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AREALIS

Optimizing signal integrity in high-end audio cables using novelty materials and implementation topologies

A paper on high-end audio cable technology featuring newly developed shielding and dielectric materials by Aequo Audio, as well as an overview of effects by their implementation and a problem solving grounding topology resulting in raised quality of system performance.

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Preface

This writing is accompanies the introduction of a new cable portfolio under the brand name of AREALIS, as developed and made in-house at Aequo Audio. In these cables two newly developed materials are implemented:

FerroGuard™: a special braided shielding material that does not need to be coupled to neutral ground or earth-ground to effectively prohibit interference noise, for it is lossy and dissipating without adding unwanted capacitive effects. More importantly, it protects the signal integrity from common modes towards ground and other relatively low-frequency noise that is in the actual audio band. This is normally only possible when connecting both ends of the (silver, copper or aluminium shields) to ground and this procedure comes often with the side effect of introducing ground loops. This unique problem-solver has therefore a very big impact on audio signal quality: it makes cables perform and sound as if unshielded, yet with an *extremely* low noise floor. It also makes for a suitable shielding solution in speaker cables, even if using two-phase push-pull amplifiers.

UDCP™: This novelty Ultra Dielectric Crystal Polymer material was born from research done on how to push further forward what was dielectrically possible in the D I L U V I U M crossover filters. Even as a solid material it far surpasses the level of foamed dielectric materials, having a dielectric constant as low as 1.2 (!). Implemented in our Exclusive signal cables as a spacer component to mount insulated cable parts in air tubes, it enables maximum signal integrity beyond today's best performance levels. As applied in our double mono RCA cable, it makes it possible to combine left and right channels in one stereo cable without electronic cross-talk between channels. We also use a soft woven version of this crystalized polymer fibre for covering the ends of Exclusive Speaker Cable (from splitter at both ends), Exclusive XLR cable for Speakers (from splitter towards speaker) and the Exclusive Double Mono RCA cable (from splitter at both ends). This crystalized material is very heat resistant (>370^{0}C).

Thanks to the above and various other proven technology, the quite spectacular results in combined properties enable to reach a lower noise floor in audio systems as a result of better attenuation of interference without the usual draw backs. This comes in full combination with exceptional overall signal integrity and speed, such as also suggested by the superb properties of the fully shielded/guarded Exclusive signal cables below:

	XLR (high gain)	**XLR** (low gain)	**RCA**	**XLR digital**
Char. Impedance:	150 ohm	100 ohm	93 ohm	110 ohm
Mutual Capacitance:	8.8 pf/ft	13 pf/ ft	13 pf/feet	13 pf/feet
Velocity factor:	78%	69%	84%	76%

In comparison, signal cables such as commonly found in the upper echelon often compromise one or more very relevant aspects such as conductor size (e.g. standard 'microphone-type' XLR cables) and/or use lower grades of dielectrics resulting in higher stray capacitance than listed above and/or often provide lower bandwidth and speed and/or higher resistive losses (for more product information, see the product specifications and info).

This writing provides the context and technical information explaining the significance of these newly-introduced cable products. Instead of adding all kinds of nice graphs that should prove how well Ferroguard™ works, I like to offer all relevant information to understand the impact of the featured technology, and stress how in truth this will differ from each practical case to the other. What stands firmly however, is that in practice it indeed offer virtually always much better protection from audible interference than current types of shielding do now. You might review this paper also as an effort for a more universal applicable understanding of the most important aspects involved with high end audio technology however, it does especially support and highlight the AREALIS products made commercially available. It explains why and how these new cables might very well help to solve real issues encountered by hooking up the most demanding high-end audio systems and have the potential of significantly upgrading its sound quality in all aspects and by any standard.

Introduction (on shielding)

Perhaps the single most relevant and imported area of achievements among our research and development on topic of improving high-end audio cables, is our new shielding method (material and implementation that also enables problem-free grounding). To understand the role of guarding against noise interference, and the consequences of applied shielding technology, we must first introduce the relevant factors described below.

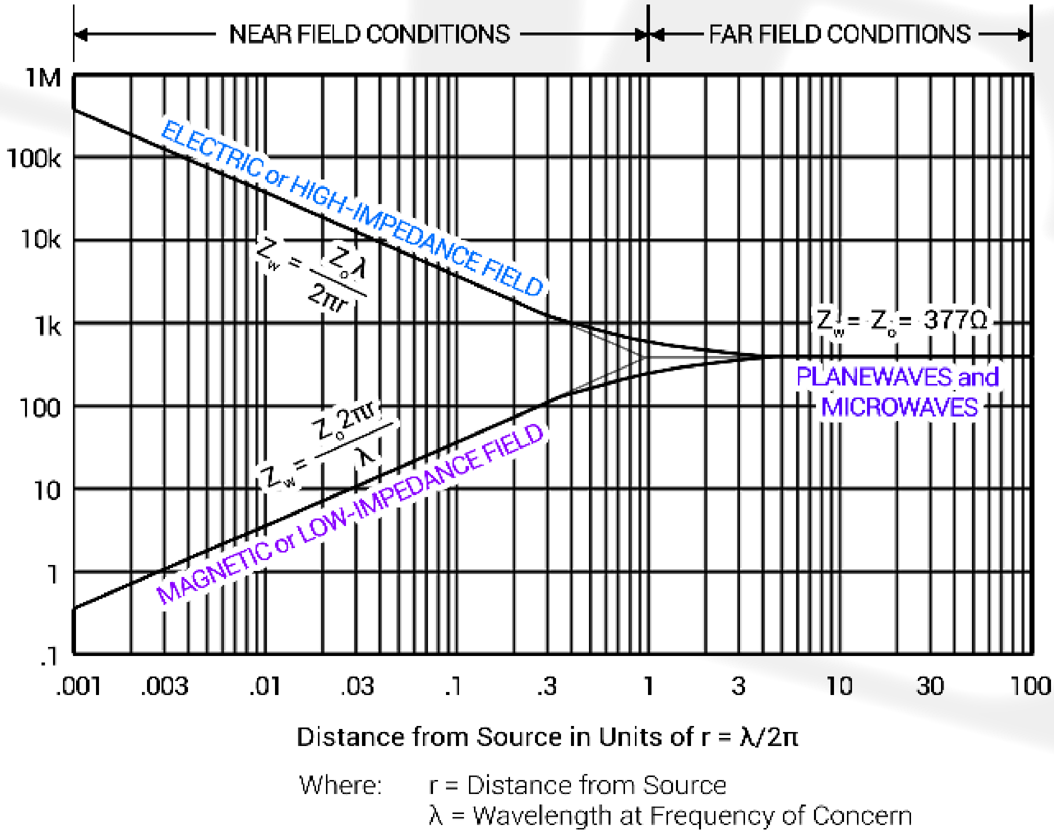
The RF (airborne noise) shielding effectiveness of a material is a function of:

1. the field-type of the energy impinging on its surface;
2. the frequency of the RF energy;
3. the material's electrical conductivity;
4. the material's magnetic permeability;
5. how well the shielding structure (around the protected item) is sealed.

For these will affect the amount of reflected energy by the material, as energy is:

1. reflected from its surface;
2. absorbed as it passes through the shielding material;
3. re-reflection on the second (inner or outer) surface;
4. not being absorbed if travelling through gaps in the material's structure.

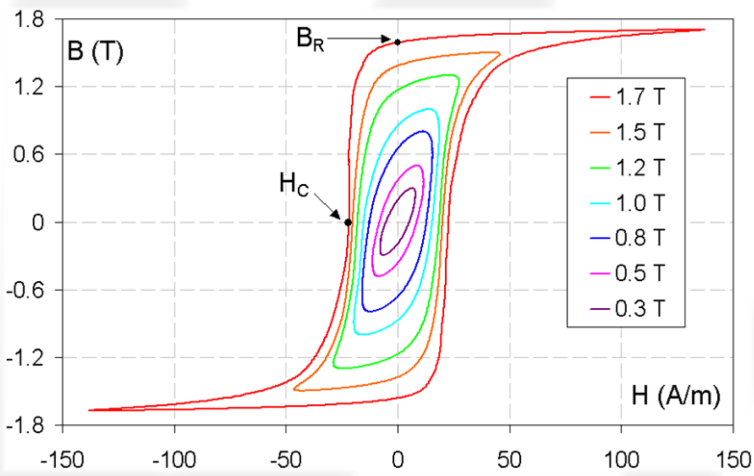
As for field-type being electric vs. magnetic (or also described as voltage vs. current), this becomes a more important parameter to consider when choosing a material at shorter distances and lower frequencies. With regards to tests and certification of consumer electronics, there is a focus on noise caused by shorter wavelengths and/or electric (voltage-driven) fields rather than noise from magnetic (current-driven) fields, with especially lack of attention regarding fields of lower frequencies that are in fact very important to *audio* from 20hz-20khz.



It's important to acknowledge that lower frequency emitters of magnetic energy such as inductive coils or carriers of harmful noise of the grid's typical 50/60hz modes and related harmonics, can be best treated with *ferro-magnetic* shielding solutions as close as possible to the emitter whilst creating maximum distance between the emitter and sensitive equipment. Such ferrous (with or without actual iron) and highly permeable and highly absorbing materials might provide shielding down to DC (zero frequency), whilst at very high frequencies (far above the audio band) the more conductive metals may provide the best shielding. Many ferro-magnetic materials can however be easily magnetically charged by this same process of absorption, potentially leading to unwanted inductive effects if used again in close proximity to the signal we want to guard from interference.

Ferro-magnetic materials can be either *soft* or *hard* in relation to how much magnetic energy they need to demagnetize: soft means low magnetic coercivity (easy to demagnetize) while hard ones are of high coercivity (hard to demagnetize). But even without applying an opposing magnetic field, magnets can lose energy over time. So when choosing an electromotor's permanent magnet we probably want to use a soft material to save cost and save energy while magnetizing it, but at the same time want it to be low-loss in order to maintain its magnetism for many years. In case of ferromagnetic shielding we want quite the opposite: soft yes, so it can attenuate noise but now high-loss so it can rapidly rid itself from magnetism without applying an opposing magnetic field. This energy is then simply turned into harmless heat.

The amount of energy left after a loop of magnetizing and de-magnetizing is defined by its level of *retentivity*. On the right: a range of hysteresis loops (counter clock wise) of orientated soft magnetic material. H_C is the coercivity and B_R is the retentivity. The wider the outside loop is, the higher the coercivity.



It is in fact not so easy to find the most suitable ferromagnetic material that has the ideal set of (sometimes contradictive) properties in order to use it as a high end audio shielding material without any unwanted side effects, such as increased induction added to the signal or consequences derived from the need for ground connections. And more problems arrive at the table, such as corrosion issues and lack of strength and flexibility. Many of these ferro-magnetic materials are brittle and unsuitable for making a shielding wire braid from it at all.

Aequo Audio's novelty FerroGuard™ shielding material for high end audio cables under the AREALIS brand name does have that ideal mix of properties. It is corrosion free, durable and flexible, whilst very effective against low frequency interference (much more effective than for example stainless steel). As being both 'soft' and very lossy of magnetic energy with minimum retentivity, this implicates that it does its job without turning into a permanent magnet and that it can be allowed to perform as a floating but very effective guard against noise without unwanted inductive effects. The many benefits and positive implications over the use of traditional shielding materials will be discussed in this paper. It will also explain more about the other most relevant cable properties and how Aequo Audio cables were specifically made to excel in each area. Furthermore, this paper tells how FerroGuard™, as well as the special UDCP™ insulation technology solve some of the most important problems encountered in audio cables ultimately pushes forward next-level performance in audio cable signal integrity.

Traditional shielding materials and components

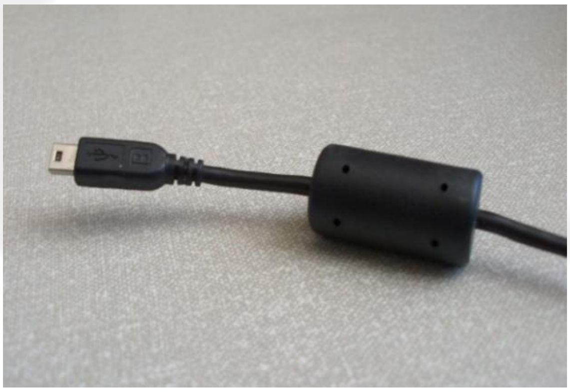
Copper (and its alloys): versatile and widely used for small shielding components and as braid (or foil) to provide shielding in cables. It is easily soldered and highly conductive to be only slightly surpassed by silver. It has limited corrosion resistance. It's easy to manufacture, but higher in raw material costs than aluminium and it has a higher melting point. Only very thick copper (unsuitable for cables) may shield down into the kHz range, yet still far from the lower frequency area where (especially power grid) interference inflicts noise in the audio band. Its higher raw material cost prevent the more common application in enclosures of consumer electronics especially since permeability and thus current-driven shielding is only a small bit better than that of aluminium.

Aluminium (and its alloys): second commonly used shielding material after copper and the most frequently used metal for various shielding foils as well as enclosures. Small aluminium parts are more difficult to manufacture than their equivalents made from copper. Surface coating is needed to prohibit the typical initial aluminium-oxide layer (that is low in conductivity). Given the 50-60% lower electrical conductivity of aluminium alloys compared to copper alloys, thicker shields are needed if to match the shielding performance of copper.

Steel tubes: sometimes in industrial cable installations, screen-less cables and wires are enclosed in steel pipes in order to protect them from interference noise. Analysis by research (literature describing both practical measurements as well as by modern Finite Element Analysis) show that this type of shielding/guarding is indeed effective against wideband frequency noise, but comes with harmful proximity effects such as raised low frequency induction and high frequency resistivity that vary per cable configuration type, spacing between wire and pipe, and the diameter and thickness of the pipe. Much like FerroGuard™, these pipes are also high in magnetic permeability explaining their effectiveness against low frequency noise, but this where all further comparisons fully stop. The technically totally different material with a complete set of different properties, as well as its different operational-topology and overall resulting characteristics, place it in a different category altogether: FerroGuard™ is very effective, yet free from these unwanted close-proximity effects.

Ferrite beads: these add-on chokes are applied to filter common mode noise and can be often found on digital cables such as generic USB cables. It consists of a short winded coil around the ends of a cable. This coil is encapsulated in a soft ferrite magnet to enhance inductive flux and dissipate the energy created by noise passing through the coil. It acts as a low pass filter to prohibit high frequency noise but helps little below that filter point that is still high, even with more than usual windings. It might also induce some effects that make it unsuitable for analogue audio cables. In contrast, FerroGuard™ is neither a coil nor a magnet and it does in fact attenuate interference noise in the lower frequency band.

Example of a typical ferrite bead implementation found mounted in a plastic cylinder on a generic USB cable:



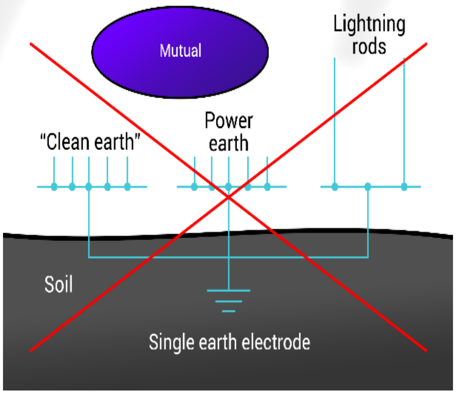
Necessity of shielding, neutral-grounding and (safe-) earth-grounding

The implementation of shielding RFI/EMI is a must in audio appliances. Harmful digital noise might be effectively dealt with in proper electronic PCB design and grounding routes, but things especially complicate when a power supply is involved. Probably the most overlooked and/or harmful type of noise affecting the audio frequency band is EMI emitted by power-supply related sources (resulting from the power-grid's 50 or 60 Hz and its harmonics), fully making their way in the lower (and very audible) frequency band of the analogue audio signal carried by speaker- and especially line-signal wires. Both switching and linear power supplies transmit magnetic fields by adding current to the voltages at these frequencies and emit interference noise, but the much larger transformer typically needed in a linear supply emits much stronger and on itself audible low frequency modes.

The typical noise induced by switching supplies is of very high frequency far above the audio band, but can still have negative interference effects, such as inflicting oscillations in op-amps or other components. This might result in audible noise or have other negative audible impact on sensitive analogue or digital equipment in the system. To keep switching power supplies on separate neutral-ground paths is therefore advisable and sometimes other additional separating measures might be implemented for best results. As explained, power transformers in general, and especially those of linear power supplies, need extra attention and sufficient distancing from other components, particularly signal carrying cables. This is why in some of the better high-end audio applications using linear power supplies with big transformers; you might probably find that a separate power supply box is implemented to provide a better barrier between the transformer and the precious signal.

For reasons of safety, high power appliances such as power amps need to be safe-earth-grounded. Any touchable and conductive surface of these devices needs to be directly connected to earth-ground. If for some reason 230V (or 110-120V) would be able to reach the outside chassis, the current wants to flow and discharge to safe-earth-ground instead of anywhere else. In a dedicated safe-earth ground system there is a switch that will break the short cut to ground when going over a small current threshold. Without proper safe earth ground switch, this current might travel to ground through your body instead. If you would somehow make good connection to earth-ground, this could be lethal if the switch wasn't there. Metal pipes and radiators in bathrooms specifically, are accompanied by sockets (such as for a hair dryer) that are connected to safe earth ground.

There are all kinds of domestic appliances in your home that are also connected to a safe earth-ground system. In power cables, the dedicated earth ground conductor sits next to the potentially noisy power phase conductor and neutral conductor throughout an impressive web of cables installed in your house. Many high-end listeners opt to use a power conditioner before bringing power to their audio system but, to clean up earth-ground whilst taking full safety issues in regard might prove to be quite difficult. Some go as far as installing an audio dedicated earth pin in their garden, but safety rules and lightning hazards determine that if this is connected to the chassis of your electronics, it still has to be connected to the original safe earth ground (with safety switch).



Even if all three wires (phase, neutral and safe-earth-ground) finally arrive cleanly and safely at your hi-fi setup; you are likely to create and/or introduce some level of noise within the connected system itself. Any energy potential will always choose the shortest path to ground: if predominantly voltage this might be earth-ground but if predominantly current (circuit based), it wants to go back to the circuit's neutral, such as your power net provider's ground point. Now let's remember the amplifier/PSU chassis where those big transformers sit in. Its enclosure is probably made from a good conductor such as aluminium. And it's probably connected to safe-earth-ground. Don't assume for even only a second it's noise-free.

Now, to connect all these electronic boxes in your system as well as your loudspeakers, you have to apply cables. Cables are especially good in picking up RFI/EMI, as is perhaps unsurprising given their resemblance to antennas. So, of course, this is where shielding comes in, but:

> *Shielded cables are normally fitted with a copper (or other highly conductive) braid and/or foil to shield them from interference noise.*
>
> *These shields have all in common that they will:*
>
> *A) act as a mutual capacitive enhancer (low pass filter) when connected to neutral ground;*
>
> *B) often introduce ground loops when connected at both ends;*
>
> *C) introduce parasitic capacitance for being highly conductive and in close proximity, even still if it's connected to ground whenever the cable is bend for having variable distance to the inner cable conductor(s);*
>
> *D) fail to properly attenuate noise if not sharing common ground to signal, such as is the case with connecting shield to earth-ground instead of neutral-ground;*
>
> *E) act as an antenna if not properly grounded; and*
>
> *F) when not grounded at both ends, fail to protect against low frequency noise issues.*

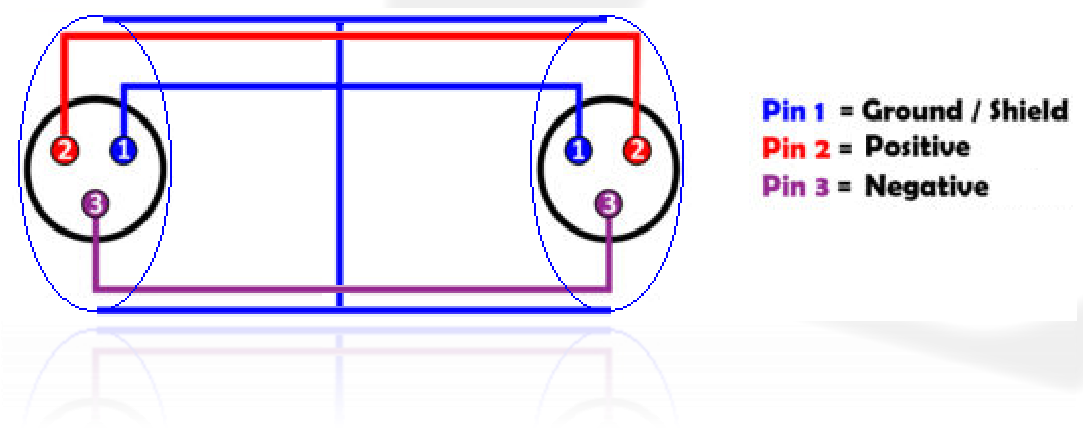
Looking at the implications of the pure and simple facts above it seems we have been confined to an electric world that allows only for making lousy compromise when applying shielded cables. And yes, one of the biggest headaches of hi-fi enthusiasts and industrial system engineers alike is the hassle (and money) spent on shielding and grounding issues, and the conquest of finding ways to apply shields and grounding points without counter-effects hurting signal integrity. To arrive at a better solution we first have still some more *ground* to cover…

Shielded high-end audio signal cables

In the previous chapter it became clear that in order to have proper useable effect, the traditional shielding materials have to be grounded to neutral: at least at one end to have proper high frequency attenuation and at two ends two also have rejection of low frequency noise. Let's first look at what this would mean if it's the cable is carrying the largest signal in the audio system: the speaker cable. What if each conductor of the speaker cable is carrying half the signal, such as is the case with differential push-pull amplifiers? I sometimes was asked by show partners who manufactured the particular amplifiers we used at the show, if perhaps in our speakers we ground the neutral speaker wire. They added this would be a big problem as half the signal would be lost towards ground. Usually, the next question was if we might have perhaps connected neutral to shield and explained how this could infect half the signal by RFI noise picked up by the shield. No worries: regardless if it's a passive or hybrid-active speaker, in both cases we only shield the inside speaker wiring with FerroGuard™ and this works very effectively *without* the need of grounding it to neutral or connecting neutral to safe-earth-ground.

In discussions on the topic of grounding, the distinction between types of shielding and grounding seems often not very clear. But there is in fact a very big and important difference between neutral-ground or reference-ground-plain and (safe)-earth-ground; as well as between single or multi grounding; between common modes or differential modes; between low frequency or high frequency shielding solutions etc. All have direct impact on the topic of shielded signal cables. Another point often missed is the mutual and/or parasite capacitance every time you introduce a highly conductive material in close proximity to your signal conductor. If it is connected to neutral, mutual capacitance goes up, leading to compromised bandwidth, and if the distance between cable-components varies (like when bending a cable) the problem of parasitic capacitance rises, it leads to compromised signal integrity that might be significant in its effect to perceived sound quality.

The nice thing about balanced/differential signal cables such as XLR line-level or XLR digital cables is that they share a common ground that acts as neutral and/or shield connected at both ends. If there is noise introduced on this grounded neutral/shield, both plus and minus phase conductors share that same zero-point. So let's say there is some noise on it, the zero point just floats somewhere else (other than zero) with very limited effect to the signal, however: locally inflicted voltage type common modes might still be an issue. This is why in professional audio sometimes 'Star-Quad' configured cables are used to reach around 10-20dB better rejection of common modes. It also reduces induction which can be helpful if you need as much as possible (LF) signal energy left intact if travelling over long distances. But it's not without compromise as the downside is higher mutual capacitance. Combined with the induction (that every wire has some) this makes for effectively a low pass filter with larger attenuation of high frequencies, which becomes audible especially over longer distances.



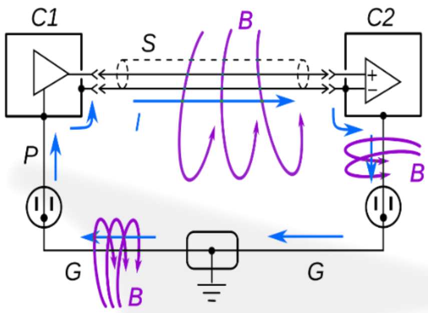
In high end audio we tend to agree on the importance to rule out any attenuation of the signal we want to transmit though the cable even if small or only near the audible frequency spectrum. Especially after taken into consideration there might be already other low pass filtering events at play. Stacking filters (such as that of the source plus pre- plus power-amplifier plus cable) might result in steep Q factors (of filtering slope) that can have harmful effects in the time domain, also including the audible frequency area either directly or by alias effects. Especially at line-level, we can expect stray capacitance to have the most predominant effect to filter point and steepness, so low mutual (or stray) capacitance is probably the most important factor to achieve in line-level signal cables. As a direct result, Star-Quad conductor XLR cables (having higher mutual capacitance) should probably be reserved to particular professional audio applications, where these cables might be packed together in crowded ducts also carrying other cable-types and where useable signal gain and noise free operation is more important than other aspects of signal integrity. High-end listeners if in need of filtering such as with playback of DSD formats, should be probably allowed full custom control of what filters to be used by the DAC (or server if DAC is used in NOS mode), rather than adding a cable-inflicted filter to the from DAC to pre amp or power amp(s).

In our experience, a well-made balanced analogue XLR cable consisting of two signal phases wrapped inside a cable covered by neutral ground (braid) is often fine without shielding, especially if there are no common mode transmitters in close proximity. This is why we provide our Luxury XLR cables without FerroGuard™ shielding to arrive at best value for money. To ensure low inductance and resistance over both short as well as longer distances, we equipped it with pure and straight-drawn copper conductors thicker than usual (so unlike typical XLR microphone/audio XLR cables). This makes the cable very suitable for lower gain outputs from source to pre amp, but also from pre amp to power amp (or full active speakers), including longer distances.

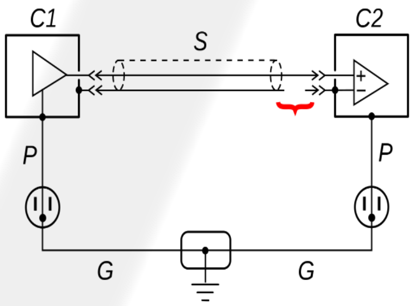
In case of our full-active speakers, we observed the speaker's power connector and signal connectors (plus connected cables) are now in close proximity. We therefore took an additional precaution: the last bit of cable towards the speakers is split into two coaxial cables, in which each phase conductor is surrounded by its own ground. We recommend using it together with the Luxury Power Cable, which is fitted with FerroGuard™ shielding. In this way, we can ensure that noise from the power grid cannot be transmitted from the power cable into the balanced signal-level speaker cable. This results in a healthy and clean signal to the active power-amp components of the loudspeakers to benefit their accurate reproduction of music.

In the Exclusive XLR Cables (for both electronics and full-active speakers) we go a few steps further. We employ them in air tubes to distance the cable from any noise source (e.g. other cables it crosses). The tube is covered with an extra dense layer of FerroGuard™ shielding. The Exclusive XLR cable for full active speakers is again split towards double WBT RCA connectors of the 152 type that are very resistant to EMI noise up to 200 kHz. To deal with noise in the audible spectrum towards these connectors, the cable is now divided using a thick metal splitting unit, and then fitted with two smaller UDCP™ covered air tubes towards termination. Just as like the larger tube over the main part of the cable these air tubes are made from a vibration-damping material to prohibit that sound from the close by speakers would inflict unwanted (resonant) cable vibrations.

By far the most challenging, is the integrity of single-ended analogue RCA interlinks. Ground is now the actual non-floating zero point (neutral) and any noise could have an actual and audible effect on the signal between conductor and that ground. Using a simple two-core wire cable without shielding is usually susceptible to some level of noise. This leaves the two commonly chosen alternatives: coaxial, or a twin core with grounded shielding. In a coaxial cable, the ground/neutral is all around the plus conductor, making this type of cable more resistant to noise even if without shielding. In the twin wire plus shield for single ended, the shield is usually only grounded to neutral on one side (so this cable is directional), in order to prohibit inductive ground loops as illustrated on the right by the purple arrows.



One end ground connection of neutral/shield prohibits ground loops, such as is pictured on the right, but it also means losing all shielding properties for low frequency noise. Fixing ground to both ends might introduce ground loops, but it's sometimes necessary for appliances like turn tables. This could make for higher mutual cable capacitance, whilst keeping this highly conductive shield floating (not grounded at all) would probably introduce parasitic capacitance: the shield is now a highly conductive antenna building up and transferring capacitive voltages towards the signal/neutral wires inside.

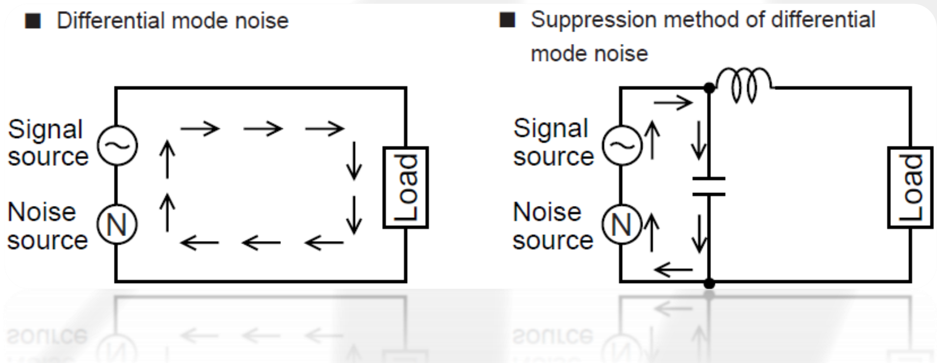


The benefit of a twin core cable is lower capacitance as it's easier to construct it in such way it keeps the two conductors closer together. Any form of traditional shielding would probably heavily compromise this feature as grounding it to neutral is needed to enable proper noise attenuation. If grounding it to anything else, such as a 'ground box' (later more on this) or a safe earth ground that doesn't share common ground with the signal, you will surely lose most of the intended noise attenuation. On the other hand, a shield that does share ground with neutral will effectively raise the average distance between the two conductors and thus also the mutual capacitance, even beyond the already higher typical value from signal to shield compared that between the twins themselves. Having variation in the distance between shield and signal conductor can especially be a problem when this non-coaxial twin-core wired cable is bent, as this leads to potentially problematic voltages of parasitic capacitance even if it's a so called 'twin-ax' cable rather than a regular twisted two-core cable. And of course: bending cables is something impossible to avoid when interconnecting electronics in the audio system.

Coaxial:

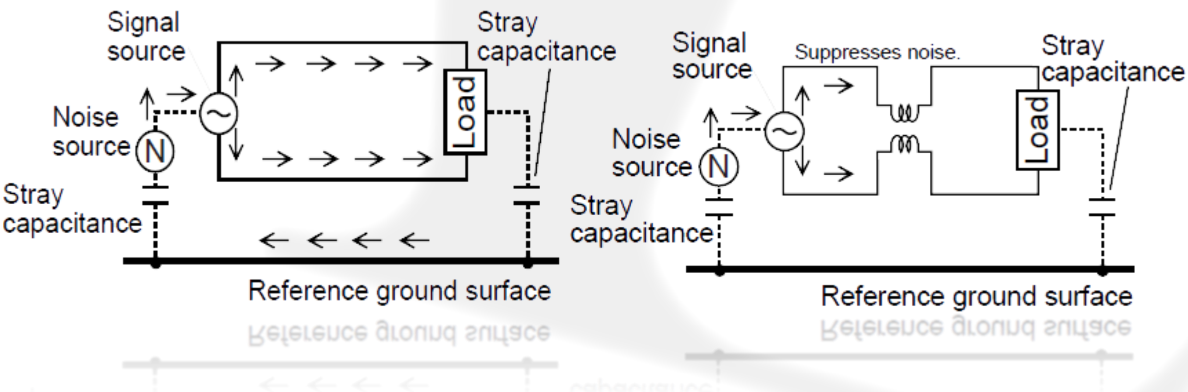
Twin-ax:

Whatever the cable type (e.g. coaxial or two/twin core): adding a highly conductive shield to these cables will not fully protect them against noise in the audible frequency band if that shield is not grounded at both ends to ground/neutral. If however you do ground shield at both ends of the RCA cable, this means effectively connecting it to neutral leading to increased mutual capacitance, even if there is a high quality dielectric material in between. Stray capacitate attenuation (a low pass filter) is a result of the quality of the dielectric, resistivity of the conductive materials and space between them and is multiplied by the cable's length. In industry, sometimes this parallel capacitance is raised on purpose, and this might even be done adding a parallel capacitor and/or an in-line inductor coil. Not something desirable to do in high end cables carrying audio signals. Let me explain:



Seen above is that the inductance in your signal cable, plus added mutual capacitance, effectively created a second order low pass filter. It's the amount of inductance and capacitance that decides how and what higher frequencies will be filtered out. Wires have some self-induction and two wires put in a cable (not a vacuum) will always have some mutual capacitance. Be careful what you choose to add to your system…

To handle common mode noise, often some kind of inductive coupling is used. This might be ferrite bead chokes or isolation transformers. Again acting effectively as a low pass filter (now attenuating/filtering out this type of common mode interference) these will only protect against high frequency common modes. So, putting an isolation transformer in the phase signal carrier is also probably not desired in high end audio signal applications, but power conditioners providing a separating transformer before the audio system are a better way to filter everything out above the grid's frequency. It's in fact much more effective than those using only a coil in line plus cap in parallel types (also mind safety and lightning issues if that cap is connected to safe earth ground!).



Given all the information explained in this chapter, it is clear why in signal cables we ideally keep all signals differential (balanced/symmetric) whenever possible. We now also now understand how shielding single ended cables with traditional shields will usually provide some kind of compromise, even if we add one or more of the other passive components defined earlier. This is why we recommend using differential cables between DAC and pre amp; between phono stage and pre amp; and between pre amp and power amp however, if your phono stage or pre amp is single ended, it would need proper transformer coupled differential outputs to use differential XLR cables with full intended benefits. These transformers will also add some distortion to signal. In these days of digital based studio recordings, often a device implementing this type of transformers is added intentionally by the producer or master engineer to gain a certain type of 'analogue' sounding coloration to the mix (e.g. by using an analogue summing mixer before feeding it into the master mixing console).

Systems might also consist of single ended phone amp connected to a single ended pre amp, or from single ended pre amp to single ended power amp (so not push pull pairs of tubes or transistors). Even if there is a XLR connection available, it doesn't necessarily mean it's properly differential. It very well might be a wire hook up only. That's why for when connecting your purely analogue sources as well as the just mentioned typical single ended system connections, you probably want, or are actually in need, to use single ended cables rather than balanced cables such as XLR.

The ultimate shielding solution for single ended audio cables starts with a coaxial construction with higher natural rejection of noise and to ensure it can be bent without loss of any type of signal integrity. To optimize signal speed (velocity of propagation) it uses a solid conductor without any surface covering. We changed the foamed dielectric insulator into another non-solid consistency of similar dielectric performance, but with even less risk of air/oxygen reaching the bare copper over time. We then don't apply copper (or silver or aluminium) shields, but put the main signal carrying coaxial cable (again with help of UDCP™ technology) totally dielectrically insulated in an air tube.

Thanks to UDCP™ we can even fit two mono RCA cables fitted in smaller air tubes together into one stereo tube without any side effects commonly encountered by choosing for a single stereo RCA cable (such as cross talk, or unwanted capacitive effects). Regardless of being single or dual mono configuration, this tube is then covered with a floating, self-dissipating and extra dense layer of FerroGuard™ that isolates the cable from noise of all frequencies in -and far beyond- the audio band without the need of being grounded. The uncompromised result embodies the best of all worlds (coax or twin, non-shielded, shielded with one or two ends connected) regarding any type of property, with an ultra-low noise floor on top.

Turning to the larger signals going over speaker cables, we can state that up to know the addition of a shield would virtually always lead to compromises rather than benefits. The single-ended but larger signal is less prawn to interference than RCA cables, but still improvements are now within reach for the first time using shielded cables. This is accomplished by doing exactly what we did inside our loudspeaker products: provide FerroGuard™ in a floating state to allow guarding against interference from e.g. power cables and other noise emitters. For the speaker wire signal, inductance is the pro-dominant source of compromised signal integrity and this is handled by providing a Star-Quad configuration in up to four times 2.5mm^2 thick conductors. We can hereby also avoid going for flat-type configurations that trade in low inductance against extremely high capacitance.

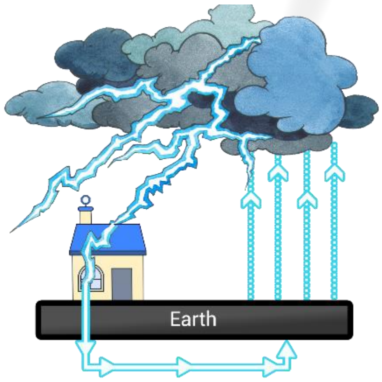
Safe/main-Earth Grounding Cables

When dealing with grounding issues or deciding on the grounding system of connected audio devices, there are many different things to consider before arriving at the ideal solution. Every specific situation might require a different and at itself unique approach. Separation of ground paths for analogue devices plus digital clocks plus other sensitive equipment away from noisy digital devices is highly recommended.

Also advisable is to have an additional separate path for switching power supplies. Within devices that carry analogue and digital components as well as clock (e.g. a DAC running asynchronous clocking and also implementing ladder resistor networks, single ended circuitry and/or a tube pre amp stage and/or phono stage), the designer of the better products has already taken care of most grounding issues for you but, there might still be challenges ahead with regards of cabling it into the system. Some grounding standards and topologies described for optimal routing cables, like the star-grounding of cabling in a system, seem easy on paper but can be harder to achieve in practice. The use of shielded cables makes everything especially complicated, as the chance on potentials to exist between devices, might make for unwanted travelling hence interference to be introduced to result in becoming an audible/perceived lack of fidelity. It therefore makes sense that some leading manufacturers of high end DAC products have not only applied separate power supplies but also ferro-magnetic shielded clock units and/or implement an optical isolation in the line between.

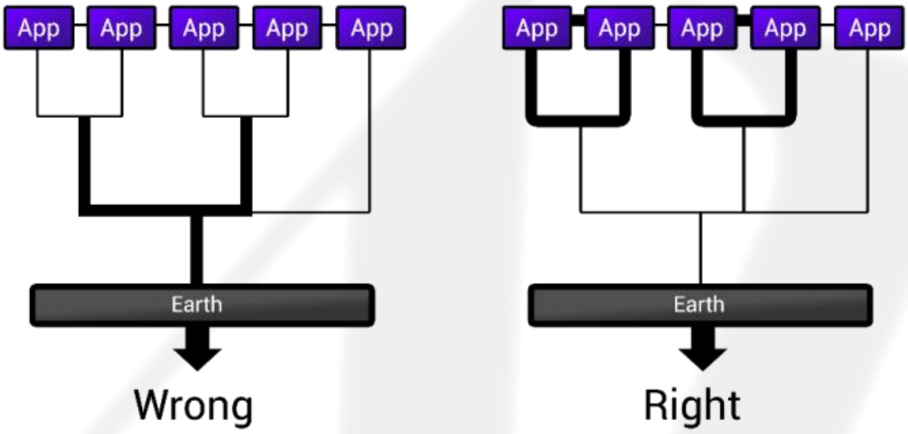
Among the system there will also be devices that add safe earth grounding. This means the common ground is now connected to mains earth. For example: a well-engineered line level device might stay clean while properly connected to common/neutral ground with no safety regulations saying it also needs to be connected to the main earth of your house. But then you connect it by a cable to your power amp. If you use single ended cables from RCA output to RCA input, you probably just connected neutral to safe earth ground, as the amp has its neutral obligatory connected to its metal chassis, and its metal chassis is often connected to safe earth ground. And this might be of significant consequence. Turning to fully symmetric audio, you might perhaps have both sides connected to safety ground, but for some reason the shortest pathway from the power amp towards earth is now through the line level or source device (e.g. for its internal circuitry or it having a thicker or shorter power cable to main earth). This means that the power amp’s noise is now travelling through your cable and fully through your sensitive live level device. It will probably now not be able to get even close to its advertised low noise floor. And what will happen if lightning strikes?

Turning to lightning events, we have to consider a mega high voltage but fairly low current to also making the loop from cloud to house to earth back into the cloud. What’s to be found on its pathway doing so? If we use a separate cable we can make the best and shortest path to feed all this power around without travelling in our precious no-go zones. This is exactly the reason why taller buildings often apply lightning-rods or cables via roof and walls (right) outside the route that might potentially finds its way through domestic appliances.



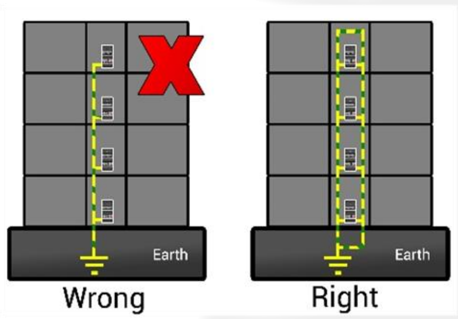
Right

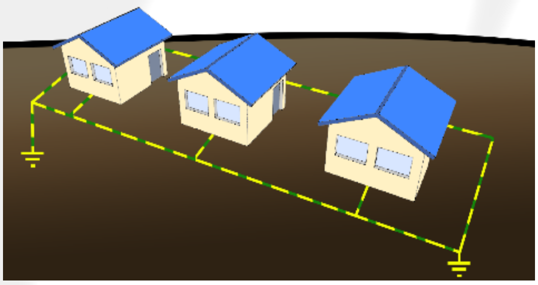
Turning our focus back to audio we find similar behaviour of interference in need of the right pathway. Below you find examples of how it's better to have proper short and easy pathways between applications/devices sharing a common ground rather than having limited common ground pathways but typically thicker/shorter pathways from each app to mains earth.



In industrial server facilities, often a grid of short-spaced ground-earth loops is implemented to hook on any device whilst being sure of a short path to ground. But for this and any other type of grounding system we have to work with and decide if, how and where connections to safe-earth ground are applied. So we arrive at the question of how the room/apartment/house/building and listening room itself is connected to earth safe earth ground (in Europe: it varies from TT, TNC, TNS, to TNCS standards of grounding). And which different types of equipment is used on different sides (or even buildings) of the main earth connection?

In apartment buildings, there is hopefully at least one loop of grounding, instead of a single grounding path. At houses, there might by a earth pin or earth wire (whilst in older houses only the water pipe acts as earth ground path) and there might be an earth pin per house, per block, or a ground loop around that block with one or multiple pins or all might be depending on the power grid supplier for earth-ground.





All the previous provided the context for the development of special grounding cable: if there is a need to have an additional ground between both ends of single ended cables (more than just the phase signal and neutral to reference ground) we offer a totally separated ground cable with a total of 3mm² copper conductors, covered with FerroGuard™ shielding. This separate cable overcomes the unwanted capacitive effects of integrated ground wires to signal cables, but also prohibits introduction of unwanted RF/EMI artifacts when making ground connections of any kind, including applications of getting rid of predominantly voltage or current potentials. The cable end splitting units are made from an extra thick and highly conductive metal alloy, and high frequency noise picked up by them (possibly for being close to the chassis of electronics) is transferred directly to the dissipating FerroGuard™ shield covering the entire length of the cable. This cable is standard fitted with two gold plated M4 forks, but on request it can be also fitted with RCA connectors or power plug (with earth ground pin) or any other connector for other applications at hand when facing grounding issues (with full safety in mind).

Ground loops might also be addressed with in-shield inductors, resistors, diodes or, parallel to shield capacitors, but many audiophiles consider this a non-option if we are speaking about thereby also directly applying it to the zero point of the signal (neutral). In contrast, within industrial high-tech environments, if differential is no option, often the route of connecting both ends of a shield to ground is chosen to help shielding from common modes otherwise impossible by the copper or aluminium shielding. And along the shielded cable itself one or more connection points might be added to connect the shield to mains earth. Ferrite-beads on cables might also be implemented as well as the method of consistently grounding any active system component on one side to neutral-ground and one side to earth-ground. Key in these applications, were there is usually a more clear distinction between different devices with different roles in the production line, is to have the best conductive path available between the problematic potential towards ground with minimal induction along the way to allow it to work in full speed. Therefore thick flat copper braid ground cables or even solid plates are often applied to best fit the specifics and demands of that situation.

In audio, we can expect many systems to be handling both single ended as well as differential signals, as well as combined digital and analogue interfaces plus both linear and switching power supplies. Therefore a new and different approach on shielding is needed and so it became clear for us that the development of a self-dissipating shielding material was the first step to have a shielding guard available that could be kept floating whilst still attenuate interference noise, even of lower frequencies. Having FerroGuard™ protected cables in place solves most issues, but there is still a role for our superb grounding cable to be used where it’s specifically needed to create the fastest and preferred path towards reference (neutral) ground or safe earth-ground.

Then there are some more unorthodox ways of improving grounding issues, of which some focus on dissipating energy without looking at the preferred signal/neutral to reference ground path but instead offer a ground filter device between earth-ground (sometimes literally an audio-dedicated ground pole is installed in the garden) and the system ground we want to address. But what if ground is already a straight connection to neutral ground (being the transformer building at the end of the street)? Or what if earth-ground is unavailable to provide for making a preferred path to the location of the potential in the first place? In industry, in some rare problem cases, a chemical based ground box might be implemented to dissipate the noise’s energy (voltage potential) without the need of another pole. A battery-like chemical reaction produces a source to which small voltage induced currents may flow to, after which the energy is transferred to heat or is used to break up a ground loop without the need of actual diodes or capacitive bridging.

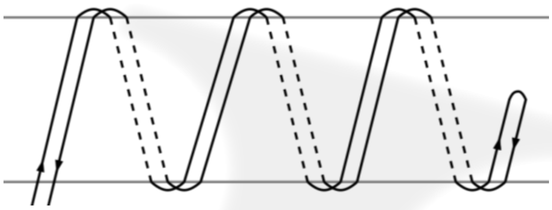
In the field of audio, devices claiming similar operational accomplishments as their industrial one-end-connected counterparts, now encased as a 'audio system ground box', are unlikely to be similar to the chemical based industrial version, and at best try to form a closed loop on their own (current potential), in which any electric energy travelling through that loop passes through an induction coil. In order to actually dissipate the energy of the now created coil's induction field, the coil should probably be combined with a transducer bringing in the compliance and moving mass to process the inductive flux: any voltage between ground and earth-ground that made it to be carried by some loop current, is now 'fed' to the transducer that dissipates the energy into heat.

Its moving parts can be made so heavy in such that no sound comes out, but everything is used up as heat instead but, this all starts with the assumption that there can be a current in that circuit, other than voltages created by the antenna-effects of that single ended loop. Unfortunately, even if giving the benefit of the doubt to these non-actual-in-circuit boxes, there are some notorious products featuring assemblies of pieces of metal plates in a wooden box: these antenna-sheets will probably introduce more noise instead removing it (on the right: unknown device found on the internet).

Although some might like the signature of the added noise, for anyone facing any kind of ground issue in their audio system they might feel to want to address it with help of a grounding box, we recommend to first get professional advice. We can also confidently state that most issues can be solved by simply using FerroGuard™ equipped cables. And in the rare case this is not sufficient, we can recommend to use the ground cable as a preferred path of potentials. The 3mm² of total conductive intersection with will do a good job at it.

If still wanting a bit more unorthodox approach, one might try to use our grounding cable rolled up into a coil. This will work similarly to adding an inductor-based high-pass filter device connected to ground. The inductive flux created will be mostly absorbed by the self-dissipating FerroGuard™ around the coiled up cable. The argument for a rolled up cable rather than a single cable connected ground box is all about the fact that you can use it between two devices or ground points in a multi-ground or star-ground system, and between any points that might have an actual (and problematic) potential between them. The partly rolled up ground cable when connected between two grounding points, would take some of the energy between the two connected sources and turn it first into inductance and then via FerroGuard™ dissipate it into heat, instead of perhaps transferring it only to become a potential voltage to another ground point. But again, this would only work for interference energy with a current in loop and of a (higher) frequency such as can be effectively addressed by this level of created induction. Will this form a relevant way of improving a system? There is a low probability of this being the case. For most cases, the implementation of a ground cable will be all about creating a preferred pathway for noise to ground. And this means we want low induction rather than high.

To use our grounding cable as intended, we have put two conductors into it, short-cut at both ends. It's done so to create a ground cable with lower induction, similar to the inductive difference between a round conductor vs. a flat braid or plate. Lower inductance means a better/more preferred path to ground for most noise-carrying phenomenon and this is why in high tech industry and measuring labs, braids and plates are often preferred to make ground connections. This fact might be interesting in a different way for those considering using it rolled up and connecting to ground at only one end only, similar to one-end-connected inductive ground boxes. This would result in a 'bifilar coil' as illustrated on the right. In this type of coil, the induction field of one individual wire cancels out the other. Any still transmitted inductive energy by these wires would be picked up by the floating FerroGuard™ shield that covers the cable, and then be dissipated into heat.



But there is more possible to enhance the system with the Exclusive Grounding Cable as it can also be used to ground the Exclusive Cable's FerroGuard™ shield via the big splitting units found at both ends of the Exclusive Speaker Cables, at one end of the Exclusive XLR Cable for Speakers, and at both ends of the Exclusive Double Mono RCA Cable. These full-metal splitting units on our cables come with a highly conductive M4 screw and this provides the possibility of easily connecting the grounding cable. This connection can be implemented to:

A) to not depend solely on the self-dissipating capabilities of the FerroGuard™ material, but be able to provide a direct path towards earth ground;

B) to enhance shielding of the highly conductive and thick full metal splitting units close to the electronics.

As a result, this might further enhance the attenuation effect of the FerroGuard™ shielding if connected to a common ground towards signal conductor; and/or prohibit the rare case of saturation effects if picked up noise gets too severe without a path to reference ground from shield.

In conclusion, given the varying quality and potential trade-offs of grounding boxes, I like to stress that FerroGuard™ is designed to be fully capable of doing its job without any further grounding tweaks. In addition, we offer our Exclusive Ground Cable to be used as a preferred ground path or to be connected specifically to the splitting unit of our cables towards ground in order to enhance noise attenuation. Or even to connect it to a clean pathway to of earth-ground, possibly with a rolled up Exclusive Ground Cable if the desired one-way potential difference is less secure or as an alternative of adding a diode bridge before reaching earth-ground.

Sometimes in noisy industrial environments, engineers add earth-ground connections to shields (but we are then speaking about non-dissipating aluminium or copper shielding materials, usually grounded to neutral at both ends). If the alternative idea to the above is to connect the Exclusive Cable's splitting unit to an inductive single ended ground box without dissipating compliance down to DC, there is the possibility of using a rolled up cable connected to the splitting unit at one end, and kept floating at the other end of the cable, if no reference is available. But here, as in any case of one-ended ground solutions, the best probable result is to only dissipate some static (non-circuitry-dependent) energy of electric-field type.

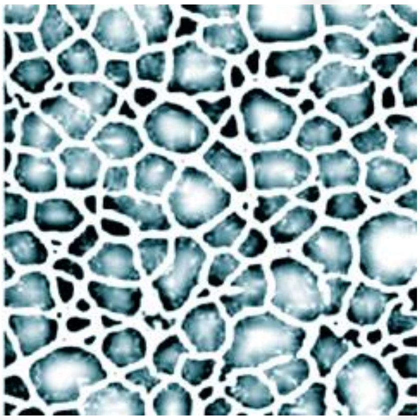
I like to point out that there are good sources available to turn to with questions about the implementation of cable products with regards to grounding aspects or other cable related issues. Please feel free to ask your local Aequo Audio dealer to forward your question, or contact us directly for further assistance.

Dielectrics

The first insulation barrier directly between the main conductive elements is the most important dielectric component. Simply put: it is what separates the conductors (phase pole(s), neutral and/or ground). Dielectric performance goes up in direct result of increasing the thickness of this insulation material, but this would also increase mutual/stray capacitance between conductors at the same time. Having less dielectric insulation between the conductive parts would decrease velocity of propagation as the leak of potential between signal and ground limits the signal's speed. Using a thicker conductor can increase speed but will also increase surface area to be potentially connected by the dielectric to its counterpart. Using larger distance between two conductive items using the same dielectric material in between, will increase their mutual capacitance, and thus raises unwanted high frequency attenuation of the signal. Both capacitive attenuation and velocity delay are accumulated values per length. Given the accumulation of facts, it's clearly important to have a material in place that increases electric resistance in between, but without the need of thicker spacing.

Gasses or air are the best dielectrics, close after vacuum. But what protects the conductor being copper or silver from oxygen-inflicted corrosion? High-end cables need bare copper to be instantly mantled while kept in protected atmosphere to prohibit oxidation/corrosion. So directly after the still pure copper wire is drawn from the cathode (which consists of only pure copper ions) and is assembled into solid or combined/stranded conductors. This is why the best high-end cable brands source customised wires that were immediately insulated at specialized global players equipped with such facilities. Aequo Audio is no exception in this reality and we have the benefit of having the best specialist partners in this process (such as the nearby former Philips Cable Factory now owned by Belden. Still we felt there was room to do the research and design our own dielectric materials. While doing so, we kept in mind that if the chosen insulation material is only slightly porous, air might still reach the conductor. In such cases the copper should ideally also be tinned to prevent corrosion over time.

Tinning is a fine solution when it comes to providing a protective layer on XLR ground braids or stranded copper wire however, in a comparable solid conductor implemented specifically for high speed; the signal now tends to travel over its surface relatively more than through its core. As even silver solder is more than six times less conductive than copper, this can become a factor to take into consideration. We can observe that a silver coating on copper might provide higher speed, but also increases the 'skin-effect' (that some consider especially an issue for analogue cables, rather than high frequency digital signals) while on the other hand, if you put a solid copper, silver or aluminium wire in an air tube, it will soon form an oxide layer with horrible conductive properties forming on the surface where signals prefer to travel. With a twin-ax surrounded by ground, ultimate low-capacitive signal integrity can be reached by using stranded tinned wires separated by foamed dielectrics. In single ended cables optimized for speed, a solid conductor without tinning will reach ultimate velocity of propagation and lowest signal delays. Long-term quality and consistency of non-tinned conductors depends especially on non-porous dielectrics. And this is exactly what we secured in the construction of our coaxial RCA cables.



There are many kinds of dielectric materials that can be compared by their dielectric constant (the value regardless of how thick the layer of insulating material is). Polymers such as PP, PE, FEP and PTFE are some of the better performing solid dielectric polymer materials. From these materials, PE, PP and FEP can be upgraded by foaming them with air or by injecting oxygen-free gas into the dielectric material. Considering dielectric performance of foam-able polymers, some specific types of PE is considered to be the most suitable and high performing polymers. Arriving second after PE is FEP (a fluorinated polymer similar to PTFE), to be preferred only when heat is an issue and a plenum-rated cable is required.

The lower the signal's energy, the more important dielectric performance becomes and therefore we use foamed dielectrics for various of top-tier cables including the Exclusive XLR cable. Foaming dielectric materials is not without the risk of introducing porosity-induced corrosive behaviour. Therefore it's advisable to use tinning in stranded cables in combination with foamed dielectrics, especially if it's carrying a relatively low frequency (audio) signal. Foaming could have aversive effect on solid conductors (where more of the signal's energy travels over the outside surface). We therefore implemented a non-solid yet non-porous oxygen-free injected dielectric version on our solid copper conductor RCA cables with similar excellence in dielectric properties as its foamed counterparts. To prohibit capacitive effects towards shield or another set of RCA in the same cable, we developed a special crystalized solid polymer (UDCP™) that can be used as a solid dielectric, as a spacer in air filled tubes or as a covering sleeve close to electronics. There are already some cable constructions using spread-out solid PTFE spacers to be found, but we believe these might still lose some speed capabilities (velocity of propagation), as the dielectric constant of PTFE is not anywhere close to that of air. Furthermore, using a tube with these spaced pieces of PTFE (or polymer of similar dielectric constant) with gaps of air in between would theoretically raise parasite capacitive effects throughout the cable.

List of Dielectric constants and some other most relevant characteristics:

Vacuum	1.0	
Gasses incl. Air	1.00xx	Dielectrically ideal, but needs a partial solid supporting structure that limits the effect of the air space. Air might also contain water.
Aequo Audio UDCP™	1.2	Aequo Audio's solid Ultra Dielectric Crystal Polymer
Foamed PE and FEP	1.3-1.4	Foamed PE has best dielectric properties and value whilst foamed FEP is more heat resistant.
PE	2.0	Excellent performance vs. cost. Can be foamed.
PTFE (polyfluorinated, known as e.g. Teflon)	2.0	Commonly used solid dielectric for high temperature: high quality heat resistant wire insulation where foamed dielectrics are no option.
FEP (also fluorinated)	2.1	Heat resistant. As a solid close to PTFE performance, but can be foamed.
PP	2.4	Durable multi-purpose polymer. Can be foamed.
Cotton	>1.5	100% dry cotton can be as low as 1.3, but it attracts water. In practise, dielectric values are at least twice as high.
PVC	3.0	Most commonly used cable insulation material. Low in cost, it provides good value if mutual capacitance is less of an issue or when used for outer cable jackets.
PA (Nylon)	3.4	Excellent machine-ability. If spacing of conductors is quite large but very limited in length, such as in XLR connectors, PA will provide adequate insulation with negligible capacitive side-effects. It can be precisely machined into the dielectric material holding the contact pins or providing the slots for the contact conductors and is the logical choice for both XLR as well as power plugs.
Silica	>3.0	Dry Silica send can be as low as 2.5 but it attracts water. Silica Glass is waterproof but has a constant of 3.8. Expect at least similar but probably higher values for non-waterproof glass/silica based solids.

Conductors and contacts

Yes, it's one combined subject in cables. Using some kind of superb conductor material does not really help if contact by conductor to connector is somehow compromised. Looking at the list of conductor and contact materials below, we can soon understand how most of the listed metals have their specific role in certain types of applications. Some materials are simply for allowing the best conductivity, some are more durable after countless connector fittings; some have better corrosion-free properties. If it's about soldering, then it's clear this bonding -but also surface covering- additive should only be used as to secure direct conductor contacts and not as a conductor on its own. And when tinning conductor ends, the flux added in the solder should also be considered a highly potential hazard for signal quality: having a layer of dirty solder flux (not listed) on the contact surface acts as a substantial and unwanted insulator. Hence overall cable production quality is key.

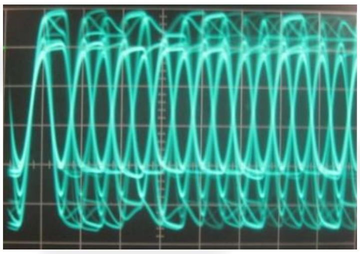
List of conductive materials being used in cable products:

Silver	6.3	Surface will corrode over time, but ideal for small but high voltage and (semi-) permanent contacts such as (speaker) power connectors.
Copper	5.96	Must be covered (e.g. by tin, gold or silver) or instantly insulated.
Tellurium copper	5.0	Improved machine-ability compared to unalloyed copper.
Gold	4.11	More expensive and less conductive than the above, but completely free (if 24 karat) from corrosion/oxidation problems. Mechanically soft so excellent surface-contact-count enhancing material while super reliable over time.
Aluminium	3.77	Affordable (the earth's most abundant metal yet not the cheapest to process). Surface will corrode to a hard oxide layer. Unsuitable as contact material.
Rhodium	2.22	Less conductive, but very reliable, tough and non-corrosive. Can be used as plating in e.g. power connectors for extra robustness over many plug cycles.
Beryllium Copper	1.6	More expensive, stiffer and lighter than unalloyed copper. Toxic.
Silver Solder	0.96	Preferred solder by Aequo Audio (this also include copper).
Platinum	0.94	Expensive and not very conductive, but non-corrosive.
Palladium	0.93	Comparable to platinum, although slightly less expensive.
Tin Solder	0.69	Low conductivity compared to conductor materials (pay extra attention to direct contact between conductors). In high end filter and cable soldering, the addition of copper and silver to the solder is desirable, combined with clamped direct contact between contacts.

Given the above, we implemented 24k gold plated copper conductors (solid or stranded, pure and straight "single crystal" drawn, instantly insulated by high end dielectrics) as a preference for all cable products. When mechanical strength was an issue for the type of connector we went for high copper containing bronze alloys. When comparing connectors and explain their differences, we can simply zoom in to actual surface connection. Under the microscope we learn that the level of fitment tolerance, surface smoothness, and adaptive softness of surface area cannot be underestimated in its significance of connective/resistive effects. While sometimes a solid silver or silver plated audio connector might be perceived as being better than a gold plated copper one at first, we see the opposite being true over time. This can be easily explained by two things at play: while silver is at itself the best conductive material, the (thick) softer gold coating provides a much better sub-micro-level surface connection, but also stays fully corrosion free over time. So, after some time the copper/gold combination often wins over the silver (plated or pure) variety even if considering the aspect of contact conductivity. Silver solder then takes on its important role to be used where bare copper would otherwise corrode, to secure direct (clamped) conductor to connector contacts. Silver is also implemented in pure form at the contacts of our power speaker cables that we recommend to keep connected to the speaker if storing the speakers over time. They provide the best clicked semi-clamped contact material available in limited contact surfaces (such as the speaker-side of power cables) with still offering the possibility of occasional disconnection.

Impedance matching

In our signal-level cables we closely observed the effect of relative characteristic and conductive impedance matching as a result of construction and materials. We arrived at selected levels of characteristic cable impedance from low (<75 ohm), middle (RCA: 93 ohm, XLR: 100ohm), digital (110 ohm) to high (XLR: 150 ohm) for signal-level cables. In digital cables, relative impedance matching is a very important aspect when ensuring optimal signal integrity and bandwidth. This is why we provide a digital-specific Neutrik connector (with gold plated contacts) on a closely matched 110 ohm twin-axial cable. This prohibits the mismatch of impedance that would cause some digital information to be reflected at the end of the cable. We strongly advice not using any other than 110 ohm specific cables for balanced digital AES/EBU type connection.



Within the analogue cable domain, mismatching cable parameters might also severely hurt signal integrity, especially where gain vs. conductive resistivity becomes a more important factor than characteristic impedance. We engineered the all-round Luxury XLR cable for analogue to be used from low to high gain applications (short to long lengths); an Exclusive 93 ohm RCA cable performing best regardless of low or high gain application including phono (moving coil and magnetic); and a 100 or 150 ohm Exclusive XLR Cable for ultimate performance of line level connections (especially low to high gain pre amp signal towards power amps). They perform beyond today's ultimate levels of signal integrity and quality to be found in high-end cables, at very competitive price levels. In these analogue cables, resistivity or conductive impedance, relative rated impedance and capacitance are all of importance for optimized vs. compromised cable design. It's hard to achieve low capacitance with high characteristic impedance if conductors also need to be of low conductive resistivity and high in their velocity of propagation. A shield connected to neutral would provide even more trade-offs.

Looking at these aspects together with inductive properties and much more, a specialist cable maker still has much ground to cover how ingredients and overall construction should be engineered. The theoretical optimum often doesn't take the practical and noisy (RFI/EMI) environment in consideration. This is where especially FerroGuard™ but also UDCP™ becomes a real game changer. Coming from a point of need of practical solutions for both passive and active high-end speaker application, whilst also depending on interconnect quality of all kinds of components at shows and demos, a strong incentive to learn, try and learn was born. To find what actually *is* best, we walked the extra mile and paved the way for all hi-fi enthusiasts, even those who own very complicated systems such as pictured below (with courtesy of Matej Isak, Mono & Stereo magazine).

Associated Equipment

A better understanding of cable design goes beyond the accumulated experience of dealing with various cables among the quite extensive list of cables to be expected to be often used for connecting all of the various high-end products. That alone can perhaps be suffice to identify sound quality of different systems and applied cable products working in a certain environment with certain building installation qualities and associated power grid. And yes, in the right hands this can be of significant value, especially if system and listening room are of high quality and there is a basic understanding of how one should take in and reflect on the perceived input from ears and brain. A trained ear on each side of a brain that itself is aware of its judging methods does help. So do blind testing procedures targeting these systems and their environments. The experience that includes the dealing with a large amount of problems and noise issues over time and solving them with use of various methods and products is priceless but, such experience alone cannot provide thorough understanding of what system parameters are most significant for providing the as better or as lesser perceived musical performance.

It is our Methodius Operandi to find the consistent logic behind experienced affairs. Before starting to unassumingly connect dots of why things universally work well (or not) and how they consistently affect our appreciation of sound, we need education. Going from subjective to objective to 'objectively subjective', the accumulation of peer-reviewed literature often provides a good ground of understanding and the basis to start effective practical experimentation taken into the highest level of detail and consistency (in components, glues, assembly etc.). Theory combined with professional experience in high end audio revealed to us how contact and dielectric quality differences and also the aspects of grounding and shielding are probably the most underestimated factors for signal quality in high-end. Reaching new and higher levels of awareness (including the research focussed on FerroGuard™ and UDCP™), we can now observe that the sound quality issues discussed throughout the sometimes controversial debate on cables might often be linked to the wrong aspects entirely.

Over time, with an ever-present and strong incentive to improve the universal sound reproduction qualities of our loudspeakers and associated systems, our team dealt with various audible grounding and shielding issues. The more subtle ones, after accumulating the lot of them and their summed mix of effects, often defined the difference between very good and excellent sound. Its recognition vastly increases if we not only hear the same system after solving such an issue, but also being able to switch back to the earlier (compromised) situation. Grounding, shielding as well as contact and connector and applied dielectrics simply proved to be of higher significance than any other cable aspect, often going against many of our own presumptions. It doesn't mean that the other specified aspects should be left behind. Nor should you expect them to be, given the often significant budget involved with the purchase of high-end cables. So yes, we spent extensive time on those too.

In the end, the effect of all combined relevant cable parameters as reviewed in their result towards their level of audibility will highly depend on transparency of the system and the quality of the recording. If you think about it as a system of sufficient resolution in space, things get exponentially more audible once all instruments and spatial effects are allowed to be more three-dimensionally perceived, coming to the listener as the holographic projections over a tall, wide and deep soundstage. As various high-end products and other components in the combined system get continuously better and more advanced, we should better not sit around and wait on our interpreted values and choices with regards to measured and trialled data to finally catch up. This is also why we at Aequo Audio always measure more things than we can comprehend in the moment (if not only simply enjoying the music at that time). This has proved its benefit in in the development of cutting edge loudspeaker technology, but also has the potential of including such data as input for future evaluation and optimization of cables. It can also be seen as an explanation for why we chose to offer two lines of cable products of which the Exclusive line can be perhaps considered to contain many 'over-engineered' components, materials and technology but, we are well aware how some of these might actually prove to be of high significance for the beholder (listener).

Measurements alone only provide a raw bunch of un-interpreted information. Their significance to sound quality with regards to interconnecting cables will first and most depend on the quality of the interpretation towards related signal integrity. Interpretations have then to be translated to more or less universally perceived musical quality and emotional impact. Some of the insights that are explanatory for best reproduction to the last details will be achieved on the long run only. There *is* universal logic to be found into why and how things work, also at the highest level of audio reproduction where things get more finesse and perhaps more complicated. We therefore had to become specialists in eliminating weak links including their potential spoil of the ever-increasing emotional and rational complexity (in scale, resolution etc.) towards more convincing, palpable and vivid sound reproduction yet there is always still more to learn. In the past, one could develop an electro-mechanical assembly or audio component by a procedure of trial and error above anything else. After putting in the right technical background, math and work effort, the result would be fair. But it could even reach excellence for the time, after trying many prototypes. Whatever simply sounded best got made. But were the very best possible configurations according the materials at hand included on this route? Where they actually tried and listened to?

We can now benefit from using smart simulation software along with sufficient computing power to carefully estimate the possible outcome of electromechanical designs in order to help select our short-list of high potential candidates before we actually make and try them. Much of the outcome still depends on how these new powers are put to work. We need to develop our brains in making better judgments and decisions along the way on how to apply what, where and when, especially if it comes to preferred construction or technology. Recently, the equipment made with purpose of arriving at better audible performance got a heck of lot more effective and efficient, such as the Finite Element Analysis computing we use. The effectiveness and final outcome of this computing power still depend on how the input, both initially data-wise as well as on-route decision-wise, is handled. If used well it will unquestionably also lead to higher achievements. Regardless of any designer's interpretation of measured performance towards perceived quality, you will still first have to measure. Next-level high end cables are no exception to that rule. Below, some of our equipment we use for that:

- Probes plus associated hardware for measuring EMI fields (see below).
- Wideband Acceleration sensors and associated calibrated hardware and software.
- Precision standalone and computer-connected LLCR devices to measure inductance, capacitance, resistivity etc.). We also measure to provide a report on each Exclusive Cable product we ship.
- High precision acoustic measurement hardware and software.
- Various modern low noise lab feeds of high-tech industrial quality.
- Various modern (industrial) stand-alone and computer connected precision scopes.
- Vacuum (and) clamping hardware.
- Top notch high-power and high-precision industrial soldering and air heating equipment.
- A constant flow of incoming and outgoing high-end audio products (such as used for demos and shows) and pro studio components in our auditorium and measurement facility.