this wouldn't be necessary, because the existing Class F definition is

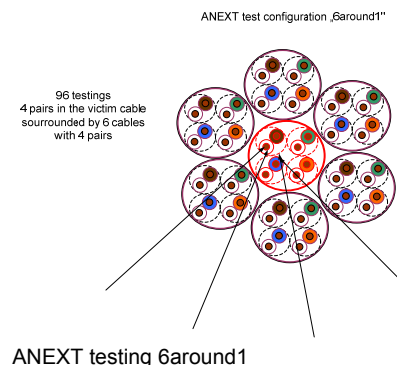


able to support 10 Gigabit Ethernet. In some countries Class F was explained as a “German problem”. In an attempt to satisfy all situations, Class E_A (Category 6_A) and Class F_A will be added to the existing Class E (Category 6) and Class F specifications. The insertion loss of the new Class E_A (Category 6_A) is the same as that for the existing Class F specifications. All other values will be extrapolated to 500 MHz.

The new Class E_A and Category 6_A will be defined up to 500 MHz. The new Class F_A and Category 7_A will be defined up to 1000 MHz.

The present market situation reflects the advantage of shielded systems. All serious suppliers guarantee systems in accordance to the new Amendment “FDPAM 1.1 to ISO/IEC 11801:2002”. They guarantee the Channel performance. All UTP suppliers just give a statement for service provision only at this point in time. There is no guarantee of future proofing.

All electrical parameters have been reworked. As mentioned before, the new parameters Alien NEXT and Alien FEXT are defined by IS 11801 but IEEE 802.3 defined additionally a minimum value for background noise of about -150 dBm.



Cabling solutions

Globally most of the installations will be implemented using UTP systems. This evolved historically and was able to support the demand in the IT world for many years. While the development of 1 Gigabit Ethernet in 2000 provided a medium challenge for UTP systems, 10 Gigabit Ethernet may be unattainable for this technology at this time. Because of the missing shield in UTP systems and therefore very weak EMC performance, all existing Class E (Category 6) systems will guarantee just 30m. Some newer systems may extend further under ideal conditions in the laboratory and maybe less stringent than the typical worst case scenario of 6-around-1.

Because of the much better EMC performance, shielded systems demonstrate their inherent advantage.

All Class E (Category 6) systems guarantee performance up to 100 m (low margin for ANEXT) and Class F systems even provide a margin of about 20 dB and more for ANEXT. The BEST solution is a system with a PiMF cable. The common characteristic of these cables is the individually shielded pair. All pairs are surrounded by braid with different optical coverage. This is today the highest performing cable on the market, the Mercedes Benz of cables. It is interesting to note the fact, that these cables have been installed in Europe since 1996.

Cable type	Bandwidth	Diameter	EMC factor	ANEXT margin
Cat.6 UTP	250 MHz	6,5mm	40 dB	No margin
Cat.6 _A UTP	500 MHz	8,4 mm	40 dB	No margin
Cat 6 FTP	250 MHz	6.5 mm	60 dB	15 dB
Cat.7 PiMF	600 MHz	7,8 mm	80 dB	25 dB
Cat. 6 _A FTP	500 MHz	6,5 mm	60 dB	15 dB
Cat. 7 _A PiMF	1000 MHz	7,8 mm	80 dB	25 dB

In regards to 10 Gigabit Ethernet it is the first time that UTP cables are thicker than STP cables. Even the UTP patch cords are now thicker than STP patch-cords. The reason is the use of solid conductors (instead of stranded conductors which are required to make patch-cords flexible) which generate the additional problems of bend radius and installation issues.

Installation

In the past, this was often an argument for UTP systems. This is now an argument favouring STP. To come close to the desired performance, some UTP suppliers are offering solid conductor horizontal cable, solid conductor patch cords and furthermore complicated installation procedures. Some of them are writing books on how to install this UTP cabling, which on careful scrutiny, would be impossible to implement on a building site. How could an installer continually control the number and size of cable bundles during installation? Who is making sure that data cables and power cables are always separated in accordance with the supplier's recommendations? In Europe it is even more interesting as the EN 50174-2 gives clear instructions in regards to the separation between power and communication cables.



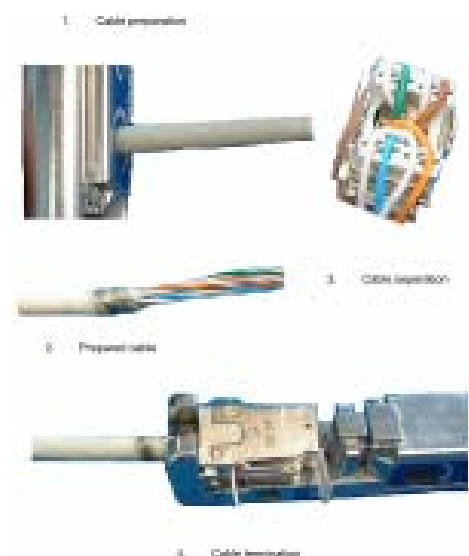
AMP Twist 6S SL Jack

Type of installation	Distance A		
	Without divider or non-metallic divider	Aluminium divider	Steel divider
Unscreened power cable and unscreened IT cable	200mm	100 mm	50 mm
Unscreened power cable and screened IT cable	50 mm	20 mm	5 mm
screened power cable and unscreened IT cable	30 mm	10 mm	2 mm
screened power cable and screened IT cable	0 mm	0 mm	0 mm

In the end, nobody is able to properly comply with this requirement.

In the case of shielded systems, the situation is much easier. Separation of the data cables is not necessary (for EMC purposes) and separation from power cables is mostly handled by pathway systems or is very small as seen in the table above. Note: for safety reasons, a rigid continuous barrier or minimum separation may be required in some countries.

In the last couple of years, the shielded product termination has been improved significantly. In the beginning it used to be a specialist's job, today many installers can install and terminate a shielded system. In terms of shielded systems installers had doubts about the correct termination of the shield.



In 2006 all these concerns and doubts have disappeared. An example of a simplified shielded connector is the AMP Twist 6-S jack with the revolutionary AMP Twist tool.

The tool has the following main functions:

- Cutting the sheath
- Cutting the foil
- Guarantee reliable terminations at any time

Both are done automatically and reliably. The next step is the jack termination. With the patent AWC technology and the fact that the jack is just based on two parts, the whole termination time is about 1 minute. This is the same as for UTP jacks. A great feature in the field is the AWC technology. As the jack is squeezed in the AWC tool, the wires will be cut and properly terminated automatically.

Earthing and bonding

If shielded systems have to be installed, the question of Earthing and Bonding needs to be addressed. There are many wrong and misleading statements in the market disseminated by some suppliers for their own reasons to support arguments about the difficulties of Earthing and Bonding. In fact Earthing and Bonding have just one main reason:

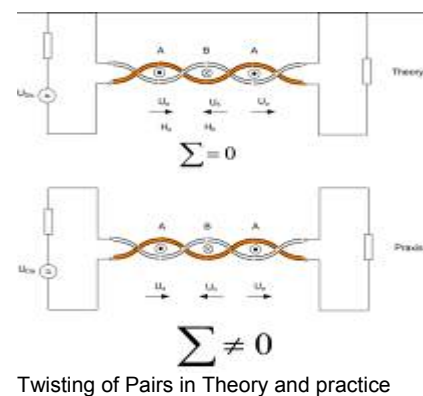
Save human lives in case of a fault in an electrical installation!

The Earthing and Equipotential Bonding has to be provided by the power cabling system installer. Since this is a safety requirement, Earthing has to be properly installed and in a good condition all the time.

As a result of more electronic and IT equipment in the building, the industry is slowly being educated to reduce the confusion about Earthing. In the past Earthing and Equipotential bonding were just for safety reasons, today there are other systems that need protection, such as:

- Lightning protection system
- IT systems
- EMC performance of the building

Therefore all these systems have to be seen as a whole. The most negative influence of modern systems is the 4 wire power distribution system. Because of the fact that in the last 20 years more and more non linear devices have been installed, more harmonics exist within a installation. Harmonics are the odd multiples (1,3 or n) of the supply frequency (50 Hz or 60Hz). Because of the 4 wire system, the neutral, N and protective earth (PE) are one conductor which is called PEN conductor. Normally, both of them are connected at the electrical sub distribution board.



As the current follows Kirchhoff's rules, it will flow on all PEN circuits within the building.

The effects are the following:

- Corroded water pipes
- Corroded metal
- Strange behaviour of alarm or facility systems
- Defective of power supplies
- Unexplained behaviour of IT systems

All these effects happen independently of the cabling system or even if an optical fibre system is installed. Statements like "Install a UTP system and you have no problem" are not serious and misleading. UTP and STP systems can be affected in the same way. In the STP case, the terminated shield may be crucial, in the UTP case, the signal ground which is connected to the PE may be affected by ground loops. In any case, UTP systems are difficult in complying with EMC requirements.

The reason is simple. No cable has a perfect and ideal twist! This only happens in theory and it has been shown in practice that all UTP systems have a very weak EMC performance. Alien Next and background noise are the best evidence of this weakness. If the Twisting were perfect, both effects wouldn't influence the transmission. The unsymmetry is based on production tolerances and installation (pulling) of the cable

In regards to Earthing and equipotential bonding, EN 50174-2 clearly states:

Earthing and bonding are applicable to both, shielded and unshielded systems

Only a 5 wire power cabling system provides the best conditions for all those systems. This is recognised by EN 50310 and 50174-2 which strictly recommends a 5 wire system, known as a TN-S system. In this case there is no current on the PE conductor and therefore no current on all conductors connected to the PE. Again, a uniform 5 wire power cabling system is helpful for the proper operation of the electrical system in the whole building even if a data cabling system is not installed.



Corroded water pipe (GHMT AG)

Conclusion

10 Gigabit Ethernet shows the limitations of UTP cabling technology. The weak performance of the UTP system was masked in the past by complex DSP technology used by IT equipment. Today, there is no simple way to eliminate the limiting factors like Alien NEXT or background noise.

With tighter EMC requirements in modern buildings and extensive deployment of electronic equipment, the only solution to EMC compliance is shielded or optical fibre cabling. Shielded cabling solutions have been used in Europe for decades and more customers are demanding it in Eastern Europe and Asia as well. The advantages at a glance include:

- Shielded technology is used in many industrial applications
- Already meets today the requirements of future standards
- Installation is the same as for UTP for 10 GBE and beyond
- Guarantee 10 Gigabit Ethernet today with a high margin
- No special installation procedure necessary
- Reliable and meaningful field testing of 10 Gigabit Ethernet possible
- 3rd party tested inclusive Alien Crosstalk
- Guaranties today the future channel requirements and not some pseudo pattern testing
- Excellent EMC performance
- 1,2,3 and more services over one cable (sheath sharing)
- CATV up to 862 MHz without any special equipment

A strong recommendation is to check and maybe rework the power distribution system. The effect is enormous and if a TN-S system is installed as it improves the overall efficiency of any system within a building. Depending on each project, the pricing of a shielded system is overall (termination and installation) not more than for a UTP system. With new products and termination features, there is no cost difference anymore between both technologies.

Field testing of 10 Gigabit Ethernet UTP systems is impossible as Alien crosstalk, which needs to be measured, cannot be completed in a meaningful and reliable manner. Alien crosstalk strongly affects these UTP cabling systems.

If shielded systems have been tested and qualified by a 3rd party laboratory, a field test of Alien Next is not necessary. All other parameters can be tested with the latest generation of field testers.

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