(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 293 992 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.03.2003 Bulletin 2003/12

(51) Int Cl.[7]: **H01B 11/18**, H01B 7/00

(21) Application number: **02102337.9**

(22) Date of filing: **10.09.2002**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **11.09.2001 FR 0111752**

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(54) **Optical-electrical hybrid cable**

(57) Coaxial cable (1) comprising a first set (2) of conductors protected in a first insulating jacket (3), and a second set (4) of conductors positioned around this first jacket, and themselves protected by an insulating sheath (5) of the cable. The sheath is designed to be stripped so as to enable a local connection with an electrical instrument. This connection is possible inasmuch as the cable comprises at least one zone (19) at which the conductors of the second set of conductors are twisted according to a close twist pitch. Thus, when the cable is stripped at this zone, in sectioning the conductors arranged in this tight winding, two portions (22, 23) of conductors are cleared, and these portions of conductors can easily be connected with the instrument.

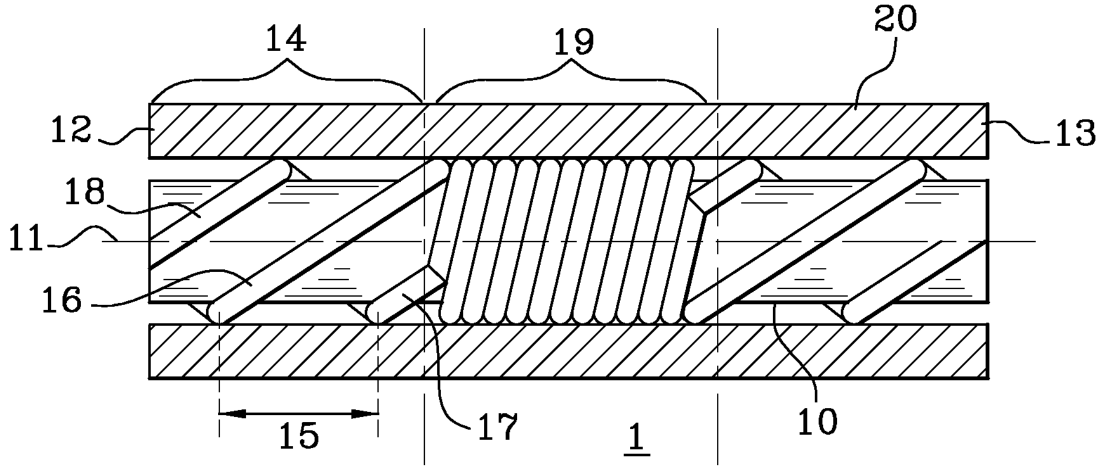

Fig. 2

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Description

[0001] An object of the present invention is an optical-electrical hybrid cable. It can be used more particularly in the field of cables used for studies in seismic geophysics, especially cables designed to be connected with a plurality of geophysical sensors distributed throughout the length of such a cable. In the prior art, there is a known method for directly connecting these different sensors to the cable, by locally stripping this cable in order to connect the geophysical sensor thereto. The value of the invention lies in the fact that it proposes a cable on which it is possible to mount several sensors without any need to strip this cable over a great length.

[0002] In the prior art, there are known coaxial cables used in the field of geophysics. These coaxial cables comprise a conductive core positioned inside a first protective insulating sheath, and a conductive braiding wound about the protective insulating sheath so as to form a second conductive channel. In general, the assembly thus formed is furthermore surrounded with a second highly thick insulating, protective sheath. In general, the conductive core comprises metal conductors and/or if necessary optical fibres laid out lengthwise in parallel to one another along a main lengthwise axis of the cable.

[0003] However, the external conductive braid for its part comprises conductive strands which are gradually wound about the first insulating sheath so that a first end of this braid corresponds to a first end of the cable and so that a second end of this very same braid corresponds to a second end of the cable, the second end of the cable being opposite the first end along a main lengthwise axis of the cable. The main lengthwise axis of the cable may be superimposed on a central axis of symmetry of a cylindrical tube formed by this cable when it is not subjected to any strain.

[0004] This coaxial cable may receive direct connections with one of the conductive elements positioned inside the cable, even in areas located between the two ends of the cable. To this end, the cable is locally stripped between the two ends. This means that a window is made in the second protective sheath so as to access at least the conductive braid. To connect an instrument serially with such a braid, it is cut or sectioned at a cutting or sectioning point. The braid is therefore sectioned and is no longer continuous. To ensure the continuity of this braid when it passes through the sensor mounted on the cable, the sheath is stripped sufficiently so as to leave two braid portions visible on either side of the sectioning point. These two braid portions may be detached from the outer periphery of the first protective sheath.

[0005] If a loop is made with the non-stripped part of the cable (the conductive core surrounded by the first sheath), these two braid portions may be brought closer together so as to be placed in parallel with one another. They thus constitute unattached ends. These unattached ends are then directed toward a connector of the instrument to be connected thereto. To connect these two braid portions, it is absolutely necessary to bring the bases of these braid portions closer together, the bases corresponding to the level of these tresses located on either side of the window, up to the stripped limits of the second protective sheath.

[0006] In the prior art, this solution of connecting an instrument such as a sensor to a cable poses a problem. Indeed, when the cable is a hybrid cable and comprises especially optical fibres inside the first sheath then, given the technical characteristics of optical fibres, it becomes almost impossible to obtain curvatures in this cable. Indeed, the curvatures tolerated by optical fibres are wide-angled curvatures. Thus, when two braid portions have to be brought together, it must be possible to make a big loop with the portion of the stripped cable, namely the one containing the optical fibres. To be able to make a loop as big as this, the length of the stripped zone should be great so that a wide angle of curvature can be obtained.

[0007] The problem raised by this embodiment of the connection between an instrument and a cable is that the large-sized loops formed out of partially stripped cable portions create brittle zones. Furthermore, the space requirement generated by such loops augments the risks of damage during the handling of these cables. At the same time, the compliance with the angle of curvature, which is imposed on the optical fibres, may be modified during this handling and this may therefore lead to the irreversible destruction of the optical fibres contained in the cable.

[0008] It is an object of the invention to overcome the problems cited by proposing a cable that does not necessitate any curvature to connect instruments thereto in zones of this cable located between the two ends of the cable. Indeed, in the invention, it is provided that the optical fibres will be placed inside the first insulating, protective sheath and that this sheath will never be subjected to any excessively great friction. To this end, when the instrument is to be connected, the second external sheath of the cable is stripped, always locally, so as to form a window therein.

[0009] However, this window is made at a specific place in the cable. This specific place in the cable corresponds to a zone at which the braid is denser. This means that the braid is formed here by a set of conductive strands wound and twisted about the first conductive sheath. However, at this particular zone, these conductive strands have an extra thickness. This extra thickness corresponds actually to a winding of the conductive strands with a winding pitch that is tighter than it is at other places along the cable.

[0010] Indeed, instead of winding the conductive strands around this first conductive sheath so as to minimise the total length necessary for these conductive strands to connect a first end of the cable to a second end of the cable, these conductive strands are extended so as to make it possible to modify the winding pitch of the cable around the first sheath and thus form a tighter winding zone placed between two looser winding zones. In the tighter winding zone, the conductive strands form turns that are almost parallel to one another and orthogonal to the main lengthwise axis of the cable whereas, in the other zones of the cable, where there is no provision for making any window, the turns formed by the winding of the conductive strands around the first sheath are still parallel to one another but, in this case, form an acute angle with the main lengthwise axis of the cable.

[0011] The value of these zones in which the conductors of the cable are variably tightened is that, when a section is made at a sectioning point in these conductors, it is easy to unwind them from the outer periphery of the first sheath and thus, in unwinding them, obtain conductive portions ready to be directly connected with a connector of the instrument. Neither making a loop with the partially stripped cable part nor stripping the cable on a large portion is necessary to obtain these long cable portions. The length of the conductive portions depends on the number of turns made in the zone in which the window is made. The more turns there are, adjoining each other, the easier will it be to mount the instrument on the cable, given the working margin provided by the conductive portions.

[0012] The invention relates to a coaxial cable comprising a first set of conductors, a first insulating protective jacket mounted around this first set, a second set of conductors twisted around the first jacket with a twist pitch, and a protective sheath mounted around the second set and the first jacket, characterized in that the coaxial cable comprises, along a lengthwise axis of the cable, a first zone and a second zone, the twist pitch of the second zone being smaller than the twist pitch of the first zone.

[0013] The invention will be understood more clearly from the following description and the accompanying figures. These figures are given purely by way of an indication and in no way restrict the scope of the invention. Of these figures:

- Figure 1 shows a cross-section of the cable according to the invention;
- Figure 2 shows a longitudinal section of a cable according to the invention;
- Figure 3 shows a longitudinal section of a cable according to the invention, designed to be connected to an external instrument.

[0014] Figure 1 shows a cable 1 according to the invention. This cable 1 is preferably a coaxial cable. It comprises a first set of conductors 2 surrounded by a first protective insulator jacket 3. This protective insulator jacket 3 acts as a stiffening piece. It rigidifies the lengthwise disposition of the conductors of the first assembly 2 inside the cable 1. Furthermore, the cable 1 has a second set of conductors 4 positioned around this first jacket 3.

[0015] Conductors of this second set 4 are, for example, sheathed metal strands. These metal strands are twisted around the first jacket 3. Indeed, these strands of the second set 4 do not extend in parallel to an axis formed by the conductors of the first set 2, but turn about the jacket 3. The axis formed by the conductors of the first set 2 corresponds to a main lengthwise axis 11 of the cable when this cable is not subjected to any strain. The strands of the second set 4 are positioned so as to form turns spaced out from one another. These turns are positioned slightly obliquely with respect to the axis 11. This second set of conductors 4 is positioned in such a way that the conductors of this set get wound in being made to adjoin the first jacket 3. To protect the set thus formed, the first jacket 3 surrounded by the twisted strands of the second set of conductors 4 is surrounded by a protective sheath 5.

[0016] Preferably, the protection sheath 5 is made out of polyurethane and forms a continuous cylinder covering the totality of the cable 1 such that this cylinder has a thickness of about 2.1 millimetres. The first jacket 3 forms a reinforcement sheath positioned between the first set of conductors 2 and the second set of conductors 4. It too has a cylindrical shape throughout length of the cable, but this reinforcement sheath has a wall with a thickness preferably smaller than that of the protective sheath 5.

[0017] In one preferred embodiment, the first set of conductors 2 is hybrid, for it has different kinds of conductors. In one exemplary embodiment, this first set of conductors 2 comprises both metal conductors 6 and optical fibres 7. For example it has four metallised conductors such as 6 and two optical fibres such as 7.

[0018] The four metal conductors may then have the following technical characteristics: a cross-section area of about 0.34 square millimetres, a flexible, tin-plated copper core surrounded by an insulator. Preferably, the optical fibres 7 and the metal conductors 6 are positioned on an outer periphery of a rod 8. This rod 8 is preferably made of aramid fibre chosen for its non-flammable properties and high abrasion resistance and high longitudinal tensile strength. This rod 8 therefore gives the cable high tolerance with respect to external physical and climatic conditions. If the metal conductors 6 and the optical fibres 7 do not entirely cover an outer periphery 9 of this rod 8, filler rods are positioned in the interstices left between the metal conductors and/or the optical fibres. Preferably, these filler rods have a same diameter as the metal conductors 6.

[0019] In a preferred embodiment, the first set of conductors 2 is of a type different from that of the second set of conductors 4. For example, the second set of conductors 4 comprises pairs of conductive metal strands. In particular, as seen in figure 1, the cable 1 has three pairs of conductive strands. These three pairs of strands are positioned at equal distance on an outer periphery

10 of the first protective jacket 3. In particular, these pairs of strands may be such that each strand has a flexible tin-plated copper core with a cross-section area of about 0.09 square millimetres, each of these strands being isolated and the pairs themselves being isolated.

[0020] In figure 2, the cable 1 is shown in cross section. In other words, the cable 1 is sectioned parallel to the lengthwise axis 11 of this cable. The lengthwise axis 11 connects a first end 12 to a second end 13 of the cable 1, the first end 12 being opposite the second end 13. In a first zone 14, defined as a section along the axis 11 of the roughly cylindrical tube formed by the cable 1, a special feature is observed at the second set of conductors 4. Indeed, in this first zone 14, a twist pitch is observed for each of the pairs of strands of the second set 4 such that it is about three times a distance 15 evaluated between a turn of a first pair of strands 16 and a neighbouring turn of a second pair of strands 17, given that there is a third pair of strands 18. Should there be N pairs of strands in the set of conductors 4, the twist pitch is about N times the distance between two juxtaposed turns.

[0021] In a second zone 19 juxtaposed with the first zone 14, the twist pitch of each of the conductors of the second set 4 is smaller than the one presented in the first zone 14. Indeed, in the example shown in figure 2, it can even be seen that a turn formed by the second pair of strands 17 is attached to a turn formed by the third pair 18 itself attached to a turn formed by the first pair of strands 16 itself attached again to a new turn of the second pair of strands 17 and so on and so forth. In the example shown in figure 2, the turns are tightened, to the point of completely adjoining one another.

[0022] In one variant, it is possible to maintain a minimum space between two different pairs of turns. In another variant, the turns can be arranged in unitary groups, themselves separated by small spaces.

[0023] When the turns are adjoining, they are almost at right angles to the lengthwise axis 11. This angle is slightly smaller than a right angle so that it enables the different pairs of strands to go forward from the first end 12 to the second end 13 of the cable 1.

[0024] The cable 1 which, in one example, may be 200 metres long may comprise several second zones such as 19 distributed between the first zones such as 14. For example, these second zones such as 19 may be distributed evenly every 50 metres along the cable. These zones, such as 19, have for example a length along the axis 11 in the range of some centimetres.

[0025] Preferably, in the zone 19, the turns formed by the conductors of the second set 4 locally form an extra thickness visible at an outer periphery 20 of the protection sheath 5. Thus it is easier to detect the zone 19 in the cable 1.

[0026] Indeed, when an instrument has to be connected to the cable 1, it must be connected with conductors of the second set 4. To this end, it is preferably chosen to connect it to the zone 19. A window 21 is then made in the protective sheath 5 so as to make it possible to reach the conductors of the second set 4. Since the window 21 is formed at the zone 19, the relatively tight turns of each of the conductors of the second set 4 are then uncovered. For purposes of the connection, each of the pairs of conductors of this second set 4 is sectioned so as to give two independent portions 22 and 23 of conductors on either side of a sectioning point.

[0027] These two independent portions of conductors, respectively 22 and 23, each comprise at least one portion of at least one pair of strands of the cable 1. Each of them may be unwound from the outer periphery 10 of the first jacket 3. Indeed, the number of turns formed by these conductors at the window 21 is such that makes it possible to present portions 22 and 23 having a certain length.

[0028] Each of the portions 22 and 23, depending on the sectioning point with respect to the width of the second zone 19, has a length sufficient for it to be capable of being connected with a complementary apparatus. A first input of a connector of the instrument is connected with the first portion 22 and a second input of the connector, equivalent for example to an output of the instrument, is connected to the second portion 23. In this case, this instrument is series-mounted on the cable.

[0029] Preferably, the sectioning point is made in a central part of this second zone 19 so as to propose two portions of conductors such as 22 and 23 having equivalent lengths.

[0030] With a method such as this, it is no longer necessary to make curvatures in the part of the partially stripped cable, this part of the stripped cable corresponding to the first set of conductors 2 surrounded by the first protective jacket 3 of the window 21. Thus the optical fibres 7, contained inside the first set of conductors 2, are protected. They may be kept parallel to the lengthwise axis 11.

[0031] Should this cable 1 be used for geophysical studies, the instrument mounted on the cable may, for example, be a terrestrial seismic geophysical sensor.

Claims

1. Coaxial cable (1) comprising a first set (2) of conductors, a first insulating protective jacket (3) mounted around this first set, a second set (4) of conductors twisted around the first jacket, and a protective sheath (5) mounted around the second set and the first jacket, **characterized in that** the coaxial cable comprises, along a lengthwise axis (11) of the cable, at least one first zone (14) in which the conductors of the second set are twisted according to a twist pitch (15) and at least one second zone (19) in which the twist pitch is smaller than the twist pitch of the first zone.

2. Cable according to claim 1, **characterized in that**

the conductors of the second set form turns around the first jacket, the turns being close together or adjoining each other in the second zone.

3. Cable according to one of the claims 1 to 2, **characterized in that** the first set of conductors is of a type distinct from the type of conductors of the second set.

4. Cable according to one of the claims 1 to 3, **characterized in that** the first set of conductors is a hybrid set and comprises metal conductors (6) and optic fibres (7).

5. Cable according to one of the claims 1 to 4, **characterized in that** it comprises several second zones evenly distributed along the lengthwise axis of the cable.

6. Cable according to one of the claims 1 to 5, **characterized in that** the second zone has a length, along the lengthwise axis, that is reduced as compared with the length of the first zone.

7. Cable according to one of the claims 1 to 6, **characterized in that** it has an extra thickness at the second zone.

8. Method for connecting an instrument to the second zone of a cable according to one of the claims 1 to 7, **characterized in that** it comprises the following steps:

- a window (21) is made in the sheath at this second zone,
- conductors of the second set are sectioned at said second zone,
- the portions (22, 23) of these conductors on either side of a sectioning point are unwound to clear ends that can be connected to the instrument,
- this instrument is series-connected to the cable

9. Method according to claim 8, **characterized in that** the instrument is a terrestrial seismic geophysical sensor.

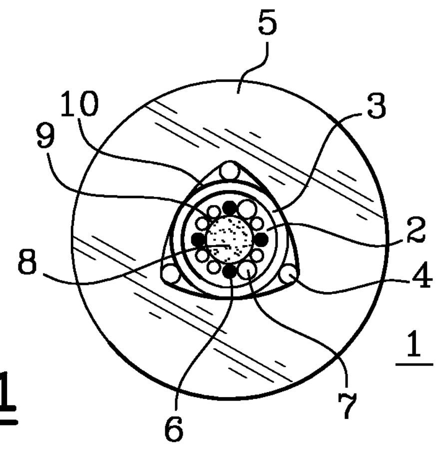

Fig. 1

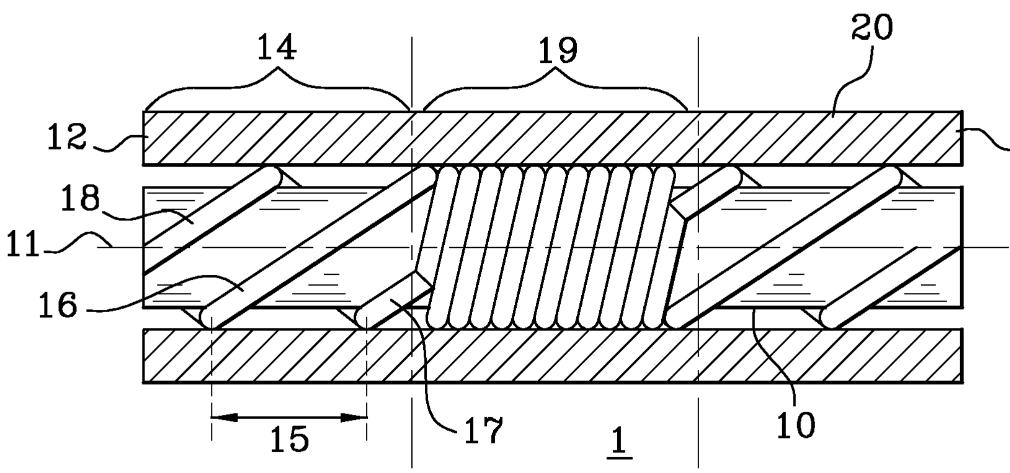

Fig. 2

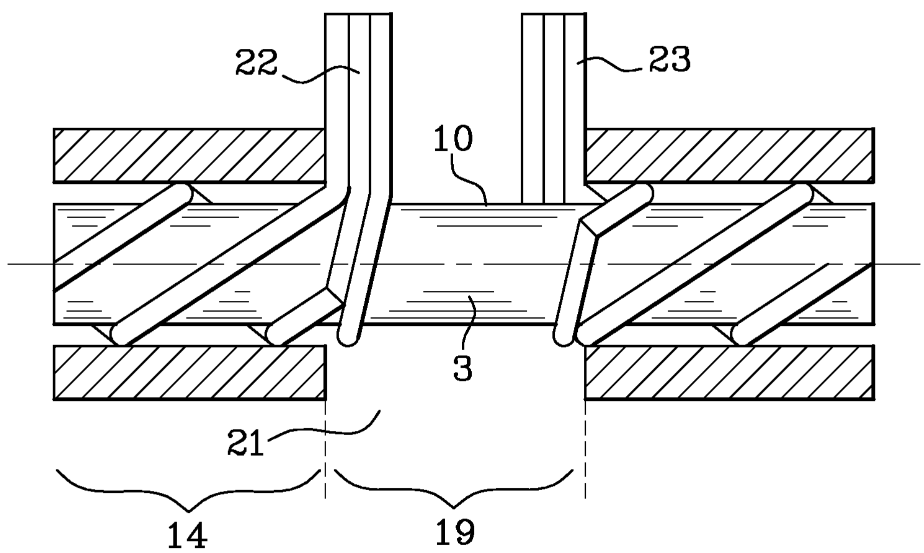

Fig. 3