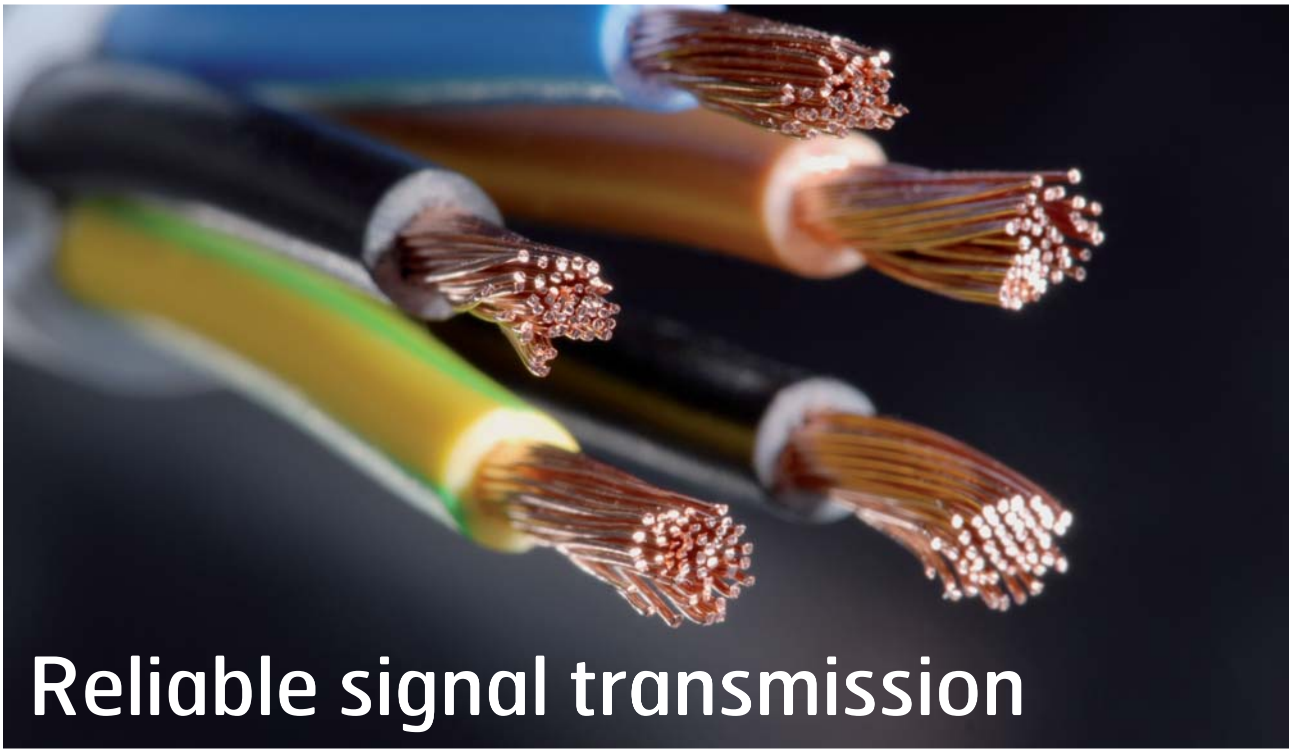

Cable shielding must be connected at both ends to the equipment shielding, otherwise it provides almost no benefit. Support for this statement is illustrated by simplified models in this article.

Everything relating to where and how cable shielding should be connected is discussed (the term "grounding the shielding" is incorrectly used, "connecting" is more appropriate). Some people claim that it is best to connect the cable shielding only at one end, while others say that it must be connected at both ends. Elements of the "one-end" school state that the end from which the signal is conducted is the one that must be connected, while others maintain that it is at the other end that the cable shielding should be connected. As usual, there are grounds for everyone being more or less right, depending on what you want to achieve with your cable shielding.

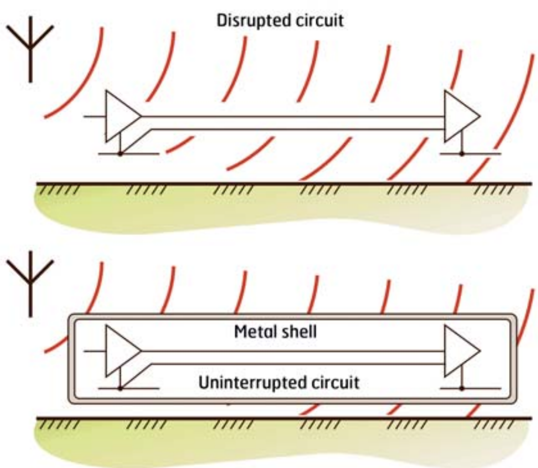

Figure 1. *Metal shielding reduces field connection to and from a circuit.*

BASIC MODEL

Imagine a signal transmission circuit (driver – cable – receiver) being disrupted by an electromagnetic field (see figure 1). One way (there are several) of protecting the circuit is to encase it in a metal box; we then say that the circuit is shielded. Correctly implemented, this reduces the field sufficiently so that the circuit is uninterrupted. If we now want the driver – receiver to be positioned far apart and still be shielded, the box will become cumbersome. So we make it two boxes with a flexible tube between them, i.e. a cable with a flexible metallic shell (see figure 2). This simple model shows that the cable shielding must be connected at both ends to both boxes; the cable shielding is a flexible replacement for a rigid cumbersome box.

Not connecting the cable shielding to only one, or none, of the boxes is the same as dividing the shielding box in the first instance into two or three sections. There is presumably no one who would claim that if you had a long, rigid box, this box shielding would be better if you divided the box into two or more sections, is there?

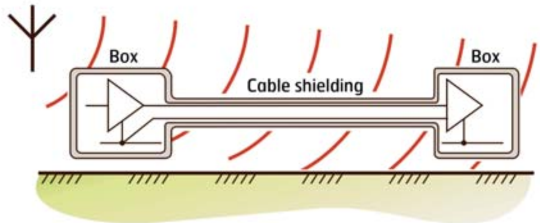

Figure 2. *Cable shielding is a flexible element of a shielding box.*

Shielding connection

Experience has shown that the signal transmission and the equipment function when the cable shielding is connected at both ends and when it is only connected at one end. There are explanations for this, but let's first look at the basic principles of cable shielding.

Another variant is that the signal transmission and the equipment function despite the fact that the cable shielding is not connected at all to any box, but then the cable shielding is not needed for any reason other than mechanical! This instance can also be electrically inferior to having at least one connection; the cable shielding boosts the connection to the surroundings.

SHIELDING PRINCIPLE

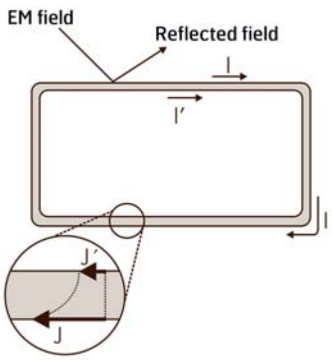

Figure 3. *Shielding through both reflection and reduced current density (absorption).*

The field, which exposes the metallic box, causes current to flow into the metal shell (see figure 3). The current on the surface results in a counter field and we get reflection. At low frequencies, this current utilizes the entire material thickness, but with increasing frequency a smaller and smaller proportion of the plate's thickness is used. The current density is lower on the "lee side" of the plate due to the so-called skin effect. We get a weaker field and inside due to both reflection and absorption. If the box, mentioned above, is now divided into two boxes, linked together by a homogeneous tube, this does not change the situation in principle. The shielding function of the slightly cumbersome "box" is the same as before.

Now you might wonder how current can flow into a metal box suspended in empty space and not connected to anything? The answer is that it is the same way current passes through a wire end suspended in the air, otherwise known as an antenna. Boxes with electronics are not often suspended in "empty space" (apart from battery-powered mobile devices, such as mobile phones, pocket calculators, laptops, etc.); there is generally some electrical connection somewhere, at least via a current supply cable or stray capacitance, to surrounding conductive structures. This connection usually consists of the protective earth conductor (PE) in the current supply cable.

The field's magnetic component induces a loop voltage in the loop that is formed (see figure 4). The loop voltage conducts a current through the shield structure (building structure; PE conductor, boxes and cable shielding). The current in turn gives rise to a counter field (reflection) and thus reduced effect, i.e. we have a shielding action due to

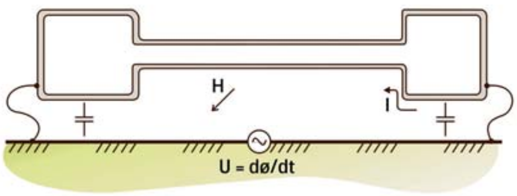

Figure 4. *The field gives rise to a current in the shielding structure.*

this loop current. Compare with a short-circuited winding around a transformer! The better the short circuit, i.e. the lower the impedance in the loop, the better the shielding action.

Unless the cable shielding is connected at one end, we will probably still have a loop via the signal transmission circuit, the common for which is generally connected to the equipment casing at both ends. A loop like this has higher impedance than a cable shielding loop and thus produces a lower shielding effect. But what is worse is that the portion of the loop voltage divided between the ends of the signal circuit will disrupt it (see figure 5)!

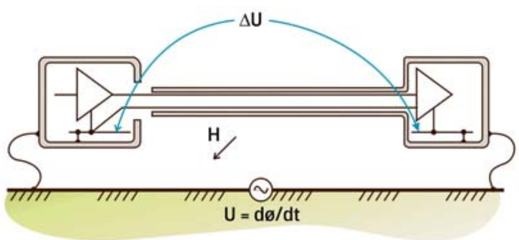

Figure 5. *Induced loop voltage disrupts signal transmission circuit.*

The common conductor (return conductor) is subject to impedance and the portion of the loop voltage that arises over this conduction impedance is thus in series with the useful signal voltage.

Cable shielding can be found connected at one end via a capacitor; one reason will probably be to avoid the circulating current at relatively low frequencies. But we then gain no shielding effect either! Even if the cable shielding is connected to the boxes at both ends, at low frequencies (the penetration depth is equal to or greater than the metal thickness) there will be voltage between the circuit ends (known as common mode voltage), but this is lower, due partly to the lower impedance in the cable shielding and partly to the aforementioned shielding effect.

The only effective way to avoid this type of effect is to introduce isolation somewhere in the loop, usually in the signal transmission circuit.

IDEAL CABLE SHIELDING

If the frequency is sufficiently high, i.e. the metal shielding (boxes and tube) is two–three times greater than the penetration depth, a minimal current will flow to the inside of the shielding, which gives rise to a much smaller field than the original, and a significantly lower voltage on the inside of the shielding. This applies to both the boxes and the tube.

The current that flows to the inside of the shielding, as mentioned, gives rise to a drop in voltage due to the impedance of the surface. For boxes where the surfaces are almost as broad as they are long, this drop in voltage is fairly small. On the inside of the tube, however, the internal surface is relatively narrow and long, which means, for low frequencies at least, where sufficient current penetrates the material, a substantial drop in voltage occurs. At high frequencies, the drop in voltage on the inside of the tube is almost always negligible.

NON-IDEAL CABLE SHIELDING

The tube as cable shielding is rather impractical, which is why the cable shielding is normally designed as a braided hose of numerous metal wires with appropriate surface treatment (tin-plated copper). This hose is not as impervious as a tube, because current can follow the wires to the inside of the hose and any field can leak in through the small unavoidable gaps between the wires. This internal current and field leakage give rise to an internal drop in voltage, which increases with increasing frequency. This is just the opposite to the situation with the homogenous tube; the homogenous tube becomes better shielding with increasing frequency, while the braided hose becomes worse.

The ratio between the voltage on the inside of the cable shielding and the current on its outside is known as transfer impedance, among other things, and is measured in ohms per meter of cable shielding length. The transfer impedance is a measure of the cable shielding's quality; the lower the transfer impedance, the better the shielding. Or in other words, the lower the voltage for a specific current, the better the shielding effect. Examples of cable shielding transfer impedance can be found in figure 6. Good cable shielding has a transfer impedance in the region of 10 milliohms per meter.

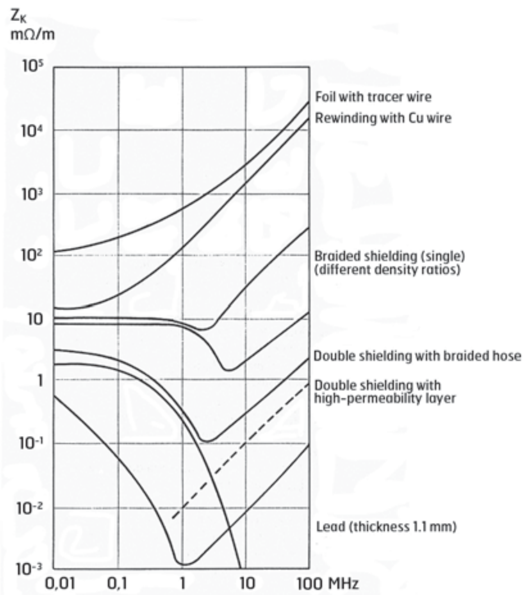

Figure 6. *Transfer impedance of different types of cable shielding. Reference: Nissen, "EMC Manual".*

IDEAL CABLE SHIELDING CONNECTION

Thus far we have assumed that the cable shielding (tube or hose) is connected to the boxes around its periphery by its entire cross section. This does not produce any significant contribution to the drop in voltage on the inside of the shielding and thus does not impair the shielding effect.

The reality, however, is not so ideal. If the cable shielding is connected to the boxes using connecting wires, a drop in voltage will arise in the wires (see figure 7).

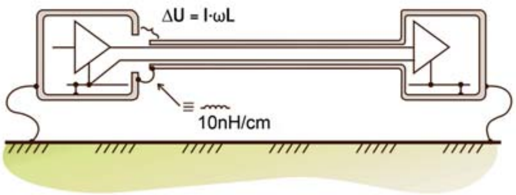

Figure 7. *The danger of connecting cable shielding using small-gauge wire. Induced voltage increases over the internal circuit.*

This drop in voltage is dependent on frequency, because the wires are both resistive and inductive. The inductance in an ordinary connecting wire is in the region of 10 nH per cm. Consequently, the longer the wire and the higher the frequency, the higher the drop in voltage. This drop in voltage can be several orders of magnitude higher than the drop in voltage inside the cable shielding, even if the cable shielding is several meters long.

Example: a 5 cm wire has an inductive reactance of approximately 300 milliohms at 1 MHz. This is equivalent to leakage in 30 meters of cable shielding with a transfer impedance of 10 milliohms per meter.

The circuits inside the boxes now detect the internal voltage as a "common mode" voltage. The current in the shielding connection wires also gives rise to a magnetic field that induces voltage in the adjacent signal conductors. The drop in voltage in the wire also conducts a capacitive current to the signal conductors via stray capacitance between the conductors and the cable shielding. Wire connection of cable shielding is therefore not a good connection method except as a means of protection against low-frequency disruptions.

If you remove the cable shielding connection, the voltage across the gap is largely equal to the loop voltage and thus the shielding effect is even poorer (see figure 8). The capacitive connection to the signal conductors increases, but no voltage is induced because there is no current.

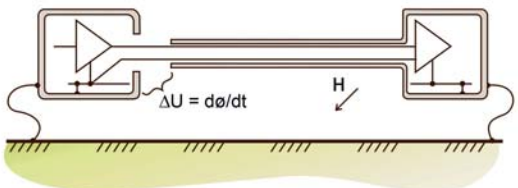

Figure 8. *The danger of not connecting cable shielding. The entire loop voltage is over the internal circuit.*

Shielding connection

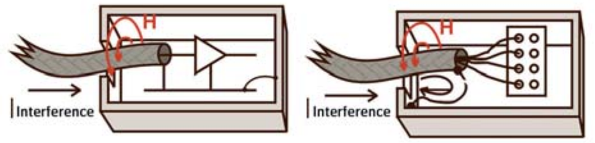

Figure 9. *Cable shielding connection that connects interference to circuits in the box.*

In specific low-frequency cases, this can be one explanation for wire-connected cable shielding functioning worse than non-connected shielding, but it can then be due to the cable not being connected to the box in its wall at the lead-through point (see figure 9). The current in the cable shielding or in its, often long, connection ("grounding") then gives rise to a field inside the box and the field disrupts any circuit in its vicinity. Improper handling (two faults cancel each other out) is no reason to issue a poor rule of thumb.

It's foolish to open up shielding to make it better. A poor connection is almost as bad as no connection. In principle therefore, cable shielding should be connected in the same way as you would using a coaxial cable, i.e. around its entire periphery and with very low contact resistance to the shielding boxes' walls at the lead-through point (in the connector).

EXCEPTION

In some cases, cable shielding may function despite not being ideally connected:

• at low interference frequency with short wire connections at both ends and short electric cable.

• at low interference frequency with wire connection only at one end where the unshielded section of the signal circuit is very short electrically with a very high circuit impedance as well as capacitively coupled field.

One example of the latter is an unshielded encoder insulated and installed far from disruptive cables and equipment and connected to a long shielded cable. The encoder is a few centimeters long and the cable several hundred meters, and the interference frequency is 50 Hz. The cable shielding is then only connected at the box end and must definitely not be connected ("grounded") to a building or machine structure at the encoder end!

There is probably a risk, if you use short conductors for cable shielding connection and powerful stray currents (50 Hz) occur or short-circuit faults, that the thin wire connection will burn out. Strong 360° cable shielding connections can handle these currents. However, this risk is no reason not to connect the cable shielding to the box, but is grounds for not connecting the box to the building structure or to protective earth conductors. With a well-designed potential equalization system there will probably not be very much current in the cable shielding, because it has higher impedance than the potential equalization system.

One method for achieving isolation in a permissible manner is with an isolation transformer. Encoders and other circuits that do not need 230V supply should be isolated from the building's ground and protective earth conductor system. When using wire connections for cable shielding this gives rise to additional interference connection to the electronic circuits in the boxes (see figure 9). The cable shielding or cable shielding connection conducts interference current inside the box shielding. By connecting the cable shielding to the outside of the box the interference current is diverted to the box instead. In some installations it is prohibited to connect cable shielding at both ends (why?) and the cable shielding can then still function passably at higher frequencies if it is connected to a capacitor. Please note that this capacitor connection will be fairly frequency-dependent, including resonance problems, and also burdened with the same failings as wire connections.

You may feel that the cable shielding functions, as it reduces the effect on the specific signal transmission circuit between the boxes. In other contexts, you may feel that if the equipment in one box or the other is not being disrupted, then the shielding is functioning. Both views are, of course, sound. If the equipment functions when the cable shielding is not connected at one end or the other, but is disrupted when it is connected at both ends, this is probably due to the cable shielding being connected incorrectly and not the cable shielding as such not functioning because it is connected at both ends. One reason for the equipment functioning despite the shielding only being connected at one end could also be that the cable shielding is not actually needed.

RULE OF THUMB

In the current situation, with increasing quantities of high-frequency interference sources, cable shielding tends to be used at all frequencies and in all possible instances. The basic rule is to connect the cable shielding at both ends to the equipment boxes' metal casing (see figure 4), and the cable shielding connection must be around the shielding's entire circumference with the equipment casing (see figure 10), either directly via a specific fitting or via the connecting device's metal casing. Please note that all components of the connecting device must have good 360° contact with each other, and the half of the device attached to the equipment must have good electrical contact with the metallic equipment casing. It is possible to look out for the latter through the choice of surface treatment and by using metallized plastic boxes.

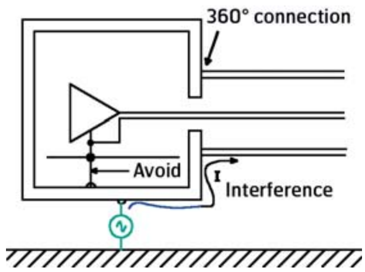

Figure 10. *Principle for correct cable shielding connection.*

The contents of this folder have been drawn from an article written by Ulf Nilsson in the magazine Electronic Environment no. 2, 2008. Ulf Nilsson from EMC Services has been involved in the EMC field for more than 35 years and has conducted EMC training for hundreds of engineers in Europe and the USA. He is a member of IEEE EMC Chapter, a NARTE-certified EMC engineer and technical EMC editor of the magazine Electronic Environment. Ulf has been co-author of "Praktisk El- och Telestörskydd" (Practical Electrical and Telecommunication Interference Protection), FMV's EMMA handbook and has delivered lectures at a number of EMC seminars.