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The Naked Truth about Speaker-Cables

Bananas, bananas. More lengths of cable talk we have to do....

[\[Italian version\]](#)

Well folks, it has been a while since I have written about Cables. So, if you don't believe in Cables, or if you have bought the latest boutique Wire and want to remain happy with your Purchase, you best stop reading now....

This "naked Truth about Speaker-Cables" could be seen as second installment to "[The Naked Truth about Interconnect-Cables](#)". It deals with a few more of the issues around Cables in general and focuses on Speaker-Cables.

The DIY-part will attempt to provide a simple, inexpensive and easy to make Speaker-Cable. It will nevertheless, due to its inherent construction, provide a significant improvement over most commercial Speaker-Cables and if I dare say so myself, even over the TNT-Star DIY Speaker-Cable.

Anyone intending to save the dry theory and just wanting to get stuck in with making cables; you can go ahead and make one out of these two:

A Cable intended to be an all out Assault on the state of the Art, [the "UBYTE-2" Cable](#) .

Alternatively you can keep it a bit simpler and more sane. Just make [the "FFRC" \(Full Frequency Range Cable\)](#). This is a Cable intended to be a significant Upgrade over something like the common, moderately expensive, multi-stranded Cable generally employed and sold as "Specialist Speaker-Cable".

The stark naked and ugly truth

I think first of all it is important to realise that VERY few so called Cable Manufacturers really make their own Wire and Cable. More often the actual wire employed is only a slightly customised version of what any of the large cable and wire making companies like Belden produce.

In more than a few cases I have seen Cables, where the "customisation" actually meant a Jacket in the latest Designer-colour and some fancy print. Some Companies do exist, which do a lot of fundamental research and often make some or all components for their Cable in their own Factories.

The numbers are however VERY few, as such an approach requires a lot of capital to be invested. Other Companies have found by accident or research a certain commercially made cable or wire which worked very well. They strated to market a cable based on this and later managed to have this Wire improved by adjusting it to their Spec.

In many cases I have found that the price cannot be taken as indicator as to how and by whom the Cable you are buying has actually been manufactured. So I think it is fair and true (but very uncomfortable) to say that most specialist "HiFi-Cables" are an exercise in marketing to about 95 % and maybein Research for 5%.

Please remember, not all companies selling specialist HiFi-Cables are guilty of these practices, but many are. Please also note that in my following Article I do mention a number of companies making or selling HiFi-cables.

Their inclusion does not constitute as such an endorsement of their products or indeed a statement to the contrary. It is simply that their products are well known and often are typical for

a specific design-technique mentioned.

Cables - are they different?

So what makes the average High-End Cable tick and what can be considered as "universally" good?

I divide audible effects affecting the performance of the Cable into three Orders. They are the First, Second and Third in order of Importance and sonic impact. See "[The Naked Truth about Interconnect-Cables](#)" for a more detailed description of these orders of effects.

It should be noted that depending on external and interface conditions second order effects and first order effects can sometimes change places in terms of magnitude....

I would propose, that the usual RLC parameters (as with Resistance [R] , Inductance [L] and Capacitance [C]) should be viewed as first order effects, though not in all situations each parameter carries the same weighting.

Let's have an example for the different weighting in RLC Parameters, due to the relevant source and load impedance's. In Interconnects the source-impedance is between a few ohms and a few kilo-ohm and load impedance between 10 kilo-ohm and about 1 mega-ohm (both usually mostly resistive).

As a result the Capacitance (C) is a prevalent characteristic with Resistance (R) and Inductance (L) relegated usually BELOW most second Order Effects in their magnitude of sonic impact. A second order effect, the Dielectric Absorption (DA) becomes here a first order effect in audible magnitude. So the main parameters for Interconnects are C and DA as long as R and L are kept in sane regions ([see "The naked Truth about Interconnects"](#)).

The Skin effect remains relevant (but firmly in the second Order Camp) as does the Maxwell Effect (more on both later).

The limitation in bandwidth is mostly effected by the Lowpass Filter composed out of the source-impedance and the cable's capacitance. A Bandwidth of about 100 kHz is desirable for this interface to make sure that the phase-shift and frequency response drop at 20 kHz remain acceptable.

The DA will determine time-smear and distortion of the Cable together with further second order effect and the third order effects.....

Let's look at Speaker-Cables.

Here the impedance's are, a source impedance of about 0.1 Ohm to about 8 ohm. It is mostly resistive with small inductive component and the load is 2-16 Ohm average impedance but has large reactive variations. Most Speakers also show an about 50 uH - 100 uH residual inductance from the uncompensated tweeter inductance.

Thus, unlike as in Interconnects, the Capacitance and DA can (mostly) be relegated into the second Order Camp. Due to the low impedance's in the load and the Source impedance of the Amplifier, the R and L of the Speaker Cable become highly relevant.

The Skin and Maxwell-Effects are being promoted from second order effect to first order Status. The bandwidth of the Cable and the frequency-dependent phaseshift will be a direct function of these parameters.

The Situation is complicated by the fact that certain amplifiers are very sensitive to capacitive components in the Speaker-load (NVA, NAIM, Linn to name a few culprits). So with Speaker-Cables indeed many bet's are off.

It seems that for Speaker-cables a low but matched R and L (so that the attenuation remains constant with Frequency over the Audio-band) is desirable combined with a low Capacitance

and high quality dielectric.

It is essential that the Skin-effect and the Maxwell-effect are taken into account.

>From my simulations and practical tests it also seems desirable to allow for an optional Speakerside "Terminator" Network. This should compensate the Inductive Rise of the Tweeter if required (depends on the Cables RL Values and the Speakers X-Over Design).

It may also be advisable to build into the Cable an (optional) Pi-Network at the Amplifier Side. This will ensure the stable operation of even the most "Hairshirt" designed Amplifiers and prevent RF Ingress into the Amplifiers feedback loop (if any is used) via the output.

First, Second - Third - who cares as long as we get to the Finish....

Having already touched on the Second Order Effects, let's look at some of these effects and how to avoid the negative influence of these.

The possibly most objectionable second order effect is due to the choice of the conductor. Here we could be using multiple non-individually insulated Conductors or the use of so called "solid core" cable.

A specific form of the Solid Core Cable is the so called "Litzendraht" a braid made from individually insulated (enameled) conductors.

True "Litzendraht" (Litz-wire) is braided similar to Kimber Cable and was originally invented by Nicola Tesla WAY BACK in time. Modern realisations are often called "Hyper-Litz" arrangements, why the "Hyper-Litz" I do not know.

Because these cables eschew the braiding and instead use simple parallel wires, they lose the Litzwire's advantage of canceling the wires magnetic field to a good degree....

Now let's look at the typical multistranded speaker-cable, which may be the well-known "Monster Speaker-Cable" or the many clones sold by anyone from Radioshack/Tandy to Wall-mart.

This uses a large number of non individual insulated copper conductors twisted together for each Conductor. It is usually sheathed in transparent or clear PVC or PU. The Geometry is the so called figure-8 pattern, also called shotgun configuration.

Multistranded conductors have a problem. In an Ideal world, no electrons would ever "cross" the boundaries between the individual conductors. In the real world they do that all time.

(see Article Quantum Tunnel of Love, issue 8a,9a/92 of Bound for Sound)

Both the huge metal-to-metal surfaces themselves, crystal grain boundaries and surface oxidation make the interstrand conduction much less linear than conduction through pure copper.

In effect we introduce something not entirely unlike (but also not entirely like) the crossover distortion of a Solid State Class B Amplifier.

A solid copper conductor or a Litz-type wire will still have some non-linear conduction due to impurities and Grain-boundaries, but these are much less in magnitude.

Our next stops are Skin- and Maxwell- Effect.

The skin effect says that with rising AC frequency the electron flow is being pushed more and more to the outer surface of the Conductor.

It does not matter if a Conductor is 12 Gauge solid Copper, or a Conductor of a 12 Gauge multistranded Cable ("Monster-Cable"), both will appear as 12-Gauge solid Copper round conductors.

So, the higher the frequency, the more of the signal conduction will happen in the outer layers of the cable.

The conventional cables multistranded conductor will show even more problems, due the non-linear interstrand conduction near the surface, the presence of surface oxidation and the like.

Can you spell Treble Grit....?

For all it is worth, the Skinddepth for a round Copper Conductor at 20 kHz is about equivalent to the Diameter of a 20 AWG Conductor.

At this depth from the conductors surface the current density is 63 %. Hence a 20 Gauge

conductor should not experience skin-effect related problems below 20 kHz. As I have already mentioned the 100 kHz Bandwidth Requirement we should really expand this to apply to the Skin effect.

It should be noted that the remaining current-flow between this depth and the surface is heavily skewed towards the surface of the conductor, so in more ways than one we'd rather like as thin a solid conductor as feasible.

It appears that 24 to 26 Gauge individual conductors make for a good compromise between bandwidth and manufacturing requirements (or the ability to adapt readily available commercial wire for Speaker-cables).

The Maxwell Effect works at the other end of the Spectrum (bass) and is a bit harder to explain. I will not even try. Read the Paper Prof. Malcom Hawkesford submitted to AES (Audio Engineering Society) if you feel like doing a bit of serious mathematical self abuse.

The Upshot is that a thin conductor will also IMPROVE the LOW-END performance. Hence the Conductor providing the widest bandwidth (measured and subjective) all else being equal is the thinner one.

A thin conductor introduces a lot of resistance, giving us problems with the Series Resistance in our Cable.

So we to use for example flat, thin and wide Foil Conductors to get the resistance down to a sensible level for Speaker-Connections as implemented for example by Goertz Cable, Sonolith and Magnan Cables.

Another option is to arrange a lot of thin individual Conductors in a Litz or "Hyper-Litz" pattern (XLO, Audioquest, Cardas, Kimber and Tara).

Either solution provides us usually with some problems regarding the Cables Geometry and hence often the RLC Parameters are shifted in ways that are undesirable.

Let's summarise:

A (universally) good Speaker-Cable has a low Resistance and Inductance (though a certain balancing Act is recommended for Speakers with a non-resistive impedance) and moderately low Capacitance.

It will ideally employ multiples of very thin round Conductors with individual insulation or use thin Foils.

It will not use multistranded Conductors and it will minimise both Skin- and Maxwell- Effects.

And where do the DIY Cables fit in?

The UBYTE-2 Cable, developed by me, conforms to most conditions.

An exception is that about one third of the Conductor-CSA (cross-sectional Area) for each "leg" is made up from 18-Gauge Solid round copper. This will restrict the Bandwidth of Cable slightly, but helps to utilise a relatively easily available commercial coaxial wire and to achieve a reasonably low DCR.

The outer copper Foil Conductor carries the major load of the current and conforms to the solid and thin model.

The specific geometry (as developed by Jon M. Risch) allows for a fairly good set of RLC parameters.

For a 5m Length of Speakercable there is about 0.1 Ohm DCR combined with about 1uH Inductance. The Capacitance is around 800 pF for 5m.

Into a resistive 6 ohm load (respective of most modern tweeters + Zobel) load that will allow a -3dB Bandwidth in excess of 300 kHz.

The maximum frequency response deviation over the 20 Hz to 20kHz frequency range for a

Speaker falling to a 4 Ohm Minimum will be about -0.2 dB. This will be at the 4 Ohm minimum, as compared to an infinite load impedance.

So a DC to 60 kHz bandwidth with a ± 0.1 dB deviation from the 1 kHz point and minimal phase response deviation should be possible into a compensated Loudspeaker. The compensation may be part of the Cable if required.

That is not very good, but I think it a tolerable technical performance. In many cases the Output impedance of the driving Amplifier will produce larger errors. Many expensive commercial cables do not remotely achieve this standard of performance.

Also the FFRC - "Full Frequency Range Cable" is still very good with respect to fulfilling the requirements for high quality Audio.

The use of multiple individually insulated conductors of 24-Gauge thickness guarantees freedom from the effects of non-linear conduction as found in multistranded cables. The thickness is such that any skin-effect related problems are pushed out of the audiorange.

With a high quality insulation and a geometry to minimise inductance and capacitance even the lowly FFRC still is miles ahead of all multistranded cables, regardless of make or price.

I have carried out an extensive series of Measurements and PSpice Simulation that included popular Cables (like Kimber 4TC, Goertz MI-2, Cable Talk 3 and Reson LS-350 and others). These confirmed that both into a matched and an unmatched simulated Speaker-load the "UBYTE-2" Cable will give the overall flattest response.

The FFRC is not that far behind, but is solidly beaten by the Goertz MI-2 and ever so slightly by the Kimber 4TC.

The rest of the Cables was just terrible.

A partial exception was interestingly the Reson LS-350, a very thin Cable with a pair of widely spaced thin and solid conductors.

This cable has a high series-resistance and inductance. Most people and reviewers take an instant dislike to this cable because of the thinness of its conductors. Yet its bandwidth into a real-world Speaker was surprisingly large.

However with its rather thin cross-section it will likely not make a good match with quite a number of speakers, so as a universally applicable speaker-cable, it is not too well suited. Hence I think it can be said that the basic engineering for both the "UBYTE-2" and the "FFRC" is sound and fit for the purpose.

The fact that it outperforms on measurements and listening tests almost any sensibly priced Speakercable on the Market earns the "UBYTE" (Usually Beats Your Terrible Engineering) tag for the "UBYTE-2" Speaker-cable.

In combination with (optional) Speaker- and Amplifier-Side Networks we can match this Cable to almost any conceivable combination of Equipment.

Various "audiophile" construction details (Air/Polyethylene Dielectric, Solid Conductors, Foil Conductors and the like) address many suspected but scientifically largely unconfirmed effects, detrimental to sound quality.

The UBYTE-2 has yet to be bettered by a commercially available Cable in the Mid-Price Range up to at least 30-50 Dollar Meter. I have not yet been able to try even more expensive cables in a head to head test....

In comparison, the "FFRC" is only "good". Its main advantage is material cost below many of even the most basic "Speaker-Cables" with a performance more akin to serious "High-End" Cable.... It also is much easier to make.

Where do we go from here?

With the above, regardless if care to make your own High-End Speaker-Cable or to use what you might have learned to avoid the worst pitfalls of buying expensive Speaker-Cables, you should be well equipped....

The next time around I will be talking about the biggest gripe in High-End Cables.

Something few people of any remotely engineering related background would put any Stock in. I will be talking about Mains-Cables.... And Mains conditioning. Until then, good tunes to all of you....

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