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(71) **Applicant** *(for all designated States except US)*: **CORNING CABLE SYSTEMS LLC** [US/US]; Intellectual Property Department, SP-TI-3-1, Corning, NY 14831 (US).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **CHAMARTI, Aravind** [IN/US]; 6 Dreams Lane East, Painted Post, NY 14870 (US). **GREVELING, Johannes, I** [US/US]; 2210 Willow Creek Drive, Newton, NC 28658 (US). **JONES, Ashley, W** [US/US]; 900 Panhandle Street, Denton, TX 76201 (US). **SUTHERLAND, James S** [US/US]; 248 E 4th Street, Corning, NY 14830 (US). **WHITING, Matthew, S** [US/US]; 71 Cross Road, Lawrenceville, PA 16929 (US).

(74) **Agent**: **ADUSEI-POKU, Kwadjo**; Corning Incorporated, Intellectual Property Department, SP-TI-3-1, Corning, NY 14831 (US).

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(54) **Title**: OPTICAL FIBER CONNECTOR ASSEMBLY WITH WIRE-BASED RFID ANTENNA

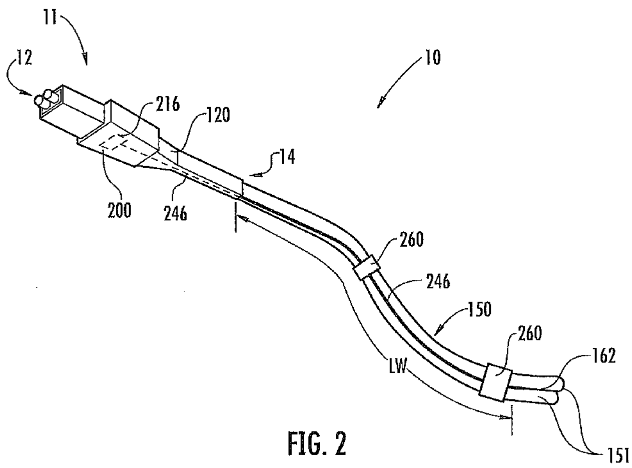

FIG. 2

(57) **Abstract**: An optical fiber connector assembly (10) that provides improved radio-frequency (RF) antenna capability for a radio-frequency identification (RFID) tag (200). The assembly includes a connectorized fiber optic cable (150) having a connector (11). The assembly also includes a wire (246) that either is connected to the RFID tag or is configured to electrically connect to the RFID tag. The wire runs alongside a portion of the fiber optic cable length and is loosely held thereto. The wire serves as at least a portion of an RFID antenna (220) for the RFID tag. The RFID tag may be supported by the connector or may be supported by a connector adapter that is configured to operably engage the connector. The optical fiber connector assembly allows for improved RF antenna capability that provides improved RF communication with an RF reader (400), particularly in RFID applications where existing RFID tag antennas are inadequate. The wire can also serve as substantially the entire RFID antenna, thereby obviating the need to include an RFID antenna as part of the RFID tag.

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OPTICAL FIBER CONNECTOR ASSEMBLY WITH WIRE-BASED RFID ANTENNA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to U.S. Application No. 12/286,186, filed on September 28, 2008.

TECHNICAL FIELD

[0002] This application relates generally to the use of radio-frequency identification (RFID) systems as used in telecommunication systems, and in particular is directed to optical fiber connector assemblies that have wire-based RFID antennas.

BACKGROUND

[0003] Typical telecommunications data centers include large numbers of optical and electrical cable connections that join various types of network equipment. Examples of network equipment include electrically-powered (active) units such as servers, switches and routers, and unpowered (passive) units such as fanout boxes and patch panels. This network equipment is often installed within cabinets in standard (e.g., 19") equipment racks. Each piece of equipment typically provides one or more adapters where optical or electrical patch cables can be physically connected to the equipment. These patch cables are generally routed to other network equipment located in the same cabinet or another cabinet.

[0004] A common problem in telecommunications data center management is determining the latest configuration of all the optical and electrical links among all the network equipment. The configuration of optical and electrical links can be completely determined if the physical locations of all connected patch cable (or "jumper cable") connectors on installed network equipment are known.

[0005] Information about the physical location and connection status of the patch cables and their corresponding ports in a data center cabinet is typically manually recorded and added to a network management software database. Unfortunately, this process is labor-intensive and prone to errors. Additionally, any changes made to the physical configuration of a cabinet must be followed up with corresponding changes to the network management software database, which delays providing the most up-to-date information about the network configuration. Furthermore, errors from manual recording and entering configuration data tend to accumulate over time, reducing the trustworthiness of the network management software database.

[0006] It is particularly important to be able to perform connector-port identifications quickly and reliably. It is therefore desirable to be able to automatically and remotely identify individual connections (i.e., connector-port connections) in a telecommunications cabinet. Current commercially available automated solutions utilize an overlay of copper wiring, which adds cost and complexity to the cabinet while providing only a limited ability to perform connector-port identifications.

[0007] While RFID systems have been employed in telecommunication systems to identify system components, one of the difficulties presented in standard “4U” telecommunication cabinets (where “U” is a standard measurement unit of 1.75”) is the density and number of the connections involved, which leaves little room for RFID tags. For example, a typical present-day 4U data center cabinet contains up to 144 ports, and if each of these ports has at least one RFID tag, then the RFID tags need to be very compact. Further, future data center cabinets are likely to include an even greater number of ports, such as about 400 ports, which translates into over 1200 tags within the 4U cabinet if each port includes three RFID tags. Such dense arrangements of RFID tags leaves very little room for RFID tag antennas that can adequately and efficiently harvest energy from the RFID interrogation signals from the RF reader and ensure that all of the tags in the relatively small volume can communicate the connector-port information to the RF reader. In some cases, standard RFID tag antennas that might work for one RFID application do not work as well for other applications such as telecommunication cabinets and like telecommunication assemblies where the density of RFID tags can interfere with RF communication between the RFID tags and the RF reader.

SUMMARY

[0008] A first aspect of the invention is an optical fiber connector assembly that provides improved radio-frequency antenna capability for at least one RFID tag. The assembly includes a fiber optic cable having an end, a length and an outer surface, and at least one optical fiber. The assembly also includes an optical fiber connector operably connected to the fiber optic cable end. The assembly further includes at least one wire either electrically connected to the at least one RFID tag or configured to electrically connect to the at least one

RFID tag. The at least one wire runs along a portion of the fiber optic cable length so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

[0009] A second aspect of the invention is a telecommunications assembly with RFID capability. The telecommunication assembly includes a plurality of connector assemblies as described briefly above, and a plurality of connector adapters having respective RFID tags and that are operably engaged with the plurality of connector assemblies so that the RFID tags are respectively electrically connected to respective wires of the corresponding connector assemblies. The telecommunications assembly also includes at least one RF reader arranged in relation to the wires so as to operably communicate with the plurality of RFID tags via the respective wires.

[0010] A third aspect of the invention is an optical fiber connector assembly that provides improved radio-frequency antenna capability for at least one RFID tag. The assembly includes a fiber optic cable having an end, a length and an outer surface. The assembly also includes an optical fiber connector operably connected to the fiber optic cable end. The assembly also includes a connector adapter configured to operably engage the optical fiber connector and that includes the at least one RFID tag. The assembly further includes at least one wire that runs along a portion of the fiber optic cable length and that is configured to electrically connect to the at least one RFID tag when the connector and connector adapter are operably engaged so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

[0011] A fourth aspect of the invention is a method of providing improved radio-frequency antenna capability for at least one RFID tag having an integrated circuit chip. The method includes providing a connectorized fiber optic cable having a length and a connector, and disposing at least one wire to run from the connector and along an outside portion of the fiber optic cable length. The method also includes electrically connecting the at least one wire to the integrated circuit chip of the RFID tag so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

[0012] It is to be understood that both the foregoing general description and the following detailed description present embodiments of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention, and are incorporated into and constitute part of this specification. The drawings illustrate various exemplary embodiments of the invention, and together with the description serve to explain the principles and operations of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is an exploded perspective view of an example embodiment of an optical fiber connector assembly ("connector assembly") according to the present invention that supports a wire used as an RFID tag wire antenna;

[0014] **FIG. 2** is a bottom-up perspective view of the assembled connector assembly of **FIG. 1**, showing the wire loosely secured to the fiber optic cable;

[0015] **FIG. 3** is a cross-sectional view of a fiber optic cable formed from two fiber optic cables each having a single optical fiber, wherein the protective covers of the cables join to form a "figure-eight" cross-sectional shape that defines two grooves;

[0016] **FIG. 4** is similar to **FIG. 3**, further showing the routing of the wire antenna in one of the grooves;

[0017] **FIG. 5** is similar to **FIG. 4**, and illustrates an example embodiment wherein the connector assembly includes two wires, with one wire disposed in each groove;

[0018] **FIG. 6** is a schematic side view of an example connector assembly shown with the connector mated with a connector adapter that includes an integrated circuit (IC) chip, and also showing an RF reader transmitting interrogation and write signals and receiving an RFID tag signal;

[0019] **FIG. 7** is similar to **FIG. 6** and illustrates an example embodiment where the connector adapter includes an RFID tag that connects to the wire supported by the connector assembly;

[0020] **FIG. 8** is similar to **FIG. 7**, and illustrates an example embodiment where the connector adapter and connector assembly each include an RFID tag, and wherein the connector assembly supports a first wire that serves as an antenna for the connector-adapter RFID tag and also supports a second wire antenna in the connector that serves as an antenna for the connector RFID tag when the connector adapter engages with the connector;

[0021] **FIG. 9** is similar to **FIG. 7** and illustrates an example embodiment where the connector adapter includes two RFID tags and where the connector assembly supports two wires used as respective antennas for the two connector-adapter RFID tags;

[0022] **FIG. 10A** is a cross-sectional view of an example fiber optic cable that has a round cross-section and that includes a groove formed in the protective cover that at least partially accommodates a wire that serves as an RFID antenna;

[0023] **FIG. 10B** is similar to **FIG. 10A**, and shows an example embodiment wherein the protective cover includes two grooves that each at least partially accommodate a wire that serves as an RFID antenna;

[0024] **FIG. 10C** is similar to **FIG. 10A**, and illustrates an example embodiment wherein the protective cover includes a raised portion with a groove formed therein that at least partially accommodates a wire that serves as an RFID antenna;

[0025] **FIG. 10D** is similar to **FIG. 10C**, and illustrates an example embodiment wherein the protective cover includes two raised portions each with a groove formed therein that at least partially accommodates a wire that serves as an RFID antenna;

[0026] **FIG. 11** is a schematic side view of an example connector adapter that includes an RFID tag and a flange that supports at least a portion of the RFID antenna;

[0027] **FIG. 12** is an exploded perspective view of an example connector adapter such as shown in **FIG. 11**;

[0028] **FIG. 13** is a perspective diagram of an example RFID tag and RFID antenna for use in combination with the connector adapter of **FIG. 11** and **FIG. 12**;

[0029] **FIG. 14** is a schematic close-up cross-sectional diagram of a portion of a telecommunications assembly in the form of a patch panel assembly that includes connector adapters with optical fiber connector assemblies engaged therewith (shown in side view), and also showing an RF reader; and

[0030] **FIG. 15** is a schematic diagram of an example embodiment of a telecommunications assembly in the form of a telecommunications rack that has RFID capability integrated therewith and that employs optical fiber connector assemblies of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Reference is now made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Whenever possible, like or similar reference numerals are used throughout the drawings to refer to like or similar parts. Various modifications and alterations may be made to the following examples within the scope of the present invention, and aspects of the different examples may be mixed in different ways to achieve yet further examples. Accordingly, the true scope of the invention is to be understood from the entirety of the present disclosure, in view of but not limited to the embodiments described herein.

Optical fiber connector assembly

[0032] **FIG. 1** is an exploded perspective view of an example embodiment of an optical fiber connector assembly ("connector assembly") **10** that supports a wire **246** used as an RFID antenna as described in detail below. Connector assembly **10** includes an optical fiber connector ("connector") **11** that, by way of illustration, is shown in the form of a duplex LC connector. An example LC connector **11** is described in U.S. Patent No. 5,638,474, which is incorporated herein by reference. Connector assembly **10** has a plug end **12** at connector **11** and an opposite back end **14**.

[0033] The example LC-type connector **11** of **FIG. 1** includes two cylindrical ferrules **30** that are engaged at their rear end **32** by respective flanges **40**. Connector **10** also includes a housing **50** having a wishbone-type housing body **52** with an output end **54**. Housing body **52** includes a flat bottom portion **57** and has a bifurcation **51** at about the middle of housing body **52**, thereby defining a rear housing portion **58** having a rectangular cross section that connects to square-cross-section prongs **60** that define a front housing portion. Rear housing portion **58** includes a central channel (not shown).

[0034] Each prong **60** has sides **62**, a top **63** and a channel **64** formed therein. Each prong **60** includes a front end **70** open to channel **64**. Channels **64** connect to the rear-portion channel at bifurcation **51** and are sized to accommodate an optical fiber. Channels **64** at front end **70** are sized to engage respective flanges **40**. Prongs **60** each include on sides **62** a set of indents **76** and an aperture **65** formed in top **63** that has edges **67**. Apertures **65** are configured to receive respective protrusions **82** of clip members **80** so that the clip members each reside on top **63** of respective prongs **60**. Each clip member **80** includes a latch **84**.

[0035] Connector **11** further includes a tapered rear flange **100** configured to fit over housing end **54**. Rear flange **100** includes open front and rear ends **102** and **104**, an open interior **106**, and a top surface **108**. Rear flange **100** also includes a trigger member **110** configured to operably engage with latches **84** when the connector is assembled.

[0036] Connector **11** also includes a bend-limiting strain-relief boot **120** having front and rear ends **122** and **124** and a central channel **130** therebetween. Boot front end **122** is configured to engage with rear flange rear end **104**, and boot rear end **124** is configured to operably hold at least one fiber optic cable **150** in channel **130**, as described below. Fiber optic cable **150** includes at least one optical fiber **156** and has an end **150E** to which connector **11** is attached. Fiber optic cable **150** includes a protective cover **158** having an outer surface **159** and that surrounds the at least one optical fiber **156**.

[0037] **FIG. 2** is a bottom-up perspective view of the assembled connector assembly **10** of **FIG. 1**. **FIG. 3** is a cross-sectional view of an example fiber optic cable **150** formed from two fiber optic cables **151**. Each fiber optic cable **151** carries an optical fiber **156** within their respective outer protective covers **158** wherein the protective covers are joined to form a single protective cover having a "figure eight" cross-section that defines two grooves **162**. Fiber optic cable **150** is said to be "connectorized" when connector **11** is operably attached to fiber optic cable end **150E**.

[0038] With reference again to **FIG. 1** and **FIG. 2**, an end portion of fiber optic cable **150** is operably held by boot **120** in boot channel **130** and the ends of the fiber optic cables are stripped so that the (bare) optical fibers **156** can be held in ferrules **30**, which partially extend from connector plug end **12**. Fiber optic cable **150** has a length and in an example embodiment is used to form a "jumper cable" when the length is relatively short (e.g., on the order of a meter or a few meters). Such a section of fiber optic cable **150** can also be referred to as a "zipcord."

[0039] With continuing reference to **FIG. 1** and **FIG. 2**, connector assembly **10** includes an RFID tag **200** attached to flat bottom portion **57** of housing body **52** of connector **11**. RFID tag **200** includes a planar substrate **210** with an upper surface **212**, a front end **213** and a rear end **214**. RFID tag **200** includes an integrated circuit (IC) chip **216** arranged on upper surface **212**, and in an example embodiment includes an antenna system ("antenna") **220**, which is electrically connected to the IC chip and which in an example embodiment is at least partially supported by substrate **210**.

[0040] RFID tag **200** is adapted to store information in IC chip **216**. In an example embodiment, this information includes at least one piece of data relating to the connector assembly of which it is a part. In an example embodiment, information can be written to IC chip **216**.

[0041] In example embodiments, RFID tag **200** does not have a full RFID antenna **220** or any antenna, so that without wire **246** RFID tag **200** could not effectively communicate with an RF reader placed within a typical read range of the RFID tag. In another example embodiment, RFID tag **200** has a standard RFID antenna **220** or a portion of an RFID antenna **220**, but this antenna or antenna portion does not provide adequate RF communication with an RF reader for the application being considered, such as in a telecommunication rack assembly that is densely packed with RFID tags as discussed briefly above and also in greater detail below. In the example embodiments where RFID tag **200** does not include an antenna **220**, wire **246** electrically connects to IC chip **216** and serves as substantially the entire RFID antenna **220**, thereby obviating the need to include either a full RFID antenna or an RFID antenna section on the RFID tag. This enables the RFID tag **200** to be made very small so that it can be supported by relatively small telecommunication system components such as connectors and connector adapters.

[0042] In an example embodiment, RFID tag substrate **210** includes prongs **224** at substrate front end **213** that are configured to correspond to prongs **60** of housing body **52**. Arranged on prongs **60** are upwardly extending flexible electrical contacts **230** with inwardly extending tabs **232**. Electrical contacts **230** fit within side indents **76**, while tabs **232** serve to grip sides **67** of apertures **65** so as to hold RFID tag **200** to bottom **57** of housing body **52**. In an example embodiment, electrical contacts **230** are electrically connected to RFID IC chip **216** via wiring **231** on prongs **224** of RFID tag substrate **210**.

[0043] Electrical contacts **230** as shown in **FIG. 1** represent one example configuration of a number of different types of electrical contact configurations that can be used, including single contacts and multiple contacts. In example embodiments of connector assembly **10** that are not intended for electrically contacting the RFID tag **200** to another IC chip or other RFID tag when the connector is engaged with a connector adapter as discussed below, contacts **230** are not necessary. Also, RFID tag **200** may be supported by connector **11** in a number of ways, including in or on the connector.

[0044] In an example embodiment, antenna system **220** includes an antenna section **240** such as a planar serpentine section formed on substrate surface **212** near substrate rear end **214** and electrically connected to IC chip **216**. Antenna system **220** also includes at least one wire **246** operably connected to the planar serpentine section. Planar serpentine antenna section **240** is formed, for example, from a metal conducting film such as copper. Wire **246** preferably comprises a single, flexible conducting wire (e.g., copper wire), though multiple wires may also be used. Wire **246** is thus shown and discussed as a single wire for the sake of illustration.

[0045] In an example embodiment, wire **246** is routed through rear flange **100** and boot channel **130** of boot **120** (see dashed line in **FIG. 2**) and then exits the boot channel at boot rear end **114**. The exposed portion of wire **246** that extends from boot **120** is preferably loosely held to fiber optic cable **150** with one or more securing members **260**, e.g., one or more sections of heat-shrink wrap. The exposed portion of wire **246** serves as at least a portion of antenna **220**, while the blocked portion within connector **11** serves to electrically connect the wire to RFID tag **200** (e.g., to antenna section **240** or directly to IC chip **216**). In an example embodiment, a thin protective cover (not shown), such as shrink wrap, can be placed over wire **246** without significantly impacting the ability of the wire to serve as antenna. In this regard, the otherwise exposed portion of wire **246** is still considered an "exposed portion" in the context of its ability to provide RF communication to an RF reader, as one skilled in the art will appreciate.

[0046] In an example embodiment illustrated in the cross-sectional view of fiber optic cable **150** shown in **FIG. 4**, wire **246** is disposed in one of grooves **162**. Loosely holding wire **246** to fiber optic cable **150** allows the wire to move to accommodate bending of the cable. In an example embodiment illustrated in the cross-sectional view of **FIG. 5** that is similar to that of **FIG. 4**, the exposed portion of two wires **246** are shown disposed in respective grooves **262**.

[0047] In an example embodiment, wire **246** has a length $\mathbf{L_W}$ representing an exposed portion of the wire (see **FIG. 2**) in a preferred range defined by 10 cm $\leq L_W \leq$15 cm, and in an example embodiment L_W = 12.5 cm. Also in an example embodiment, wire **246** has a diameter of about 0.2 mm. For certain applications, length $\mathbf{L_W}$ can either longer or shorter than that of the preferred range mentioned above, which range represents what is believed to be the most common length range suitable for most applications.

[0048] **FIG. 6** is a schematic side view of an example connector assembly **10** shown with connector **11** mated with a connector adapter **300**. Connector adapter **300** includes a housing **302** with a front end **304,** a back end **305** and sides **306**. Housing **302** defines a port (socket) **310** open at front end **304** and sized to accommodate connector plug end **12**. In the example embodiment of **FIG. 6**, connector adapter **300** includes an IC chip **316** that includes information, such as information about the connector adapter (e.g., make, model, serial number, etc.). IC chip **316** is electrically connected to one or more electrical contacts **330** via wiring **331**.

[0049] When connector **11** mates with connector adapter **300**, the one or more electrical contacts **230** from the connector make contact with the one or more electrical contacts **330** of the connector adapter, thereby allowing IC chip **316** to be in electrical communication with IC chip **216** of RFID tag **200** of connector assembly **10**. Electrical contact **230** is in turn electrically connected to RFID tag **200**, which is electrically connected to wire **246**, which runs through or along connector housing **52** and through or along connector boot **120** and then along fiber optic cable **150**. Wire **246** is loosely held to fiber optic cable **150** via one or more securing members **260** as discussed above with respect to **FIG. 4**. This example configuration for connector assembly **10** (which in the present example embodiment also includes connector adapter **300**) allows for the connector adapter to communicate information to the connector RFID tag **200**, and then allows the connector RFID tag to communicate both connector and connector information via an RFID tag signal **ST** to an RF reader **400**, which is discussed in greater detail below. Information can also be provided to IC chip **216** in connector adapter **300** via connector RFID tag **200** via a write signal **SW** from RF reader **400**. Thus, this configuration obviates the need in certain cases for connector adapter **300** to have an RFID tag and instead include just an IC chip, thereby making good use of the limited amount of space associated with connector assembly **300**.

[0050] **FIG. 7** is a schematic diagram similar to **FIG. 6** that illustrates an example embodiment wherein connector adapter **300** includes an RFID tag **200** and connector **11** does not include an RFID tag. In the example embodiment of **FIG. 7**, connector-adapter RFID tag **200** does not necessarily include a full antenna **220**, but rather includes an antenna section **240**, such as a serpentine section, or short wire section as represented by wiring **331** connected to electrical contact **330**. In some example embodiments, RFID tag **200** does not include an antenna **220**.

[0051] In an example embodiment, electrical contact **230** is a pin-type contact, such as a POGO pin. Upon engaging connector **11** and connector adapter **100,** connector contact **230** contacts connector adapter contact **330,** thereby establishing an electrical connection between connector-adapter RFID tag **200** and wire **246** supported by the connector and fiber optic cable **150**. Wire **246** is thus able to serve as at least a portion of antenna **220** for connector-adapter RFID tag **200**, and in an example embodiment, serves as substantially the entire antenna for the RFID tag.

[0052] The configuration whereby at least one wire **246** of fiber optic cable assembly **10** serves as at least a portion of antenna **220** allows for connector adapter **300** to have at least one RFID tag **200** without having to make room within, on or adjacent the connector adapter **300** for one or more full-sized antennas **220**. This also allows for antenna **220** to be sufficiently long to provide a strong return signal (i.e., tag signal **ST**) when interrogated by an interrogation signal **SI** from RF reader **400** and to more easily receive write signal **SW** that writes information to IC chip **216**. Further, wire **246** also allows antenna **220** to harvest the needed amount of power from interrogation signal **SI** to power the IC chip **216** within RFID tag **200.** Thus, wire **246** provides improved RF communication with an RF reader as compared to using the RFID tag without the wire.

[0053] **FIG. 8** is similar to **FIG. 7**, and illustrates an example embodiment where both connector **11** and connector adapter **300** include respective RFID tags **200**. In the example embodiment of **FIG. 8**, the connector RFID tag **200** has an antenna **220** that includes a first wire **246** that runs along fiber optic cable **150**. The connector-adapter RFID tag **200** electrically connects via contacts **230** and **330** to a second wire **246** that also runs along fiber optic cable **150**, e.g., such as shown in **FIG. 5**. Thus, when connector **11** of connector assembly **10** engages connector adapter **300**, each RFID tag **200** has at least a portion of its antenna **220** in the form of respective wires **246** supported by connector **11** and fiber optic cable **150** in the manner described above. This allows for robust communication between an RF reader and both RFID tags **200** while also making good use of limited space.

[0054] **FIG. 9** is similar to **FIG. 7** and illustrates an example embodiment where the connector adapter includes two RFID tags **200** and where the connector assembly **10** supports two (i.e., first and second) wires **246** that respectively serve as the antennas (or portions thereof) for the two RFID tags. One of wires **246** is shown in phantom to indicate that it is located on the opposite side of fiber optic cable **150** as the other wire. **FIG. 9** thus illustrates that the present invention can accommodate a plurality of RFID tags **200** supported by connector adapter **300** and/or connector **11**.

[0055] **FIG. 10A** through **FIG. 10D** are cross-sectional views of an example embodiment of a round fiber optic cable **150** that carries two optical fibers **156** and that is adapted for use with optical fiber connector assembly **10** of the present invention. Generally, fiber optic cable **150** carries one or more fibers **156** and the two-fiber cable is shown merely by way of example. Protective cover **158** is shown as defining a circular cross-section, as opposed to the "figure eight" cross-section defined by the fiber optic cable **150** of **FIG. 3** through **FIG. 5**. Protective cover **158** can define other cross-sectional shapes, such as elliptical, rectangular, etc.

[0056] **FIG. 10A** illustrates an example embodiment wherein a groove **174** is formed in protective cover **158**, wherein the groove travels along at least a portion of the length of fiber optic cable **150** and is sized to accommodate at least a portion of wire **246**. In an example embodiment, wire **246** is partially seated in groove **174** and partially extends out beyond protective cover outer surface **159**. One or more securing members **260**, such as one or more heat-shrink wrap sections, circumferentially surround protective cover **158** at one or more locations along the length of fiber optic cable **150** to hold wire **246** within groove **174**. As mentioned above, wire **246** is preferably loosely held within groove **174** so that the wire can move as fiber optic cable **150** is bent.

[0057] **FIG. 10B** is similar to **FIG. 10A** and illustrates an example embodiment wherein fiber optic cable **150** includes two grooves **174** so that the fiber optic cable supports two wires **246**, such as in the example embodiment discussed above in connection with **FIG. 8**. More than two grooves **174** can also be formed to accommodate corresponding more than two wires **246**.

[0058] **FIG. 10C** illustrates an example embodiment of fiber optic cable **150** that includes a raised portion **178** on protective cover outer surface **159** and that runs along at least a portion of the length of the fiber optic cable. A groove **174** is formed in raised portion **178** and is sized to accommodate at least a portion of wire **246**. One or more securing members **260**, such as one or more heat-shrink wrap sections, circumferentially surround protective cover **158** and raised portion **178** to hold (e.g., loosely hold) wire **246** within the raised-portion groove **174**.

[0059] **FIG. 10D** is similar to **FIG. 10C** and illustrates an example embodiment wherein fiber optic cable **150** includes two raised portions **178** with respective grooves **174** formed therein so that the fiber optic cable supports two wires **246**. More than two raised portions **178** with grooves **174** can also be formed to accommodate corresponding more than two wires **246**.

Connector adapter with RFID antenna

[0060] **FIG. 11** is a schematic side view of an example connector adapter **300** that includes an RFID tag **200**. Connector adapter **300** includes a flange **318** that extends along one of sides **306** and beyond back end **305**. Flange **318** is adapted to support at least a portion of antenna **220** of RFID tag **200**. In an example embodiment, flange **318** includes a serpentine section **240** of antenna **220** that is formed, for example, by a zig-zag metal film. Also in an example embodiment, side **306** supports a portion of antenna **220**.

[0061] **FIG. 12** is an exploded perspective view of an example connector adapter **300** similar to that shown in **FIG. 11**. The connector adapter of **FIG. 12** includes a connector inner housing **350** having a bottom **352**, and a connector outer housing **360**. Connector outer housing **360** defines an open interior **362** and surrounds at least a portion of the connector inner housing **350**. Connector adapter **300** also includes a fiber aligner member **366** that fits within inner housing **350**. RFID tag **200** attaches to inner housing bottom **352**. Inner and outer housings **350** and **360** each include respective flanges **318A** and **318B** that join to form a single flange **318**.

[0062] **FIG. 13** is a perspective diagram of an example RFID tag **200** and antenna **220** connected thereto for use in the connector adapter **300** of **FIG. 11** and **FIG. 12**, wherein the antenna is at least partially supported by flange **318**. In an example embodiment, a thin film of material **319**, such as MYLAR, is used to cover the portion of antenna **220** that resides on flange **318**.

Telecommunications assembly

[0063] **FIG. 14** is a schematic close-up cross-sectional diagram of a portion of a telecommunications assembly in the form of a patch panel assembly **380**. Patch panel assembly includes a number of connector adapters **300** with optical fiber connector assemblies **10** (shown in side view) engaged therewith (see, e.g., **FIG. 6**). **FIG. 14** also shows an RF reader **400**. RF reader **400** has a RFID antenna system **402** with at least one antenna element **403**. RF reader **400**, and in particular antenna system **402**, is preferably arranged relative to patch panel module **380** so that in response to interrogation signals **SI** from the RF reader, it can receive RFID tag signals **ST** from RFID tags **200**. Note that antennas **220** for the RFID tags **200** include wires **246** supported by connector **11** and fiber optic cable **150**, as described above.

[0064] **FIG. 15** is a schematic diagram of an example embodiment of a telecommunications assembly **500** with RFID capability and that employs the optical fiber connector assemblies **10** of the present invention. Telecommunications assembly **500** includes a telecommunications rack **510** that supports a number of patch panel shelves **520** that in turn support an even larger number of patch panel assemblies **380** that in turn support an even larger of connector adapters **300** (see first inset **In-1**). The second inset **In-2** in **FIG. 15** is similar to **FIG. 14** and shows a close-up side view of a portion of one of the patch panel assemblies **380** that includes a number of connector adapters **300** with optical fiber connector assemblies **10** engaged therewith via corresponding connectors **11**. At least one RF reader **400** is disposed within, upon or adjacent telecommunications rack **510** so that it can receive RFID tag signals **ST** from RFID tags **200** within telecommunications rack **510** via respective antennas **220** in response to interrogation signals **SI**.

[0065] In example embodiments such as those discussed above, RFID tags **200** are supported by connector assembly **10** (e.g., by connector **11**) or by connector adapter **300**, or RFID tags are respectively supported by the connector assembly and the connector adapter. Two RF readers **400** are shown by way of example as integrated with telecommunications rack **510**, with one RF reader one atop the communications rack and one at the bottom. In general, one or more RF readers **400** can be used, and can be integrated with or simply arranged adjacent to telecommunications rack **510** in any number of ways.

[0066] Because of the large number of connector adapters **300** and connectors **11** within the relatively small space associated with telecommunications rack **510**, the optical fiber connector assemblies **10** of the present invention provide RFID tags **200** with improved RF communication ability. This is accomplished by respective wires **246** having sufficient length L_W so that the corresponding RFID tags **200** can receive interrogation signals **SI** and adequately extract power therefrom. Wires **246** also enable or improve the ability of antennas **220** to send (reflect) respective tag signals **ST** to RF reader **400** with enough strength so that the RF reader can read information from the large number of interrogated RFID tags. The RF reader **400** can also write information to the RFID tags **200** using write signals **SW** because antennas **220** have a sufficient length as provided by wires **246** supported by connector assembly **10**.

[0067] It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. An optical fiber connector assembly that provides radio-frequency antenna capability for at least one radio-frequency identification (RFID) tag, comprising:

a fiber optic cable having an end, a length and an outer surface, and at least one optical fiber;

an optical fiber connector operably connected to the fiber optic cable end; and

at least one wire either electrically connected to the at least one RFID tag or configured to electrically connect to the at least one RFID tag, wherein the at least one wire runs along a portion of the fiber optic cable length so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

2. The optical fiber connector assembly of claim 1, wherein the at least one wire is loosely held to the fiber optic cable to accommodate movement of the fiber optic cable.

3. The optical fiber connector assembly of claim 2, wherein the fiber optic cable outer surface includes at least one groove that at least partially accommodates the at least one wire.

4. The optical fiber connector assembly of claim 2, wherein the at least one wire resides adjacent the fiber optic cable outside surface.

5. The optical fiber connector assembly of claim 1, wherein the at least one RFID tag is included in the optical fiber connector and is electrically connected to the at least one wire.

6. The optical fiber connector assembly of claim 1, wherein the at least one wire includes a first wire and the at least one RFID tag includes a first RFID tag, the assembly further comprising:

a connector adapter configured to operably engage with the optical fiber connector and that includes the first RFID tag and a first electrical contact electrically connected to the first RFID tag; and

a connector electrical contact supported by the optical fiber connector and electrically connected to the first wire and configured to electrically contact the first electrical contact when the connector and connector adapter operably engage so that the first wire serves as at least a portion of the RFID antenna for the first RFID tag.

7. The optical fiber connector of claim 6, wherein the at least one wire further includes a second wire and the at least one RFID tag includes a second RFID tag, and wherein:

the connector supports the second RFID tag; and

the second wire is electrically connected to the second RFID tag and serves as the portion of the RFID antenna for the second RFID tag.

8. The optical fiber connector assembly of claim 1, further including:

a connector adapter configured to operably engage with the optical fiber connector and that includes the at least one RFID tag and a flange portion that includes at least a portion of an antenna connected to the at least one RFID.

9. The optical fiber connector assembly of claim 1, wherein the at least one wire has an exposed section with a length L_W in a range defined by 10 cm $\leq L_W \leq$ 15 cm.

10. A telecommunications assembly with RFID capability, comprising:

a plurality of connector assemblies according to claim 1;

plurality of connector adapters having respective RFID tags and that are operably engaged with the plurality of connector assemblies so that the RFID tags are respectively electrically connected to respective wires of the corresponding connector assemblies; and

at least one RF reader arranged in relation to the wires so as to operably communicate with the plurality of RFID tags via the respective wires.

11. The telecommunications assembly of claim 10, wherein one or more of the RFID tags have respective antennas, and wherein the respective wires of said one or more RFID tags are electrically connected to the respective antennas.

12. The telecommunications assembly of claim 10, wherein the respective wires of said one or more RFID tags serve as substantially an entire antennas for the corresponding one or more RFID tags.

13. An optical fiber connector assembly that provides radio-frequency antenna capability for at least one radio-frequency identification (RFID) tag, comprising:

a fiber optic cable having an end, a length and an outer surface;

an optical fiber connector operably connected to the fiber optic cable end;

a connector adapter configured to operably engage the optical fiber connector and that includes the at least one RFID tag; and

at least one wire that runs along a portion of the fiber optic cable length and that is configured to electrically connect to the at least one RFID tag when the connector and connector adapter are operably engaged so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

14. The optical fiber connector assembly of claim 13, wherein the at least one wire serves as substantially an entire RFID antenna for the at least one RFID tag.

15. The optical fiber connector assembly of claim 13, wherein the at least one wire is loosely held to the fiber optic cable to accommodate movement of the fiber optic cable.

16. The optical fiber connector assembly of claim 13, wherein the fiber optic cable includes at least one groove, and wherein the at least one wire is at least partially supported within the at least one groove.

17. A method of providing radio-frequency antenna capability for at least one radio-frequency identification (RFID) tag having an integrated circuit chip, comprising:

providing a connectorized fiber optic cable having a length and a connector;

disposing at least one wire to run from the connector and along an outside portion of the fiber optic cable length;

electrically connecting the at least on wire to the integrated circuit chip of the RFID tag so as to serve as at least a portion of an RFID antenna for the at least one RFID tag.

18. The method of claim 17, further comprising:

supporting the at least one RFID tag by the connector.

19. The method of claim 17, further comprising:

supporting the at least one RFID tag by a connector adapter that is configured to operably engage with the connector; and

operably engaging the connector and connector adapter so as to cause the at least one wire to be electrically connected to the integrated circuit chip.

20. The method of claim 19, where electrically connecting the at least one wire to the integrated circuit chip further comprises electrically connecting the at least one wire to an RFID antenna section that is electrically connected to the integrated circuit chip.

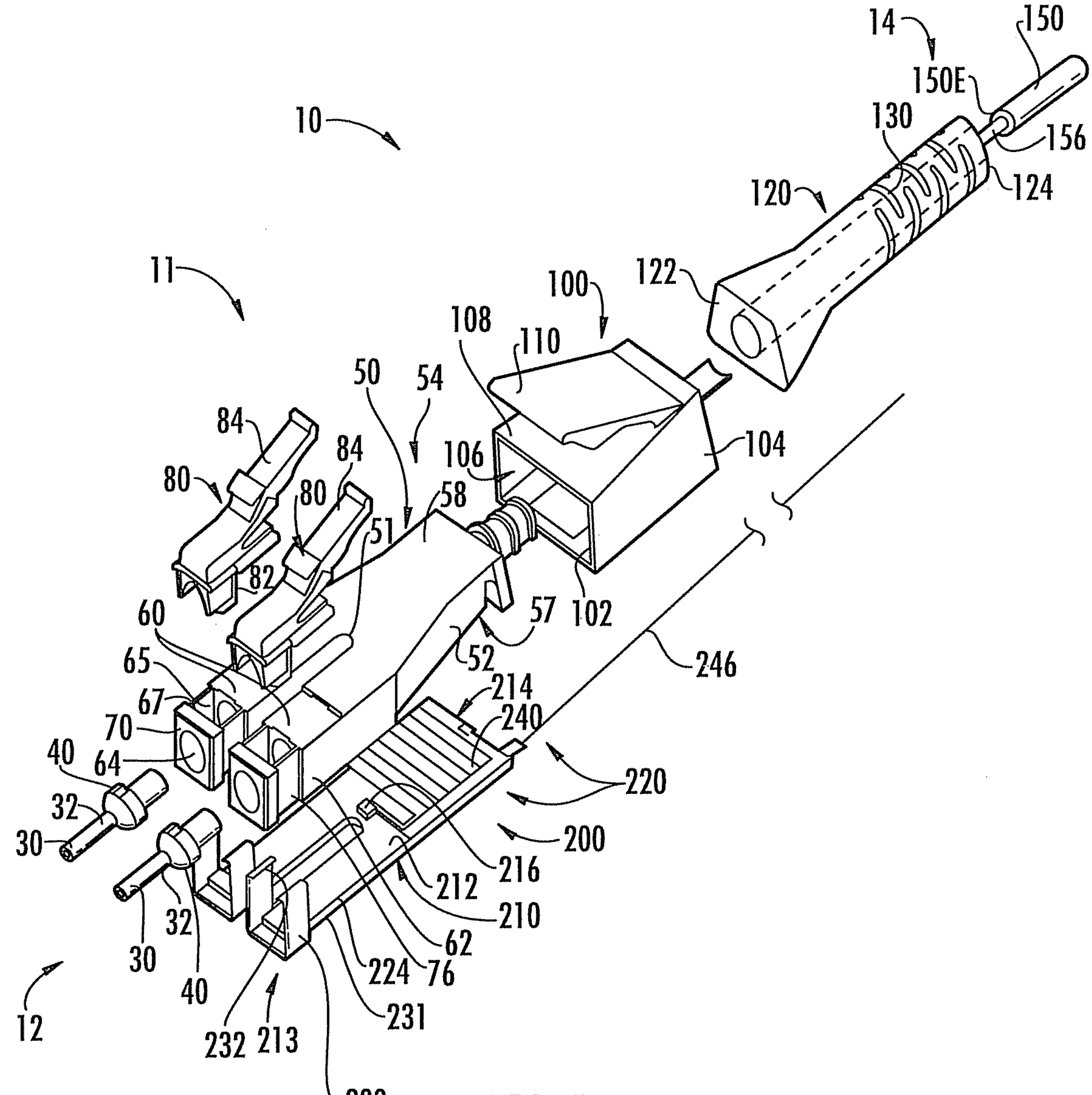
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FIG. 1

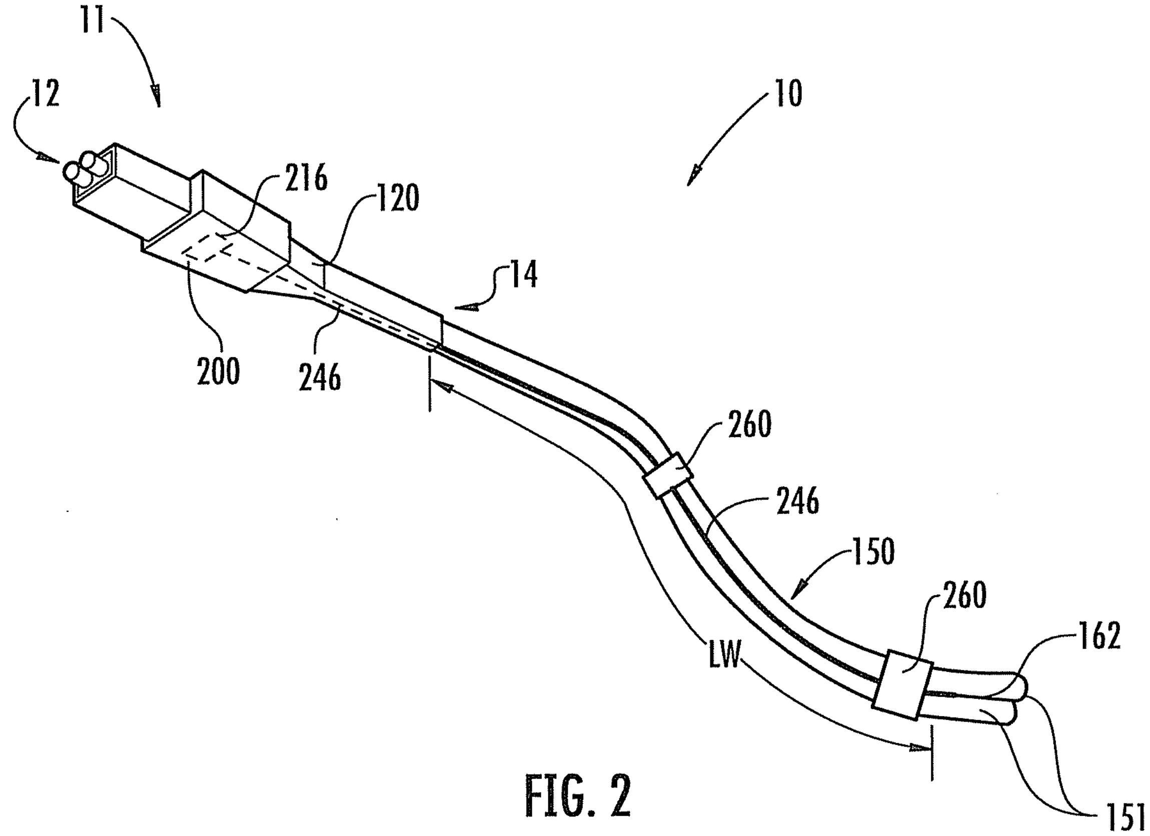


FIG. 2

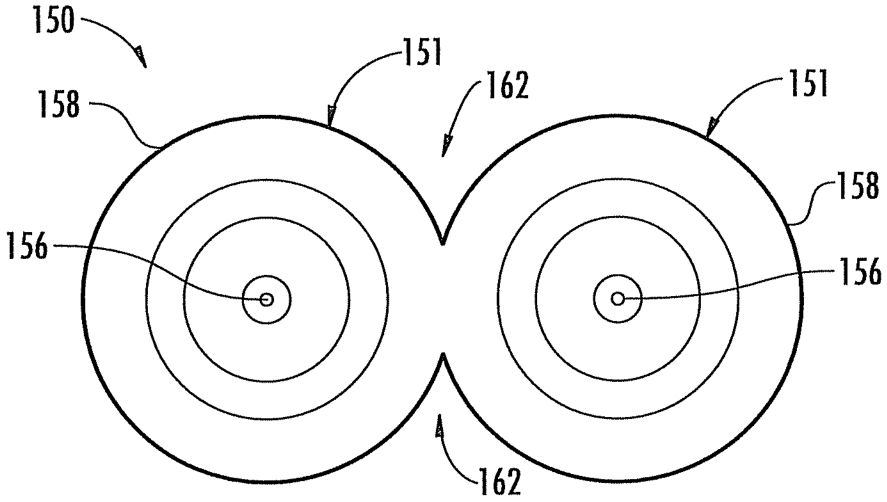


FIG. 3

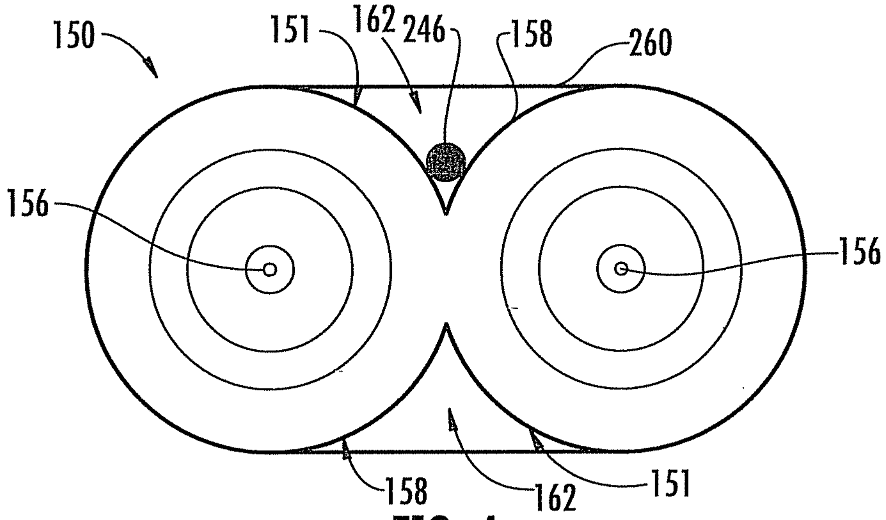


FIG. 4

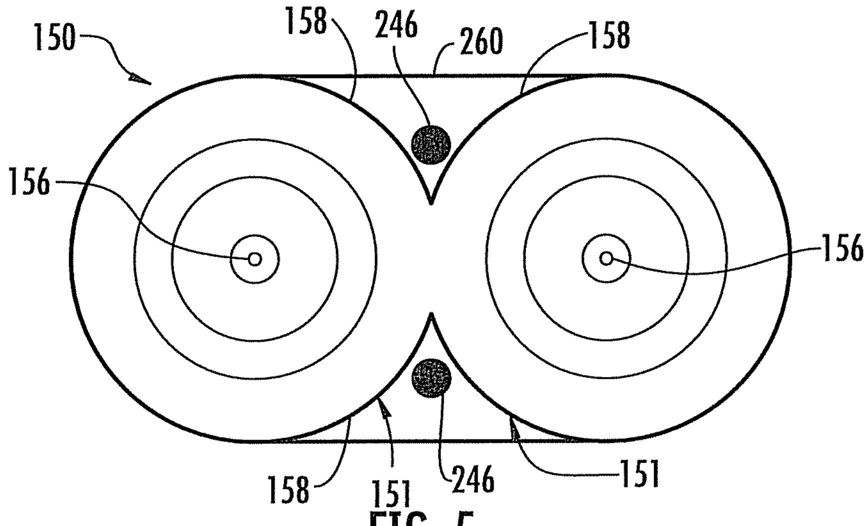
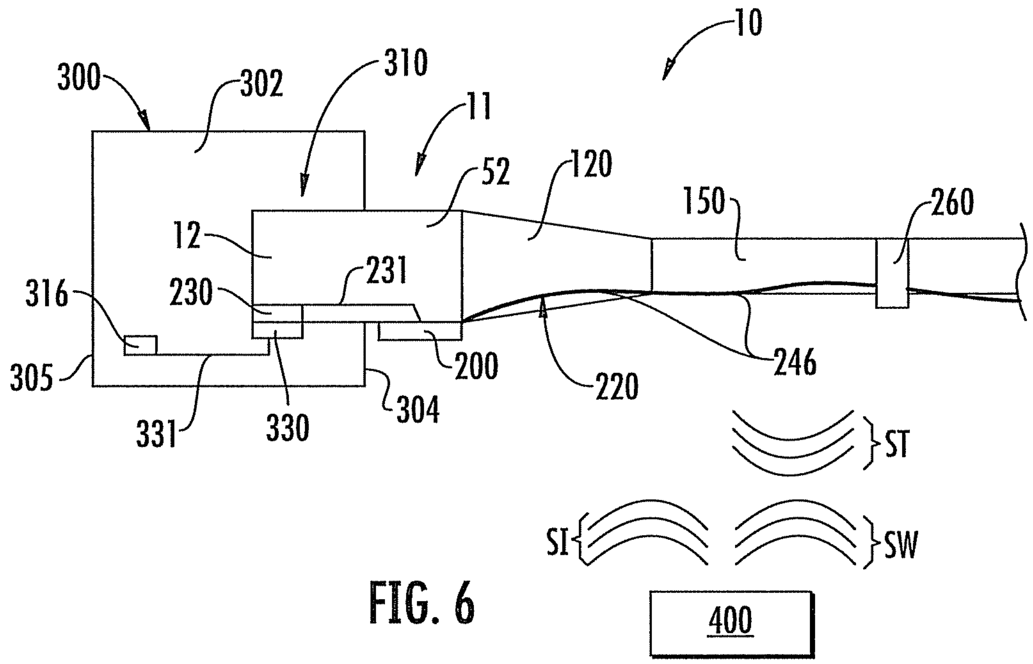


FIG. 5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316
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220
246
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SW
400

FIG. 6

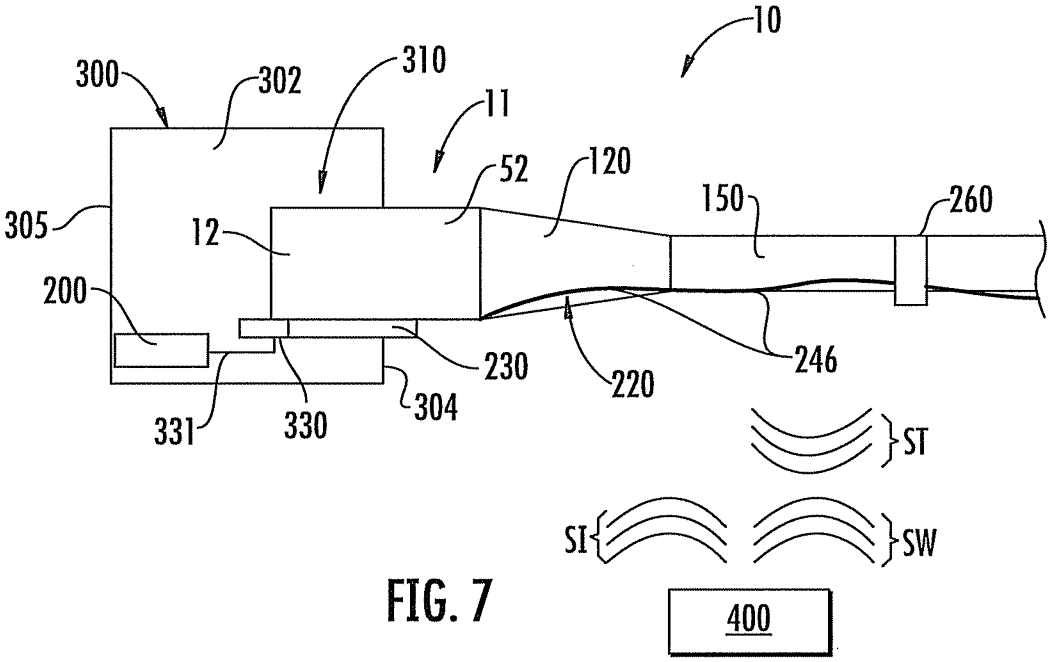
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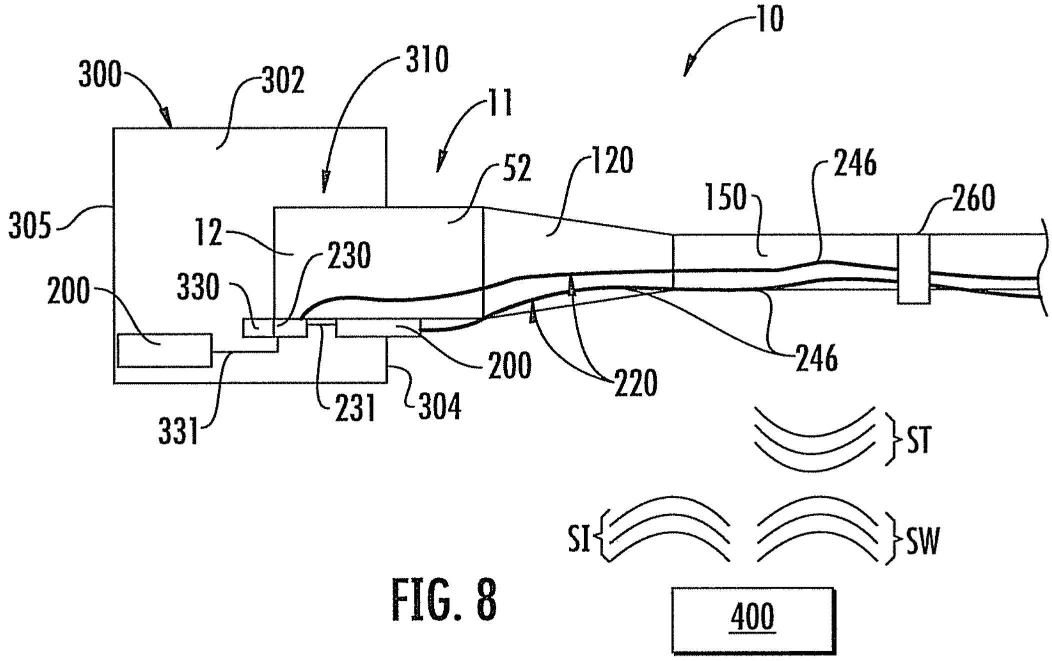
FIG. 7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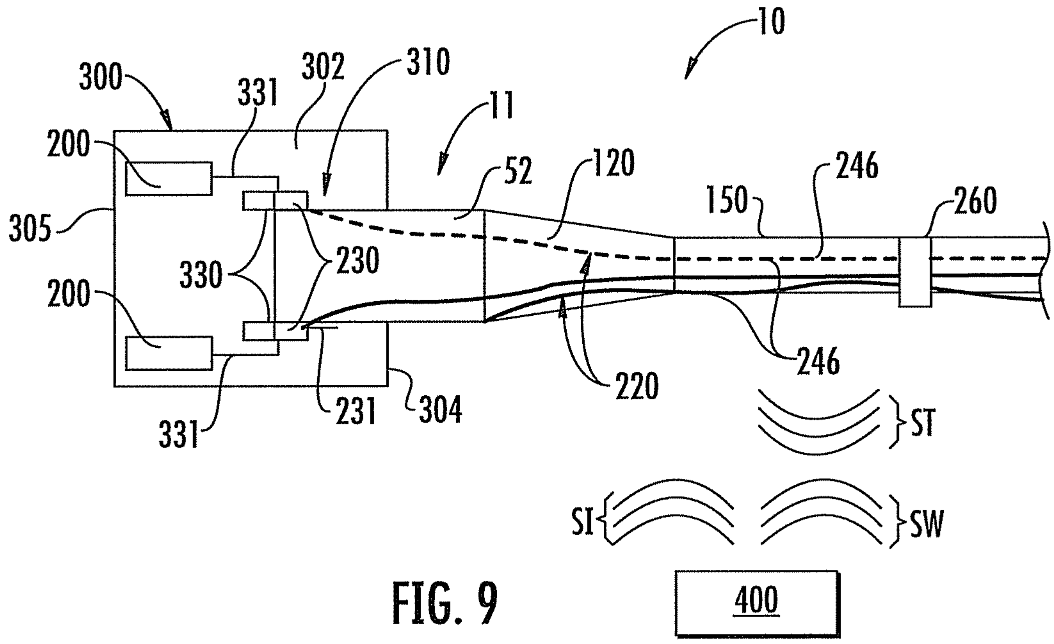
304
ST
SI
SW
400

FIG. 8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SI
SW
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FIG. 9

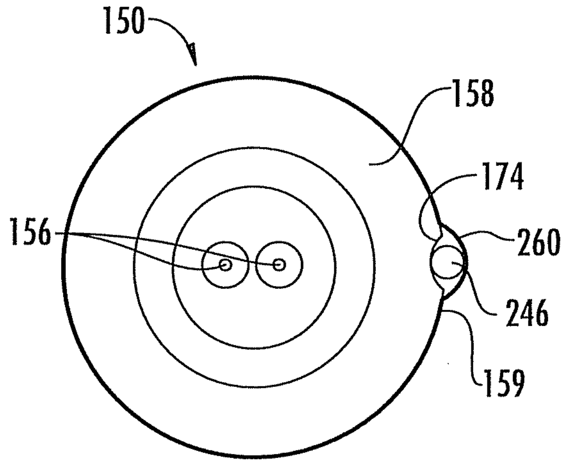

FIG. 10A

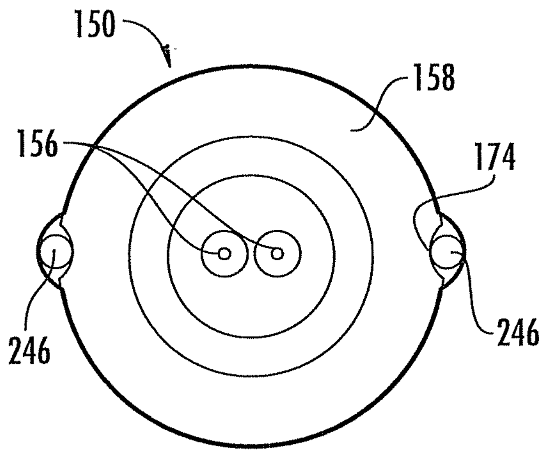

FIG. 10B

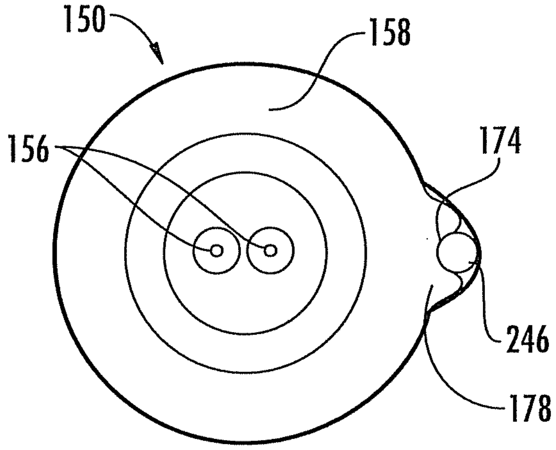

FIG. 10C

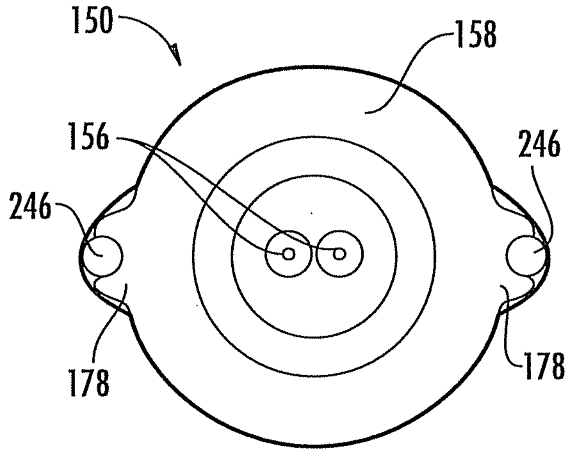

FIG. 10D

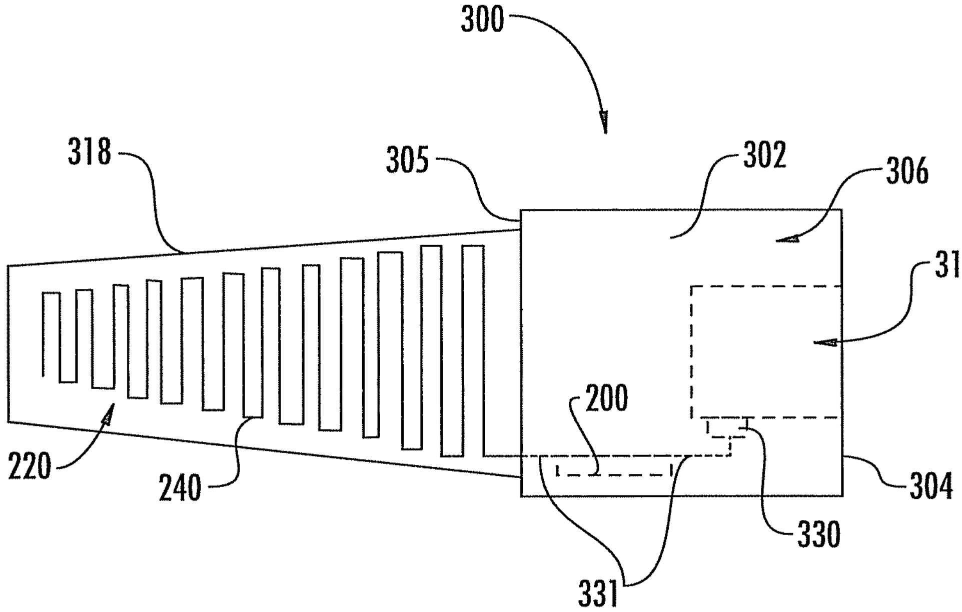

FIG. 11

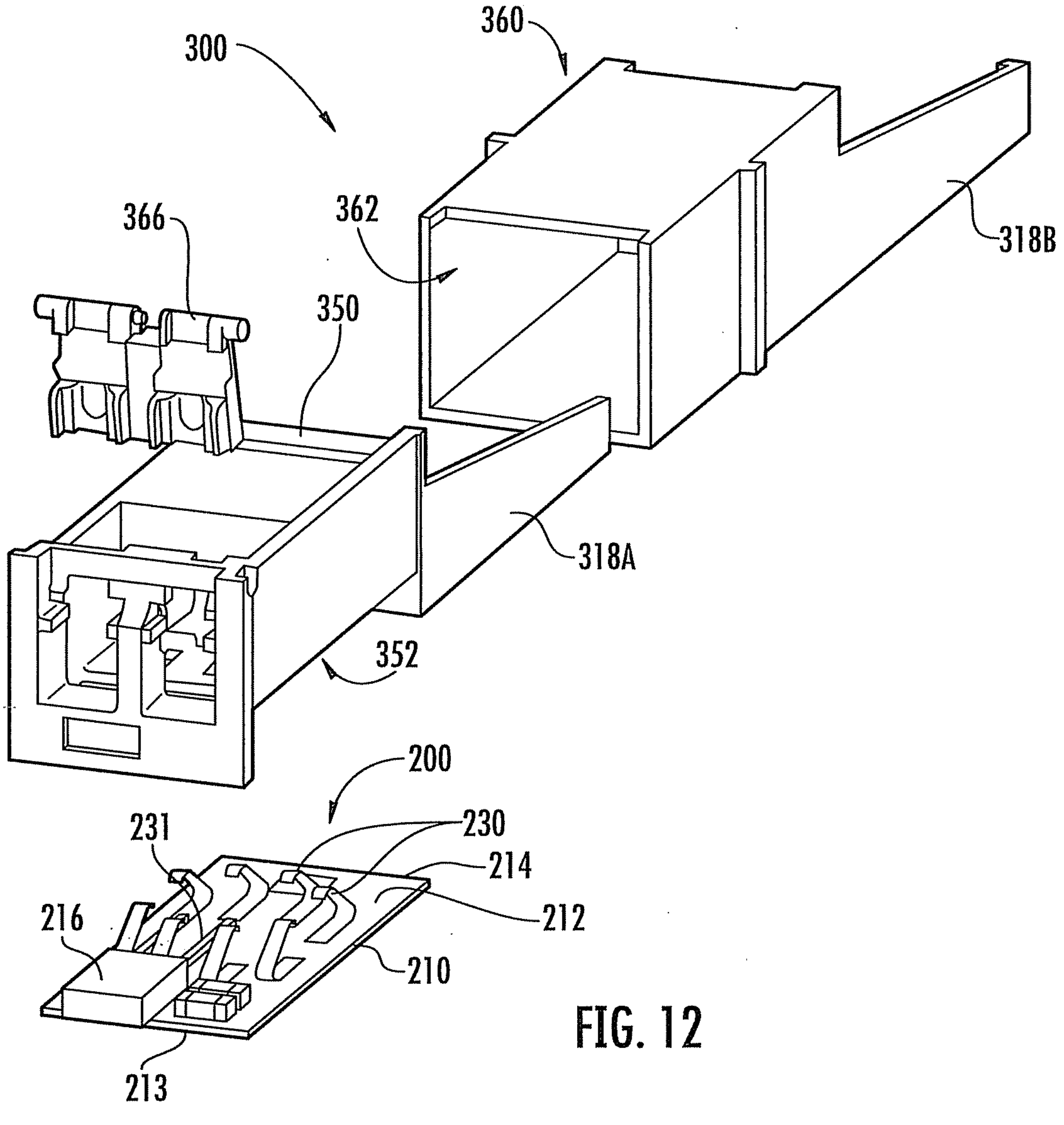
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FIG. 12

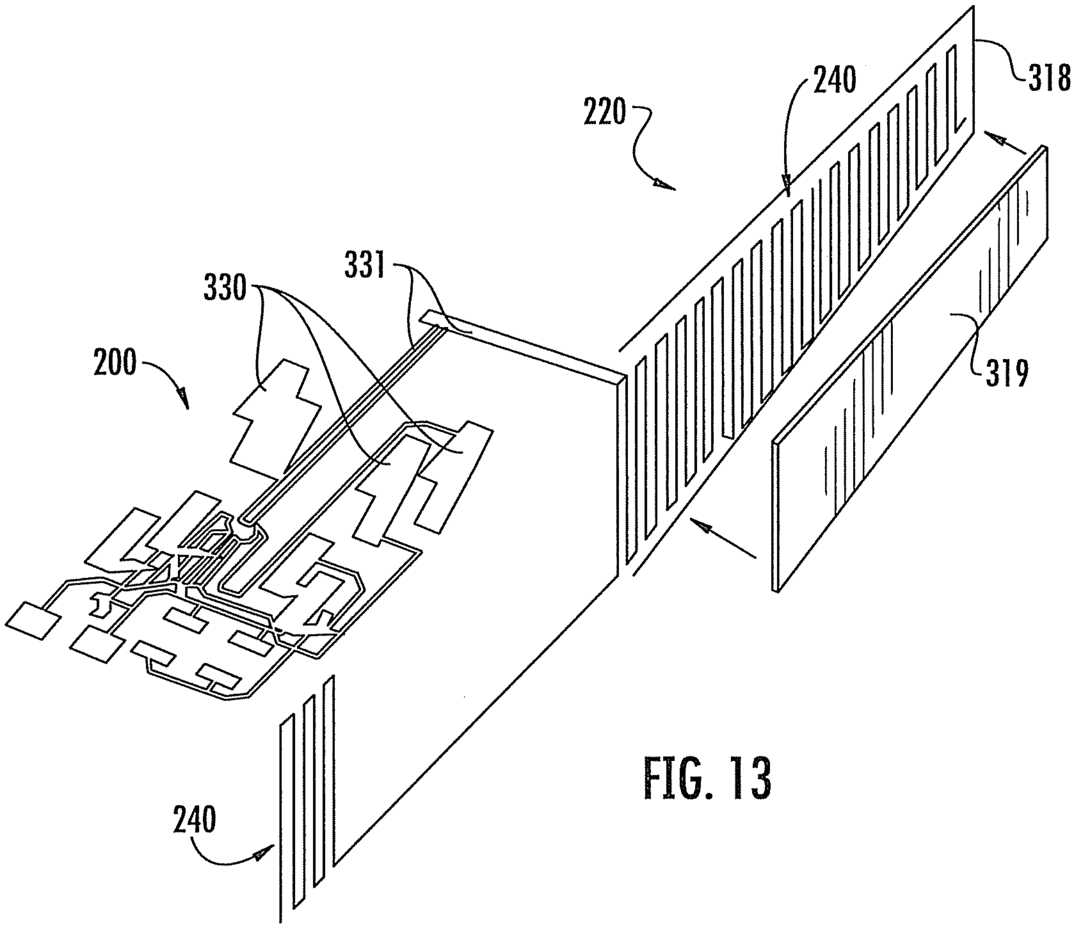
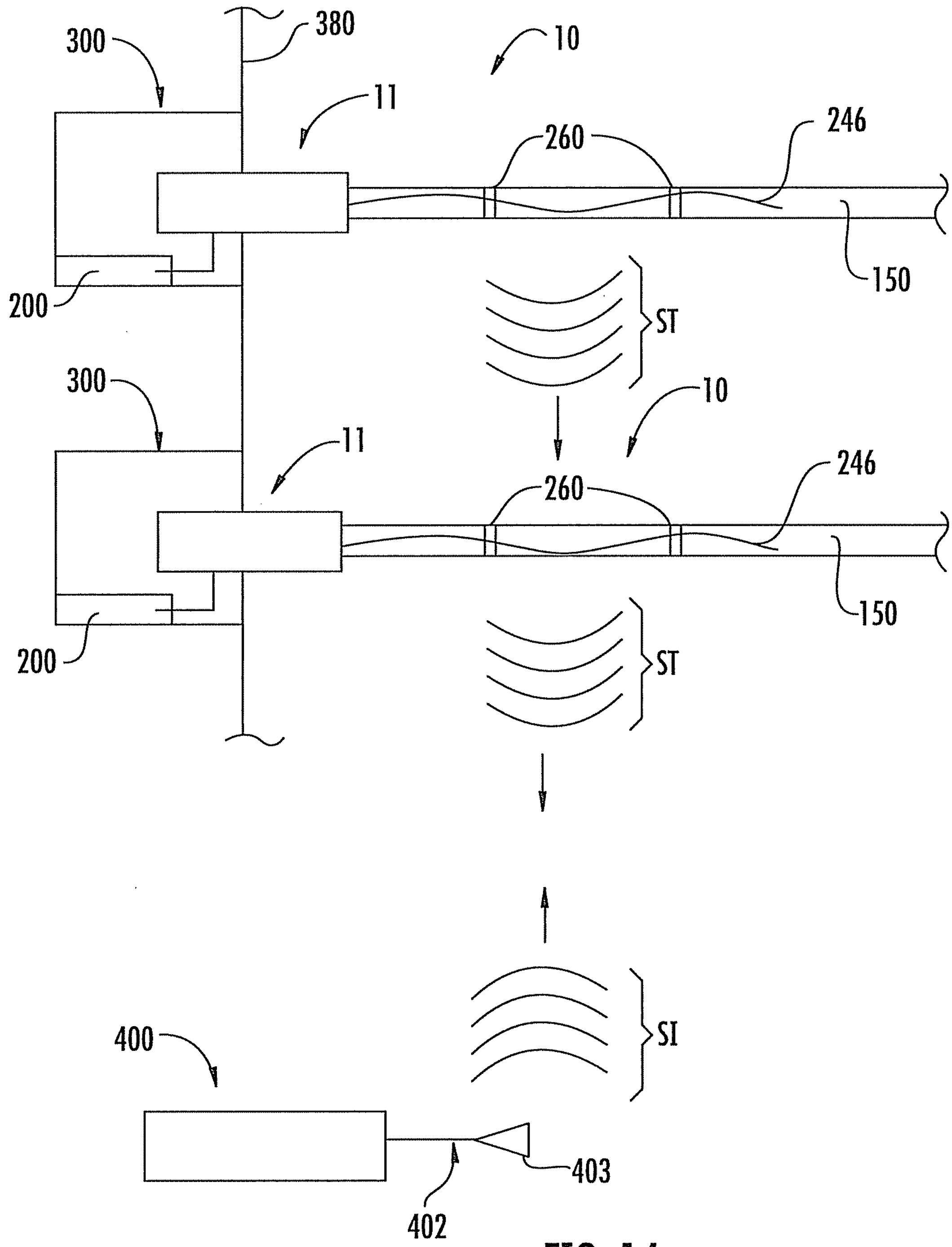


FIG. 13


380
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ST
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10
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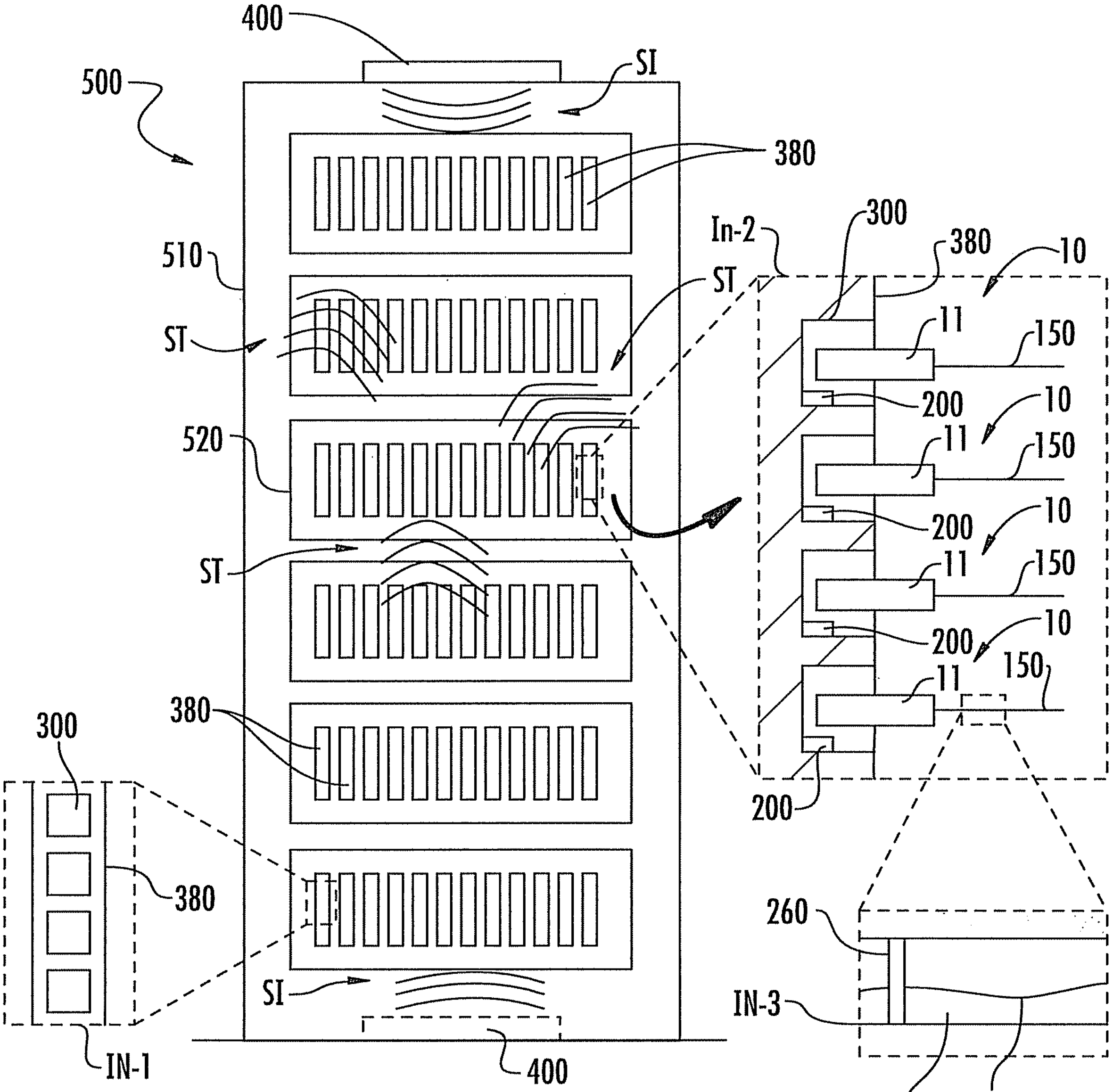
150
200
ST
SI
400
403
402

FIG. 14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246

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/058192

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B6/38
ADD. G06K7/00

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)
G02B G06K H01R

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008/100467 A1 (DOWNIE JOHN D [US] ET AL) 1 May 2008 (2008-05-01) abstract paragraphs [0004], [0006], [0011], [0012], [0044] - [0050]; figures 8-11	1-20
Y	WO 2007/138669 A (MATSUSHITA ELECTRIC IND CO LTD [JP]; MATUURA IWAO) 6 December 2007 (2007-12-06) figure 1	1-20
A	US 6 808 116 B1 (ESLAMBOLCHI HOSSEIN [US] ET AL) 26 October 2004 (2004-10-26) abstract column 5, line 4 - column 6, line 19	1,13,17

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"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	Date of mailing of the international search report
27 November 2009	07/12/2009

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/058192

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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P,X	US 2008/273844 A1 (KEWITSCH ANTHONY S [US]) 6 November 2008 (2008-11-06) abstract paragraphs [0020], [0024], [0029], [0032], [0033], [0038], [0045] - [0054]; figures 5-7 -----	1-8, 10-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2009/058192

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