

# Basics of EMI and EMC



**Earthing, earthing and equipotential bonding**

**Practical information for cabling systems**

## Introduction

Earthing, equipotential bonding and earthing are a major part of all new buildings and facilities. These have a great influence on the EMC of the system and the mitigation of EMI wherever applicable.

As the number of electronic devices increases, every building owner is required to abide by all applicable EMC regulations and laws. In regards to telecommunications equipment and cabling systems, there is often an uncertainty about what to do and to find the correct way for a proper installation.

This guide is intended to give some basic explanation of these issues as they relate to cabling systems. In general EMC is a vast subject and there are various books and literature available.

This guide briefly highlights the parts covering earthing, equipotential bonding and electrical power distribution. But all parts are important in regards to EMC and are valid for shielded and unshielded cabling systems.

There is often a misunderstanding between the requirements for earthing and equipotential bonding for both shielded and unshielded systems.

This misunderstanding is often the problem in practise. It is often assumed that this is the responsibility of the electrical installer or the architect and not the responsibility of the data cabling installer. But in fact it is a responsibility shared by all parties. In regards to EMC it is the responsibility of the consultant and or architect to ensure the installed systems are compliant.

EMC is more and more important and therefore its relevance is crucial to understand. Therefore European standards continue to emphasis this importance.

With 10 Gigabit Ethernet most of the existing rules have to be reconsidered. The future is shielded and EMC is the key issue.

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## Earthing and equipotential bonding

EMI and EMC are heavily dependant on sounding earthing and equipotential bonding principles. The main functions of earthing are Safety and EMI mitigation. The primary function of earthing is to:

### **Save the life of humans and animals in case of any electrical fault.**

This can be achieved by installing a low impedance connection to the protective conductor. At the other end of this conductor there is a connection to an electrode in the ground. The main connection to ground is called the protective earth (PE) and is recognised by the typical green/yellow insulation colour.

A second function is to have a defined path for surges in the power system, lightning and emissions from outside sources like radar station, broadcast stations etc. It is fundamental to understand, that only a proper earthing system can prevent harm from the issues referred to above. The intention of European standard EN 50310 is to provide the optimum earthing and equipotential bonding conditions for buildings. Even though the focus of this discussion is for buildings with communication technology installation, the standard shall be applied for at least all new buildings and if possible for existing buildings.

All office and company buildings today have a communication technology installation, and even more so residential buildings. Many problems can result from an improper earthing system. In practice screening, earthing and equipotential bonding will be combined. To make it clear:

**Earthing and equipotential bonding are applicable for any IT cabling system! Furthermore, these systems apply to both unscreened and screened cabling systems!**

**An earthing and equipotential bonding implementation is necessary for EMC and safety reasons!**

**The latest edition of EN 50310 and EN 50174-2 state clear that these efforts are applicable to any IT system!**

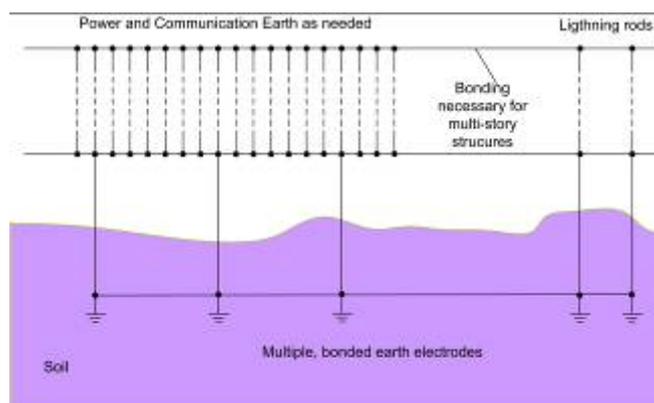


Fig 1: Bonding of earthing systems

**Safety:** This is valid for all components if they are able to carry dangerous voltages and currents in case of an electrical fault. As a rule, all metal enclosures are connected as part of an equipotential bonding network to all other parts like metallic conduits, metal beams, steel girders etc. The aim of an equipotential bonding network is to improve the EMC performance.



Fig 2: Termination earthing system to steel armour for Mesehd bonding concept (Obo Bettermann)

**Functional earthing:** A functional earth connection serves a purpose other than providing protection against electrical shock. In contrast to a protective earth connection, a functional earth connection may carry a current during the normal operation of a device. Functional earth connections may be required by devices such as surge suppression and electromagnetic-compatibility filters, some types of antennas and various measurement instruments. Generally the protective earth is also used as a functional earth though this requires care in some situations.

**Note: A good functional earthing system is necessary for safety reasons! A cabling system requires a well designed earthing system to perform properly.**

**This is applicable for both unshielded and shielded systems! Even when a fibre optic cabling system is installed a fully functional earthing system is mandatory (earthing of metal enclosures)!**

**Any other interpretation is against electrical safety rules in most countries!**

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## Equipotential bonding

This refers to the need to connect all metalwork or conducting parts within an electrical panel or on a machine to the protective earth. Equipotential bonding has a safety and an EMC aspect. This is also the case in a house or commercial building, where ideally all metallic components are connected to the equipotential bonding network. These include:

- All metal conduits within the building, e.g. water and gas conduits
- All metal parts of the building or the construction
  - steel girder
  - Metal Facade
  - Steel in cement
- Metal cabinets for data or power distribution
- Raised floors with metal uprights
- Metal cable conduit



Fig 3:Equipotential bonding connector during building phase (Obo Bettermann)

All connections will terminate at the main equipotential bonding terminal.

**Note:**

In regards to IT systems all relevant disciplines shall be terminated at the terminal bar.

- PE Power system
- PE Telecom system
- Upright Pins of raised floors
- Metallic cable trays
- All parts of a cabinet

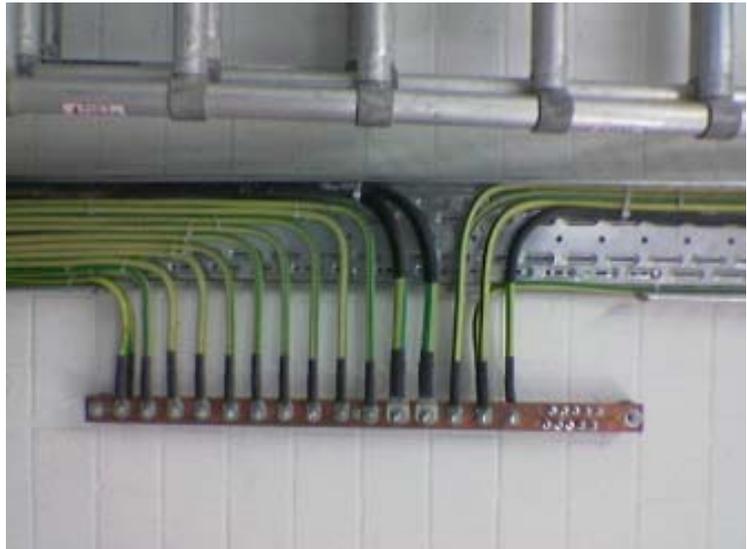


Fig 5: Main bonding terminal

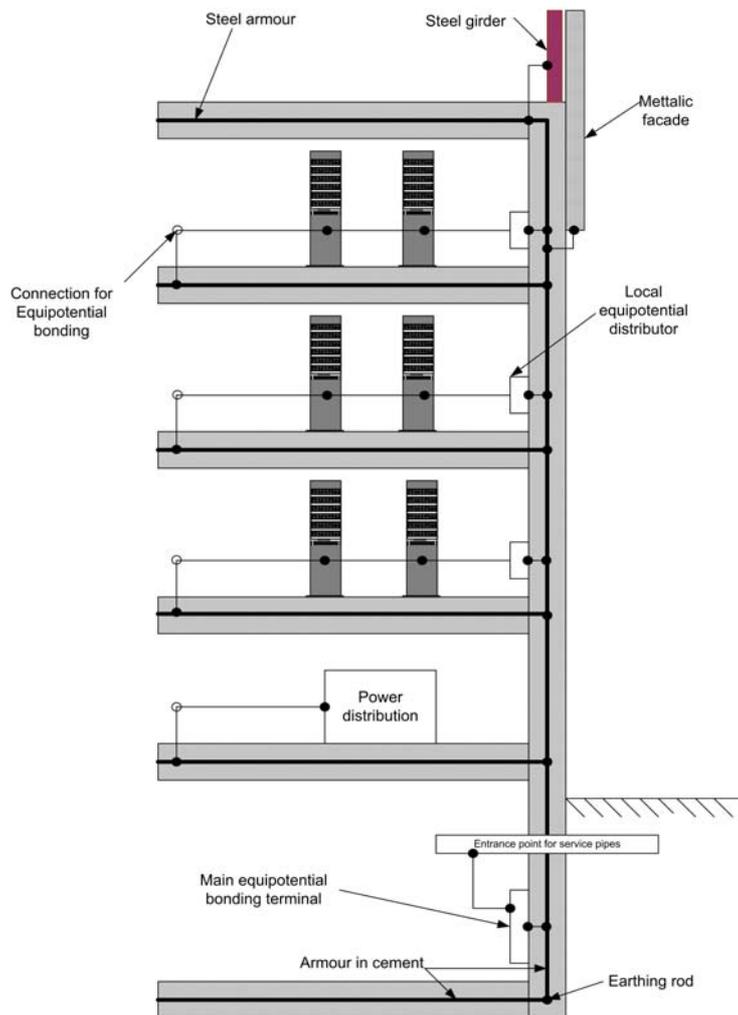


Fig 4: Meshed Equipotential bonding network EN 50174-2

## Facts:

- **Earthing and equipotential bonding is a must for safety and EMC reasons**
- **A TN-S system is mandatory for all buildings with IT!**
- TN-S shall be installed and is recognised by most electrical standards
- The equipotential system (equipotential bonding) has to be part of the EMC design
- All metal parts have to be included
- A meshed equipotential bonding system is better than a star equipotential bonding system

## Power distribution System

For residential buildings and small buildings serviced directly by the power authority, 4-conductor power cables will enter the buildings.

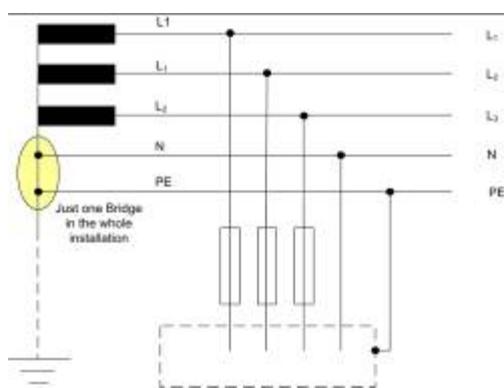


Fig 6: TN-S system

In the main switchboard, there is a connection from the PEN conductor to the equipotential terminal bar. All metallic parts and systems which have to be part of the equipotential bonding system will be connected to this terminal bar.

Note: The link between the PE conductor and the PEN conductor shall be close to the source (transformer or point of supply) and **the only one** in the whole installation. Beyond this point all cables shall have either 3 or 5 conductors. EN 50310 prohibits the use of a PEN connection, in other words:

### TN-S installation only!!!

This guarantees that the PE conductor carries no current (unless there is an electrical fault) and the return current is only flowing through the N conductor. Therefore the total current at the main equipotential bonding bar is 0.



Fig 7: TN-S: Bridge between 3 transformers

**Note: TN-S is preferred in EN 50310 and meanwhile the default system in accordance to most local electrical wiring regulations!**

In some countries (e.g. Australia and New Zealand, the TN-C-S earthing system is used.

## Installation of IT cabling systems

As any building today contains IT equipment, electrical and other standards reflect this in their content.

This means that all rules and recommendations in regards to EMC and safety apply to any kind of IT system. From a practical point of view, the most common equipment includes racks and metal panels, metal path ways, raised floors with metal frames.

In regards to safety and EMC all equipment needs a defined path to EB (equipotential bonding).

In the cabinet all patch panels must have very good electrical connection (zero dc resistance) to the cabinet. This cabinet shall be connected to the equipotential bonding system. All bonded panels have to be terminated to the terminal bar (Fig 85). The insulation colour of the earthing conductor shall be green/yellow as used for the PE.

**Note: Bonding of panels is applicable for both shielded and unshielded systems!**

All parts in the rack have to be connected to the earth bar. That includes cabinet doors and metallic parts which are maybe electrically isolated

The outlet side is terminated with the shielded patch cord on the NIC. The metal housing of the RJ-45 jacks on the NIC provides the connection to earth in the device.

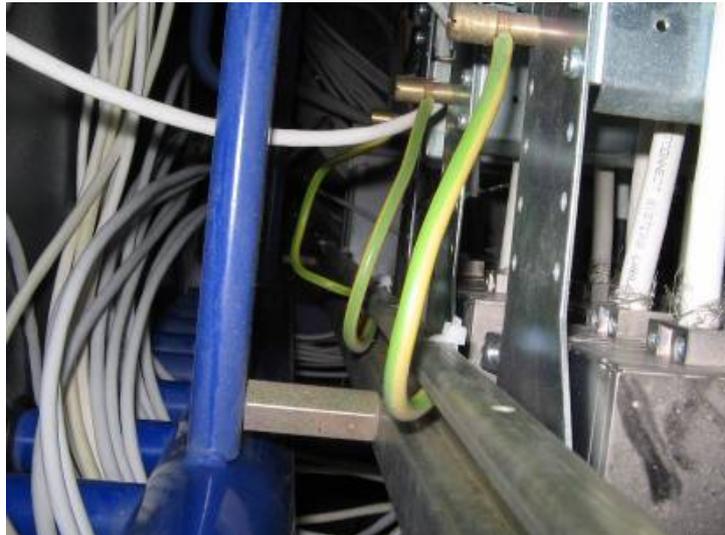


Fig 8: Bonded panels in a cabinet

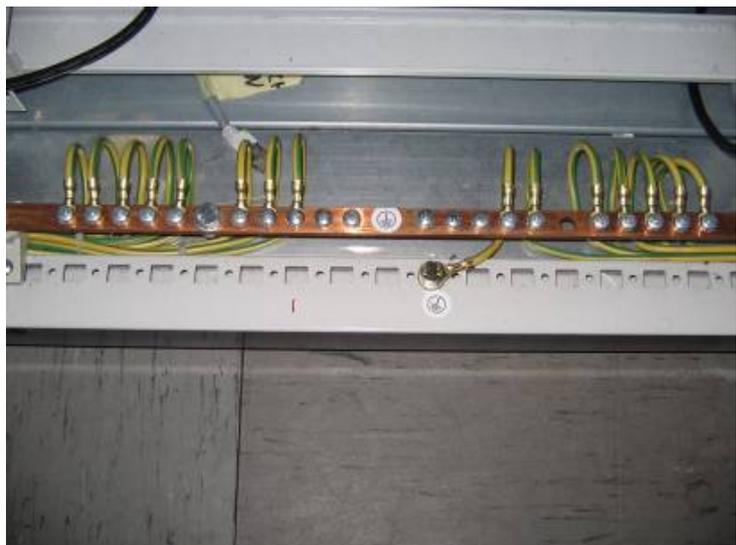


Fig 9: Bonded panels to the terminal bar

## Shielded systems



Fig 10: Screen transfer panel and mounted shielded jack

New products provide automatically excellent earth connection to the panel. The “closed” principle is done by design. Once the cable is terminated the jack has just to be clicked into the panel, and that’s all.

**Old technology products have UTP jacks where the installer has to “build” the shield around it.**

**By installing the shield to each jack the installer automatically fulfils the requirement of EN 50310:**

**“Cable screens shall be bonded directly to racks, cabinets or where required to the dedicated SRPP at least at each end. Circumferential (i. e. 360 °) connections are most effective.”**

**Note: The only additional effort is the shield termination to the jack. This takes about 10 seconds for the integrated shielded technology designed products. The**



Fig 11 : Screen transfer Plug/Jack

**connection to the EB system of the shielded link is done by the panel. As stated earlier, earthing and equipotential bonding have to be done for all IT systems!**

There are sometimes misunderstandings in regards to screening, earthing, one side, two sides. In fact it is very easy.

Example: We have shielded jacks, as shielded cable and shielded patch cords

The total channel shall contain shielded products only. The screen shall be terminated on both sides. This is done by terminating the screen at both sides with the connecting hardware, in our example the jacks. In case of modern die cast jacks this is done automatically. Old fashion products need an extra connection which causes difficulties.

This complete channel shall be terminated to the equipotential bonding system. This is done by the panel, as this has to be terminated to the equipotential system (SRPP).

In the case of die cast jacks (integrated shielded technology) the cable link includes a connection at the fixing points in the panel, (see picture above).

Outlets do not have to be bonded. To improve the overall EMC performance the link is connected at the device side to the PE of the power system. All Switches, NIC's and Notebooks have shielded RJ 45 ports. Those ports are connected to the PE of the power side in the device.

In this configuration the shielded system provides additional EMC performance and support the idea of a meshed concept.

### **Cable routing**

With higher data rates and more electronic devices installed, cabling installation and routing have to be done in the proper way. Much of this useful information can be found in EN 50174-1/-2.

The main issue for IT systems is the separation from power cables, as they are mostly commonly installed in one cable tray system.

Today EN 50174-2 contains the following table:

Type of installation	Distance A		
	Without divider or non-metallic divider	Aluminium divider	Steel divider
Unscreened power cable and unscreened IT cable	<b>200mm</b>	100 mm	50 mm
Unscreened power cable and screened IT cable	<b>50 mm</b>	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

As shown above, metal dividers or cable screens help to reduce the separation. This is the best way, otherwise large separations would be required. There is no other way. Best example is a screened power and IT cable, where therequired separation distance is 0 mm!

**Note: If the cable conduit is metallic, it has to be bonded properly!**

## The fairy tales

Although the physical environment is clear, some parties propagate misleading statements and confusion. The following pages explain basic of physics and follow existing standards and EMC rules.

### Fairy tale No. 1

**If a shielded system is used, the screen is propagating EMI, is dangerous and an earth loop is creating problems.**

As mentioned we have an equipotential bonding network. This means electrically everywhere on the bonded network is at the same potential = 0V!

In practice the following components are at the same potential

- PE of electrical system
- Metallic parts of the building
- Metallic service conduits (e.g. water conduits)
- All metal-enclosed IT devices
  - Cabinet
  - Panels
  - Screen of IT cabling system

### Conclusion

- No loop
- No antenna effect

There can't be any loop as everything is at zero 0 potential. This is again the main intention of equipotential bonding.

To propagate EMI any kind, electrical energy must be present. This can only be done, if a conductor is carrying some kind of electrical energy. The screen of a cabling system is terminated to the equipotential bonding network, which, under normal conditions carries no current and has 0V potential to earth.

Therefore the screen is unable to propagate any EMI.

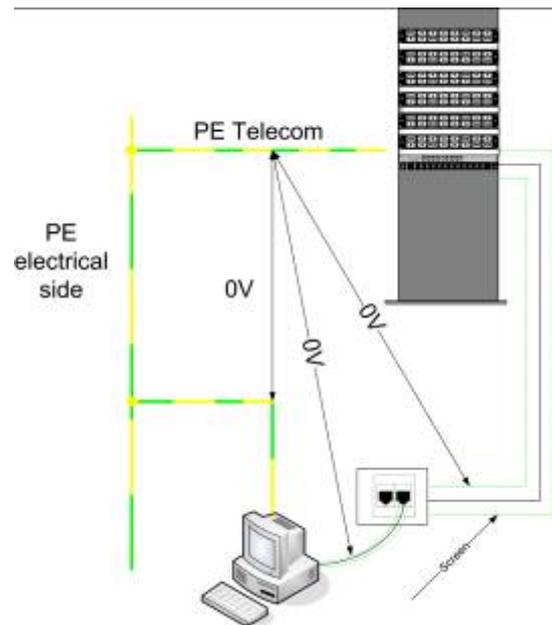


Fig 12: Equipotential bonding

## Fairy tale No. 2

### The Symmetry (Twist) is the only way to provide good EMC conditions.

To explain this we have to come back to the basics. Modern data transmission is called symmetrical data transmission. All copper systems (UTP and STP) have the same design. Each system contains 4 pairs which are twisted.

The degree of symmetry of a pair defines the ability of a cabling system to provide a level of EMC. This is called **coupling attenuation**.

**Note: Coupling attenuation is applicable to both, shielded and unshielded systems and is part of the global cabling standard IS 11801 /EN 50173**

**This parameter is an indicator the quality of a cabling system is to mitigate any EMI.**

There are two ways to fulfil this.

- Twisting
- Shielding

In practice each cable is a victim of electromagnetic waves and disturbing signals from other cables, mostly power cables.

Now the facts:

	UTP (Symmetry, Balanced Pair)	STP (Symmetry, Balanced Pair, Screen)
EMC Mitigation mechanism	<b>Twist Rate</b>	<b>Twist Rate + EM Screen</b>
Coupling attenuation (EMC factor)	<b>40 dB</b>	<b>90 dB</b>
Separation from power cables (EN50174-2)	<b>50mm up to 200 mm</b>	<b>No separation up to 35m, 5mm up to 50mm</b>
ANEXT margins (ISO IEC 11801 Amend.)	<b>0 dB</b>	<b>25 dB</b>

The Pair Twist is just one component of the EMI mitigation method. The complete solution to EMI mitigation is Pair **Twist and a shield**. This results in 100% more coupling attenuation and explains why all systems with PimF cable have no issues with ANEXT. The Twist Rate of a UTP cable is higher than that of an FTP or PimF cable. This results in higher TCL. But this is just 50% of the total. Shielded cables have a shield, therefore the Twist Rate is different and both have to be taken into consideration.

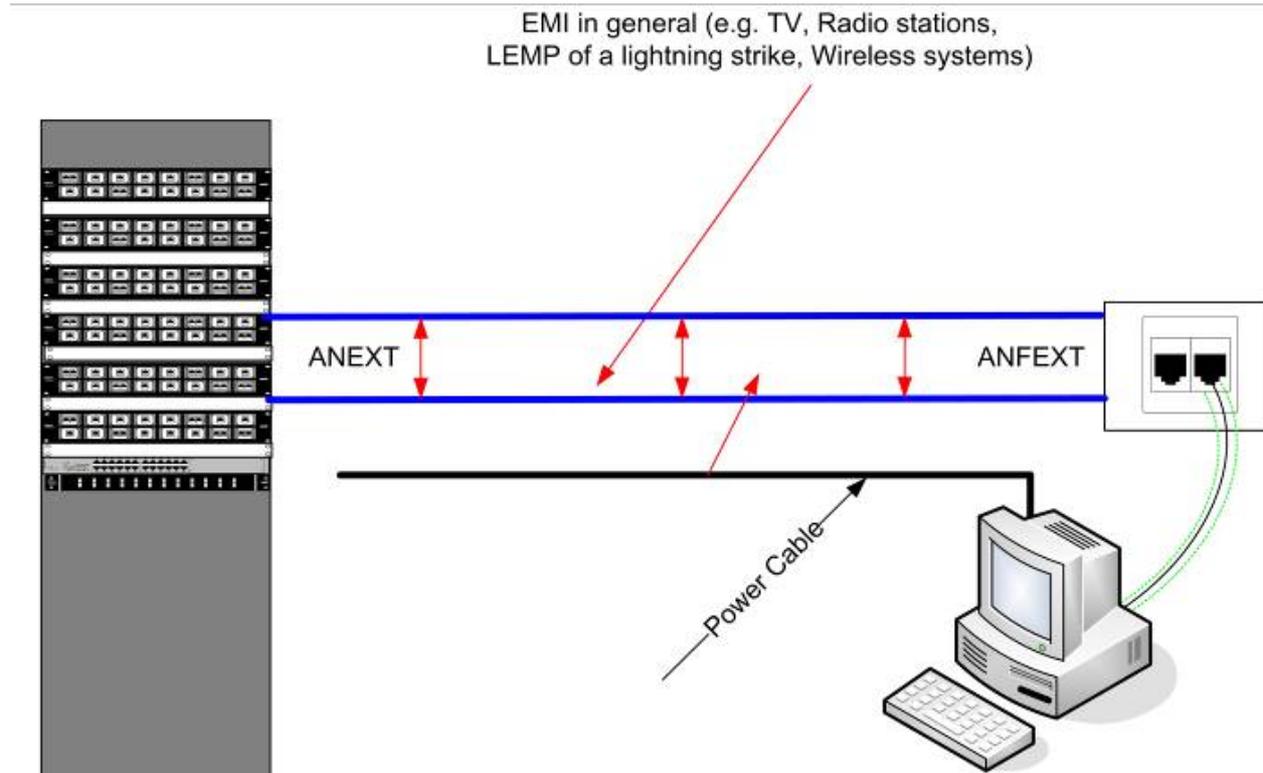


Fig 13: The real EMC situation

**Conclusion: Only coupling attenuation is an indicator of the EMC ability of cabling systems and UTP cabling has the weaker characteristics. The current 10G discussion shows this dramatically.**

### Fairy tale No. 3

[A 50 Hz field can't be mitigated by a shield, the shield makes no sense](#)

In general shielding is the common way to mitigate EMI. This is the common practice in any industry. The kind of shield depends on the application and transmitting frequency (e.g. 10G =417 MHz). With higher frequencies the shield thickness can be low, while low frequencies need a thicker shield. This based on the skin effect.

The shield of modern PiMF cables has been designed to mitigate frequencies in the operating spectrum (MHz). The 50 Hz field is definitely out of this scope.

Quick comparison:

	UTP	STP
Bandwidth	500 MHz	1400 MHz
Maximum Shannon Capacity	18 Gigabit/s	28 Gigabit/s
Sheath sharing with CATV (862 MHz)	No	Yes
ANEXT margins	<b>0 dB</b>	25 dB
Background Noise (IEE 802.3 an)	Need additional protection	Fulfilled by design
Complete field testing	<b>No</b> (No reliable ANEXT and AEFEXT possible)	<b>Yes</b> , no ANEXT and AEFEXT testing necessary
Coupling attenuation (EMC factor)	<b>40 dB</b>	<b>90 dB</b>
Connection to Earthing and EB	<b>Yes</b>	<b>Yes</b>
Margins for future applications	<b>No</b>	<b>Yes</b>
Lightning protection (LEMP)	<b>Low</b>	<b>High</b>
Patch Cords	<b>9mm (solid conductor)</b>	<b>6mm (stranded conductors)</b>
Cable diameter	<b>9 mm</b>	<b>7,9 mm</b>
Separation from power cables (EN50174-“2)	<b>50mm up to 200 mm</b>	<b>No separation up to 35m, 5mm up to 50mm</b>
Installation time	<b>About 1-2 minutes</b>	<b>About 1-2 minutes</b>
Accredited ISO3rd party certifications with worst case ANEXT conditions	<b>No</b>	<b>Yes</b>

## Conclusion

The efforts and cost for a well designed earthing and bonding system is independent of the kind of media that is installed. This is recognised by EN 50310 and EN 50174-2.

The illusion to save money or avoid trouble by installation of fibre optic cables or UTP cables is an old fairy tale. All standards state this clearly in their publications. Fibre connections shall be installed **between** buildings. This is applicable for large installations and plants.

With respect to 10 Gigabit Ethernet, the combination of a shielded system and a well designed EB system provides maximum EMC performance of the building. The ANEXT and background noise issues emphasise this.

Consultants in particular should take care of these issues during the planning phase.

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**Facts:**

- **Earthing and equipotential bonding are a must for safety and EMC reasons**
- **They are applicable without exception for any IT system**
- **The cable screen has to be terminated on both sides with the connecting hardware**
- **The whole channel has to be bonded at least once to the EB system (Panel)**
- **Outlets do not have to be bonded**
- **The total effort for earthing and bonding is the same for all cabling systems**

With 10 Gigabit over copper cabling, shielded systems show the advantage of a shield by completely meeting the **100 m channel ANEXT performance requirement by a margin of about 20 dB.**

The overall future parameter will be Coupling Attenuation for cabling systems and their EMC performance. While STP systems with PimF cables have about 90dB of coupling attenuation, UTP systems have only 45 dB. In any case, for both technologies a well designed Earthing and Bonding system is mandatory. There is no reason anymore not to join the shielded world.

**We extend an invitation to you to join**

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