Cables

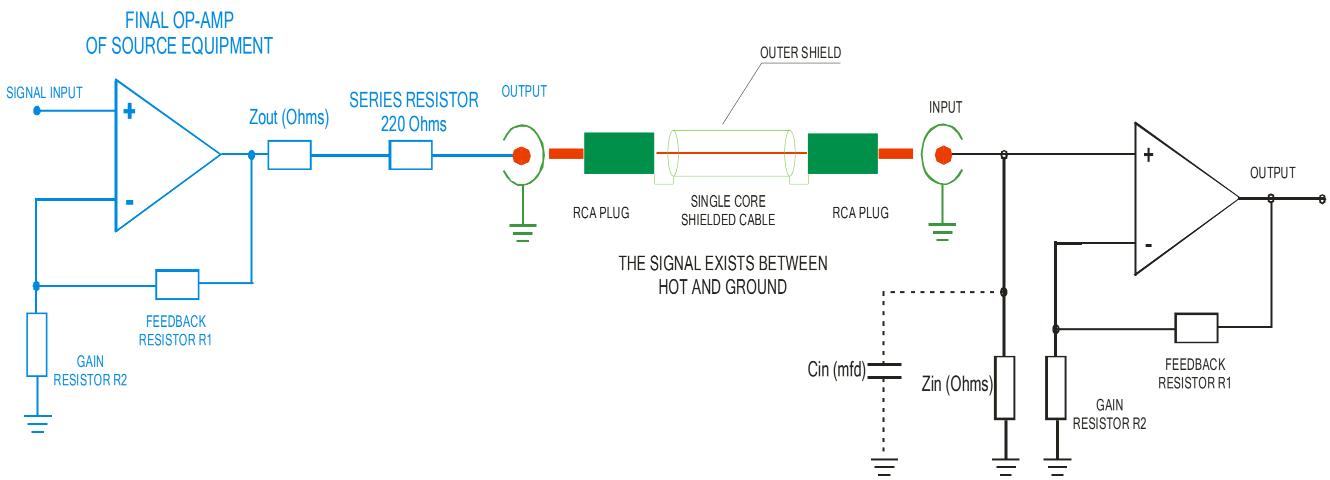
This subject along with some others has to be at the top of my top ten peeve list. In the past years there has been so much hype written and sprouted by untrained mouths that it could fit in a 4 inch thick book. When profits on traditional stereo components started going south, the snake oil and magic suppliers had to find new avenues for revenue – and they surely found one in cables. Interconnect cables, speaker cables and power cables. As the saying goes. “There is always room for one more sucker” and boy there were and are lots of those suckers running around. But there is hope and another saying goes like this, “You can fool some of the people some of the time but you cannot fool all the people all of the time”.

There is no doubt in my mind that there are bad cables out there. Bit it is like an amplifier designer deliberately designing a real bad sounding product. Why would a cable manufacturer go out and make bad cables. Yes they do exist but the average audiophile should never come into contact with these products.
The following discussions will be for audio frequencies and so any frequency above 100KHz will be ignored. At last check my hearing did not go near 100KHz!

Interconnect cables are the first cables which the signal passes through from signal sources to preamplifier (in the home stereo) and from head unit to processor or amplifier (in the car stereo). We shall only discuss cables with RCA plugs at each end as they are by far the predominant cable type in this category. As in any interconnection, there are THREE main issues to consider. First the source’s output impedance, secondly the cable’s electrical impedance and lastly the receiving gear’s electrical input impedance.

Note: Please read my link on Balanced line as well

The source has a finite output impedance and in the case of CD players, FM tuners, etc. this is in the order of 10 ohms to hundreds of ohms. The lower this source impedance the better. Most of these sources use op-amps as their final output stage. I shall talk about op-amps often in the various tech talk subjects and these are typically integrated circuits. They are in essence small “power” amplifiers with microwatt or milliwatt capability. Most op-amps do not like capacitive loading. All cables exhibit capacitance between adjacent conductors and they present a capacitive load on the preamplifier output stage. The simplest way to cure this is to insert a low value series resistor in the output of the op-amp which isolates the output stage inside the op-amp from the capacitor. The value is anywhere from a few ohms to hundreds of ohms, the latter being more typical. So what we end up with is an output stage with a series resistor in the “hot” leg and hanging on this is a shielded cable. Let us examine the drawing below.



The op-amp of the source equipment is at the left side. It has an output impedance of Zo and in series we have added a 220 ohm resistor (typical) which isolates this op-amp from the capacitive loading effects of the cable AND the input capacitance of the receiving equipment. I have lumped these together as “Cin”.

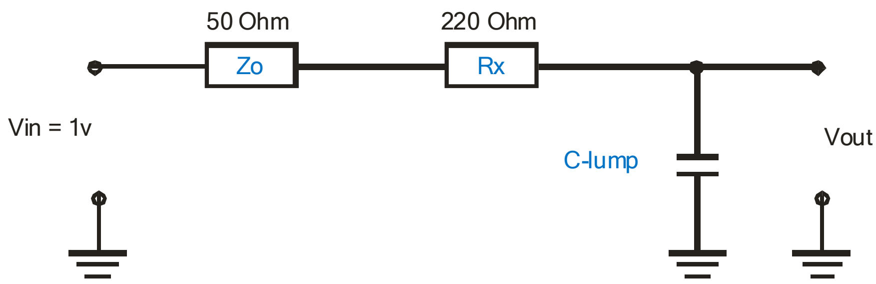
The shielded cable also has inductance. This is determined by the area between the inner and outer cores and the diameter of each core of the cable and is proportional to this. Typically inductance in interconnects is very low indeed and can be neglected in our audio discussions. Of course at very high frequencies it becomes a factor since inductance (L) is proportional to frequency (F). The inductive reactance is XL = 6.28 x F x L. (The 6.28 = 2 x Pi where Pi is 3.14)

The shorter the cable, the lower are its reactive components being inductance and capacitance. This stands to reason as cable has xx micro-farads of capacitance per unit length and yy Henries of inductance per unit length. If we could make our cables less than say 6.35mm (0.25”) all would be well in audio land since then the cable would be essentially out of the picture. Of course this is impossible and so we must deal with practical cables.

Back to our op-amp and let us examine the effect which the cable has on the performance. The series resistor which we have manually inserted in the output of the op-amp (The Zo of the op-amp is added to the 220 ohm we added) forms a low pass filter with the lumped cable and destination equipment’s input capacitance. Zo depends on the amount of negative feedback which is applied in the source. Let us assume it is 50 ohms which is typical for most op-amps. We now have a total series impedance of 270 ohms. Cable capacitance in either those high end “snake oil” types or the RCA interconnects which come with the average VCR are about 150-195pF per metre or 50-60pF per foot maximum and typically are far lower. I have some cheap RCA-RCA cable at the factory which has a capacitance value of only 8pF per foot.

Note: (0.001mfd = 1000pF)

In a home stereo environment interconnects are relatively short, mostly less than 1 metre in length and in automobiles the longest is maybe 5 metres. Let’s do some calculations based on these two cases and also taking into account the input capacitance of the destination equipment. These examples only take the series output resistors of the source into account.



In the case of the 1 metre cable, C-lump is 50pF + Cin (say 220pF) = 270pF
C-lump forms a potential divider with the 270 ohm resistors. The capacitive reactance of C-lump (C) is Xc = 1/6.28 x F x C.
At 1KHz Xc = 589,761 ohms and at 20KHz it is 29,488 ohms and at 100KHz it is 5,897 ohms.

So now using our formula to calculate Vout we arrive at the following. (Vout = Xc/Xc+R)
1KHz : Vout = 589761/589761+270 = 0.999 of the input which is 0.999 volt, a drop of 0.0086dB hardly audible I would imagine.
20KHz: Vout = 29488/29488+270 = 0.9909 of the input which is 0.9909 volt, a drop of 0.079dB again not audible unless you are bat!
100KHz: Vout = 5897/5897+270 = 0.9562 of the input which is 0.388dB which is barely audible EXCEPT that our hearing does not go anywhere close to 100KHz! (Unless you are one of those cable manufacturers who claim that we can hear several octaves above 20KHz but then again they may be relatives of the bat)

In the case of the 5 metre cable, C-lump is 250pF + Cin (say 220pF) = 470pF
At 1KHz Xc = 338,799 ohms and at 20KHz it is 19,439 ohms and at 100KHz it is 3,388 ohms.

So now using our formula to calculate Vout we arrive at the following. (Vout = Xc/Xc+R)
1KHz : Vout = 338799/338799+270 = 0.999 of the input which is 0.999 volt, a drop of 0.0086dB hardly audible I would imagine.
20KHz: Vout = 19439/19439+270 = 0.986 of the input which is 0.986 volt, a drop of 0.112dB again not audible.
100KHz: Vout = 3388/3388+270 = 0.926 of the input which is 0.66dB which is audible EXCEPT that our hearing does not go anywhere close to 100KHz! (Unless you are one of those cable manufacturers who claim that we can hear several octaves above 20KHz but then again they may be relatives of the bat).

If we lower the value of the resistor we insert in the output lead of the preamplifier to say 50 ohms, you may redo all the above calculations and the differences are not worth discussing. Also reducing the value of the destination equipment's input capacitor ** will also not change the numbers by any significant amount. Do the mathematics for yourself. Even if cable manufacturers eliminated nearly all capacitance, the input capacitance of the destination equipment will be dominant. There are cables out there that have very low capacitance of around 26pF per metre (8pF per foot) and the results with these cables would be mathematically different but not audible.

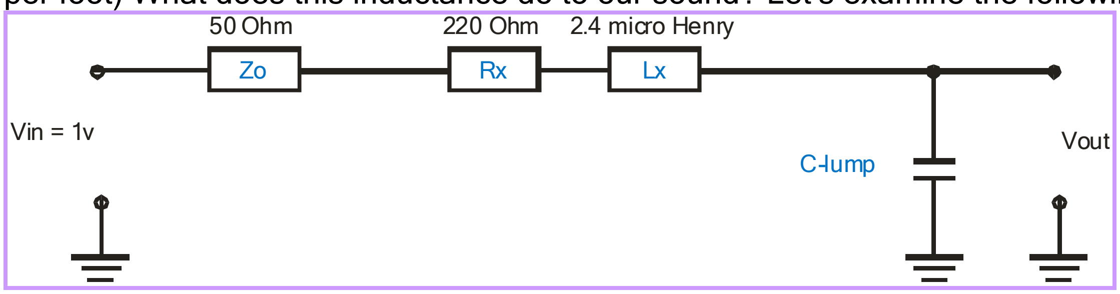
So what have we learned from the above calculations. Yes we must use low capacitance cable. We must know what the input capacitance of the equipment is and we must also know the total output impedance of the source equipment. Knowing these parameters we can easily calculate the dB drop at any frequency. Of course at lower than say 15KHz the drop is of ABSOLUTELY no consequence.

Another point to consider is that the low output impedance of the source will tend to discharge the cable/equipment capacitance very quickly so this notion of the charge held by the cable is nonsense.

Almost all manufacturers DO NOT specify the input impedance of their equipment in a 20Hz-20KHz bandwidth. If they did it would be relatively simple to work out the capacitance at the input. The amplifiers which Zed Audio produces have low pass 6dB/octave filters at the RCA input. The 3dB point of these filters is set at 339KHz. The reason for these filters is to prevent very high frequencies from entering the input stage of the preamplifier.

The DC resistance of these cables is very low and even if it was 1 Ohm per metre this 1 Ohm is not even a factor compared to the series output impedance of the final stage of a preamplifier and then any added resistance completely swamps any cable resistance. This is easily confirmed by anyone with access to an Ohmmeter. Just measure the resistance from RCA tip to RCA tip of your favourite 5 metre cable.

As I stated above, the inductance of interconnect cables is very low. A reasonable quality interconnect should have inductance of about 0.48 micro Henry per metre (0.15 micro Henry per foot) What does this inductance do to our sound? Let's examine the following diagram.



What we have is the lumped inductance of the 5 metre cable shown as "Lx" and it's value is 2.4 micro Henry. Typical cable inductance is about 0.48 micro Henry per metre (0.15 micro Henry per foot). The inductive reactance of a 2.4 micro Henry inductor is XL = 6.28 x F x L As we see from the formula, the higher the frequency, the higher the value of XL. This value of XL will add to the value of the two resistances, Zo and Rx. Three of these will form a low pass filter with C-lump. So the total series impedance is Zo +Rx + Lx. Lets us calculate this at three frequencies again.

<u>1KHz:</u> XL = 6.28 x 1000 x 2.4/1,000,000 = 0.015 ohms. Not worth considering since Zo and Rx are 270 ohms!
<u>20KHz:</u> XL = 6.28 x 20000 x 2.4/1,000,000 = 0.3 ohms. Not worth considering since Zo and Rx are 270 ohms!
<u>100KHz:</u> XL = 6.28 x 100000 x 2.4/1,000,000 = 1.5 ohms. Not worth considering since Zo and Rx are 270 ohms!

So the inductance of a 5 metre cable is totally negligible and certainly on a 1 metre cable it is even less of a concern.

The material of the cable is some what important. The cable should be flexible, so multi-strand cable is generally used. The insulation should be of good quality and the RCA jacks at each end should be durable and not clinch the female RCA sockets on the equipment. All the mumbo jumbo about OFC wire, silver wire, ten thousand stranded wire is nonsense. The reactive properties of these cables are affected to such a small degree by the wire material used for their construction that it is hard to believe that they contribute anything. I am not saying for one moment that one should use interconnects made from slivers of iron but simply that if reasonable care is taken in the manufacture of cables they will not affect the sound. There has never been any proof that the dielectric properties of the insulating materials affect the sound in any way.

Note: A very easy way to compare two RCA cables is to use a high quality signal source such as a CD player (A high quality turntable with an outboard phono preamplifier is even better). Use a Y-adaptor and connect the two sample cables to the Y-adaptor and then one cable to any high level input on your home preamplifier and the other to the tape monitor loop. The Y-adaptor cannot impart any change to the sound – I do not believe it. Also the tape monitor switch contacts are in circuit whether the switch is in “source” or “monitor” positions. Now sit in your favourite armchair with your favourite music playing and ask someone to alternately flip the tape monitor switch to either position at your command. You of course cannot know which position it is in at any given time. There will be NO difference in the sound with any pair of test cables you choose. I have tried this with cheap VCR cable and $900/foot cable – no difference whatsoever. Rather use acceptably good cables and use your hard earned money for something else. Nearly all who buy useless expensive additions to their sound systems (be it car or home) have to “hear” a difference in order to justify their expensive toy.

Skin effect is often talked about. The electrons tend to flow on the outside surface of the wire as the frequency increases. The following equation approximates the difference between the DC resistance and the AC resistance of a strand of cable.
Res AC = Res DC x n x square root of freq (MHz) and n is the wire gauge factor. For typical interconnects it is about 7.

So at a frequency of 1MHz, Resistance at AC = 10 x 7 x 1 = 70 ohms. Assume that we have a high DC resistance cable of 10 ohms. The 70 ohms added to all our above equations does not change the answers significantly especially that I have just done this at 1MHz. This equation is not 100% accurate for lower frequencies but is a good enough indicator. Plug in say 50KHz to the above equation and we get 3.5 ohms of AC resistance. This is of course lower than the DC resistance but what is clear is that at all audio frequencies, skin effect has NO effect on the sound.

For some useful information on cables go to this link
http://www.audioholics.com/techtips/buyingguides/interconnects/cable_budget.php

One cable manufacturer says the following and I quote

- it has to be high quality, solid core silver
- diameter must not exceed 0.5mm (skin effect and its implications)
- insulation has to be as thin as possible (dielectric absorption, electrostatic micro-discharges)
- insulation has to be as natural as possible (unbleached cotton)
- connectors have to use as small as possible quantities of metal
- sensitivity to vibrations

What a lot of rubbish if ever I have heard.

Another respected home amplifier manufacturer states the following and I concur 100%

> The main implications are that the cable used should have reasonably low values for its capacitance and d.c. resistance per metre. From the above, a capacitance of around 100 pF/metre or less seems likely to be adequately low for interconnects that are no more than 2·5 metres long unless the source impedance is significantly higher than 600 Ohms. In practice, most good quality domestic audio sources are likely to have a source impedance below 600 Ohms, and the interconnects employed may often be only 1 metre in length. Thus even keeping to no more than 100 pF/m seems to be erring on the side of caution.
>
> When the load impedance is much higher than the impedance of the source and the characteristic impedance of the cable the signal current is likely to be relatively small. Since this is true in most domestic systems it seems reasonable to expect that effects due to interconnect co-ax inductance, series resistance, and internal impedance should be very small, and it is questionable whether they are audible. Given its shielding properties co-axial cable seems a good choice for interconnect provided that we follow the general implications drawn above.

Speaker Cables are the next on our list. They are different from interconnects because of the source impedance and the load impedance. The same situation exists as far as cable resistance, capacitance and inductance is concerned. In the case of speaker cables driving conventional dynamic speakers the capacitance of the cable is of very little concern** but the DC resistance and inductance are.

**Some power amplifiers behave adversely when loaded with significant capacitance.

The DC resistance of the cable should be an order of magnitude lower than the load impedance simply because we do not want any volt drop across the cable. How do we obtain low DCR? Simply use heavy gauge wire. The table below shows the resistance of #10 wire using various metals.

Material	Resistance in Ohms/metre
Silver	0.003068
Copper	0.003246
Gold	0.003705
Aluminium	0.00533
Brass	0.013
Iron	0.0188
Platinum	0.0188

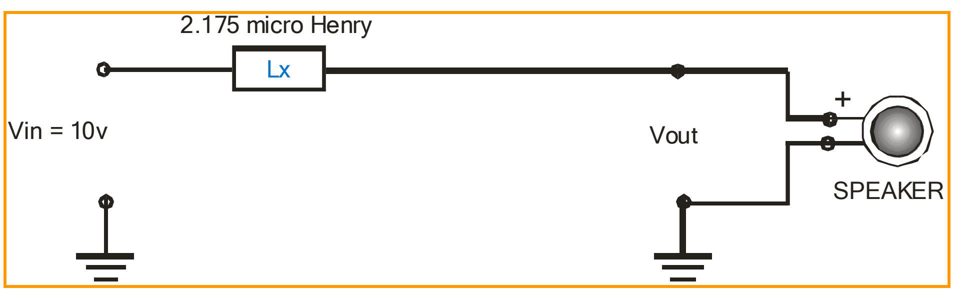
Lead	0.0412

The table shows that silver and copper are so close to each other that the difference is negligible but the cost of silver is a lot higher than copper. In a car system the longest speaker cable length is maybe 5 metres. So if we use #10 copper wire the resistance is 0.03246 ohms per leg for a total resistance of 0.0649 ohms. Let as assume we are using a 500 watt amplifier to drive a 4 ohm speaker. The RMS current is 11.18 amps and the peak is 15.8 amps. Using Ohm's Law the volt drop over the length of this cable is 0.0649 x 11.18 = 0.71552 volts RMS or 1.02 volts peak. Assuming the amplifier was playing at maximum power (an impossibility of course since we cannot average 500 watts from a 500 watt amplifier but let us be ridiculous and say we can) then the volt drop of about 1 volt as compared to 44.72v (500w with 4 ohms) is a drop of 13 watts or 1.22dB. Of course this does not occur in practice and a realistic number due to a crest factor of 10dB is an average of 50 watts per channel.
The RMS current is 3.5 amps and peak is 5 amps. So the volt drop is 5 x 0.0649 = 0.32 volts. Not a number to get excited about!

The capacitance of speaker cable is normally low and can be ignored BUT there are some of these fancy cables that have high capacitance and this can cause problems with amplifiers which are on the borderline of stability. Typically using say #8 wire for speaker wire lengths of less than 6 metres (20 feet) will not cause any problems for 99% of amplifiers.

The inductance of speaker cable can play a part in affecting the sound. Again common sense should rule. Keeping the inductance low is not a problem in car systems as the speaker runs are very short. Home systems are a little more complex. Let's look at a few examples.
The inductance of twin speaker cable is given by this formula
L= 0.913 x log (w/r) micro Henries per metre or L= 0.281 x log (w/r) micro Henries per foot where "w" is spacing between cable centers and "r" is the radius of each conductor.

Typically the ratio "w/r" is about 3 with average #10 or #12 wire. Solving for "L" in the above formula we get 0.435 micro Henries per metre or 0.134 micro Henries per foot. OK this looks good and now we can apply this to say a 5 metre (15') run of cable. The answer is 2.175 micro Henry. What does this mean to the sound and how can we measure it? The circuit below shows what happens.



The inductance is in series with the speaker, and let us assume it is a 4 ohm speaker which remains at 4 ohms from 20-20KHz (not true as the impedance will rise near 20KHz). The inductive reactance is XL = 6.28 x F x L where F is frequency and L is in Henries so 6.28 x 20000 x 0.000002175 = 0.273 ohms. So what we have at 20KHz is a series impedance of 0.273 ohms with our 4 ohm speaker and the attenuation is -0.573dB. Vout is 9.36 volts. This 0.573dB loss is not typical of the real world since the impedance of the tweeter will rise to almost 10 Ohms at 20KHz and so the attenuation falls to -0.23dB. At 20KHz we would be hard pressed to hear a 0.5dB drop. If we move our head off axis from the tweeter by a say 20-30 degrees the dB drop is far greater. I challenge anyone to drive their car and keep their head still and on axis with the front tweeters. (Do not attempt this as it is dangerous)

The ratio of "w/r" should be kept as small as possible to keep the inductance of the cable short. At lower frequencies the inductance has less effect since the inductive reactance reduces with lower frequencies. At 1KHz it would be a twentieth of the above at 0.013 ohms.

Dielectric absorbtion is also not worth worrying about because at ALL audio frequencies the worst dielectric which is PVC has shunt impedances of many millions of ohms. This parallel impedance cannot affect a 4-8 ohm speaker.

Skin Effect is caused by the self inductance of the wire. This causes the inductive reactance to rise at higher frequencies and electrons are forced to the surface. The circumference of the wire is therefore preferred at these higher frequencies and so the net resistance of the conductor is increased. The center core of the wire is not used. At 20KHz the losses with a 4 ohm speaker are less than 0.01dB with a 3 metre (10') cable. I hardly think that this is worth worrying about. I quote from a renowned source.

"Some so called "exotic" Cable Companies enjoy spreading the fallacy that Skin Effect can cause deleterious effects on your audio performance. While Skin Effect is a real world problem in high frequency applications such as RF Power and Transmission, it is negligible at audio frequencies as I will demonstrate in this article based on fundamental engineering and scientific principles. "

EMI and RFI are not a problem with speaker cables since the impedances are so low that it is very difficult for these types of signals to enter the cable. I of course assume that your speaker run is not 3Km (1.8 miles) long which may act as an antenna.

One of the cutest products I have seen are cable lifters. Yes you read this correctly – cable lifters. These are little stands which are used at maybe 1 metre intervals to lift the speaker cables a few cm off the floor. So, several must be used on average length speaker runs. They claim that by lifting the cable off the floor affects the sound. They are about $20-$30 each! Of course they do not affect the sound BUT after spending a few hundred bucks on this junk you better hear some difference @#$%. You could of course just use small pieces of 2x4 wood blocks and save your money.

Power cables both for 12 volt and 120/230v 50/60Hz. Don't you love those 12 volt #2 gauge power cables with the little arrows printed on the insulation which indicate that the cable must be connected with a certain "polarity". What is amazing that there are some out these who ACTUALLY BELIEVE THIS JUNK! The cable which delivers current to your amplifiers has one mission in life, to deliver the current without losses. It has NO knowledge of which way it is connected (Electrons are dumb and do not care either) This means one thing and one thing only. Use the largest gauge wire possible. This cable carries DC and so there is no skin effect, dielectric absorption, inductance issues, capacitance issues. In fact if the cable is inductive (which it is in fact because every piece of wire no matter how short is inductive) it is advantageous since the inductance helps to reject alternator noise.

The connections at each end should be of high quality and the connectors should be of robust construction. Contact resistance is important to avoid losses and again common sense should prevail here. Zed Audio does not recommend the use of power distribution blocks when using multiple amplifiers. The reason is that when an amplifier draws current it causes voltage spikes to be induced in the power lead. These can interfere with other amplifiers. The capacitors used in every amplifier across the power input are not large enough to dampen these spikes. The battery being an enormous battery has the capacitance to do this. We advocate the use of separate power cable for each amplifier.

AC power cables for the home stereo have to be the biggest con which cable manufacturers and suppliers have pulled on the unsuspecting public. The claims of how “the noise floor of your home system is reduced” and “the sound seems to come out of total blackness” is their favourite. “The mids and highs seem to be so much more transparent than before once I substituted my power cables with cable XXX”. Only a fool can believe such silly comments.

I have a catalog in front of me and I see real hot specials. How does $175 for a power cord sound? Or even $649? No way those are cheap… let us look at one for $1,995.00 yeah nearly two grand for a dumb power cable that this company claims will almost cure the common cold if asked to do so! If $1,995 is too much they have a slightly less expensive model at $998.00 – wow what a bargain. There is another company offering what they call the “Magic Power Cord” at a steal of a price of $1,499.99 for 1.8 metres (5.85 feet). The reporter who “tested” the cable said “The first thing I notice is the presentation becomes BIG, stage width, depth and the space between instruments all seem larger, images are more solidly located in space and don’t wonder about” I think this dude has been wondering about himself. It performs magic on your wallet and that is about all it does. It lifts the Dollar bills right out of your back pocket without you being aware.

A long with the power cable rip off artists are the guys who sell AC outlets. They paint them a new colour and claim all wild and wonderful things for “their” scientifically designed AC outlet. Or what about those hospital grade types which cost almost $50 per pair! The same company sells a power strip for $199 for 6 outlets, that is $33 per outlet!

I think that maybe these power cables at two grand and the hospital grade outlets with nice colours and silkscreened logos would do better if we could rewire our home with solid 99% pure silver wire, replace the circuit breaker board with gold plated contactors and fuses and then the ultimate demand of your city that they run the same silver wire from YOUR home to the substation and then from the substation to the main distribution grid. Wow what a deal and then the music will jump right out at you. PS I just woke up from my dream.

One simple question one should ask. The power to your home comes from a transformer some many kilometers away in some cases. It enters your home and a distribution board with many circuit breakers distributes the power throughout your home. NOW HOW CAN THE ADDITION OF MAYBE 2 METERES (6’) OF CABLE AFFECT THE SOUND? The electricity has traveled a torturous route to get to you and now it encounters a magical piece of cable and all of a sudden all the ills of your stereo are cured. I say, you must believe this if you have spent a stupid amount of money on your new power cable because how would you justify this expense to your family and friends! Reading the hype which these snake oil merchants put out makes me sick, but if these kinds of things ring the bells of some people, be my guest.

I am a firm believer in direct A-B blind listening tests. The brain cannot remember the differences (if any) between two pieces of gear when the time between the listening experiences is more than a few seconds and even then this may be too long. Immediate comparison is the ONLY way to find out if one can detect any difference. Those who say “I took out the standard power cord and replaced it with brand XXX and wow the sound was transformed” are simply lying. The time interval to substitute one power cord, interconnect or speaker cable with another is just too long to allow the test to have any meaning whatsoever. To compare cables is a tedious process. A multi-pole changeover switch is required or a switch with multi-pole relays. I did this once with the power cable to my preamplifier. I borrowed a “snake oil” type IEC power cord and compared it to a standard off the shelf #18 version. I had a friend do the switching and I could not detect any difference. He listened and he could tell no difference.

The brains of those who spend money on these magical wires, cable, etc. have to “hear” a difference because the shame attached to not hearing any would be too much too bare.

It is sort of similar to those claims made by the companies who advocate a 600 pound block of exotic rock taken from the frozen wastes of Antarctica and place it carefully on the top of your CD player. This will enhance the upper midrange of your CDs whilst also improving your stamina to run the mile in under 4 minutes. Also it shall allow the resident bats in your home to hear the music with more air and prescence. In addition use those $290 rubber feet under you speakers to improve the bass. I read some of these audiophile magazines (there are nice pictures inside I must admit) and the claims made by both advertisers and reviewers alike astound me. They really do believe the rubbish they print. The one magazine I read (it shall remain anonymous) has reviewers who review some gear and then 9 months later review an updated version or a similar piece from another supplier and start saying how the subtle differences between A and B are bla bla bla. Give me a break, how can they remember what A sounded like 9 months ago? You know what it is about – ADVERTISING. If they did not write this junk the companies would not advertise and I would have no magazine to look at some nice pictures.