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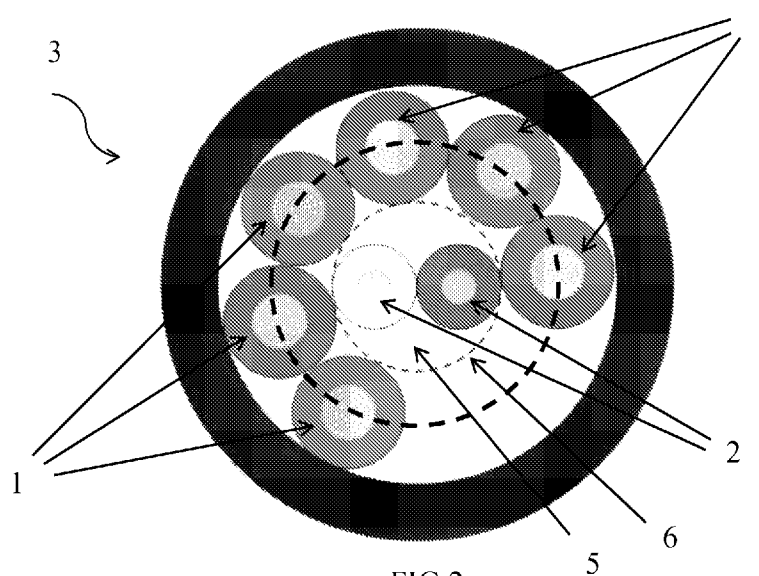


FIG. 2

(57) Abstract: A complex cable for connection to an Electric Parking Brake (EPB) and Wheel Speed Sensor (WSS). The complex cable provides improved switching characteristics of a WSS data line under bending conditions. The complex cable provides electromagnetic interference attenuation to data wires of the cable by implementing a spatial configuration of a split load line.



EPB AND WSS CABLE WITH SPLIT POWER

Field of Invention

[0001] The disclosure generally relates to load/data cables, and particularly to an Electric Parking Brake (EPB) and Wheel Speed Sensor (WSS) cables with a split load line and improved switching characteristics of the WSS data line under bending conditions.

Background of the Invention

[0002] A WSS and an EPB are integral components of contemporary automobiles. The WSS functions to continuously measure angular velocity of a vehicle's wheel. Data collected from the WSS is supplied to several vehicle systems, including, for example, ABC, traction control, speedometer, etc., which help a vehicle to safely navigate on the road. The EPB commonly utilizes a brushless DC motor, which via the EPB's gear train and spindle piston apply pressure to braking pads when a vehicle is intended to stay motionless. Since both the WSS and EPB are generally located in proximity to each other, it is a practical solution to integrate two lines, namely a line that feeds power to the EPB and a data line supplying voltage to a WSS into a single cable.

[0003] There are different approaches in the art to provide a combination of two data wires with two load wires, which are used in multiple applications, and in particular used with the EPB and WSS. Shielding in the form of a metallic braid or foil screens are routinely used for protecting data lines from inductive fields of load lines in such cables. It is a common practice in the art to have data wires stranded together. Solutions may be found in the art where data wires are not conventionally twisted, but rather lay parallel to each other. Unfortunately, attempts to

use such solutions for WSS and EPB cables, which intrinsically require a lot of cable bending (i.e., bending necessary to feed the cable from the WSS and EPB to a controller in an automobile), proved to be unsuccessful due to such a cable's switching characteristic deterioration. For that reason the stranding of data wires in WSS and EPB application is still routinely in use.

Summary of the Invention

[0004] Various illustrative embodiments of the present disclosure provide a cable with plurality of load wires, in their totality comprising a split load line, and related methods. In accordance with aspects of illustrative embodiments of the present disclosure, a cable is implemented for connection with the WSS and EPB.

[0005] The present disclosure is based on developing a WSS and EPB cable with a spatial configuration that mechanically protects a data line from mechanical stress when bending takes place and protects a data line from interference fields (e.g., both EMI and EMC fields) of a load line. According to aspects of the invention, the above spatial configuration includes surrounding a data line with an even number of load wires, greater than 2, which are connected alternately in opposite polarities.

[0006] According to embodiments, a self-twisted data line pair is located along a central line of symmetry of a complex cable according to the present disclosure. Four load wires with approximately identical diameters are positioned along the cable such that the geometrical centers of their traverse-sections belong to an imaginary circle. Two fillers with the same diameters as the power wires may be positioned along the cable in such a way that the

geometrical centers of their traverse-sections belong to the same imaginary circle. The load wire and fillers may be twisted together with the data line.

[0007] According to further embodiments, a self-twisted data line pair is located along the central line of symmetry of a cable; and six load wires, with approximately equal diameters, are positioned along the cable in the same manner as described with regard to the above embodiments (i.e., the load wires are positioned along the cable such that the geometrical centers of their traverse-sections belong to an imaginary circle).

[0008] According to still further embodiments, a self-twisted data line pair is located along the central line of symmetry of a cable; six load wires, with approximately equal diameters, are positioned along the cable in the same manner as described with regard to the above embodiments (i.e., the load wires are positioned along the cable such that the geometrical centers of their traverse-sections belong to an imaginary circle). Additionally, a filler with approximately the same diameter as the power wires is positioned along the cable such that its geometrical center, in a transverse cross-sectional view, belongs to the same imaginary circle.

[0009] According to the above described embodiments, a data line pair is approximately located at a mechanically neutral position at the cable's center. The cables overall geometry protects the data line against mechanical stress, including bending, stretching and compression. Such a configuration further makes the data line more resilient to alternating bends, thereby ensuring a reliable data transmission. Data lines are protected from electro-magnetic interference (e.g., magnetic and electrical interference) produced by load wires at least in part due to the fact that the load wires are connected in alternant polarities. Such an alternating polarity

configuration of counter currents ensures that a electro-magnetic field in the space where data wires are arranged is at a minimum.

[0010] Alternative embodiments of this disclosure include two, three or four self-twisted data wires located along the central line of symmetry of a cable; eight, nine, ten, or more load wires positioned inside the cable and connected with alternating polarities; zero, one, two, or more filler situated inside a cable in the same manner as load wires are positioned in the above described embodiments.

[0011] According to certain embodiments, a material with low volume resistivity of less than 1×10^{10} ohm*m, such as thermoplastic urethane elastomers (TPE-U) with black carbon particles added thereto, is utilized as a jacket for the data wires. Such a jacket material adequately shields the data wires against load voltages up to 48 V. Such a jacket material also has low electromagnetic radiation permeability, and facilitates the natural conversion of undesirable electromagnetic radiation into heat.

Brief Description of the Drawings

[0012] 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:

[0013] FIG. 1 illustrates a transverse-sectional view of a complex cable according to embodiments of the present disclosure;

[0014] FIG. 2 illustrates a transverse-sectional view of a complex cable according to further embodiments of the present disclosure;

[0015] FIG. 3 illustrates a transverse-sectional view of a complex cable according to still further embodiments of 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 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.

[0017] With reference to FIG. 1, a transverse-sectional view of a first embodiment of a complex cable 3 of the present disclosure is illustrated. The complex cable 3 comprises two self-twisted data wires 2 located along a central line of symmetry of the cable 3. Four load wires 1, having approximately equal diameters, are positioned along the internal periphery of cable 3. Each of the data wires 2 and load wires 1 includes a conducting core surrounded by an insulating material. The outer diameter of the load wires 1 is larger than the outer diameter of the data wires 2. According to specific embodiments, load wires 1 are arranged such that their geometrical

centers, in a transverse-sectional view, belong to an imaginary circle 6. Load wires 1 may further abut or contact each other along imaginary circle 6

[0018] Two fillers 4 with approximately the same diameter as load wires 1 may further be included in complex cable 3. The two fillers 4 are arranged such that their geometrical centers, in a transverse-sectional view, belong to imaginary circles 6. fillers 4 may be isolated from one another and from load wires 1, as illustrated by FIG. 1. As further evidenced by FIG. 1, load wires 1 and fillers 4 encircle data wires 2. By encircling data wires 2, load wires 1 and fillers 4 act as a physical shielding or barrier for data wires 2. As further evidenced by Figs. 1–3, the load wires 1, fillers 4, and data wires 2 are encased in an outer sheath.

[0019] According to embodiments, fillers 4 may be made from a plastic material. According to preferred embodiments, fillers 4 are made from the material used for the insulation of the power lines. According to alternative embodiments, fillers 4 may be made from other plastic materials in the same temperature range like the complete cable need. An alternative is to made the filler from cotton (yarn) or made from fibrillated plastic.

[0020] A filler material may be located in the spaces between the wires (and fillers) 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 3 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.

[0021] 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 load wires 1, fillers 4, and data wires 2, 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 three wires. According to alternative embodiments the separator may take the form of a powder that is placed (e.g., sprayed) on the fillers and wires. According to alternative embodiments, the separator may only surround the data wires 2. According to still further embodiments, two separators may be implemented, where one separator surrounds the load wires 1, fillers 4, and data wires 2, and a second separator surrounds only the data wires 2.

[0022] According to embodiments, the load wires 1 are connected alternatingly in opposite polarities, so that a direction of current flow in each load wire is opposite to that in adjacent load wires 1. For example, according to embodiments as illustrated in FIG. 1, the four load wires 1 may alternate in polarity such that the load wires 1 along imaginary circle 6 are + - + -. Similarly, the polarity may alternatively be - + - +, but not ---++ or +++--. Similarly, with regard to embodiments illustrated by FIGS. 2 and 3, the six wires 1 may alternate in polarity such that the load wires 1 along imaginary circle 6 are + - + - + -. Similarly, the polarity may alternatively be - + - + - +, but not include any configuration of where two negative polarities are adjacent one another (i.e., --) or two positive polarities are adjacent one another. (i.e., ++).

[0023] With reference to FIG.2, a transverse-sectional view of a second embodiment of a complex cable 3 of the present disclosure is illustrated. The complex cable 3 comprises two self-twisted data wires 2 located along the central line of symmetry of cable 3. Six load wires 1

having approximately equal diameters positioned along the inner periphery of cable 3. Each of the data wires 2 and load wires 1 includes a conducting core surrounded by an insulating material. The outer diameter of the load wires 1 is larger than the outer diameter of data wires 2. According to specific embodiments, load wires 1 are arranged such that their geometrical centers, in a transverse-sectional view, belongs to an imaginary circles 6. Load wires 1 may further abut or contact each other along imaginary circle 6.

[0024] With reference to FIG.3, a transverse-sectional view of a third embodiment of a complex cable 3 of the present disclosure is illustrated. The complex cable comprises two self-twisted data wires 2 located along a central line of symmetry of cable 3. Six load wires 1 having approximately equal diameters positioned along the internal periphery of cable 3. Each of the data wires 2 and load wires 1 includes a conducting core surrounded by an insulating material. According to specific embodiments load wires 1 are arranged such that their geometrical centers, in a transverse-sectional view, belong to an imaginary circle 6. Load wires 1 may further abut or contact each other along imaginary circle 6.

[0025] A filler 4 with approximately the same diameter as load wires 1 is further included in cable 3. Filler 4 is arranged such that its geometrical center, in a transverse-sectional view, belongs to imaginary circles 6. Filler 4 may be isolated from load wires 1, as illustrated by FIG. 3. In particular, an outer surface of fillers 4 may not abut adjacent load wires 1. As further illustrated by FIG. 3, load wires 1 and filler 4 encircle data wires 2. By encircling data wires 2, load wires 1 and filler 4 act as a physical shielding or barrier for data wires 2.

[0026] In each cable's architecture the data wires 2 are positioned close to the mechanically neutral position inside cable 3. This makes the data wires 2 more resilient to

mechanical stress, including bending, stretching and compression, which contribute to deterioration of the cable's switching characteristics. The data wires 2 of each of the embodiments described is protected from electromagnetic interference produced by load wires 1 due at least in part to the fact that the load wires 1 are connected in alternating polarities. For example, the current flow in each load wire is opposite to that in adjacent load wires. Such a configuration of alternating currents ensures that a magnetic field in the space around the central line of symmetry of a cable, where the data wires 2 are arranged, is reduced. The resultant electro[magnetic]-magnetic field in the center of a cable along its central line of symmetry depends on a number of load wires, which in their totality, constitute a split load line. For example, a modification, containing 6 load wires provides a better result than that with four load wires.

[0027] According to embodiments, a jacket 5 with a low volume resistivity, for example, less than 1×10^{10} ohm*m, is implemented and surrounds the data wires 2. The jacket may comprise thermoplastic polyurethane (TPE-U). According to specific embodiments, the TPE-U has black carbon particles added thereto. A drawback of low volume resistivity materials is that they may leak current at high voltages, thereby causing undesirable electrochemical processes and degradation of a material itself, but if supplemented with black carbon particles, they do not exhibit current leakage at voltages, e.g., up to 48 V. The implementation of this material facilitates the natural conversion of the harmful electromagnetic radiation into heat. Traditional jacket materials such as polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE), thermoplastic elastomers (TPE), have a higher volume resistivity, for example, exceeding 1×10^{14} ohm*m (according to DIN EN ISO 62631-3-1), and for that reason they exhibit strong insulation properties. However, such traditional jackets have high electromagnetic radiation permeability,

i.e., they do not attenuate electromagnetic radiation well. Thus, additional shielding (e.g., a metal foil or braid) is usually incorporated with traditional jackets.

WHAT IS CLAIMED IS:

1. A complex cable, comprising:

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

a plurality of unshielded load wires configured to be connected to an electric parking
break mechanism;

a jacket surrounding the two unshielded data wires; and

a common sheath;

wherein the plurality of unshielded load wires encircle the two unshielded data wires.
2. The complex cable of Claim 1, wherein the common sheath covers the two unshielded
data wires, the plurality of unshielded load wires, and the jacket.
3. The complex cable of Claim 1 or 2,

wherein centers of the plurality of unshielded load wires, along a transverse cross-section
of the complex cable, are located along a circle.
4. The complex cable of Claim 1, 2 or 3,

wherein the jacket comprises a low volume resistivity material.
5. The complex cable of Claim 4,

wherein the low volume resistivity material comprises a thermoplastic polyurethane.

6. The complex cable of Claim 4 or 5,
wherein the low volume resistivity material further comprises black carbon particles.
7. The complex cable of Claim one of the preceding claims,
wherein adjacent load wires of the plurality of load wires contact each other along the circle.
8. The complex cable of Claim 7,
wherein adjacent load wires of the plurality of load wires have opposing polarities.
9. The complex cable of one of the claims before, further comprising at least one filler;
wherein the center of the at least one filler, along a transverse cross-section of the complex cable, is located along the circle.
10. The complex cable of one of the preceding claims,
wherein an outer diameter of the two unshielded data wires are approximately equal; and
wherein an outer diameter of the plurality of unshielded load wires are approximately equal.
11. The complex cable of one of the preceding claims,
wherein the outer diameter of the two unshielded data wires is different than the outer diameter of the plurality of two unshielded power wires.

12. The complex cable of Claim 9,
wherein an outer diameter of the at least one filler is approximately equal to the outer diameter of the plurality of load wires.

13. The complex cable of Claim 9 or 12,
wherein the plurality of unshielded load wires comprises four load wires; and
wherein the at least one filler comprises two fillers.

14. The load and data cable of Claim 9 or 12,
wherein the plurality of unshielded load wires comprises six load wires.

15. The load and data cable of Claim 14,
wherein the at least one filler comprises one filler.

16. The complex cable of Claim 13,
wherein the complex cable consists essentially of:

- the two unshielded data wires;
- the jacket;
- the common sheath;
- the four load wires; and
- the two fillers.

17. The complex cable of Claim 14,
wherein the complex cable consists essentially of:

- the two unshielded data wires;
- the jacket;
- the common sheath; and
- the six load wires.

18. The load and data cable of Claim 15,
wherein the complex cable consists essentially of:

- the two unshielded data wires;
- the jacket;
- the common sheath;
- the six load wires; and
- the one filler.

19. A complex cable, comprising:
two twisted, unshielded data wires configured to be connected to a wheel speed sensor;
a jacket surrounding the two twisted, unshielded data wires;
three or more unshielded load wires configured to be connected to an electric parking
break mechanism; and
a common sheath;
wherein the unshielded load wires encircle the two unshielded data wires.

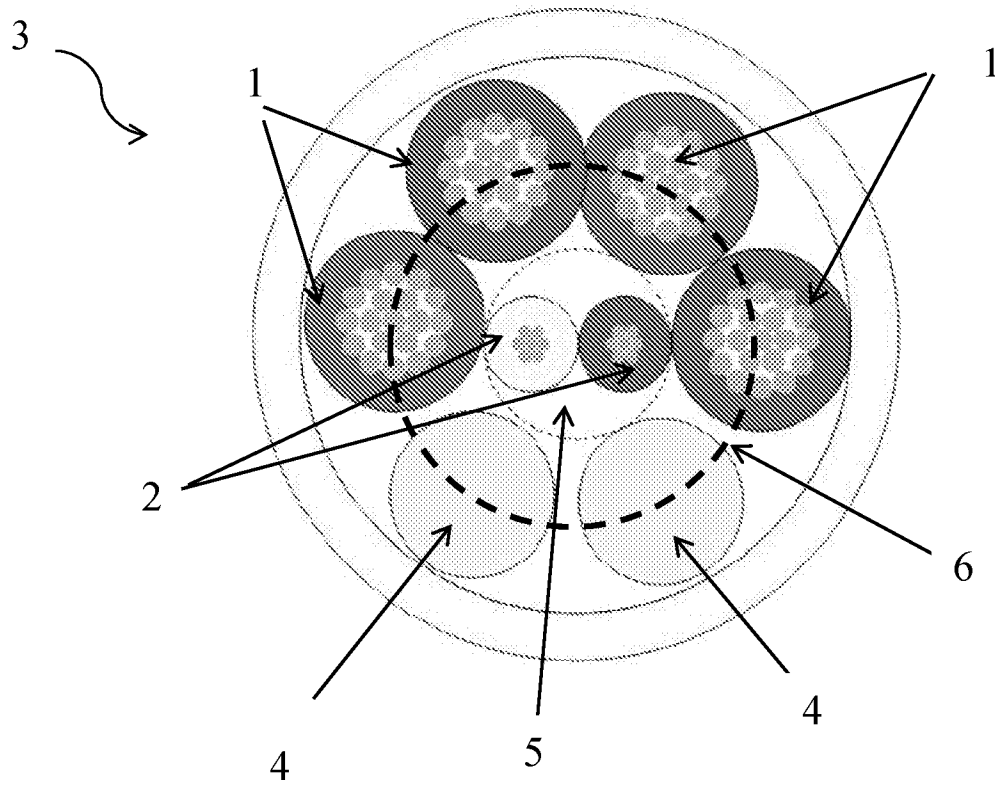


FIG.1

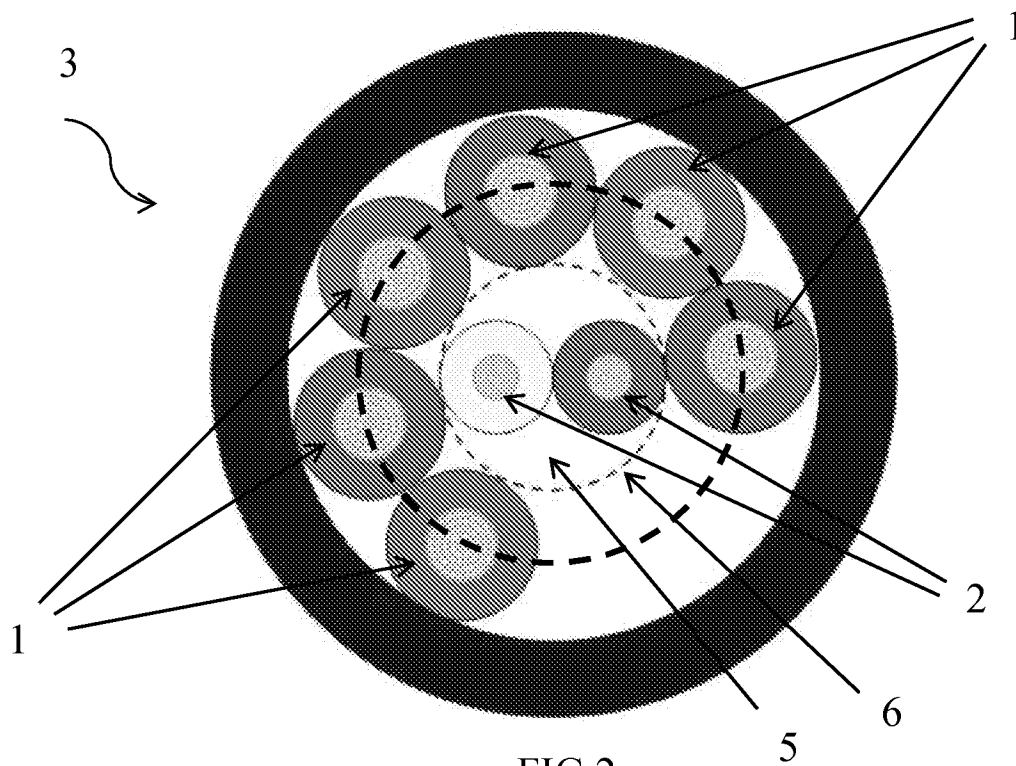


FIG.2

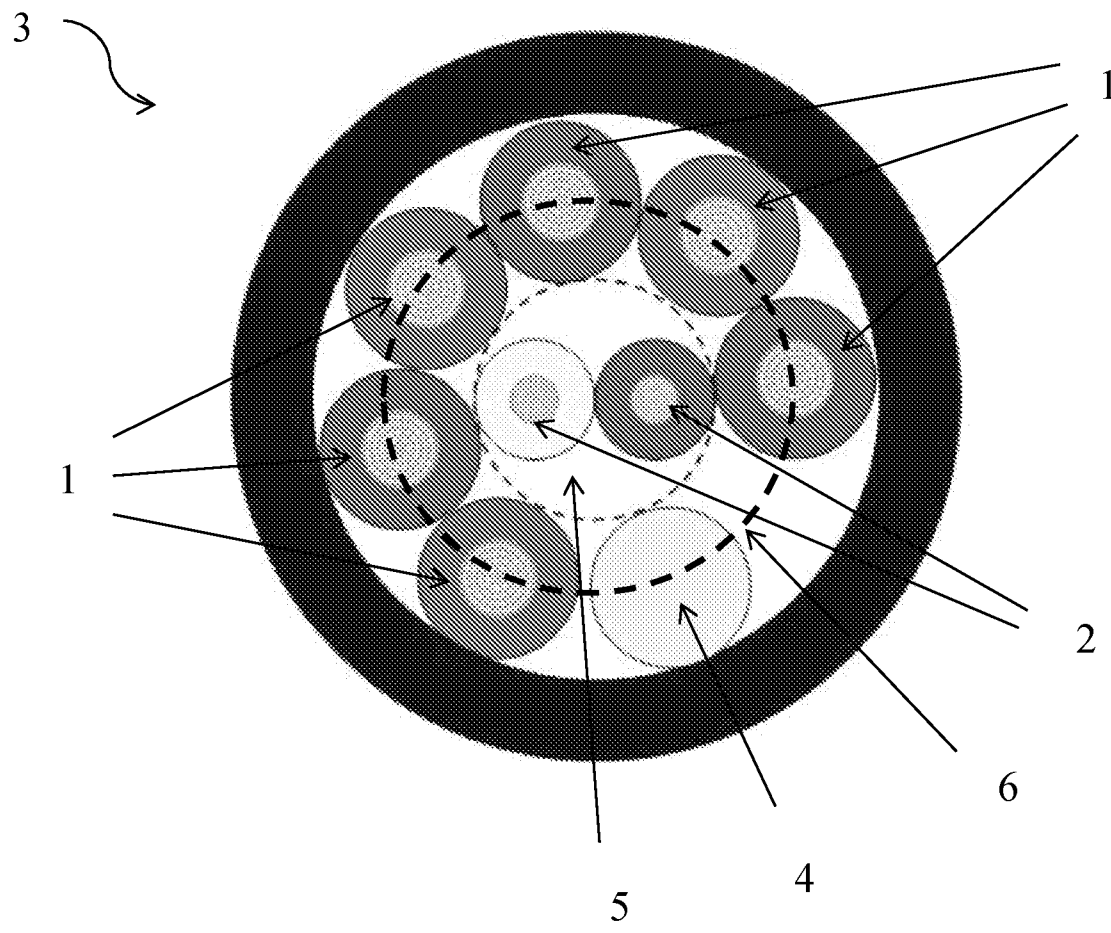


FIG.3

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2019/000072

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H01B9/00 H01B11/06
 ADD. H01B11/10

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2001/002773 A1 (HYOGO TAKASHI [JP]) 7 June 2001 (2001-06-07) figure 7 -----	1-3,7,8, 10,11, 14,19 4-6
Y	EP 0 572 276 A2 (WESTERN ATLAS INT INC [US]) 1 December 1993 (1993-12-01) column 4, line 45 - line 54; figure 2 -----	4-6
A	US 2015/165987 A1 (HAYAKAWA YOSHIKAZU [JP] ET AL) 18 June 2015 (2015-06-18) figure 1A -----	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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