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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 July 2020 (30.07.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/152491 A1

(51) International Patent Classification:
H01B 9/00 (2006.01) *H01B 11/10* (2006.01)

(21) International Application Number:
PCT/IB2019/000071

(22) International Filing Date:
23 January 2019 (23.01.2019)

(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))*

(54) **Title:** LOAD AND DATA CABLE

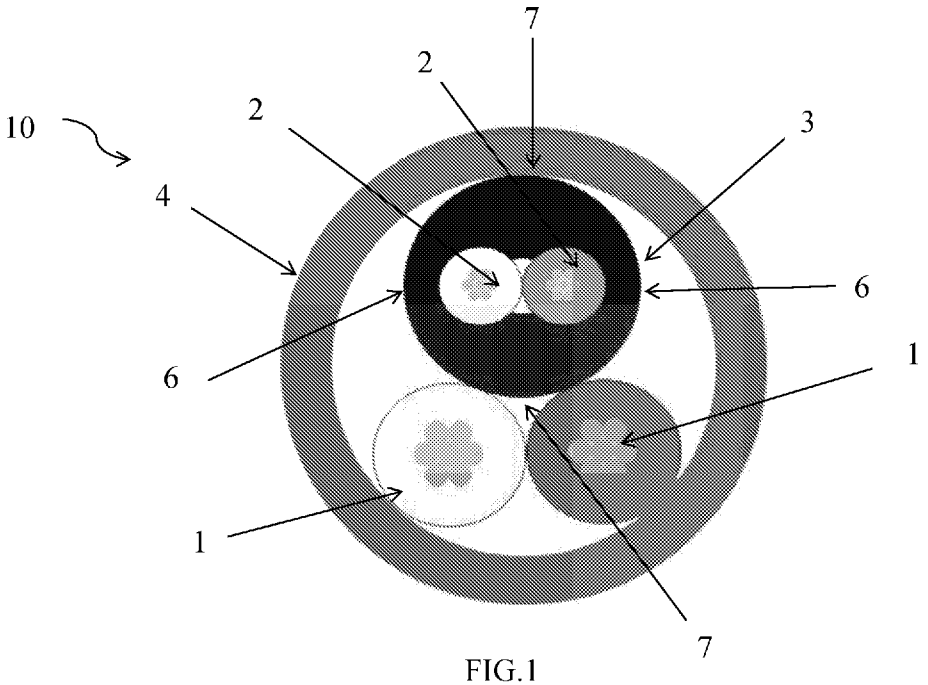


FIG.1

(57) **Abstract:** A load/data cable comprising: two power wires and two data wires. The power wires are configured to transmit a voltage across the cable and the data wires are configured to transmit a data signal across the cable. The data wires may be encased in a jacket material with low volume resistivity for interference attenuation between load and data lines.

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LOAD AND DATA CABLE

Field of Invention

[0001] This disclosure relates generally to load/data cables, and particularly to 12 Mbit to 6 MHz load/data cables also known as USB 1.1. The load/data cable configuration alleviates internal inductive and electromagnetic interference without the use of traditional means, for example traditional shielding means.

Background of the Invention

[0002] Many types of cables, such as a USB cable, transmit digital or analog signals and depend on an external source of voltage. Such cables commonly incorporate at least two load wires and at least two data wires. In certain applications where a moderate current is utilized, the cable's load line does not produce a significant inductive and/or electromagnetic impact on data line. However, where a load/data cable transmits large current, the inductive interference created by the load line often disrupts signal transfer in the data line. Different methods are known in the art for alleviating interference in load/data cables. For example, shielding of data wires by metallic braid or foil screens is routinely used in the art to protect data lines from inductive and electromagnetic interference generated by load lines. However, these shielding are difficult to manufacture, expensive, and add significant weight to the overall cable.

[0003] Although certain industries are tolerant to higher wiring weights, others industries, such as aeronautical, aviation and transportation, are not. For example, the burgeoning drive-by-wire technology in the automotive industry that has led to driverless automobiles requires extensive use of multiple electronic and electro-mechanical devices. These devices

require a lot of electrical connections for transmitting data and delivering power. Moreover, federal and state authorities have already imposed strict regulations on automotive manufactures, and many new regulations are under way. For the sake of consumer and general public safety, regulators want to ensure that all electric systems in driverless vehicles to be duplicated, if they can be duplicated. This means that driverless vehicles will contain much more wiring than today's most advanced automobiles. For that reason, many industries, and in particular the automotive industry, are very interested in load/power cable related innovations. In particular, it would be advantageous to provide cables that enable the reduction in weight of wirings and alleviate impending duplication associated costs. Light and reliable cables are also especially important for the aeronautical industry. For example, nascent, but promising electric VTOL (vertical take-off and landing) technology desire lightweight, reliable cables. This is of particular importance in electric ultralight applications (e.g., "one pilot, no license" segment), where the maximum empty weight of applications is limited to 245 pounds (in the US).

[0004] Metallic braided and foil screens have substantially different electromagnetic radiation damping characteristics. Particularly, foil screens have a poor shielding effect from very low-frequency interference fields, such as when a load line is switched on or off. Braided metallic shields, also referred to as C-shields, are commonly more efficient in shielding low-frequency electromagnetic radiation. However, such braided metallic shields have to be relatively thick to efficiently counteract electromagnetic radiation. The result is a heavy shield that tends to break under bending and torsional external forces. For example, typical metallic braided and foil screens used to shield lower cables from lower frequencies cause a doubling of the cables overall weight.

[0005] The aforementioned intrinsic limitations of metallic braided and foil screens makes it challenging to design and manufacture lightweight and affordable load/data cables that are suitable for transmission of both low- and high- frequency signals. There is a need to develop a load/data cable configured to operate at a wide signal spectrum range; is more resilient to mechanical stresses, is light weight, and has lower manufacturing costs. The disclosure, outlined below, provides a solution to the aforementioned problems.

Summary of the Invention

[0006] Various illustrative embodiments of the present disclosure provide load/data cable configurations, and related methods.

[0007] According to a first aspect of the disclosure, the load/data cable is configured to prevent inductive and/or electromagnetic interference of load lines on data lines without the utilization of a metallic braided or foil shielding. Such a configuration reduces the cable's weight and manufacturing costs. It also allows the independent stripping or packaging of data and power lines as it obviates additional connections for defusing interference voltage from a metallic screen.

[0008] According to an aspect of the present disclosure, a load/data cable comprises two load wires and two data wires. Each of the load and data wires includes a conductive core and insulation surrounding the core. The two data wires are further encased in a jacket. The jacket may comprise a low-volume resistivity material and black carbon particles. The load wires, data wires, and the jacket are covered by a common outer sheath.

[0009] According to embodiments of the present disclosure, the jacket material may have a low-volume resistivity of equal or less than $1x10^{10}$ ohm*m. According to embodiments, the jacket material includes thermoplastic polyurethane (TPU). According to preferred embodiments, the jacket material includes thermoplastic polyurethane elastomer (TPE-U).

[0010] According to embodiments, the jacket material may further include carbon-based particles/materials. According to embodiments, the carbon-based particles/materials include carbon-based nano-sized particles that are randomly distributed within the jacket.

[0011] According to certain embodiments, the carbon-based particles/materials include carbon black particles. The quantity of carbon black particles within the jacket may be between approximately 0.3 to 3% by volume percent. The carbon black particle may have a diameter from approximately 30nm to 500nm.

[0012] According to alternative embodiments, the carbon-based particles/materials include graphene, carbon nano-tubes, or graphite. The quantity of these materials within the jacket may be between approximately 0.3 to 3% by volume percent.

[0013] According to embodiments implementing the carbon-based particles/materials, the particle size and quantity is selected such that the particles do not agglomerate to one another within the jacket material.

[0014] According to these embodiments, the jacket is configured to have at least four orders of magnitude lower volume resistivity than conventional materials, for example, traditional inner sheaths routinely utilized. Such a configuration allows for a natural conversion

of unwanted electromagnetic radiation into heat. According to embodiments, the heat radiation is low enough to be neglected, and thus, not considered in the thermal balance of a power line.

[0015] According to aspects of the present disclosure, the data wires of the load/data cable undergo a continuous angular rotation about a central axis of symmetry (e.g., the data wires may have a specific stranding orientation). In other words, the data wires may be considered a twisted wire pair. According to embodiments, such stranding orientation allows electromagnetic radiation not converted into heat by the jacket material to be blocked in such a way that metallic shielding is unnecessary. For example, the jacket is configured with a geometry to address electromagnetic radiation. At points along a cable where the alignment of load and data wires is parallel, and interference is at maximum, the jacket's wall is the thickest, and thus, the attenuation of irradiated energy by the jacket's material is the greatest.

Brief Description of the Drawings

[0016] 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:

[0017] FIG. 1 illustrates a cross-sectional view of a load/data cable of the present disclosure, where alignment of load and data wires is parallel;

[0018] FIG.2 illustrates a cross-sectional view of a load/data cable of the present disclosure where the data line has undergone an angular rotation.

Detailed Description

[0019] 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 drawings and photographs are 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.

[0020] With reference to FIGS. 1 and 2, transverse-sectional views of a load/data cable 10 of the present disclosure are illustrated. The load/data cable 10 comprises two power wires 1 and two data wires 2. The two data wires 2 are encased in a jacket 3. The two power wires 1, the two data wires 2, the jacket 3 are covered by a common sheath 4.

[0021] According to embodiments, the two power wires 1 include a central core and an insulation surrounding the core. The two power wires may have approximately the same outer diameter. An outer surface of each of the power wires 1 may abut one another. The power wires 1 may have central axes that are parallel to each other along the length of load/data cable 10. According to embodiments, the two power wires 1 in combination may be referred to as a power line. According to embodiments, the power line includes the two power wires 1. According to further embodiments, the power line essentially consists of the two power wires. According to still further embodiments, the power line consists of the two power wires.

[0022] According to embodiments, the two data wires 2 include a central core and an insulation surrounding the core. The two data wires 2 may have approximately the same outer diameter. The outer diameter of the data wires may be less than the outer diameter of the power wires 1. An outer surface of each of the data wires 2 may abut one another.

[0023] According to embodiments, an angular orientation of data wires 2 cyclically varies along the central axis of symmetry of the data wires, and thus the central axis of the load/data cable 10. The data wires thus form two helixes, having similar radii and pitches, with their phases shifted relative to each other by 180°. This configuration advantageously results in the electromagnetic radiation, not converted into heat by the jacket material 3, being blocked by the spatial disposition of the load 1 and data wires 2. For example, within a complete 360° angular orientation of the data wires 2, there are always two segments of data wires 2 positioned within a half pitch distance from each other, which are parallel and counter-directed to each other. In accordance with the law of electromagnetic induction, the radiated disturbances emerging on these two segments with thus, compensate each other. This configuration maintains a sufficient signal-to-noise ratio within a wide frequency range, for example, from a few Hz up to several MHz.

[0024] According to embodiments of the present disclosure, the jacket material of jacket 3 has a low volume resistivity, for example, a volume resistivity of equal or less than $1x10^{10}$ ohm*m. According to embodiments, the jacket material includes thermoplastic polyurethane (TPU). According to preferred embodiments, the jacket material includes thermoplastic polyurethane elastomer (TPE-U).

[0025] According to embodiments, the jacket material may further include carbon-based particles/materials. According to embodiments, the carbon-based particles/materials include carbon-based nano-sized particles that are randomly distributed within the jacket.

[0026] According to a preferred embodiment, the carbon-based particles/materials include carbon black particles. The quantity of carbon black particles within the jacket may be between approximately 0.3 to 3% by volume percent. The carbon black particle may have a diameter from approximately 30nm to 500nm.

[0027] According to alternative embodiments, the carbon-based particles/materials include graphene, carbon nano-tubes, or graphite. The quantity of these materials within the jacket may be between approximately 0.3 to 3% by volume percent.

[0028] This material composition of the jacket is configured to efficiently attenuate unwanted electromagnetic radiation more efficiently, as compared to standard jacket materials, which commonly have four orders of magnitude higher volume resistivity. For example, routinely, cable manufactures use such jacket materials, such as polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE), or thermoplastic elastomers that have a volume resistivity greater than $1x10^{14}$ ohm*m (according to DIN EN ISO 62631-3-1). Although materials in this category exhibit strong insulation properties, one of their disadvantageous attributes is that they have high electromagnetic radiation permeability, i.e., the radiation passes through them without significant attenuation. The jacket material of the present disclosure does not exhibit electrochemical processes, and subsequent degradation of the material at voltages, e.g., not exceeding 48 V.

[0029] According to embodiments, and as illustrated by FIGS. 1 and 2, jacket 3 has a geometry in consideration of electromagnetic radiation produced, for example, by power wires 1. According to a preferred embodiment, jacket 3 has a generally circular outer circumference. According to this embodiment, the thickness of jacket 3 varies. Jacket 3 may have a first, minimum thickness at locations 6. These locations generally correspond to portions of jacket 3 that are located parallel to a longitudinal axis of data wires 2. Jacket may have a second, maximum thickness at locations 7, which are approximately 90° from portions 6. The thickness of jacket 3 at areas between locations 6 and 7 may continuously vary such that data wires 2 are fixed within jacket 3. As seen in FIGS. 1 and 2, jacket 3 may have a maximum thickness in an area perpendicular to a central longitudinal axis of data wires 2; and jacket 3 may have a minimum thickness in an area parallel to a central longitudinal axis of data wires 2. Thus, at points along cable 10 where the alignment of load and data wires is parallel, and interference is at maximum, the jacket's wall is the thickest, and thus, the attenuation of irradiated energy by the jacket's material is the greatest as well.

[0030] According to embodiments, the two data wires 2 and jacket 3 in combination may be referred to as a data line. According to embodiments, the data line includes the two data wires 2 and jacket 3. According to further embodiments, the data line consists essentially of the two data wires 2 and jacket 3. According to still further embodiments, the data line consists of the two data wires 2 and jacket 3.

[0031] A common outer sheath 4 may encase the data wires 2, power wires 1, and jacket 3 so as to form a generally cylindrical cable. Outer sheath 4 may be made from thermoplastic polyurethane (TPU). According to preferred embodiments, may be made from thermoplastic

polyurethane elastomer (TPE-U). According to alternative embodiments, outer sheath 4 may be made from ethylene propylene diene rubber particles. The ethylene propylene diene rubber particles may be in a polypropylene matrix.

[0032] The space in load/data cable 10 between the outer sheath 4 and power wires 1 and/or jacket 3 may be filled or left empty. According to embodiments, the space is filled with a filler material.

[0033] 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 10 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.

[0034] 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.

[0035] With the above description in mind, load/data cable 10 may be configured to transmit both power and a data signal utilizing two pairs of wires, namely a power line with two

power wires and a data line with two data wires. The load/data cable 10 may thus consist essentially of two power wires, two data wires, a jacket surrounding the data wires, and an outer sheath. According to a preferred embodiment, load/data cable 10 may consists of two power wires, two data wires, a jacket surrounding the data wires, and an outer sheath

[0036] The configurations of the load/data cable of the present disclosure provides the advantages of reducing the manufacturing costs and weight of load/data cables by substituting heavy metallic braided and foil screens with above-described configuration.

WHAT IS CLAIMED IS:

1. A load and data cable, comprising:

a data line comprising two unshielded data wires;

a power line comprising two unshielded load wires; and

a jacket surrounding the data line;

wherein the jacket has a thickness that varies around the circumference of the jacket.

2. The load and data cable of Claim 1, further comprising a common sheath covering the data line, the power line, and the jacket.

3. The load and data cable of Claim 1 or 2,

wherein the data wires have a transverse angular orientation, cyclically varying all along a central axis of symmetry of the cable; and

wherein the angular orientation of the data wires comprises a helical configuration with a substantially constant radius and pitch such that the two data wire have phases shifted by 180° relative to each other.

4. The load and data cable of Claim 1 or 2,

wherein the jacket comprises a low volume resistivity material.

5. The load and data cable of Claim 4,

wherein the low volume resistivity material comprises a thermoplastic polyurethane.

6. The load and data cable of Claim 4 or 5,

wherein the low volume resistivity material further comprises black carbon particles.

7. The load and data cable of Claim 1, 2 or 4

wherein the centers of the two unshielded data wires form a straight line in a transverse section of the load and data cable; and

wherein the thickness of the jacket is a maximum at an area perpendicular to the straight line.

8. The load and data cable of Claim 7,

wherein the thickness of the jacket is a minimum at an area along the straight line.

9. The load and data cable of Claim 1, 2, 4 or 7,

wherein the thickness of the jacket varies between the minimum thickness and the maximum thickness along the circumference of the jacket.

10. The load and data cable of Claim 1 or 7,

wherein an outer diameter of the two unshielded data wires are approximately equal; and

wherein an outer diameter of the two unshielded power wires are approximately equal.

11. The load and data cable of Claim 1, or 7,

wherein the outer diameter of the two unshielded data wires is different than the outer diameter of the two unshielded power wires.

12. The load and data cable of Claim 1, 7, 10 or 11,

wherein an outer surface of the jacket is configured to contact the two unshielded power wires; and

wherein an inner surface of the jacket is configured to contact the two unshielded data wires.

13. The load and data cable of Claim 1, 7, 10, 11 or 12,

wherein the two unshielded power wires contact each other and are parallel to each other along a length of the load and data cable.

14. The load and data cable of one of the Claims 1, 7, 10 to 13,

wherein the two unshielded data wires contact each other along a length of the load and data cable.

15. The load and data cable of one of the Claims 1, 7, 10 to 14,

wherein the data line consists of the two unshielded data wires; and

wherein the power line consists of the two unshielded load wires.

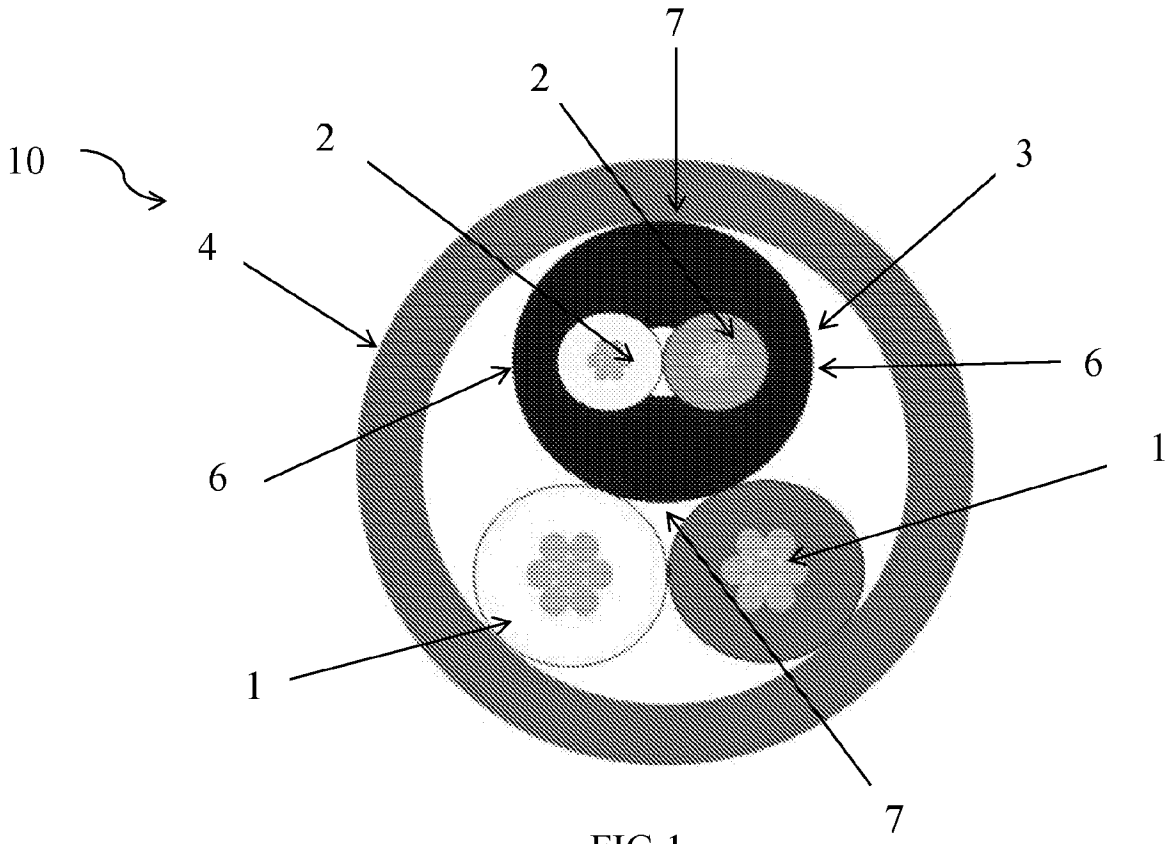


FIG.1

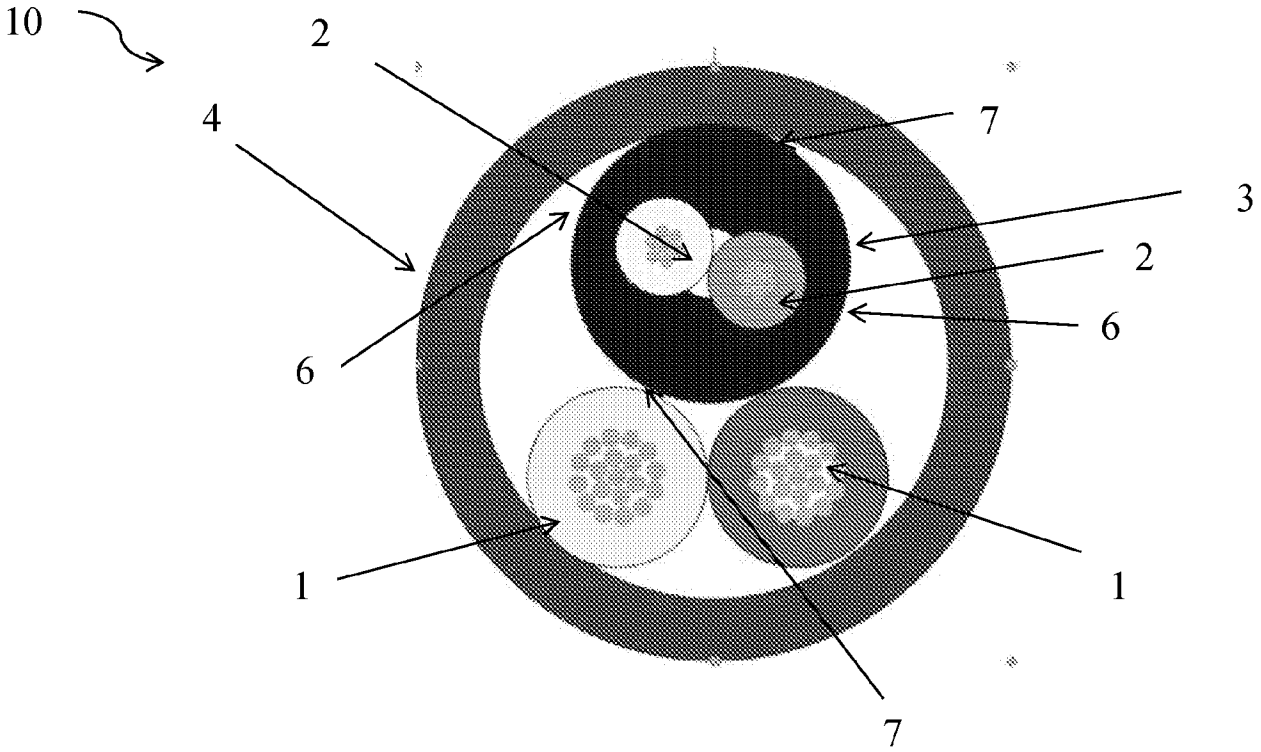


FIG.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/000071

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01B9/00 H01B11/10
ADD.

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

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X	US 2016/176369 A1 (ITO HIROYUKI [JP] ET AL) 23 June 2016 (2016-06-23) paragraph [0072]; figure 8	1-3,7-15
Y	EP 0 572 276 A2 (WESTERN ATLAS INT INC [US]) 1 December 1993 (1993-12-01) column 4, line 37 - line 57; figure 2	4-6
A	US 2013/233592 A1 (LI HUABING [CN]) 12 September 2013 (2013-09-12) figure 1	1-15

☐ 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

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 July 2019	11/07/2019

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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