

# **10 Gigabit Ethernet over copper**

## **The impact for the IT infrastructure**

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## Introduction

### 10 Gigabit and the impact for IT infrastructure

EMC is a key issue for devices and systems in many engineering disciplines. Good examples are the automotive and avionic industries where equipment suppliers are aware of the EMC requirements. Therefore EMC compliance is part of any design objective of electronic systems.

Equipment malfunction is neither permitted nor desirable. It would be a disaster if an aeroplane crashed or a car operated in an uncontrolled manner as a result of non-compliance with EMC. The automotive industry experienced this problem some years ago, when cars suddenly stopped under high voltage cables or in areas with a of strong radar emissions.

Hence, all electronic equipment in new cars comply with EMC requirements. Plastic optical fibres or shielded components are used in cars to provide high EMC performance.

Modern buildings, either office or residential buildings are in a similar situation. More complex electronics have been installed the last years and EMC compliance between different electronic devices is mandatory.

In modern buildings today, many systems will be installed. These include:

- Security systems
- IT systems
- Facility systems
- Sprinkler systems
- Power systems
- Control systems (e.g. for production)

All these systems have to work together without any electrical interference. This is in Europe the basic rule of the European EMC directive.

“1. This Directive regulates the electromagnetic compatibility of equipment. It aims to ensure the functioning of the internal market by requiring equipment to comply with an adequate level of electromagnetic compatibility. This Directive applies to equipment as defined in Article 2”.

Within the last 20 years, this basic rule became applicable in modern buildings and has become a serious issue. The reason is a complex mix of different systems which use electricity. Over the last 20 years more electronic equipment has been installed. Hence EMC compliance is a major consideration.

Because of the increased bandwidth and sensitive coding mechanisms used in communication systems, EMC compliance is a critical design objective for any IT system. For 10 Gigabit Ethernet over copper, EMC compliance is for the first time a challenge and the impact for cabling systems is enormous.

Some of the existing cabling systems have a distance limitation to provide this service which is well below the full channel length of 100m.

| Bit Rate | Length   | Media                  | ANEXT Margin | EMC Factor | Background Noise margin |
|----------|----------|------------------------|--------------|------------|-------------------------|
| 10G      | 100m     | Cat 7 Shielded         | 25 dB        | 80dB       | 10dB                    |
| 10G      | 100m     | Cat 6 Shielded         | 15 dB        | 60dB       | 0-5dB                   |
| 10G      | 55 (33)m | Cat 6 UTP              | No margin    | 40dB       | No margin               |
| 10G      | 100m     | Cat 6 <sub>A</sub> UTP | 0dB          | 40dB       | No margin               |

Table 1: Channel length in accordance to IEE 802.3an

But there is a huge difference between the two copper technologies, UTP and STP. Both Category 6 STP and Category 7 STP fulfil all the electrical performance requirements of the forthcoming 10 gigabit cabling standard!

But why is this?

Two key issues influence the 10 Gigabit Ethernet transmission:

- Alien Crosstalk
- Background noise

Both parameters affect EMC compliance.

As the transmission frequency increases, cables and components in a communication channel will disturb each other. It is like NEXT within cable. The worst case is shown in Figure 1. One cable is surrounded by 6 other ones. This configuration is common practice as cables are installed in this way.

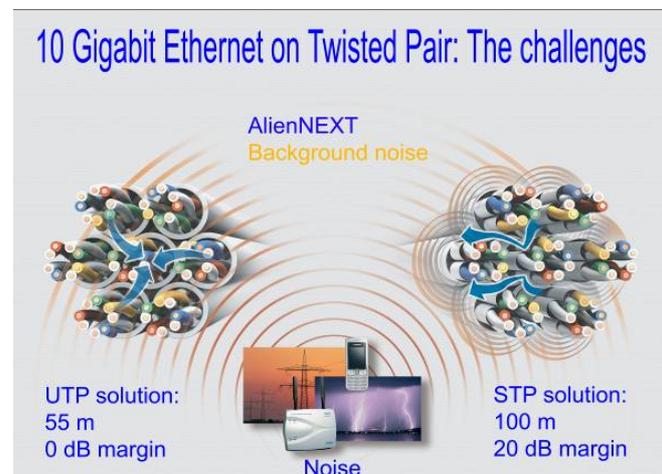


Fig. 1 Comparison UTP and STP

UTP cabling systems have just one method of protection from electrical disturbance - the twist rate of the pairs. The twist rate is unable to mitigate effectively the interference from adjacent pairs at high frequencies. This is the cause of the major problem for these UTP systems at the required frequencies for the new application.

STP systems have an electrical shield, which surrounds each pair and the cable (under the jacket).

The shields are able to suppress the electrical interference effectively. This explains the results in Table 1

The second main issue is background noise. Background noise refers to any electrical interference present in our environment.

As the operating frequency of 10 gigabit Ethernet extends to about 500 MHz, any other application operating within this frequency range is able to disturb the transmission channel.

In practice these sources will include:

- TV stations
- Radio stations
- Mobile phone stations

In general any system which transmits electromagnetic energy within the operating frequency band of 10 gigabit Ethernet will create interference to the application.

**Note: IEEE 802.3 an has defined a maximum background of -150 dBm/Hz. This means that the physical layer (cabling channel) has to provide a mitigation technique not to exceed this level.**

**Some typical values:**

Cellular phones have a typical field strength of -75 to-90 dBm/Hz

Free-to-air TV has typical field strength of -80 to-95 dBm/Hz

WiFi equipment has typical field strength of -75 to-95 dBm/Hz

All of these have influence on the background noise received in cables.

The cabling systems are able to mitigate some of this electromagnetic noise. The question now is, how much?

The indicator is coupling attenuation. This parameter describes the ability of a cabling system to suppress electromagnetic noise. Coupling attenuation is applicable to both shielded and unshielded cabling systems.

| <b>Cable</b> | <b>EMC performance</b> | <b>Twist</b> | <b>Screening</b> |
|--------------|------------------------|--------------|------------------|
| UTP          | 40 dB                  | x            | -                |
| FTP          | 60 dB                  | x            | X                |
| STP Cat.6    | 70 dB                  | -            | X                |
| STP Cat. 7   | 80 dB                  | -            | X                |

Table 1: EMC performance of cabling systems

To provide the required immunity, the calculation is as follows:

-150 dBm/Hz is the maximum level. Each system has a certain EMC factor (Coupling attenuation). For a given noise level, the difference can be calculated.

| Cable      | Noise dBm/Hz | EMC performance | Result dB | Mitigation dB | Background noise max. dB |
|------------|--------------|-----------------|-----------|---------------|--------------------------|
| UTP        | -80          | -40 dB          | -120      | 30            | 150                      |
| FTP        | -80          | -60 dB          | -140      | 10            | 150                      |
| STP Cat.6  | -80          | -70 dB          | -150 dB   | 0 -           | 150                      |
| STP Cat. 7 | -80          | -80 dB          | -160 dB   | +10           | 150                      |

Table 2: Mitigation of background noise

The calculations show that UTP and some FTP systems fall short of the required mitigation. A way to improve the situation is to use a shielded housing, such as a metallic pathway system or enclosed metallic cable duct systems. Background noise can only be mitigated by a shield! Alien cross-talk reduction can also be improved as well by physical separation. This requires additional space or increased cable size, which explains some of the disadvantages of UTP cabling systems.

STP cabling systems, especially those with two shield layers have enough coupling attenuation reserve and can be installed without any change today. This is explained by the results in Table 1. Therefore, many shielded systems can support 10 Gigabit Ethernet up to 100m, especially Category7 cabling systems, which can do this with a high margin.

**Note: The Earthing system shall be properly installed for all cabling systems.**

### Installation environment

The market reacts in different ways. As alien crosstalk is mainly a capacitive EMC issue, one solution is separation. This has to be provided within the cable and at the connecting hardware.

New 10 Gigabit UTP cables have a diameter of 9mm up to 10 mm, as is the case for patch cords. Hence the bending radius is much bigger then for Category6 UTP cables used today.

A second important issue is the installation itself. The increase of the outside diameter of the cables results in the need for more space and further more

separation from potential disturbers such as power cables. EN 50174-2 has recognized this by recommending separation between power and data cables. For installers and consultants this is a much more important requirement than in the past.

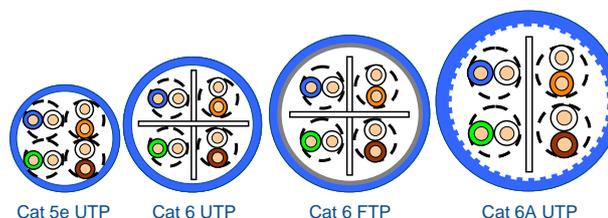


Fig 2: Comparison of cables

Another point is fire stopping. Where most of barriers are designed for 24 AWG cables, the design for new 22 AWG cables presents a new challenge. Some systems don't support these cables.

In fact to install the same number of cables as today more space is needed or less cables can be installed in the available environment.

In the case of optical fibre or shielded cables, the installation requirements are not so demanding and commonly used pathway systems and fire barriers can be used. There is no difference from the installation practices of today.

All the methods discussed above assist in the reduction of alien crosstalk. To provide Background Noise mitigation a shield is mandatory. There are two ways of providing shielding. One is a shielded pathway, the other is a shielded cabling system.

As discussed, UTP cabling systems need protection to achieve the required background noise immunity. In this case only a fully enclosed metallic pathway will be suitable. This may not always be practical.



Fig 3: Shielded jack/or EMT Plug

A shielded cabling system inherently includes a fully enclosed protection. In this case, standard plastic pathway systems can be used. Another advantage is that all components are shielded as well to satisfy a closed shielded concept. Products which use modular UTP (RJ 45) connecting hardware and a shielded cable fail to provide a fully enclosed channel and the ability to stop the ingress of interference at the UTP-shielded interface.

## Earthing and bonding

In both cases a well designed Earthing and Bonding system is mandatory. To make this clear, the main task of Earthing and Bonding is:

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

This is mandatory, irrespective of the media used. Some consultants and customers feel safe to use optical fibres or UTP systems. This is misleading as potential differences, if they exist, will flow in any case. They just use any other conductive path such as water pipes or metal pathway systems. This explains for instance the reason for corroded water pipes or electrically disturbed signal cables, even though there is no shield. If these media were installed on metallic trays and these trays carry fault currents (due to an electrical fault) flowing in the protective Earthing system, they can be potentially effected.

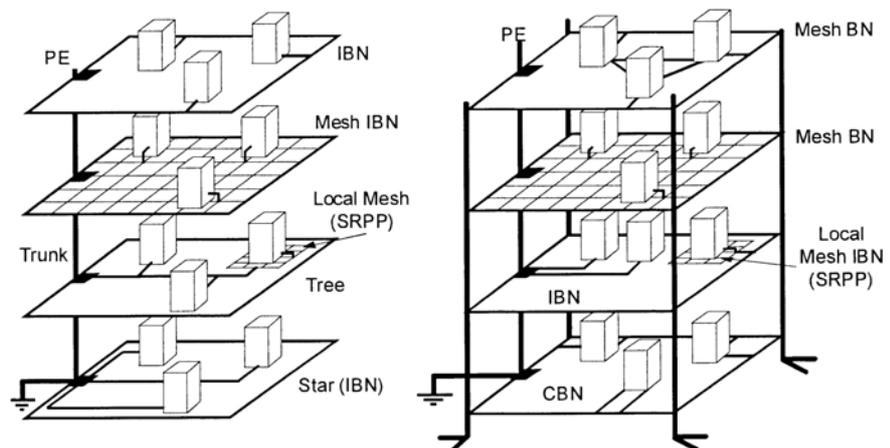


Fig 4: Meshed bonding network EN 50174-2

European standards recognised this some years ago. EN 50310 provides information about an EMC friendly Power distribution system. For new buildings, the TN-S system or a so called 5 wire system is recommended. This system is imperative to provide nearly zero current on the PE.

Another important point is to provide a Meshed Bonding design. That means that all metallic parts within a building are connected together at many points. The idea is to provide a Faraday cage for external protection and the same potential in all parts of a building.

Practical experience shows that these buildings have an excellent EMC performance without problems caused by unexpected operation of electrical or electronic systems.



Fig 5: Earthing system during building phase

For existing buildings, there are two

ways to improve the Earthing situation.

In existing installations a power audit is necessary to check out the current flow situation. This means that the first thing to do is to measure the current flowing through the PE conductor as mentioned before at several distribution points. If a current is detected, the next step is to locate the link between the PE and N. Any PEN links have to be removed and a separate PE conductor installed. This may sound expensive and complicated but is easier and cheaper than it looks like.

This has to be done in all the buildings. After all PEN links have been removed the PE conductor needs to be checked as it may additionally be connected to some metallic parts.

The second solution is to install a Equipotential bonding conductor (EBC) as recognised by EN 50310 and EN 50174-2. This requires the installation of a parallel conductor with a large crosssectional area ( $16\text{mm}^2$ ) and low impedance in the problematic channel. This is just a solution for an emergency situation as it doesn't fix the problem.

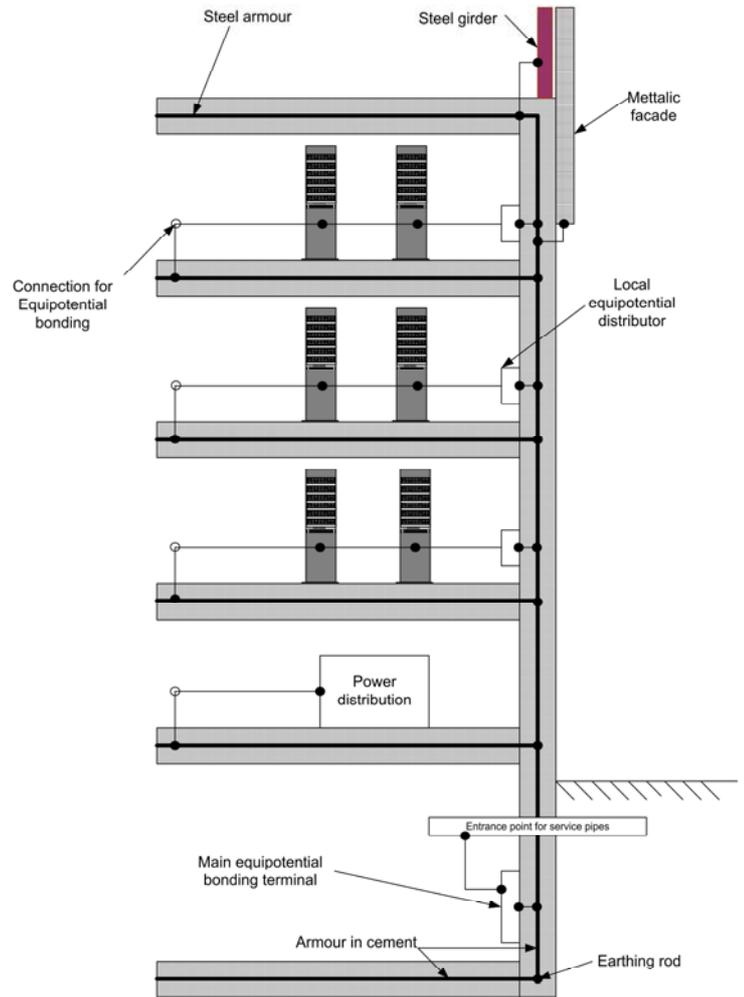


Fig 6: Meshed Equipotential bonding network

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## Conclusion:

10 Gigabit on copper is one of the biggest challenges in one hand and change on the other hand. 10 Gigabit Ethernet over copper allows a lot of opportunities for different areas and application. With Power over Ethernet it can be used for any future application.

On the other hand with more electronic devices in many buildings, EMC is now more important. Existing rules and traditional techniques have to be reconsidered and changed.

Shielded systems show impressive technical characteristics and maybe, for the first time confirm what a shield is good for.

IEEE as well ISO have recognised that most of the physical layers have to provide a much higher performance. While all Category 7 systems provide this even today, it is more than a challenge for UTP systems. Background noise can only be mitigated by a shield.

Even new Category 6<sub>A</sub> UTP systems have just a marginal or zero dB ANEXT margin and fail to provide the necessary background noise mitigation as requested by IEE.

Even metallic trays laid with large diameter UTP cables, will bring up many new issues.

As shielded technology is used in all kinds of sensitive industries, there is no reason not to use it for structured cabling systems. In this case it is not a coincidence that all high bandwidth systems (Category 6 STP or Category 7 STP) fulfil easily the new requirements.

With new termination technologies and a “built in EMC” guarantee, it is a safe and future-proof solution. Additionally the lifetime is much longer. Another feature is the cost-effective sheath sharing. This allows multiple services over one cable.

A worldwide installed base of STP cabling systems with more than 20 years of operation, underlines this impressive ability. Even the most famous cabling system from IBM was shielded.

The worldwide trend in all countries shows a slow but significant growth of shielded systems for new installations.

In some European countries the whole market is 10 Gigabit Ethernet ready as they have been installing shielded Category 6 and Category 7 shielded solutions within the last 4 years.

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