



- (51) International Patent Classification:
H01B 11/18 (2006.01)
- (21) International Application Number:
PCT/US2013/055435
- (22) International Filing Date:
16 August 2013 (16.08.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/654,236 17 October 2012 (17.10.2012) US
- (71) Applicant: RAYTHEON COMPANY [US/US]; 870 Winter Street, Waltham, Massachusetts 02451-1449 (US).
- (72) Inventors: MILLER, Darrell; 823 Weeping Willow Court, Allen, Texas 75002 (US). CHAPLA, Kevin; 1101 Haskell Road, Melissa, Texas 75454 (US). KASEMODEL, Justin A.; 9325 Harrell Drive, McKinney, Texas 75070 (US).
- (74) Agents: LOVELESS, Ryan S. et al.; Munck Wilson Mandala, LLP, 600 Banner Place Tower, 12770 Coit Road, Dallas, Texas 75251 (US).

(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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, 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: LOW LOSS AND LOW PACKAGED VOLUME COAXIAL RF CABLE

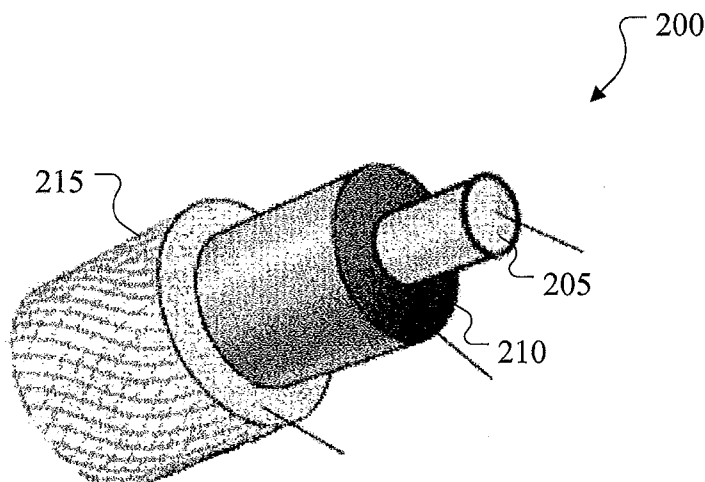


FIG. 2

(57) Abstract: A low loss and low packaged volume coaxial RF cable according to embodiments is configured to conduct electrical signals, such as RF energy signals. The coaxial RF cable includes a three-layer structure (200) that includes a non-conductive composite braid (210) disposed between a first conductive composite braid (205) and a second conductive composite braid (215). The coaxial cable is a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

LOW LOSS AND LOW PACKAGED VOLUME COAXIAL RF CABLE

TECHNICAL FIELD

[0001] This disclosure is generally directed to conductor for radio frequency
5 transmission and, more particularly, to a system and method for a low loss and low packaged
volume coaxial radio frequency cable.

BACKGROUND

[0002] Many radio frequency (RF) applications use one or more coaxial cables. The
10 systems can utilize coaxial cable as a transmission line for the RF signals. Other applications
of the coaxial cable include uses as: computer network connections; feedlines connecting
radio transmitters and receiver with respective antenna elements; and used to connect satellite
and local broadcast antennas to receivers, monitors or televisions. Coaxial cable includes a
shield that minimizes electrical and radio frequency interference.

15

SUMMARY

[0003] This disclosure provides an apparatus for a low loss, low packaged volume, ultra-flexible coaxial conductor.

5 [0004] In a first embodiment, a coaxial cable includes a three-layer structure comprising a non-conductive layer disposed between a first conductive layer and a second conductive layer. The coaxial cable is a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

10 [0005] In a second embodiment, a system includes a transmitter configured to transmit electrical signals; a receiver configured to receive the electrical signals; and a coaxial cable coupled on a first end to the transmitter and on a second end to the receiver. The coaxial cable comprises a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

15 [0006] In a third embodiment, a method includes transmitting electrical signals, by a transmitter coupled to a coaxial cable. The coaxial cable comprises a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

20 [0007] Although specific advantages have been enumerated above, various embodiments may include some, none, or all of the enumerated advantages. Additionally, other technical advantages may become readily apparent to one of ordinary skill in the art after review of the following figures and description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of this disclosure and its features, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

5 [0009] FIGURE 1 illustrates a coaxial cable according to the present disclosure;

[0010] FIGURE 2 illustrates a low loss and low packaged volume coaxial RF cable according to embodiments of the present disclosure;

[0011] FIGURE 3 illustrates a conductive composite braid according to embodiments of the present disclosure;

10 [0012] FIGURE 4 illustrates a non-conductive composite braid according to embodiments of the present disclosure;

[0013] FIGURES 5 and 6 illustrate the coaxial RF cable according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0014] FIGURES 1 through 6 described below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention.

5 Those skilled in the art will understand that the principles of the present invention may be implemented in any type of suitably arranged device or system.

[0015] In radio frequency (RF) communications, communication systems often use coaxial cables as transmission lines, computer network connections; feedlines connecting radio transmitters and receiver with respective antenna elements; and used to connect satellite
10 and local broadcast antennas to receivers, monitors or televisions. Coaxial cable includes a shield that minimizes electrical and radio frequency interference. However, problems may be encountered in low volume settings where space constraints require a high degree of flexibility.

[0016] Given such concerns, certain embodiments of the disclosure teach a system
15 and method to provide a low loss and low packaged volume coaxial RF cable. Additionally, in particular embodiments, the low packaged volume coaxial RF cable is configured to recover to a linear state after being compressed within a low volume space. Certain embodiments of the disclosure also provides a coaxial cable capable of operating in extreme temperatures without damaging the conductor.

20 [0017] FIGURE 1 illustrates a coaxial cable according to the present disclosure. The coaxial cable 100 of FIGURE 1 is configured to conduct electrical signals, such as RF signals. Although certain details will be provided with reference to the components of the coaxial cable 100 of FIGURE 1, it should be understood that other embodiments may include more, less, or different components. The coaxial cable 100 includes a core 105, a dielectric
25 insulator 110, a metallic shield 115 and a plastic jacket 120.

[0018] The core 105 is configured to conduct electrical signals. The core 105 is a conductive metal such as a solid copper wire or plurality of stranded copper wires. A core 105 of stranded copper wires is more flexible than a flexible solid copper wire. In certain
30 embodiments, the core 105 includes a silver-plated conductive metal. In certain embodiments, the core 105 includes a copper-plated iron conductive metal. In certain embodiments, the core 105 includes a steel wire.

[0019] The core 105 is surrounded by a dielectric insulator 110. The dielectric insulator 110 can be solid plastic, a foam plastic, or air with spacers supporting the core 105.

In certain embodiments, the properties of dielectric control some electrical properties of the coaxial cable 100. For example, the dielectric insulator 110 can be a solid polyethylene insulator, such as used in lower-loss cables. In certain embodiments, the dielectric insulator 110 is solid TEFLON. In certain embodiments, the dielectric insulator 110 includes air, or
5 another suitable gas, and spacers configured to maintain physical separation between the core 105 and the metallic shield 115.

[0020] The metallic shield 115 is configured to provide additional interference insulation. In certain embodiments, the metallic shield 115 is a metal layer disposed around the dielectric insulator 110. In certain embodiments, the metallic shield is composed of a
10 woven metallic braid to provide increased flexibility. The metallic shield 115 can be silver-plated, include two braids, or be a thin foil shield covered by a wire braid.

[0021] The plastic jacket 120 is disposed around the metallic shield 115. The plastic jacket 120 is configured as an insulating jacket and can be made from many materials. The plastic jacket 120 can be composed of one or more of: polyvinyl chloride (PVC); fire-
15 resistant materials, ultraviolet light resistant material; and oxidation resistant material.

[0022] However, the construction of a coaxial cable 100 can cause a degree of rigidity and inflexibility that inhibits the ability of the coaxial cable from being packaged in low volume spaces. For example, bending the coaxial cable 100 (which has a $\frac{1}{4}$ inch diameter) to have a 90° bend, or greater, within a 1 inch^3 volume can result in a kink in the coaxial cable
20 100. That is, when bending the coaxial cable 100 to have a 90° turn (or larger, such as 180°), the metal in core 105 or the metallic shield 115 can stretch or warp, creating a condition in which the bend remains in the coaxial cable 100 because the metal is no longer able to be returned to its previous form. In addition, either the dielectric insulator 110 or the plastic jacket 120 may crack or damage such that the dielectric insulator 110 or the plastic jacket 120
25 is no longer able to be returned to its previous form. Therefore, the coaxial cable 100 is unable to fold or curl within a limited volume area such as an area defined by $1 \text{ inch} \times 1 \text{ inch} \times 1 \text{ inch}$ (1 inch^3) without causing a kink or other damage in the coaxial cable 100. In addition, the coaxial cable 100 is unable to make multiple loops (e.g., 360° folds or coils) within the 1 inch^3 area. The coaxial cable 100 is too large and too inflexible to be used in
30 applications with low volume restrictions.

[0023] In addition, low temperature extremes further inhibit the flexibility of the coaxial cable 100. In certain applications, in which operating at temperatures below 0° Celsius (C) is required, the components of the coaxial cable 100 increase in rigidity and can

take a set, that is, become fixed. In certain embodiments, restrictive volume applications use flex circuits. Flex circuits may fit in the restricted volume applications; however, the flex circuits are restricted in power handling and have increased conductor losses relative to coaxial cables. In addition, at low temperatures, such as below 0°C, flex circuits also become stiff.

[0024] FIGURE 2 illustrates a low loss and low packaged volume coaxial RF cable according to embodiments of the present disclosure. The coaxial RF cable 200 of FIGURE 2 is configured to conduct electrical signals, such as RF energy signals. Although certain details will be provided with reference to the components of the coaxial RF cable 200 of FIGURE 2, it should be understood that other embodiments may include more, less, or different components. The coaxial RF cable 200 includes a core 205, an insulative layer 210, and a conductive outer layer 215.

[0025] The core 205 is configured to conduct electrical signals, such as RF signals. The core 205 includes a conductive composite braid. The conductive composite braid includes a fiber coated with a conductive metal. For example, the conductive composite braid is composed of a plurality of aramid fibers plated in one or more of: silver, copper, gold, aluminum, or any suitable conductive metal.

[0026] The coaxial RF cable 200 is configured to transmit electrical signals. That is, a transmitter that transmits electrical signals is coupled through the coaxial RF cable 200 to a receiver that receives the electrical signals. The coaxial RF cable 200 is coupled on a first end to the transmitter and on a second end to the receiver. As illustrated above, the coaxial RF cable 200 can be a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

[0027] FIGURE 3 illustrates a conductive composite braid according to embodiments of the present disclosure. The conductive composite braid 300 of FIGURE 3 is configured to conduct electrical signals, such as RF energy signals. Although certain details will be provided with reference to the components of the composite braid 300 of FIGURE 3, it should be understood that other embodiments may include more, less, or different components. The composite braid 300 includes a plurality of fiber strands 305. Each fiber strand 305 can include a plurality of fibers. The fibers can be organic or synthetic. For example, the fibers can be cotton fibers or aramid fibers. In certain embodiments, the fibers are non-conductive. Each fiber strand 305 is coated with a conductive metal, such as one or more of: silver, copper, gold, of aluminum. In certain embodiments, the coating is applied to

each individual fiber prior to formation of the fiber strand 305. In certain embodiments, the coating is applied to each fiber strand 305 after formation of the fiber strand 305. The plurality of fiber strands 305 are woven to form the composite braid 300. In certain embodiments, the plurality of fiber strands 305 are woven to such that a via 310 is formed within the composite braid 300. In certain embodiments, the plurality of fiber strands 305 are woven to form a flat, or otherwise solid or compressed, composite braid 300, i.e., no via 310.

[0028] The core 205 is surrounded by the insulative layer 210. The insulative layer 210 includes a non-conductive composite braid 400, as shown in FIGURE 4. The non-conductive composite braid includes a plurality of non-conductive fiber strands 405. Each fiber strand 405 can include a plurality of non-conductive fibers. The fibers can be organic or synthetic. For example, the fibers can be cotton fibers or aramid fibers. The insulative layer 210 is configured to insulate the core 205 and provide separation between the core 205 and the conductive outer layer 215. The insulative layer 210 provides electrical to ground separation between the core 205 and the outer conductive layer 215. In certain embodiments, the fibers in the composite fiber of the insulative layer 210 have a different dielectric constant than the fiber sin the composite fibers of one or both of the core 205 and the outer conductive layer 215.

[0029] The conductive outer layer 215 is configured to conduct electrical signals, such as RF energy signals. The conductive outer layer 215 is configured to form a reference voltage point and to cooperate with the core 205 to communicate the RF energy signals. The conductive outer layer 215 includes a conductive composite braid, such as shown in FIGURE 3. The conductive composite braid includes a fiber coated with a conductive metal. For example, the conductive composite braid is composed of a plurality of aramid fibers plated in one or more of: silver, copper, gold, aluminum, or any suitable conductive metal. In addition, the insulative layer 210 and conductive outer layer 215 provide electromagnetic interference (EMI) to enable the RF signals to propagate through the core 205.

[0030] Therefore, the coaxial RF cable 200 is constructed from two composite braids and one insulating composite braid. The coaxial RF cable 200 is configured to have ultra-flexibility and compressibility to enable the coaxial cable to support restrictive volume applications. For example, bending the coaxial RF cable 200 (which has a diameter < 0.08 inches) to have a 90° bend, or greater, within a 1 inch³ volume does not result in a kink in the coaxial cable 100. That is, when bending the coaxial RF cable 200 to have a 90° turn (or larger, such as 180°), neither the core 205 nor the conductive outer layer 215 irreversibly

stretch or warp. Therefore, the coaxial RF cable 200 is able to be returned to its previous form regardless of the degree of bend or amount of coiling. In addition, as a result of the composite fiber construction, the insulative layer 210 and the conductive outer layer 215 are not susceptible to cracking or damage resulting from bending, compression or coiling.

5 Therefore, the coaxial RF cable 200 is able to fold or curl within a limited volume area such as an area defined by 1inch×1inch×1inch (1inch³) without causing a kink or other damage in the coaxial RF cable 200. In addition, the coaxial RF cable 200 is able to make multiple loops (e.g., 360° folds or coils) within the 1inch³ area.

[0031] In certain embodiments, the core 205 and the outer conductive layer 215
10 include different metals. Accordingly, the core 205 and the outer conductive layer can have different electrical conductive properties.

[0032] In certain embodiments, the coaxial RF cable 200 is configured to operate at extreme temperatures without loss of performance and without taking a set in a larger diameter construct and is configured to remain compliant in limited volume applications. For
15 example, the coaxial RF cable 200 has higher power levels and a low insertion loss as a result of an extension of its base materials ability to handle high temperatures and therefore higher power levels. In addition, the coaxial RF cable 200 can operate a -65° C without becoming rigid or setting.

[0033] The coaxial RF cable 200 is adapted to receive multiple coupling types. For
20 example, the coaxial RF cable 200 is adapted to receive a crimp-on connector and a solder-on connector.

[0034] The coaxial RF cable 200 is configured to provide ultra-flexibility, reduced weight and compressibility for use as an RF transmission line. For example, as shown in
25 FIGURE 5, twenty inches (20") of coaxial RF cable 200 can be bended and coiled multiple times within a limited volume. For reference a standard U.S. Quarter coin 505 is shown. The coaxial RF cable 200 can be returned to its previous "uncoiled" state as shown in FIGURE 6. In certain embodiments, the layers of conductive and non-conductive composite fibers provide a "rope-like" structure to the coaxial RF cable 200. Accordingly, the coaxial RF
30 cable 200 can be bended, twisted and compressed such that the coaxial RF cable 200 can be tied into knots 605 (without discernible or visible gaps) without kinking, stretching, warping, cracking, or otherwise damaging the coaxial RF cable 200. It is noted that the knot comprises a compact intersection of interlaced material as is known by one of ordinary skill in the art.

[0035] It may be advantageous to set forth definitions of certain words and phrases

used throughout this patent document. The terms “include” and “comprise,” as well as derivatives thereof, mean inclusion without limitation. The term “or” is inclusive, meaning and/or. The phrase “associated with,” as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to
5 or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, have a relationship to or with, or the like.

[0036] While this disclosure has described certain embodiments and generally associated methods, alterations and permutations of these embodiments and methods will be apparent to those skilled in the art. Accordingly, the above description of example
10 embodiments does not define or constrain this disclosure. Other changes, substitutions, and alterations are also possible without departing from the spirit and scope of this disclosure, as defined by the following claims.

WHAT IS CLAIMED IS:

1. A coaxial cable comprising:
a three-layer structure (200) comprising a non-conductive layer (210) disposed between a first conductive layer (205) and a second conductive layer (215), wherein the
5 coaxial cable is a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

2. The coaxial cable of Claim 1, wherein at least two layers of the three-layer structure comprise conductive composite fibers (300).

3. The coaxial cable of Claim 2, wherein the conductive composite fibers comprise a plurality of fibers (305) plated in a conductive metal.

4. The coaxial cable of Claim 3, wherein the conductive metal comprises one of:
15 silver, copper, gold, of aluminum.

5. The coaxial cable of Claim 2, wherein the composite fibers comprise an aramid fiber.

6. The coaxial cable of Claim 1, wherein the coaxial cable is configured to operate below -65° Celsius without becoming rigid or setting.

7. The coaxial cable of Claim 1, wherein ultra-flexibility includes an ability of the coaxial conductor to be one or more of:

25 folded within a one-inch³ volume,
coiled multiple times within a one-inch³ volume; and
tied into a compact knot (605), without discernible or visible gaps, and without damage to the coaxial conductor.

8. A system comprising:

a transmitter configured to transmit electrical signals;

a receiver configured to receive the electrical signals;

a coaxial cable coupled on a first end to the transmitter and on a second end to

5 the receiver, wherein the coaxial cable comprises a ultra-flexible, compressible conductor configured to be folded multiple times within a low volume area without damage.

9. The system of Claim 8, wherein the coaxial cable comprises a three-layer structure (200) wherein at least two layers (205, 215) of the three-layer structure comprise
10 conductive composite fibers (300).

10. The system of Claim 9, wherein the conductive composite fibers comprise a plurality of fibers (305) coated in a conductive metal.

15 11. The system of Claim 10, wherein the conductive metal comprises one of: silver, copper, gold, of aluminum.

12. The system of Claim 9, wherein the composite fibers comprise an aramid
fiber.

20

13. The system of Claim 8, wherein the coaxial cable is configured to operate at -65° Celsius without becoming rigid or setting.

14. The system of Claim 8, wherein ultra-flexibility includes an ability of the
25 coaxial conductor to be one or more of:

folded within a one-inch³ volume,

coiled multiple times within a one-inch³ volume; and

tied into a compact knot (605), without discernible or visible gaps, and without
damage to the coaxial conductor.

30

15. A method for transmitting signals comprising:
transmitting electrical signals, by a transmitter coupled to a coaxial cable,
wherein the coaxial cable comprises a ultra-flexible, compressible conductor configured to be
folded multiple times within a low volume area without damage.

5

16. The method of Claim 15, wherein at least two layers (205, 215) of a three-
layer structure (200) comprise conductive composite fibers (300).

17. The method of Claim 16, wherein the conductive composite fibers comprise a
10 plurality of fibers (305) plated in a conductive metal.

18. The method of Claim 17, wherein the conductive metal comprises one of:
silver, copper, gold, of aluminum.

15 19. The method of Claim 16, wherein the composite fibers comprise an aramid
fiber.

20. The method of Claim 15, wherein the coaxial cable is configured to operate
below -65° Celsius without becoming rigid or setting.

20

21. The method of Claim 15, wherein ultra-flexibility includes an ability of the
coaxial conductor to be one or more of:

folded within a one-inch³ volume,

coiled multiple times within a one-inch³ volume; and

25 tied into a compact knot (605), without discernible or visible gaps, and without
damage to the coaxial conductor.

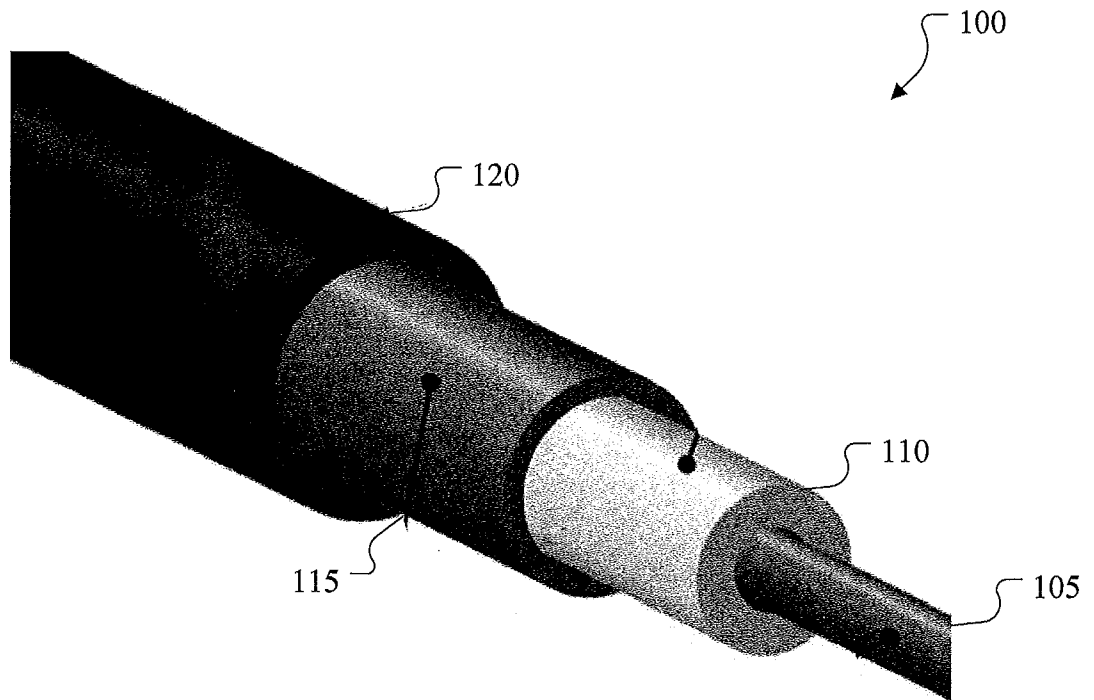


FIG. 1

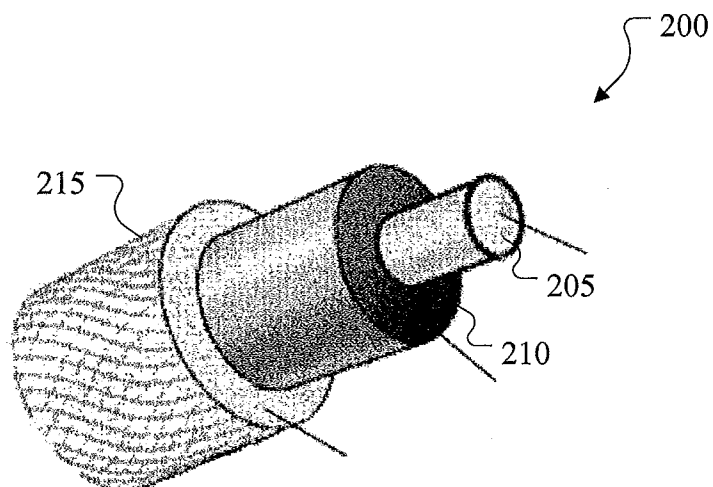


FIG. 2

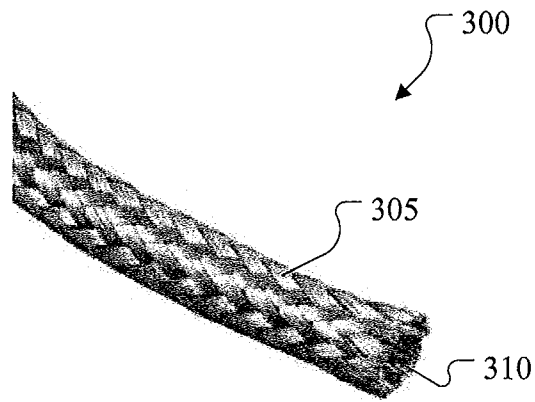


FIG. 3

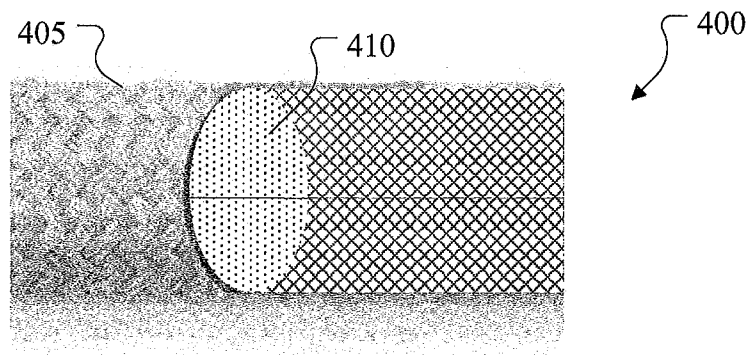
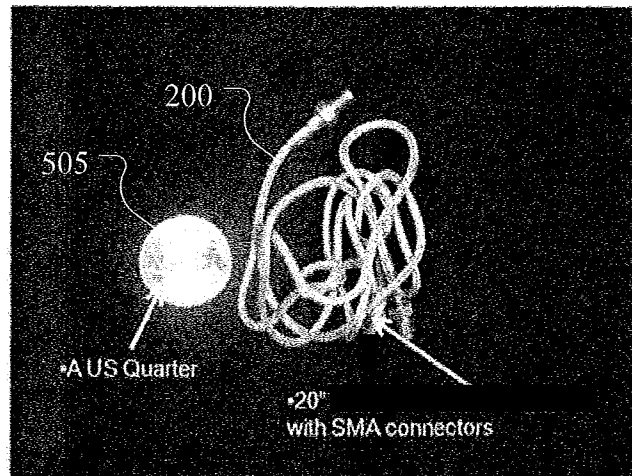
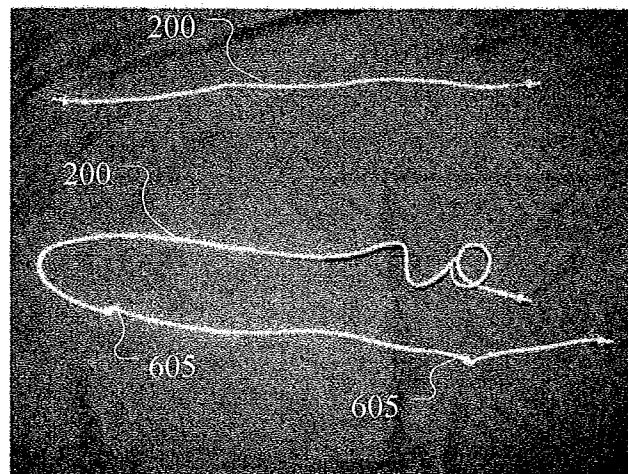


FIG. 4

*FIG. 5**FIG. 6*

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/055435

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01B11/18
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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 475 185 A (TOKARSKY EDWARD W [US]) 12 December 1995 (1995-12-12) column 2, line 29 - line 55; figure 1 -----	1-5,8-12
A	WO 2011/078190 A1 (FUJIKURA LTD [JP]; KOJIMA SHIGERU [JP]; OGASAWARA TAKASHI [JP]; SATOH) 30 June 2011 (2011-06-30) abstract -----	1

☐

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)

"O" document referring to an oral disclosure, use, exhibition or other means

"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

3 December 2013

Date of mailing of the international search report

13/12/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Salm, Robert

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/055435

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5475185	A	12-12-1995	NONE	

WO 2011078190	A1	30-06-2011	NONE	
