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GB 2547263 B

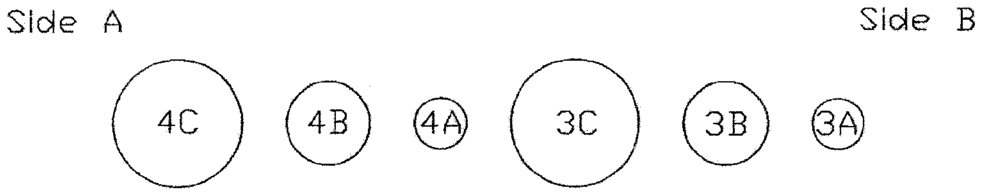

Figure 1

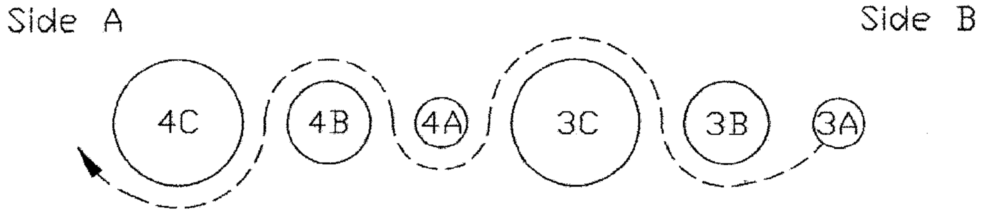

Figure 2

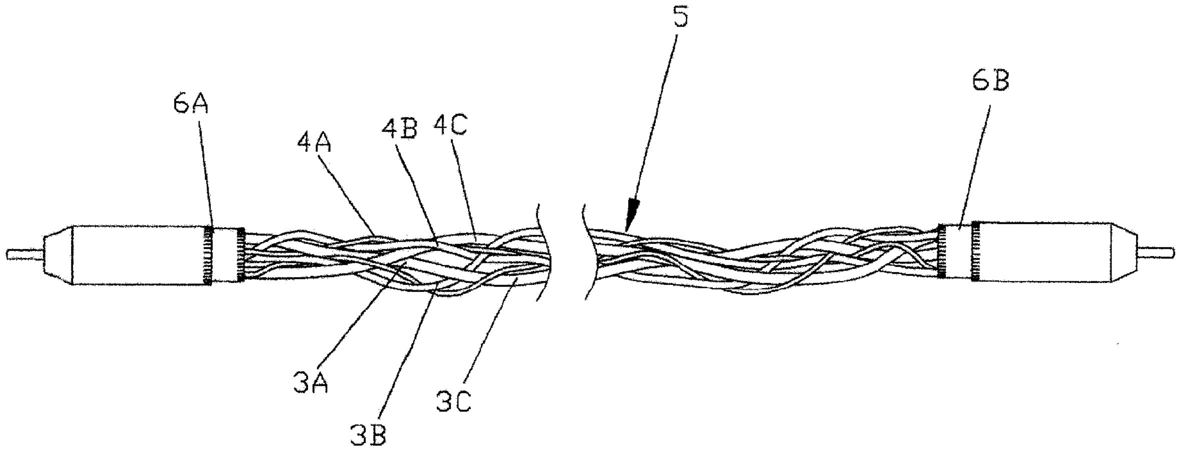

Figure 3

Electric Cable

The present invention relates to an electric cable. More especially the invention relates to a Hi-fi audio “interconnect” or loudspeaker cable.

Background of the Invention

Typically many high-end audiophile systems consist of separate pieces of audio equipment such as CD player, turntable, amplifier and loudspeakers all of which can be interconnected by electrical cables or interconnect cables.

Experience has shown that interconnect cables may greatly influence the quality of signal reproduced by the audio system according to the human ear, which has an estimated dynamic range in the order of 140dB challenging the performance of many pieces of test equipment. Its ability to detect changes in an audio signal that is not detectable using conventional measuring equipment has long been recognised in the audio industry.

Although the theoretical physics underpinning interconnect cable design is well established it is also understood that just because a cable measures well, it will not necessarily sound good. This has resulted in a variety of approaches to cable construction.

Interconnect cables are known to influence at least: the tone colour of the signal; the spatial reconstruction of the audio “image”; the amount of lost information such as clarity of voice; the focussing of the sound sources; the dynamic range; the audibility of the sound event; the naturalness of the reproduced sound; and the noise level introduced into the audio signal.

Factors taken into account when constructing a cable include matters such as the type of conducting material (e.g., oxygen free copper); whether or not it is plated; the thickness and geometry of the conductors and whether they are solid or multi-stranded; the type of insulation used and how the conductors are combined.

Methods of combining conductors includes the use of twisted pairs (a good method of reducing common mode interference, e.g., noise); the use of parallel arrangements of conductors; co-axial arrangements; different forms of weaving and braiding; the use of Litz wire arrangements.

Such are the claimed variations that an interconnect cable can introduce to the sound signal they can be viewed as tone controls that audiophiles use to help tune their systems to their own personal requirements. From a practical point of view this means trying different cable designs or geometries until the desired audio effect is achieved.

The present invention has variable geometry that allows the user to alter the relationship between the conducting filaments so as to change the audible sound allowing the interconnect cable to better adapt to the differing circuit designs it is asked to link.

A multi-polarity audio cable carrying two polarities of signal, or a signal and reference ground, via two separate conducting filaments (which may comprise one or more individual conductors) may be considered as a circuit with inherent resistance R; inductance L (resistance to current flow) consisting of self-inductance of an individual conductor and mutual inductance between two conductors; and capacitance C (the ability to store charge) between conductors.

High values for resistance, inductance or capacitance can adversley affect transmission of an audio signal, in particular affecting the high frequency response of the cable.

Reducing the overall resistance of an audio interconnect is considered good practice by audiophiles and the larger the diameter of conducting filament used the lower the resistance. However, increasing the diameter of conducting filaments increases the parasitic capacitance in the circuit. High capacitance values can create instability in amplifiers through harmful oscillations resulting in audible clipping and even damage to the amplifier.

High capacitance can also cause phase shifts, which when greater than 10 degrees may become audible and the combination of significant parasitic capacitance with overall cable resistance (known as impedence) may act as a low pass filter.

Those practised in the art would seek to combine such conductoring filaments by using twisted pairs or bundles of twisted pairs held together by an enclosing jacket; separating the conducting filaments by helically winding them around a non-conducting core; using individual litz conducting filaments placed in a configuration and held in place by supporting structures; placing conducting fibres in parallel but separated from each other by an intervening supportive material.

The present invention provides separation of the larger conductors so reducing the cable capacitance without the need for fillers, spacers or intervening supportive material or supportive jacket. It also addresses the problem of large conductors in parallel by allowing them to pass under and over each other at an angle so reducing effects of inductance.

The present inventions also addresses the need by many audiophiles because of the improved sound to use conducting filaments of different diameter within the same cable. Although accepted methods of achieving this within the practised art include Litz wires of different diameter, or bundles of twisted pair conducting filaments these geometries are not self-supporting. Woven or braided methods of combining conducting filaments of different diameter, although self supporting, are not possible where the difference between diameters is large; where the thickness of the conducting fibres is large; where the properties of the dielectric around the conducting fibres is not capable of holding its position due to friction effects. This invention does allow a wide range of conducting filament gauges to be used within the same self-supporting geometry and movement within the geometry between conducting filaments allows for variability of conducting filament positions.

Inductance is also related to the geometry of the conductors through phase cancellation of magnetic waves. Two positive leads side by side with current travelling in the same direction each generate a magnetic field that at a point between the leads is equal and in the opposite direction, cancelling each other out. Similarly a positive and negative lead side by side generate magnetic fields in the same direction increasing the field strength.

By increasing the angle at which such leads cross by using weaving or braiding techniques, reduces total inductance compared to parallel and opposing leads. Because the induced current in a wire due to a magnetic field is proportional to the cosine of the angle between the field direction and wire, as this angle approaches 90 degrees due to the geometry of the braid the induced current in each conductor approaches zero.

However, one problem with weaving and braiding is that it is not easy to use this method when combining conducting filaments with larger diameters nor is it easy to combine multiple conducting filaments with different diameters or stiffness. This type of braiding results in a breakdown in the regular symmetrical orientation of the conductors.

Thicker conducting filaments resist deformation making it difficult to bind them into a close braid or weave where the angle of the magnetic field direction and wire can approach 90 degrees. Also smaller gauge woven conducting filaments when used in isolation are brought close together so increasing the capacitance.

One aim of the present invention is to provide a self-supporting geometry that separates the smaller and larger diameter conducting filaments preventing an increase in capacitance.

Woven or braided pairs of conductors of opposing polarity (pole pairs) follow separate paths between crossing points, first diverging and then converging. In conventional weaves or braids this change of spacing is fairly linear and also symmetrical (in terms of axial distance travelled).

This alternating divergence and convergence Ben Duncan (Interference and Distortion Reducing Capabilities of Woven PowerKords-16/02/2009) has christened *The Glissando effect*.

The result of this geometry is that whilst inductance is rising, capacitance is falling. With symmetrical repetition these effects could be seen to lead to a constant resonant frequency although slight alterations during manufacture and the influence of interference from adjacent conductors creates a random variance in the resonant frequency. This random variance in resonant frequencies can help in the absorption of RF.

A further aim of the present invention is to overcome a build up of a symmetrical repetition of rising inductance and falling capacitance. By employing open asymmetric variable geometry that moves with handling and through deliberate manipulation.

At sufficiently high frequencies and for narrow diameter conductors the internal inductance may be ignored. Here high frequencies are forced into the outside of the conductor, which then behaves like a very thin hollow tube with a zero current field everywhere except the surface of the conductor and with no stored energy or inductance in the internal portion of the wire.

However total cable inductance will increase with increasing conductor separation.

U.S. Pat. No. 4,767,890 (“Magnan”) addresses the so-called “skin effect” problem in interconnect cables. Magnan teaches that when signals at audio frequencies are transmitted through prior art cables comprising a plurality of conductors the high frequency components propagate along conductors on the outside of the cable and travel at a faster speed than the lower frequency components which propagate along the conductors at the center of the cable and travel at a lower speed.

This is an issue addressed by U.S. Pat. No. 4538023A (Brisson) wherein conductors of different lengths and gauges are used so that the different frequency components arrive in phase. This invention provides a cable with geometry that provides for smaller diameter or more flexible conducting filaments to have a longer length per unit distance than the larger diameter less flexible conducting filaments so addressing possible phase differences.

It is worth looking at different forms of weaving and braiding and twisting because even within the industry such terms are used interchangeably resulting in some confusion.

Two important features to take not of when using such terms are 1) whether or not the method produces a hollow tube at its centre as more conducting filaments are used 2) whether or not conducting filaments of different polarity pass above and below each other or only pass in one direction only, for example, under.

Weaving and braiding are often used to mean the same thing within the cable manufacturing industry.

As more filaments are used in a weave or a braid the resulting structure becomes tube like and displays a hollow centre.

The other aspect to the cable's geometry is that filaments of opposite polarity pass under and over each other repeatedly. In this respect this geometry represents a development of the twisted pair but adding a spatial 3D aspect.

Plaiting and True Flat Braiding may be considered the same. As more filaments are used on a True Flat Braider the resulting braid becomes wider and remains flat. This is also true of a Plait.

Filaments of opposite polarity pass under and under each other or over and over each other but do not pass under and over each other as with the woven or braided tube.

There are provided cable architectures useful for constructing high-performance audio interconnection cables. A plurality of conducting filaments, at least two having different flexibility are braided to construct both balanced and unbalanced interconnect cables, speaker cables and power cords. Conducting filaments of large gauge and conducting filaments of small gauge may be combined using a braiding technique into one self-supporting structure. A self-supporting structure such as this allows individual conducting filaments to cross each other at different angles leaving the conducting filaments between crossing points unsupported and separated from each other. Positions of the conducting filaments can be varied in relation to each other effecting changes in the capacitance C and inductance L of the cable whilst allowing the overall geometry of the cable to remain self-supporting.

The low capacitance cable described here addresses the problem of combining a plurality of large and small gauge conducting filaments whilst maintaining an overall low capacitance in the finished cable. Unlike the prior art outlined here different gauge conducting filaments are held apart (to reduce capacitance) in a self-supporting framework without the need for supporting filaments, packing material or supportive sheaths. Conducting filaments are surrounded by space except where they cross each other at different angles.

Because the smaller gauge conducting filaments follow a more sinuous path due to their flexibility they travel a further distance per unit length of the cable than do the larger gauge conductors. This allows for phase shift compensation due to the skin effect.

A further aim of the invention is to addresses the problem associated with the repeating pattern between conducting filaments that exists in traditional symmetrically woven or braided geometries.

The result of this geometry is that whilst inductance is rising, capacitance is falling as pairs of conductors move across each other. With symmetrical repetition these effects could be seen to lead to a constant resonant frequency. Although slight alterations during manufacture and the influence of interference from adjacent conductors creates a random variance in the resonant frequency in traditionally braided or woven products, this invention's variable design deliberately encourages a marked asymmetric orientation between conductors to address this problem. This random variance in resonant frequencies can help in the absorption of radio frequency interference.

It is accepted by those in the audiophile world that audio interconnects 'tune' the audible sound they hear, which has significant advantages in adapting different pieces of equipment to work well together. This invention improves on any prior art because its variable geometry allows the user to alter the properties of the interconnect cable by altering the relative positions of the conducting filaments so changing the interconnect cable's capacitance C and inductance L.

Furthermore, traditional weaving and braiding techniques are not designed to produce a flattened braid of this sort.

The self-supporting framework is a product of the differing flexibility of the gauges of conducting filaments used combined with a braiding technique referred to here as “Binary” Braiding.

This involves passing one conducting filament at a time under and over adjoining filaments from one side of the braid to the other. This has properties of both of the above. The resulting braid does not have a hollow centre and does have a flattened appearance, however, unlike the true flat braid the filaments of opposite polarity pass under and over each other providing there is an even number of filaments.

The present invention seeks to provide an improved electric cable that overcomes at or least alleviates all the aforementioned problems with existing cables, by providing a cable with variable geometry braid formed with a plurality of conducting filaments, at least two having different flexibility are braided to construct both balanced and unbalanced interconnect cables, speaker cables and power cords.

Conducting filaments of large gauge and conducting filaments of small gauge are combined using a braiding technique into one self-supporting structure. A self-supporting structure such as this allows individual conducting filaments to cross each other at different angles leaving the conducting filaments between crossing points unsupported and separated from each other. Thus, the cable has variable geometry.

Positions of the conducting filaments can be varied in relation to each other effecting changes in the capacitance C and inductance L of the cable whilst allowing the overall geometry of the cable to remain self-supporting.

Statement of Invention

According to a first aspect of the invention, there is provided an electric cable formed as a variable geometry braid having a plurality of conducting filaments, at least two of the conducting filaments having different flexibility.

Preferably, the conductive filaments have different cross sections to create differing flexibility or stiffness.

Preferably, connectors are attached to the both ends of the cable.

Preferably, the filaments are made from silver plated copper.

Preferably, the cable is formed from at least two pairs of filaments having different cross sectional area, each pair of filaments forming signal and return paths and wherein both filaments of each pair have an equal cross sectional area.

Preferably, the cable comprises three pairs of filaments.

According to a second aspect of the invention, there is provided a method of producing a cable, the method comprising the steps of : laying out at least two pairs of conductive filaments having different cross sectional area, both filaments of each pair having equal cross section; interweaving each cable to form a braid; and attaching a connector to each end of the braided cable.

Brief description of drawings

One embodiment of the invention will now be described with reference to the accompanying figures in which :

Figure 1 illustrates a cable constructed in accordance with the invention;

Figure 2 illustrates a cross section of six conducting filaments forming part of the cable of figure 1; and

Figure 3 provides an illustration of how the filaments of figure 2 are braided together.

Description of a preferred embodiment

Figure 1 shows a braided cable 5 of variable geometry. The cable 5 is formed by a braid of wires in the form of insulated conductive filaments 3A-C, 4A-C. These are show individually in figure 2. Filaments 3A, 3B & 3C provide conductive paths in use and filaments 4A, 4B & 4C provide return paths in use.

Each wire filaments has a core of silver plated copper of varying diameter surrounded by an insulating outer sheath. Filaments 3A & 4A form a pair of filaments of the same cross section. Similarly, filaments 3B & 4B and 3C & 4C form pairs if equal cross section. Each filament pair form conductive signal and return paths.

The cross sections of the A, B and C pairs are different with the "A" pairs (3A & 4A) having the smallest cross section, the "B" pairs (3B & 4B) having greater cross section than the A pairs and the "C" pairs (3C & 4C) having the largest cross section.

The rigidity of the filament increases as the filament cross section is increased. The flexibility of the filament decreases as the cross section is increased. Consequently, the pairs of the filaments have different rigidity (stiffness) and flexibility.

The method of braiding the filaments will now be explained, with reference to figure 3, ultimately resulting in production of the cable of figure 1.

Lengths of filaments 3A-C and 4A-C are laid out side-by-side in the order shown in figures 2 and 3. The filaments are then braided together as follows.

Filament 3A is passed under filament 3B. Filament 3A is then passed over 3C, under filament 4A, over filament 4B and finally under filament 4C.

Filament 3B is then passed under filament 3C over filament 4A, under filament 4B, over filament 4C and finally under filament 3A.

The braiding process is continued the next filament in line being passed over and under the next filaments in line.

The process continues until the desired length of cable has been produced.

Once braided, connectors 6A & 6B are attached to each end of the cable 5. The connectors 6A, 6B are illustrated in figure 1 as standard phono plugs but it is recognised that any suitable connector could be applied depending on the intended use of the cable.

As each filament pair has varying flexibility each filament will bend differently when woven. This allows of a variety of angles and intersections between the filaments in the braid and as such the filaments do not have a constant relationship with each other, leading to a cable braid asymmetric braid having variable non-uniform geometry.

Moreover, the filament lengths will vary as smaller diameter, more flexible, filaments will be longer as they need to bend more around the larger diameter, less flexible, filaments.

The braided cable 5 has different angles of filament bisection and filament pathways. This prevents the formation of high density of symmetrically repeating arrangements of the wire conductors and creates variable distances between the wire filaments. This, in turn, reduces the effect of inductance and capacitance induced crosstalk.

The cable 5 may be housed in an outer sleeve.

Whilst the embodiment described shows three pairs of conductive filaments of differing flexibility, it is recognised that the cable could be formed from any number of filament pairs, depending on its intended use and purpose.

Claims

1. An electric cable formed as a variable geometry braid having at least three pairs of conducting filament, wherein the pairs of the conducting filaments having different flexibility and wherein conducting filaments cross each other at different angles such that the conducting filaments are unsupported and separated from each other between the crossing points.

2. An electric cable according to claim 1, wherein the conductive filaments have different cross sections to create differing flexibility or stiffness.

3. An electric cable according to claim 1 or claim 2, wherein connectors are attached to the both ends of the cable.

4. An electric cable according to any one of claims 1 to 3, wherein the filaments are made from silver plated copper.

5. An electric cable according to any one of claims 1 to 4, wherein the cable is formed from at least two pairs of filaments having different cross sectional area, each pair of filaments forming signal and return paths and wherein both filaments of each pair have an equal cross sectional area.

6. An electric cable according to claim 5, wherein the cable comprises three pairs of filaments.

7. A method of producing a cable, the method comprising the steps of :

    laying out at least two pairs of conductive filaments having different cross sectional area, both filaments of each pair having equal cross section;

interweaving each cable to form a braid; and

attaching a connector to each end of the braided cable.

8. An electric cable as hereinbefore described and referred to in the figures.

9. A method of producing an electric cable as hereinbefore described and referred to in the figures.