21AWG EXTENDED DISTANCE POE, NETWORK CABLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

[001] The present invention relates to a twisted pair cable for communication of high-speed data signals and Power over Ethernet (PoE), such as a local area network (LAN) cable. More particularly, the present invention relates to a large gauge twisted pair cable for transmitting data and power over an extended distance, wherein the insulated wires of the cable are dimensioned to be terminated to a standard RJ45 connector.

2. Description of the Related Art

[002] Most twisted pair network cables utilize a 23 AWG (American Wire Gauge) copper conductor, per standard TIA 568-B.2, section 4.3.1, published April 23, 2001, allowing such network cables to have 22 to 24 AWG conductors. A 23 AWG conductor has a diameter of about 0.573 mm (22.6 mil), while a 22 AWG conductor has a diameter of about 0.644 mm (25.3 mil). The copper conductor is surrounded by a layer of insulation having a radial thickness in the range of nine to eleven mils, such as about ten mils to eleven mils for a typical CAT 6 cable. The thickness and dielectric constant of the insulation layer provide a nominal 100 ohm impedance to the twisted pair of conductors.

[003] The typical 23 AWG networking cable is rated to reliably transmit data and PoE for up to 100 meters (328 ft). If a technician tries to run the 23 AWG cable longer than 100 meters, there may be significant voltage drop and the device at the end of the long cable run may not power up and run properly. The voltage drop is due to the resistive heating of the 23 AWG conductors within the cable. Further, the data transmission on the cable may suffer packet failures. Increasing the voltage on the networking cable to compensate for voltage drop is not an option for typical networking cables designated for low voltage applications.

[004] There is a general understanding in the cabling art that a larger conductor offers a lower resistance and can carry more power with less voltage drop, i.e., without

heating up. To this end, several companies have offered and/or patented network cable designs with 22 AWG conductors.

[005] On June 9, 2010, Quabbin Wire and Cable, Inc. offered T1 cable with 22 AWG conductors, which is a heavier gauge than most category 5A cables which usually have 24 AWG conductors. Insertion loss on a 22 AWG cable is approximately 25% lower than that measured in a 24AWG cable. This leads to more distance. Quabbin's "9720, 22 AWG cable" can meet the required T1 pulse mask at a full 200 meters rather than the approximate 150 meters from a 24AWG cable.

[006] In 2013, Panduit offered a Cat 7 cable with four twisted pairs having 22 AWG stranded copper conductors, insulated with foamed polyethylene.

[007] In September 2014, General Cable offered a PoE CAT 6 networking cable with four pairs under the name GenSpeed® EfficienC™ Max. The cable utilized 22 AWG conductors. General Electric recognized that the industry drive was toward sending more power over the PoE cabling. As stated in the release bulletin "Large-Gauge Conductors for High-Powered Applications - The 22 AWG conductors provide reduced heat generation, higher maximum current carrying capabilities and improved attenuation performance."

[008] On July 19, 2016, Belden released a Specifications and Technical Data sheet for their cable 7922A Category 5e DataTuff® twisted pair cable. The 7922A cable included 22 AWG bare copper conductors surrounded by a layer of polyolefin insulation in a thickness of 11 mils, making the overall diameter of the insulated conductor 48 mils.

[009] Twisted pair networking cables with 22 AWG conductors are also shown in the Patent literature. For example, see US Patents 6,297,454; 6,787,697; 6,815,611; 10,249,410, 10,453,589; 11,107,605; 11,562,835 and 11,646,133, which are herein incorporated by reference.

[010] The currently produced RJ45 plugs and RJ45 jacks include organization sleds with guide tracks or channels to keep network cables in fixed predictable locations as the cable ends are terminated to the conductive blades and lead frames of the plugs and jacks, respectively. It is important keep the cable ends in predictable and consistent locations within the plugs and jacks because the plug and jacks have counteraction effects for crosstalk compensation. If the individual wires are not consistently positioned within

the plug sled or the jack sled, the compensating crosstalk of the jack will not match the induced crosstalk caused by the plug, and visa versa. More detail concerning this consideration can be found in the Assignee's prior US Patent 7,972,183, which is herein incorporated by reference.

[011] A published five-page document by CommScope®, SYSTIMAX® Solutions (Instruction Sheet 860344274, Issue 10, October 2019, Rev. B), which is herein incorporated by reference, shows a method of terminating a CAT cable to a CommScope RJ45 jack. On page four of the instruction sheet, a punch down operation is shown, wherein each insulated conductor is punched down into a respective slot leading to an insulation displacement connector (IDC). Figure 1A shows a side view of the slot section 1 on one side of the CommScope RJ45 jack. Figure 1A labels a width 5 of one of the slots or openings 3 leading to one of the IDCs of the RJ45 jack. The slot or opening 3 is formed by plastic sidewalls, between which an insulated wire is passed to reach an IDC, which cuts through the insulation layer to establish an electrical connection with a conductor inside the insulation layer. The width 5 of the opening 3 between the plastic sidewalls leading to the IDC is 46 mils, with a tolerance of +0.003 mils and -0.002 mils. The other seven slots or openings of the slot section 1 of the RJ45 jack have a same size with a same tolerance.

[012] CommScope's US Patent 7,972,183, which is herein incorporated by reference, shows an RJ45 plug. Figure 1B is based on a portion of Figure 7 of US Patent 7,972,183. Figure 1C is based on Figure 9 of US Patent 7,972,183. A sled 7 of the RJ45 plug includes slots, between which insulated conductors must 9, 11, 13 and 15 pass through before being terminated to conductive blades of the RJ45 plug. Figures 1B and 1C show that two stacked insulated conductors 9 and 11 must pass between a first pair of facing shoulders 17 and 19 and a second pair of facing shoulders 21 and 23 in order to be held in consistent positions to produce a predictable amount of crosstalk. Figures 1B and 1C also show that two stacked insulated conductors 13 and 15 must pass between a third pair of facing shoulders 19 and 23 and a fourth pair of facing shoulders 17 and 21 in order to be held in consistent positions to produce a predictable amount of crosstalk.

[013] The size of conductors, in accordance with the American wire gauge (AWG) standard, are established. One example chart of the AWG sizes can be found on

the Internet at: https://www.engineeringtoolbox.com/awg-wire-gauge-circular-mils-d_819.html, which is herein incorporated by reference. Figure 2 reproduces a portion of the chart with some numbers relevant to the present invention.

SUMMARY OF THE INVENTION

[014] Applicants have appreciated that a 21 AWG conductor has a diameter of 28.5 mils from the chart in Figure 2. A network cable formed with a 21 AWG conductor would require an insulation layer of about 9.1 to 11.1 mils, depending upon the dielectric constant of the material used in the insulation layer in order to have the required 100 ohm nominal impedance of a twisted pair. Hence, each insulated wire of the twisted pairs, would have a diameter of about 46.7 to 50.7 mils, depending upon the dielectric constant of the material used in the insulation layer. Such a dimension is too large to pass into the opening 3 between the plastic sidewalls leading to the IDCs of the slot section 1 of the RJ45 jack of Figure 1A and too large to be routed between the facing shoulders of the RJ45 plug sled 7 of Figures 1B and 1C. Therefore, insulated conductors used with the RJ45 jacks and plugs of Figures 1A, 1B and 1C have had a conductor size of 22-24 AWG, which is logical, since standard TIA 568-B.2, 4.3.1, published April 23, 2001, allows network cables to have 22 to 24 AWG conductors.

[015] However, there is a desire to extend the reach of a PoE, twisted pair cable beyond the distances enabled by a 22 AWG conductor, such as those sold by Panduit, General Cable, Belden and Paige Electric. Also, more than a billion of the RJ45 jacks, shown Figure 1A, are in use today. It would be wasteful to replace so many RJ45 jacks (Figure 1A) and RJ45 plugs (Figures 1B and 1C) in order to accommodate a twisted pair network cable with 21 AWG conductors.

[016] The Applicant has appreciated a solution to the need of having a small diameter insulated 21 AWG conductor to be terminated into a standard RJ45 jack and plug, while still exhibiting a 100 ohm nominal impedance over the length of the network cable. More specifically, the Applicant has invented a twisted pair cable with 21AWG conductors, wherein the first and second insulated conductors of each twisted pair each have an overall diameter of 45.8 mils or less, while still exhibiting a 100 ohm nominal impedance over the length of the network cable. Such insulated conductors may fit into

the opening 3 between the plastic sidewalls leading to the IDCs of the slot section 1 of the RJ45 jack of Figure 1A, which are 0.046 – 0.002 inches, or 45.8 mils at the lower end of the tolerance, i.e., the narrowest slot dimension. Further, the Applicant has invented a cable with 21AWG conductors wherein the first and second insulated conductors of each twisted pair each have an overall diameter of 45.8 mils or less, so as to fit between the facing shoulders 17-19, 21-23, 19-23 and 17-21 of the RJ45 plug sled 7 of Figures 1B and 1C.

[017] These and other objects are accomplished by a network cable having four twisted pairs. Each twisted pair includes first and second insulated conductors of 21 AWG. Each twisted pair includes a bisector tape located between the first and second twisted insulated conductors. The 21 AWG conductor allows for longer distance transmission of data and PoE. A thinner wall of insulation on 21 AWG conductors allows the network cable to be terminated to industry standard RJ45 jacks and plugs, which were designed to accommodate 22-24 AWG insulated conductors, while the bisector tapes allow the network cable to exhibit 100 ohm nominal impedance between the insulated conductors of each twisted pair.

[018] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[019] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limits of the present invention, and wherein:

[020] Figure 1A is a side view of a slot section on one side of a CommScope RJ45 jack, in accordance with the prior art;

[021] Figure 1B is a top view of a portion of an RJ45 plug sled, in accordance with the prior art;

[022] Figure 1C is a cross sectional view of the RJ45 plug sled of Figure 1B taken along line Fig. 1C – Fig. 1C;

[023] Figure 2 is a chart showing the dimensions associated with the American Wige Gauge (AWG) standards, in accordance with the prior art;

[024] Figure 3 is a perspective view of a twisted pair cable, in accordance with a first embodiment of the present invention;

[025] Figure 4 is a cross sectional view of the twisted pair cable of Figure 3 taken along line IV--IV;

[026] Figure 5 is a close-up cross sectional view of a twisted pair from Figure 4;

[027] Figure 5A is a close up cross sectional view of a twisted pair similar to Figure 5, but illustrating that the dielectric tape may include a hollow air pocket;

[028] Figure 6 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a second embodiment of the present invention;

[029] Figure 7 is a cross sectional view of a twisted pair cable employing twisted pairs in accordance with Figure 6;

[030] Figure 8 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a third embodiment of the present invention;

[031] Figure 8A is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a fourth embodiment of the present invention;

[032] Figure 8B is a cross sectional view of a twisted pair cable employing twisted pairs in accordance with Figure 8A;

[033] Figure 9 is a perspective view of a twisted pair cable, in accordance with a fifth embodiment of the present of the present invention;

[034] Figure 10 is a cross sectional view of the twisted pair cable of Figure 9 taken along line X--X;

[035] Figure 11 is a close-up cross sectional view of a twisted pair from Figure 10; and

[036] Figure 12 is a close-up cross sectional view of a twisted pair, having a dielectric tape with an alternative shape, in accordance with a sixth embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[037] The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[038] Like numbers refer to like elements throughout. In the figures, the thickness of certain lines, layers, components, elements or features may be exaggerated for clarity. Broken lines illustrate optional features or operations unless specified otherwise.

[039] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

[040] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As

used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. As used herein, phrases such as "between X and Y" and "between about X and Y" should be interpreted to include X and Y. As used herein, phrases such as "between about X and Y" mean "between about X and about Y." As used herein, phrases such as "from about X to Y" mean "from about X to about Y."

[041] It will be understood that when an element is referred to as being "on", "attached" to, "connected" to, "coupled" with, "contacting", etc., another element, it can be directly on, attached to, connected to, coupled with or contacting the other element or intervening elements may also be present. In contrast, when an element is referred to as being, for example, "directly on", "directly attached" to, "directly connected" to, "directly coupled" with or "directly contacting" another element, there are no intervening elements present. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

[042] Spatially relative terms, such as “under”, “below”, “lower”, “over”, “upper”, “lateral”, “left”, “right” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is inverted, elements described as “under” or “beneath” other elements or features would then be oriented “over” the other elements or features. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the descriptors of relative spatial relationships used herein interpreted accordingly.

[043] Generally, twisted pair network cables, in accordance with the present invention, are formed of conductors having a 21 AWG size surrounded by a thin insulation layer. Several embodiments showing different configurations will now be described in detail. Figure 3 is a perspective view of a twisted pair cable 31, in accordance with a first embodiment of the present invention. Figure 4 is a cross sectional view of the cable 31 taken along line IV--IV in Figure 3. The cable 31 includes a jacket 32 formed around and surrounding first, second, third and fourth twisted pairs 33, 34, 35

and 36, respectively. The jacket 32 may be formed of polyvinylchloride (PVC), low smoke zero halogen PVC, polyethylene (PE), fluorinated ethylene propylene (FEP), polyvinylidene fluoride (PVDF), ethylene chlorotrifluoroethylene (ECTFE), or other foamed or solid materials common to the cabling art.

[044] A separator 37 within the jacket 32 resides between and separates the first and fourth twisted pairs 33 and 36 from the second and third twisted pairs 34 and 35. In Figures 3 and 4, the separator 37 is formed by a thin strip of dielectric material, having a thickness of about fifteen mils or less, more preferably thirteen mils or less, such as about seven to twelve mils. However, other sizes and shapes of separators 37 may be employed in combination with the present invention, such as plus-shaped or star-shaped separators, sometimes referred to as a flute, isolator, or cross-web. The separator 37 may be formed of any solid or foamed material common to the cabling art, such as a polyolefin or fluoropolymer, like fluorinated ethylene propylene (FEP) or polyvinylchloride (PVC).

[045] As best seen in the cross sectional view of Figure 4, the first twisted pair 33 includes a first insulated conductor 38, a first dielectric tape 39, and a second insulated conductor 40. The first insulated conductor 38 is twisted with the second insulated conductor 40, in a helical fashion, with the first dielectric tape 39 residing between the first insulated conductor 38 and the second insulated conductor 40.

[046] The second twisted pair 34 includes a third insulated conductor 41, a second dielectric tape 42, and a fourth insulated conductor 43. The third insulated conductor 41 is twisted with the fourth insulated conductor 43, in a helical fashion, with the second dielectric tape 42 residing between the third insulated conductor 41 and the fourth insulated conductor 43.

[047] The third twisted pair 35 includes a fifth insulated conductor 44, a third dielectric tape 45, and a sixth insulated conductor 46. The fifth insulated conductor 44 is twisted with the sixth insulated conductor 46, in a helical fashion, with the third dielectric tape 45 residing between the fifth insulated conductor 44 and the sixth insulated conductor 46.

[048] The fourth twisted pair 36 includes a seventh insulated conductor 47, a fourth dielectric tape 48, and an eighth insulated conductor 49. The seventh insulated conductor 47 is twisted with the eighth insulated conductor 49, in a helical fashion, with

the fourth dielectric tape 48 residing between the seventh insulated conductor 47 and the eighth insulated conductor 49.

[049] Figure 5 is a close-up view of the first twisted pair 33, which is similarly constructed although not identically constructed (as will be detailed later in the specification) to the second, third and fourth twisted pairs 34, 35 and 36. Each of the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47, 49 is formed by a conductor K surrounded by a layer of dielectric insulating material R, such as a polymer or foamed polymer, common to the cabling art like fluorinated ethylene propylene (FEP), polyethylene (PE) or polypropylene (PP). Further, the insulating material R may be formed by an enamel coating, or another nonconductive coating from a diverse art like motor armature windings. The conductor K may be solid or stranded, and may be formed of a conductive metal or alloy, such as copper. In a preferred embodiment, the conductor K is a solid, copper wire of about twenty one gauge size, i.e., about 28.5 mil in diameter.

[050] In one embodiment, the insulating material R may have a radial thickness of about less than 8.65 mils, more preferably about seven mils or less, more preferably about 6 mils or less, such as about 5.2 to 5.8 mils. This radial thickness of the insulating layer R is at least 20% less than the standard insulation layer thickness of a conductor in a typical equivalent twisted pair of insulated conductors in a network cable, more preferably at least 25% to 30% less. Typically, such a thin insulation layer R would not be possible due to the incorrect nominal impedance obtained when the conductors K of the first and second insulated conductors 38 and 40 become so closely spaced during the twisting operation due to the thinner insulating layers R. Typically, such thin insulation layers were not practiced in the background art, because there was no appreciation of a solution to the mechanical and performance problems. By the present invention, the interposed first dielectric tape 39 eases the mechanical stresses during twisting so that the thinner insulating layer R is undamaged and also spaces the conductors K apart so that a proper nominal impedance may be obtained, e.g., one hundred ohms.

[051] As best seen in Figure 5, the first dielectric tape 39 has a first width which extends approximately perpendicular to an extension length of the first dielectric tape 39 from a first edge 51 of the first dielectric tape 39 to an opposing second edge 53 of the first dielectric tape 39. The first width is less than a diameter of the first insulated

conductor 38 plus a diameter of the second insulated conductor 40 plus a thickness of the first dielectric tape 39, wherein the thickness is measured by the spacing created between the first and second insulated conductors 38 and 40. A typical spacing might be between four to twelve mils, such as about eight mils or about ten mils. By this arrangement, the twists of the first twisted pair 33 occupy a space within the dashed line 55, which is circumscribed by the helical twisting of the first and second insulated conductors 38 and 40. In this arrangement, the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact each other if adjacent and also may contact the inner wall of the jacket 32.

[052] In Figure 5, the dielectric tape 39 is formed as a single unitary structure (e.g., the dielectric tape does not include multiple pieces attached together or layered). Figure 5A illustrates that the solid dielectric tape 39 of Figure 5 may be replaced with a dielectric tape 39A having a hollow core filled with a gas, like air (with a dielectric constant of 1.0) or a foamed insulation material (with a dielectric constant approaching 1.0). By filling the hollow core with a gas or material with a lower dielectric constant than a material used to form said first dielectric tape 39 or 39A, the overall dielectric constant of the first dielectric tape 39A may be reduced. The hollow core may extend the entire length of the dielectric tape 39A, resulting in a "straw-like" structure. Alternatively, support structures may be formed at intervals along the length of the dielectric tape 39A to form closed-cell air pockets, each having a short length, such as 1/2 inch, one inch, two inches, etc. Alternatively, one or more support structures may be formed within the hollow core, which extend along the length of the dielectric tape 39A and connect between the lateral walls of the hollow core to resist crushing of the hollow core during the twisting of the first twisted pair 33A. Although the other embodiments of the dielectric tapes of the present invention are illustrated with solid cores, hollow cores, as described in connection with Figure 5A, may be employed in any or all of the other dielectric tapes. The first twisted pair 33A depicted in Figure 5A may be substituted into the place of the first twisted pair 33 depicted in Figure 4.

[053] The first through fourth twisted pairs 33, 34, 35 and 36 may be stranded together in the direction 57 (see the arrow 57 in Figure 3) to form a stranded core. In one embodiment, the core strand direction 57 is opposite to the pair twist directions of the

first through fourth twisted pairs 33, 34, 35 and 36. However, this is not a necessary feature, as in a preferred embodiment, the strand direction 57 is the same as the pair twist directions. In a preferred embodiment, the twist directions of the twisted pairs and the core strand are all to the lefthand direction.

[054] In preferred embodiments, the strand length of the core strand is about six inches or less, more preferably about five inches or less. In a more preferred embodiment, the core strand length is purposefully varied, or modulates, from an average strand length along a length of the cable 31. Core strand modulation can assist in the reduction of alien crosstalk. For example, the core strand length could modulate between three inches and six inches along the length of the cable 31, with an average value of about 4.4 inches.

[055] The first twist length w (See Figure 3) of the first twisted pair 33 is preferably set to a short length, such as between approximately 0.22 inches and approximately 0.47 inches. The second twist length x of the second twisted pair 34 is different from the first twist length w and is between approximately 0.22 inches and approximately 0.47 inches. For example, the first twist length w may be set to approximately 0.405 inches and the second twist length x may be set to approximately 0.438 inches.

[056] In one embodiment, the first twist length w purposefully modulates from a first average value, such as 0.405 inches. For example, the first twist length could purposefully vary by a percentage range, e.g., +/- 30%, along the length of the cable. Likewise, the second twist length could purposefully modulate from a second average value, such as 0.438 inches. For example, the second twist length could purposefully vary within a same or different percentage range along the length of the cable.

[057] The third twisted pair 35 would have a third twist length y, such as 0.607 inches, and the fourth twisted pair 36 would have a fourth twist length of z, such as 0.683 inches. In one embodiment, the third twist length y is different from the first, second and fourth twist lengths w, x and z, while the fourth twist length z is different from the first, second and third twist lengths w, x and y. Of course, the third and fourth twisted pairs 35 and 36 could employ a similar twist length modulation, as described in conjunction with the first and second twisted pairs 33 and 34.

[058] Figure 6 is a close-up cross sectional view of a twisted pair 60, having a dielectric tape 61 with an alternative shape, in accordance with a second embodiment of the present invention. The dielectric tape 61 has a width which extends approximately perpendicular to an extension length of the twisted pair 60 from a first edge 62 of the dielectric tape 61 to an opposing second edge 63 of the dielectric tape 61. The width, in the embodiment of Figure 6, is equal to or less than the diameter of the first insulated conductor 38. Less material is used to form the dielectric tape 61 in the embodiment of Figure 6. This presents advantages in reducing the amount of consumable material in the case of a fire, and in reducing the amount of smoke emitted from the cable 31 in the case of a fire. This structure may also reduce the weight and outer diameter of the cable and improve the flexibility of the cable. As seen in Figure 6, the dielectric tape 61 has a cross sectional shape in a direction perpendicular to an extension length of the twisted pair 60, which presents a first recessed portion 64 for seating the first insulated conductor 38 and a second recessed portion 65 for seating the second insulated conductor 40.

[059] The cross sectional shapes of the dielectric tapes 39 and 61 in Figures 5 and 6 are mirror symmetrical. However, it is not necessary that the shape be mirror symmetrical in order to achieve many of the advantages of the present invention. Further, the first and second recessed portions 64 and 65 of the dielectric tape 61 in Figure 6 are semi-circular in shape. However, it is not necessary that the first and second recessed portions 64 and 65 be semi-circular. In fact, the recesses in the dielectric tape 39 of Figure 5 for receiving the first and second insulated conductors 38 and 40 are not semi-circular in shape. Also, the first and second recessed portions 64 and 65 may include serrations to create pockets of air adjacent to the seated portions of the first and second insulated conductors 38 and 40.

[060] Figure 7 is a cross sectional view of a twisted pair cable 66 employing the first twisted pair 60 of Figure 6. The twisted pair cable 66 also includes similarly configured second, third and fourth twisted pairs 67, 68 and 69. The twists of the first, second, third and fourth twisted pairs 60, 67, 68 and 69 occupy respective spaces within the dashed lines 55 (See Figure 6). In this arrangement, the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact each other and also may contact the inner wall of the jacket 32.

[061] Figure 8 is a close-up cross sectional view of a twisted pair 70, having a dielectric tape 71 with an alternative shape, in accordance with a third embodiment of the present invention. The dielectric tape 71 has a width which extends approximately perpendicular to an extension length of the twisted pair 70 from a first edge 72 of the dielectric tape 71 to an opposing second edge 73 of the dielectric tape 71. The width, in the embodiment of Figure 8, is equal to or less than the diameter of the first insulated conductor 38.

[062] The embodiment of Figure 8 illustrates that the dielectric tape 71 need not have recessed portions 64 and 65 (as shown in Figures 5 and 6) to seat the insulated conductors 38 and 40. Rather, the dielectric tape 71 may be formed as a generally flat member. The dielectric tape 71 will remain between the first and second insulated conductors 38 and 40 due to the frictional forces created during the twisting operation, when the twisted pair 70 is formed.

[063] Figure 8A is a close-up cross sectional view of a twisted pair 70A, having a dielectric tape 71A with an alternative shape, in accordance with a fourth embodiment of the present invention. The dielectric tape 71A has a width which extends approximately perpendicular to an extension length of the twisted pair 70A from a first edge 72A of the dielectric tape 71A to an opposing second edge 73A of the dielectric tape 71A. The width, in the embodiment of Figure 8A, is equal to or slightly less than (e.g., two to four mils less than) the diameter of the first insulated conductor 38 plus the diameter of the second insulated conductor 40 plus a thickness of the dielectric tape 71A.

[064] The embodiment of Figure 8A illustrates that the dielectric tape 71A may be a generally flat member having a width which is approximately equal the diameter of the first insulated conductor 38 plus the diameter of the second insulated conductor 40 plus a thickness of the dielectric tape 71A, such as about eighty-eight mils plus or minus about five mils.

[065] Figure 8B is a cross sectional view of a twisted pair cable 76 employing the first twisted pair 70A of Figure 8A, in accordance with a preferred embodiment of the present invention. The twisted pair cable 76 also includes similarly configured second, third and fourth twisted pairs 77, 78 and 79. The twists of the first, second, third and fourth twisted pairs 70A, 77, 78 and 79 occupy respective spaces within the dashed lines

55 (See Figure 8A). In this arrangement, the first through eighth insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may contact a plus-shaped separator 37A (sometimes referred to as an isolator, a flute or a crossweb) and also may contact inner ends of projections or fins 32A on the inner wall of the jacket 32. Figure 8B shows twelve projections 32A, however more or fewer projections may be included, with the goal being to hold the core of twisted pairs 70A, 77, 78 and 79 in the center of the cable 76 while creating air pockets around the perimeter of the core of twisted pairs.

[066] Figure 9 is a perspective view of a twisted pair cable 81, in accordance with a fifth embodiment of the present invention. Figure 10 is a cross sectional view of the cable 81 taken along line X--X in Figure 9. The cable 81 includes a jacket 82 formed around and surrounding first, second, third and fourth twisted pairs 83, 84, 85 and 86, respectively.

[067] The fifth embodiment of the invention, as illustrated in Figures 9 and 10, does not include a separator 37. However, pair separators (sometimes referred to as tapes, isolators, flutes or crosswebs) may optionally be included, if desired.

[068] As best seen in the cross sectional view of Figure 10, the first twisted pair 83 includes a first insulated conductor 88, a first dielectric tape 89, and a second insulated conductor 90. The first insulated conductor 88 is twisted with the second insulated conductor 90, in a helical fashion, with the first dielectric tape 89 residing between the first insulated conductor 88 and the second insulated conductor 90.

[069] The second twisted pair 84 includes a third insulated conductor 91, a second dielectric tape 92, and a fourth insulated conductor 93. The third insulated conductor 91 is twisted with the fourth insulated conductor 93, in a helical fashion, with the second dielectric tape 92 residing between the third insulated conductor 91 and the fourth insulated conductor 93.

[070] The third twisted pair 85 includes a fifth insulated conductor 94, a third dielectric tape 95, and a sixth insulated conductor 96. The fifth insulated conductor 94 is twisted with the sixth insulated conductor 96, in a helical fashion, with the third dielectric tape 95 residing between the fifth insulated conductor 94 and the sixth insulated conductor 96.

[071] The fourth twisted pair 86 includes a seventh insulated conductor 97, a fourth dielectric tape 98, and an eighth insulated conductor 99. The seventh insulated conductor 97 is twisted with the eighth insulated conductor 99, in a helical fashion, with the fourth dielectric tape 98 residing between the seventh insulated conductor 97 and the eighth insulated conductor 99.

[072] Figure 11 is a close-up view of the first twisted pair 83, which is similarly constructed to the second, third and fourth twisted pairs 84, 85 and 86. Like the embodiment of Figures 3-8, each of the first through eighth insulated conductors 88, 90, 91, 93, 94, 96, 97 and 99 is formed by a conductor K (constructed as a solid or stranded conductor having a 21 AWG size) surrounded by a layer of dielectric insulating material R. Also, the insulating material R may have a radial thickness of about 8.65 mils or less, such as seven mils or less, more preferably about five mils or less.

[073] As best seen in Figure 11, the first dielectric tape 89 has a first width which extends approximately perpendicular to an extension length of the first twisted pair 83 from a first edge 101 of the first dielectric tape 89 to a second edge 103 of the first dielectric tape 89. The first width is greater than a diameter of the first insulated conductor 88 plus a diameter of the second insulated conductor 90 plus a thickness of the first dielectric tape 89, wherein the thickness is measured by the spacing created between the first and second insulated conductors 88 and 90. A typical spacing might be between four to twelve mils, such as about eight mils or about ten mils. By this arrangement, the twists of the first twisted pair 83 occupy a space within the dashed line 105, which is circumscribed by the helical twisting of the first and second edges 101 and 103 of the first dielectric tape 89. In this arrangement, the first through eighth insulated conductors 88, 90, 91, 93, 94, 96, 97 and 99 do not contact each other and also do not contact the inner wall of the jacket 82. Rather, a small air pocket 107 is maintained around the outer perimeter of the dielectric insulating material R. Hence, the first insulated conductor 88 would be spaced from the inner wall of the jacket 82 by a first minimum distance, where the first minimum distance could be fixed in the range of one to twenty mils, such as two mils or four mils. Moreover, the first insulated conductor 88 would be spaced from any other insulated conductor of another twisted pair 84, 85 or 86 of the cable 81 by a second minimum distance. The second minimum distance would equal twice the first minimum

distance, because the small air pocket 107 of the first twisted pair 83 would be added to the small air pocket 107 of the other twisted pair 84, 85 or 86.

[074] As in the first embodiment of Figures 3-5, the first through fourth twisted pairs 83, 84, 85 and 86 may be stranded together in the direction 109 (see the arrow in figure 9) to form a stranded core. In one embodiment, the core strand direction 109 is opposite to the pair twist directions of the first through fourth twisted pairs 83, 84, 85 and 86. However, this is not a necessary feature. The core strand length and pair twist lengths w, x, y and z may be tight, as described in conjunction with Figures 3-5, and may optionally be modulated.

[075] As best seen in the cross sectional view of Figure 11, the first dielectric tape 89 includes first and second recesses 111 and 113 to seat the first and second insulated conductors 88 and 90. The first and second recesses 111 and 113 may assist in properly positioning the three parts 88, 89 and 90 of the first twisted pair 83 during a manufacturing process, and may also assist in keeping the three parts 88, 89 and 90 of the first twisted pair 83 in place during use of the cable 81 (e.g., pulling of the cable through conduits or ductwork). However, many advantages of the invention may be achieved without the recesses 111 and 113, as will be seen in Figure 12.

[076] Figure 12 is a close-up cross sectional view of a twisted pair 120, having a dielectric tape 121 with an alternative shape, in accordance with a sixth embodiment of the present invention. The dielectric tape 121 has a width which extends approximately perpendicular to an extension length of the twisted pair 120 from a first edge 122 of the dielectric tape 121 to a second edge 123 of the dielectric tape 121. Like the embodiment of Figures 9-11, the width of the dielectric tape 121 is greater than the diameter of the first insulated conductor 88 plus the diameter of the second insulated conductor 90 plus a thickness of the first dielectric tape 121. The dielectric tape 121 may be formed as a generally flat member. The dielectric tape 121 will remain between the first and second insulated conductors 88 and 90 due to the frictional forces created during the twisting operation, when the twisted pair 120 is formed.

[077] In cables of the background art, different twist lengths were applied to each of the four twisted pairs. The different twist lengths had the benefit of reducing crosstalk between adjacent pairs within the cable. However, employing different twist

lengths also created drawbacks, such as delay skew (e.g., it takes more time for a signal to travel to the far end of the cable on a relatively tighter twisted pair, as compared to a relatively longer twisted pair in the same cable). Differing twist lengths can also cause relative differences between the twisted pairs in such performance characteristics as attenuation and impedance.

[078] In the background art, the insulation layers R were varied in thickness and/or material composition to compensate for the differences. For example, the insulation layers R of the insulated conductors 91 and 93 in the tighter twisted pair 84 (in Figure 9) could be formed of a material with a different dielectric constant than the insulation layers R of the insulated conductors 94 and 96 in the longer twisted pair 85 (in Figure 9). Also, air could be introduced into the insulation layers R to foam the insulation layers R. The foaming could be set at different levels for one or more of the twisted pairs, depending upon their twist length.

[079] Such measures of the background art helped to offset the different performance characteristics induced by the different twist lengths of the twisted pairs. However, there was an added cost in that the insulated conductors used in different twisted pairs of the same cable had to be manufactured differently. This created a need for inventorying different types of insulated conductors and added more complexity in the manufacturing process.

[080] In accordance with one embodiment of the present invention, the insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 of each of the twisted pairs 33, 34, 35 and 36 in the cable 31 may be made structurally identical (noting that certain non-structural features, like colors, stripe patterns or printed indicia may be employed to merely identify the insulated conductors from each other). In this embodiment of the present invention, the dielectric tape structure can be used to mitigate the performance differences, which arise when different twist lengths are employed in the twisted pairs. Moreover, the insulated conductors 38, 40, 41, 43, 44, 46, 47 and 49 may be made structurally identical and also be identical in appearance. In this embodiment, the color of, or indicia on, the first through fourth dielectric tapes 39, 42, 45 and 48 could be used to distinguish between the first through fourth twisted pairs 33, 34, 35 and 36 of the cable 31, when the cable 31 is terminated and a connector is attached thereto.

[081] For example, the dielectric tape of one twisted pair of a given cable may be different in shape, size or material content as compared to the dielectric tape of another twisted pair in the same cable. In Figure 4, the first dielectric tape 39 of the first twisted pair 33 has a first thickness, which sets a spacing distance between the first insulated conductor 38 and the second insulated conductor 40. In the third twisted pair 35, the third dielectric tape 45 has a second thickness, which sets a spacing distance between the fifth insulated conductor 44 and the sixth insulated conductor 46. The second thickness is different from the first thickness, which also means that the shape of the first dielectric tape 39 is different than the shape of the third dielectric tape 45.

[082] In one embodiment, the difference between the second thickness and the first thickness is at least 1 mil. For example, the first dielectric tape 39 could have a thickness of about 10 mils, whereas the third dielectric tape 45 could have a thickness of about 8 mils. Such a change in thickness and shape will affect the respective performance characteristics of the first twisted pair 33 and the third twisted pair 35, such as their respective attenuation, impedance, delay skew, etc.

[083] Also in Figure 4, the first dielectric tape 39 of the first twisted pair 33 has a first width, which extends approximately perpendicular to an extension length of said cable 31 from its first edge 51 to its second edge 53 (See Figure 5). In the fourth twisted pair 36, the fourth dielectric tape 48 has a second width, which extends approximately perpendicular to the extension length of said cable 31 from its corresponding first edge 51 to its corresponding second edge 53. The second width is different from the first width. For example, the second width may be several mils shorter than the first width, such as about 2 to 12 mils shorter, e.g., about 5 mils shorter. Again, the respective differences in width will serve to create differences in performance characteristics, which can be adjusted and used to offset for the performance differences created by the different twist lengths.

[084] Also in Figure 4, the first dielectric tape 39 of the first twisted pair 33 is formed of a first material having a first dielectric constant. In the second twisted pair 34, the second dielectric tape 42 is formed of a second material having a second dielectric constant (as illustrated by the different thicknesses in the cross hatching). The second dielectric constant is different from the first dielectric constant. For example, the second

dielectric constant could differ from the first dielectric constant by about 0.1 to about 0.8, e.g., the first dielectric constant might be 1.2, whereas the second dielectric constant is 1.4, thus illustrating a difference of 0.2 in dielectric constant between the two materials. Again, the respective differences in material will serve to create differences in performance characteristics, which can be adjusted and used to offset for the performance differences created by the different twist lengths. Of course, the differences between the dielectric tapes can also be employed as a supplemental measure in conjunction with differences in insulation layers on the insulated conductors to provide an additional ability to compensate for performance differences between the twisted pairs.

[085] The cables 31, 66, 76 and 81 of the present invention may be manufactured using standard twisting equipment, such as a double twist twinning machine, known in the art of twisted pair cable making. An additional spool would be added to feed the dielectric tape into the twisting machine between the insulated conductors of the twisted pair. Additional details concerning the manufacturing of a similar cable with 23 AWG conductors, which would not be capable of transmitting data and PoE over a same distance, which the cables of the present invention can, is shown in the Applicant's granted US Patents 11,424,052; 10,573,430; 9,978,480; 9,418,775 and 7,999,184, which are herein incorporated by reference.

[086] Although, the cables illustrated in the drawing figures have included four twisted pairs, it should be appreciated that the present invention is not limited to cables having only four twisted pairs. Cables having other numbers of twisted pairs, such as one twisted pair, two twisted pairs or even twenty-five twisted pairs, could benefit from the structures disclosed in the present invention. Further, although the drawing figures have illustrated that each of the twisted pairs within the cable have a dielectric tape, it would be possible for less than all of the twisted pairs to have the dielectric tape. For example, the first through third twisted pairs could include a dielectric tape, while the fourth twisted pair could be formed without a dielectric tape. Further, although the drawing figures have illustrated an unshielded cable, it is within the scope of the appended claims that the cable could include a shielding layer and/or a core wrap between the core of twisted pairs and the inner wall of the outermost jacket. Further, although some drawing figures have illustrated a jacket having a smooth inner wall, it is within the scope of the

present invention that in all embodiments the inner wall of the jacket could include fins or projections (as illustrated in Figure 8B) for creating air pockets around the perimeter of the core of twisted pairs. Further, all embodiments of the present invention may include a separator (e.g., tape, isolator, flute, cross web). Further, all embodiments of the present invention may include a dielectric tape, e.g., 71, 121, formed as a single unitary structure (e.g., the dielectric tape does not include multiple pieces attached together or layered).

[087] Examples of cables made in accordance with several embodiments of the present invention having 21 AWG conductors have been constructed and tested with good performance results. The test data of the cables is included in the Applicant's priority provisional application Serial No. 63/555,203, filed Feb. 19, 2024, which is herein incorporated by reference. In the tested embodiments, each twisted pair included first and second insulated conductors of 21 AWG size. Each twisted pair had a bisector tape located between the first and second twisted insulated conductors. The 21 AWG conductors allowed for longer distance transmission of data and PoE, e.g., extended reach. A thinner wall of insulation on the 21 AWG conductors permitted the network cable to be terminated to industry standard RJ45 jacks and plugs, which were designed to accommodate 22-24 AWG insulated conductors, while dielectric tapes between the insulated conductors of the twisted pairs maintained the required 100 ohm nominal impedance of each twisted pair of insulated conductors.

[088] The network cables of the present invention can be made in plenum, riser, outdoor, and LSZH (low smoke zero halogen) offerings. The network cable construction can include a cross-web isolator or a flat tape separator. Alternatively, no cross-web isolator or flat tape separator can be used in the cable core. The network cable may be shielded or unshielded. In a preferred embodiment, both twist and strand modulation are used. With twisted pairs one through four respectively, a preferred mean twist length will be about 0.683", 0.405", 0.607" and 0.438" with a mean core strand lay of about 4.4". In a preferred embodiment, all twisted pair twists and the strand lay are in the left hand direction.

We Claim:

1. A power over ethernet, network cable comprising:

four twisted pairs of insulated conductors; and

a jacket formed around said four twisted pairs of insulated conductors, with each twisted pair of insulated conductors including:

a first insulated conductor having a first 21 AWG or larger conductor surrounded by a first layer of first dielectric insulating material;

a first dielectric tape; and

a second insulated conductor having a second 21 AWG or larger conductor surrounded by a second layer of second dielectric insulating material, wherein said first insulated conductor is twisted with said second insulated conductor with said first dielectric tape residing between said first insulated conductor and said second insulated conductor to form the twisted pair.

2. The cable according to claim 1, wherein said first layer of first dielectric insulating material has a radial thickness of 8.65 mils or less, and said second layer of second dielectric insulating material has a radial thickness of 8.65 mils or less, whereby each of said first and second insulated conductors has an overall outer diameter of 45.8 mils or less.

3. The cable according to claim 1, wherein said first layer of first dielectric insulating material has a radial thickness of 7 mils or less, and said second layer of second dielectric insulating material has a radial thickness of 7 mils or less, whereby each of said first and second insulated conductors has a diameter of 42.5 mils or less.

4. The cable according to claim 1, wherein said first layer of first dielectric insulating material has a radial thickness of 6 mils or less, and said second layer of second dielectric insulating material has a radial thickness of 6 mils or less, whereby each of said first and second insulated conductors has a diameter of 40.5 mils or less.

5. The cable according to claim 1, wherein said first layer of first dielectric insulating material has a radial thickness of about 5.2 mils, and said second layer of second dielectric insulating material has a radial thickness of about 5.2 mils, whereby each of said first and second insulated conductors has a diameter of about 38.9 mils.

6. The cable according to claim 1, wherein said first layer of first dielectric insulating material has a radial thickness of between 4 to 7 mils, and said second layer of second dielectric insulating material has a radial thickness of between 4 to 7 mils.

7. The cable according to claim 1, wherein twist lengths of said four twisted pairs are set at different median values and purposefully modulate from their median values.

8. The cable according to claim 1, wherein said four twisted pairs are stranded together to form a stranded core, said stranded core has a strand length of about 4 to 5 inches.

9. The cable according to claim 8, wherein said strand length of said stranded core modulates along a length of said cable.

10. The cable according to claim 1, further comprising:

a flat tape separator within said jacket wherein said flat tape separator is located to space first and second twisted pairs of said four twisted pairs from third and fourth twisted pairs of said four twisted pairs.

11. The cable according to claim 1, further comprising:

a cross web separator within said jacket wherein said cross web separator is located to space each of said four twisted pairs from the others of said four twisted pairs.

12. A power over ethernet, network cable comprising:

four twisted pairs of insulated conductors, each twisted pair of insulated conductors exhibiting a nominal 100 ohm impedance; and

a jacket formed around said four twisted pairs of insulated conductors, with each twisted pair of insulated conductors including:

a first insulated conductor having a first 21 AWG or larger conductor surrounded by a first layer of first dielectric insulating material having a radial thickness of 8.65 mils or less; and

a second insulated conductor having a second 21 AWG or larger conductor surrounded by a second layer of second dielectric insulating material having a radial thickness of 8.65 mils or less, whereby each of said first and second insulated conductors has an overall outer diameter of 45.8 mils or less.

13. The cable according to claim 12, wherein said first layer of first dielectric insulating material has a radial thickness of 7 mils or less, and said second layer of second dielectric insulating material has a radial thickness of 7 mils or less, whereby each of said first and second insulated conductors has a diameter of 42.5 mils or less.

14. The cable according to claim 12, wherein said first layer of first dielectric insulating material has a radial thickness of 6 mils or less, and said second layer of second dielectric insulating material has a radial thickness of 6 mils or less, whereby each of said first and second insulated conductors has a diameter of 40.5 mils or less.

15. The cable according to claim 12, wherein said first layer of first dielectric insulating material has a radial thickness of about 5.2 mils, and said second layer of second dielectric insulating material has a radial thickness of about 5.2 mils, whereby each of said first and second insulated conductors has a diameter of about 38.9 mils.

16. The cable according to claim 12, wherein twist lengths of said four twisted pairs are set at different median values and purposefully modulate from their median values.

17. The cable according to claim 12, wherein said four twisted pairs are stranded together to form a stranded core, and wherein said stranded core has a strand length of about 4 to 5 inches.

18. The cable according to claim 17, wherein said strand length of said stranded core modulates along a length of said cable.

19. The cable according to claim 12, further comprising:

a flat tape separator within said jacket wherein said flat tape separator is located to space first and second twisted pairs of said four twisted pairs from third and fourth twisted pairs of said four twisted pairs.

20. The cable according to claim 12, further comprising:

a cross web separator within said jacket wherein said cross web separator is located to space each of said four twisted pairs from the others of said four twisted pairs.