ATLAS | Cables

The DNA of Atlas Audio Interconnects & Cables. (Analogue, Digital, HDMI, and USB).

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Why do some cables clearly sound better than others?

To understand the philosophy behind the products of Atlas Cables you need to start by knowing that when we design an audio, video or a digital cable we start by considering four main elements. The conductor material and its construction; the insulating material (also known as the dielectric); the connectors and the overall construction of the cable – is it co-axial; a twisted pair; etc.

Each of these items contribute to the final complete cable and each is important. So in general terms Atlas Cables will use the best possible conductors; dielectrics and connectors available within the price category and then select a form of construction that best suits the intended application.

Over the next few pages we explain why the choice of these components is so important and show just some of the work and research Atlas has needed to undertake to come up with the best solutions.

The importance of very pure metal conductors

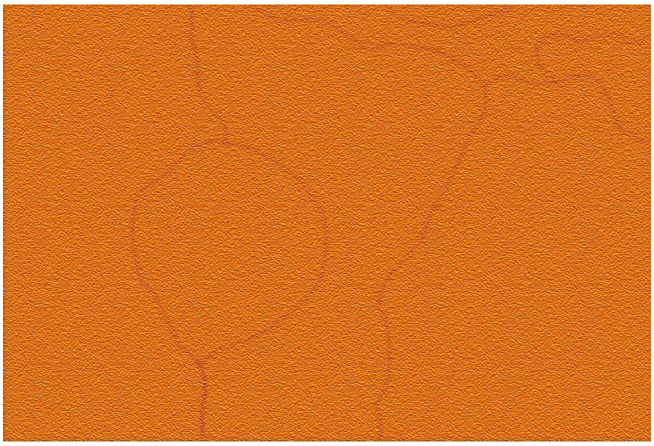
We would all intuitively agree that our cables should use pure metal conductors because obviously nobody would consider using pieces of rusty steel barbed wire as loudspeaker cables. But how pure does the conductor need to be and why? Those are questions rarely answered by hi-fi cable manufacturers who prefer to concentrate on obscure theories of how electrical signals pass through wires.

The purity of metal is normally expressed by the shorthand term “Nines” or “Ns” which refers to the number of figure 9s in defining the level of purity. Thus a 4N purity copper means that the material is 99.99% copper with just 0.01% of impurities whilst a 5N copper bar is 99.999% pure with impurities of below 0.001%. Such metal ingots are normally completely free of Oxygen, Nitrogen and Carbon and after manufacture need to be stored in special sealed containers conserved in a vacuum or in the inert gas Argon until they are turned into wire conductors. Copper to a purity of up to 8N is also available but it is almost impossible to use in cables because exposure to our polluted atmosphere immediately causes oxidation and other reactions giving a reduction in purity.

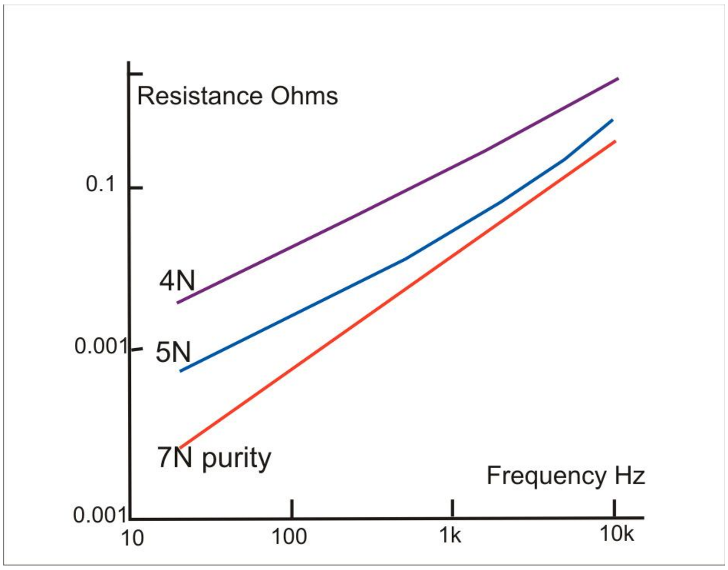
The best conductors currently available are those made by the process of Continuous Casting (OCC) originally developed by Professor Ohno of the Chiba Institute of Technology. Such OHNO conductors are drawn as a single continuous crystal so it has no crystal boundaries except at either end of the cable. Prof. Ohno found that impurities gather wherever there is a boundary so if you want to reduce the level of impurities you must first reduce the number of boundaries.

Subsequent processing to produce fine copper wires changes the crystalline form of the material but retains the uniform structure compared to the chaotic granular structure of commercial grade copper. The pictures below show a magnified transverse cut across a thin wire and a longitudinal cut (a cut along the length) of a wire. This shows that although the wire is no longer a single crystal it retains a very clean structure with just 3 or 4 crystals instead of the thousands of crystal boundaries which would be found in a normal OFC wire.


Longitudinal Section


Transverse Section

There is scientific work (Nakane, Watanabe, et. al.) that supports the supposition that the signal electrons flow more easily through a uniform crystalline structure and all the current research indicates that the purity of the conductor is important. The graph below shows the behaviour of some test conductors or various levels of purity and it can be seen that the higher the purity the lower the electrical resistance right across most of the audio band frequencies. This work demonstrated the improved electrical performance of high purity wires; the graph below being one of the simpler and more easily understood results



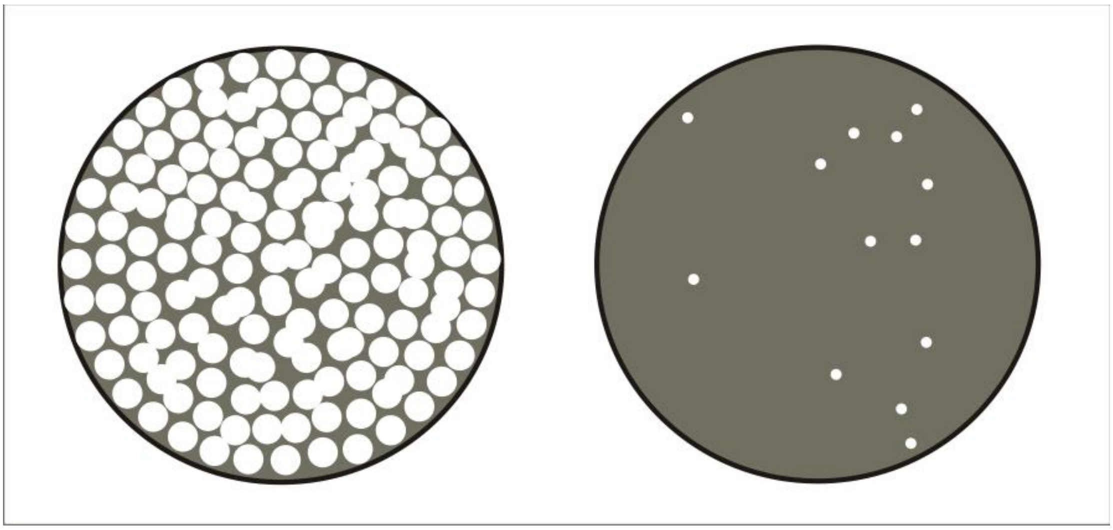
This and other work independently undertaken by Atlas Cables demonstrates that high purity cables constructed in the correct way have a clear measurable effect upon the transmission of the audio signal. For this reason Atlas takes immense care in the selection and production of the conductors it uses in its cables.

The importance of the Insulator or Dielectric

The perfect cable is an un-insulated conductor in free air. It will then perform exactly as described in the text books and the cable will be a simple resistor with no complex impedance components or frequency response variations. However this theoretical cable is not practical or is at least inconvenient to use so a layer of insulation is added in the form of a dielectric layer. Now the cable has a complex impedance; the capacitance causes charge storage; the cable now has a defined frequency response and so on and so forth.

The quality of this dielectric largely defines the performance of the cable so Atlas Cables takes great care in only using those dielectric materials that get closer to ideal for the given cable. For the best of these cables Atlas has engineered a form of dielectric construction that is a major step forward and gets closer to the perfect “no dielectric” construction than any other material. This new material has made its debut in the Atlas Asimi and Mavros interconnect and loudspeaker cables. The effects of this cable dielectric are certainly measurable and therefore are almost certain to be audible. So the use of a dielectric whose behaviour is closer to that of air is a good thing.

This new Micro-porous PTFE foam (porous polytetra-fluoroethylene) has a dielectric constant or around 1.2 compared to the previously favoured high performance material PTFE which has a dielectric constant of 2.3 or more – the lower the figure the better. In fact with this material it is possible to build a cable even closer to the ideal of "no insulator" by having an extremely porous PTFE foam which is mostly composed of air. The picture below shows a section of a typical micro-porous material compared to the solid material. It is clear that the micro-porous material is mostly air with a few “honeycomb” style links of the solid PTFE material.

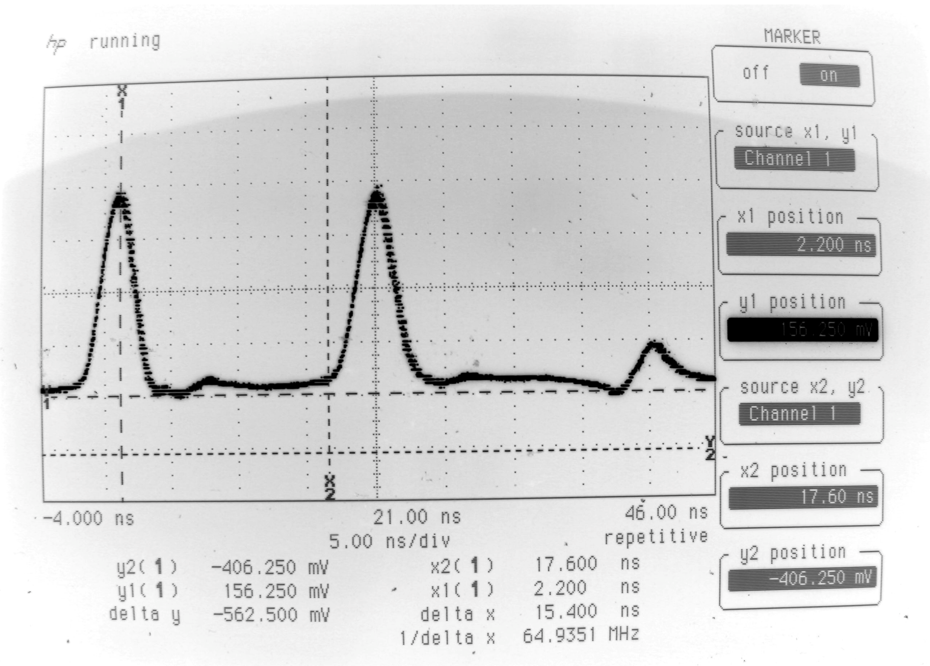


Why is the “Speed” of cables important?

We know that in theory an excellent cable will simply comprise of a pair of pure conductors in free air; in fact this is virtually a perfect interconnect cable. However in practice the conductors need to be covered by an insulating material, normally a plastic, to stop the two wires from shorting together and also to protect the conductors from corrosion; copper & silver being particularly vulnerable in this respect. But now instead of free air between the conductors there are the two insulating “tubes” forming a dielectric. This turns the cable into a capacitor or a series of small capacitors along its length. If the cable is a co-axial interconnect then the capacitance is between the inner conductor and the shield or braid and as the inductance is very small so the cable becomes a series of small electrical filter networks; attenuating the higher frequencies.

As a rule of thumb the higher this capacitance the longer it will take for the signal to pass through the cable; so the “slower” the cable. What do we mean when we refer to the “speed” of a cable? Well the most common term in use is the Velocity of Propagation (VOP); the speed at which the signal travels down the conductor. The VOP is defined as a figure relative to the speed of light in a vacuum (C=299 792 458 metres per second). We can say that light travels about 3 metres in 10 nano-seconds (one nano-second is one billionth of a second) so if we measure how long it takes for a pulse to travel down a wire we can define the speed or VOP as a fraction of the time light would take; with light being defined as 1.00. This measurement is made using a technique called Time Domain Reflectometry. The TDR technique is based upon the surprising fact that if you fire a pulse down an open ended cable the pulse will be reflected back by the open end and return back to the beginning. Looking at the figure below you can see that time T represents the time taken for the pulse to travel along the length of the cable and then back again.

This measurement is difficult to make with good accuracy because the test pulse needs to be really narrow otherwise it will mask the start of the reflected pulse. And to measure such a narrow pulse requires the use of very high speed oscilloscopes rarely seen in audio laboratories. The waveform photograph below shows such a measurement where the time delay is 19.1 Nano seconds and the cable length was measured at 2.14 metres. So this particular cable has a measured VOP of 0.75 that is high for an audio cable.



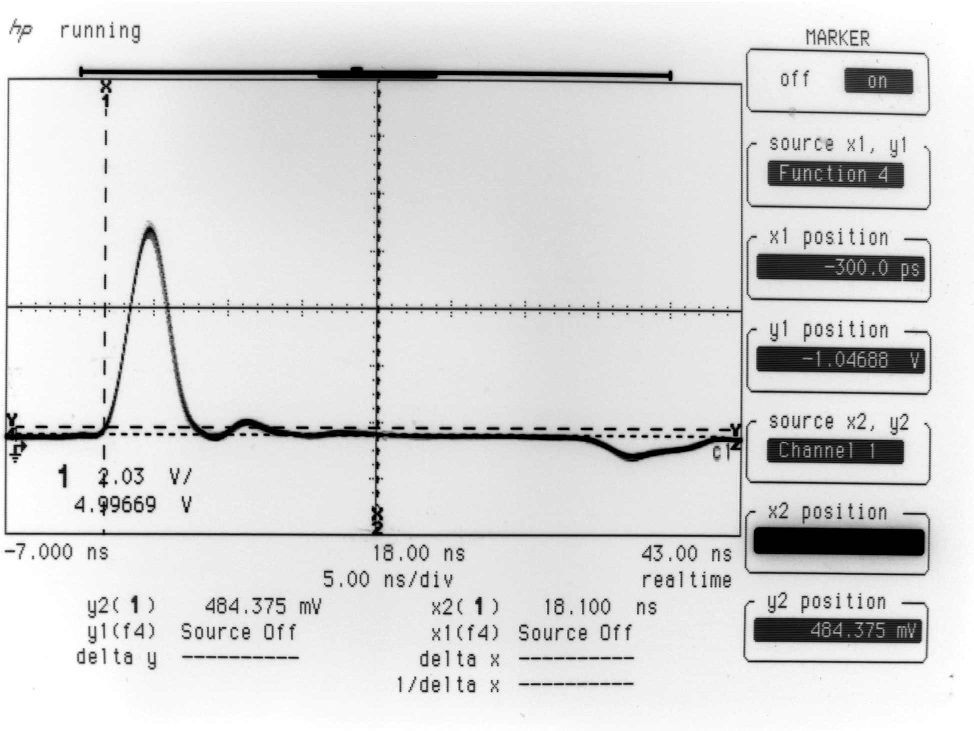
Reducing the capacitance to the low level necessary for high VOP cables is very difficult and in the case of Atlas Cables it has been the result of extensive development work which led to the use of new dielectric materials. One of these is the Microporous PTFE Foam mentioned above which allows a greater signal velocity than when the previously highest performance insulator, solid PTFE or Teflon, is used.

How do these high speed cables benefit the listener? Well obviously a very fast (high VOP) cable will have a wide bandwidth so it will transmit all the signal frequencies of interest without any loss. And this same wide bandwidth will ensure that all the audio frequencies are carried without any measurable amplitude or phase errors so the audio signal is preserved perfectly. We can also look at the benefits in a different but equally valid way because as described at the start of this piece we know that the theoretically perfect cable would just have two pure conductors with no resistance; inductance or capacitance. In practice it is only the last two parameters which are problematic because any resistance will simply attenuate all signals by an equal amount whereas the effects of inductance and capacitance are frequency dependent. As a consequence of this ongoing research work the **"HighV"** family of Atlas interconnects and loudspeaker cables all have very low figures of inductance and capacitance and hence high VOP figures. These cables have consequently moved one step closer to matching the theoretically perfect cable. As a result the many audible benefits of these new cables, particularly the outstanding Ascent, Mavros and Asimi ranges, are there to be heard when you take the opportunity to audition their performance.

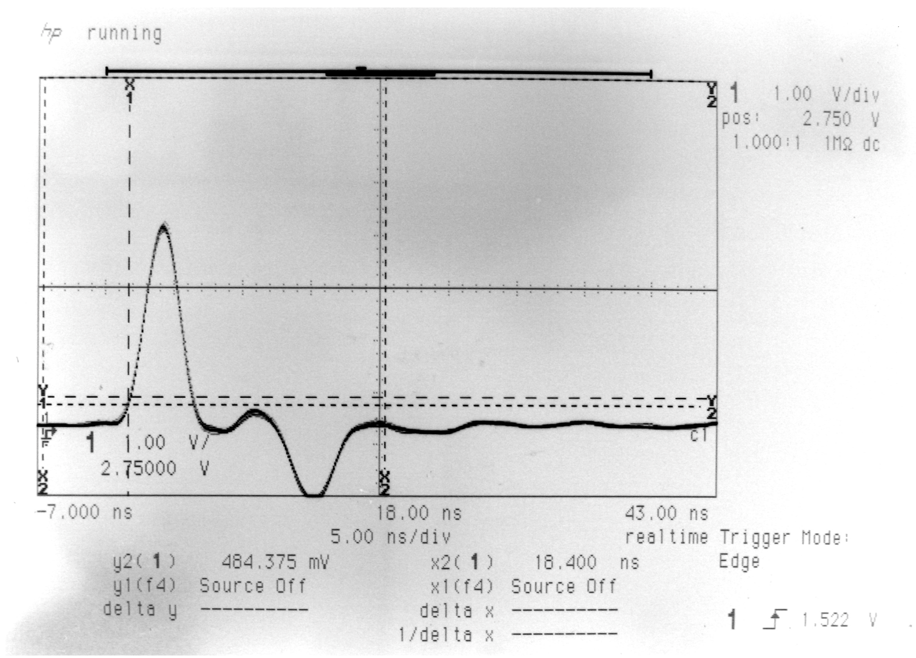
The Importance of using the best Digital Interconnect Cables

Many people believe that the design and construction of digital interconnect cables is not critical or indeed important because, after all, we are only dealing with "1s" and "0s" so as long as these pulses reach the end of the cable their quality is unimportant. Yet most listeners can hear the difference between the best digital interconnect cables and the others. So how can this be? How can a cable which just has to carry DC voltage pulses effect the sound?

Much of the answer lies in the way real cables behave. In the section dealing with the speed, or VOP of cables we explain that when a pulse is sent down a cable then a similar pulse will be reflected back from the end of the cable. Transmit a thousand pulses and you'll get a thousand reflected pulses. However there is one condition where you do not get any reflections. This is when the cable is terminated with an impedance which exactly matches the impedance of the cable. So in the case of digital sources we ensure that the output (such as the SP-DIF output of a CD player) has a source impedance of 75 ohms and that the input (such as the input of a Digital-to-Analogue Converter) also has an input impedance of 75 ohms. Then if the interconnect cable has a characteristic impedance of exactly 75 ohms there will be no reflected pulses. You can see this effect in the pictures below which show the cable un-terminated and plugged into a 75 ohm input. The matching is close to perfect and there are no significant reflections. This particular cable is the Atlas Mavros 75R.



Now look at the results with another cable; a cable which is claimed to have a high performance by its manufacturer. This time the matching is not exact and there is a reflection. With a number of pulses there are a number of reflected pulses. Now imagine the millions of pulses per second of a digital audio signal which are going to be mixed up with the millions of reflected pulses. The next digital processing circuit (such as a the DAC) will try decode the signal accurately but will it be able to identify which are the original source pulses and which are the added refection pulses? Unfortunately not so errors will creep in and the final sound quality will be effected; sometimes quite severely.



And it is not just the cable itself that is important but the connectors as well. There is only one true 75 ohm connector available and that is the standard BNC connector. So when RCA phono jack connectors are used care has to be taken to match the cable and connectors as precisely as possible so that the complete interconnect has a matched impedance.

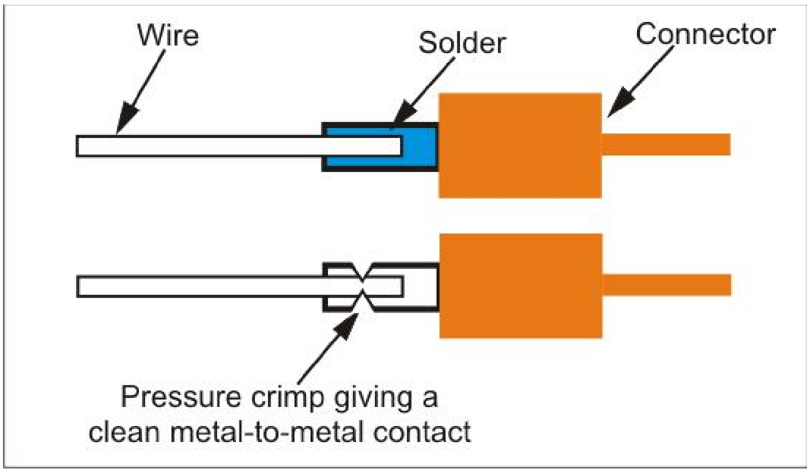
So there we have it. Digital interconnect cables do make a difference to the quality of the sound you hear and it is a difference that can be identified by measurements and virtually eliminated by careful design and construction.

The Importance of good Connector Design

Of course the wire itself is just part of an interconnect cable or a loudspeaker cable. The other equally important part is the connector. These days most high quality cables are fitted with connectors that look impressive but how they actually perform with real signals is more important than their cosmetic appearance. The connector must make a good connection, both to the matching socket and to the attached wire; it must match the wire in terms of impedance and structure and it must be durable. Very few connectors meet all three criteria.

To make a good contact the plug must mate to the socket firmly so that there is a metal to metal contact. Ideally the connection must be tight enough so that during the connection process a very thin layer of molecules will be scrapped off both contact surfaces to remove any surface pollution leaving pure metal bonded to pure metal. At the same time the connection must not be so tight that the connectors are damaged or deformed during the connection process. And a tight connection must be ensured for both parts of the connector, not just the centre pin, because the electrical circuit needs both the signal path and the ground or return path.

The connection to the wires must also be as homogenious as possible. Traditionally these connections have been made with a tin-based solder but when that is used there is invariably a layer of solder between the copper wire and the connector and this is a source of signal degradation. If we have taken great care to minimise the number of crystal boundaries within the wire it would make no sense whatsoever to have the major break in the signal path that the solder join represents. So how can this be avoided? Atlas Cables avoids this problem by using connectors which are joined to the wires by crimping; where the metal of the connector and the wire are squeezed together to form a strong air-tight metal to metal contact. The result is a smooth signal path with no interruptions and hence no degradation of the signal.



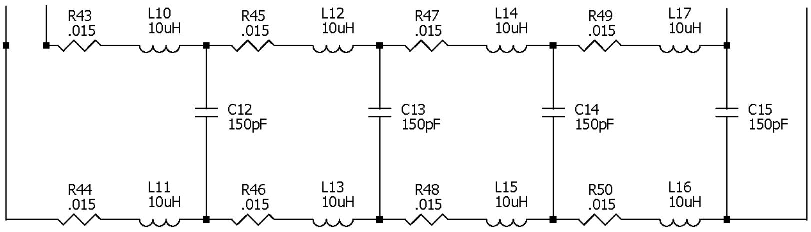
The other factor we mention is the impedance of the connector. This is one aspect of cable design that seemingly most manufacturers ignore. In the laboratory the ultra-accurate measuring instruments use either 50 ohm or 75 ohm BNC connectors with the matching 50 or 75 ohm cable. Everything is matched so that there is almost no interference with the signal being matched. Similarly in the broadcast world most of the wiring is done using 75 ohm cable fitted with matching 75 ohm connectors. However in the audio world little thought has been given to the connectors so there are numerous examples of what is loosely termed the “RCA Phono Jack”. At Atlas we cannot influence the sockets used on the equipment made by numerous manufacturers but because we design and make our own connectors we can ensure that the cable and connectors are well matched as a complete transmission system.

Radio Frequencies and other interference – keeping it at bay

The world we live in today is swamped by electromagnetic waves; radio frequencies of numerous kinds from short transients created by machinery and burst transmitters such as is used for radar to the Wi-Fi and Bluetooth wireless system used throughout most homes. We are all aware of the effect of audible interference breaking into our audio signal when, for example, a taxi with a badly installed transmitter passes by. But few of us are aware of the insidious effects of the interference signals which we cannot hear.

Most amplifiers restrict the bandwidth of the input signal with a simple low-pass filter so any high frequencies picked up in the interconnect cables are attenuated. However this is a simple 6dB per octave filter and it will be swamped by a large high-frequency transient signal. Such a signal will reach the input transistor stage and cause it to “latch” for a time. During that time and any additional time it takes for the amplifier to recover it will not be operating correctly and the sound quality will be severely degraded although not in a way that any of us could easily describe.

But even worse such interference can actually enter an amplifier through the loudspeaker connections. At higher frequencies a cable is no longer a simple conductor with a small resistance between; say, the amplifier terminals and the loudspeaker terminals, but a complex impedance network similar to the small section of equivalent circuit shown below.



High frequency interference signals can be picked up within the cable and enter the amplifier through the negative feedback loop which is normally connected to the speaker output terminals. Once in the sensitive feedback loop where is can cause the amplifier to latch or lock for a short time or even cause the amplifier to oscillate with the risk of damage and a long-term loss of performance. And this can often be happening without the listener becoming aware of the problem.

RF and interference signals can be minimised within cables by two techniques; twisting the two signal wires closely together and by screening or shielding the complete cable.

Twisting wires together rejects noise from electro-magnetic fields because the voltage induced in the two conductors will be more nearly equal. The "tighter" the twist, the more equal the induced voltage will be even at the highest frequencies. To understand how this works consider any interfering source and a cable running past it. If the cable is not twisted, one conductor will be closer to the source, so a slightly higher noise current will be induced into it than in the other conductor. If the conductors are twisted, one conductor will be closer at one point along the cable, but one half twist further along the cable, the other conductor will be closer. The difference in spacing between the conductors may not seem to cause much of a difference in level, but if we need 100 dB of noise cancellation, the two voltages must be equal to within .0001%, a very tiny margin of error.
Twisted conductors are to be found in telephone; computer and network cables including the popular Cat5 and Cat6 cables.

A cable shield may be composed of braided strands of a metal such as copper or a non-braided spiral winding of copper tape, or a layer of conducting polymer; ametal foil which is bonded to a plastic film. This shield acts as a Faraday cage so that any electrical signals on the outside of the cage will not be present on the inside of the cage.

The shield works by shunting electromagnetic energy (the RF or interference signal) to the ground. To do this effectively a shield needs to have good coverage, so that energy cannot readily pass through any holes in the shield; it must have good

conductivity so that energy can be easily conducted to the ground; and naturally there must be a good connection to the ground at the end of the cable.
The shielding foil and braid have very different characteristics, which is why many of our cables use both types of shield. Foil shields offer complete coverage; as it is very easy to apply the foil to a cable so as to cover every last bit of the conductors. But foil has a rather high resistance, so doesn't provide the best path to ground, and it is not easy to reliably join the foil to the connector ground. Braid cannot provide the 100% coverage achieved by foil; as the weave inevitably has some small holes and when the cable is flexed, these holes open up wider. The larger the holes, the less effective the shield, and the best braids achieve only about 95% coverage. But braid has very low resistance and it is easy to get a good connection to the ground terminal.

The effectiveness of the shielding in keeping out noise varies with the frequency of the interference source and here braid is generally more effective at lower frequencies, whilst foil is very effective at the higher frequencies. Just how effective is this shielding? The best measurement method is termed "Transfer Impedance" which determines how much of a signal outside of the cable reaches the inside. The lower the value of the transfer impedance, the more effective the shielding. This Transfer Impedance varies with frequency and typical performance figures are given below for a typical type of cable shielding and for the comprehensive shielding adopted by Atlas. The difference is quite dramatic.

	5 MHz	**10 MHz**	**50 MHz**	**100 MHz**	**500 MHz**
60% copper braid + foil	**20**	**15**	**11**	**20**	**50**
95% copper braid + foil	**1**	**0.4**	**0.09**	**0.1**	**1**

Putting it all together to make exceptional cables

In the preceding pages we have described the many requirements of the “perfect” cable and how Atlas Cables incorporates these needs into its designs. It is important to realise that, contrary to the claims of many competing manufacturers there is no “magic bullet”; no special feature that will solve all the limitations of the cable. Rather the best cables are the result of a careful balance in the design where all requirements are weighted and balanced against each other. Thus it would be no good to have a super-fast cable but made with impure conductors, nor would anything be achieved by having an excellent cable terminated with low-quality connectors.

By having a full understanding of cable technology and by adopting a careful balance of all the parameters at the design stage Atlas Cables is able to produce products that offer exceptional performance in each of the price categories.

ATLAS | Cables

The Digital World

In the analogue world bandwidth is defined as the max frequency that can be transmitted freely without undue attenuation (-3db points) and is usually expressed in Hz. In the digital domain bandwidth is often defined as the throughput that can be achieved through a chosen media and expressed in multiples of bits per second.

Bandwidth can be described as being ***analogous*** to a water-pipe.

Imagine a pipe which water flows along. The pipe has a fixed size and therefore there is a limitation to how much water can flow through it at any one time. Bandwidth can be thought of as the WIDTH of the pipe. This constrains how much water can get through at any moment in time. The flow of water down the pipe is therefore the data that we wish to send from our source devices; Blu Ray, DVD players etc. to our processing devices; AV amplifiers, Displays etc. We can think of our Hifi or Home Cinema cables as the pipes in a water system and our Hifi and Home Cinema devices as joints and pumps. The water as above can be thought of as our data. There are two main ways of increasing the flow of water (data);

Increase the width of the pipe so that more water can get through at any one time (increase bandwidth). Push the water through the pipe faster (increase data throughput). A pipe has certain physical properties, though. If you push too much water through the pipe then there is a chance it will break and the water flow will be disrupted.
And here we have the great digital cable debate conundrum, when trying to differentiate the qualities of digital transmission cables -we often get distracted by the coding system used (binary 1's and 0's) which is used to help minimise data errors and we speak less about the bandwidth and data throughput which ultimately affect system performance more.

Common Home Digital bandwidths

Home Broadband	Typically 8 (Mega bits per second) Mbps, possibly up to 20 Mbps
Home Ethernet Network	10Mbps, 100Mbps
USB 2.0	480Mbps
Gigabit Ethernet	1000Mbps (=1Giga bits per second) Gbps
HDMI	10.2Gbps!!!!!!!!

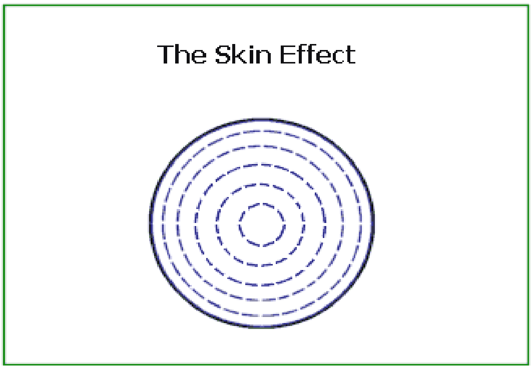
So does the Atlas design philosophy change when approaching high speed digital cable design? Well actually not at all!

In the previous section we concerned ourselves about the choice of conductor, dielectric and the critical importance of connector design and shielding. Now we must add to that list of critical parameters some others;

- Skin Effect
- Intra pair skew
- Inter pair skew

Whilst we are aware that attenuation (frequency dependent resistance) and increasing impedance slows the edges of binary data down and that thermal and conductive noise results in bandwidth and throughput reduction we also need to pay specific attention to the high frequency content of the digital signal and to the problems this creates.

There is a phenomenon known as the skin effect which manifests itself in that the higher the frequency of a signal propagating down a conductor then the higher the radial position it takes up on that conductor. Unfortunately the higher the radial position the higher the resistance to its flow and therefore propagation delays take place at the destination end.



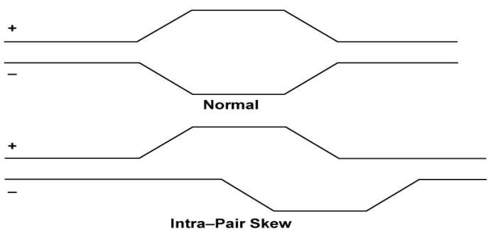
At Atlas we minimise this problem (in Digital cables ONLY) by silver plating our conductors, this reduces the effective resistance near the surface and minimise propagation delay. (Note: Silver plating analogue cables in our view provides a skewed, bright, artificial sound that tires and fatigues listener.)

High speed digital cables have many applications and as we all know the cost of cabling infrastructure is a major concern to industry but as many problems arise so innovative solutions are delivered that help us in the Audio Video world.
In data communication there is wide use of UTP (unshielded twisted pair) cable. Twisting provides shielding from interference, noise and crosstalk due to cancellation effects. This innovative approach to providing transmission at a price helps to control the crosstalk in general purpose data cables but also introduces two other problems which in high bandwidth digital audio video cables cause us additional problems, these are the inter and intra pair skew.

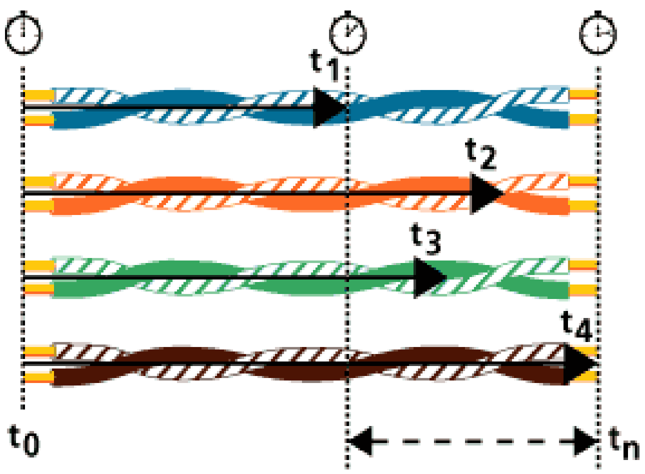
General purpose HDMI uses twisted pairs, this necessitates matched twist ratios for each TMDS (transition minimised differential signalling) twisted pair **(which is not the case today)**, and increased capacitance between pairs can increase crosstalk dramatically. Atlas HDMI cables combat this effect by using shielding around every precision matched pair, and even more shielding around the entire cable to help reject noise from being injected into the cable. The tight tolerances, additional shielding, parallel conductor structure and active processing result in a more accurate and wider bandwidth cable than that used for general data transfer (UTP).

Intra pair skew

The time difference in propagation of a TDMS differential signal over the length of one internal HDMI twisted pair.



Inter pair skew
The time difference in propagation between individual TDMS differential signals (RGB + clock) within an HDMI cable.



Signal degradation as a result of frequency dispersion and skin effect losses are detrimental to the delivery of error free transmission. These losses are compounded by the quality of the cable construction and are worsened by; the use of poor quality Conductors, the mismatch between conductor lengths, twist ratios between differential conductor pairs as well as the dielectric and shielding strategies put in place. These physical issues add to the other negative effects of Crosstalk, Skew etc to create attenuation of the signal amplitudes slowing down of the signal edges effectively closing down the eye pattern of the differential signal thus increasing bit error rates jitter and delivered audio video quality.

Why do you need to bother as surely its Digital, simply all 1's and 0's!!!

Well it's all to do with the definition of an analogue and digital signal.

An analogue signal is defined as "time continuous" where a digital signal is defined as "time discrete". The common element is "time". Time based errors or "uncertainty" derived from all the variances described above manifest themselves in Jitter.

Why is Jitter so difficult to deal with in a digital system and why are its effects so disastrous on performance.

Jitter manifests itself in display and processor electronics as a concept called "work done". That is the easier the display or audio processing device can recover the data from the interface then the lower the work done and therefore the higher the potential audio and video performance achievable. If the display device is continually checking and correcting errors then this uncertainty is transferred onto the power supplies, the clocking circuits as well as the digital to analogue converters. This can manifest itself in pixilation, noise within the deepest blacks and worst case complete loss of audio and video fidelity.

At Atlas all our high bandwidth digital cables are designed to minimise transmission errors, deliver improved throughput and increased audio and video fidelity by engineering out all unwanted, inaccurate, nonlinear and reflected sources of uncertainty.

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