An embodiment electrical cable includes an elongated sheath, and a first chain of permanent magnet spheroids disposed within the sheath, wherein the spheroids are physically and electrically coupled in series with each other. The electrical cable further includes a first connector body mechanically attached to a first end of the sheath, and a first active signal contact mechanically attached to the first connector body, and electrically connected to the chain of permanent magnet spheroids.
The present invention relates generally to electrical signal conduction, and more particularly to magnetically-enhanced electrical signal conduction cables and methods.

BACKGROUND

Generally, there currently exists a large variety of cables and connectors for signal conduction. The signals transmitted via cables and connectors generally may be data signals or power signals. For example, in an audio-video system, power cables and connectors provide power from a power source (e.g., 110/120 volts alternating current (VAC), 220/240 VAC) to the various components of the system. Data cables transfer data signals between components of the system, such as from analog or digital content-source components (e.g., optical disk players, satellite, cable or fiber boxes, media servers, digital video recorders, computers, cassette tape players) to an amplifier (e.g., pre-amplifier/power amplifier, integrated amplifier, receiver). The amplifier processes the input data signals (e.g., source switching, surround sound decoding, and amplification). Other data cables transfer outputs from the amplifier to devices that directly interact with a user (e.g., loudspeakers, headphones, televisions, monitors). In some systems, various combinations of these components may be integrated into a single unit. For example, a television may contain amplifier components so that a source device may connect directly to the television.

SUMMARY OF THE INVENTION

Deficiencies in the prior art are generally solved or circumvented, and technical advantages are generally achieved, by preferred embodiments of the present invention, which utilize magnets to improve the quality of electrical signal transmission.

An embodiment electrical cable includes an elongated sheath, and a first chain of permanent magnet spheroids disposed within the sheath, wherein the spheroids are physically and electrically coupled in series with each other. The electrical cable further includes a first connector body mechanically attached to a first end of the sheath, and a first active signal contact mechanically attached to the first connector body, and electrically connected to the chain of permanent magnet spheroids.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram of an audio-video system having cables with permanent magnets;

Fig. 2 is a diagram of an electrical system showing magnet orientation;

Fig. 3 is a diagram of an electrical cable containing a chain of permanent magnetic spheroids and a wire conductor;

Fig. 4 is a diagram of a portion of an electrical cable having a socket connector;

Fig. 5 is a diagram of an electrical cable containing two chains of permanent magnetic spheroids;

Fig. 6 is a diagram of a portion of an electrical cable having a stack of permanent magnet disks between two chains of permanent magnet spheroids;

Fig. 7 is a diagram of a portion of an electrical cable having permanent magnet cylinders disposed side-by-side;

Fig. 8 is a diagram of a portion of an electrical cable having permanent magnet wedge sections;

Fig. 9 is a diagram of a portion of an electrical cable having permanent magnet arc sections; and

Fig. 10 is a diagram of a portion of an electrical cable having a variety of different permanent magnet sections.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

The present invention will be described with respect to preferred embodiments in a specific context, primarily the utilization of magnets to improve signal quality transmission in audio-video systems. The invention may also be applied, however, to other systems, such as computer systems, power transmission systems, automobile and other vehicular electrical systems, and the like.

An embodiment cable includes a plurality of permanent magnets shaped to allow the cable to flex at intersections between the permanent magnets and/or at intersections of permanent magnet and non-permanent-magnet electrically-conductive materials. Another embodiment includes manufacturing steps to manufacture such cables. Another embodiment method includes the use of such cables.

Fig. 1 illustrates an audio-video system and examples of cables connecting the various components. Embodiment cables may be used for any of the cables connecting the different components in an audio-video system. As described below, and as described in detail in U.S. Pat. No. 8,272,876, issued Sep. 25, 2012 to R. Schultiz, and entitled “Magnetically Enhanced Electrical Signal Conduction Appa-
ratus and Methods," which patent is hereby incorporated herein by reference, the particular type of cable and connectors used to connect different components may be selected from a wide variety of cables and connectors. In this embodiment, a media source device, such as digital video disc (DVD) player 152, generates both audio and video signals, which are output through cables 154 and 156, respectively. Cables 156 provide the video signal to television 158. As an example, a single RCA cable may provide a composite video signal to television 158. As another example, three RCA cables may provide component video signals to television 158. Audio signals are provided to amplifier 160 via cables 154. As an example, two RCA cables may provide left and right audio signals to amplifier 160. Amplifier 160 provides speaker level outputs via cables 162 and 164 to speakers 166 and 168, respectively. As an example, these cables may comprise connectors that allow connection to five-way binding posts, which allow the connection of banana plugs, pin connectors, bare wire, or ring or spade lug terminals. For loud speaker connections, the active signal and ground generally are connected with separate connectors.

While various embodiments primarily are described herein with respect to electrical cables, the present invention also may be implemented in any other type of wired electrical signal conduction application. That is, embodiments may be implemented anywhere an electrical signal is transferred over a wired connection, such as any of the embodiments disclosed in U.S. Pat. No. 8,272,876. These include, for example, the non-cable embodiments shown in FIGS. 18-20 and 28-30 of U.S. Patent No. 8,272,876. As another example, embodiments may be implemented as all or part of an electrical signal connection between any discrete components within a device, such as between the windings of a transformer and its associated binding posts. As another example, embodiments may be implemented as all or part of an electrical signal connection between a printed circuit board (PCB) and another component, or between any discrete components mounted on a PCB, such as capacitors, resistors, inductors, transistors, integrated circuits, etc. As another example, embodiments may be implemented as all or part of an electrical signal connection between the components in a power supply, between the components in an audio-video device (e.g., power supply, PCBs, power amplifiers, speakers, mounted connectors, etc.), between the components in a power transfer device such as a transformer, and the like.

FIG. 2 illustrates an electrical system showing the coordinated orientation of magnets placed throughout the system. In this example, the permanent magnets are oriented such that the north pole of the magnets generally faces the source of that signal, and the south pole faces downstream from the signal source. Alternatively, the permanent magnets may be oriented such that the south pole of the magnets generally faces the source of that signal, and the north pole faces downstream from the signal source.

In general, high-voltage multi (e.g., single, two or three) phase power is supplied from the power grid via transmission lines 250. As explained in more detail below, permanent magnets may be disposed in-line at various points of the power grid, for example in cables at transmission line towers, telephone poles, underground junction boxes, and the like. The permanent magnets may have the same orientation on the multiple phases, as shown by the N/S arrow next to the three high voltage lines 250.

The high voltage lines feed into a step-down transformer 252, which is connected to ground 254 and drops the high voltage down to standard 120V/240V power on power signal lines 256 and neutral line 258. Permanent magnets may be disposed in cables connected to step-down transformer 252. The permanent magnets follow the orientation of the signal flow in a given cable or interface, with active signals flowing in one direction and the associated ground or neutral signals flowing in the opposite direction. For example, permanent magnets in active signal (hot) leads 256 have north/south orientations, and in the neutral line 258 have a south/north orientation, as shown in FIG. 27. These lines feed into breaker box 260, which is disposed, for example, at a residential or commercial location. Breaker box 260 also may be connected to ground 262 and may have permanent magnets installed in cables in the input and output signal paths, again with the active signal leads 256 and 264 and ground 262 permanent magnets having north/south orientations, and the neutral lines 258 and 268 and ground 266 permanent magnets having south/north orientations.

Power lines comprising active power signal 264, neutral line 268 and ground line 266, one or more of which include permanent magnets, run from the breaker box 260 to wall outlet 270. Wall outlet also may have permanent magnets disposed in the signal paths with orientations shown in FIG. 2. A power cable 272 having permanent magnets may be plugged into wall outlet 270. An audio-video system comprises components 152, 158, 160, 166 and 168, as shown in FIG. 1, and receives power from power cable 272. The components that receive power may have permanent magnets disposed in their internal power cables corresponding to those in power cable 272, similar to that of internal wall cables for wall outlet 270.

Permanent magnets utilized with the data signals transferred between the components of the audio-video system also follow the magnetic orientation of the power signals. Speaker cables 162 and 164 have permanent magnets such that each active signal being transmitted to each speaker has a north/south orientation, and the neutral signals being sent back have south/north orientations, with respect to amplifier 160. In data cables transmitting signals between source component 152 and monitor 158, and between source component 152 and amplifier 160, permanent magnets again follow the orientation convention of the rest of the system. That is, in cables 154 and 156, the magnetic north pole of the magnets in the active signal path faces the source component output, while the magnetic north pole of the magnets in the neutral/ground signal path faces the destination component input (monitor 158 and amplifier 160).

FIG. 3 illustrates an embodiment electrical cable 300 having a chain of permanent magnet spheroids serving as the active signal conductor in the cable. In this embodiment, the cable has two Radio Corporation of America (RCA) male connectors 302, 304, one at each end. Connectors 302, 304 have active signal pins 306, 308, respectively, each comprising a permanent magnet. In this embodiment, the magnet for pin 306 is oriented to have its north pole at the tip of the connector, while its south pole is oriented toward the cable end of the connector. Further, the magnet for pin 308 is oriented to have its south pole at the tip of the connector, while its north pole is oriented toward the cable end of the connector. In other embodiments, the poles of the magnets may be reversed.
Each connector also includes a ground contact or ring inside the connector, and an insulator disposed between the active signal pin and the ground ring. The insulator may comprise a plastic, ceramic, or other type of insulating material. Each connector also may include a jacket surrounding the ground contact. The jacket may comprise metal, plastic, or other type of protective material. Active signal pins 306, 308 are electrically connected to the chain of permanent magnet spheroids 310 in cable 308, and the ground ring in the connectors is connected to ground wire 312 in cable 300. Spheroids 310 are separated from ground wire 312 by an insulator, which may comprise a plastic, ceramic, or other type of insulating material. In one embodiment, both the chain of spheroids 310 and the wire 312 are surrounded by individual insulators. Spheroids 310 and ground wire 312 are surrounded by an elongated cable sheath 314, which may be metal, plastic, or other type of protective material.

The use of permanent magnet spheroids 310 (or other shapes as discussed below) allows a cable to have some flexibility at the junctions or intersections between the spheroids, or between the spheroids and adjacent components in the conduction path. The non-rigid physical coupling of the spheroids provides the cable with flexibility so that it can bend at the intersections of the spheroids. This allows, in one embodiment, an entire signal path in a cable to be a permanent magnet material, and still be flexible or bendable. A strong magnetic attraction between the spheroids maintains the signal path even as the cable is flexed in one direction or another. In any given embodiment there may be any number of permanent magnets in a cable, such as two or more magnets, five or more magnets, ten or more magnets, fifty or more magnets, one hundred or more magnets, etc.

The magnetic spheroids may have a variety of shapes, or within the same implementation, such as spheres, oblate spheroids, prolate spheroids, hemi-spheroids, partial spheroids, stretched spheroids, etc. Further, as used herein, the term spheroid is intended to include those shapes that have a partial spheroid shape at the electrical connection junction with another spheroid or other electrically conductive component. For example, a spheroid may have a partial spheroid shape at either end, joined together, e.g., with a polyhedron, cylinder, cuboid, or other shape in the center. Again, the spheroid or rounded shape at the interface to the adjacent component allows rotation or angular adjustment outward or away from a straight-line long central axis of the cable, so that the cable is flexible or bendable.

Permanent magnet spheroids 310 are electrically coupled to each other and to active signal pins 306, 308. In one embodiment, the magnetic attraction between the permanent magnets holds them together to provide a solid electrical signal path from connector to connector. In another embodiment, the insulator and or sheath surrounding the spheroids may be placed under tension to force and retain the spheroids in contact with each other, as well as with the signal pins. Permanent magnet spheroids 310 are oriented so that their magnetic poles are aligned with those of the active signal pins 306, 308, with the north poles toward pin 306 and the south poles toward pin 308.

Nickel and gold plated neodymium magnets, for example, can be used for the active signal pins 306, 308 and the spheroids 310. Potential benefits of using a permanent magnet in the circuit path with active (data or power) signal contacts such as pins and sockets may include improved signal to noise ratio, lower total harmonic distortion, lower intermodular distortion, an increase in low-level resolution, lower losses in the cabling, lower resistance in the connections, and a potential increase in energy efficiency, for example.

These benefits may be further enhanced by the entire electrical path between the pins being permanent magnets. As an alternative, pins 306, 308 may be made from a non-permanent-magnetic material such as gold, copper, aluminum, or a combination thereof. As another alternative, pins 306, 308 may be made from a non-permanent-magnet ferromagnetic material, such as steel, nickel or mu-metal. In yet another embodiment, some of the spheroids may be made from other conductive materials, such as gold, copper, aluminum, or a combination thereof. As an alternative, some of the spheroids may be made from a non-permanent-magnet ferromagnetic material, such as steel or nickel or mu-metal.

In an alternative embodiment, the chain of permanent magnet spheroids may be surrounded by a sealed insulating tubing filled with some type of fluid. The fluid may be a conductive or partially conductive fluid, such as a liquid alloy of gallium, indium and tin (e.g., a liquid eutectic alloy such as Galinstan®), a contact stabilization material (e.g., a contact stabilant such as Stabilant 22®), a ferromagnetic fluid or ferrofluid, and the like. A ferrofluid may have a composition of about 5% magnetic solids, 10% surfactant and 85% carrier, by volume. The magnetic solid may comprise nanoscale particles (e.g., diameter of less than 10 nm) of magnetite, hematite, other compounds containing iron, or combinations thereof. The surfactant coating the nanoscale particles may comprise oleic acid, tetramethylammonium hydroxide, citric acid, soy lecithin, or combinations thereof. The carrier may be an organic solvent, water, or combinations thereof.

In another embodiment, once the cable is formed or bent to a desired shape, the spheroids may be fixed in place using solder, glue or adhesive to further stabilize the structure and set the cable in the desired shape.

FIG. 4 illustrates cable 400 having a chain of permanent magnet spheroids serving as the active signal conductor in the cable. RCA female connector 402 has active signal socket 304 comprising a permanent magnet. In this embodiment, the magnet is oriented to have its north pole at the tip of the connector, while its south pole is oriented toward the cable side of the connector. In other embodiments, the poles of the magnet may be reversed so that the south pole is at the tip of the connector, and the north pole is oriented toward the cable side of the connector. Connector 402 also comprises a ground contact, ring 406, and an insulator disposed between the active signal socket 304 and the ground ring 406. The insulator may comprise a plastic, ceramic, or other type of insulating material. Connector 402 also may include a jacket surrounding the ground contact. The jacket may comprise metal, plastic, or other type of protective material.

Active signal pin 404 is electrically connected to the chain of permanent magnet spheroids 408 in cable 400, and the ground ring 406 is electrically connected to a ground wire in cable 400. Spheroids 408 are separated from the ground wire by an insulator, which may comprise a plastic, ceramic, or other type of insulating material. In one embodiment, both the chain of spheroids 408 and the ground wire are surrounded by individual insulators. Spheroids 408 and the ground wire are surrounded by a cable sheath, which may be metal, plastic, or other type of protective material.

As with the embodiment shown in FIG. 3, another connector disposed at the other end of the cable. The other
connector may be a male or female RCA connector. Female connector 402 may be mounted on an electronic device for mating with a cable comprising a male RCA connector. In this case, instead of an insulating jacket, connector 402 generally may comprise a mount for attaching the connector to a panel of the electronic device.

[0040] A cable may comprise (per signal) two male connectors, two female connectors, or one or more of each. Alternatively, a connector adaptor may comprise a male connector on one end and a female connector on the other end, which adaptor may be connected inline with an existing cable. For any of the embodiments, either one connector or both connectors in a cable may comprise a permanent magnet for the active signal contacts, such as pins and sockets.

[0041] FIG. 5 illustrates an embodiment electrical cable 500 having two chains of permanent magnet spheroids serving as the active signal conductor and the return or ground signal conductor in the cable. In this embodiment, the cable has two RCA male connectors 502, 504, one at each end. Connectors 502, 504 have active signal pins 506, 508, respectively, each comprising a permanent magnet. Each connector also includes a ground contact or ring inside the connector, and an insulator disposed between the active signal pin and the ground ring. Each connector also may include a jacket surrounding the ground contact. The jacket may comprise metal, plastic, or other type of protective material.

[0042] Active signal pins 506, 508 are electrically connected to a first chain of permanent magnet spheroids 510 in cable 500. Ground rings in the connectors are electrically connected to a second chain of permanent magnet spheroids 512 in cable 500. Spheroids 510 and spheroids 512 are separated from each by an insulator, which may comprise a plastic, ceramic, or other type of insulating material. In one embodiment, both chains of spheroids 510 and 512 are surrounded by individual insulators. Spheroids 510 and 512 are surrounded by a cable sheath 514, which may be metal, plastic, or other type of protective material. Thus, in addition to the active signal, the ground and/or neutral connections also may utilize permanent magnets in their signal paths, in this and all other embodiments disclosed herein. In this embodiment, active signal chain of spheroids 510 has a first magnet field orientation (N-S), while the ground signal chain of spheroids 512 has the opposite orientation (S-N). Various magnetic field orientations, and the use of non-permanent magnet materials may be implemented with these embodiments as discussed above with respect to FIG. 3. Further discussion of magnetic field orientations is provided in U.S. Pat. No. 8,272,876, issued Sep. 25, 2012 to R. Schultz, and entitled "Magnetically Enhanced Electrical Signal Conduction Apparatus and Methods."

[0043] Cables utilizing permanent magnets in the signal path(s) can enhance any electrical connection. These include cables with many different types of connectors well known to those of ordinary skill in the art, including the fields of audio, video, communication, radio frequency (RF), computer, and combinations thereof. These include RCA connectors, balanced connectors, XLR connectors, Bayonet Neill-Concelman (BNC) connectors, Syndicate des Constructeurs d’Appareils Radiosècepteurs et Téléviseurs (SCART), Sony/Philips Digital Interconnect Format (S/PDIF), and coaxial digital audio. Also included are tie ring sleeve (TRS) jacks and plugs, such as 1/8 inch microphone jacks and plugs, phone jacks and plugs, 1/4 inch jacks and plugs, 1/4 inch headphone jacks and plugs, mini jacks and plugs, 1/8 inch jacks and plugs (plugs and jacks may be mono or stereo). Speaker connections such as 5-way binding post connections, other binding posts and adapters, spade terminals, ring terminals, banana plugs etc. also may be included. Many video signals, such as composite video, component video, S-video, all high-definition multimedia interface (HDMI) type connectors, and video graphics array (VGA) connectors would benefit from utilizing permanent magnets in the active signal path. Power type cables include alternating current (AC) and direct current (DC) power plugs (such standard 15 amp power cable ends), power adapter plugs, power supply DC connectors, power lugs, power connectors, breaker lugs, and the like.

[0044] Many computer and other electronic cables may utilize this technology, including all types of universal serial bus (USB) connections, all types of small computer system interface (SCSI) connections, IDC50, CN50, DB25, DHE8, HD68, serial advanced technology attachment (ATA), external ATA (ESATA), HD630, HPNC50, redundant array of inexpensive disks (RAID), DB50, DB37, integrated drive electronics (IDE), HDN60, HDG60, FireWire, ICE3 320, digital video interface (DVI), peripheral component interconnect (PCI), industry standard architecture (ISA), Institute of Electrical and Electronics Engineers (IEEE) 1394, International Business Machines Corporation (IBM) personal computer (PC) parallel port, peripheral component interconnect express (PCI-E), mini-channel architecture (MCA), Personal Computer Memory Card International Association (PCMCIA), tip ring sleeve (TRS), Deutches Institut für Normung (DIN), Mini DIN, and Audio Engineering Society/European Broadcasting Union (AES/EBU). Many cables with other types of connectors include RF coaxial, RG-6 coax connectors, F-Type connectors, National Electrical Manufacturers Association (NEMA) type plugs, TRS, 2-pin, 3-pin and 4-pin connectors, snap-in connectors, friction connectors, magnetically held connectors, DE-9, 8P8C, 4 mm plug, d-subminiature, RJ-XX connectors such as RJ-11 and RJ-45, terminal blocks, crimp on connectors, connectors for resistors, transistors, diodes, capacitors, anodes, cathodes, shielded compact ribbon (SCR), and telephone and communication cable ends (Ethernet and other network cables).

[0045] A variety of cables with other types of connectors include RF coaxial, RG-6 coax connectors, F-Type connectors, National Electrical Manufacturers Association (NEMA) type plugs, TRS, 2-pin, 3-pin and 4-pin connectors, snap-in connectors, friction connectors, magnetically held connectors, DE-9, 8P8C, 4 mm plug, d-subminiature, RJ-XX connectors such as RJ-11 and RJ-45, terminal blocks, crimp on connectors, connectors for resistors, transistors, diodes, capacitors, anodes, cathodes, shielded compact ribbon (SCR), and telephone and communication cable ends (Ethernet and other network cables).

[0046] As can be seen, there are a vast number and variety of electrical cables, only some of which are listed above. All of these cables can benefit from the magnetic principles described herein.

[0047] The electrical connections described herein generally use ferromagnetic material as part of the conductive path for an electrical signal, allowing electrical energy to flow through permanent magnets. Achieving a strong magnetic field generally is desirable, and the magnetic material generally should have a high magnetic permeability. A stronger magnetic field may be generated by, for example, using a magnet with a larger volume, a larger cross-section, a longer length, or a higher Maximum Energy Product, BHmax. BHmax measures magnetic field strength at the point of maximum energy product of a magnetic material, and is measured in MegaGauss-Oersted (MGOe).

[0048] A wide array of materials with varying magnetic strength may be used as the permanent magnets in the disclosed embodiments. As examples, Nd₃Fe₁₄B magnets generally have a BHmax in the range of about 8 to 53 MGOe, Sm₂Co₁₇ magnets generally have a BHmax in the range of about 14 to 32 MGOe, Alnico magnets generally have a BHmax in the range of about 1 to 10 MGOe; and ferrite
magnets such as SrO-6(Fe₂O₃) (strontium hexaferrite) or BaO-6(Fe₂O₃) (barium hexaferrite) generally have a BH in the range of about 1 to 5 MGöe.

[0049] Generally, the higher the material grade, the stronger the magnet field of the material. Preferably, a material or combination of materials used has both high magnetic field strength and high electrical conductivity. These parameters may be traded off for each other as well. For example, a lower conductivity material may be acceptable if it has a higher magnetic field strength. Likewise, a lower magnetic field strength material may be acceptable if it has a higher electrical conductivity.

[0050] Rare earth permanent magnets generally have relatively strong magnetic fields compared to non-rare earth permanent magnets. Rare earth elements are a family of elements with atomic numbers from 57 to 71, plus 21 and 39, and specifically are lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, and yttrium. Rare earth magnets include rare earth elements and their alloys, such as neodymium and neodymium-based alloys, samarium and samarium-based alloys, praseodymium and praseodymium-based alloys, gadolinium and gadolinium-based alloys, dysprosium and dysprosium-based alloys. Commonly used rare earth magnets include neodymium (NdFeB), or NiB magnets and samarium cobalt (SmCo) magnets.

[0051] Sintered neodymium magnets with grades from N3x to N4x to N5x are preferable for applications benefiting from high magnetic field strength. These include N35, N40, N42, N48, N50 and N52 grades, for example. The specific magnet used for a particular application may depend on tradeoffs between parameters such as magnetic field strength, cost, and availability.

[0052] Another type of neodymium magnet that may be used is a bonded neodymium magnet. While bonded materials generally are not as powerful as sintered materials, bonded neodymium magnets are quite strong and still work well. Sintered and bonded samarium cobalt magnets generally have a high Curie temperature, resist corrosion well and may be used with or without surface coatings, but generally are less powerful than neodymium magnets.

[0053] Non-rare earth magnets include iron and iron-based alloys and iron alloyed with carbon that also may comprise other elements such as manganese, chromium, vanadium, molybdenum, nickel and tungsten, nickel and nickel-based alloys, permalloy (nickel iron alloy that also may comprise molybdenum), and cobalt and cobalt-based alloys.

[0054] Alnico (AlNiCo) magnets generally are less powerful than rare-earth magnets, but typically are easily machined and can be made into many different shapes, allowing for use with a wide range of connector shapes and sizes. Alnico alloys typically comprise 8-12% Al, 15-20% Ni, 5-24% Co, up to 6% Cu, up to 1% Ti, with the balance being Fe.

[0055] Mu-metal is a nickel-iron alloy (approximately 75% nickel, 15% iron, plus copper and molybdenum) that has very high magnetic permeability. Mu-metal may be useful in some applications because of its high magnetic permeability and conductivity.

[0056] Ferrié magnets such as strontium ferrite and barium ferrite magnets generally have the lowest magnetic field strength, and may be usable but are less preferred than the stronger permanent magnet materials.

[0057] Some permanent magnets may comprise materials that are more brittle, less conductive, or more corrosion resistant than desired for a given application. Therefore, magnets may be plated or coated to increase physical strength, corrosion resistance, conductivity, or any combination thereof. Conductive metals, such as copper, nickel, gold, silver, or any combination thereof, may be used to coat permanent magnets. Nickel benefits by being ferromagnetic. Copper and silver both are highly conductive. Gold is both quite conductive and has high corrosion resistance.

[0058] Magnets may be plated in layers such as combinations of the above, or nickel-nickel, copper-nickel or nickel-copper-nickel. Black nickel, zinc, aluminum and other conductive metals and metal alloys may be possible as well. As an example, because nickel is less conductive than some other metals, plating alternatively or additionally with highly conductive metals such as gold, copper, silver, and the like, may increase conductivity.

[0059] One embodiment coating selected from the various materials comprises nickel for mechanical strength, copper for conductivity and smooth quality plating, and gold plating on the outside to protect against corrosion and further aid in conductivity. These coatings may be used with sintered neodymium magnet cores of N30 grade higher, or more preferably N40 grade or higher, or more preferably N50 grade or higher, for various applications.

[0060] In view of the wide variety of applications for utilizing permanent magnets in electrical cables, it also can be beneficial to use a permanent magnet to magnetically charge another material that is making the connection, or is part of the circuit path. For example, a portion of the conductive signal path in a cable can be a chain of permanent magnets, while another portion can be a non-permanent magnet ferromagnetic conductor or high magnetic permeability conductor such as nickel or steel. An embodiment comprises a non-permanent-magnet ferromagnetic material, such as a steel center core conductor, in conjunction with a chain of permanent magnet spheroids in the signal path. The ferromagnetic properties of the steel conductor cable generally allowed the magnetic effects to extend beyond the permanent magnets and perhaps effectively run through the entire cable, without having the entire signal path in the cable be made of permanent magnets.

[0061] Preferably the ferromagnetic conductor material is a hard ferroelectric material, but also may be a soft ferroelectric material. A ferromagnetic material with high magnetic permeability or a ferromagnetic material with high conductivity, or both, may offer a stronger effect. Various ferromagnetic materials have different values for resistivity. By way of example for relative comparison, cobalt may have a resistivity in the range of about 62.4 nano-ohms per meter, nickel may have a resistivity in the range of about 69.3 nano-ohms per meter, iron may have a resistivity in the range of about 96.1 nano-ohms per meter, steel may have a resistivity in the range of about 150 nano-ohms per meter, and stainless steel may have a resistivity in the range of about 700 nano-ohms per meter.

[0062] Steel provides sufficient conductivity, although there are materials that are more magnetically permeable and more conductive. Nickel, for example, may be utilized to increase conductivity and magnetic permeability. Accordingly, nickel may be a preferred material for interconnects, speaker cables and specialty power cords based on its cost and other characteristics.
Steel may be coated with copper and silver to increase conductivity and corrosion resistance. Silver is a good outer coating because silver oxide generally remains almost as conductive as silver. The permanent magnets at least partially or completely magnetize the steel, thereby enhancing the effect observed when using a permanent magnet in conjunction with a non-ferromagnetic material in an electrical signal path. The ferromagnetic conductor may be used in conjunction with any of the permanent magnet embodiments disclosed herein.

FIG. 6 illustrates an embodiment in which a portion of an electrical cable 600 having a stack of permanent magnet disks 604 disposed between two chains of permanent magnet spheroids 602. Remaining portions of the cable may be constructed as discussed above with respect to FIGS. 3-5. The stacked magnets 604 are cylinder-shaped permanent magnets generally have a larger contacting surface area than the spheroids 602. On the other hand, the stacked permanent magnets 604 do not provide flexibility at the mating face or intersection between any adjacent stacked magnets. In either case, both the stacked permanent magnets and the multiple permanent magnet spheroids generally lower losses, increase performance of audio and video circuits, and increase energy transfer, as compared to using a single magnet.

Furthermore, increasing the quantity of north-south pole changes in the stack or chain (i.e., the number of magnets in the stack or chain) generally improves the general flow of electricity and power/data transfer over embodiments with a fewer number of magnets. The number of permanent magnets may be increased by adding more magnets to the stack or chain, and the overall size of the rigid stack may be kept to a reasonable size by utilizing thinner magnets.

A stacked magnet configuration generally offers added benefits over a single permanent magnet of equal size and strength. As with increasing conductivity, increasing magnetic field strength, and increasing cross-section, increasing the number magnets generally increases performance. Generally, the larger the number of magnets in a stack, the wider the cross-section, the longer the length of the stack, the higher the material conductivity, and the higher the material magnetic field strength or the stronger the individual magnets, the greater the benefit.

FIG. 7 illustrates a portion of an electrical cable 700 having permanent magnet cylinders 702. In this embodiment, the permanent magnet cylinders are place adjacent to each other, side-by-side. This can provide a greater amount of contact area between the permanent magnets than, e.g., a straight sphere to sphere connection. The structure is flexible or bendable in a direction perpendicular to the long axes of the cylinders, but would not be flexible in a direction parallel to the long axis of the cylinders.

FIG. 8 illustrates a portion of an electrical cable 800 having permanent magnet wedge sections 804. Instead of a rounded contacting edge, a permanent magnet in a cable may have a wedge shape 804 disposed between other sections 802 of the cable. The adjacent sections 802 each mate to a flat face of the wedge 804. These other sections 802 may be single permanent magnets in the shape of, e.g., cylinders, or they each may be a series of stacked magnets disposed end-to-end. The permanent magnet wedge section 804 allows the cable to be flexible in a rotational direction about each face of the wedge.

FIG. 9 illustrates a portion of an electrical cable 900 having permanent magnet arc sections 904. As an alternative to the wedge section, a permanent magnet in a cable may have a rounded are shape 904 disposed between other sections 902 of the cable. The adjacent sections 902 each mate to a flat face of the arc section 904. Here again these other sections 902 may be single permanent magnets in the shape of, e.g., cylinders, or they each may be a series of stacked magnets disposed end-to-end. The permanent magnet wedge section 904 allows the cable to be flexible in a rotational direction about each face of the wedge.

FIG. 10 illustrates a portion of an electrical cable 1000 having a variety of permanent magnet sections with different geometries. As shown by the example cable 1000, any of the embodiments disclosed herein may be combined with each other, as well as with any of the embodiments disclosed in U.S. Pat. No. 8,272,876. Depending on the specific application, the shape of each magnet may be a spheroid, pyramid, cylinder, cube, arc, wedge, and the like. As further examples, a pyramid shape may have a base that is a trilateral, quadrilateral, or any polygon shape. As another example, a cylinder may have a height that is smaller, equal to, or longer than its diameter. Electrical cable 1000 has a connector 1002 with pin 1004, which may be a permanent magnet, a non-permanent magnet ferroelectric material, or another type of conductive metal. Pin 1004 is electrically connected to a series of stacked magnets 1006, which may be the shape of circular disks.

Stacked magnets 1006 are electrically coupled to a permanent magnet 1008, of which there may be others dispersed throughout the cable 1000. Permanent magnet 1008 is coupled to permanent magnet oblate spheroid 1012. Other types of spheroids also may be disposed in cable 1000, such as spheroid 1010, and prolate spheroid 1014. There also are two permanent magnet wedge shapes 1016 are implemented in cable 1000. Any of these permanent magnets alternatively may be a non-permanent magnet ferroelectric material, or a non-ferrous conductor, as described above. Further, the variously shaped sections may be disposed in any order and quantity in the cable, either adjacent like-shaped sections or differently-shaped sections. Solid or stranded wire also may be used in the cable in any combination with the other types of sections.

In various embodiments, a metal (e.g., steel) mesh may be used to surround the permanent magnets to act as a Faraday cage to block electric fields and some electromagnetic radiation. The Faraday cage may be either directly contacting the permanent magnets, or there may be another conducting or insulating material disposed between the magnets and the Faraday cage. In one embodiment, the sheath of a cable may be a braided function as a Faraday cage. The braid also may serve as the conductor for a ground signal in the cable. The Faraday cage may be a conducting or ferromagnetic material. The holes in the mesh generally should be significantly smaller than the frequency of the electromagnetic radiation generated by the signal traveling through the magnet(s). The Faraday cage may be ungrounded, grounded on one side of a cable, or grounded on both sides of a cable. A single conductive mesh may be used, or multiple (e.g., two, three, four) concentric meshes may be used.

A Faraday cage may be used any of the embodiments disclosed herein, and may be particularly effective for alternating current or fast-changing signal applications. For example, a Faraday cage may be used for the outer ground of an RCA connector. As another alternative, an insulating mate-
rial made of, e.g., plastic, acrylic, plexiglass, a flexible laminate or other dielectric material may be disposed on the outside of the Faraday cage.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

What is claimed is:

1. An electrical cable comprising:
   - an elongated sheath;
   - a first chain of permanent magnet spheroids disposed within the sheath, wherein the spheroids are physically and electrically coupled in series with each other;
   - a first connector body mechanically attached to a first end of the sheath; and
   - a first active signal contact mechanically attached to the first connector body, and electrically connected to the chain of permanent magnet spheroids.

2. The electrical cable of claim 1, wherein each of the permanent magnet spheroids comprises a material selected from the group consisting of: nickel, neodymium, samarium, mu-metal, cobalt, and a combination thereof.

3. The electrical cable of claim 1, further comprising a first active signal electrical conductor coupled in series with the first chain of permanent magnet spheroids.

4. The electrical cable of claim 3, wherein the first active signal electrical conductor comprises a non-permanent-magnet ferromagnetic material.

5. The electrical cable of claim 1, further comprising an electrically conductive sleeve disposed around at least a portion of the first chain of permanent magnet spheroids.

6. The electrical cable of claim 1, further comprising:
   - a ground signal wire disposed within the sheath; and
   - an insulator disposed within the sheath and separating the ground signal wire from the first chain of permanent magnet spheroids.

7. The electrical cable of claim 6, further comprising a ground signal contact mechanically attached to the first connector body, and electrically connected to the ground signal wire.

8. The electrical cable of claim 1, wherein a north-south pole orientation of each of the permanent magnet spheroids is in a same direction as a signal flow direction through the permanent magnet spheroids.

9. The electrical cable of claim 1, further comprising a Faraday cage disposed around the first chain of permanent magnet spheroids.

10. The electrical cable of claim 1, wherein the permanent magnet spheroids each comprises:
   - a first magnetic material; and
   - a coating of conductive metal different from the first material.

11. An electrical cable comprising:
   - an elongated sheath;
   - a first chain of permanent magnet spheroids disposed within the sheath, wherein the spheroids are physically and electrically coupled in series with each other;
   - a first connector body mechanically attached to a first end of the sheath;
   - a first active signal contact mechanically attached to the first connector body, and electrically connected to the chain of permanent magnet spheroids;
   - a second connector body mechanically attached to a second end of the sheath; and
   - a second active signal contact mechanically attached to the second connector body, and electrically connected to the first chain of permanent magnet spheroids.

12. The electrical cable of claim 11, wherein each of the permanent magnet spheroids comprises a material selected from the group consisting of: nickel, neodymium, samarium, mu-metal, cobalt, and a combination thereof.

13. The electrical cable of claim 11, further comprising:
   - a second chain of permanent magnet spheroids disposed within the sheath, wherein the spheroids in the second chain are physically and electrically coupled in series with each other;
   - an insulator disposed within the sheath and separating the first and second chains of permanent magnet spheroids from each other;
   - a third signal contact mechanically attached to the first connector body, and electrically connected to the second chain of permanent magnet spheroids; and
   - a fourth signal contact mechanically attached to the second connector body, and electrically connected to the second chain of permanent magnet spheroids.

14. The electrical cable of claim 11, wherein each of the permanent magnet spheroids is a sphere.

15. The electrical cable of claim 11, wherein each of the permanent magnet spheroids is an oblate sphere.

16. The electrical cable of claim 11, further comprising:
   - a ground signal wire disposed within the sheath; and
   - an insulator disposed within the sheath and separating the ground signal wire from the first chain of permanent magnet spheroids.

17. The electrical cable of claim 16, further comprising:
   - a first ground signal contact mechanically attached to the first connector body, and electrically connected to the ground signal wire; and
   - a second ground signal contact mechanically attached to the first connector body, and electrically connected to the ground signal wire.

18. The electrical cable of claim 11, wherein each of the first and second active signal contacts is a pin.

19. A method of forming an electrical cable, the method comprising:
   - forming a first chain of permanent magnet spheroids physically and electrically coupled in series with each other;
   - disposing the first chain of permanent magnet spheroids an elongated insulating sheath;
   - attaching a first active signal contact to a first connector body;
   - attaching the first connector body to a first end of the sheath;
electrically connecting the first active signal contact to the first chain of permanent magnet spheroids;
attaching a second active signal contact to a second connector body;
attaching the second connector body to a second end of the sheath; and
electrically connecting the second active signal contact to the first chain of permanent magnet spheroids.

20. The method of claim 19, further comprising:
disposing a first ground signal wire in the elongated insulating sheath and insulated from the first chain of permanent magnet spheroids;
attaching a third signal contact to the first connector body;
electrically connecting the third signal contact to the ground signal wire;
attaching a fourth signal contact to the second connector body; and
electrically connecting the fourth signal contact to the ground signal wire.

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