Cable Sound - Do Cables Make a Difference?

Neville Roberts

There's been much discussion on the subject of cables – both mains and interconnects. Some maintain that they make a huge difference to the quality of the sound and others think they don't. Neville Roberts attempts to shed some light on the subject!

In the Letter of the Month in the March 2011 issue of Hi-Fi World, a reader asked for an explanation of how cables might influence sound. Noel explained a number of important parameters of cable design which can be measured, but also said that there is a lot more to cables than just measurable factors. David commented that, just because we can't measure a particular aspect of a cable, it doesn't mean there's no influence on the overall sound.

Although once a sceptic, I am now thoroughly convinced that cables do indeed have an influence on sound quality. Those who analyse the evidence from a purely engineering point of view may argue that there is little to support such claims. However, as a physicist by training (albeit many years ago!), I make judgements based on what my ears, and not just the calculations, are telling me. I feel justified in this approach which frees me from many of the constraints of engineering practice – a fact that I have exploited over the years when successfully tightening up nuts with a pair of pliers!

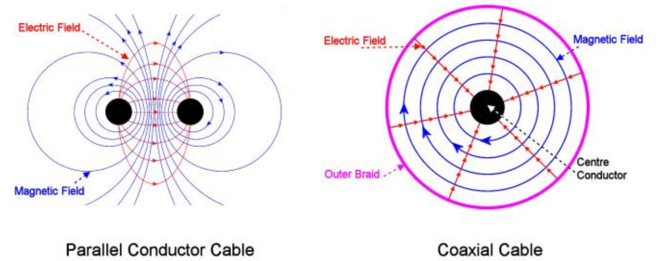
Before the reader panics, thinking that I am going to bombard him with a whole load of theory, let me reassure him – I won't! There are plenty of excellent articles on the subject written by electronics engineers who can explain far better than me the importance of capacitance, inductance, characteristic impedance and so-on. The things that we can measure are very important, but they don't explain the whole picture.

I realise this may promulgate a series of arguments from the cable-sceptics. Perhaps what originally annoyed people most was the plethora of over-priced cables which suddenly appeared on the market and were sold with all sorts of extravagant claims. However, I hope to put the matter into perspective to enable people to make a more informed decision on whether the extra investment in high quality cables is worth the expense.

The Issues

With direct current (DC), a cable is simply two conductors of electricity which are insulated from each other to prevent shorting. The electric and magnetic fields resulting from the current flow soon stabilise into a fixed pattern around the conductor. The conductors need to offer negligible resistance to the current flowing within them in order to avoid wasting power through heat generation. Oxygen-free copper has splendid properties but, alas, when it comes into contact with the air or is subjected to high temperatures during the process of applying the insulation, it doesn't stay oxygen-free for long! Silver or silver and gold wire is really excellent, but rather expensive as would be expected. The metal can be cryogenically treated to modify its crystalline structure which, if done correctly, can produce noticeable audible improvements. More on this later.

However, as soon as we start to send alternating current (AC) through cables we need to consider other issues. Apart from the DC electrical resistance of the wires, whether they are audio interconnects, mains cables or loudspeaker cables, the reactive elements of the cables come into play and these in turn will affect the impedance of the cable and the phase characteristics of the signal. The electric and magnetic fields around the conductors will be constantly changing, and that in itself will have the potential to induce undesirable signals in the cable. As frequencies increase, current tends to flow through the surface of the conductors due to what is known as the Skin Effect. Furthermore, the dielectric properties of the insulator play an important part in modifying the electric and magnetic fields around the conductors. The best dielectric is air, with a Dielectric Constant close to 1.0 (that of a vacuum). However, air would not be a good choice for several reasons, not the least of which is the lack of support for the conductor! Teflon with a Dielectric Constant of 2.1 and Polyethylene at 2.3 would be better choices, but even these will start to have an influence on the fields around the conductor.



Cross section of parallel wire and coaxial cables showing the electric and magnetic fields

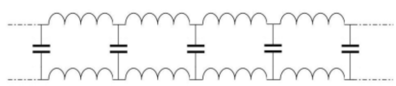
Not only are the choices of material important in the design of cables, but also in their construction. Coaxial cables have the benefit of containing the electric and magnetic fields within the cable and help to screen out interference from outside sources and are therefore the design of choice for audio interconnects. Mains and loudspeaker cable construction ranges from simple parallel wires to complex weaves of individually insulated wires.

Of course, one must not forget the two ends! Plugs and sockets will all play an important part in maintaining the physical layout (such as the use of RCA phono plugs to maintain the coaxial structure). Low contact resistance is extremely important in order to avoid such issues as a connector becoming a point-contact diode, changing its resistance depending on the direction of current flow!

Another complication is interference from outside sources. This can be in the form of electrical interference from the mains transformers or radio frequency signals, such as those generated by mobile phones. It can also be physical interference caused by external vibrations or even internal vibrations from the cables themselves, all of which will induce unwanted signals in the cables.

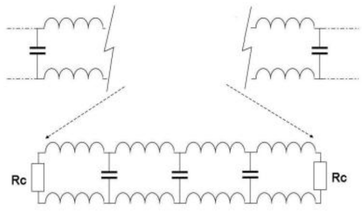
So, I think it is fair to say that the issues affecting cable performance are complex, to say the very least!

Discussion



A cable can be viewed as series inductors and parallel capacitors

Let's start by examining what we can explain – capacitance, inductance, dielectric properties, interference suppression, conductivity, and so on. A cable of any length and configuration can be viewed as a network of series inductors and parallel capacitors, as shown in the accompanying diagram. Each of these elements is a little inductance-capacitance (LC) filter, which has an impedance which varies with frequency. This is insignificant at low frequencies, but starts to become important as the frequency increases. The actual values of inductance and capacitance will give a particular cable its own unique character. As inductance causes the current to lag the voltage (and capacitance has the inverse effect), cables will cause minute phase errors between current and voltage which are frequency-dependent.



Rc = Characteristic Impedance of Cable

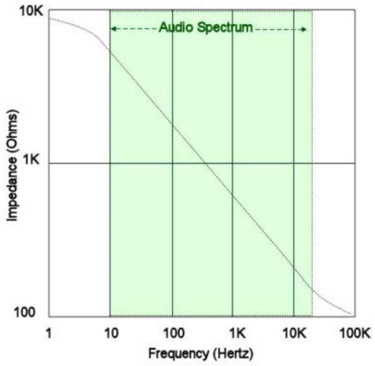
How a correctly loaded cable can be perfectly matched with no reflected signal.

At higher frequencies, a cable can also be considered as a transmission line with a defined characteristic impedance, and therefore we must also consider the wave propagation properties of the cable. Many would argue that even with frequencies of 100KHz or higher, the transmission line effects are not relevant. A frequently quoted rule of thumb is that this only becomes relevant in cables longer than a tenth of the wavelength of the signal – that's about 300m long at 100KHz! However, it's not that signals suddenly change from being the movement of matter to the movement of energy as the frequencies increase, it's just that we need different ways to explain the relevant factors. Let me explain…

It is often thought that it is the movement of electrons that constitutes the signal, when in fact the velocity of the signal is much faster than the speed at which the electrons move. It is actually close to 3×10^8 m/sec, the speed of light. The signal travels through the conductor by displacing electrons in much the same way as a wave moves across the surface of a pond or more accurately as sound travels through the air (as the air molecules vibrate in the direction of propagation, rather than perpendicular to it as with water). This speed is modified by the properties of the cable, such as the Dielectric Constant of the insulator and the physical configuration of the cable itself. However, even this is an over simplification of the issues as there is still no universally agreed explanation for the phenomenon of signal propagation. As with light, the true behaviour of signal propagation through a cable is likely to be best explained by a combination of both particle (the propagation of matter, such as electrons) and wave (the propagation of energy) properties and how they interact.

So, why are the transmission line properties of a cable important for audio? As I mentioned earlier, a cable has a defined characteristic impedance. This is the impedance of an infinitely long length of the cable (at a particular frequency). For the sake of argument, let's consider a standard 75 ohm coax cable, although the same discussion will apply to any cable design. Being infinitely long, there is nothing to reflect the signal back along the cable. If one then removes a finite section from the cable (say, a 1m length), the two pieces left are also infinitely long, by definition, and each has a characteristic impedance of 75 ohms. Therefore, our 1m length of coax would have seen 75 ohms at both its ends and, as I said before, there is nothing to cause reflections of the signal within the cable. So, if this cable is terminated at each end with a 75 ohm load, then the cable is said to be perfectly matched with no reflections to attenuate or distort the signal. This is great for radio frequencies and, in any case, has no relevance at audio frequencies – right? Well, actually, no!

I mentioned that the characteristic impedance of a cable varies with frequency. If we look at a graph of the variation of this for a standard 75 ohm coax cable, the greatest variation occurs between 5Hz and 50KHz – right across the audio spectrum! This is going to give rise to unwanted reflections within the cable which vary with frequency. Granted, these reflections will be tiny, but my argument is that any unwanted signals, however small, are going to add to interference and other unwanted affects that, cumulatively, may well affect the sound that we hear.



How the characteristic impedance of a typical 75 ohm coaxial cable varies with frequency, with the greatest changes occurring within the audio spectrum!

The point of mentioning all this is to highlight that the performance of cables is hugely complex and all we can do is surmise what things could be affecting what we hear. The issue is that we can't explain the whole picture at the moment. When we seem to have a nice flat frequency response, why do some interconnect cables sound clearer and cleaner and have better bass control as well as improved imaging? Why do we get similar effects with mains cables, especially mains cables driving turntable electric motors? The fact is that many people, including myself (and I started out as a sceptic many years ago), can hear a difference.

I previously mentioned cryogenic treatment of audio cables. This is a fairly common process applied to metallic alloys to improve their mechanical properties through stress relief and the formation of micro-precipitates, a technique that can also be applied to cables and valves. The physical changes to the metals are clearly evident, which is why, for example, some musical instruments are subjected to cryogenic treatment. There are claims that these instruments experience improved tonal performance due to the altered physical and mechanical characteristics after cryogenic treatment. It is even claimed that tympanic instruments will resist cracking and sliding parts will resist wear and last longer as a consequence of this treatment! In addition to modifications to the physical properties, some people speculate that cryogenic treatment causes the crystal boundaries and the impurities in the metals to be changed and the properties of the dielectric insulators to be modified. The truth here is that no one really knows why this all works – it just does!

As with cryogenic treatment, opinions differ about the value of burning-in cables. Some say that it is a complete waste of time. However, many people have experienced permanent changes in sound quality once a cable has been used for a period of time. A typical comment from someone who had upgraded his interconnects was that he was initially very disappointed with the sound, which was harsher and lacked the body and weight he was used to with his cheaper, six year old cables. A colleague then mentioned the importance of burning-in the cables, urging him to continue playing music (or pink noise) for at least 100 hours using his new cables before making a final judgement. He was understandably very sceptical as he had never heard of the concept of burning-in something as "passive" as a cable. However, he followed their advice and, to his great surprise, having played music through them for a suitable length of time, he found the changes to be far from subtle. The weight, body and smoothness had returned and the overall tonal quality was far more profound and involving when compared to his old cables. Incidentally, should you want to try burning-in your own cables, you can download from the internet a modified pink noise file created for this very purpose by searching for "frybaby.mp3" on Google.

Physics is the study of how and why things work. We are taught to keep an open mind in all that we do and update our theories based on the input of new information. The theories should then converge on what is actually correct, but we can never be 100% sure. Different people will have different perspectives – take the joke about a philosopher, a physicist, and a mathematician who were travelling through Scotland in a train when they saw a black sheep through the window. "That's interesting," says the philosopher, "I see that Scottish sheep are black." "Hmm," says the physicist, "you mean that *some* Scottish sheep are black." "You are both incorrect," says the mathematician. "All we know is that there is at least one sheep in Scotland and that it is black on at least one side!"

Conclusions

As we improve our systems, other more subtle changes become apparent. Crudely put, if you spend £20,000 on a high-end audio system, you are very likely to hear the improvements that good quality interconnect cables make. Conversely, a cheap system purchased from your local supermarket is unlikely to show any benefit from a Russ Andrews cable upgrade!

When I started out with my budget system comprising mainly home-made bits of equipment, I had the opportunity to try out different cables, but to be honest, I could discern little difference between them and my trusty ‘home brewed’ concoctions. This was just as well as these elite products were way out of my price range as a student! It was only in recent years, as my system has grown in quality, that I started to perceive the subtle improvements offered by one cable above another. Over time, I started to hear the subtle benefits that higher quality cables offered - better clarity and realism, a greater involvement with the performances and lower noise floor.

I should mention at this point that, in my opinion, all of the above applies to any cable, whether an audio interconnect cable, a mains cable or a loudspeaker cable. Moving on to consider mains cables, many would argue that a mains lead can’t possibly affect the sound as any undesirable signal will be filtered out by the power supply before it gets to the amplifier. However, I still maintain that I can hear subtle differences when using different mains cables. Given that filters have different effects at different frequencies, I consider it unlikely that the components of a power supply will remove all unwanted mains-borne signals. Especially with a Class A amplifier where the power supply is effectively in series with the signal, it is highly probable that noise and non-linearity effects coming into my equipment from the mains will find its way into the audio path.

Cable-sceptics will point out the apparent irrelevance of typical steady state measurements and are pleased to point out that the calculated frequency effects of the inductive and capacitive values of any normal audio cable at normal lengths are much higher than any audible frequency, including the all-important harmonics. This simplistic argument implies that such delicate, complex and highly variable sonic qualities affected by different cables such as imaging, sound stage depth, clarity and ambience can be completely explained by simple frequency attenuation. Whilst it is easy to define the "first order" effects of LC filters and how they affect frequency attenuation, their indirect effects of phase errors and time delay of the audio signal on our perception of the more subtle aspects of sound reproduction cannot be so easily defined.

Many people are sceptical about claims of sonic benefits, which they consider to be unsubstantiated since they can’t be backed up with scientific proof. With all due respect to the sceptics, that’s rather like saying that bumble bees couldn’t fly until around 2005 when scientists finally managed to put this perplexing mystery to rest! We constantly live in a world where new, unexplained issues arise. The latest mystery puzzling scientists that I read about in the February 2011 issue of Physics World is the phenomenon of LED Droop where the efficiency of white Light Emitting Diodes plummets when the current is increased! Answers on a postcard please to assure your place in history!

Maybe one day, as with the bumble bee, we will be able to explain most, if not all, of the ways in which cables affect sound, but if that’s not in my lifetime, I’ll be content to enjoy the unexplained!

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