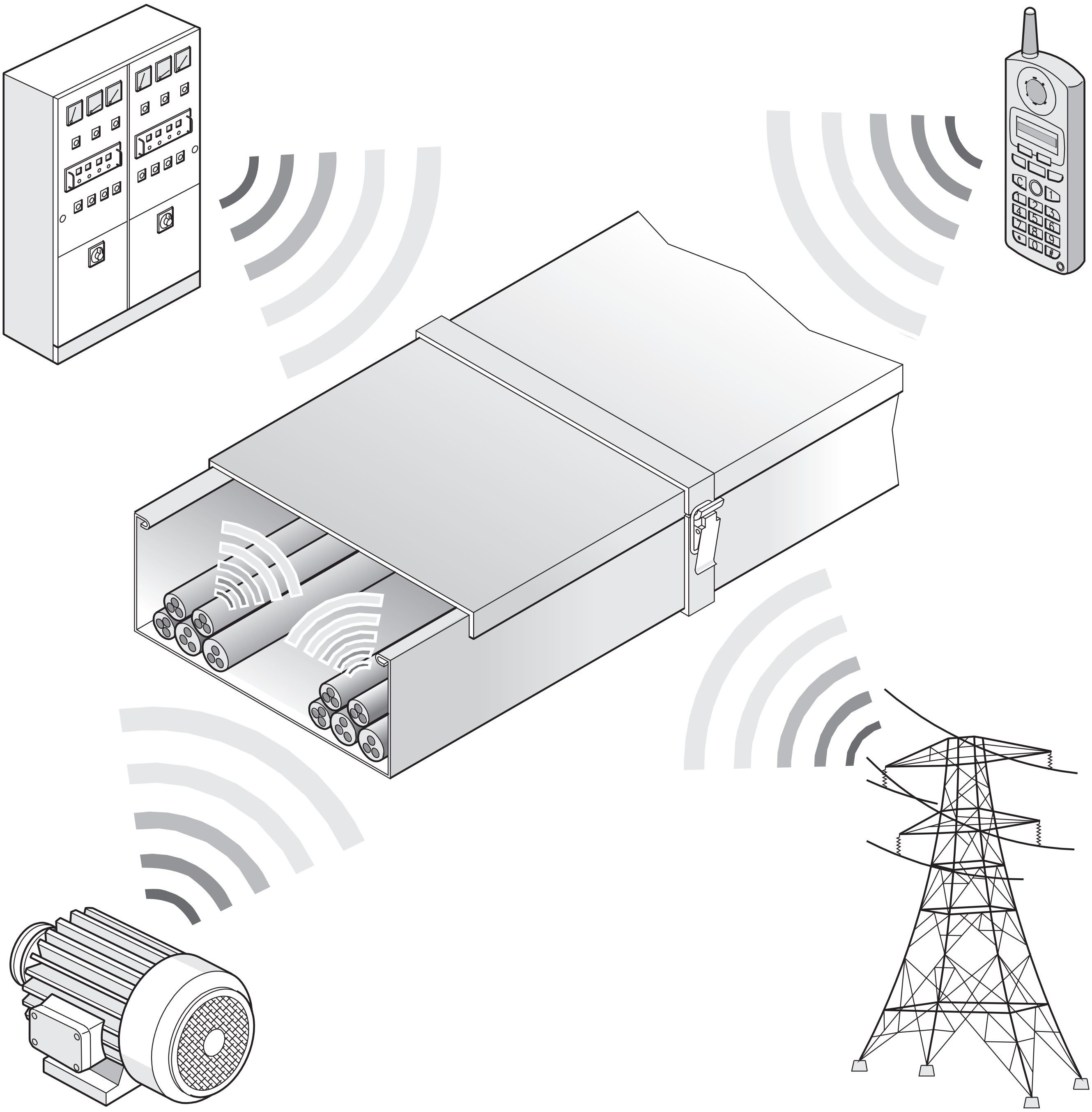
EMC and cable ducts

GoudaHolland

EMC



EMC

Contents

Introduction

Gouda Holland

An increasing number of customers continually inquires about the influences of cable ducts on ElectroMagnetic Compatibility (EMC).

Various investigations in the field of EMC have proved, that the design and construction of cable ducts play a significant role in the achievement of the EMC of installations.

As a specialist in the field of industrial cable ducts, Gouda Holland decided to inform their customers about the newest trends in the field of EMC.

Therefore Gouda Holland has asked Mr. D.S.J.Schuuring M.Sc. of PEMCO Physical and EMC Consultancy at Delden to research the effects of the several types of cable ducts on the EMC of installations.

The results of this research are discussed in this brochure which gives practical advice for the application of cable ducts in the electromagnetic environment.

EMC

ElectroMagnetic Compatibility (EMC) is a field of electrics and electronics that is gaining attention. This applies not only to the equipment level, but also to the project level, for instance for systems and installations.
This is due to several reasons. The electronic equipment applied, such as PC's (Personal Computers) and PLC's (Programmable Logic Controllers), has an increasing susceptibility to disturbances. On the other hand there is an increasing use of sources generating disturbances, such as e.g. frequency convertors for motors.
Also the equipment is packed more densely than before. This results in a closer location of disturbance sources and susceptible equipment.

The EM-environment outside the installation can also create disturbances for example through the increasing use of wireless communication (e.g. portable telephones).

Therefore it is necessary to apply EMC-measures to protect installations against unwanted effects caused by electromagnetic disturbances.
These EMC-measures are also necessary to make the installation meet the European Union (EU) regulations, introduced from 1st January 1996, and laid down in the EMC-directive.

It is because of these EMC-requirements that the construction and installation industry makes extra costs to ensure that EMC-measures are implemented. This means applying the EMC-requirements to the electrical parts of the installation. But also the mechanical parts can play an important role in improving the earthing system. This can be achieved by connecting metal mechanical parts, such as cable ducts which run through large parts of an installation. Given their importance, it is vital that the cable ducts meet the EMC-regulations.

Basics of EMC

Basic knowledge

Introduction
Before explaining the EMC-measures to be applied to cable ducts, a brief outline of some of the definitions and theories in the field of EMC will be given.

Basic knowledge of EMC is necessary in order to understand the effects of its measures. Designers and constructors often acquire their knowledge through practical experience of solving interference problems. But when one has a theoretical understanding of the EMC-measures, they can be implemented much more effectively.

Definitions
Definitions used, are those which are given in the standards of the IEC (International Electro-technical Commission).
These definitions apply to 'devices, equipment and systems', but can also be used for installations.

Installations
When systems are mentioned in the definitions or the text installations will be included.

This brochure deals mainly with installations of industrial projects.

EMC
The definition of ElectroMagnetic Compatibility (EMC) is:

'The ability of a device, equipment or system to function satisfactorily in its ElectroMagnetic (EM) environment without introducing intolerable electromagnetic disturbances to anything in that environment'.

From this definition follows:
- equipment within a system shall not disturb each other. This is called 'Intra system EMC'.
- the system shall not be disturbed by equipment or systems in the EM-environment
- the system shall not disturb equipment or systems in the EM-environment.

The last two statements are called 'Inter System EMC'.

Interference
The definition of ElectroMagnetic Interference (EMI) is:

'Degradation of performance of an equipment, a transmission channel or a system caused by an electromagnetic disturbance'.

Instead of 'electromagnetic interference' often simple 'interference' is used.

Difference between EMI and EMC
EMI is the interference of one equipment or system. EMC is the compatibility between equipment or systems.

Disturbances
The definition of electromagnetic disturbance is: 'Any electromagnetic phenomenon which may decrease the performance of a device, equipment or system'.

Disturbances may exist of:
- conducted disturbing signals
- radiated disturbing signals or radiation

EM-environment
The definition of ElectroMagnetic (EM) environment is: 'The totality of electromagnetic phenomena existing at the given location'.

The electromagnetic phenomena at the location of the installation may exist of:
- conducted disturbances of other installations via power cables or interconnection cables
- radiated disturbances, e.g. of transmitters for communication, radar transmitters or trans-mitters of industrial processes for heating, gluing, drying etc.
- lightning. Protection against the effects of lightning will only be treated briefly.

The installation itself may also generate disturban-ces in the EM-environment, which may cause interference in other parts of the installation.

Emission, susceptibility and immunity

Emission
The definition of electromagnetic emission is:

'The phenomenon by which electromagnetic energy emanates from a source'.
The 'source' is also called 'emittor'.

Susceptibility
The definition of electromagnetic susceptibility is:

'The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance'.
The device which is interfered is called 'susceptor' or 'victim'.

Immunity
The definition of immunity to a disturbance is:

'The ability of a device, equipment or system to perform without degradation in the presence of an

Basics of EMC

Basic knowledge

electromagnetic disturbance'.
Immunity is the opposite of susceptibility.
The disturbances from a source and to a victim are shown in *fig. 1*.

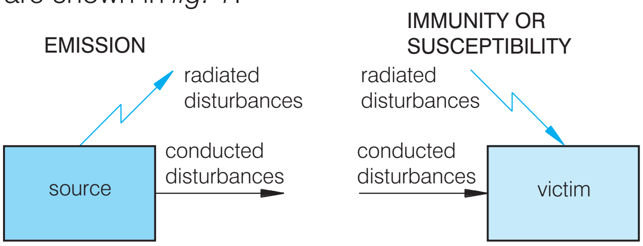


Figure 1 Emission, susceptibility and immunity

Basic form of an interference problem

In each interference problem three elements are present (three-element-model; *fig. 2*):

- source : device emanating disturbances
- victim : device which is interfered
- coupling channel : the way by which the disturbance is transported

Figure 2 The three elements of an interference problem

Coupling channels

Coupling channels for the disturbances from the source to the victim are (*fig. 3*):

- conduction via:
  - power cables
  - interconnection cables
  - earthing system
- coupling:
  - via common impedancies
  - capacitive coupling
  - inductive coupling
- radiation

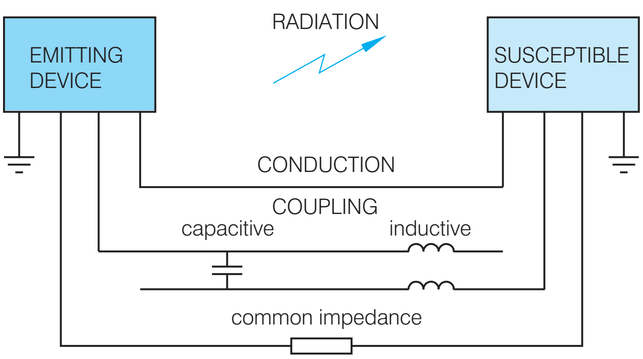


Figure 3 Coupling channels for disturbances

Frequency ranges

The frequency range of electromagnetic disturbances is large. It starts at the supply frequency (50 Hz) and ranges up to tens of gigahertz. In the EMC-standards for measurements the frequency range is divided in a number of subranges. The frequency ranges as mentioned in the so called 'generic standards' are shown in *fig. 4* as solid lines. In product standards other frequency ranges may be present and also in standards under consideration; some of these ranges are shown in *fig.4* with dotted lines.

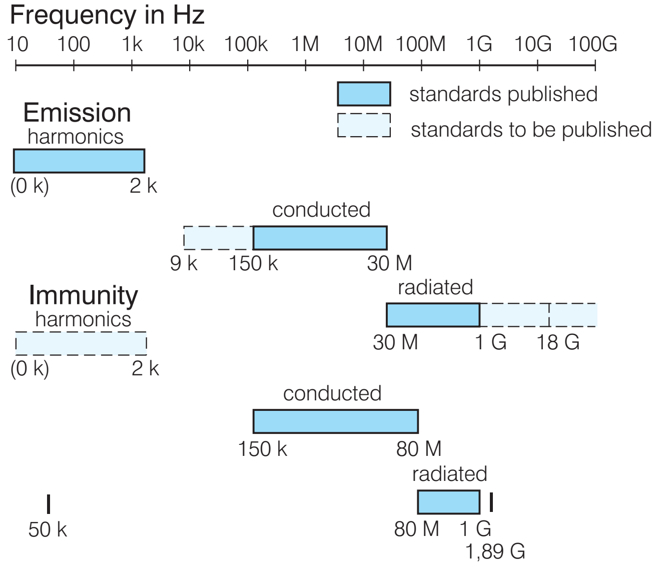


Figure 4 Frequency ranges of emission and immunity tests

The most important frequency ranges are:

Emission

Conducted disturbances

- frequency range: 0 - 2 kHz
  Supply frequencies and harmonics
- frequency range: 150 kHz - 30 MHz
  Disturbances generated by electrical and electronic circuits, switch actions etc.

Radiation

- frequency range: 30 MHz 1 GHz
  Electric fields of electronic circuits, transmitters etc.

Immunity (frequency domain)

Conducted disturbances

- frequency range: 150 kHz - 80 MHz

Radiation

- frequency range: 50 Hz (magnetic field)
- frequency range: 80 MHz - 1 GHz, 1,89 GHz (electric fields)

Basics of EMC

Types of disturbing signals

Next to the immunity tests in the frequency domain there are tests in the time domain; these are:

Immunity (time domain)

- ESD (ESD - electrostatic discharge)
- EFT/burst (EFT - electrical fast transients)
- Surge
- Voltage variations, dips and interruptions

Types of disturbing signals

As already mentioned disturbances can be divided into some classes:

Conducted disturbing signals

Conducted disturbing signals are divided into:

Disturbing voltage

The disturbing voltage can be divided into:

- differential mode (DM) voltage (*fig. 5a and 6*)

This is the voltage between lines of a circuit.

- common-mode (CM) voltage (*fig. 5b and 6*)

This is the voltage between all lines of a cable and earth.

The DM voltage is important in the low frequency range, frequencies below 10 Mhz. The CM voltage is important above the frequency of 10 MHz.

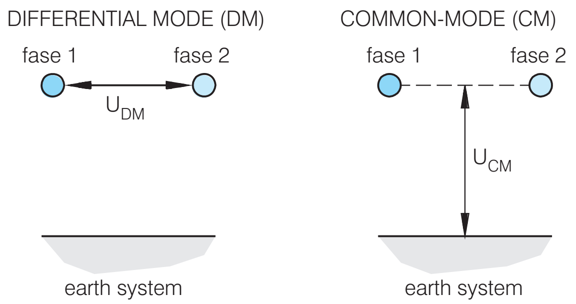


Figure 5 Disturbing voltages

Disturbing current

The disturbing current appears as:

- DM current through the lines of a circuit
- CM current through a cable and a return. The return usually is the earthing system (*fig. 6*)

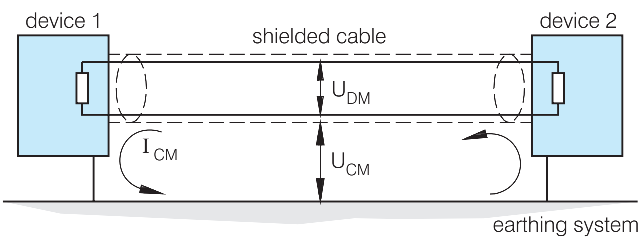


Figure 6 Common-mode disturbing signals

Disturbing power

The disturbing power is the product of the disturbing voltage and the disturbing current in a circuit. Disturbing power is sometimes used for CM signals above the frequency of 30 MHz.

Disturbing radiation

Disturbing radiation can be divided into:

Magnetic induction and magnetic fields:

Magnetic induction B is used to expres magnetic fields at short distances of the source. Magnetic fields or H-fields mainly exist in the low frequency range (below 30 MHz).

Electric fields and electromagnetic fields:

Electric fields or E-fields are mainly disturbing in the higher frequency range (above 1 MHz). At high frequencies, that means above 0,3 GHz, the fields become electromagnetic.

Pulses

Next to the signals in the 'frequency domain', as mentioned above, disturbing signals in the 'time domain' may be present in the form of pulses, sometimes called 'transients'. Types of pulses important in the EMC are defined in the EMC-standards for measuring the immunity (IEC 1000-4-series).

Theory of electrics

Impedances

Introduction

Parts of the theory of electrics are refreshed briefly for a better understanding of the EMC-phenomena. Only subjects of direct importance for cable laying in installations are treated.

An overview of dimensions and units of quantities used in this paragraph is given in the annex.

Some properties and physical constants of metals are given in *Table 1*.

Resistance of a wire and a strip

The ohmic resistance of a wire or strip is calculated with the formula:

$$R = \rho . l / A$$

where: R - resistance in W
ρ - specific resistivity of metal in W m
l - length of wire or strip in m
A - cross section of wire or strip in m^2

Impedance of a wire

The impedance of a wire in the low frequency range is determined by the resistance. However each conductor also has a self-inductance which becomes noticeable at higher frequencies. The value of the inductance is determined by the dimension and the form of the cross section. A rule of thumb for the self-inductance of a wire is:

$$L = 1\ \mu H/m$$

For the impedance due to the self-inductance the formula applies:

$$Z = 2\,\pi\, f\, .\, L$$

where: Z - impedance in Ω
f - frequency in Hz
L - self-inductance in H

Above the frequency of a few hundreds of hertz (depending on the dimensions of the conductor) the value of the impedance due to the self-inductance becomes higher than the value of the resistance (*fig. 7*). Above this frequency the impedance of the wire increases with the frequency.

Impedance of a strip

In general a strip has a lower self-inductance than a wire. A strip with dimensions (*fig. 8*) (width) b

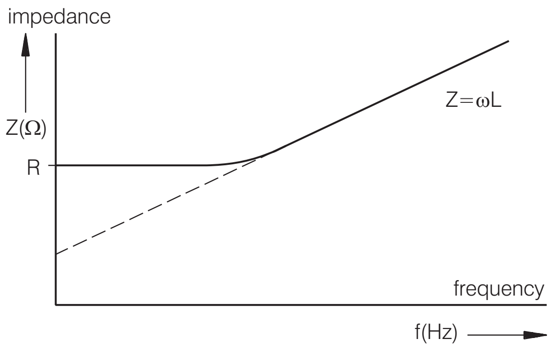


Figure 7 Impedance of a conductor as a function of the frequency

and (thickness) c, is compared with a round wire with diameter d.

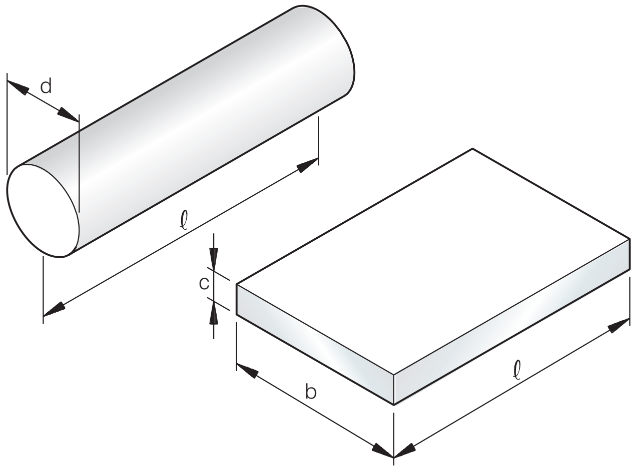


Figure 8 Self-inductance of a round wire is higher than of a strip

Theoretically an approximation for the ratio of the self-inductance of the wire to that of the strip is a factor: 2d/(b + c). From this formula it follows that the broader the strip the lower the self-inductance. Another conclusion is, that the thickness of broad strips is not important. In practice the thickness is mainly determined by the mechanical strength.

Besides the lower self-inductance, the strip has the advantage of the skin effect. Due to this effect at high frequencies the impedance of a strip is lower than the impedance of a wire, which will be discussed later on.

The impedance of a conductor can be kept relatively low by the use of broad strips. This effect can be brought into practice by using cable ducts as conductors for the earthing system. Keeping the lenght as short as possible also reduces the impedance.

Theory of electrics

Magnetic field

Magnetic field strength of a wire

The magnetic field strength H generated by a wire carrying a current I is according to the law of Biot and Savart given by the formula (*fig. 9*):

$$H = I / 2 \pi r$$

where: H - magnetic field strength in A/m
I - current in A
r - distance to the wire in m

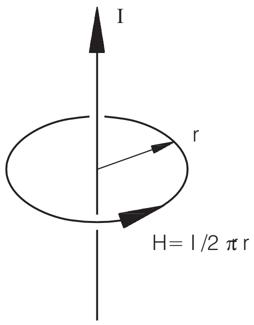


Figure 9 Magnetic field of a wire

Magnetic field strength of two parallel wires

The magnetic field strength of two parallel wires at a distance d in which currents flow of the same amplitude, but in opposite directions (*fig. 10*) is given by:

$$H = I \, . \, d / 2 \pi r^2$$

where: H - magnetic field strength in A/m
d - distance between the wires in m
I - current in A
r - distance to the wire in m

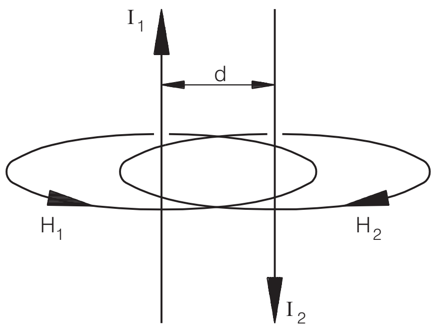


Figure 10 Magnetic field of two parallel wires

Because the currents in the wires flow in opposite directions, the generated magnetic fields compensate each other partly. The smaller the distance between the wires is, the smaller the remaining field strength is. The magnetic field strength of the two wires together decreases with the square of the distance to the measuring point.
This method of reduction of field strength due to two conductors with currents in opposite directions is applied in laying cables close to cable ducts in case of common-mode currents flowing through the cable shield with a return current in the cable duct.

Magnetic field strength of a circular loop

The magnetic field strength H of a loop of circular shape with radius r in which a current I is flowing is in the centre of the loop (*fig. 11*):

$$H = I / 2 r$$

where: H - magnetic field strength in A/m
I - current in A
r - radius of the loop in m

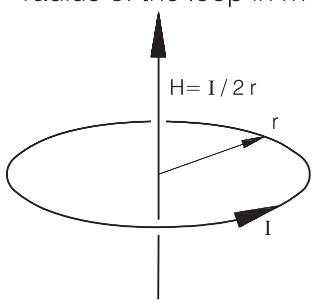


Figure 11 Magnetic field of a circular loop

Outside the loop the field strength decreases with increasing distance to the loop. On a certain distance of the loop, e.g. in the point P at a distance d of the centre, the field strength has decreased with the third power of the distance to the centre (*fig. 12*).

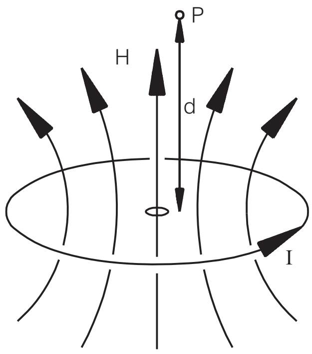


Figure 12 Decreasing magnetic field strength as a function of the distance to the loop

Magnetic field

Magnetic field strength of a non-circular loop
For the special case of a non-circular loop the formula for the magnetic field strength of two parallel wires can be used.

Magnetic induction
For the calculation of the magnetic induction the following formula can be applied:

$$B = \mu \,.\, H = \mu_o \,.\, \mu_r \,.\, H$$

where:
- B - magnetic induction in T
- μ - magnetic permeability in H/m
- μ_o - magnetic permeability of vacuum ($4 \pi \, 10^{-7}$ H/m)
- μ_r - relative magnetic permeability
- H - magnetic field strength in A/m

Magnetic flux
The formula for the calculation of the magnetic flux is:

$$\Phi = B \,.\, A = \mu \,.\, A \,.\, H$$

where:
- Φ - magnetic flux in Wb
- A - area of the loop in m^2
- H - magnetic field strength in A/m

The described formulas are used to calculate the magnetic field strength, the magnetic induction or the magnetic flux of loops in the earthing system, e.g. formed by a cable shield and a cable duct.

Electric field

Behaviour of a conductor as antenna
A conductor acts as an electric antenna.
A voltage on a conductor will generate an electric field. Besides a conductor a second element is necessary. Usually the other element, to which the voltage is refered, is the earthing system. The effectivity of a conductor as antenna depends on the ratio wavelength of the signal to the length of the conductor. The wavelength of the signal is calculated from the frequency with the formula:

$$\lambda = c / f$$

where:
- λ - wavelength in m
- f - frequency in Hz
- c - speed of light (3.10^8 m/s)

Electric field

Short antennas, i.e. antennas with a length smaller than a tenth of a wavelength, have an effectivity proportional to the ratio length to wavelength.
A conductor with one open end functions as a rod antenna. The antenna works effectively when the length is a quarter of a wavelength or in general at lengths:

$$\ell = \tfrac{1}{4} \lambda \, (1 + 2n) \qquad \text{with } n = 0, 1, 2, 3, \ldots$$

A conductor which is connected at both ends functions effectively as a antenna when the length is a half wavelength or in general at lengths:

$$\ell = \tfrac{1}{2} \, l \,.\, n \qquad \text{with } n = 1, 2, 3, \ldots$$

Example:
Cable shields function as effective antennas. They are connected at both ends to the earthing system. Suppose a disturbing voltage is present with a frequency: f = 10 MHz. The wave length of that signal is:

$$\lambda = c / f = 3.10^8 / 10.10^6 = 30 \text{ m}$$

The cable will function as an effective antenna for the following lengths:

$$\ell = 15 \text{ m}, 30 \text{ m}, 45 \text{ m etc.}$$

Reversely, when a cable has a certain length, the frequencies at which it will act as an effective antenna can be calculated.

Actually the wavelengths in the cables will be smaller, because the transmission velocity of a signal in a metal is smaller than the speed of light.

Electric field strength
The electric field strength E at a distance r of a source, of which the power P is known, can be calculated by an approximation formula which is:

$$E = 7 \sqrt{P} / r$$

where:
- E - electric field strength in V/m
- P - power of the transmitter in W
- r - distance to the source in m

Theoretically this formula is valid for distances from the source that are larger than 1/6 of a wavelength. In practice the formula can be used even for smaller distances.

Physical laws and effects

Kirchhoff's law

Kirchhoff's law for currents says:

The algebraic sum of the currents flowing towards any point is zero (*fig. 13a*). For this summation the direction of the currents must be taken into account. From this law it follows, that currents can only flow in loops (*fig. 13b*).

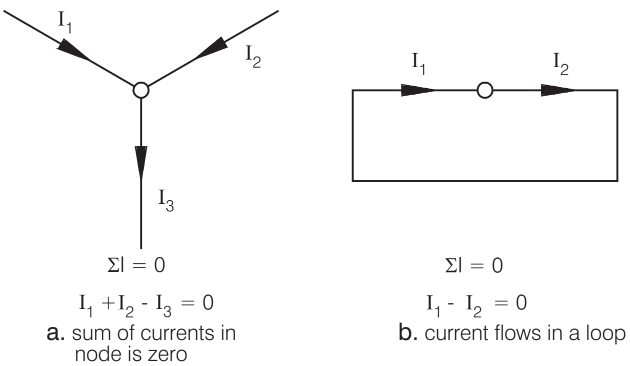


Figure 13 Kirchhoff's law for currents

Lenz's law

Lenz's law says:

For currents induced by motion in a magnetic field, the induced currents have such a direction that their reaction tends to oppose the motion which produces them.

The same is valid for alternating currents, where the magnetic field changes due to the alternation. From this law it can be derived, that in circuits the return current takes a path so that the magnetic flux is as small as possible.

As already given the formula for the magnetic flux is:

$$\Phi = \mu A H$$

where:
- Φ - magnetic flux in Wb
- μ - magnetic permeability in H/m
- A - area of a loop in m^2
- H - magnetic field strength in A/m

The magnetic flux is frequency dependant, as is evident from the dimension: Wb = V . s = V/Hz.

The magnetic flux can be kept small by keeping the area of the loop (A) small. This can be achieved when the return current is able to flow through a path close to the original current.

This occurs, when a common-mode current in a cable shield is able to flow back through a conducting plane below the cable. The current will flow as close as possible to the current in the shield. The cable duct acts as the conducting plane.

Experiment

This phenomenon can be shown in an experiment. In a U-shaped metal tube a wire is installed (*fig. 14*). One end of the wire is connected to one end of the tube. The other end of the wire is via a current source connected to the other end of the tube. The ends of the tube are also connected via a heavy bar.

At low frequencies most of the return current will flow through the bar. With increasing frequency the largest part of the return current will flow through the tube. At the supply frequency (50 Hz) already 90 % of the current will flow through the tube ($I_B = 10\ I_A$).

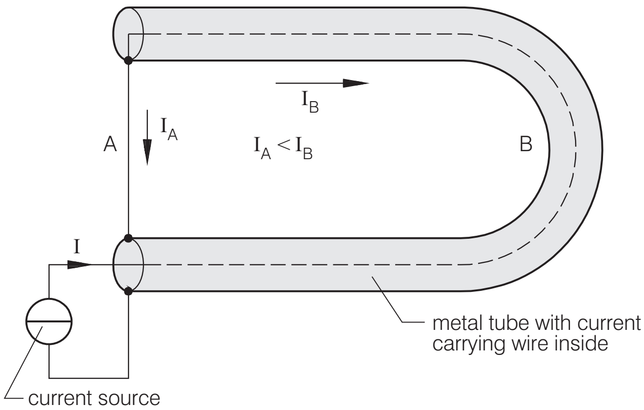


Figure 14 Experiment to show the effect of Lenz's law

Skin effect

The skin effect is the electromagnetic effect, that in a conductor carrying an alternating current, the current density will be greater at the surface of the conductor than in the centre. At sufficiently high frequencies the current is practically confined to the skin layer of the conductor. The depth at which the current is decreased to 1/e of the value at the surface is called the skin depth (e - base of the natural logarithm; e = 2,718...).

For calculations normally it is assumed, that at a depth of three skin depth the current is negligible small.

The formula for the calculation of the skin depth is:

$$\delta = 1 / \sqrt{\pi . f . \sigma . \mu} = 503 / \sqrt{f . \sigma . \mu_r}$$

where:
- δ - skin depth in m
- f - frequency in Hz
- σ - specific conductivity in S/m
- μ_r - relative permeability of the metal

Remark:
The specific conductivity is the reciprocal of the specific resistivity ρ , thus σ = 1 / ρ (ρ in Ω . m).

From the formula follows:
- the higher the frequency the thinner the skin layer
- the higher the specific conductivity, thus the lower the specific resistivity, the thinner the skin layer
- for a magnetizible metal, e.g. iron or steel, the μ_r is higher than one and the skin layer is thinner.

For some metals used for the construction of cable ducts the skin depths are given (*Table 1*). Where for some metals a range of values is given, the skin depth is calculated from the mean value.

To reduce the influence of the skin effect on current carrying conductors it is advantageous to use strips instead of round wires. This is shown in *fig. 15* for a wire and a strip of identical cross section. The shaded area of the strip is larger than that of the wire.

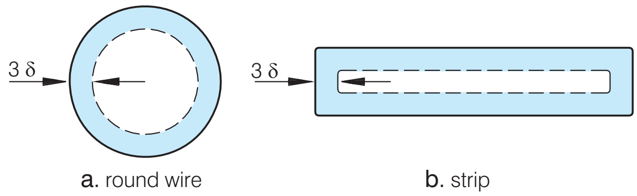


Figure 15 Skin effect

A cable duct consists of broad metal strips, which is advantageous with respect to the skin effect. Stainless steel is more advantageous in conducting high frequency currents because of the large skin depth. Steel is more advantageous in shielding magnetic fields because of the high relative magnetic permeablity. In practice both steel and stainless steel proved to be satisfactory.

Table 1 Skin depths for some metals

material	specific resistivity ρ in 10^{-9} Ω.m	relative permeability μ_r	skin depth δ in m	skin depth δ in mm	frequency f = 1 MHz 3 δ in mm
Copper	18	1	0,067/√f	67/√f	0,20
Aluminum	28	1	0,084/√f	84/√f	0,25
Steel	110	500-1000 (750)	0,006/√f	6/√f	0,02
Stainless steel	720-800 (760)	1,0	0,44/√f	440/√f	1,3

Installation of cables on cable ducts

Installation of cables

The way the cable lay-out of an installation is designed is important in order to achieve EMC.

The EM-environment also plays a role. In a noisy EM-environment the laying of sensitive cables requires extra attention. The same is true for noisy cables in a quiet EM-environment.

The cable types used are also important. It is assumed that where necessary, shielded cables are used. The cable shields have to be connected at both ends. In this way currents are able to flow in the cable shields, which will reduce the influence of the fields. This is the only way to shield high frequency fields.

Normally shields made of copper are used. When only low attenuation values are required, also steel armours can be used as cable shield.

In exceptional cases, cable shields have to be connected at one end only. This happens when low frequency analog signals are transported by the cables. In this situation two insulated shields have to be used. The inner shield is bonded at only one end to reduce the influence on the signals by low frequency currents which may flow in the cable shield. The outer cable shield is bonded at both ends to shield high frequency fields.

In practice often disturbing electrical fields are present in the megahertz range, e.g. in tens of MHz. The wavelengths belonging to these frequencies are tens of meters. In installations, often cables of these lengths are present and will act as antennas.

Cabinets and consoles usually have dimensions of meters. This means they are able to radiate or pick up fields in the frequency range of hundreds of megahertz.

In installations cables will usually be the main radiators of (*fig. 16*) and receivers (*fig. 17*) from disturbing fields.

Remark: Also the signals to be transported by cables may be disturbing for circuits, connected to lines in other cables. This is for example the case for supply currents and cables with pulses.

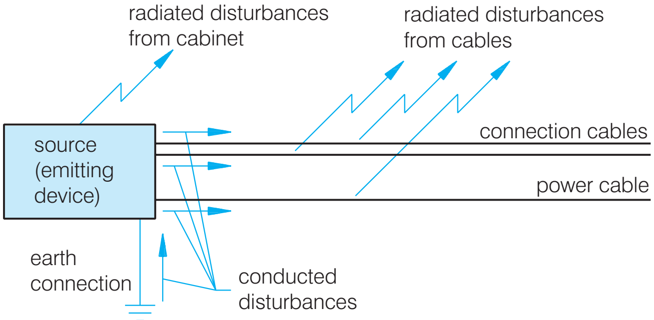


Figure 16 Emission of disturbing signals by a system

Cables as emittors:

Cables are able to transport signals and disturbances through the installation over large distances. During the transport the following phenomena may take place:

- disturbing signals of a cable may couple into parallel running cables
- cables may radiate electric fields in the frequencies of the disturbing signals
- cables may radiate magnetic fields when they are part of a loop
- cables may radiate magnetic fields when they are carrying high currents. This is mainly the case for currents in the supply frequency and their harmonics
- cables may couple disturbing signals directly into susceptible equipment.

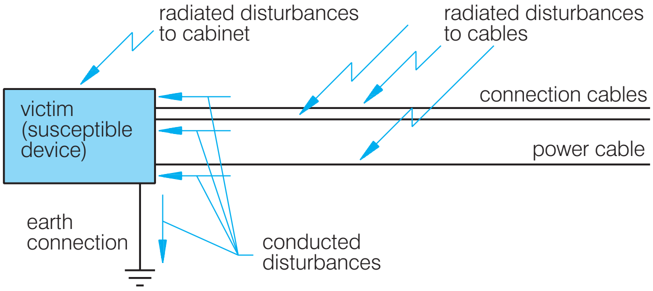


Figure 17 Coupling of disturbing signals into a system

Cables as susceptors:

In the same way that cables emit disturbances, cables may also pick up disturbances:

- a cable may pick up disturbing signals of a cable running in parallel
- cables may pick up electric fields
- cables may pick up magnetic fields when they are part of a loop
- cables may pick up magnetic fields of cables carrying high currents. This is mainly the case for currents in the supply frequency and their harmonics
- cables may directly pick up disturbing signals from equipment generating these signals.

When these cables are connected to susceptible circuits, interference may occur.

These effects can be diminished in several ways, e.g. by:

- dividing cables into cable categories
- separation between cables of the several cable categories
- decreasing the antenna behaviour of cables by:
- cable laying on a conducting earthed plane
- shielding, e.g. by cable ducts
- prevention of the formation of loops in cables.

Installation of cables on cable ducts

Cable categories

Cables can be divided into categories depending on the signals they are transporting. This division is made on the bases of signal levels and frequencies, or for pulses on the bases of amplitude and the pulse rise and decay times.

In practice often a division into three categories is made:

- indifferent cables
  Cables of this category contain less jamming and less sensitive signals. Examples are power cables.
- sensitive cables
  This category contains instrumentation and data cables.
- jamming or noisy cables
  This category contains control cables as e.g. motor cables of frequency converters.

In special cases more categories can be added, such as:

- very sensitive cables
  Cables with very low signals as from sensors.
- strong jamming cables
  Cables with high power signals, high frequencies or high level pulses.

Remark:
An equipment supplier may prescribe to lay all the cables of a system together. In that case it is recommended to lay these cables as a separate category.

Table 2 Measures to be taken on cable ducts carrying different cable categories in several EM-environments

	EM-environment		
Cable category	very sensitive	normal	strong jamming
very sensitive	X	E	EE
sensitive	X	X	E
indifferent	X	X	X
jamming	E	X	X
strong jamming	EE	E	X

Measures
X - normal
E - extra
EE - double extra

The cables are laid in groups of one category. The distance between the groups of successive categories laid on the same cable duct shall be:

- minimum 0,2 m for cable categories on cable ladders
- minimum 0,15 m for cable categories on cable ducts with a solid or perforated bottom.

Also a distance of 10 times the diameter of the thickest cable is sufficient.

The distance between open cable ducts shall be at least 0,15 m.

Next to the use of open cable ducts, in some cases covered cable ducts can be used. This depends mainly on the EM-environment in combination with the sensitivity of the cables.

In a strong jamming EM-environment the sensitive cables shall be laid in cable ducts of solid metal; the very sensitive cables shall be laid in cable ducts with covers.

In an EM-environment which contains sensitive equipment the jamming cables have to be given extra attention.

This is shown in *Table 2*. This table will be discussed in extend below when discussing the types of cable ducts.

Divide cabinets into zones

Electrical and electronic parts and components can, analogous to cable categories, be divided into zones of different disturbance behaviour. Some EM-zones are:
- EM-zone 2 for susceptible parts
- EM-zone 3 for parts which are indifferent or neutral
- EM-zone 4 for disturbing parts

It is recommended to install parts belonging to a certain EM-zone into a separate cabinet and keep some distance between cabinets of different EM-zones (*fig. 18*).

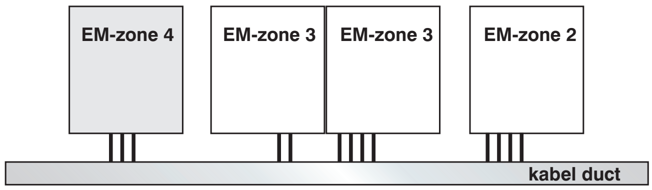


Fig. 18 Cabinets with circuits of different levels of disturbances shall be placed into shielding compartment, mounted at some separation distance

If all electrical and electronic parts are mounted into a single cabinet, parts belonging to one EM-zone shall be mounted into a shielded compartment and some distance shall be present between compartments of different EM-zones (*fig.19*).

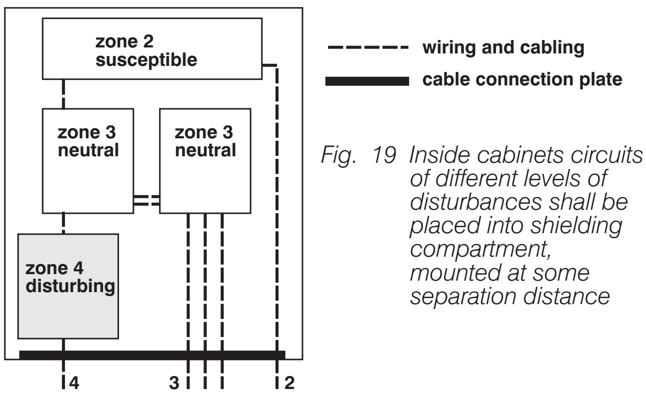


Fig. 19 Inside cabinets circuits of different levels of disturbances shall be placed into shielding compartment, mounted at some separation distance

Installation of cables on cable ducts

Behaviour of cables as antennas

Electric antenna

The behaviour of cables as antennas can be decreased by laying the cables close to a conducting surface, e.g. the earthing system. The capacity of the cables to earth becomes so large, that their effectivity as a radiator diminishes. Thus the generation of electric fields will also diminish.

Electric fields arise when voltages are present in the cables. This may be the case on the lines of non-shielded cables. In a shielded cable, when the shield is connected at both ends to earth, hardly any voltages will occur and thus only very weak electric fields will be generated. This is only true when the cable length is much smaller then the wavelength of the disturbing signal. For cable lengths resembling half, or multiples of a half, wavelengths of the disturbing signals resonances may occur and high electric field strengths may be generated.

Loop

Suppose the cable shield is carrying a disturbing current, e.g. a CM-current, of which the return current flows through the earthing system (*fig. 20a*). The current in the loop generates a magnetic field. Reversely a magnetic field is able to induce a current into the loop.

The loop in which the current is flowing can be made smaller by introducing an earth conductor close to the cable (*fig. 20b*); this is called a PEC (Parallel Earth Conductor).

A cable duct can also form a PEC (*fig. 20c*). In that case the cable duct shall form a continuous conducting path over the whole length.

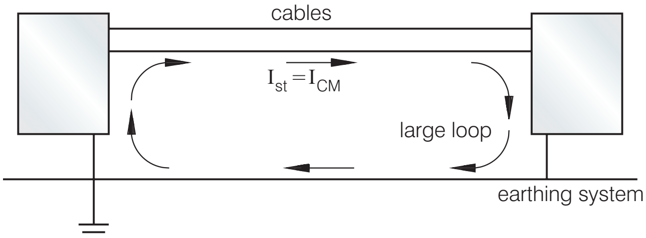


Figure. 20a Loop with CM-current

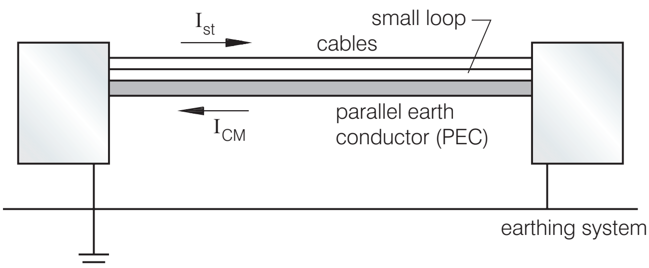


Figure 20b Diminishing of the loop by a PEC (Parallel Earth Conductor)

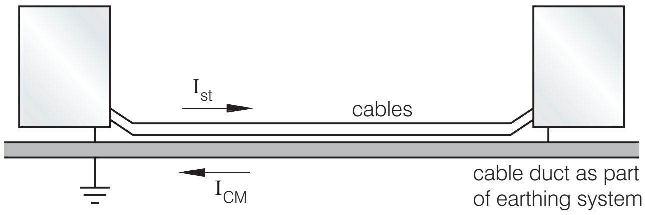


Figure 20c Diminishing of the loop by a cable duct

Single wire or cable

The magnetic field strength generated by a current in a wire or cable can be decreased by laying the return wire close to the current carrying wire. Therefore each circuit shall have its own return. Strong currents appear mainly in power cables, especially as the mains network is constructed as bars. Decoupling with other cables can be achieved by enlarging the distance. Shielding of low-frequency magnetic fields is difficult.

Prevention of field generation

Besides the reduction of the generation of fields by laying the cables on conducting surfaces, some other measures will be discussed.

Electric field strength generated by cables can be decreased by the shielding of the cables or by using closed cable ducts, e.g. cable ducts with a cover.

Magnetic field strength due to CM-currents in cables can be reduced by reducing the area of the loop in which the currents are flowing. This can often be reached by changing connections in the earthing system. Before improvements can be introduced, measurements are necessary to locate the paths of the currents.

Results of the introduction of conducting surfaces

Results of the introduction of conducting surfaces beneath cables are:

Electric field:

- electric field strength reduces, due to the reduction of the effectivity as antennas
- coupling between parallel running cables decreases. The reduction is proportional to the reduction of the ratio capacitance to parallel cable and capacitance to conducting surface.

Magnetic field:

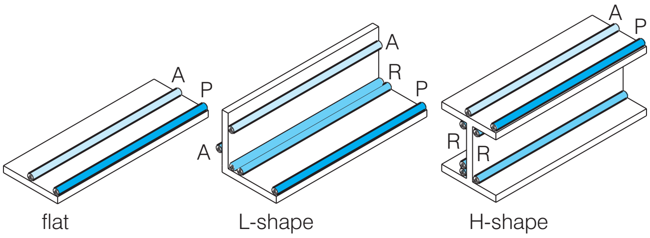
- magnetic field strength reduces, due to reduction of the loop in which currents flow as a result of the closer neighbourhood of a conducting surface
- coupling between parallel running cables decreases, due to the fact that of both cables the area of the loop is reduced as a result of the closer neighbourhood of a conducting plane.

Installation of cables on cable ducts

Behaviour of cables as antennas

Shielding by metal plates

Metal plates and beams show a shielding effect on cables routed on them (*fig. 21*). On a strip the cables shall be laid in the middle of the plate. This gives a moderate shielding effect. On a L-shaped beam the cables shall be laid in the corner; this gives a good shielding attenuation. A canal, such as present at a H-shaped beam, gives the best shielding attenuation, when the cables are laid into the corners.



R - best: recommended
A - good: acceptible
P - poor: not recommended

Fig. 21 Shielding behaviour of plates and beams

The deeper the canal, the higher the attenuation. The highest shielding attenuation is attained when using canals with a cover or pipes (*fig. 22*).

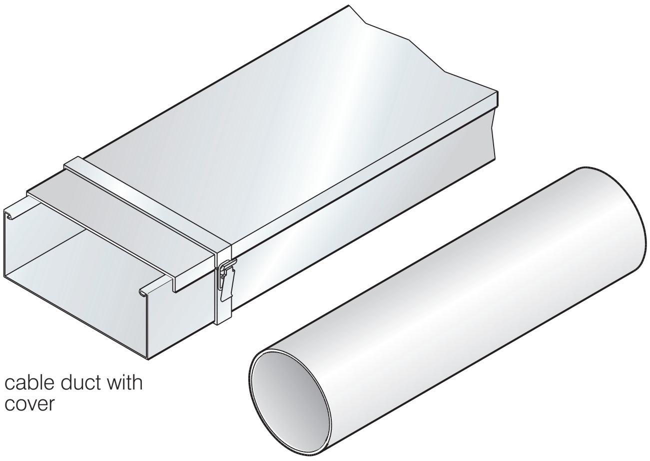


Figure. 22 Highest shielding attenuation is gained with closed constructions

Earthing system

Attenuation factors

EMC

Earthing system

The construction of the earthing system of an installation needs a lot of attention. This is because the proper working of several EMC-measures, such as shielding, filtering, protection measures against the generation of overvoltage and protection against lightning, depends on a low-impedance earthing system. The ideal earthing system is a plane. In installations this cannot be realised and an earth grid is used.

The earthing system shall include all constructional metal parts. Such metal parts are e.g. steel beams, plates, ironwork of reinforced concrete, frames and also the cable ducts (*fig. 23*). These metal parts shall be bonded to the earthing system at least every 10 m. with a low impedance.

Besides the EMC earthing system the safety earth is present, this is the Protective Earth (PE).
Often conductors of the PE, e.g. in the form of bars with dimensions 5 mm x 20 mm, are laid parallel to the cable ducts. This safety system is connected to the EMC earthing system at many places.

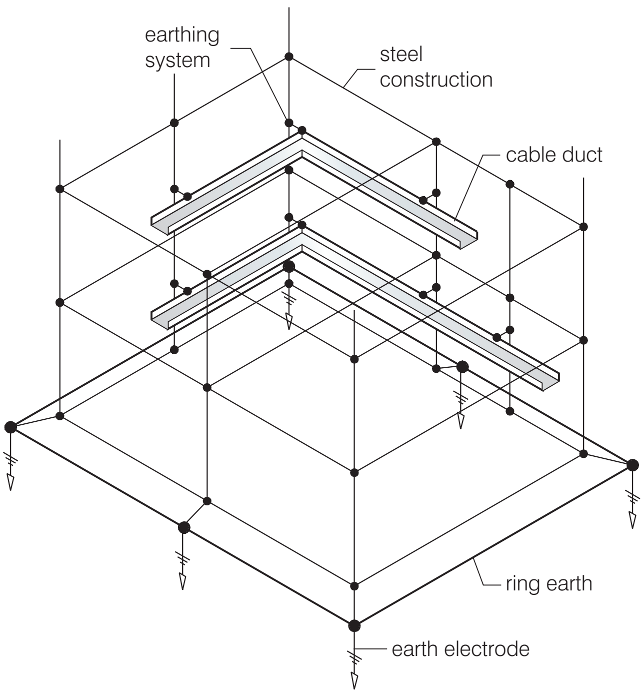


Figure 23 EMC-earthing system of building (schematic)

From an EMC point of view it is not necessary to ground the EMC earth system but for other reasons this is practiced; because the system can also be used for, or connected with the safety earth and the lightning protection installation.

Attenuation factors

In the literature often attenuation factors or attenuation values in dB are given. For that reason the way attenuation is calculated will be mentioned.

The attenuation factor of an EMC-measure is the ratio of the original signal to the attenuated signal. As an example the attenuation of the electric field strength by a shielding wall will be explained (*fig. 24*).

The attenuation factor S of a shielding device is the ratio of the incoming field strength E_{in} to the outgoing field strength E_{out}, so:

$$S = E_{in} / E_{out}$$

where: S = attenuation factor
E_{in} = incoming electric field strength in V/m
E_{out} = electric field strength after attenuation in V/m

For the dB-value of the shielding attenuation follows :

$$A = 20 \log (E_{in} / E_{out})$$

where: A= attenuation in dB
Numerical example:
When the signal is attenuated by a factor 10, so :

$$E_{in} / E_{out} = 10$$

then the attenuation value is :

$$A = 20 \log 10 = 20 \text{ dB}$$

In the same way an attenuation with a factor 100 gives an attenuation value of 40 dB, a factor 1000 a value of of 60 dB, and so on.

From this example it becomes clear, that relative low attenuation values already give a large decrease signal amplitude. In many cases an attenuation of 20 - 30 suffices, reducing a field strength of E = 100 V/m to E = 3 - 10 V/m.

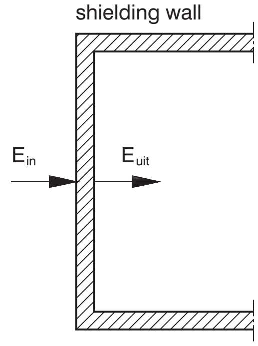


Figure 24 Attenuation of an electric field by a shielding wall

Application of the EMC-theory to cable ducts

Introduction

The proper construction of cable ducts can improve the EMC of a system. This is only valid for metal cable ducts which form part of the earthing system. These cable ducts:

- improve the earthing system by reducing the impedance of it
- reduce the coupling between cables
- reduce radiation of electric and magnetic fields
- reduce the pick up of electric and magnetic fields.

In order to perform these functions the construction of the cable ducts shall fulfil specific requirements, which are discussed below.

Some of these requirements are also laid down in the standard IEC 61000-5-2 (*Ref. 3*).

Cabinets

Requirements for cable ducts between cabinets will be discussed. The term 'cabinets' will be used as the general term for all kind of enclosures as consoles, panels, junction boxes, equipment racks etc. It is assumed that the cabinets are made of metal and show a certain amount of shielding attenuation.

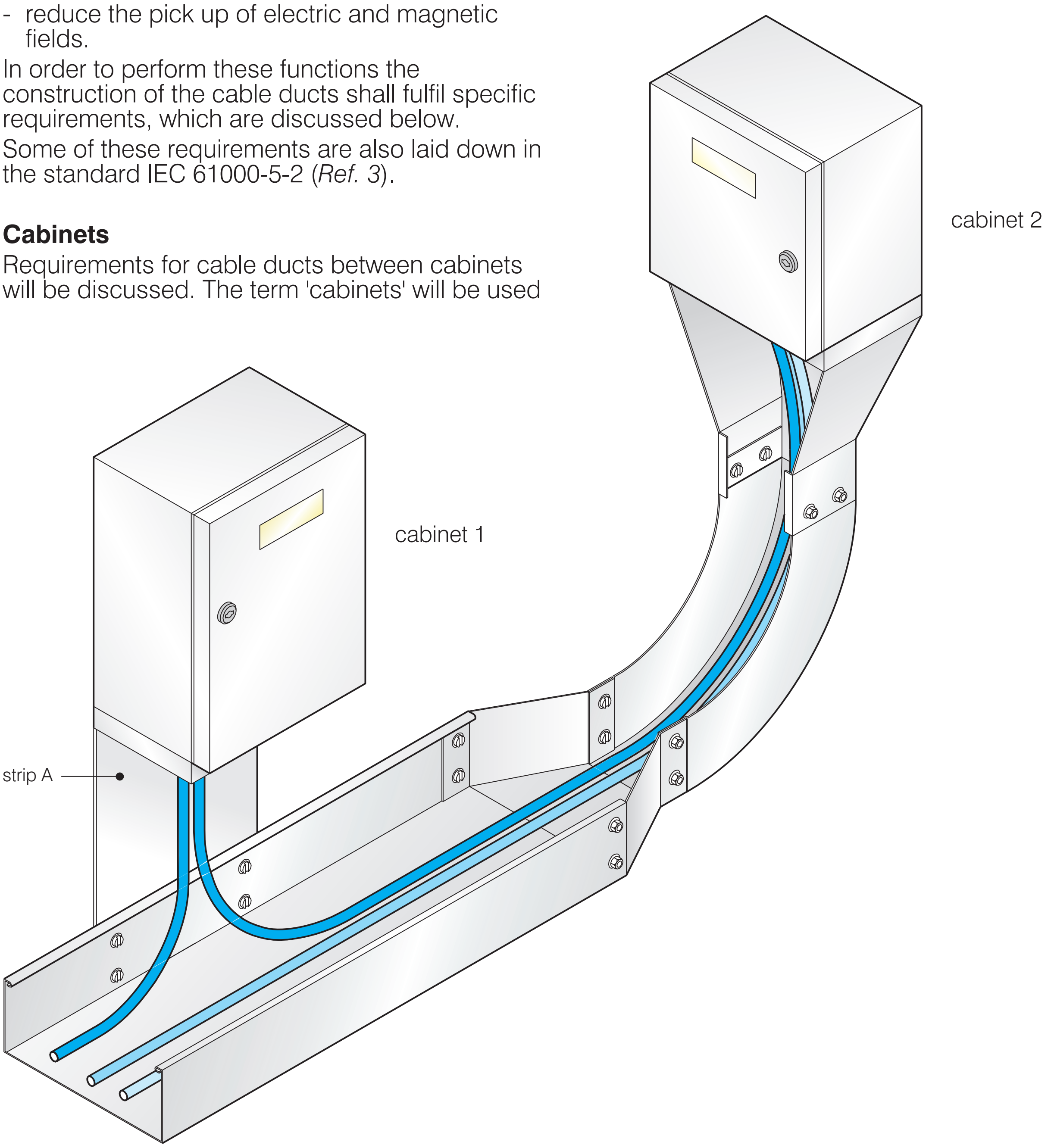


Figure 25 Cable ducts form a continuous earthing system from cabinet to cabinet

Application of the EMC-theory to cable ducts

Cable ducts

CM-currents

Cable ducts are used to conduct the return currents of CM-currents flowing through the cables, especially through the cable shields. These return currents shall be able to run close to the cables to reduce the area of the loop between cables and cable duct (*fig. 25*). The ways this can be reached are discussed.

Connections of low impedance

The sidewalls of the cable ducts have a low impedance due to their construction as broad strips. The connections between the parts mutually and between the cable duct and the cabinets shall also be of low resistance and low impedance. This connection can be achieved by the use of lips or strips (splice plates) connected with bolts. The lips or strips shall have heights which are approximately the same as the height of the cable duct (*fig. 26, 27 and 28*). The number of bolts that must be used is discussed on page H1E-1-19.

Low resistance between the parts of a cable duct can be achieved by using bare metal surfaces (galvanized or stainless steel) connected by bolts. When the surfaces have a non-conducting finish lockwashers have to be used to scratch through the finish to make electrical contact (*fig. 29*).

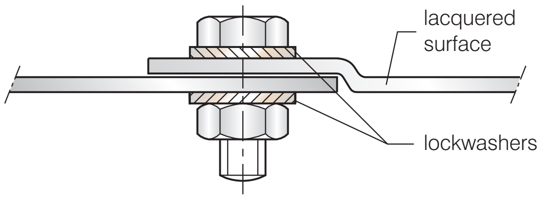


Figure 29 Lockwashers are used to contact parts having a non-conducting surface

The bonding resistance between two connected parts shall be lower than 0,01W.

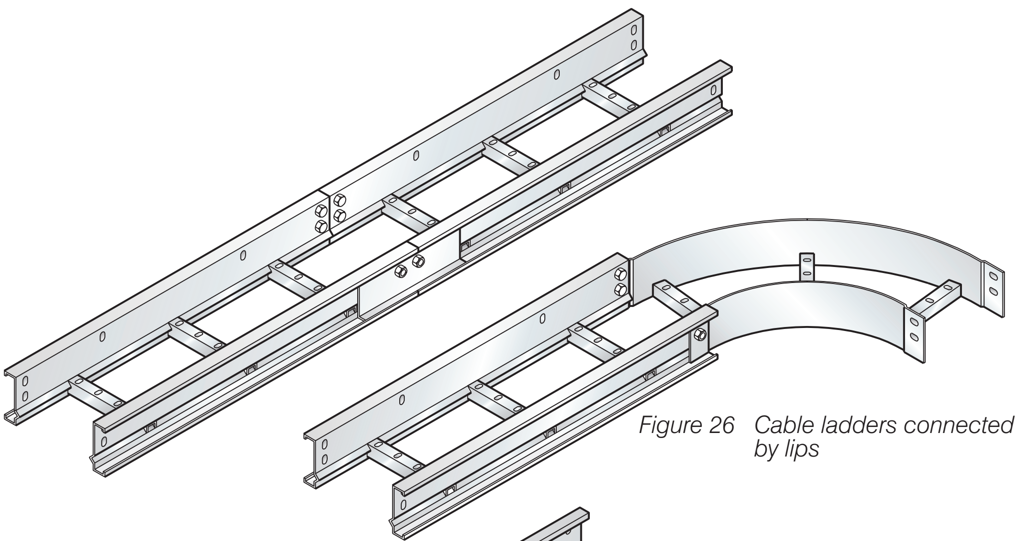


Figure 26 Cable ladders connected by lips

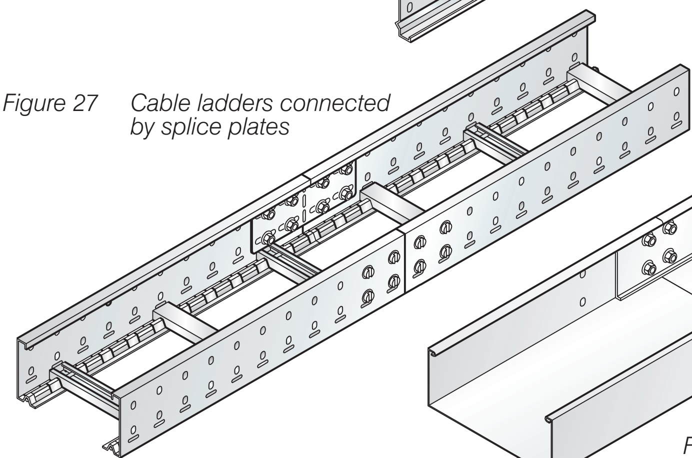


Figure 27 Cable ladders connected by splice plates

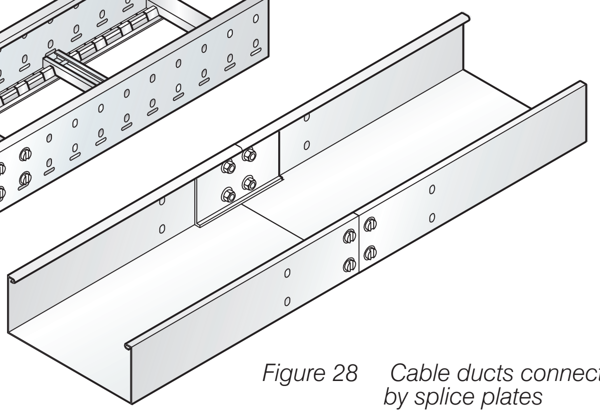


Figure 28 Cable ducts connected by splice plates

Application of the EMC-theory to cable ducts

Between the cable ducts and the cabinets to which the cables are connected also broad plates have to be installed (*fig. 21, strip A*).

A connection with wires between the parts is not sufficient because of the high impedance of wires at high frequencies.

In the connection between parts of the cable duct, and also between cable ducts and cabinets, no interruptions bridged with the help of wires may be present. Some wrong constructions are shown, accompanied by the right ones (*fig. 30*). Examples are the interruption at wire branches (*fig. 30a*), cable ducts going around a comer (*fig. 30b*) and cable ducts carried through a wall (*fig.30c*).
(*Fig. 30* is an improvement of the former *fig. 26*)

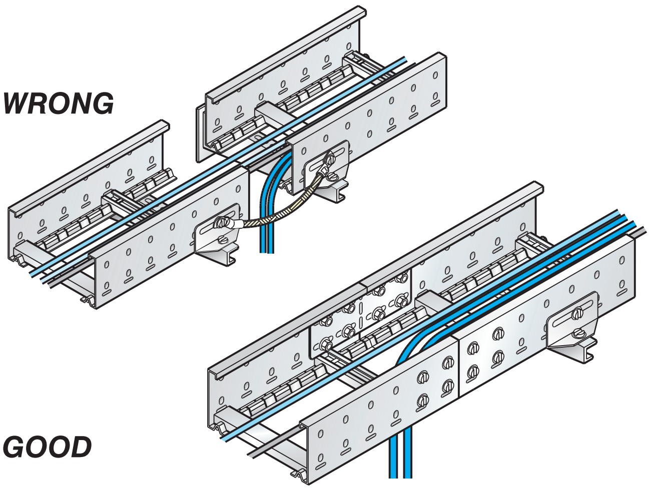


Figure. 30a   Cable duct with branch

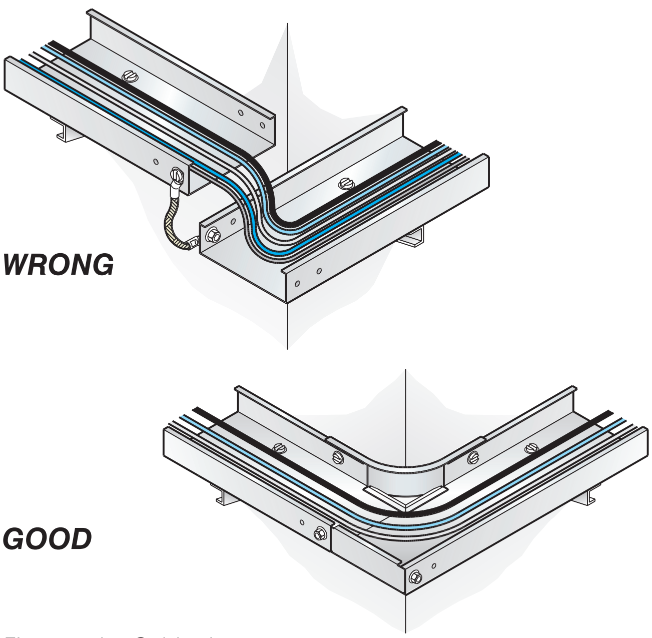


Figure 30b   Cable duct at a corner

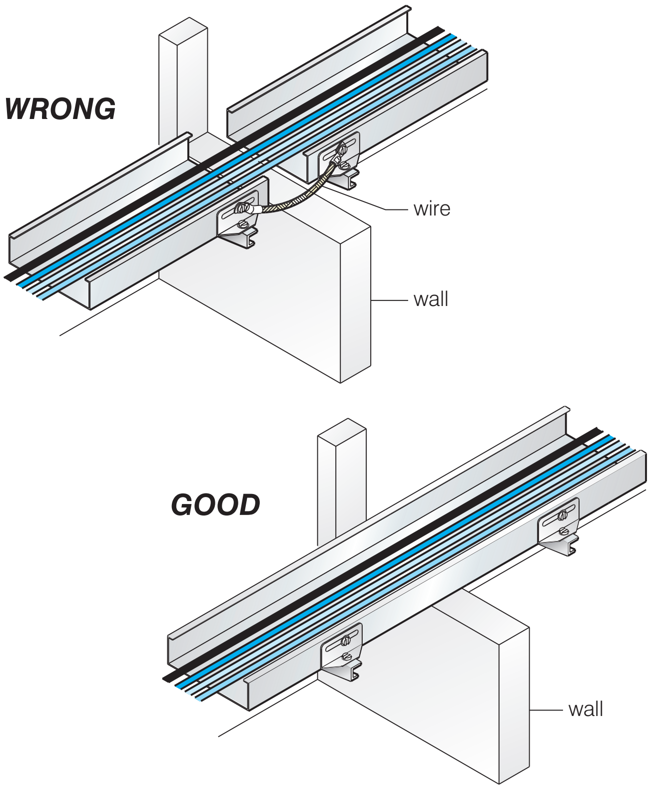


Figure. 30c   Cable duct fed through a wall

Remark:
In connection with firesafety-instructions it is not permitted in some cases to pass a metal cable duct through a wall.
In that case it is advisable to fit the highest number of permitted strand winding connections.

Figure. 30   Connection between parts with wires has a too high impedance

Shielding

Metal cable ducts provide shielding attenuation as already mentioned at *fig. 21*. Of cable ladders only the side panels provide shielding analogous to *fig. 21a*. Open cable ducts have a high shielding attenuation in the comers according to *fig. 21c*. This is shown in *fig. 31*. These zones are especially suited for the laying of susceptible cables. Covered ducts give the highest shielding attenuation.

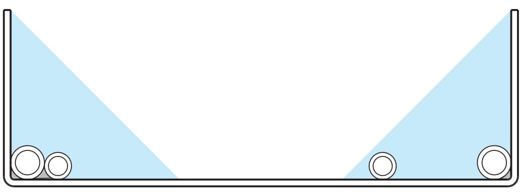


Figure. 31   Zones of a cable duct with the highest shielding attenuation

Application of the EMC-theory to cable ducts

Transfer impedance

Analog to the transfer impedance of wires, cable ducts also have a transfer impedance.

The definition of the transfer impedance of cables can be found in books on EMC (*e.g. Ref 1 and 2*).

The transfer impedance of a cable duct carrying a cable is shown in *fig. 32*.

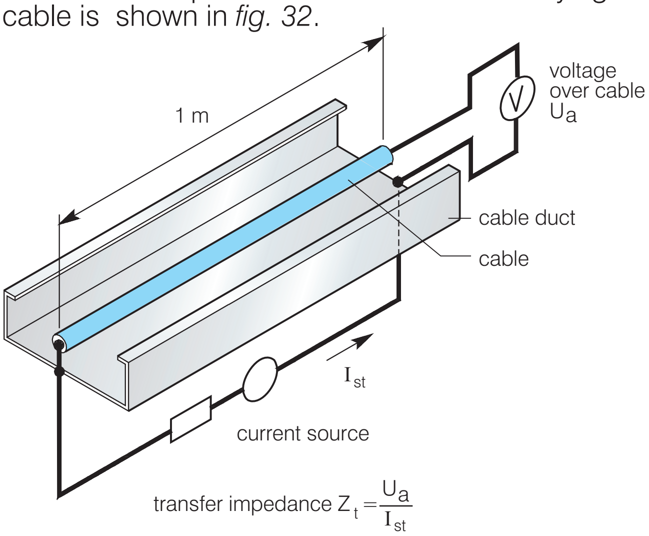


Figure 32 Transfer impedance of a cable duct

The transfer impedance Z_t of a cable duct is roughly the ratio between the voltage over the cable U_a and the inducted current in the cable duct (I_{CM}):

$$Z_t = U_a / I_{CM}$$

The transfer impedance is specified per meter length. The lower the transfer impedance of the cable duct the lower the voltage which is coupled into the cable. For a shielded cable this voltage is induced over the cable shield.

The parts of the cable duct each have a low impedance. In practice the impedance of the cable duct is mainly determined by the impedance of the connections between the parts and the connections between the cable ducts and the cabinets. By keeping these impedances low, a current flowing in the cable duct will induce a low voltage over the cable.

Experiments on a U-shaped cable duct have shown (Ref. 4) that the increase of the number of bolts used for a connection with strips from 4 to 12 decreases the transfer impedance at low frequencies (< 1 kHz) with a factor 2 and at higher frequencies (> 10 kHz) with a factor 4.

An increase from 4 bolts to 8 bolts, which number is often used in practice, decreases the transfer impedance at low frequencies with a factor 1,5 and at higher frequencies with a factor 2 (*fig. 33a*).

The transition from a connection with two strips to a connection with a U-shaped strip, fastened with the same number of bolts, decreases the transfer impedance at low frequencies with a factor 2 and at higher frequencies with a factor 4 (*fig. 33b*).

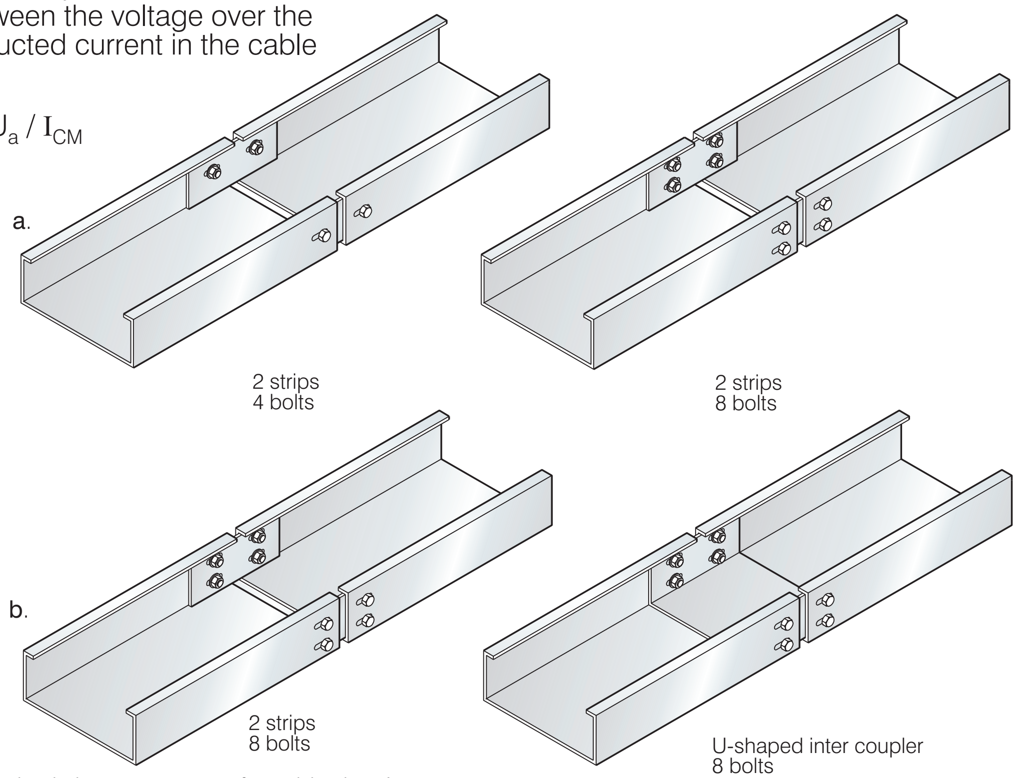


Figure 33 Connection methods between parts of a cable duct in connection with the value of the transfer impedance

Application of the EMC-theory to cable ducts

Holes and perforations

For fastening purposes the cable ducts are provided with holes. In practice these holes have no noticeable influence on the transfer impedance.

Some types of cable ducts are provided with perforation slots. The slots have to be punched in the lengthway direction of the cable duct (*fig. 34*). In that way currents in the cable duct will be obstructed as little as possible. Slots lying transverse to the lengthway shall not be used (*fig. 35*).

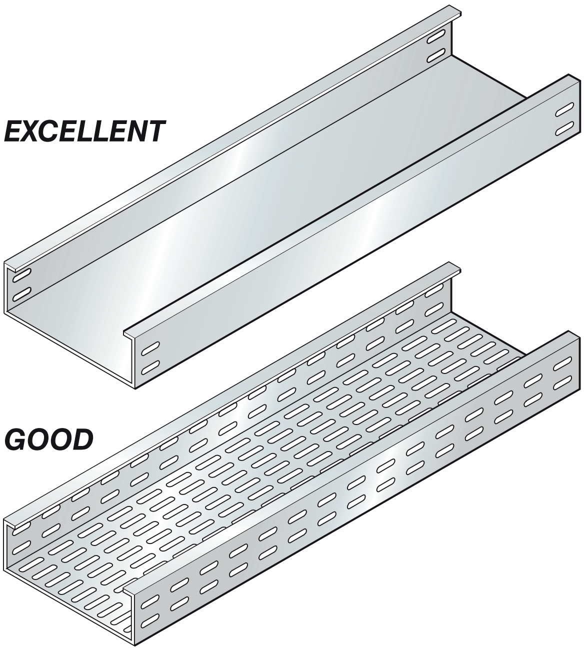


Figure 34 Slots in the lengthway

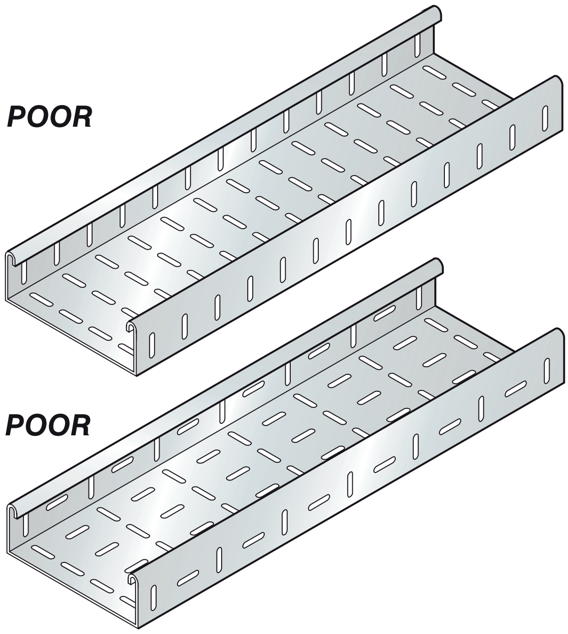


Figure 35 Slots transverse to the lengthway

Application of cable ducts

Cable laying on cable ducts
Cable ducts will be divided into some groups in sequence of preference from an EMC point of view:
- flat bottom cable ducts
- cable ladders
- wire mesh trays

In practice cable ladders are widely used.

Cables can be divided into three cable categories:
- indifferent cables, e.g. power cables
- sensitive cables, e.g. data cables
- jamming cables, e.g. control cables

The most sensitive and strongest jamming cables have to be laid close to the beams or plates of the cable ducts.

Preferably each cable category shall be placed in a separate cable duct (*fig. 36*).

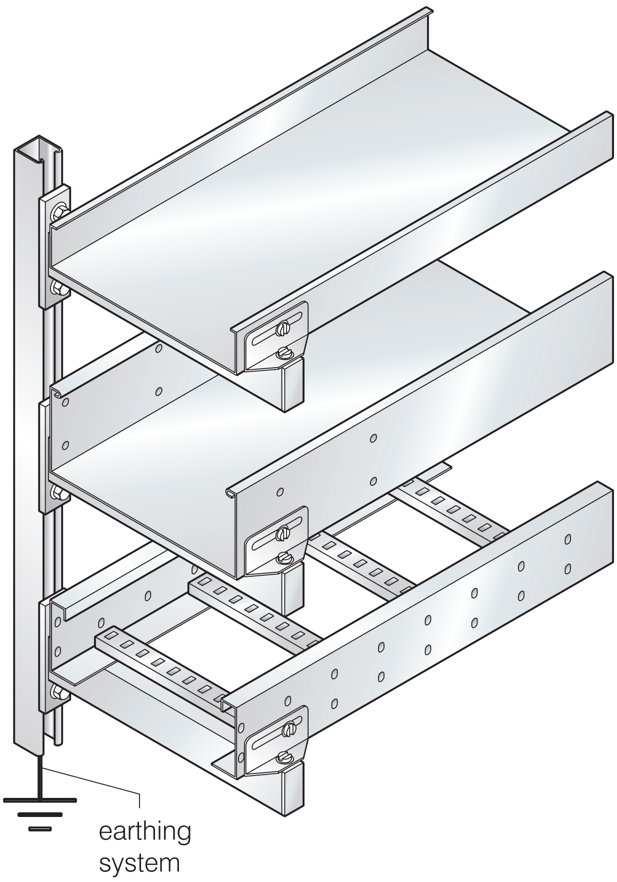


Figure. 36 Separate cable duct for each cable category Bounding of the cable ducts to the brackets

When more than one cable category is laid on the same cable duct a spacing between 15 cm (for flat bottom cable ducts) and 20 cm (for cable ladders) has to be applied between the categories (*fig. 37*).

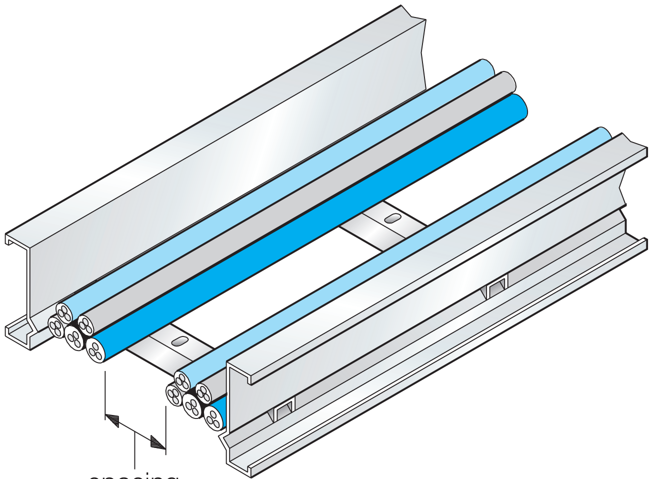


Figure 37 Spacing of 20 cm between cable categories on a cable ladder

Cable categories have to be laid in sequence of disturbing power of the signals. For instance the indifferent group has to be laid as a shielding barrier between the sensitive group and jamming group (*fig. 38*).

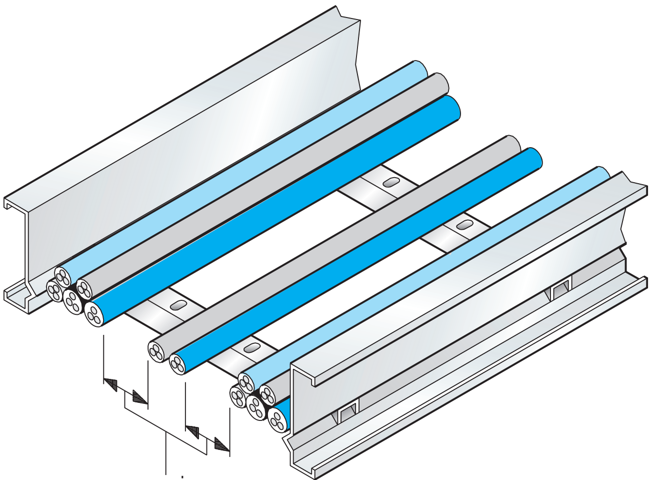


Figure 38 Indifferent cable category between sensitive and jamming categories

Application of cable ducts

Application of cable ladders and flat bottom cable ducts

For 'normal' applications cable ladders are used. These are applicable for cases where no strong jamming or very sensitive EM-environment is present.

Special situations may however be present such as:

- strong jamming cables running through an EM-environment with sensitive cables or equipment
- very sensitive cables running through an EM-environment with strong jamming cables or equipment
- both strong jamming and very sensitive cables are present.

In these cases often the use of cable ladders is not sufficient to shield the cables. Use has to be made of flat bottom ducts (*fig. 39*).

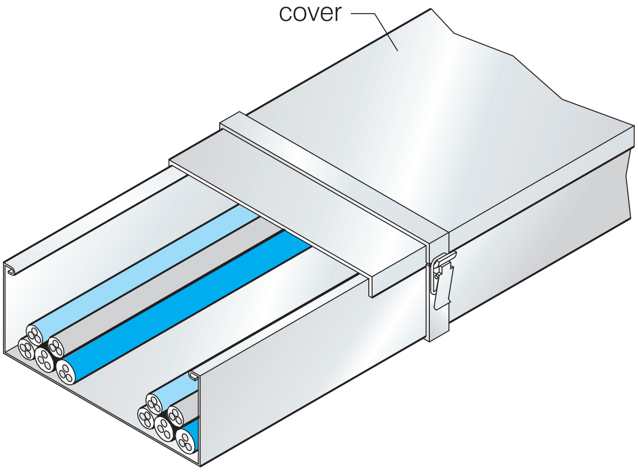


Figure 39 Flat bottom cable ducts have a shielding effectivity. The shielding attenuation can be enlarged by the use of covers.

Flat bottom cable ducts have the following advantages with respect to cable ducts:

- more cables are situated on or close to a conducting surface
- the shielding attenuation is larger than for cable ladders.

The shielding attenuation can be improved by installing covers over the ducts and by not filling them with cables to the top, but to remain one or more centimeters below the rim. The best way is to use one or only a few layers.

By high demands on the shielding effectivity the parts of the cable ducts shall not be connected by strips but by U-shaped inter couplers (*fig. 40*). These also reduce the transfer impedance of the cable ducts.

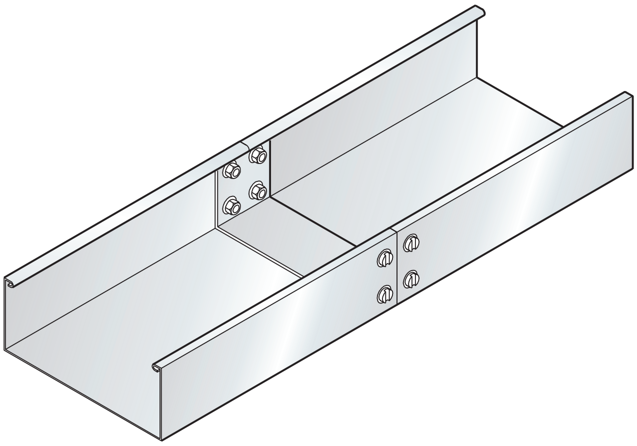


Figure 40 Connection with U-shaped inter coupler

When the foregoing-mentioned measures are related to Table 2 then the signs in the table mean:

X - 'normal' cable laying, e.g. with cable ladders

E - extra. Extra measures needed, e.g. cable ladders provided with perforated or solid plates or the use of flat bottom ducts

EE - extra-extra. All available measures needed, e.g. the use of flat bottom cable ducts with

Remark:

For most types of cable ladders covers are available. Because the bottom side of the ducts remains open the shielding attenuation of these ducts with covers is limited. If necessary bottom plates can be applied.

Separation strips

In case more than one cable category is laid on a cable duct, as well as applying distance between the categories, separation strips may be used between the categories (*fig. 41*). The cables may be laid against both sides of the strips.

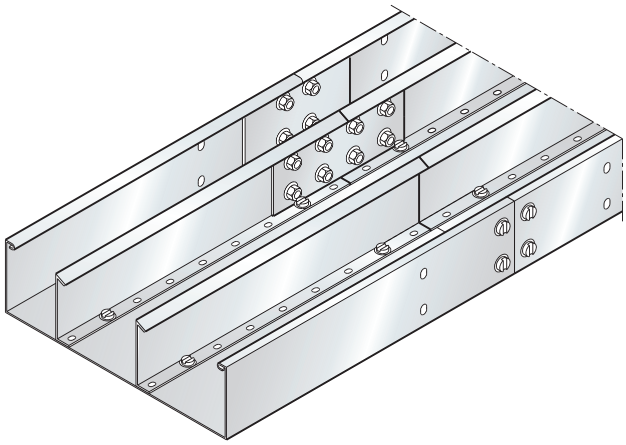


Figure 41 Cable duct with separation strips

Application of cable ducts

The separation strips shall be contacted with each other. At branches the strips may be interrupted for some length, but not for distances larger than 0,5 m (*fig. 42*). Separation strips function well, as the cable categories on both sides differ no more than one category. For open ducts there is a chance on signal coupling when the cables differ more than one category.

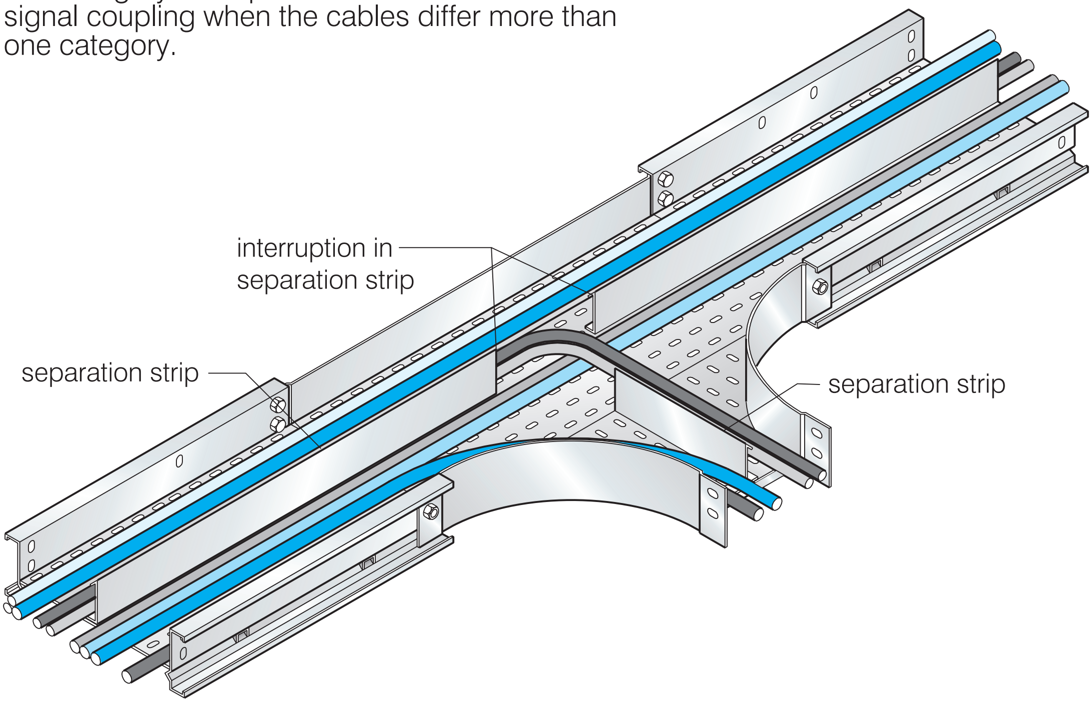


Figure 42 Cable ladder with conducting plates and separation strips

Cable ladders with additional plates

When in an EM-environment with strong jamming or very sensitive signals cable ladders should be used, these can be provided with bottom plates (*fig. 42*). The plates have to be contacted with each other. In this way the cable ladder resembles a flat bottom duct. With high demands on the shielding attenuation the cable ducts shall not be fully filled with cables or covers shall be used.

Wire mesh trays

Wire mesh trays function as a PEC (Parallel Earth Conductor) but have no shielding attenuation.

Wall channels

Wall channels are mainly used in office buildings. When they have to fulfil EMC-requirements the same measures as for cable ducts apply.

Conclusion

From an EMC point of view cable ducts shall be of metal. The parts of the ducts shall be connected with a low impedance, both mutual and with the cabinets, which also shall be constructed of metal. The best way to achieve this is a connection with broad plates of bare metals. In this way is achieved an earthing plane under the cables and an earthing system between the cabinets.

If next to that other EMC-measures as a good earthing system and a separation of cables into categories is present, the EMC of the installation can be improved with simply means and the chance on the occurrence of interference lowered.

Delden, October 2001

D.S.J.Schuuring M. Sc.

Annexes

EMC

Dimensions and conversion of units

H	=	Wb/A	=	V.s/A
Hz	=	1/s		
Ω	=	V/A		
S	=	1/W	=	A/V
T	=	Wb/m^2		
Wb	=	V.s	=	V/Hz

Abbreviations

CM - Common-mode

DM - Differential Mode

EM - ElectroMagnetic
EMC - ElectroMagnetic Compatibility
EMI - ElectroMagnetic Interference
EU - European Union

IEC - International Electrotechnical Commission

PC - Personal Computer
PE - Protective earth
PEC - Parallel Earth Conductor
PLC - Programmable Logic Controller

Symbols and units of quantities

Symbol	Quantity	Unit
A	area	m^2
A	attenuation	dB
B	magnetic induction	T
E	electric field strength	V/m
f	frequency	Hz
H	magnetic field strength	A/m
I	current	A
l	length	m
L	self-inductance	H
P	power	W
R	resistance	Ω
r	distance	m
Z	impedance	Ω
δ	skin depth	m
λ	wavelength	m
ρ	specific resistivity	Ω.m
σ	specific conductivity	S/m
Φ	magnetic flux	Wb

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Selection of cable duct types in accordance with the EMC-requirements

Introduction

Indications are made which cable ducts should be used in the specific EM-environments of an installation and which EMC-measures have to be applied.
The following aspects will be treated:

- material
- measures
- connection of parts
- earthing and bonding
- cable categories
- shielding.

Material

The materials used for the cable ducts are:

- Mill galvanized steel
  Thickness 1 - 2 mm
  Zinc layer ca 22 μm
- Mill galvanized and lacquered steel
- Hot dip galvanized steel
  Thickness 1,5 - 2 mm
  Zinc layer 50 - 70 μm
- Stainless steel
  Thickness 1 - 2 mm
- Aluminum, anodized.

Plastic as a material for cable ducts is not discussed because this material is not conductive and cannot be used to improve the EMC of the installation.

The thickness of the material is not very important from an EMC point of view. This is because at low frequencies the resistance is dominant and depends on the cross section of the conductor. This is usually large enough because of mechanical strength requirements. The thickness is normally not smaller than 1 mm. The self-inductance has small values.

The thickness of the material at high frequencies (above approximately 1 MHz) is for most metals larger than the skin depth. In this situation the skin layer determines the impedance.

Galvanized steel

From an EMC point of view the way the zinc is applied on the steel makes no difference.
Galvanized steel has the following advantages:

- the connection places can be left bare without a chance on corrosion
- the resistance between parts is low, which is also the case for the self-inductance because of the large contacting surface

Stainless steel

For the electrical contact between the parts the same applies as for galvanized steel.

Aluminium

Aluminum as a construction material can be used because of its low resistivity. A disadvantage is that the surfaces can have an insulating oxyde layer or can be anodised. The electrical contact between parts has to be achieved via the bolts with the help of lockwashers.

Lacquered surfaces

Lacquered surfaces insulate. To make electrical contact the insulating layer has to be scratched with the help of lockwashers, which intrude through the layer.

From an EMC point of view the electrical contact between parts provided with insulating layers is less effective than between bare surfaces, since the contact is only made via the bolts, while bare materials make contact via a surface area.

Choice of material

In an EM-enviroment containing high frequency signals both galvanized steel and stainless steel can be used.

When low frequency signals, e.g. in the supply frequency or harmonics, are also present, then steel is prefered because of its high magnetic permeablity, which achieves a higher shielding attenuation at low frequencies.

Dimensions of cable ducts

The cross section of a cable duct is important for the resistance of the cable duct, but the outline of the cross section is important with respect to the inductance. To keep the value of the inductance low, the outline shall be large.

In this situation many cables can be laid directly on the conducting surface. This improves the decoupling of cables and the shielding attenuation to the EM-environment.

In order of increasing size of cross section, the cable ducts are:

- wire mesh trays
- cable ladders with small height
- cable ladders with large height
- flat bottom cable ducts with perforations
- flat bottom cable ducts with solid bottom
- cable ducts with covers.

Selection of cable duct types in accordance with the EMC-requirements

Connection of the parts
The low impedance connection of the parts of the cable ducts is important. This applies to the connection between parts mutually and the connection of the duct to cabinets.
In sequency of improving electrical contact holds:
- 2 strips on each side of the cable duct
- connection via lips (one transition instead of two)
- U-shaped inter coupler.

For all connections:
- increased number of connection bolts.

Earthing and bonding
The earthing and bonding of cable ducts is achieved via the brackets and the connection to cabinets. The bonding via brackets shall be at distances not larger than 10 m.

Selection of cable ducts
The several types of Gouda Holland cable ducts are discussed on the pages H1E-1-28 up untill H1E-1-31. Requirements used in the selection of cable ducts are:
- mechanical strength
- required width
- required heigth
- chemical requirements
- hygienic requirements
- cost considerations.

Cable ladders can be used in most situations. This is the case, when the electrical and electronic parts of the installation follow the EMC-requirements.
Cable ladder types are:

Unic	H60 and H100	: page H1E-1-28
Resist	H60 and H100	: page H1E-1-28
Crafty	H100 and H130	: page H1E-1-29
Streamline	H40 and H60	: page H1E-1-29

When in the cable categories 'strong jamming' and 'very sensitive' only a few cables have to be laid, flat bottom cable ducts can be applied on the cable ladders to reduce coupling to other cables and the EM-environment.
Flat bottom cable duct types are:

Tray
Lock

In an EM-environment where high disturbance levels are present and cables of the cable category 'sensitive' have to be laid, flat bottom cable ducts are advised.
The same applies when 'jamming cables' are present in an EM-environment with low levels.
Cable ducts with solid bottoms fulfil higher requirements than cable ducts with perforated bottoms.
If necessary these cable ducts can be provided with covers.
Flat bottom cable duct types are:

Tray H28R and H53R (ZP or GP)
with (GP) or without (ZP) perforations
Lock OK3 and OK6: page H1E-1-31

In an EM-environment where very high disturbance levels are present and cables of the cable category 'very sensitive' have to be laid, flat bottom cable ducts without perforations are advised. The same applies when 'strong jamming cables' are present in an EM-environment with low levels. Cable ducts with solid bottoms fulfil higher requirements than cable ducts with perforated bottoms. If necessary these cable ducts can be provided with covers.
Flat bottom cable duct types are:

Tray H28R and H53R: page H1E-1-30
without (ZP) perforations
Lock OK3 and OK6: page H1E-1-31

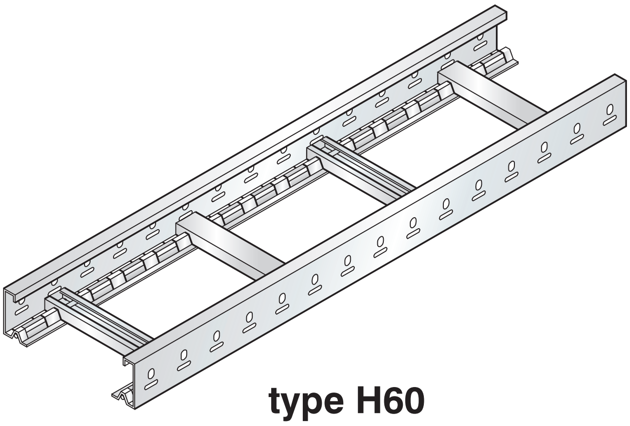
In an EM-environment where only disturbances of low level are present or all disturbances are of the same level wire mesh trays can be used. These cable ducts function as PEC's (Parallel Earth Conductors) and improve the EMC only slightly.
Wire Mesh Tray:

Tandem H53: page H1E-1-31

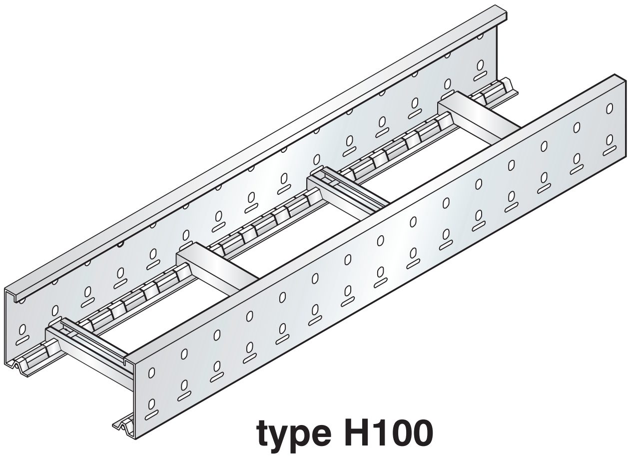
Plastic cable ducts do not improve the EMC of an installation.

Selection of cable duct types in accordance with the EMC-requirements

UNIC
Cable ladders



type H60



type H100

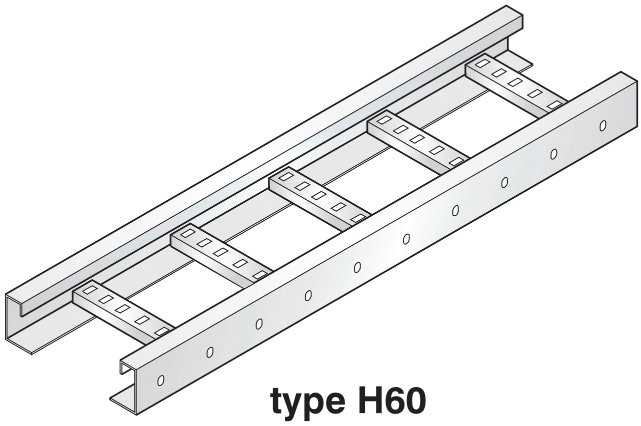
Material: Mill galvanized steel
Mill galvanized and lacquered steel
Hot dip galvanized steel

Cable ladders can be used in most situations, where the electrical and electronic devices of the installation are fulfilling the EMC-requirements.

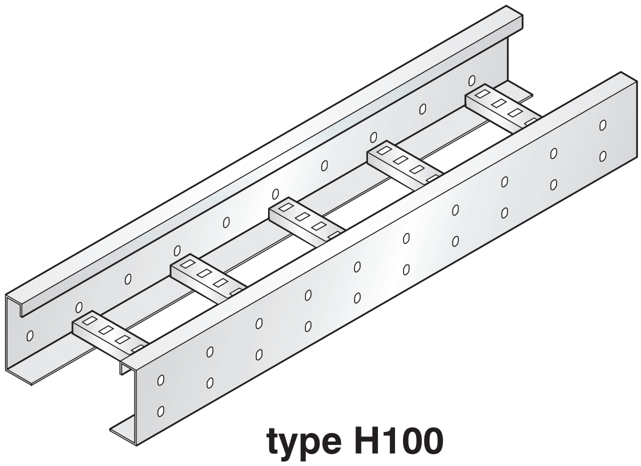
Measures to increase the shielding effectivity to reach EMC are the use of:
- flat bottoms cable ducts or bottom plates below the cable categories 'very sensitive' and 'strong jamming'
- use of covers.

With one or both of these extra measures the type Unic also can be used in EM-environments with high level disturbances.

RESIST
Cable ladders



type H60



type H100

Material: Stainless steel AISI 304
Stainless steel AISI 316

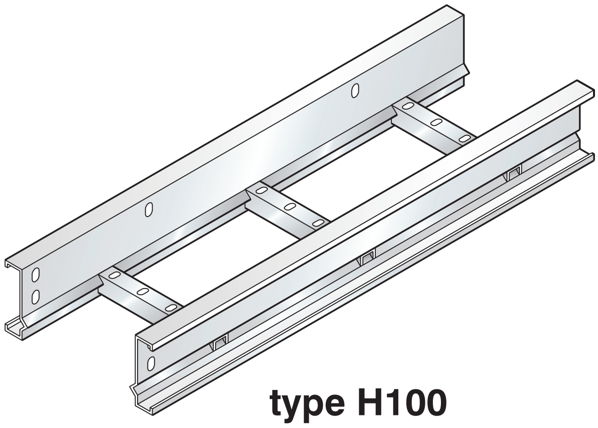
Cable ladders can be used in most situations, where the electrical and electronic devices of the installation are fulfilling the EMC-requirements.

Measures to increase the shielding effectivity to reach EMC are the use of:
- flat bottoms cable ducts or bottom plates below the cable categories 'very sensitive' and 'strong jamming'
- use of covers.

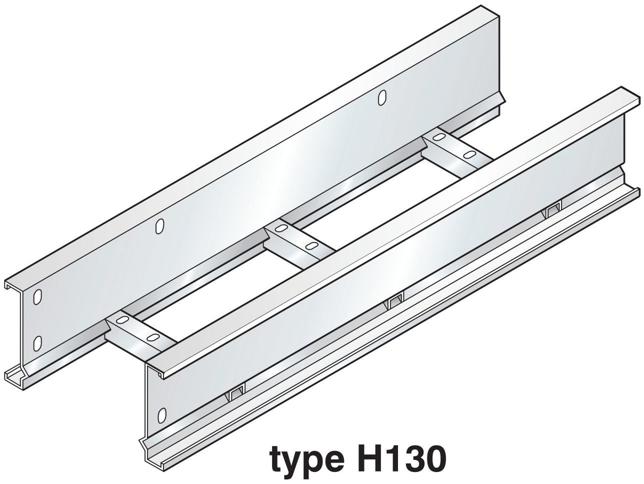
With one or both of these extra measures the type Resist also can be used in EM-environments with high level disturbances.

Selection of cable duct types in accordance with the EMC-requirements

CRAFTY
Cable ladders



type H100



type H130

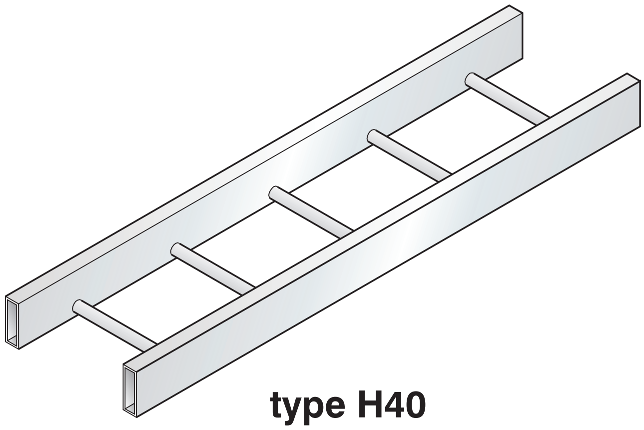
Material: Hot dip galvanized steel
Stainless steel AISI 304
Stainless steel AISI 316

Cable ladders can be used in most situations, where the electrical and electronic devices of the installation are fulfilling the EMC-requirements.

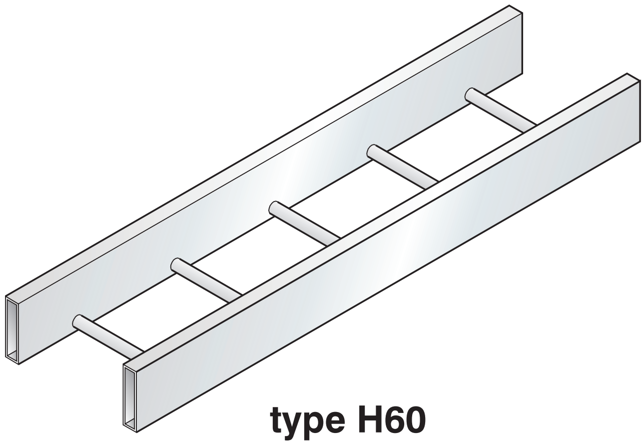
Measures to increase the shielding effectivity to reach EMC are the use of:
- flat bottoms cable ducts or bottom plates below the cable categories 'very sensitive' and 'strong jamming'
- use of covers.

With one or both of these extra measures the type Crafty also can be used in EM-environments with high level disturbances.

STREAMLINE
Cable ladders



type H40



type H60

Material: Stainless steel AISI 304
Stainless steel AISI 316

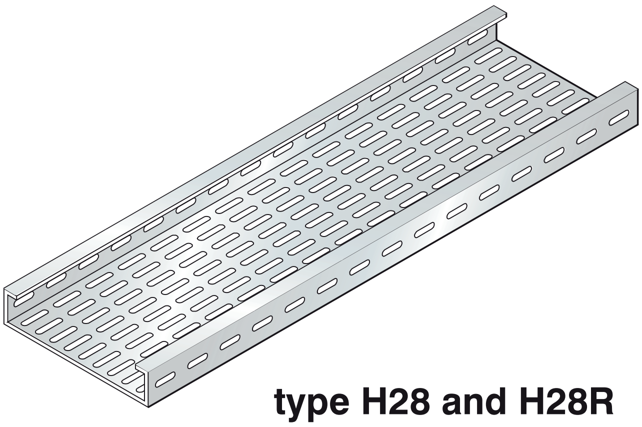
Cable ladders can be used in most situations, where the electrical and electronic devices of the installation are fulfilling the EMC-requirements.

Measures to increase the shielding effectivity to reach EMC are the use of:
- flat bottoms cable ducts or bottom plates below the cable categories 'very sensitive' and 'strong jamming'
- use of covers.

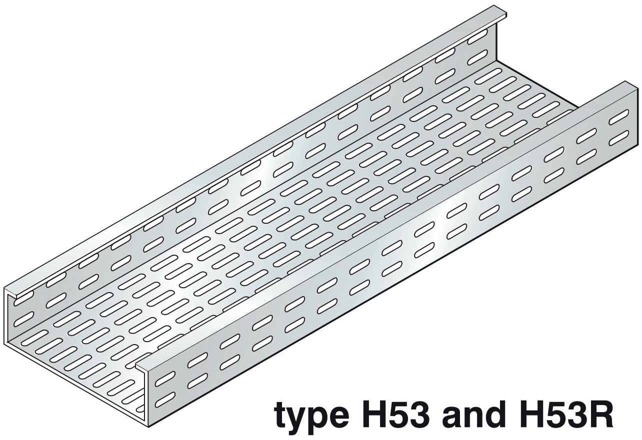
With one or both of these extra measures the type Streamline also can be used in EM-environments with high level disturbances.

Selection of cable duct types in accordance with the EMC-requirements

TRAY GP
Flat bottom cable duct perforated



type H28 and H28R



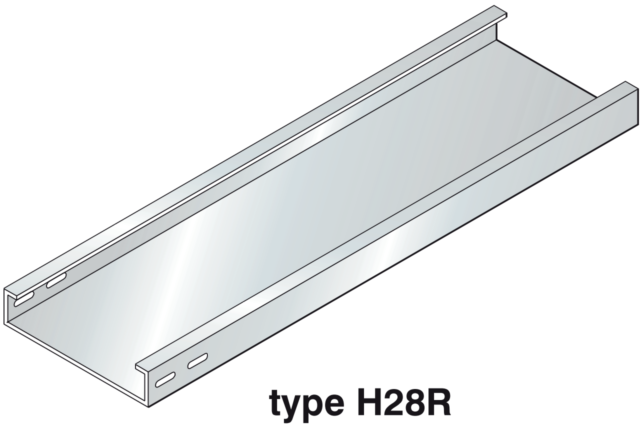
type H53 and H53R

Material: Mill galvanized steel
Mill galvanized and lacquered steel
Hot dip galvanized steel
Stainless steel 304/316

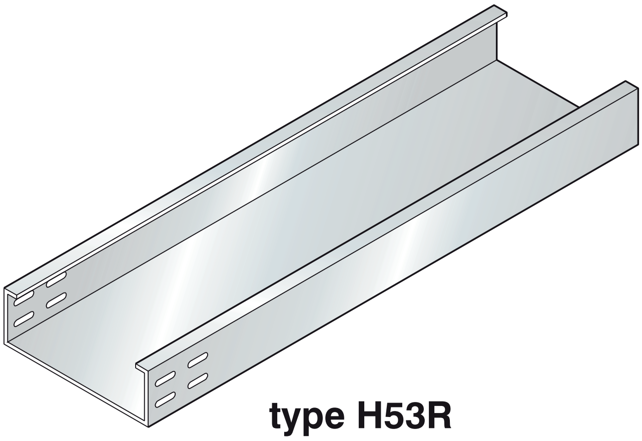
Perforated flat bottom cable ducts can be used in most situations. They can be used for sensitive cables in EM-environments with high level disturbances and for strong jamming cables in EM-environments containing low levels.

Measures to increase the shielding effectivity are the application of:
- covers
- U-shaped inter couplers.

TRAY ZP
Flat bottom cable duct



type H28R



type H53R

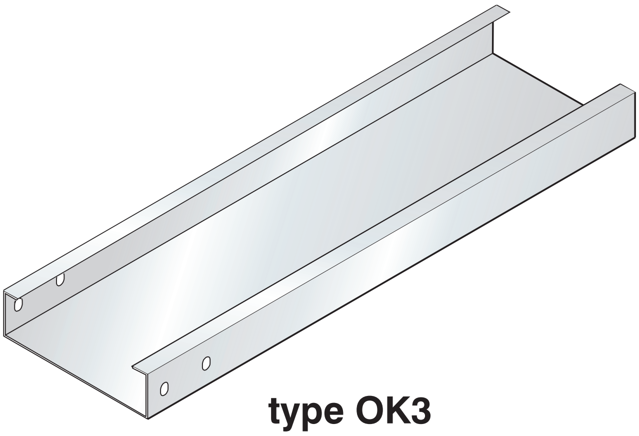
Material: Mill galvanized steel
Mill galvanized and lacquered steel
Hot dip galvanized steel

Flat bottom cable ducts can be used in most situations. They can be used for sensitive cables in EM-environments with high level disturbances and for strong jamming cables in EM-environments containing low levels.

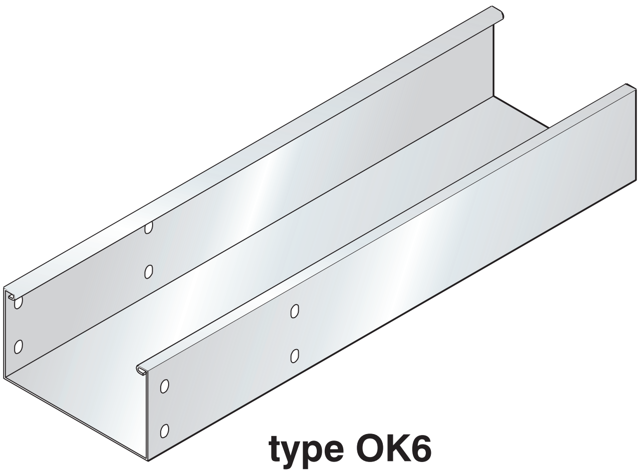
Measures to increase the shielding effectivity are the application of:
- covers
- U-shaped inter couplers.

Selection of cable duct types in accordance with the EMC-requirements

LOCK
Flat bottom cable duct



type OK3



type OK6

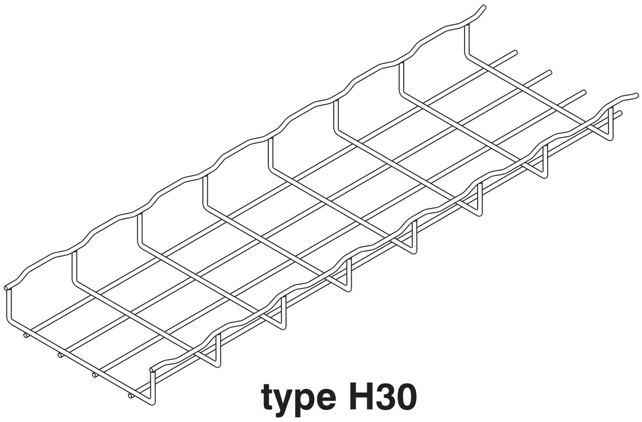
Material: Stainless steel AISI 304
Stainless steel AISI 316

Flat bottom cable ducts can be used in most situations. They can be used for sensitive cables in EM-environments with high level disturbances and for strong jamming cables in EM-environments containing low levels.

Measures to increase the shielding effectivity are the application of:

- covers
- U-shaped inter couplers.

TANDEM
Wire mesh tray



type H30

Material: Mill galvanized steel
Epoxy coating
Hot dip galvanized
Stainless steel AISI 304
Stainless steel AISI 316

In an EM-environment with only low level disturbances or only disturbances with levels of the same kind, wire mesh trays can be used.

These have no shielding attenuation, but improve the EMC by their function as PEC (Parallel Earth Conductor).

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