(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 October 2020 (15.10.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/208392 A1

(51) International Patent Classification:
H01B 9/00 (2006.01) *H01B 11/04* (2006.01)

(21) International Application Number:
PCT/IB2019/000419

(22) International Filing Date:
12 April 2019 (12.04.2019)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *with amended claims (Art. 19(1))*

(54) **Title:** EPB AND WSS CABLE WITH INTERFERENCE DAMPING

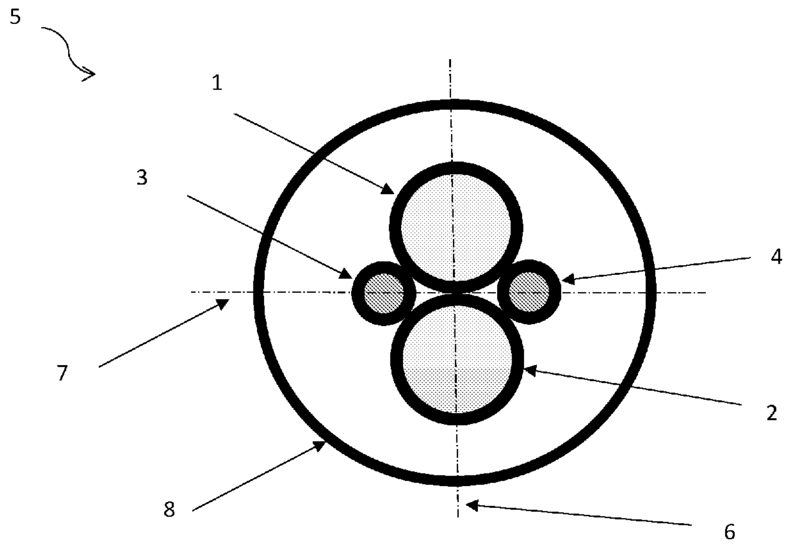

FIG. 1

(57) **Abstract:** A load/power cable for an electric parking brake (EPB) and wheel speed sensor (WSS). The load/power cable includes two load wires and two power wires in a star quad geometric configuration, which efficiently dampens electromagnetic interference between load and power wires. The load/power cable further includes a co-polymer material for insulation that is resistant to degradation.

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EPB AND WSS CABLE WITH INTERFERENCE DAMPING

Field of Invention

[0001] This disclosure relates generally to load/data cables and in particular to an Electronic Parking Break (EPB) and Wheel Speed Sensor (WSS) cable in which the electromagnetic interference between the cable's wires is damped by the arrangement of wires in combination with cladding materials.

Background of the Invention

[0002] The drive-by-wire technologies have dramatically expanded during the last five to seven years. One challenge of cost reduction and steadily increased vehicle's engineering architecture relates to heightened safety requirements, for example those enforced by federal and state regulators, as well as optional safety requirements, prompted by the market. This challenge compels manufactures to install more and more complex electronic equipment, which in turn requires additional and more complex wirings in vehicles. WSS and EPB, are important components of a brake-by-wire system, which is a segment of vehicle's drive-by-wire system.

[0003] In the art, various designs of a WSS and EPB cable include a combination of two data wires with two load wires. Traditionally, WSS data wires are stranded together and shielded by a metallic braid or foil screen in cases when they are provided with their own jackets with power wires, and in certain cases they can be laid separately. EPB load wires may similarly be laid separately. However, such hybrid cables typically include two load wires and two data wires. In such hybrid cables, data lines require shielding as a protective measure against an electromagnetic radiation of load lines.

[0004] In the art, various other types of cable geometries are known, e.g., a star quad cable which is a symmetrical copper cable. In this cable, four wires are stranded together in a cross shape. This means that the opposite wires each form a wire pair. Due to the perpendicular line pairs very little crosstalk occurs. The structure of the star quad cable must be stable, so that the wires do not shift during installation, as this would change the transmission characteristics. For this reason, star quad cables are often additionally supported and stabilized by elements to hold the wires in an optimal position relative to each other. The main advantage of the star quad stranding is the higher packing density as compared to standard stranding wires.

[0005] The problem, which is unanimously recognized in the art, is that because certain portions of each data wire are positioned farther from the central axis of symmetry of a cable than others, and when the cable is flexed or bent, the mechanical stress is particularly greatest at the locations of the data wires. It is a common approach in the art to use fluorine-containing polymers, such as tetrafluoroethylene (ETFE) or fluorinated ethylene propylene (FEP) as a sheathing material for such cables. In addition, both materials, i.e., ETFE and FEP, exhibit a specific weight of round about 2.1 kg/L, which is heavy for the inventors. Alternatively, non-metallic cross-linked materials are used for insulating wires inside a cable. The problem is that such materials are not always compatible with the aforementioned fluorine-containing polymers in addition to other known polymers, and may dissolve under continuous operation.

Summary of the Invention

[0006] Illustrative embodiment of the present disclosure provides a load/data cable architecture and material. In accordance with one aspect of an illustrative embodiment of the present disclosure, the cable is implemented with a WSS and EPB. The cable, disclosed thereafter, advantageously provides a low-cost, light weight alternative to existing applications.

[0007] According to an aspect of the present disclosure, the load/data cable includes two data wires and two load wires. Each wire may comprise a central conductive core surrounded by insulation. The load wires may be configured to be connected to the EPB and the data wires may be configured to be connected to the WSS. The outer diameters of the load wires are usually greater than the outer diameter of the data wires.

[0008] According to embodiments, the load wires may be located parallel to each other along a central axis of symmetry of the cable. According to these embodiments, the load wires have a center along a same imaginary plane of the cable. According to embodiments, the load wires are adjacent to and contact each other at, at least one point along their outer circumference such that the load wires are in contact with each other along the entire length of the cable.

[0009] The data wires may also be parallel to each other along the central axis of symmetry of the cable. According to these embodiments, the data wires have a center along a same imaginary plane of the cable that is different from the imaginary plane for the load wires. According to embodiments, one of the data wires is located within an area created by the adjacent load wires, for example, in a recess formed by the adjacent load wires. The other data wire is located within an opposite area created by the adjacent load wires, for example, in a second recess formed by the adjacent load wires. The alignments of load wires and that of a data wires are perpendicular to each other all along the cable (e.g., the imaginary planes created by the centers of the data wires and the load wires are perpendicular to each other).

[0010] Such a configuration of the cable solves the above identified problems. The described spatial arrangement of load and data wires creates such configuration of inductive fields in the cable system, that the interference of load wires on data wires is substantially reduced due to the law of electromagnetic induction. In order to prevent the resulting overdriving of the electronic and inductive field lines and to ensure the data flow without interference, an impact co-polymer is used, which comprises hetero-phasic amorphous structures within a semi-crystalline polypropylene ("PP") phase, for the new construction of the WSS and EPB cable, according to the present invention. In other words, the interaction between geometrical direction and material is crucial. When the two load line have geometries such that they contact each other along the center of the cable, the electric and inductive field lines change in a direction such that they negligibly burden the data lines. Additionally, it has been recognized when that occurs, the data lines located within an area adjacent to the load wires is frequently impacted by electrical or inductive field coupling between the affected load lines. In particular, it is known in the art that an EPB, when activated, generates a large current. A large spike in current caused by the EPB normally interferes with, and causes degradation of, a signal in co-located data wires. But the spatial arrangement of the load and data wires according to the present disclosure mitigates such interference. Furthermore, the spatial arrangement of the load and data wires according to the present disclosure prevents the voltage surge caused by activation of the EPB, and associated electromagnetic interference, from damaging the WSS sensor and associated control unit.

[0011] In order to address mechanical and chemical concerns associated with such a configuration, certain materials may be selected for the load lines as well as the data lines. According to embodiments, the insulation for the load lines each comprises a thermoplastic elastomer. According to preferred embodiments, the thermoplastic elastomer comprises PP.

According to a preferred embodiment, the thermoplastic elastomer comprises a co-polymer comprising PP and an ethylene-octane copolymer (POE). In a most preferred embodiment, the insulation is an impact co-polymer, which could be changed in physical properties by adjusting the co-monomer, co-catalyst and/or catalyst modifier concentration. For example, for production of the impact co-polymer (ICP) polypropylene production, the ethylene concentration within the polyolefin reactor must be changed to achieve the specific properties for various ICP grades. A change in ethylene concentration results in an altered rubber content in the manufactured polyolefin product. In other words, the ICP comprises hetero-phasic amorphous structures within a semi-crystalline PP phase. This impact co-polymer ensures that the methyl group is always on the same side of the main chain. In addition, to increase the low-temperature flexibility, a POE is further added to the above-described particularly impact-resistant base material. These thermoplastic polymers based on PP (as used in the load lines 1 and 2) meet the requirements and is different than polyurethane (PU) known that can no longer achieve the desired overload temperatures.

[0012] According to embodiments, the insulation for the data wires each comprises a thermoplastic elastomer. According to preferred embodiments, the thermoplastic elastomer comprises a crosslinked polyethylene.

[0013] The present disclosure advantageously provides an EPB and WSS cable with reduced manufacturing costs and weight. These advantages are attained at least in part by the spatial configuration of all four constituent wires, which allows for dramatically reducing inductive interference of load wires on data wires without using a metallic braided or foils shielding on the data wires. Whereas these conventional shielding materials make the load/data cables heavy and expensive, the disclosed configuration dispenses with them, resulting in lighter and less expensive load/data cables. Moreover, the present disclosure advantageously provides an insulation material with superior electromagnetic insulating properties that is resistant to degradation during use

Brief Description of the Drawings

[0014] The following description is given as an example, and is not intended to limit the scope of the invention to the disclosed details, is made in conjunction with the accompanying drawings, wherein:

[0015] FIG. 1 illustrates a cross-sectional view of a complex cable according to the present disclosure.

Detailed Description

[0016] Detailed embodiments of the present cable system and methods are disclosed herein; however, it is to be understood that the disclosed embodiments are merely illustrative of a cable system, and methods that may be embodied in various forms. In addition, each of the examples given in connection with the various embodiments of the cable systems and methods are intended to be illustrative, and not restrictive. Further, the drawing is not necessarily to scale, and some features may be exaggerated to show details of particular components. In addition, any measurements, specifications and the like shown in the figures are intended to be illustrative, and not restrictive. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present cable system, and methods.

[0017] With reference to FIG.1, an embodiment of a load/data cable 5, and in particular, a WSS and EPB cable of the present disclosure is illustrated. The load/data cable 5 includes two insulated load wires 1, 2 and two insulated data wires 3, 4. According to embodiments, the outer diameters of each of the load wires 1, 2, is greater than the outer diameter of each of the data wires 3, 4. The wires are encased in an outer sheath 8.

[0018] According to embodiments, load wires 1, 2 have approximately the same outer diameter. The load wires 1, 2 may be located parallel to each other along a central line of symmetry of the cable. According to these embodiments, load wires have cross-sectional centers that are located along an imaginary line 6. Load wires 1, 2, may also contact or otherwise abut each other at an approximate center of load/data cable 5 (i.e., where imaginary lines 6 and 7 cross).

[0019] According to embodiments, data wires 3, 4 have approximately the same outer diameter. The outer diameter of data wires 3, 4 may be less than the outer diameter of load wires 1, 2. The data wires 3, 4 may also be located parallel to each other along the central axis of symmetry of the cable. According to these embodiments, data wires 3, 4 have cross-sectional centers that are located along an imaginary line 7. It is noted that imaginary lines 6, 7 are straight lines along a longitudinal cross-section of cable 5 that are perpendicular to each other and that each split the cross section of load/data cable 5 into equal halves. Said another way, imaginary lines 6, 7, may be considered perpendicular diameters of the load/data cable 5.

[0020] As illustrated by FIG. 1, the geometry of load wires 1, 2, create two recesses, each recess being located on opposite sides of imaginary line 6, and thus on opposite sides of load/data cable 5. One of the data wires 3 or 4 may be located in a first of the recesses created by the adjacent load wires 1, 2. The other data wire 3 or 4 may be located in a second of the recesses created by the adjacent load wires 1, 2.

[0021] According to these embodiments, the transverse alignments of load wires 1, 2 and data wires 3, 4 are perpendicular to each other along the cable. In other words, for each transverse-section of the cable an imaginary straight line 6, crossing the geometrical center of both load wires' and an imaginary line 7, crossing the geometrical centers of both data wires' both cross a central line of symmetry of the cable and are perpendicular to each other.

[0022] According to embodiments, the wires (i.e., load wires 1, 2 and data wires 3, 4) are twisted together. According to alternative embodiments, the wires are not twisted, and instead are linearly arranged within cable 8. Regardless, the wires maintain the spatial configuration illustrated in FIG. 1.

[0023] With further reference to FIG.1, the described spatial arrangement of load and data wires creates a configuration of magnetic fields in the cable system such that the interference created by load wires on data wires is substantially reduced due according to the law of electromagnetic induction. For example, in load/data cable's 5 transverse-section, such as that depicted in FIG.1, the lines of magnetic fields generated by the load wires 1, 2 along imaginary straight line 7 are co-directed, and the resultant vector of the magnetic field is parallel to the imaginary straight line 7. Accordingly, the magnetic flux passing through the flat infinitesimal area lying on the straight line 7 equals zero. The same is true for each cable's transverse-section along any cable's substantially straight longitudinal segment.

[0024] With further reference to FIG.1, the ratio of the length of each straight line segment of the imaginary line 7 between the geometrical centers of symmetry of the traverse-sections of the load wires to the length of each straight line segment of the imaginary line 6 between the geometrical centers of symmetry of the traverse-sections of the data wires, wherein the imaginary lines 6, 7 cross a geometrical center of cable's longitudinal-section, vary from approximately 2 to 1. In other words, a ratio of the distance between geometric centers of the load wires 1, 2, and the distance between the geometric centers of the data wires 3, 4 may approximately be between 1 and 2. This results in a length ratio of the forming virtual of fictitious axes from 1:2 to 1:1.1.

[0025] A filler material may be located in the spaces between the wires and the outer sheath such that the wires do not move within the cable. According to certain embodiments, during manufacture the outer sheath may be formed via an extrusion process (e.g., pressure extrusion), such that its thickness fills the interior space of cable 8 and makes contact with the outer surface of the wires. Accord to alternative embodiments, the spaces between the wires and the outer sheath may be filled with a filler material (e.g., yarn, filaments, etc.). According to alternative embodiments, the space between the wires and the outer sheath is left empty (e.g., filled with a gas), such that the wires may move within the cable.

[0026] According to embodiments where the outer sheath may be formed via an extrusion process, and in particular a pressure extrusion process, a separator (not shown) may surround the wires, thus separating them from contacting the outer sheath. According to embodiments, the separator may take the form of a foil, paper, or fleece sheath, and thus act as an inner sheath for encasing the wires. According to alternative embodiments the separator may take the form of a powder that is placed (e.g., sprayed) on the wires.

[0027] The present disclosure additionally includes plastics or polymers used as insulating material for each wire. Suitable polymers selected for insulation of the wires are known in the art. According to embodiments, polymers are selected in order to address environmental, mechanical and chemical concerns associated with a configuration of wires according to the present disclosure. For example, the cables of the present disclosure are subject to bending (i.e., necessary bending for placement within a vehicle wiring system). Upon bending, one side the cable is tensioned (i.e., stretched), while the other side is compressed. This causes movement (i.e., laminar friction) between the outer sheath of the cable and an outer surface of the insulation of the load wires. Such movement causes abrasions on the respective surfaces of the outer sheath and insulation, leading to failure. Accordingly, preferred insulating materials are sufficiently smooth. Additionally, the insulating material should have sufficiently thermally insulative properties to protect the wires from the high temperatures generated by the environment (e.g., heat generated by the parking brake).

[0028] According to embodiments and with the above considerations in mind, the insulation for the load wires each comprises plastics or polymers. According to preferred embodiments, the polymer comprises a thermoplastic elastomer, and in particular, comprises thermoplastic PP. In preferred embodiments, the insulation comprises an ICP of PP and POE. According to one preferred embodiment, the ICP has a modified ethylene concentration to achieve specific properties for various ICP grades. A change in ethylene concentration results in an altered rubber content in the manufactured polyolefin product. In other words, the ICP comprises hetero-phasic amorphous structures within a semi-crystalline PP phase. This IPC ensures that the methyl group is always on the same side of the main chain. In addition, a POE component is further added to the above-described particularly impact-resistant base material in order to increase the low-temperature flexibility. For example, traditional PP insulations have a glass transition temperature of approximately -10°C, which is not suitable for use in automobiles. The POE raises the glass transition temperature, for example, to up to 40°C. In one embodiment, POE is added to an impact-resistant base material, like semi-crystalline PP, resulting in an amorphous hetero-phase POE structure within the semi-crystalline PP structure.

[0029] During the manufacture of the ICP, at least one stabilizer and/or a metal deactivator may be used to facilitate the polymerization reactions. Accordingly, the at least one stabilizer may comprise a plurality of stabilizers. The concentration of the at least one stabilizer and metal deactivator may be within a range generally known in the art. According to one preferred embodiment, the plurality of stabilizers and metal deactivator comprise a long-term stabilizer, a process stabilizer, and a metal deactivator. According to a most preferred embodiment, the long term stabilizer comprises pentaerythritol tetrakis (3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate), the process stabilizer comprises tris (2,4-di-tert-butylphenyl)phosphite, and the metal deactivator comprises 2',3-bis[[3-[3,5-di-tert-butyl-4-hydroxyphenyl]propionyl]]propionohydrazide. According to the most preferred embodiment, the pentaerythritol tetrakis (3-(3,5-di-tert-butyl-4-hydroxyphenyl) propionate) is in a concentration of approximately 0.1-1.5%, the tris (2,4-di-tert-butylphenyl)phosphite is in a concentration of approximately 0.2-1.5%, and the 2',3-bis[[3-[3,5-di-tert-butyl-4-hydroxyphenyl]propionyl]]propionohydrazide is in a concentration of approximately 0.3-0.8%. The above described compounds and concentrations are meant to illustrate one preferred embodiment of the present invention. Different compounds and concentrations thereof are within the scope of the invention.

[0030] The above-described chemical structure prevents unwanted chemical reactions between the insulation of the load wires and the material of the outer sheath. For example, according to embodiments, it is advantageous for the outer sheath to comprise PU due to its light weight, thermal resistivity, and electro-magnetic interference attenuation. However, the material of the outer sheath contacts the insulation of the load wires. It is known in the art that traditional PP insulating materials adversely react with PU. Thus, traditional PU and PP materials may not be implemented for an outer sheath and wire insulation, respectively. In order to solve the above problems, the modified insulation material for the load wires (i.e., the above-described ICP) is implemented. This preferred insulation material is a thermoplastic elastomer based on a copolymer of polypropylene and an ethylene-octane co-polymer (halogen-free, non-flammable) with the following chemical and mechanical properties: Density = 0.90 g / cm^3, tensile strength 15 MPa, elongation at break 500%, Shore hardness 60D, melt index (230 ° C / 2.16kg) = 2.0g / 10min. This material exhibits high thermal resistivity and is very hard and smooth, reducing abrasive wear and tear due, at least in part, to laminar friction between the insulation and the outer sheath.

[0031] Data lines, according to spatial configurations of the present disclosure, have a smaller diameter and, thus, are not exposed to the same levels of tension and compression that the load lines experience. The material selected for their insulation does not need to be as hard and/or smooth as that for the load lines. However, the material should exhibit high temperature resistivity due to the location of the cable. According to embodiments and with the above considerations in mind, the insulation for the data lines each comprise plastics or polymers. According to preferred embodiments, the polymer comprises a thermoplastic elastomer, and in particular, comprises crosslinked polyethylene.

WHAT IS CLAIMED IS:

1. A complex cable, comprising:

two load wires, configured to be connected to an electric parking break mechanism;

two data wires, configured to be connected to a wheel speed sensor; and

an outer sheath covering the two load wires and the two data wires.

2. The complex cable of Claim 1,

wherein the two load wires are unshielded load wires; and

wherein the two data wires are unshielded data wires.

3. The complex cable of Claim 1 or Claim 2,

wherein an outer surface of the two load wires contact each other; and

wherein cetral lines of symmetry of the two load wires are parallel to each other.

4. The complex cable cable of Claim 3,

wherein in a transverse cross section of the complex cable a first data wire of the two data wires is located in a first recess formed by the two load wires; and wherein in a transverse cross section of the complex cable a second data wire of the two data wires is located in a second recess formed by the two load wires.

5. The complex cable cable of Claim 3 or 4,

wherein central lines of symmetry of the two data wires are parallel to each other; and

wherein a line, connecting centers of the two data wires in a transverse cross-section of the complex cable is perpendicular to a line connecting centers of the two load wires in a transverse cross-section of the complex cable.

6. The complex cable of one of the Claims 1 to 3,

wherein each of the two load wires comprises a conductive core surrounded by insulation; and

wherein each of the two data wires comprises a conductive core surrounded by insulation.

7. The complex cable of Claim 6,

wherein the insulation of at least one of the load wires comprises polypropylene.

8. The complex cable of Claim 7,

wherein the insulation of the at least one of the two load wires further comprises semi-crystalline copolymer comprising polypropylene and an ethylene-octene co-polymer.

9. The complex cable of Claim 6,

wherein the insulation of at least one of the two data wires comprises a thermoplastic polymer.

10. The complex cable of Claim 9,

wherein the thermoplastic polymer comprises crosslinked polyethelyene.

11. The complex cable of Claim 1,

wherein the two data wires and the two load wires are twisted within the complex cable.

12. The complex cable of Claim 1,

further comprising a separator, wherein the separator that surround the the two data wires and the two load wires.

13. The complex cable of Claim 12,

wherein the separator prevents the two data wires and the two load wires from contacting the outer sheath.

14. The complex cable of Claim 12,

wherein the separator comprises a foil, a paper, a fleece, or a powder.

15. The complex cable of Claim 1,

wherein the complex cable consists essentially of:

the two load wires;

the two data wires; and

the outer sheath.

AMENDED CLAIMS
received by the International Bureau on 19.08.2020

WHAT IS CLAIMED IS:

1. A complex cable, comprising:

two load wires, configured to be connected to an electric parking break mechanism;

two data wires, configured to be connected to a wheel speed sensor; and

an outer sheath covering the two load wires and the two data wires;

wherein, for transverse-sections of the complex cable, a ratio of (i) a straight-line distance between geometric centers of the two load wires to (ii) a straight-line distance between geometric centers of the two data wires is between approximately 1 and 2, and preferably is a value from 1.1 to 2.

2. The complex cable of Claim 1,

wherein the two load wires are unshielded load wires; and

wherein the two data wires are unshielded data wires.

3. The complex cable of Claim 1 or Claim 2,

wherein an outer surface of the two load wires contact each other; and

wherein central lines of symmetry of the two load wires are parallel to each other.

4. The complex cable cable of Claim 3,

wherein in a transverse cross section of the complex cable a first data wire of the two data wires is located in a first recess formed by the two load wires; and

wherein in a transverse cross section of the complex cable a second data wire of the two data wires is located in a second recess formed by the two load wires.

5. The complex cable cable of Claim 3 or 4,

wherein central lines of symmetry of the two data wires are parallel to each other; and

wherein a line, connecting centers of the two data wires in a transverse cross-section of the complex cable is perpendicular to a line connecting centers of the two load wires in a transverse cross-section of the complex cable.

6. The complex cable of one of the Claims 1 to 3,

wherein each of the two load wires comprises a conductive core surrounded by insulation; and

wherein each of the two data wires comprises a conductive core surrounded by insulation.

7. The complex cable of Claim 6,

wherein the insulation of at least one of the load wires comprises polypropylene.

8. The complex cable of Claim 7,

wherein the insulation of the at least one of the two load wires further comprises semi-crystalline copolymer comprising polypropylene and an ethylene-octene co-polymer.

9. The complex cable of Claim 6,

wherein the insulation of at least one of the two data wires comprises a thermoplastic polymer.

10. The complex cable of Claim 9,

wherein the thermoplastic polymer comprises crosslinked polyethelyene.

11. The complex cable of Claim 1,

wherein the two data wires and the two load wires are twisted within the complex cable.

12. The complex cable of Claim 1,

further comprising a separator, wherein the separator that surround the two data wires and the two load wires.

13. The complex cable of Claim 12,

wherein the separator prevents the two data wires and the two load wires from contacting the outer sheath.

14. The complex cable of Claim 12,

wherein the separator comprises a foil, a paper, a fleece, or a powder.

15. The complex cable of Claim 1,

wherein the complex cable consists essentially of:

the two load wires;

the two data wires; and

the outer sheath.

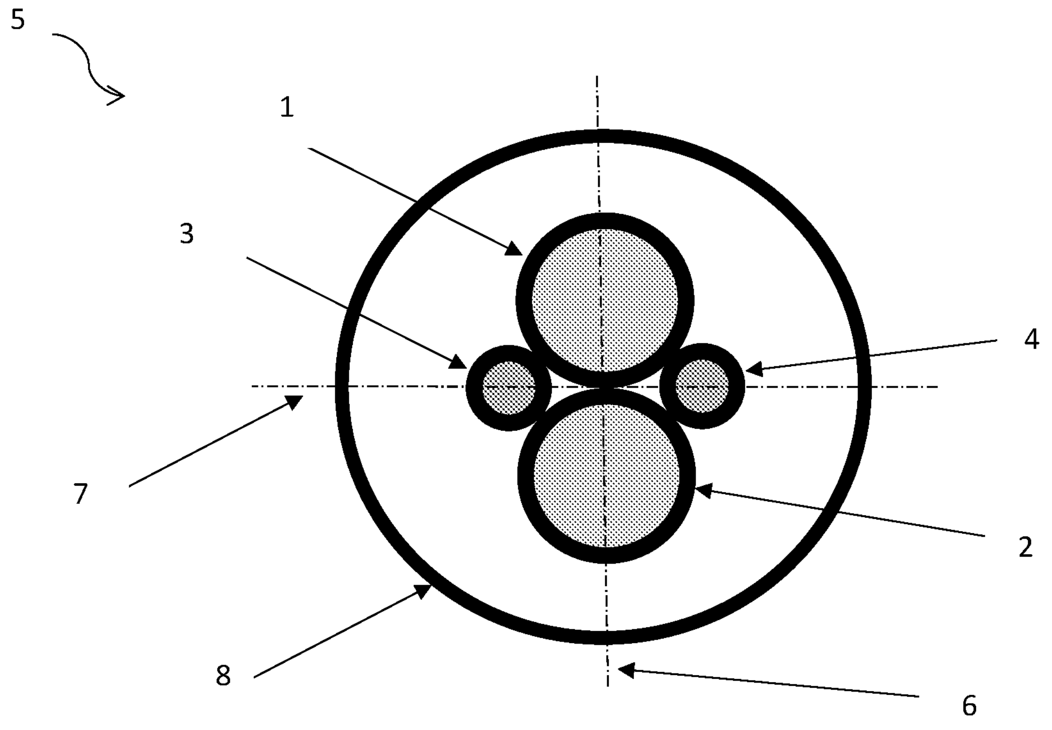

FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/000419

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01B9/00
ADD. H01B11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/077341 A1 (KOHORI TAKAYA [JP] ET AL) 14 March 2019 (2019-03-14) figure 1	1-6,9-15
X	US 2016/176369 A1 (ITO HIROYUKI [JP] ET AL) 23 June 2016 (2016-06-23) figure 10A	1-6, 9-13,15
X	US 2001/002773 A1 (HYOGO TAKASHI [JP]) 7 June 2001 (2001-06-07) paragraph [0031]; figure 2	1-6, 11-13,15
X	US 5 220 130 A (WALTERS JACK [US]) 15 June 1993 (1993-06-15) figure 2	1,2,6,7, 15
X	EP 1 589 541 A1 (NEXANS [FR]) 26 October 2005 (2005-10-26) figure 1	1,6-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 October 2019	31/10/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Alberti, Michele

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2019/000419

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019077341 A1	14-03-2019	CN 107851487 A	27-03-2018
		DE 112017000062 T5	15-03-2018
		JP WO2017209299 A1	28-03-2019
		US 2019077341 A1	14-03-2019
		WO 2017209299 A1	07-12-2017
US 2016176369 A1	23-06-2016	CN 205376200 U	06-07-2016
		JP 6219263 B2	25-10-2017
		JP 2016119245 A	30-06-2016
		US 2016176369 A1	23-06-2016
US 2001002773 A1	07-06-2001	JP 2001160322 A	12-06-2001
		US 2001002773 A1	07-06-2001
US 5220130 A	15-06-1993	NONE	
EP 1589541 A1	26-10-2005	AT 363717 T	15-06-2007
		CN 1691212 A	02-11-2005
		EP 1589541 A1	26-10-2005
		ES 2285302 T3	16-11-2007
		KR 20060046603 A	17-05-2006