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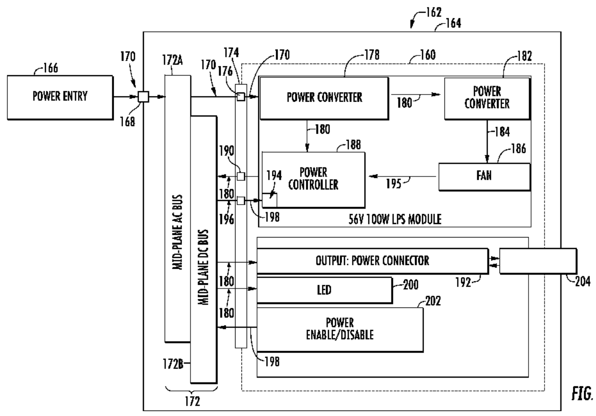

FIG. 7

(57) Abstract: Power distribution modules capable of "hot" connection and/or disconnection in distributed antenna systems (DAS), and related components, power units, and methods are disclosed. The power distribution modules are configured to distribute power to a power-consuming DAS component(s), such as a remote antenna unit(s) (RAU(s)). By "hot" connection and/or disconnection, it is meant that the power distribution modules can be connected and/or disconnected from a power unit and/or a power-consuming DAS component(s) while power is being provided to the power distribution modules. Power is not required to be disabled in the power unit before connection and/or disconnection of power distribution modules. As a non-limiting example, the power distribution modules may be configured to protect against or reduce electrical arcing or electrical contact erosion that may otherwise result from "hot" connection and/or connection of the power distribution modules.

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POWER DISTRIBUTION MODULE(S) CAPABLE OF HOT CONNECTION AND/OR DISCONNECTION FOR DISTRIBUTED ANTENNA SYSTEMS, AND RELATED POWER UNITS, COMPONENTS, AND METHODS

PRIORITY APPLICATION

[0001] The present application claims priority to U.S. Provisional Patent Application Serial No. 61/416,780 filed on November 24, 2010, entitled "Power Distribution Devices, Systems, and Methods for Radio-over-Fiber (RoF) Distributed Communication," which is incorporated herein by reference in its entirety.

RELATED APPLICATION

[0002] This application is related to U.S. Patent Application Serial No. 12/466,514 filed on filed May 15, 2009 and entitled "Power Distribution Devices, Systems, and Methods For Radio-Over-Fiber (RoF) Distributed Communication," which is incorporated herein by reference in its entirety.

BACKGROUND

Field of the Disclosure

[0003] The technology of the disclosure relates to power units for providing power to remote antenna units in a distributed antenna system.

Technical Background

[0004] Wireless communication is rapidly growing, with ever-increasing demands for high-speed mobile data communication. As an example, so-called "wireless fidelity" or "WiFi" systems and wireless local area networks (WLANs) are being deployed in many different types of areas (e.g., coffee shops, airports, libraries, etc.). Distributed communications or antenna systems communicate with wireless devices called "clients," which must reside within the wireless range or "cell coverage area" in order to communicate with an access point device.

[0005] One approach to deploying a distributed antenna system involves the use of radio frequency (RF) antenna coverage areas, also referred to as "antenna coverage areas." Antenna coverage areas can have a radius in the range from a few meters up to twenty meters as an example. Combining a number of access point devices creates an array of antenna coverage areas. Because the antenna coverage areas each cover small areas, there are typically only a few users (clients) per antenna coverage area. This allows for minimizing the amount of RF bandwidth shared among the wireless system users. It may be desirable to provide antenna coverage areas in a building or other facility to provide distributed antenna system access to clients within the building or facility. However, it may be desirable to employ optical fiber to distribute communication signals. Benefits of optical fiber include increased bandwidth.

[0006] One type of distributed antenna system for creating antenna coverage areas includes distribution of RF communications signals over an electrical conductor medium, such as coaxial cable or twisted pair wiring. Another type of distributed antenna system for creating antenna coverage areas, called "Radio-over-Fiber" or "RoF," utilizes RF communications signals sent over optical fibers. Both types of systems can include head-end equipment coupled to a plurality of remote antenna units (RAUs) that each provides antenna coverage areas. The RAUs can each include RF transceivers coupled to an antenna to transmit RF communications signals wirelessly, wherein the RAUs are coupled to the head-end equipment via the communication medium. The RF transceivers in the remote antenna units are transparent to the RF communications signals. The antennas in the RAUs also receive RF signals (i.e., electromagnetic radiation) from clients in the antenna coverage area. The RF signals are then sent over the communication medium to the head-end equipment. In optical fiber or RoF distributed antenna systems, the RAUs convert incoming optical RF signals from an optical fiber downlink to electrical RF signals via optical-to-electrical (O/E) converters, which are then passed to the RF transceiver. The RAUs also convert received electrical RF communications signals from clients via the antennas to optical RF communications signals via electrical-to-optical (E/O) converters. The optical RF signals are then sent over an optical fiber uplink to the head-end equipment.

[0007] The RAUs contain power-consuming components, such as the RF transceiver, to transmit and receive RF communications signals and thus require power to operate. In the situation of an optical fiber-based distributed antenna system, the RAUs may contain O/E and E/O converters that also require power to operate. As an example, the RAU may contain a housing that includes a power supply to provide power to the RAUs locally at the RAU. The power supply may be configured to be connected to a power source, such as an alternating current (AC) power source, and convert AC power into a direct current (DC) power signal. Alternatively, power may be provided to the RAUs from remote power supplies. The remote power suppliers may be configured to provide power to multiple RAUs. It may be desirable to provide these power supplies in modular units or devices that may be easily inserted or removed from a housing to provide power. Providing modular power distribution modules allows power to more easily be configured as needed for the distributed antenna system. For example, a remotely located power unit may be provided that contains a plurality of ports or slots to allow a plurality of power distribution modules to be inserted therein. The power unit may have ports that allow the power to be provided over an electrical conductor medium to the RAUs. Thus, when a power distribution module is inserted in the power unit in a port or slot that corresponds to a given RAU, power from the power distribution module is supplied to the RAU.

[0008] It may be desired to allow these power distribution modules to be inserted and removed from the power unit without deactivating other power distribution modules providing power to other RAUs. If power to the power unit were required to be deactivated, RF communications for all RAUs that receiver power from the power unit may be disabled, even if the power distribution module inserted and/or removed from the power unit is configured to supply power to only a subset of the RAUs receiving power from the power unit. However, inserting and removing power distribution modules in a power unit while power is active and being provided in the power unit may cause electrical arcing and electrical contact erosion that can damage the power distribution module or power-consuming components connected to the power distribution module.

SUMMARY OF THE DETAILED DESCRIPTION

[0009] Embodiments disclosed in the detailed description include power distribution modules capable of “hot” connection and/or disconnection in distributed antenna systems (DASs). Related power units, components, and methods are also disclosed. By “hot” connection and/or disconnection, it is meant that the power distribution modules can be connected and/or disconnected from a power unit and/or power-consuming components while power is being provided to the power distribution modules. In this regard, it is not required to disable providing power to the power distribution module before connection and/or disconnection of power distribution modules to a power unit and/or power-consuming components. As a non-limiting example, the power distribution modules may be configured to protect against or reduce electrical arcing or electrical contact erosion that may otherwise result from “hot” connection and/or disconnection.

[0010] In embodiments disclosed herein, the power distribution modules can be installed in and connected to a power unit for providing power to a power-consuming DAS component(s), such as a remote antenna unit(s) (RAU(s)) as a non-limiting example. Main power is provided to the power unit and distributed to power distribution modules installed and connected in the power unit. Power from the main power provided by the power unit is distributed by each of the power distribution modules to any power-consuming DAS components connected to the power distribution modules. The power distribution modules distribute power to the power-consuming DAS components to provide power for power-consuming components in the power-consuming DAS components.

[0011] In this regard in one embodiment, a power distribution module for distributing power in a distributed antenna system is provided. The power distribution module comprises an input power port configured to receive input power from an external power source. The power distribution module also comprises at least one output power port configured to receive output power and distribute the output power to at least one distributed antenna system (DAS) power-consuming device electrically coupled to the at least one output power port. The power distribution module also comprises at least one power controller configured to selectively distribute output power as the input power to the at least one output power port based on a power enable signal coupled to the enable input port. Other embodiments are also disclosed herein.

[0012] The accompanying drawings are included to provide a further understanding, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments, and together with the description serve to explain the principles and operation of the concepts disclosed.

BRIEF DESCRIPTION OF THE FIGURES

[0013] **FIG. 1** is a schematic diagram of an exemplary distributed antenna system;

[0014] **FIG. 2** is a more detailed schematic diagram of exemplary head-end equipment and a remote antenna unit (RAU) that can be deployed in the distributed antenna system of **FIG. 1**;

[0015] **FIG. 3A** is a partially schematic cut-away diagram of an exemplary building infrastructure in which the distributed antenna system in **FIG. 1** can be employed;

[0016] **FIG. 3B** is an alternative diagram of the distributed antenna system in **FIG. 3A**;

[0017] **FIG. 4** is a schematic diagram of exemplary head-end equipment (HEE) to provide radio frequency (RF) communication services to RAUs or other remote communications devices in a distributed antenna system;

[0018] **FIG. 5** is a schematic diagram of an exemplary distributed antenna system with alternative equipment to provide RF communication services and digital data services to RAUs or other remote communications devices in a distributed antenna system;

[0019] **FIG. 6** is a schematic diagram of providing digital data services and RF communication services to RAUs or other remote communications devices in the distributed antenna system of **FIG. 5**;

[0020] **FIG. 7** is a schematic diagram of an exemplary power distribution module that is supported by a power unit and is capable of “hot” connection and/or disconnection;

[0021] **FIG. 8** is a schematic diagram of internal components of the power distribution module in **FIG. 7** to allow “hot” connection and/or disconnection of the power distribution module from a power unit and remote antenna units (RAUs) in a distributed antenna system;

[0022] **FIG. 9** is a side perspective view of an input power connector in the power distribution module of **FIG. 7** configured to be inserted into an input power connector in a power unit to receive input power from the power unit, and an output power connector of a power cable configured to be inserted into an output power connector in the power distribution module of **FIG. 7** to distribute output power from the power distribution module through the output power connector and power cable to at least one power-consuming DAS device;

[0023] **FIG. 10A** illustrates a front, side perspective view of an exemplary power distribution module with a cover installed;

[0024] **FIG. 10B** illustrates a front, side perspective view of the power distribution module in **FIG. 10A** with the cover removed;

[0025] **FIG. 10C** illustrates a rear, side perspective view of the power distribution module in **FIG. 10A**;

[0026] **FIG. 11** is a schematic diagram of the power controller in the power distribution module in **FIG. 8**;

[0027] **FIG. 12** is a side view of input power receptacles of the input power connector in the power distribution module in **FIG. 8** aligned to be connected to input power ports in an input power connector of the power unit in **FIG. 8**;

[0028] **FIG. 13** is a side view of output power pins of the output power connector of the power cable in **FIG. 8** aligned to be connected to output power receptacles of the output power connector in the power distribution module in **FIG. 8**;

[0029] **FIG. 14** is a schematic diagram of an exemplary power unit configured to support one or more power distribution modules to provide power to RAUs in a distributed antenna system; and

[0030] **FIG. 15** is a schematic diagram of a generalized representation of an exemplary computer system that can be included in the power distribution modules disclosed herein, wherein the exemplary computer system is adapted to execute instructions from an exemplary computer-readable media.

DETAILED DESCRIPTION

[0031] Reference will now be made in detail to the embodiments, examples of which are illustrated in the accompanying drawings, in which some, but not all embodiments are shown. Indeed, the concepts may be embodied in many different forms and should not be construed as limiting herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Whenever possible, like reference numbers will be used to refer to like components or parts.

[0032] Embodiments disclosed in the detailed description include power distribution modules capable of “hot” connection and/or disconnection in distributed antenna systems (DASs). Related components, power units, and methods are also disclosed. By “hot” connection and/or disconnection, it is meant that the power distribution modules can be connected and/or disconnected from a power unit and/or power-consuming components while power is being provided to the power distribution modules. In this regard, it is not required to disable providing power to the power distribution module before connection and/or disconnection of power distribution modules to a power unit and/or power-consuming components. As a non-limiting example, the power distribution modules may be configured to protect against or reduce electrical arcing or electrical contact erosion that may otherwise result from “hot” connection and/or disconnection.

[0033] In embodiments disclosed herein, the power distribution modules can be installed in and connected to a power unit for providing power to a power-consuming DAS component(s), such as a remote antenna unit(s) (RAU(s)) as a non-limiting example. Main power is provided to the power unit and distributed to power distribution modules installed and connected in the power unit. Power from the main power provided by the power unit is distributed by each of the power distribution modules to any power-consuming DAS components connected to the power distribution modules. The power distribution modules distribute power to the power-consuming DAS components to provide power for power-consuming components in the power-consuming DAS components.

[0034] Before discussing examples of power distribution modules capable of “hot” connection and/or disconnection in distributed antenna systems (DASs), exemplary distributed antenna systems capable of distributing RF communications signals to distributed or remote antenna units (RAUs) are first described with regard to **FIGS. 1-6**. The distributed antenna systems in **FIGS. 1-6** can include power units located remotely from RAUs that provide power to the RAUs for operation. Embodiments of power distribution modules capable of “hot” connection and/or disconnection in distributed antenna systems, including the distributed antenna systems in **FIGS. 1-6**, begin with **FIG. 7**. The distributed antenna systems in **FIGS. 1-6** discussed below include distribution of radio frequency (RF) communications signals; however, the distributed antenna systems are not limited to distribution of RF communications signals. Also note that while the distributed antenna systems in **FIGS. 1-6** discussed below include distribution of communications signals over optical fiber, these distributed antenna systems are not limited to distribution over optical fiber. Distribution mediums could also include, but are not limited to, coaxial cable, twisted-pair conductors, wireless transmission and reception, and any combination thereof. Also, any combination can be employed that also involves optical fiber for portions of the distributed antenna system.

[0035] In this regard, **FIG. 1** is a schematic diagram of an embodiment of a distributed antenna system. In this embodiment, the system is an optical fiber-based distributed antenna system **10**. The distributed antenna system **10** is configured to create one or more antenna coverage areas for establishing communications with wireless client devices located in the RF range of the antenna coverage areas. The distributed antenna system **10** provides RF communication services (e.g., cellular services). In this embodiment, the distributed antenna system **10** includes head-end equipment (HEE) **12** such as a head-end unit (HEU), one or more remote antenna units (RAUs) **14**, and an optical fiber **16** that optically couples the HEE **12** to the RAU **14**. The RAU **14** is a type of remote communications unit. In general, a remote communications unit can support either wireless communications, wired communications, or both. The RAU **14** can support wireless communications and may also support wired communications. The HEE **12** is configured to receive communications over downlink electrical RF signals **18D** from a source or sources, such as a network or carrier as examples, and provide such communications to the RAU **14**. The HEE **12** is also configured to return communications received from the RAU **14**, via uplink electrical RF signals **18U**, back to the source or sources. In this regard in this embodiment, the optical fiber **16** includes at least one downlink optical fiber **16D** to carry signals communicated from the HEE **12** to the RAU **14** and at least one uplink optical fiber **16U** to carry signals communicated from the RAU **14** back to the HEE **12**.

[0036] One downlink optical fiber **16D** and one uplink optical fiber **16U** could be provided to support multiple channels each using wave-division multiplexing (WDM), as discussed in U.S. Patent Application Serial No. 12/892,424 entitled "Providing Digital Data Services in Optical Fiber-based Distributed Radio Frequency (RF) Communications Systems, And Related Components and Methods," incorporated herein by reference in its entirety. Other options for WDM and frequency-division multiplexing (FDM) are disclosed in U.S. Patent Application Serial No. 12/892,424, any of which can be employed in any of the embodiments disclosed herein. Further, U.S. Patent Application Serial No. 12/892,424 also discloses distributed digital data communications signals in a distributed antenna system which may also be distributed in the optical fiber-based distributed antenna system **10** either in conjunction with RF communications signals or not.

[0037] The optical fiber-based distributed antenna system **10** has an antenna coverage area **20** that can be disposed about the RAU **14**. The antenna coverage area **20** of the RAU **14** forms an RF coverage area **21**. The HEE **12** is adapted to perform or to facilitate any one of a number of Radio-over-Fiber (RoF) applications, such as RF identification (RFID), wireless local-area network (WLAN) communication, or cellular phone service. Shown within the antenna coverage area **20** is a client device **24** in the form of a mobile device as an example, which may be a cellular telephone as an example. The client device **24** can be any device that is capable of receiving RF communications signals. The client device **24** includes an antenna **26** (e.g., a wireless card) adapted to receive and/or send electromagnetic RF signals.

[0038] With continuing reference to **FIG. 1**, to communicate the electrical RF signals over the downlink optical fiber **16D** to the RAU **14**, to in turn be communicated to the client device **24** in the antenna coverage area **20** formed by the RAU **14**, the HEE **12** includes a radio interface in the form of an electrical-to-optical (E/O) converter **28**. The E/O converter **28** converts the downlink electrical RF signals **18D** to downlink optical RF signals **22D** to be communicated over the downlink optical fiber **16D**. The RAU **14** includes an optical-to-electrical (O/E) converter **30** to convert received downlink optical RF signals **22D** back to electrical RF signals to be communicated wirelessly through an antenna **32** of the RAU **14** to client devices **24** located in the antenna coverage area **20**.

[0039] Similarly, the antenna **32** is also configured to receive wireless RF communications from client devices **24** in the antenna coverage area **20**. In this regard, the antenna **32** receives wireless RF communications from client devices **24** and communicates electrical RF signals representing the wireless RF communications to an E/O converter **34** in the RAU **14**. The E/O converter **34** converts the electrical RF signals into uplink optical RF signals **22U** to be communicated over the uplink optical fiber **16U**. An O/E converter **36** provided in the HEE **12** converts the uplink optical RF signals **22U** into uplink electrical RF signals, which can then be communicated as uplink electrical RF signals **18U** back to a network or other source. The HEE **12** in this embodiment is not able to distinguish the location of the client devices **24** in this embodiment. The client device **24** could be in the range of any antenna coverage area **20** formed by an RAU **14**.

[0040] **FIG. 2** is a more detailed schematic diagram of the exemplary distributed antenna system **10** of **FIG. 1** that provides electrical RF service signals for a particular RF service or application. In an exemplary embodiment, the HEE **12** includes a service unit **37** that provides electrical RF service signals by passing (or conditioning and then passing) such signals from one or more outside networks **38** via a network link **39**. In a particular example embodiment, this includes providing cellular signal distribution in the frequency range from 400 MegaHertz (MHz) to 2.7 GigaHertz (GHz). Any other electrical RF signal frequencies are possible. In another exemplary embodiment, the service unit **37** provides electrical RF service signals by generating the signals directly. In another exemplary embodiment, the service unit **37** coordinates the delivery of the electrical RF service signals between client devices **24** within the antenna coverage area **20**.

[0041] With continuing reference to **FIG. 2**, the service unit **37** is electrically coupled to the E/O converter **28** that receives the downlink electrical RF signals **18D** from the service unit **37** and converts them to corresponding downlink optical RF signals **22D**. In an exemplary embodiment, the E/O converter **28** includes a laser suitable for delivering sufficient dynamic range for the RoF applications described herein, and optionally includes a laser driver/amplifier electrically coupled to the laser. Examples of suitable lasers for the E/O converter **28** include, but are not limited to, laser diodes, distributed feedback (DFB) lasers, Fabry-Perot (FP) lasers, and vertical cavity surface emitting lasers (VCSELs).

[0042] With continuing reference to **FIG. 2**, the HEE **12** also includes the O/E converter **36**, which is electrically coupled to the service unit **37**. The O/E converter **36** receives the uplink optical RF signals **22U** and converts them to corresponding uplink electrical RF signals **18U**. In an example embodiment, the O/E converter **36** is a photodetector, or a photodetector electrically coupled to a linear amplifier. The E/O converter **28** and the O/E converter **36** constitute a "converter pair" **35**, as illustrated in **FIG. 2**.

[0043] In accordance with an exemplary embodiment, the service unit **37** in the HEE **12** can include an RF signal conditioner unit **40** for conditioning the downlink electrical RF signals **18D** and the uplink electrical RF signals **18U**, respectively. The service unit **37** can include a digital signal processing unit ("digital signal processor") **42** for providing to the RF signal conditioner unit **40** an electrical signal that is modulated onto an RF carrier to generate a desired downlink electrical RF signal **18D**. The digital signal processor **42** is also configured to process a demodulation signal provided by the demodulation of the uplink electrical RF signal **18U** by the RF signal conditioner unit **40**. The HEE **12** can also include an optional central processing unit (CPU) **44** for processing data and otherwise performing logic and computing operations, and a memory unit **46** for storing data, such as data to be transmitted over a WLAN or other network for example.

[0044] With continuing reference to **FIG. 2**, the RAU **14** also includes a converter pair **48** comprising the O/E converter **30** and the E/O converter **34**. The O/E converter **30** converts the received downlink optical RF signals **22D** from the HEE **12** back into downlink electrical RF signals **50D**. The E/O converter **34** converts uplink electrical RF signals **50U** received from the client device **24** into the uplink optical RF signals **22U** to be communicated to the HEE **12**. The O/E converter **30** and the E/O converter **34** are electrically coupled to the antenna **32** via an RF signal-directing element **52**, such as a circulator for example. The RF signal-directing element **52** serves to direct the downlink electrical RF signals **50D** and the uplink electrical RF signals **50U**, as discussed below. In accordance with an exemplary embodiment, the antenna **32** can include any type of antenna, including but not limited to one or more patch antennas, such as disclosed in U.S. Patent Application Serial No. 11/504,999, filed August 16, 2006 entitled "Radio-over-Fiber Transponder With A Dual-Band Patch Antenna System," and U.S. Patent Application Serial No. 11/451,553, filed June 12, 2006 entitled "Centralized Optical Fiber-Based Wireless Picocellular Systems and Methods," both of which are incorporated herein by reference in their entireties.

[0045] With continuing reference to **FIG. 2**, the optical fiber-based distributed antenna system **10** also includes a power unit **54** that includes a power supply and provides an electrical power signal **56**. The power unit **54** is electrically coupled to the HEE **12** for powering the power-consuming elements therein. In an exemplary embodiment, an electrical power line **58** runs through the HEE **12** and over to the RAU **14** to power the O/E converter **30** and the E/O converter **34** in the converter pair **48**, the optional RF signal-directing element **52** (unless the RF signal-directing element **52** is a passive device such as a circulator for example), and any other power-consuming elements provided. In an exemplary embodiment, the electrical power line **58** includes two wires **60** and **62** that carry a voltage, and are electrically coupled to a DC power converter **64** at the RAU **14**. The DC power converter **64** is electrically coupled to the O/E converter **30** and the E/O converter **34** in the converter pair **48**, and changes the voltage or levels of the electrical power signal **56** to the power level(s) required by the power-consuming components in the RAU **14**. In an exemplary embodiment, the DC power converter **64** is either a DC/DC power converter or an AC/DC power converter, depending on the type of electrical power signal **56** carried by the electrical power line **58**. In another example embodiment, the electrical power line **58** (dashed line) runs directly from the power unit **54** to the RAU **14** rather than from or through the HEE **12**. In another example embodiment, the electrical power line **58** includes more than two wires and may carry multiple voltages.

[0046] To provide further exemplary illustration of how a distributed antenna system can be deployed indoors, **FIG. 3A** is provided. **FIG. 3A** is a partially schematic cutaway diagram of a building infrastructure **70** employing an optical fiber-based distributed antenna system. The system may be the optical fiber-based distributed antenna system **10** of **FIGS. 1** and **2**. The building infrastructure **70** generally represents any type of building in which the optical fiber-based distributed antenna system **10** can be deployed. As previously discussed with regard to **FIGS. 1** and **2**, the optical fiber-based distributed antenna system **10** incorporates the HEE **12** to provide various types of communication services to coverage areas within the building infrastructure **70**, as an example.

[0047] For example, as discussed in more detail below, the distributed antenna system **10** in this embodiment is configured to receive wireless RF signals and convert the RF signals into RoF signals to be communicated over the optical fiber **16** to multiple RAUs **14**. The optical fiber-based distributed antenna system **10** in this embodiment can be, for example, an indoor distributed antenna system (IDAS) to provide wireless service inside the building infrastructure **70**. These wireless signals can include cellular service, wireless services such as RFID tracking, Wireless Fidelity (WiFi), local area network (LAN), WLAN, public safety, wireless building automations, and combinations thereof, as examples.

[0048] With continuing reference to **FIG. 3A**, the building infrastructure **70** in this embodiment includes a first (ground) floor **72**, a second floor **74**, and a third floor **76**. The floors **72**, **74**, **76** are serviced by the HEE **12** through a main distribution frame **78** to provide antenna coverage areas **80** in the building infrastructure **70**. Only the ceilings of the floors **72**, **74**, **76** are shown in **FIG. 3A** for simplicity of illustration. In the example embodiment, a main cable **82** has a number of different sections that facilitate the placement of a large number of RAUs **14** in the building infrastructure **70**. Each RAU **14** in turn services its own coverage area in the antenna coverage areas **80**. The main cable **82** can include, for example, a riser cable **84** that carries all of the downlink and uplink optical fibers **16D, 16U** to and from the HEE **12**. The riser cable **84** may be routed through a power unit **85**. The power unit **85** may be provided as part of or separate from the power unit **54** in **FIG. 2**. The power unit **85** may also be configured to provide power to the RAUs **14** via the electrical power line **58**, as illustrated in **FIG. 2** and discussed above, provided inside an array cable **87**, or tail cable or home-run tether cable as other examples, and distributed with the downlink and uplink optical fibers **16D, 16U** to the RAUs **14**. For example, as illustrated in the building infrastructure **70** in **FIG. 3B**, a tail cable **89** may extend from the power units **85** into an array cable **93**.

Downlink and uplink optical fibers in tether cables **95** of the array cables **93** are routed to each of the RAUs **14**, as illustrated in **FIG. 3B**. The main cable **82** can include one or more multi-cable (MC) connectors adapted to connect select downlink and uplink optical fibers **16D, 16U**, along with an electrical power line, to a number of optical fiber cables **86**.

[0049] The main cable **82** enables multiple optical fiber cables **86** to be distributed throughout the building infrastructure **70** (e.g., fixed to the ceilings or other support surfaces of each floor **72**, **74**, **76**) to provide the antenna coverage areas **80** for the first, second, and third floors **72**, **74**, and **76**. In an example embodiment, the HEE **12** is located within the building infrastructure **70** (e.g., in a closet or control room), while in another example embodiment, the HEE **12** may be located outside of the building infrastructure **70** at a remote location. A base transceiver station (BTS) **88**, which may be provided by a second party such as a cellular service provider, is connected to the HEE **12**, and can be co-located or located remotely from the HEE **12**. A BTS is any station or signal source that provides an input signal to the HEE **12** and can receive a return signal from the HEE **12**.

[0050] In a typical cellular system, for example, a plurality of BTSs are deployed at a plurality of remote locations to provide wireless telephone coverage. Each BTS serves a corresponding cell and when a mobile client device enters the cell, the BTS communicates with the mobile client device. Each BTS can include at least one radio transceiver for enabling communication with one or more subscriber units operating within the associated cell. As another example, wireless repeaters or bi-directional amplifiers could also be used to serve a corresponding cell in lieu of a BTS. Alternatively, radio input could be provided by a repeater, picocell or femtocell as other examples.

[0051] The optical fiber-based distributed antenna system **10** in **FIGS. 1-3B** and described above provides point-to-point communications between the HEE **12** and the RAU **14**. A multi-point architecture is also possible as well. With regard to **FIGS. 1-3B**, each RAU **14** communicates with the HEE **12** over a distinct downlink and uplink optical fiber pair to provide the point-to-point communications. Whenever an RAU **14** is installed in the optical fiber-based distributed antenna system **10**, the RAU **14** is connected to a distinct downlink and uplink optical fiber pair connected to the HEE **12**. The downlink and uplink optical fibers **16D, 16U** may be provided in a fiber optic cable.

Multiple downlink and uplink optical fiber pairs can be provided in a fiber optic cable to service multiple RAUs **14** from a common fiber optic cable.

[0052] For example, with reference to **FIG. 3A**, RAUs **14** installed on a given floor **72, 74,** or **76** may be serviced from the same optical fiber **16**. In this regard, the optical fiber **16** may have multiple nodes where distinct downlink and uplink optical fiber pairs can be connected to a given RAU **14**. One downlink optical fiber **16D** could be provided to support multiple channels each using wavelength-division multiplexing (WDM), as discussed in U.S. Patent Application Serial No. 12/892,424 entitled "Providing Digital Data Services in Optical Fiber-based Distributed Radio Frequency (RF) Communications Systems, And Related Components and Methods," incorporated herein by reference in its entirety. Other options for WDM and frequency-division multiplexing (FDM) are also disclosed in U.S. Patent Application Serial No. 12/892,424, any of which can be employed in any of the embodiments disclosed herein.

[0053] The HEE **12** may be configured to support any frequencies desired, including but not limited to US FCC and Industry Canada frequencies (824-849 MHz on uplink and 869-894 MHz on downlink), US FCC and Industry Canada frequencies (1850-1915 MHz on uplink and 1930-1995 MHz on downlink), US FCC and Industry Canada frequencies (1710-1755 MHz on uplink and 2110-2155 MHz on downlink), US FCC frequencies (698-716 MHz and 776-787 MHz on uplink and 728-746 MHz on downlink), EU R & TTE frequencies (880-915 MHz on uplink and 925-960 MHz on downlink), EU R & TTE frequencies (1710-1785 MHz on uplink and 1805-1880 MHz on downlink), EU R & TTE frequencies (1920-1980 MHz on uplink and 2110-2170 MHz on downlink), US FCC frequencies (806-824 MHz on uplink and 851-869 MHz on downlink), US FCC frequencies (896-901 MHz on uplink and 929-941 MHz on downlink), US FCC frequencies (793-805 MHz on uplink and 763-775 MHz on downlink), and US FCC frequencies (2495-2690 MHz on uplink and downlink).

[0054] **FIG. 4** is a schematic diagram of exemplary HEE **90** that may be employed with any of the distributed antenna systems disclosed herein, including but not limited to the distributed antenna system **10** in **FIGS. 1-3**. The HEE **90** in this embodiment is configured to distribute RF communication services over optical fiber. In this embodiment as illustrated in **FIG. 4**, the HEE **90** includes a head-end controller (HEC) **91** that manages the functions of the HEE **90** components and communicates with external devices via interfaces, such as an RS-232 port **92**, a Universal Serial Bus (USB) port **94**, and an Ethernet port **96**, as examples. The HEE **90** can be connected to a plurality of BTSs, transceivers **100(1)-100(T)**, and the like via BTS inputs **101(1)-101(T)** and BTS outputs **102(1)-102(T)**. The notation "1-T" indicates that any number of BTS transceivers can be provided up to T number with corresponding BTS inputs and BTS outputs.

[0055] With continuing reference to **FIG. 4**, the BTS inputs **101(1)-101(T)** are downlink connections and the BTS outputs **102(1)-102(T)** are uplink connections. Each BTS input **101(1)-101(T)** is connected to a downlink radio interface in the form of a downlink BTS interface card (BIC) **104** in this embodiment, which is located in the HEE **90**, and each BTS output **102(1)-102(T)** is connected to a radio interface in the form of an uplink BIC **106** also located in the HEE **90**. The downlink BIC **104** is configured to receive incoming or downlink RF signals from the BTS inputs **101(1)-101(T)** and split the downlink RF signals into copies to be communicated to the RAUs **14**, as illustrated in **FIG. 2**. In this embodiment, thirty-six (36) RAUs **14(1)-14(36)** are supported by the HEE **90**, but any number of RAUs **14** may be supported by the HEE **90**. The uplink BIC **106** is configured to receive the combined outgoing or uplink RF signals from the RAUs **14** and split the uplink RF signals into individual BTS outputs **102(1)-102(T)** as a return communication path.

[0056] With continuing reference to **FIG. 4**, the downlink BIC **104** is connected to a midplane interface card **108** in this embodiment. The uplink BIC **106** is also connected to the midplane interface card **108**. The downlink BIC **104** and uplink BIC **106** can be provided in printed circuit boards (PCBs) that include connectors that can plug directly into the midplane interface card **108**. The midplane interface card **108** is in electrical communication with a plurality of optical interfaces provided in the form of optical interface cards (OICs) **110** in this embodiment, which provide an optical to electrical communication interface and vice versa between the RAUs **14** via the downlink and uplink optical fibers **16D, 16U** and the downlink BIC **104** and uplink BIC **106**. The OICs **110** include the E/O converter **28** like discussed with regard to **FIG. 1** that converts electrical RF signals from the downlink BIC **104** to optical RF signals, which are then communicated over the downlink optical fibers **16D** to the RAUs **14** and then to client devices. The OICs **110** also include the O/E converter **36** like in **FIG. 1** that converts optical RF signals communicated from the RAUs **14** over the uplink optical fibers **16U** to the HEE **90** and then to the BTS outputs **102(1)-102(T)**.

[0057] With continuing reference to **FIG. 4**, the OICs **110** in this embodiment support up to three (3) RAUs **14** each. The OICs **110** can also be provided in a PCB that includes a connector that can plug directly into the midplane interface card **108** to couple the links in the OICs **110** to the midplane interface card **108**. The OICs **110** may consist of one or multiple optical interface modules (OIMs). In this manner, the HEE **90** is scalable to support up to thirty-six (36) RAUs **14** in this embodiment since the HEE **90** can support up to twelve (12) OICs **110**. If less than thirty-six (36) RAUs **14** are to be supported by the HEE **90**, less than twelve (12) OICs **110** can be included in the HEE **90** and plugged into the midplane interface card **108**. One OIC **110** is provided for every three (3) RAUs **14** supported by the HEE **90** in this embodiment. OICs **110** can also be added to the HEE **90** and connected to the midplane interface card **108** if additional RAUs **14** are desired to be supported beyond an initial configuration. With continuing reference to **FIG. 4**, the HEU **91** can also be provided that is configured to be able to communicate with the downlink BIC **104**, the uplink BIC **106**, and the OICs **110** to provide various functions, including configurations of amplifiers and attenuators provided therein.

[0058] **FIG. 5** is a schematic diagram of another exemplary optical fiber-based distributed antenna system **120** that may be employed according to the embodiments disclosed herein to provide RF communication services. In this embodiment, the optical fiber-based distributed antenna system **120** includes optical fiber for distributing RF communication services. The optical fiber-based distributed antenna system **120** in this embodiment is comprised of three (3) main components. One or more radio interfaces provided in the form of radio interface modules (RIMs) **122(1)-122(M)** in this embodiment are provided in HEE **124** to receive and process downlink electrical RF communications signals **126D(1)-126D(R)** prior to optical conversion into downlink optical RF communications signals. The RIMs **122(1)-122(M)** provide both downlink and uplink interfaces. The processing of the downlink electrical RF communications signals **126D(1)-126D(R)** can include any of the processing previously described above in the HEE **12** in **FIGS. 1-4**. The notations "1-R" and "1-M" indicate that any number of the referenced component, 1-R and 1-M, respectively, may be provided. As will be described in more detail below, the HEE **124** is configured to accept a plurality of RIMs **122(1)-122(M)** as modular components that can easily be installed and removed or replaced in the HEE **124**. In one embodiment, the HEE **124** is configured to support up to eight (8) RIMs **122(1)-122(M)**.

[0059] Each RIM **122(1)-122(M)** can be designed to support a particular type of radio source or range of radio sources (i.e., frequencies) to provide flexibility in configuring the HEE **124** and the optical fiber-based distributed antenna system **120** to support the desired radio sources. For example, one RIM **122** may be configured to support the Personal Communication Services (PCS) radio band. Another RIM **122** may be configured to support the 700 MHz radio band. In this example, by inclusion of these RIMs **122**, the HEE **124** would be configured to support and distribute RF communications signals on both PCS and LTE 700 radio bands. RIMs **122** may be provided in the HEE **124** that support any frequency bands desired, including but not limited to the US Cellular band, Personal Communication Services (PCS) band, Advanced Wireless Services (AWS) band, 700 MHz band, Global System for Mobile communications (GSM) 900, GSM 1800, and Universal Mobile Telecommunication System (UMTS). RIMs **122** may be provided in the HEE **124** that support any wireless technologies desired, including but not limited to Code Division Multiple Access (CDMA), CDMA200, 1xRTT, Evolution – Data Only (EV-DO), UMTS, High-speed Packet Access (HSPA), GSM, General Packet Radio Services (GPRS), Enhanced Data GSM Environment (EDGE), Time Division Multiple Access (TDMA), Long Term Evolution (LTE), iDEN, and Cellular Digital Packet Data (CDPD). RIMs **122** may be provided in the HEE **124** that support any frequencies desired referenced above as non-limiting examples.

[0060] The downlink electrical RF communications signals **126D(1)-126D(R)** are provided to a plurality of optical interfaces provided in the form of optical interface modules (OIMs) **128(1)-128(N)** in this embodiment to convert the downlink electrical RF communications signals **126D(1)-126D(N)** into downlink optical RF communications signals **130D(1)-130D(R)**. The notation "1-N" indicates that any number of the referenced component 1-N may be provided. The OIMs **128** may be configured to provide one or more optical interface components (OICs) that contain O/E and E/O converters, as will be described in more detail below. The OIMs **128** support the radio bands that can be provided by the RIMs **122**, including the examples previously described above. Thus, in this embodiment, the OIMs **128** may support a radio band range from 400 MHz to 2700 MHz, as an example, so providing different types or models of OIMs **128** for narrower radio bands to support possibilities for different radio band-supported RIMs **122** provided in the HEE **124** is not required. Further, as an example, the OIMs **128** may be optimized for sub-bands within the 400 MHz to 2700 MHz frequency range, such as 400 - 700 MHz, 700 MHz - 1 GHz, 1 GHz - 1.6 GHz, and 1.6 GHz – 2.7 GHz, as examples.

[0061] The OIMs **128(1)-128(N)** each include E/O converters to convert the downlink electrical RF communications signals **126D(1)-126D(R)** to downlink optical RF communications signals **130D(1)-130D(R)**. The downlink optical RF communications signals **130D(1)-130D(R)** are communicated over downlink optical fiber(s) **133D** to a plurality of RAUs **132(1)-132(P)**. The notation "1-P" indicates that any number of the referenced component 1-P may be provided. O/E converters provided in the RAUs **132(1)-132(P)** convert the downlink optical RF communications signals **130D(1)-130D(R)** back into downlink electrical RF communications signals **126D(1)-126D(R)**, which are provided over downlinks **134(1)-134(P)** coupled to antennas **136(1)-136(P)** in the RAUs **132(1)-132(P)** to client devices in the reception range of the antennas **136(1)-136(P)**.

[0062] E/O converters are also provided in the RAUs **132(1)-132(P)** to convert uplink electrical RF communications signals **126U(1)-126U(R)** received from client devices through the antennas **136(1)-136(P)** into uplink optical RF communications signals **138U(1)-138U(R)** to be communicated over uplink optical fibers **133U** to the OIMs **128(1)-128(N)**. The OIMs **128(1)-128(N)** include O/E converters that convert the uplink optical RF communications signals **138U(1)-138U(R)** into uplink electrical RF communications signals **140U(1)-140U(R)** that are processed by the RIMs **122(1)-122(M)** and provided as uplink electrical RF communications signals **142U(1)-142U(R)**. Downlink electrical digital signals **143D(1)-143D(P)** communicated over downlink electrical medium or media (hereinafter "medium") **145D(1)-145D(P)** are provided to the RAUs **132(1)-132(P)**, separately from the RF communication services, as well as uplink electrical digital signals **143U(1)-143U(P)** communicated over uplink electrical medium **145U(1)-145U(P)**, as also illustrated in **FIG. 6**. Common elements between **FIG. 5** and **FIG. 6** are illustrated in **FIG. 6** with common element numbers. Power may be provided in the downlink and/or uplink electrical medium **145D(1)-145D(P)** and/or **145U(1)-145U(P)** to the RAUs **132(1)-132(P)**.

[0063] In one embodiment, up to thirty-six (36) RAUs **132** can be supported by the OIMs **128**, three RAUs **132** per OIM **128** in the optical fiber-based distributed antenna system **120** in **FIG. 5**. The optical fiber-based distributed antenna system **120** is scalable to address larger deployments. In the illustrated optical fiber-based distributed antenna system **120**, the HEE **124** is configured to support up to thirty six (36) RAUs **132** and fit in 6U rack space (U unit meaning 1.75 inches of height). The downlink operational input power level can be in the range of -15 dBm to 33 dBm. The adjustable uplink system gain range can be in the range of +15 dB to -15 dB. The RF input interface in the RIMs **122** can be duplexed and simplex, N-Type. The optical fiber-based distributed antenna system can include sectorization switches to be configurable for sectorization capability, as discussed in U.S. Patent Application Serial No. 12/914,585 filed on October 28, 2010, and entitled "Sectorization In Distributed Antenna Systems, and Related Components and Method," which is incorporated herein by reference in its entirety.

[0064] In another embodiment, an exemplary RAU **132** may be configured to support up to four (4) different radio bands/carriers (e.g. ATT, VZW, TMobile, Metro PCS: 700LTE/850/1900/2100). Radio band upgrades can be supported by adding remote expansion units over the same optical fiber (or upgrade to MIMO on any single band), as will be described in more detail below starting with **FIG. 7**. The RAUs **132** and/or remote expansion units may be configured to provide external filter interface to mitigate potential strong interference at 700MHz band (Public Safety, CH51,56); Single Antenna Port (N-type) provides DL output power per band (Low bands (<1 GHz): 14 dBm, High bands (>1 GHz): 15 dBm); and satisfies the UL System RF spec (UL Noise Figure: 12 dB, UL IIP3: -5 dBm, UL AGC: 25 dB range).

[0065] **FIG. 6** is a schematic diagram of providing digital data services and RF communication services to RAUs and/or other remote communications units in the optical fiber-based distributed antenna system **120** of **FIG. 6**. Common components between **FIGS. 5** and **6** and other figures provided have the same element numbers and thus will not be re-described. As illustrated in **FIG. 6**, a power supply module (PSM) **153** may be provided to provide power to the RIMs **122(1)-122(M)** and radio distribution cards (RDCs) **147** that distribute the RF communications from the RIMs **122(1)-122(M)** to the OIMs **128(1)-128(N)** through RDCs **149**. In one embodiment, the RDCs **147, 149** can support different sectorization needs. A PSM **155** may also be provided to provide power to the OIMs **128(1)-128(N)**. An interface **151**, which may include web and network management system (NMS) interfaces, may also be provided to allow configuration and communication to the RIMs **122(1)-122(M)** and other components of the optical fiber-based distributed antenna system **120**. A microcontroller, microprocessor, or other control circuitry, called a head-end controller (HEC) **157** may be included in HEE **124** (**FIG. 7**) to provide control operations for the HEE **124**.

[0066] RAUs, including the RAUs **14, 132** discussed above, contain power-consuming components for transmitting and receiving RF communications signals. In the situation of an optical fiber-based distributed antenna system, the RAUs may contain O/E and E/O converters that also require power to operate. As an example, a RAU may contain a power unit that includes a power supply to provide power to the RAUs locally at the RAU. Alternatively, power may be provided to the RAUs from power supplies provided in remote power units. In either scenario, it may be desirable to provide these power supplies in modular units or devices that may be easily inserted or removed from a power unit. Providing modular power distribution modules allows power to more easily be configured as needed for the distributed antenna system. It may be desired to allow these power distribution modules to be inserted and removed from the power unit without deactivating other power distribution modules providing power to other RAUs. If power to the entire power unit were required to be deactivated, RF communications for all RAUs that receive power from the power unit would be disabled even if the power distribution module inserted and/or removed from the power unit is configured to supply power to only a subset of the RAUs receiving power from the power unit.

[0067] In this regard, embodiments disclosed herein include power distribution modules capable of "hot" connection and/or disconnection in distributed antenna systems (DASs). Related components, power units, and methods are also disclosed. By "hot" connection and/or disconnection, it is meant that the power distribution modules can be connected and/or disconnected from a power unit and/or power-consuming components while power is being provided to the power distribution modules. In this regard, it is not required to disable providing power to the power distribution module before connection and/or disconnection of power distribution modules to a power unit and/or power-consuming components. As a non-limiting example, the power distribution modules may be configured to protect against or reduce electrical arching or electrical contact erosion that may otherwise result from "hot" connection and/or disconnection.

[0068] In this regard, **FIG. 7** is a schematic diagram of an exemplary power distribution module **160** that can be employed to provide power to the RAUs **14, 132** or other power-consuming DAS components, including those described above. In this embodiment, the power distribution module **160** is disposed in a power unit **162**. The power unit **162** may be the power unit **85** previously described above to remotely provide power to the RAUs **14, 132**. The power unit **162** may be comprised of a chassis **164** or other housing that is configured to support power distribution modules **160**. The power unit **162** provides support for receiving power from an external power source **166**, which may be AC power, to the power unit **162** to then be distributed within the power unit **162** to the power distribution modules **160** disposed therein, as will be described in more detail below. The power unit **162** may be configured to support multiple power distribution modules **162**. Each power distribution module **162** may be configured to provide power to multiple RAUs **14, 132**.

[0069] With continuing reference to **FIG. 7**, the distribution of power from the external power source **166** to the power distribution modules **160** and from the power distribution modules **160** to output power ports that can be electrically coupled to power-consuming DAS components will now described. In this embodiment, the power unit **162** contains an external input power port **168** disposed in the chassis **164**. The external input power port **168** is configured to be electrically coupled to the external power source **166** to supply input power **170** to the external input power connector **168**. For example, the external power source **166** may be AC power, and may be either 110 Volts (V) or 220 Volts (V). To distribute the power from the external power source **166** to the power distribution modules **160** disposed in the power unit **162**, the power unit **162** contains a midplane interface connector **172**. In this embodiment, the midplane interface connector **172** is comprised of an AC connector **172A** to carry AC signals, and a DC connector **172B** to carry DC signals. The power distribution module **160** contains a complementary connector **174** that can be connected to the midplane interface connector **172** to electrically connect the power distribution module **160** to the power unit **162**. For example, the power unit **162** may contain a midplane interface bus that contains a plurality of midplane interface connectors **172** to allow a plurality of power distribution modules **160** to interface with the midplane interface bus.

[0070] With continuing reference to **FIG. 7**, the power distribution module **160** includes an input power port **176** that is configured to receive input power from the external power source **166**. The input power port **176** is provided as part of the connector **174** to allow the external power source **166** to be electrically coupled to the input power port **176** and thus to the power distribution module **160**. The power distribution module **160** in this embodiment contains an optional power converter **178** to convert the input power **170** from the external power source **166** to DC power **180**. In this regard, the power converter **178** is electrically coupled to the input power port **176** to receive the input power **170** from the external power source **166**. The power converter **178** converts the input power **170** from the external power source **166** to output power **180**, which is DC power in this example. For example, the power converter **178** may convert the input power **170** to 56 VDC output power **180**, as a non-limiting example. A secondary power converter **182** may receive the output power **180** and may convert the output power **180** to a second output power **184** at a different voltage, such as 12VDC for example, to provide power to a cooling fan **186** in the power distribution module **160**.

[0071] With continuing reference to **FIG. 7**, the power converter **178** may also distribute the output power **180** to a power controller **188**. As will be described in more detail below, the power controller **188** controls whether the output power **180** is distributed to an output power port **190** to be distributed to power-consuming DAS devices electrically coupled to the output power port **190**. The output power port **190** in this embodiment is electrically coupled to an output power connector **192** through the connectors **172**, **174**, as illustrated in **FIG. 7**. Thus, the output power **180** can be distributed to power-consuming DAS devices by electrical coupling to the output power connector **192** in the power distribution module **160**. In this regard, the power controller **188** contains a power enable port **194**. The power controller **188** is configured to selectively distribute the output power **180** to the output power port **190** based on a power enable signal **196** provided on a power enable line **198** coupled to the power enable port **194**. In this regard, the power controller **188** is configured to distribute the output power **180** to the output power port **190** if the power enable signal **196** communicated on the power enable line **198** indicates to activate power. Activation of power means providing the output power **180** to the output power port **190** to be distributed to power-consuming DAS devices electrically coupled to the output power port **190**. When output power **180** is activated and supplied to the output power connector **192**, the output power **180** may also be coupled to a light, such as a light emitting diode (LED) **200**, to signify that output power **180** is active at the output power connector **192**. The power controller **188** is also configured to not distribute the output power **180** to the output power port **190** if the power enable signal **196** communicated on the power enable line **198** indicates to deactivate power. This power controller **188** and enable feature allows the "hot" connection and disconnection of the power distribution module **160** from the power unit **162** in this embodiment, as will be described in more detail below.

[0072] With continuing reference to **FIG. 7**, in this embodiment, one source of the power enable signal **196** is the power disable/enable feature **202**. The power enable/disable feature **202** may be a conductor or pin on the power distribution module **160**, as will be described in more detail below. The power enable/disable feature **202** may be provided by other means. The power enable/disable feature **202** in this embodiment is configured to close a circuit on the power enable line **198** when an output power connector **204** is connected to the output power connector **192** of the power distribution module **160**. When connected, the output power connector **204** will then be electrically coupled to the connector **174** of the power distribution module **160** which is connected to the midplane interface connector **172** of the power unit **162** when the power distribution module **160** is installed. As will be discussed in more detail below, the power enable/disable feature **202** may only be configured to close the circuit on the power enable line **198** until all other conductors of the output power connector **204** coupled to the output power connector **192** are fully electrically coupled to the midplane interface connector **172** via the connector **174**. In this manner, electrical arcing between the output power connector **204** and the output power connector **192** may be avoided, because the power controller **188** does not provide output power **180** to the output power port **190** and the output power connector **192** until complete electrical coupling is established between the output power connector **204** and the output power connector **192**.

[0073] Electrical arcing is a luminous discharge of current that is formed when a strong current jumps a gap in a circuit or between two conductors. If output power **180** is being provided by the power controller **188** to the output power port **190** and output power connector **192** before complete electrical contact is made between the output power connector **204** and the output power connector **192**, electrical arcing may occur. Electrical arcing can cause electrical conductor corrosion and/or damage to the power distribution module **160** and/or its components and any power-consuming DAS components connected to the output power connector **192** due to the high voltage and/or discharge.

[0074] With continuing reference to **FIG. 7**, if the output power **180** was being provided to the output power port **190** before a complete electrical connection was made between the output power connector **192** and the output power connector **204**, electrical arcing and/or electrical conductor corrosion may occur. Electrical arcing may occur during disconnection of the output power connector **204** from the output power connector **192** due to the output power **180** being "hot" and being actively supplied to the output power connector **192**. The power controller **188** herein allows an output power connector **204** to be disconnected from the output power connector **192** while the input power **170** is "hot" or active, because the power enable/disable feature **202** is configured to open the circuit to the power enable line **198** to cause the power controller **188** to not provide the output power **180** to the output power port **190** before the electrical contact is decoupled between the output power connector **204** and the output power connector **192**. In a similar regard, the power controller **188** also allows the output power connector **204** to be connected to the output power connector **192** while the input power **170** is “hot” or active, because the power enable/disable feature **202** is configured to close the circuit to the power enable line **198** to enable the power controller **188** to provide the output power **180** to the output power port **190** once complete electrical contact is established between the output power connector **204** and the output power connector **192**.

[0075] In a similar regard with continuing reference to **FIG. 7**, the power distribution module **160** is also configured to activate and deactivate providing output power **180** to the output power connector **192** upon installation (i.e., connection) or removal (i.e., disconnection) of the power distribution module **160** from the power unit **162**. More specifically, the power enable/disable feature **202** is configured to only close the circuit on the power enable line **198** to enable the power controller **188** to provide output power **180** until all other conductors of the connector **174** of the power distribution module **160** are completely coupled to the midplane interface connector **172** during installation of the power distribution module **160** in the power unit **162**. In this manner, electrical arcing between the output power connector **204** and the output power connector **192** may be avoided when the power distribution module **160** is installed in the power unit **162** when input power **170** is “hot.” This is because the power controller **188** does not provide output power **180** to the output power port **190** and the output power connector **204** until complete electrical coupling is established between the connector **174** of the power distribution module **160** and the midplane interface connector **172**. This reduces or avoids the risk of electrical arcing if a load is placed on the output power connector **204** connected to the output power connector **192** when the power distribution module **160** is connected to and disconnected from the power unit **162** when input power **170** is active.

[0076] Also, the power enable/disable feature **202** is configured to open the circuit on the power enable line **198** to disable output power **180** from being provided by the output power port **190** during removal or disconnection of the power distribution module **160** from the power unit **162**. The power enable/disable feature **202** is configured to open the circuit on the power enable line **198** to disable output power **180** before the connector **174** of the power distribution module **160** begins to decouple from the midplane interface connector **172**. In this manner, electrical arcing between the output power connector **204** and the output power connector **192** may be avoided if the power distribution module **160** is removed while input power **170** is "hot." This is because the power controller **188** disables output power **180** to the output power port **190** and the output power connector **204** before electrical decoupling starts to being between the connector **174** of the power distribution module **160** and the midplane interface connector **172** during removal of the power distribution module **160**. This reduces or avoids the risk of electrical arcing if a load is placed on the output power connector **204** connected to the output power connector **192** when the power distribution module **160** is disconnected from the power unit **162** when input power **170** is active.

[0077] Also, with reference to **FIG. 7**, the fan **186** may be configured to provide diagnostic or other operational data **195** to the power controller **188**. For example, the power controller **188** may be configured to disable providing output power **180** if a fault or other error condition is reported by the fan **186** to the power controller **188**.

[0078] **FIG. 8** is a schematic diagram of exemplary internal components of the power distribution module **160** in **FIG. 7** and the power unit **162** to allow "hot" connection and/or disconnection of the power distribution module **160** from the power unit **162** and remote antenna units (RAUs) **14, 132** in a distributed antenna system. Common element numbers between **FIG. 7** and **FIG. 8** signify common elements and functionality. Only one power distribution module **160** is shown, but more than one power distribution modules **160** may be provided in the power unit **162**. As shown in **FIG. 8**, there are two output power connectors **192A, 192B** that allow two power cables **210A, 210B**, via their output power connectors **204A, 204B**, to be connected to the output power connectors **192A, 192B** to provide power to two RAUs **14, 132**. Alternatively, one RAU **14, 132** requiring higher power could be connected to both output power connectors **204A, 204B**. The power distribution module **160** in this embodiment is configured to distribute power to multiple RAUs **14, 132**. Output connectors **212A, 212B** are disposed on opposite ends of the power cables **210A, 210B** from output power connectors **204A, 204B**. Output connectors **212A, 212B** are configured to be connected to RAU power connectors **214A, 214B** to provide power to the RAUs **14, 132**. The power cables **210A, 210B** are configured such that two conductors (pins 3 and 4 as illustrated) are shorted when the output connectors **212A, 212B** are electrically connected to RAU power connectors **214A, 214B** in the RAUs **14, 132**. The conductors in the RAU power connectors **214A, 214B** corresponding to pins 3 and 4 are shorted inside the RAU **14, 132**.

[0079] In this regard, **FIG. 9** is a side perspective view of an output power connector **204** being connected to the output power connector **192** of the power distribution module **160**. **FIG. 9** also shows the connector **174** of power distribution module **160** about to be inserted into the midplane interface connector **172** of the power unit **162** to couple input power **170** to the power distribution module **160** to be distributed through the output power connector **192** to the output power connector **204** to least one power-consuming DAS device. **FIG. 10A** illustrates a front, side perspective view of an exemplary power distribution module **160** with a cover installed. **FIG. 10B** illustrates a front, side perspective view of the power distribution module **160** in **FIG. 10A** with the cover removed. **FIG. 10C** illustrates a rear, side perspective view of the power distribution module **160** in **FIG. 10A**.

[0080] With continuing reference to **FIG. 8**, when the output power connectors **204A, 204B** are electrically connected to the power cables **210A, 210B**, the short created between pins 3 and 4 in the RAU power connectors **214A, 214B** cause pins 3 and 4 to be shorted in the output power connectors **204A, 204B** coupled to the midplane interface connector **172** and the connector **174** of the power distribution module **160**, and the output power connectors **192A, 192B**. This is a power enable/disable feature **202A**. In this regard, the power enable ports **194A, 194B** via power enable lines **198A, 198B** are activated, thereby activating the power controllers **188A, 188B** to provide output power **180** to the connector **174** through midplane interface connector **172** and to the RAUs **14, 132** via the power cables **210A, 210B**. When the output power connectors **204A, 204B** or output connectors **212A, 212B** are disconnected, pins 3 and 4 on the output power connectors **192A, 192B** are not short circuited. This causes the power enable ports **194A, 194B** via power enable lines **198A, 198B** to be deactivated, thereby causing the power controllers **188A, 188B** to deactivate output power **180** to the connector **174** through midplane interface connector **172** and the output power connectors **192A, 192B**, which may be electrically connected to the power cables **210A, 210B**. In this regard, connection and disconnection of the RAUs **14, 132** to the output power connectors **192A, 192B** causes the power controllers **188A, 188B** to activate and deactivate output power **180**, respectively.

[0081] With continuing reference to **FIG. 8**, an alternative circuit configuration **220** may be provided. Instead of pins 3 and 4 being shorted together in the power cables **210A, 210B**, pins 3 and 4 may be shorted in the RAU power connectors **214A, 214B** of the RAUs **14, 132**. This will cause a short circuit between pins 3 and 4 in the power cables **210A, 210B** when the output connectors **212A, 212B** of the power cables **210A, 210B** are connected to the RAU power connectors **214A, 214B** of the RAUs **114, 132**. The alternative circuit configuration **220** provides extra conductors in the power cables **210A, 210B** that can increase cost in the power cable **210A, 210B**. When connected, the power enable ports **194A, 194B** via power enable lines **198A, 198B** are activated, thereby activating the power controllers **188A, 188B** to provide output power **180** to the connector **174** through midplane interface connector **172** and to the RAUs **14, 132** via the power cables **210A, 210B**. When the output power connectors **204A, 204B** or output connectors **212A, 212B** are disconnected, pins 3 and 4 on the output power connectors **192A, 192B** are not short circuited. This causes the power enable ports **194A, 194B** via power enable lines **198A, 198B** to be deactivated, thereby causing the power controllers **188A, 188B** to deactivate output power **180** to the connector **174** through midplane interface connector **172** and the output power connectors **192A, 192B**, which may be electrically connected to the power cables **210A, 210B**. In this regard, connection and disconnection of the RAUs **14, 132** to the output power connectors **192A, 192B** causes the power controllers **188A, 188B** to activate and deactivate output power **180**, respectively.

[0082] With continuing reference to **FIG. 8**, output power **180A, 180B** is enabled by the power controllers **188A, 188B** when the power distribution module **160** connector **174** is connected to midplane interface connector **172** in the power unit **162**. In this regard, a short is created between pins 11 and 12 in the midplane interface connector **172** when the power distribution module **160** connector **174** is connected to the midplane interface connector **172** through the power enable/disable feature **202B**. The power enable ports **194A, 194B** via power enable lines **198A, 198B** are activated, thereby activating the power controllers **188A, 188B** to provide output power **180** to the connector **174** through midplane interface connector **172** and to the RAUs **14, 132** via the power cables **210A, 210B**. Similarly, output power **180A, 180B** is disabled by the power controllers **188A, 188B** when the power distribution module **160** connector **174** is disconnected from midplane interface connector **172** in the power unit **162**. In this regard, pins 11 and 12 are no longer shorted. This causes the power enable ports **194A, 194B** via power enable lines **198A, 198B** to be deactivated, thereby causing the power controllers **188A, 188B** to deactivate output power **180** to the connector **174** through midplane interface connector **172** and the output power connectors **192A, 192B**, which may be electrically connected to the power cables **210A, 210B**. In this regard, connection and disconnection of the power distribution module **160** to the power unit **162** causes the power controllers **188A, 188B** to activate and deactivate output power **180**, respectively.

[0083] The power converter **178** can be provided to produce any voltage level of DC power desired. In one embodiment, the power converter **178** can produce relatively low voltage DC current. A low voltage may be desired that is power-limited and Safety Extra Low Voltage (SELV) compliant, although such is not required. For example, according to Underwriters Laboratories (UL) Publication No. 60950, SELV-compliant circuits produce voltages that are safe to touch both under normal operating conditions and after faults. In this embodiment, two power controllers **188A, 188B** are provided so no more than 100 Watts (W) in this example are provided over output power ports **190A, 190B** to stay within the Underwriters Laboratories (UL) Publication No. 60950, and provide a SELV-compliant circuit. The 100VA limit discussed therein is for a Class 2 DC power source, as shown in Table 11(B) in NFPA 70, Article 725. Providing a SELV compliant power converter **178** and power unit **162** may be desired or necessary for fire protection and to meet fire protection and other safety regulations and/or standards. The power converter **178** is configured to provide up to 150 W of power in this example. The 150 W is split among the output power ports **190A, 190B**.

[0084] **FIG. 11** is a schematic diagram of an exemplary power controller **188** that may be provided in the power distribution module **160** in **FIG. 7**. Common element numbers between **FIG. 11** and **FIG. 7** indicate common elements and thus will not be re-described. As illustrated in **FIG. 11**, an integrated circuit (IC) chip **230** is provided to control wherein output power **180** from the power converter **178** will be provided to the connector **174** of the power distribution module **160** configured to be connected to the midplane interface connector **172** of the power unit **162**.

[0085] To provide for "hot" connection of the power distribution module **160** to the power unit **162**, and more particularly the connector **174** to the midplane interface connector **172**, the power controller **188** should not enable output power **180** until complete electrical contact is made between the conductors of the connector **174** and the midplane interface connector **172**. Otherwise, electrical arcing may occur. To provide for "hot" disconnection of the power distribution module **160** to the power unit **162**, the power controller **188** should disable output power **180** before complete electrical contact is decoupled between the conductors of the connector **174** and the midplane interface connector **172**. Similarly, to provide for "hot" connection of power-consuming DAS devices to the output power connector **192** of a power distribution module **160**, it is important that the power controller **188** not enable output power **180** until complete electrical contact is made between the output power connector **192** and the output power connector **204**. Otherwise, electrical arcing may occur. To provide for "hot" disconnection of the power distribution module **160** to the power unit **162**, the power controller **188** should disable output power **180** before complete electrical contact is decoupled between the conductors of the output power connector **192** and the output power connector **204**.

[0086] In this regard, short conductor pins are provided in the midplane interface connector **172** and the output power connector **204** that are configured to be coupled to the power enable line **198** when contact is established. This is illustrated in **FIGS. 12** and **13**. **FIG. 12** is a side view of the midplane interface connector **172** that includes a short conductor pin **202A**, which is the power enable/disable feature **202** in this embodiment. **FIG. 13** is a side view of output power pins of the output power connector **204** of the power cable **210** aligned to be connected to the output power connector **192** of the power distribution module **160**.

[0087] With reference to **FIG. 12**, the interface connector **174** includes other conductors **225** that are longer than the short conductor pin **202A**. Thus, when the midplane interface connector **172** is connected to the connector **174**, electrical contact is fully established to the other conductors **225** before the short conductor pin **202A** enables the power enable line **198** to enable the power controller **188** to distribute the output power **180**. Thus, electrical arcing can be avoided when "hot" connection is made between the midplane interface connector **172** and the connector **174** of the power distribution module **160**. Similarly, to provide for "hot" disconnection, the short conductor pin **202A** will electrically decouple from the connector **174** first before electrical decoupling occurs to the other conductors **225**. Thus, the power controller **188** will disable output power **180** before electrical contact is decoupled between the other conductors **225** and the connector **174**. Thus, electrical arcing can be avoided when "hot" disconnection is made between the midplane interface connector **172** and the connector **174** of the power distribution module **160**. The short conductor pin **202A** could be reversed and disposed in the connector **174** of the power distribution module **160** output power connector **192** as opposed to the midplane interface connector **172**.

[0088] With reference to **FIG. 13**, a similar arrangement is provided. Therein the output power connector **204** includes other conductors **227** that are longer than the short conductor pin **202B**. Thus, when the output power connector **204** is connected to the output power connector **192**, electrical contact is fully established to the other conductors **227** before the short conductor pin **202B** enables the power enable line **198** to enable the power controller **188** to distribute the output power **180**. Thus, electrical arcing can be avoided when "hot" connection is made between the output power connector **204** and the output power connector **192** of the power distribution module **160**. Similarly, to provide for "hot" disconnection, the short conductor pin **202B** will electrically decouple from the output power connector **192** first before electrical decoupling occurs to the other conductors **227**. Thus, the power controller **188** will disable output power **180** before electrical contact is decoupled between the other conductors **227** and the output power connector **192**. Thus, electrical arcing can be avoided when "hot" disconnection is made between the output power connector **204** and the output power connector **192** of the power distribution module **160**. The short conductor pin **202B** could be reversed and disposed in the output power connector **192** as opposed to the output power connector **204**.

[0089] **FIG. 14** is a schematic diagram of an exemplary power unit **162** configured to support one or more power distribution modules **160** to provide power to RAUs **14, 132** in a distributed antenna system. In this regard, **FIG. 14** is a schematic top cutaway view of a power unit **162** that may be employed in the exemplary RoF distributed communication system. The power unit **162** provides power to remote units, and connectivity to a first central unit, in a manner similar to the power unit **85** illustrated in **FIG. 3**. The power unit **162**, however, may also provide connectivity between RAUs **14, 132** and a second central unit **244** (not illustrated). The second central unit **244** can be, for example, a unit providing Ethernet service to the remote units. For the purpose of this embodiment, the first central unit will be referred to as the HEU **91**, and the second central unit will be referred to as a central Ethernet unit, or CEU **244**. The CEU **244** can be collocated with the power unit **162**, as for example, in an electrical closet, or the CEU **244** can be located with or within the HEU **91**.

[0090] According to one embodiment, if Ethernet or some other additional service (e.g. a second cellular communication provider) is to be provided over the system **10**, four optical fibers (two uplink/downlink fiber pairs) may be routed to each remote unit location. In this case, two fibers are for uplink/downlink from the HEU **91** to the remote unit, and two fibers are for uplink/downlink from the CEU **244**. One or more of the remote units may be equipped with additional hardware, or a separate, add-on module designed for Ethernet transmission to which the second fiber pair connects. A third fiber pair could also be provided at each remote unit location to provide additional services.

[0091] As illustrated in **FIG. 14**, the power unit **162** may be provided in an enclosure **250**. The enclosure **250** may be generally similar in function to the wall mount enclosure, except that one or more sets of furcations in the power unit **162** can be internal to the enclosure **250**. One or more power units **162** can be located on a floor of an office building, a multiple dwelling unit, etc. to provide power and connectivity to remote units on that floor. The exemplary power unit **162** is intended as a 1U rack mount configuration, although the power unit **162** may also be configured as a 3U version, for example, to accommodate additional remote units.

[0092] A furcation **260**, located inside the enclosure **250**, of the riser cable **84** (e.g., **FIG. 3A**) breaks pairs of optical fibers from the riser cable **84** that are connected at an uplink end to the HEU **91**, to provide optical communication input links to the HEU **91**. The furcation **260** can be a Size 2 Edge™ Plug furcation, Part 02-013966-001 available from Corning Cable Systems LLC of Hickory NC. If the CEU **244** is located with the HEU **91**, optical fibers connecting the CEU **244** to the power unit **162** can be included in the riser cable **84**. A furcation **270** breaks fiber pairs from the CEU **244** to provide optical communication input links to the CEU **244**. The furcation **270** can be a Size 2 Edge™ Plug furcation, Part 02-013966-001 available from Corning Cable Systems LLC.

[0093] The optical communication input links from the HEU **91** and the CEU **244** are downlink and uplink optical fiber pairs to be connected to the remote units. In this embodiment, the furcated leg contains eight (8) optical fiber pairs to provide connections from the CEU **244** and HEU **91** to up to four (4) remote units, although any number of fibers and remote units can be used. The legs are connected to the power unit **162** at furcations **280**, which can be arranged as two rows of four 2-fiber connectors on one face of the enclosure **250**. The illustrated furcations **280** are internally mounted in the enclosure **250**. In an alternative embodiment, the furcations **280** can be mounted on a tray **286** that is mounted to an exterior of the enclosure **250**.

[0094] For communication between the HEU **91** and the remote units, the furcated leg **262** from the furcation **260** can be pre-connectorized with a fiber-optic connector to facilitate easy connection to a first adapter module **290** within the power unit **162**. The first adapter module **290** includes a multi-fiber connector **292** that receives the connector of the furcated leg **262**. The connector **292** can be, for example, a 12-fiber MTP connector. A series of six 2-fiber connectors **294**, for example, at the other side of the first adapter module **290**, connects to fiber pairs **282** from each furcation **280**. Each fiber pair **282** can be connectorized with a 2-fiber connector that connects to one of six connectors **294** of the first adapter module **290**. In this arrangement, the first adapter module **290** has the capacity to receive twelve fibers at the connector **292**, and six separate connectorized fiber pairs **282**. This exemplary arrangement allows for optical communication between six remote units and the HEU **91**, although only four such connections are shown in the illustrated embodiment. The first adapter module **290** can be, for example, a 12/F LC EDGE™ Module/07-016841 for riser connection available from Corning Cable Systems LLC.

[0095] For communication between the CEU **244** and the remote units, or an add-on module of a remote unit, etc., the furcated leg **272** from the furcation **270** can be pre-connectorized with a fiber-optic connector to facilitate easy connection to a second adapter module **300** within the power unit **162**. In the illustrated embodiment, the second adapter module **300** is directly beneath the first adapter module **290**, and thus is not visible in **FIG. 14**. The second adapter module **300** includes a multi-fiber connector **293** that receives the connector of the leg **272**. The connector **293** can be, for example, a 12-fiber MTP connector. A series of six 2-fiber connectors, for example, at the other side of the second adapter module **300**, connects to fiber pairs **284** from each furcation **280**. Each fiber pair **284** can be connectorized with a 2-fiber connector that connects to one of six connectors of the second adapter module **300**. In this arrangement, the second adapter module **300** has the capacity to receive twelve fibers at the connector **293**, and six separate connectorized fiber pairs **284**. This arrangement allows for optical communication between, for example, six Ethernet modules that are collocated or within respective remote units, and the CEU **244**, although only four such connections are shown in the illustrated embodiment. The second adapter module **300** can be, for example, a 12/F LC EDGE™ Module/07-016841 for riser connection available from Corning Cable Systems LLC.

[0096] One or more power distribution modules **160** can be included in the enclosure **250**. According to one embodiment, one power distribution module **160** can be connected to each remote unit by a pair of electrical conductors. Electrical conductors include, for example, coaxial cable, twisted copper conductor pairs, etc. Each power distribution module **160** is shown connected to a twisted pair of conductors **324**. The power distribution modules **160** plug into a back plane and the conductors that power the remote units connect to the back plane with a separate electrical connector from the optical fibers, although hybrid optical/electrical connectors could be used. Each cable extending to remote units can include two fibers and two twisted copper conductor pairs, although additional fibers and electrical conductors could be included.

[0097] The power distribution modules **160** are aligned side-by-side in the enclosure **250**. One power distribution module **160** can be assigned to each remote unit, based upon power requirements. If an add-on module, such as an Ethernet module, is included at a remote unit, a second power distribution module **160** can be assigned to power the add-on module. If the remote unit and add-on module power budgets are low, a single power distribution module **160** may suffice to power that location. The allocation of power and optical connectivity is accordingly adaptable depending upon the number and power requirements of remote units, additional modules, and hardware, etc. The power distribution modules **160** can be connected to a power bus that receives local power at the power unit **162** location.

[0098] As previously discussed, the power distribution modules **160** may include a fan **186** that is powered by the module **160**. Each power distribution module **160** can have two output plugs, to allow for powering of high or low power remote units. In **FIG. 14**, unused twisted conductor pairs **326** are parked at location **328**. The conductor pairs **326** could be used to power Power-over-Ethernet applications, etc., although that might require fewer remote units to be used, or additional power distribution modules **160**.

[0099] The illustrated power distribution modules **160** can have a power output of 93-95W. The power distribution modules can operate without fans, but the power ratings may drop, or a larger enclosure space may be required to ensure proper cooling. If no fan is used, the power ratings can drop from, for example, 100W to 60-70W. UL requirements can be followed that limit the power distribution to 100VA per remote unit array. In an alternate 1U module configuration, the power unit **162** could have six power distribution modules **160** and no adapter modules. The modules could supply, for example, remote units with greater than 80W loads. In an alternate 3U module configuration, the power unit **162** could have twelve power distribution modules **160** and can support twelve remote units.

[00100] The power unit **162** discussed herein can encompass any type of fiber-optic equipment and any type of optical connections and receive any number of fiber-optic cables or single or multi-fiber cables or connections. The power unit **162** may include fiber-optic components such as adapters or connectors to facilitate optical connections.

These components can include, but are not limited to the fiber-optic component types of LC, SC, ST, LCAPC, SCAPC, MTRJ, and FC. The power unit **162** may be configured to connect to any number of remote units. One or more power supplies either contained within the power unit **162** or associated with the power unit **162** may provide power to the power distribution module in the power unit **162**. The power distribution module can be configured to distribute power to remote units with or without voltage and current protections and/or sensing. The power distribution module contained in the power unit **162** may be modular where it can be removed and services or permanently installed in the power unit **162**.

[00101] **FIG. 15** is a schematic diagram representation of additional detail regarding an exemplary computer system **340** that may be included in the power distribution module **160** and provided in the power controller **188**. The computer system **340** is adapted to execute instructions from an exemplary computer-readable medium to perform power management functions. In this regard, the computer system **400** may include a set of instructions for causing the power controller **188** to enable and disable coupling of power to the output power port **190**, as previously described. The power controller **188** may be connected (e.g., networked) to other machines in a LAN, an intranet, an extranet, or the Internet. The power controller **188** may operate in a client-server network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. While only a single device is illustrated, the term “device” shall also be taken to include any collection of devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. The power controller **188** may be a circuit or circuits included in an electronic board card, such as a printed circuit board (PCB) as an example, a server, a personal computer, a desktop computer, a laptop computer, a personal digital assistant (PDA), a computing pad, a mobile device, or any other device, and may represent, for example, a server or a user’s computer.

[00102] The exemplary computer system **340** of the power controller **188** in this embodiment includes a processing device or processor **344**, a main memory **356** (e.g., read-only memory (ROM), flash memory, dynamic random access memory (DRAM) such as synchronous DRAM (SDRAM), etc.), and a static memory **348** (e.g., flash memory, static random access memory (SRAM), etc.), which may communicate with each other via the data bus **350**. Alternatively, the processing device **344** may be connected to the main memory **356** and/or static memory **348** directly or via some other connectivity means. The processing device **344** may be a controller, and the main memory **356** or static memory **348** may be any type of memory, each of which can be included in the power controller **188**.

[00103] The processing device **344** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processing device **344** may be a complex instruction set computing (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a processor implementing other instruction sets, or processors implementing a combination of instruction sets. The processing device **344** is configured to execute processing logic in instructions **346** for performing the operations and steps discussed herein.

[00104] The computer system **340** may further include a network interface device **352**. The computer system **340** also may or may not include an input **354** to receive input and selections to be communicated to the computer system **340** when executing instructions. The computer system **340** also may or may not include an output **364**, including but not limited to a display, a video display unit (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)), an alphanumeric input device (e.g., a keyboard), and/or a cursor control device (e.g., a mouse).

[00105] The computer system **340** may or may not include a data storage device that includes instructions **358** stored in a computer-readable medium **360**. The instructions **358** may also reside, completely or at least partially, within the main memory **356** and/or within the processing device **344** during execution thereof by the computer system **340**, the main memory **356** and the processing device **344** also constituting computer-readable medium. The instructions **358** may further be transmitted or received over a network **362** via the network interface device **352**.

[00106] Further, as used herein, it is intended that terms “fiber optic cables” and/or “optical fibers” include all types of single mode and multi-mode light waveguides, including one or more optical fibers that may be upcoated, colored, buffered, ribbonized and/or have other organizing or protective structure in a cable such as one or more tubes, strength members, jackets or the like. The optical fibers disclosed herein can be single mode or multi-mode optical fibers. Likewise, other types of suitable optical fibers include bend-insensitive optical fibers, or any other expedient of a medium for transmitting light signals. An example of a bend-insensitive, or bend resistant, optical fiber is ClearCurve® Multimode fiber commercially available from Corning

Incorporated. Suitable fibers of this type are disclosed, for example, in U.S. Patent Application Publication Nos. 2008/0166094 and 2009/0169163, the disclosures of which are incorporated herein by reference in their entireties.

[00107] Many modifications and other embodiments of the embodiments set forth herein will come to mind to one skilled in the art to which the embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. For example, the distributed antenna systems could include any type or number of communications mediums, including but not limited to electrical conductors, optical fiber, and air (i.e., wireless transmission). The distributed antenna systems may distribute any type of communications signals, including but not limited to RF communications signals and digital data communications signals, examples of which are described in U.S. Patent Application Serial No. 12/892,424 entitled "Providing Digital Data Services in Optical Fiber-based Distributed Radio Frequency (RF) Communications Systems, And Related Components and Methods," incorporated herein by reference in its entirety. Multiplexing, such as WDM and/or FDM, may be employed in any of the distributed antenna systems described herein, such as according to the examples provided in U.S. Patent Application Serial No. 12/892,424.

[00108] Therefore, it is to be understood that the description and claims are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. A power distribution module for distributing power in a distributed antenna system, comprising:

an input power port configured to receive input power from an external power source;

at least one output power port configured to receive output power and distribute the output power to at least one distributed antenna system (DAS) power-consuming device electrically coupled to the at least one output power port; and

at least one power controller comprising a power enable port, the at least one power controller configured to selectively distribute the output power based on the input power to the at least one output power port based on a power enable signal coupled to the power enable port.

2. The power distribution module of claim 1, further comprising at least one power converter electrically coupled to the input power port, the at least one power converter configured to:

receive input power from the external power source when the external power source is electrically connected to the input power port;

convert the input power to the output power; and

distribute the output power to at least one power controller.

3. The power distribution module according to any of the preceding claims, wherein the at least one power controller is configured to distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to activate power.

4. The power distribution module according to any of the preceding claims, wherein the at least one power controller is configured to not distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to deactivate power.

5. The power distribution module according to any of the preceding claims, wherein the at least one output power port is comprised of a plurality of output power ports

configured to distribute power to a plurality of power-consuming DAS components electrically coupled to the plurality of output power ports.

6. The power distribution module according to any of the preceding claims, wherein the input power port comprises at least one input power conductor electrically coupled to the at least one power converter and at least one input power enable conductor electrically coupled to the power enable port.

7. The power distribution module of claim 6, wherein the at least one input power conductor is configured to receive the input power from the external power source when the external power source is coupled to the input power port.

8. The power distribution module of claim 6, wherein the at least one input power enable conductor is configured to receive a power enable signal.

9. The power distribution module of claim 6, wherein the at least one input power conductor is comprised of at least one input power connector receptacle, and the at least one input power enable conductor is comprised of at least one input power enable receptacle.

10. The power distribution module of claim 6, wherein the at least one input power conductor is comprised of at least one input power connector pin, and the at least one input power enable conductor is comprised of at least one input power enable pin.

11. The power distribution module of claim 10, wherein the at least one input power enable pin is shorter in length than the at least one input power connector pin, such that when the at least one input power conductor is electrically coupled to the external power source, an electrical connection is established to the at least one input power connector pin before an electrical connection is established to the at least one input power enable pin.

12. The power distribution module according to any of the preceding claims, wherein the at least one output power port comprises at least one output power conductor

electrically coupled to the at least one power converter and at least one output power enable conductor electrically coupled to the power enable port.

13. The power distribution module of claim 12, wherein the at least one output power conductor is configured to receive the output power from the at least one power controller when the external power source is coupled to the input power port and the power enable port receives the power enable signal indicating to distribute power.

14. The power distribution module of claim 13, wherein the at least one output power enable conductor is configured to receive a power enable signal.

15. The power distribution module of claim 12, wherein the at least one output power conductor is comprised of at least one output power connector receptacle, and the at least one output power enable conductor is comprised of at least one output power enable receptacle.

16. The power distribution module of claim 12, wherein the at least one output power conductor is comprised of at least one output power connector pin, and the at least one output power enable conductor is comprised of at least one output power enable pin.

17. The power distribution module of claim 16, wherein the at least one output power enable pin is shorter in length than the at least one output power connector pin, such that when the at least one output power conductor is electrically coupled to the at least one DAS power-consuming device, an electrical connection is established to the at least one output power connector pin before an electrical connection is established to the at least one output power enable pin.

18. The power distribution module according to any of the preceding claims, wherein the at least one DAS power-consuming device is comprised of at least one remote antenna unit (RAU).

19. The power distribution module of claim 2, wherein the at least one power converter is configured to convert alternating current (AC) input power from the external power source to direct current (DC) output power.

20. The power distribution module according to any of the preceding claims disposed in an optical fiber transmission medium-based distributed antenna system.

21. The power distribution module according to any of the preceding claims disposed in an electrical conductor transmission medium-based distributed antenna system.

22. The power distribution module of claim 1 disposed in a power unit in a distributed antenna system.

23. The power distribution module of claim 22, wherein the power unit further comprises a plurality of communication links each configured to carry radio-frequency (RF) communications signals from head-end equipment (HEE) to a plurality of RAUs.

24. A method of distributing power from a power distribution module to at least one power-consuming distributed antenna system (DAS) component in a DAS, comprising:

receiving input power from an external power source electrically connected to an input power port;

selectively distributing from at least one power controller, output power based on the input power to at least one output power port based on a power enable signal coupled to a power enable port on the at least one power controller; and

distributing the output power from the at least one output power port to the at least one power-consuming DAS component electrically coupled to the at least one output power port.

25. A system for distributing power to a power-consuming device in a distributed antenna system (DAS), comprising:

an external input power connector configured to be electrically coupled to an external power source to supply power to the external input power connector; and

a power distribution module, comprising:

an input power port configured to receive input power from the external input power connector; and

at least one power controller comprising a power enable port, the at least one power controller configured to selectively distribute output power based on the input power to at least one output power port based on a power enable signal coupled to the power enable port;

wherein the external input power connector comprises at least one external input power conductor configured to be electrically coupled to the input power port and at least one external input power enable conductor configured to be electrically coupled to the power enable port.

26. The system of claim 25, further comprising at least one power converter electrically coupled to the input power port, the at least one power converter configured to:

receive the input power from the external power source when the external input power connector is electrically coupled to the input power port;

convert the input power to the output power; and

distribute the output power to at least one power controller.

27. The system according to any of the preceding system claims, wherein the at least one external input power conductor is comprised of at least one external input power connector pin, and the at least one external input power enable conductor is comprised of at least one external input power enable pin.

28. The system of 27, wherein the at least one external input power enable pin is shorter in length than the at least one external input power connector pin, such that when the at least one external input power conductor is electrically coupled to the external power source, an electrical connection is established to the at least one external input power connector pin before an electrical connection is established to the at least one external input power enable pin.

29. The system according to any of the preceding system claims, wherein the at least one power controller is configured to distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to activate power.

30. The system according to any of the preceding system claims, wherein the at least one power controller is configured to not distribute the output power to the at least one

output power port if the power enable signal coupled to the power enable port indicates to deactivate power.

31. The system according to any of the preceding system claims, wherein the input power port comprises at least one input power conductor configured to receive the input power and at least one input power enable conductor electrically coupled to the power enable port.

32. The system according to any of the preceding system claims, wherein the at least one output power port comprises at least one output power conductor configured to receive the input power and at least one output power enable conductor electrically coupled to the power enable port.

33. A system for distributing power to a power-consuming device in a distributed antenna system (DAS), comprising:

at least one external output power connector configured to be electrically coupled to at least one output power port of a power distribution module to receive power from the power distribution module; and

the power distribution module, comprising:

an input power port configured to receive input power from an external power source;

at least one output power port configured to receive output power and distribute the output power to at least one distributed antenna system (DAS) power-consuming device electrically coupled to the at least one output power port; and

at least one power controller comprising a power enable port, the at least one power controller configured to selectively distribute output power based on the input power to the at least one output power port based on a power enable signal coupled to the power enable port;

wherein the at least one external output power connector comprises at least one external output power conductor configured to be electrically coupled to the at least one output power port and at least one external output power enable conductor configured to be electrically coupled to the power enable port.

34. The system of claim 33, further comprising at least one power converter electrically coupled to the input power port, the at least one power converter configured to:

receive input power from the external power source when the external power source is electrically connected to the input power port;

convert the input power to output power; and

distribute the output power to at least one power controller.

35. The system according to claims 33 or 34, wherein the at least one external output power conductor is comprised of at least one external output power connector pin, and the at least one external output power enable conductor is comprised of at least one external output power enable pin.

36. The system according to claim 35, wherein the at least one external output power enable pin is shorter in length than the at least one external output power connector pin, such that when the at least one external output power conductor is electrically coupled to the at least one output power port, an electrical connection is established to the at least one external output power connector pin before an electrical connection is established to the at least one external output power enable pin.

37. The system according to claims 33, 34, 35, or 36, wherein the at least one external output power conductor is disposed in an external power cable.

38. The system according to claims 33, 34, 35, 36, or 37, wherein the at least one power controller is configured to distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to activate power.

39. The system according to claims 33, 34, 35, 36, 37, or 38, wherein the at least one power controller is configured to not distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to deactivate power.

40. The system according to claims34, 35, 36, 37, 38, or 39, wherein the input power port comprises at least one input power conductor electrically coupled to the at least one power converter and at least one input power enable conductor electrically coupled to the power enable port.

41. The system according to claims 34, 35, 36, 37, 38, 39, or 40, wherein the at least one output power port comprises at least one output power conductor electrically coupled to the at least one power converter and at least one output power enable conductor electrically coupled to the power enable port.

42. A power unit for distributing power to a power-consuming device in a distributed antenna system (DAS), comprising:

a chassis;

an external input power connector disposed in the chassis, the external input power connector configured to be electrically coupled to an external power source to supply power to the external input power connector; and

at least one external output power connector disposed in the chassis, the at least one external output power connector configured to be electrically coupled to at least one output power port of a power distribution module to receive power from the power distribution module; and

at least one power distribution module, comprising:

an input power port configured to receive input power from an external power source;

at least one output power port configured to receive output power and distribute the output power to at least one distributed antenna system (DAS) power-consuming device electrically coupled to the at least one output power port; and

at least one power controller comprising a power enable port, the at least one power controller configured to selectively distribute output power based on the input power to the at least one output power port based on a power enable signal coupled to the power enable port;

wherein the external input power connector comprises at least one external input power conductor configured to be electrically coupled to the input power port and at least one external input power enable conductor configured to be electrically coupled to the power enable port; and

wherein the at least one external output power connector comprises at least one external output power conductor configured to be electrically coupled to the at least one output power port and at least one external output power enable conductor configured to be electrically coupled to the power enable port.

43. The power unit of claim 42, further comprising at least one power converter electrically coupled to the input power port, the at least one power converter configured to:

receive input power from the external power source when the external power source is electrically connected to the input power port;

convert the input power to output power; and

distribute the output power to at least one power controller.

44. The power unit according to claims 42 or 43, wherein the at least one power controller is configured to distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to activate power.

45. The power unit according to claims 42, 43, or 44, wherein the at least one power controller is configured to not distribute the output power to the at least one output power port if the power enable signal coupled to the power enable port indicates to deactivate power.

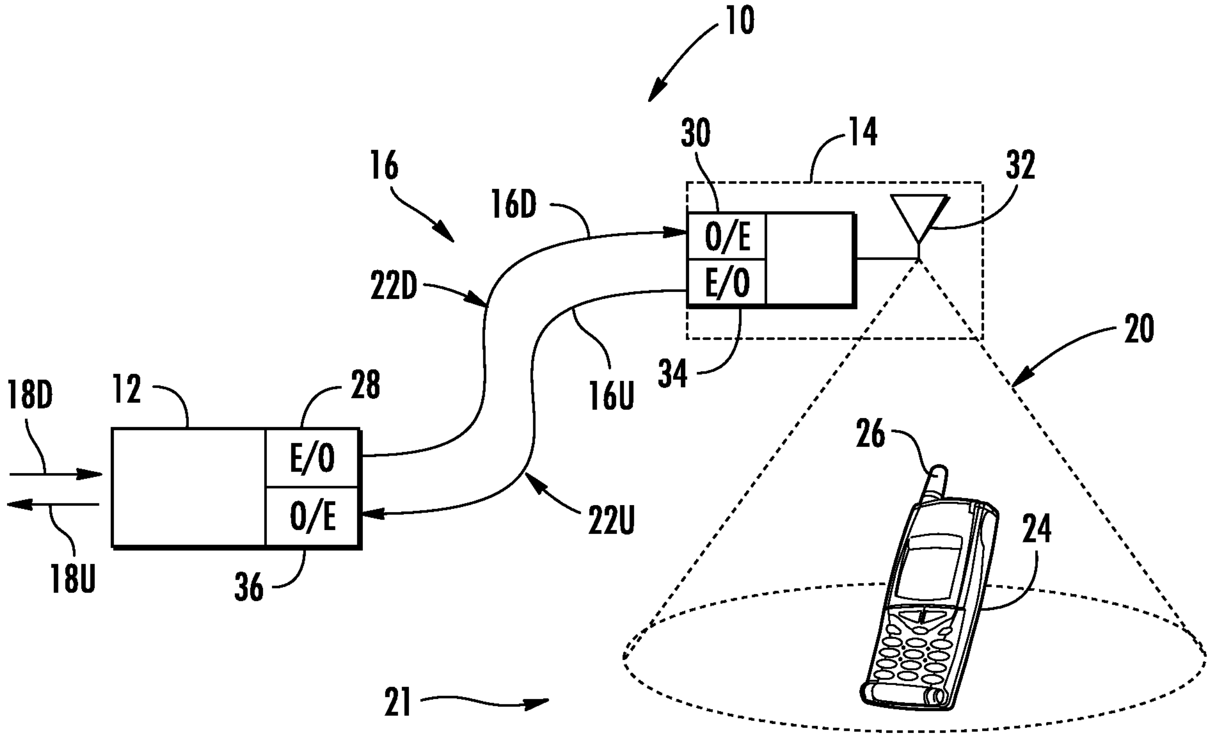

10
16
16D
22D
30
O/E
E/O
14
32
34
16U
20
12
28
18D
E/O
O/E
18U
36
22U
26
24
21

FIG. 1

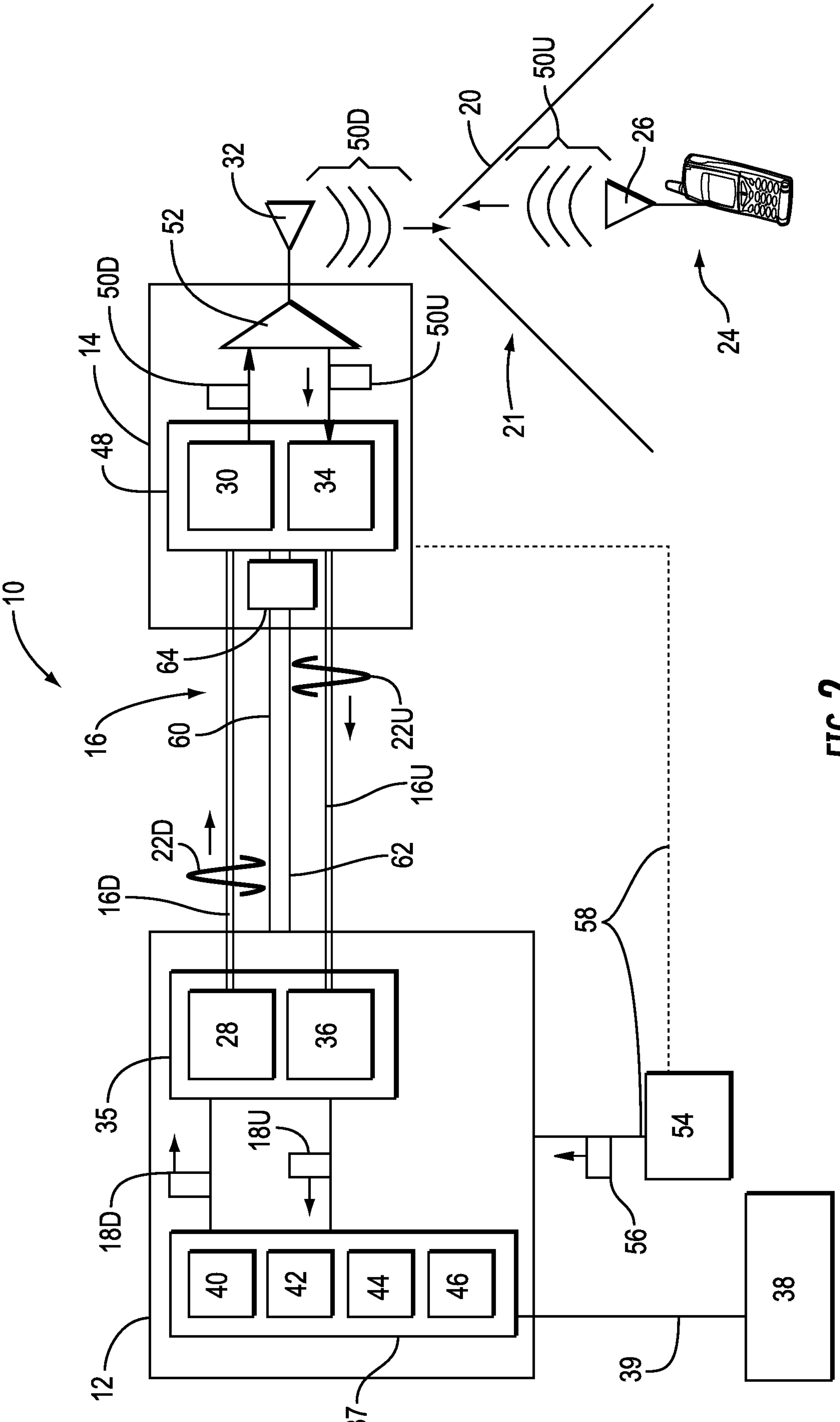

10
12
14
16
16D
16U
18D
18U
20
21
22D
22U
24
26
28
30
32
34
35
36
37
38
39
40
42
44
46
48
50D
50U
52
54
56
58
60
62
64

FIG. 2

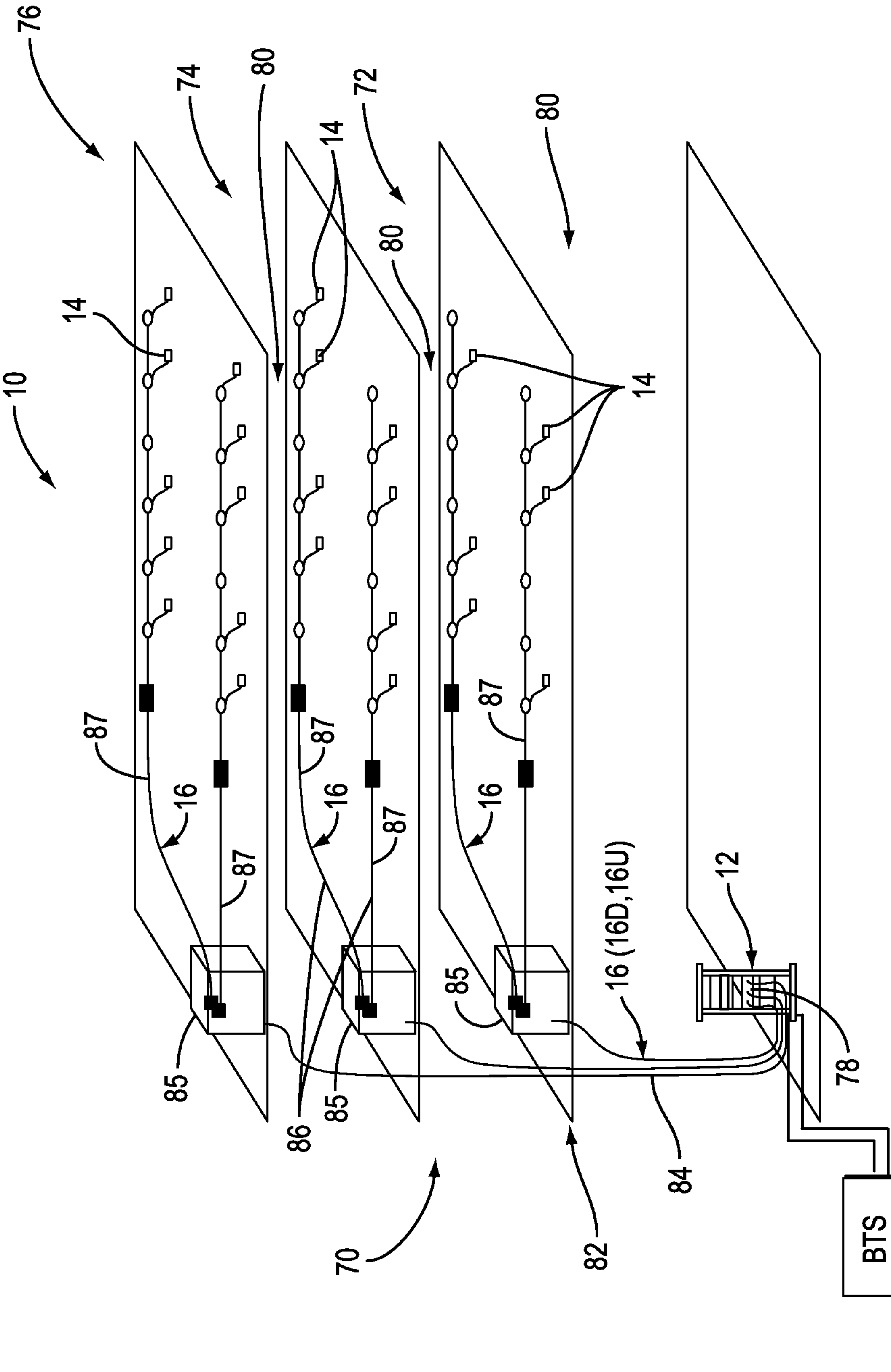

76
74
80
72
80
14
10
14
14
87
16
87
16
87
16
87
85
85
85
86
70
82
84
16 (16D,16U)
12
78
BTS
88

FIG. 3A

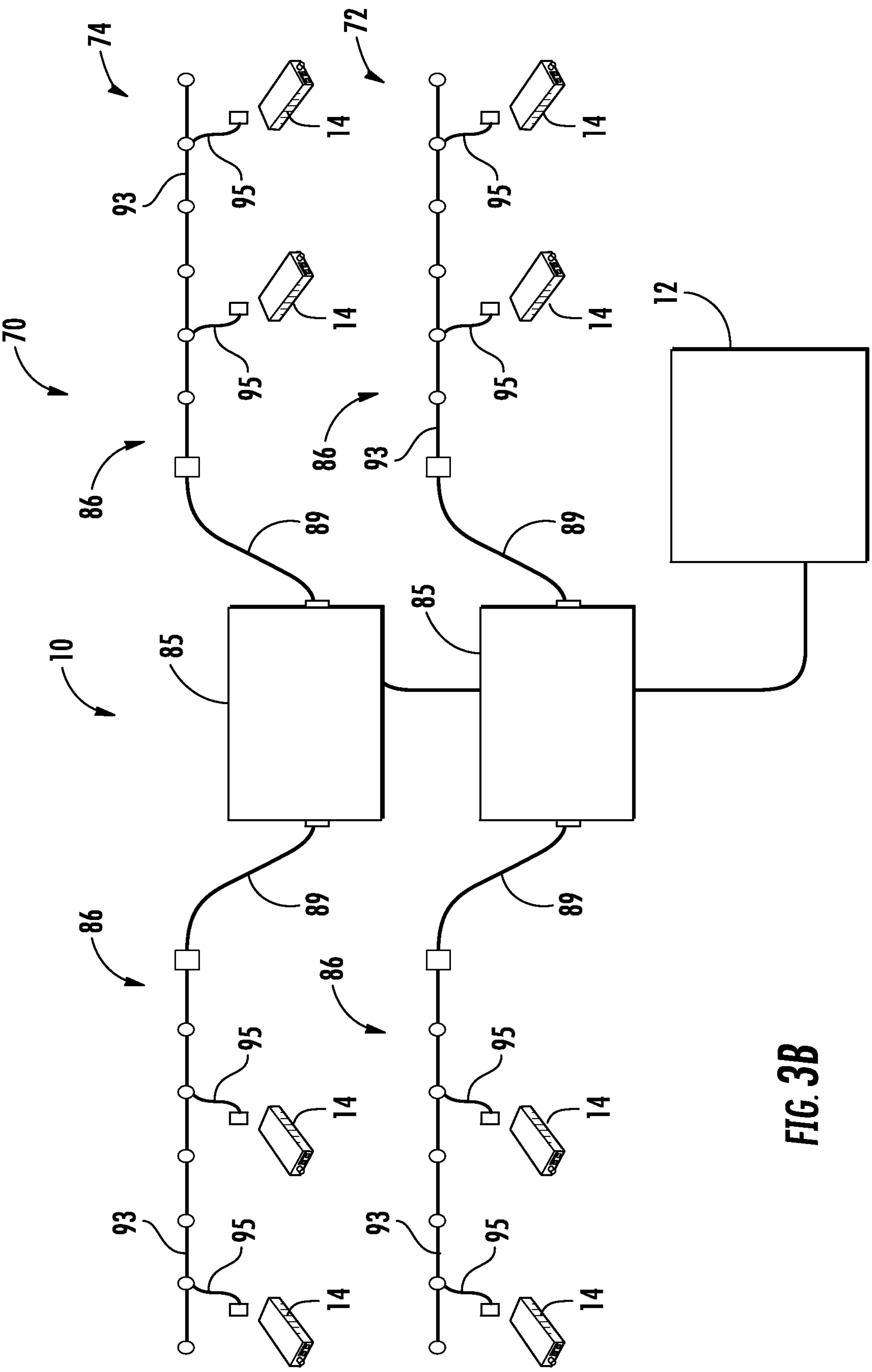

74
72
70
10
85
85
86
86
86
86
89
89
89
89
93
93
93
93
95
95
95
95
95
95
95
95
14
14
14
14
14
14
14
14
12

FIG. 3B

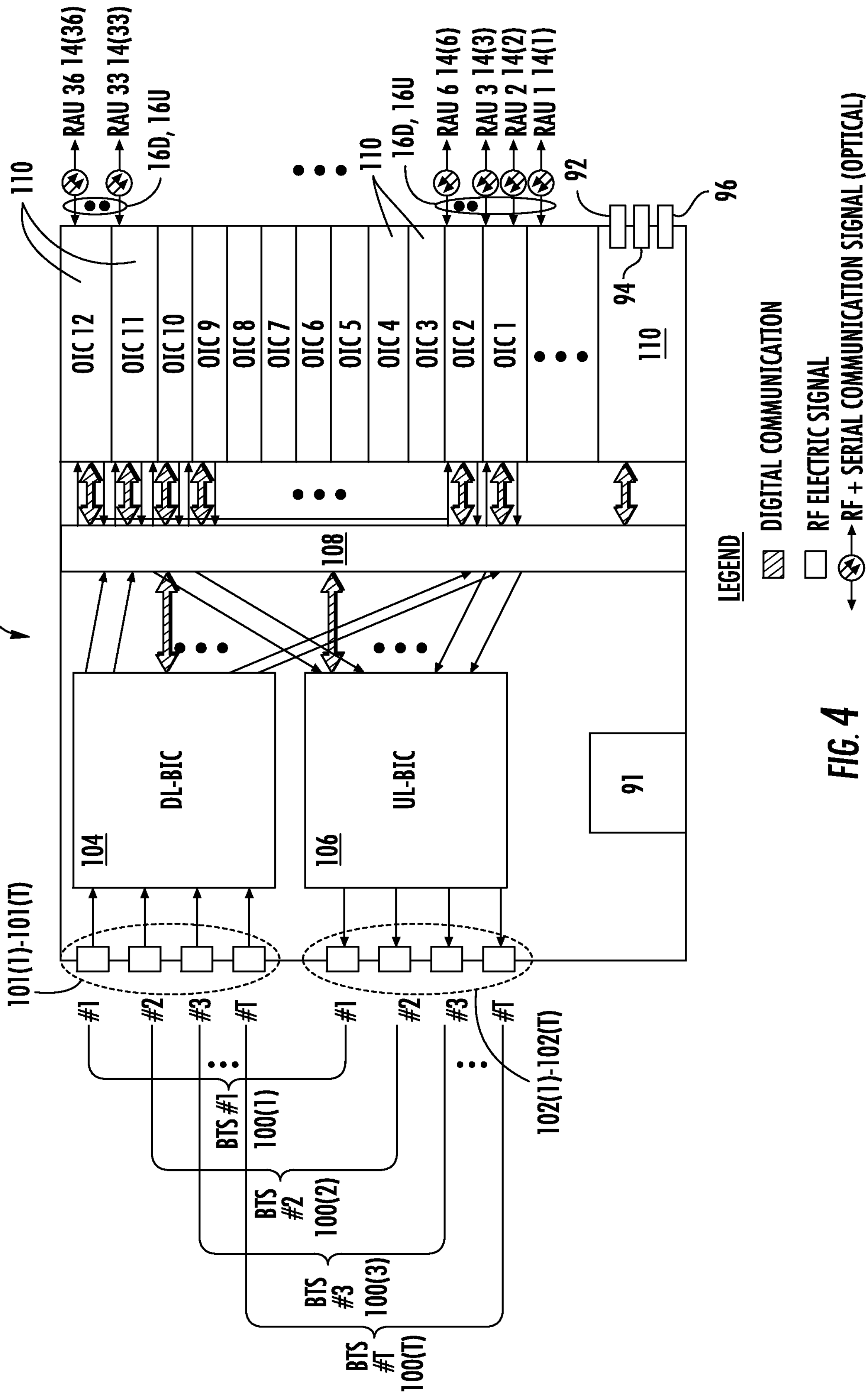

90
DL-BIC
104
UL-BIC
106
91
108
110
OIC 12
OIC 11
OIC 10
OIC 9
OIC 8
OIC 7
OIC 6
OIC 5
OIC 4
OIC 3
OIC 2
OIC 1
RAU 36 14(36)
RAU 33 14(33)
16D, 16U
RAU 6 14(6)
RAU 3 14(3)
RAU 2 14(2)
RAU 1 14(1)
92
94
96
101(1)-101(T)
102(1)-102(T)
#1
#2
#3
#T
BTS #1 100(1)
BTS #2 100(2)
BTS #3 100(3)
BTS #T 100(T)
LEGEND
DIGITAL COMMUNICATION
RF ELECTRIC SIGNAL
RF + SERIAL COMMUNICATION SIGNAL (OPTICAL)

FIG. 4

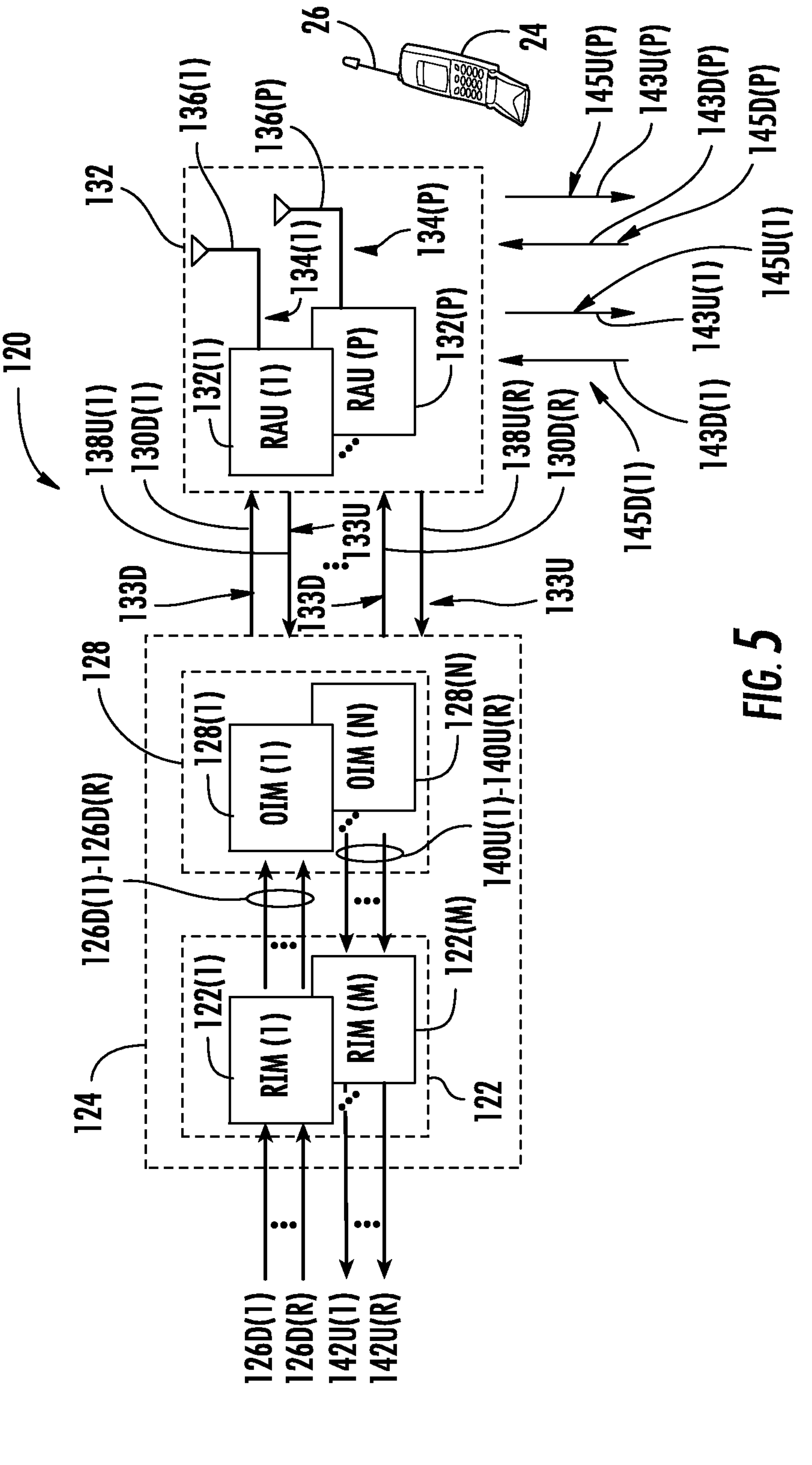

120
26
24
132
136(1)
136(P)
134(1)
134(P)
132(1)
132(P)
RAU (1)
RAU (P)
138U(1)
130D(1)
138U(R)
130D(R)
133D
133U
145U(P)
143U(P)
143D(P)
145D(P)
145U(1)
143U(1)
143D(1)
145D(1)
124
128
128(1)
128(N)
OIM (1)
OIM (N)
126D(1)-126D(R)
140U(1)-140U(R)
122
122(1)
122(M)
RIM (1)
RIM (M)
126D(1)
126D(R)
142U(1)
142U(R)

FIG. 5

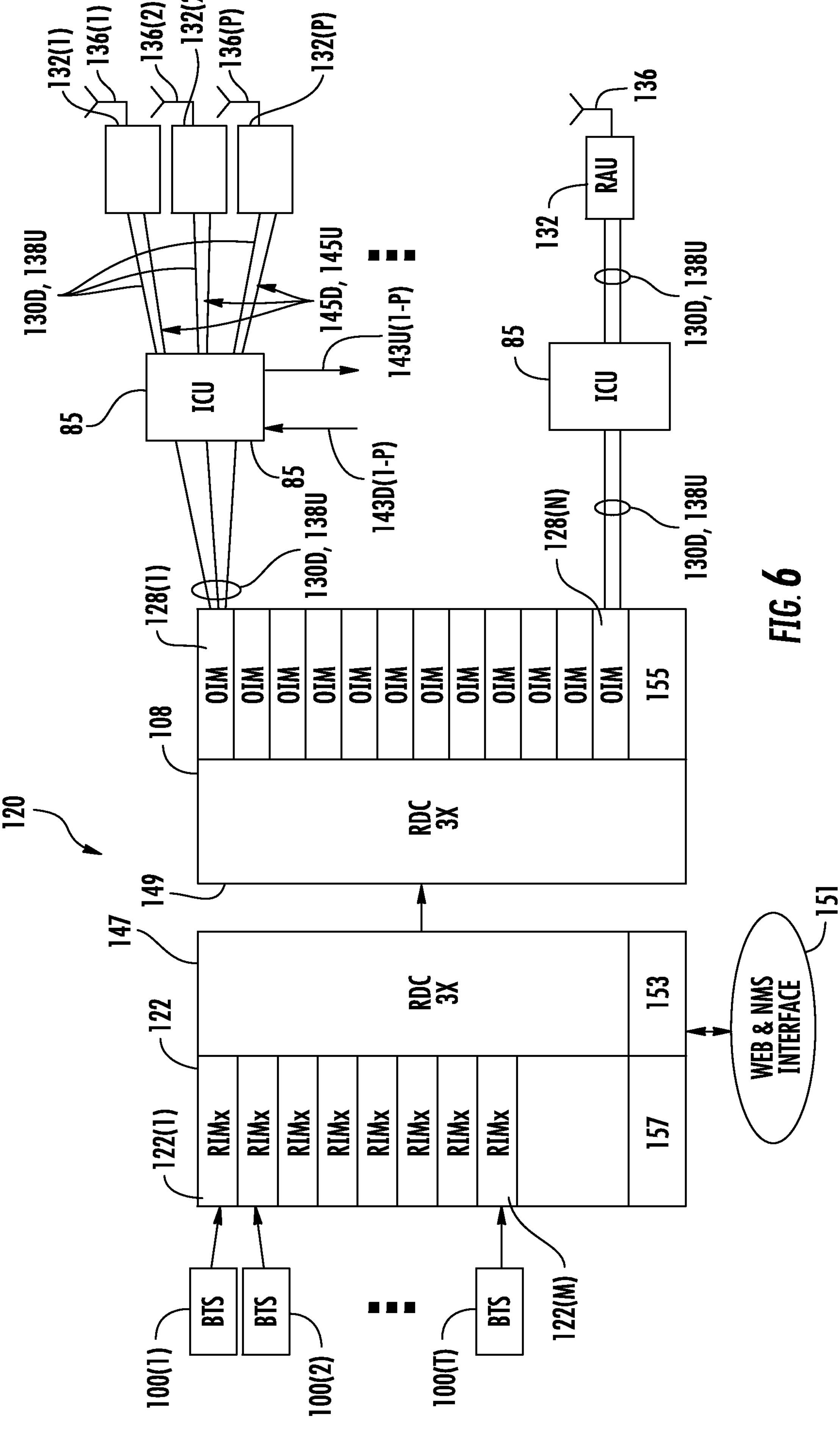

120
BTS
100(1)
BTS
100(2)
BTS
100(T)
122(1)
RIMx
122(M)
122
147
RDC
3X
153
157
WEB & NMS
INTERFACE
151
149
108
RDC
3X
OIM
155
128(1)
128(N)
130D, 138U
ICU
85
143D(1-P)
143U(1-P)
145D, 145U
132(1)
136(1)
136(2)
132(2)
136(P)
132(P)
RAU
132
136

FIG. 6

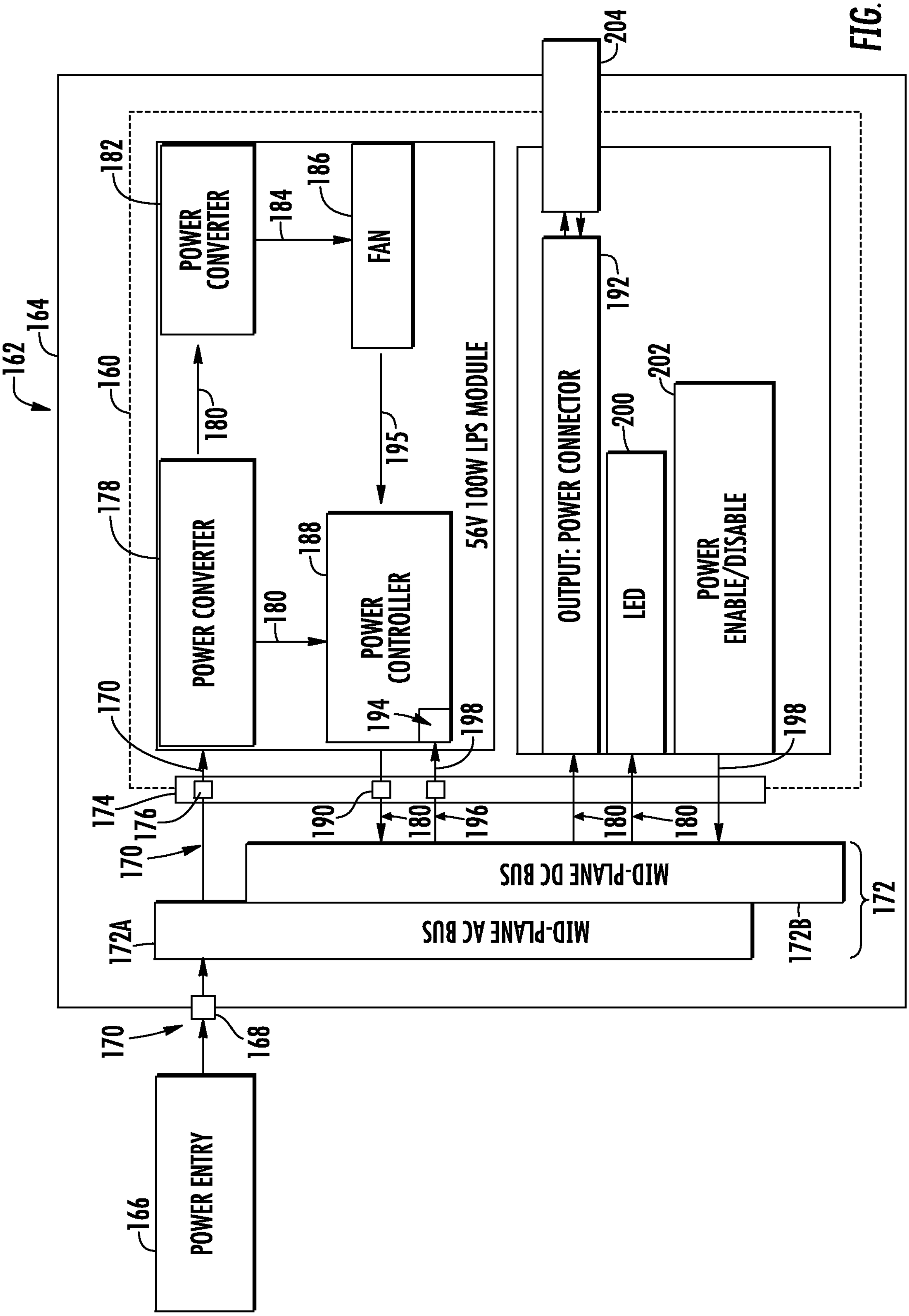
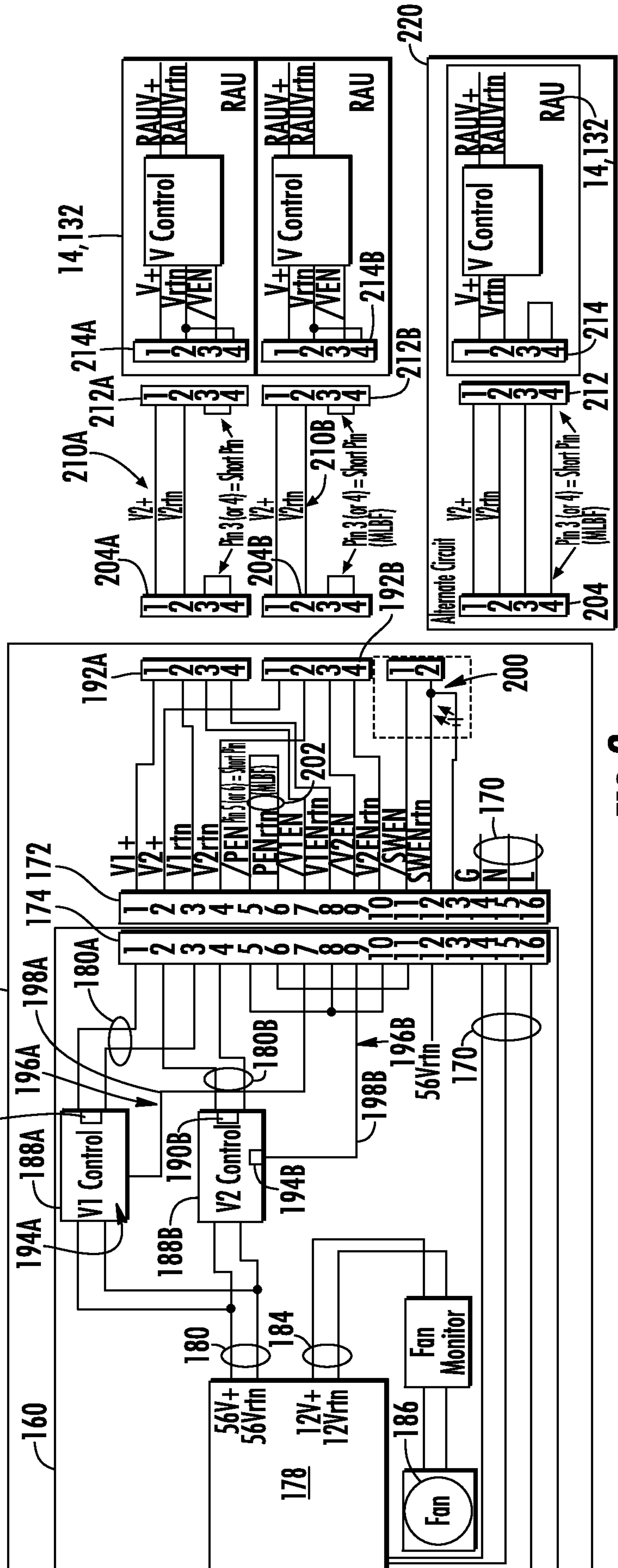

POWER ENTRY
MID-PLANE AC BUS
MID-PLANE DC BUS
POWER CONVERTER
POWER CONVERTER
FAN
POWER CONTROLLER
56V 100W LPS MODULE
OUTPUT: POWER CONNECTOR
LED
POWER ENABLE/DISABLE
162
164
160
166
168
170
172
172A
172B
174
176
178
180
182
184
186
188
190
192
194
195
196
198
200
202
204

FIG. 7



RAUV+
RAUVrtn
RAU
V Control
V+
Vrtn
/VEN
14,132
214A
214B
214
212A
212B
212
210A
210B
220
204A
204B
204
192A
192B
200
V2+
V2rtn
Pin 3 (or 4) = Short Pin
Pin 3 (or 4) = Short Pin (MLBF)
Alternate Circuit
V1+
V2+
V1rtn
V2rtn
/PEN
PENrtn
Pin 5 (or 6) = Short Pin (MLBF)
/V1EN
V1ENrtn
/V2EN
V2ENrtn
/SWEN
SWENrtn
G
N
L
202
172
174
170
162
160
180A
180B
198A
198B
196A
196B
190A
190B
188A
188B
194A
194B
V1 Control
V2 Control
56Vrtn
180
184
Fan Monitor
56V+
56Vrtn
12V+
12Vrtn
178
186
Fan

FIG. 8

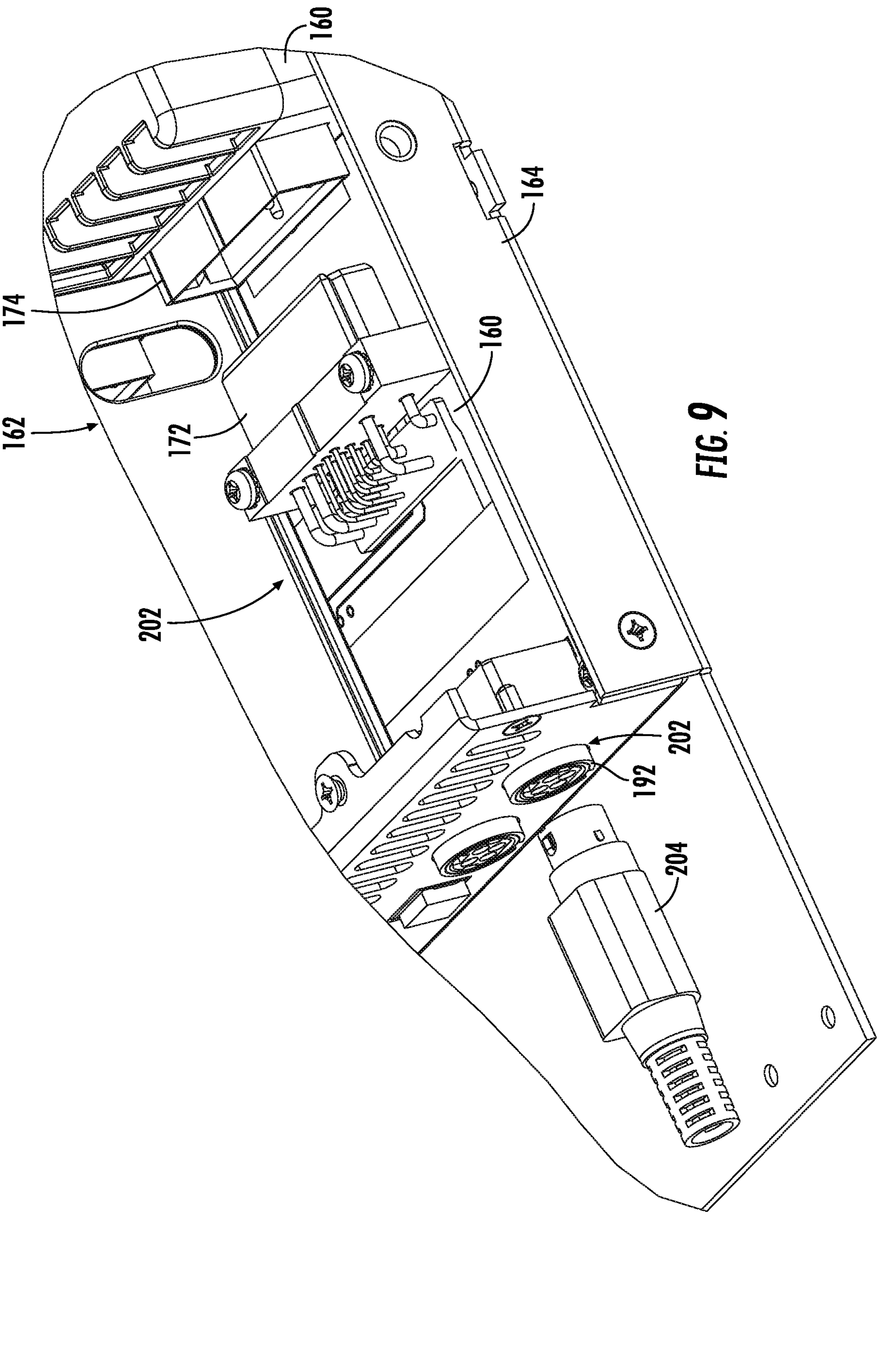


FIG. 9

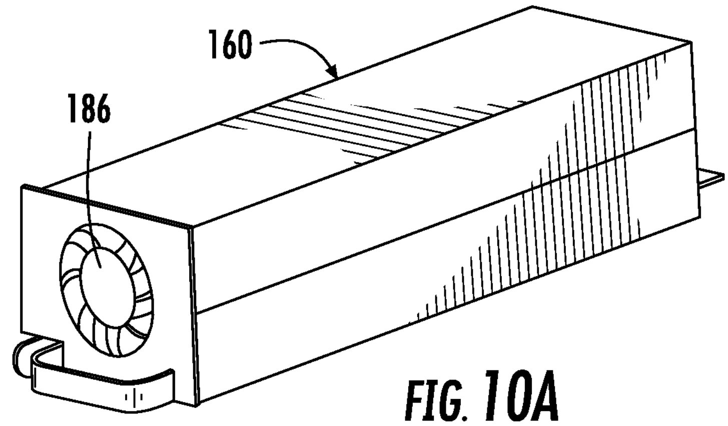


FIG. 10A

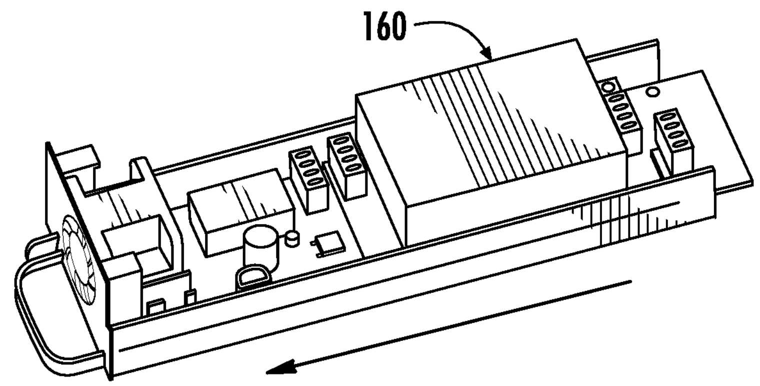


FIG. 10B

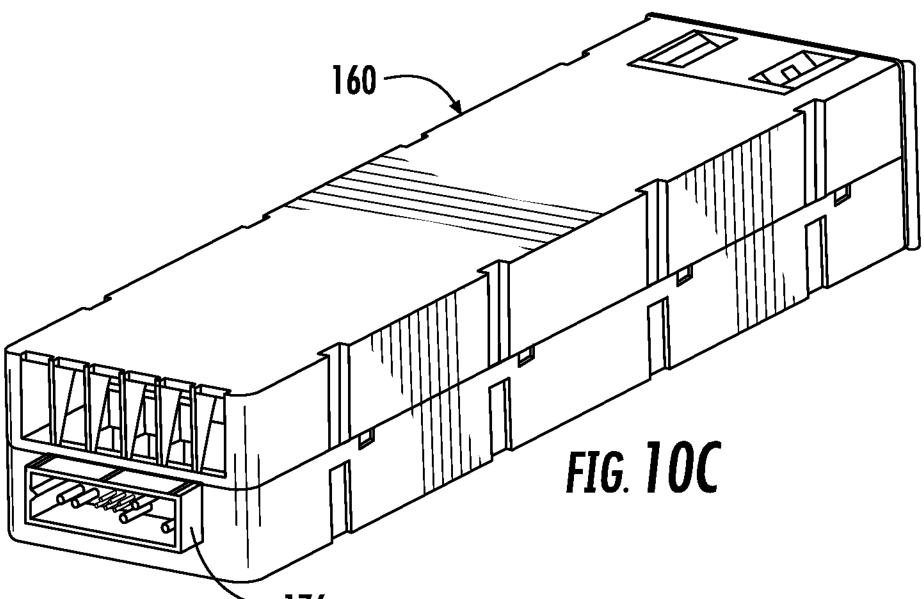


FIG. 10C

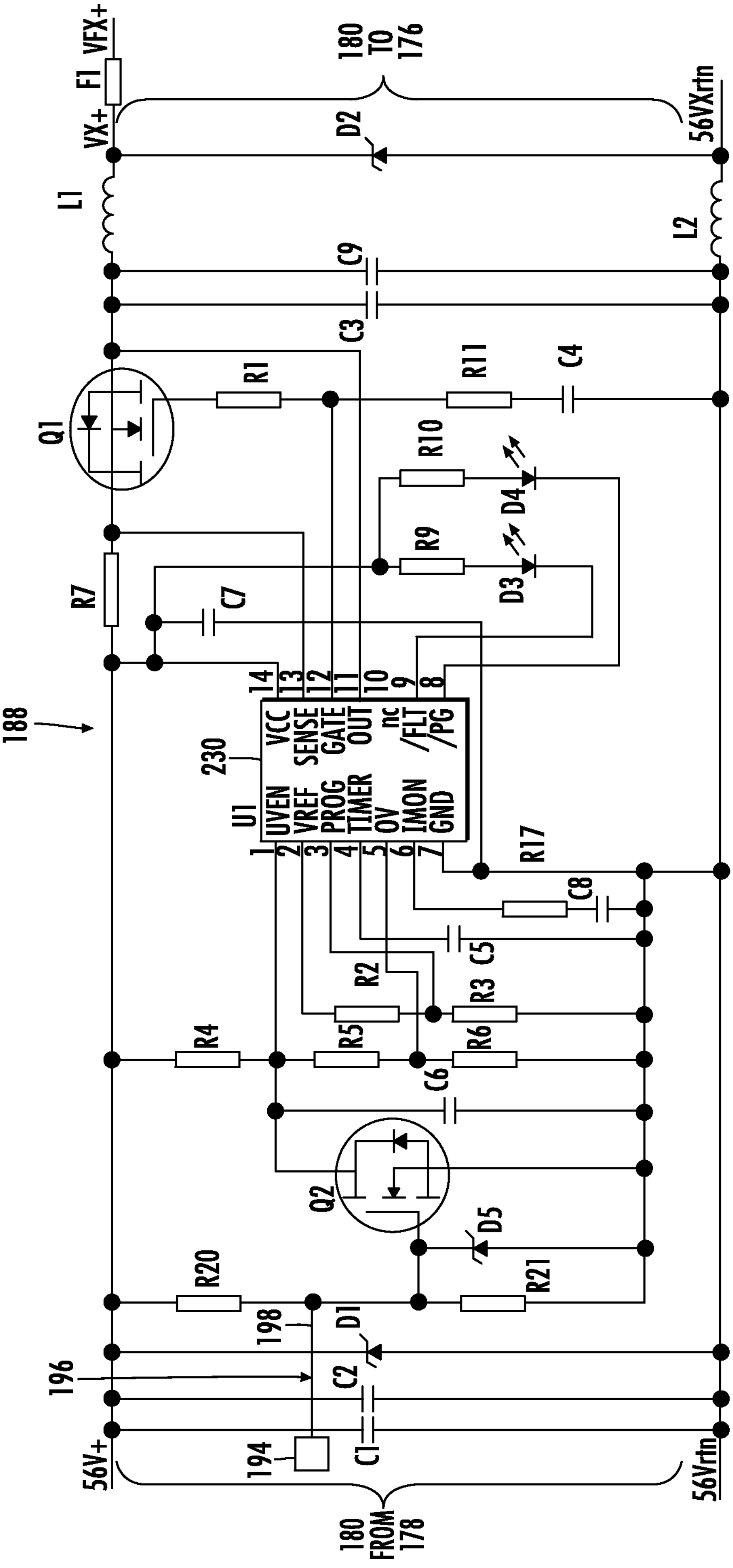

F1
VFX+
VX+
180
TO
176
56VXrtn
D2
L1
L2
C9
C3
Q1
R1
R11
C4
R10
D4
R9
D3
R7
C7
188
230
U1
VCC
SENSE
GATE
OUT
nc
/FLT
/PG
UVEN
VREF
PROG
TIMER
OV
IMON
GND
14
13
12
11
10
9
8
1
2
3
4
5
6
7
R17
C8
C5
R2
R3
R4
R5
R6
C6
Q2
D5
R20
R21
D1
198
196
C2
C1
194
56V+
56Vrtn
180
FROM
178

FIG. 11

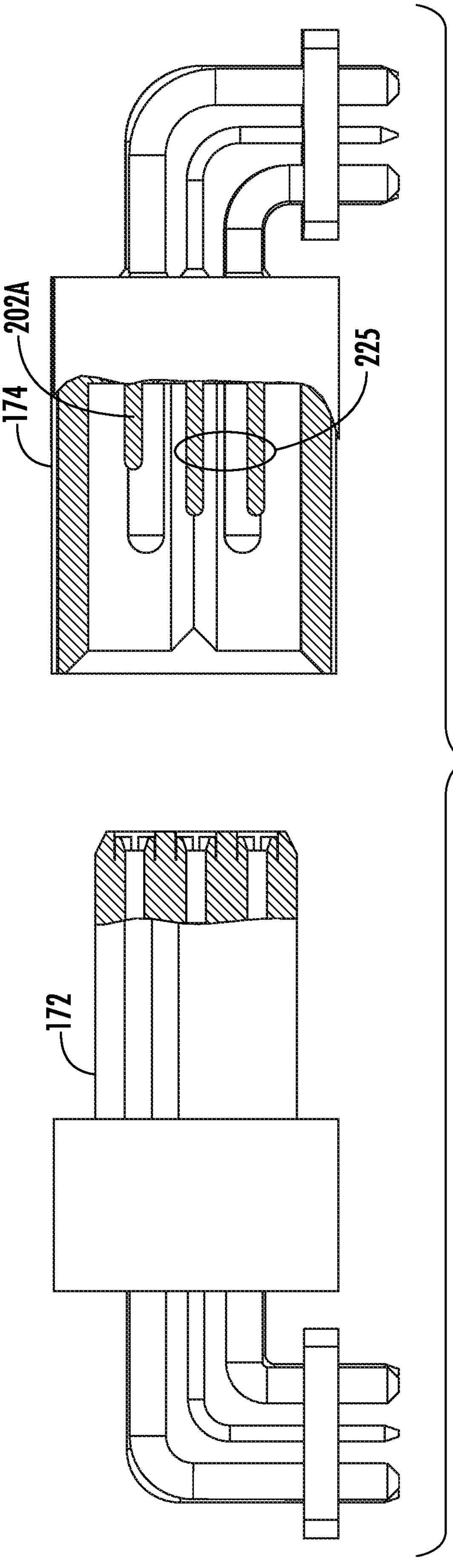


FIG. 12

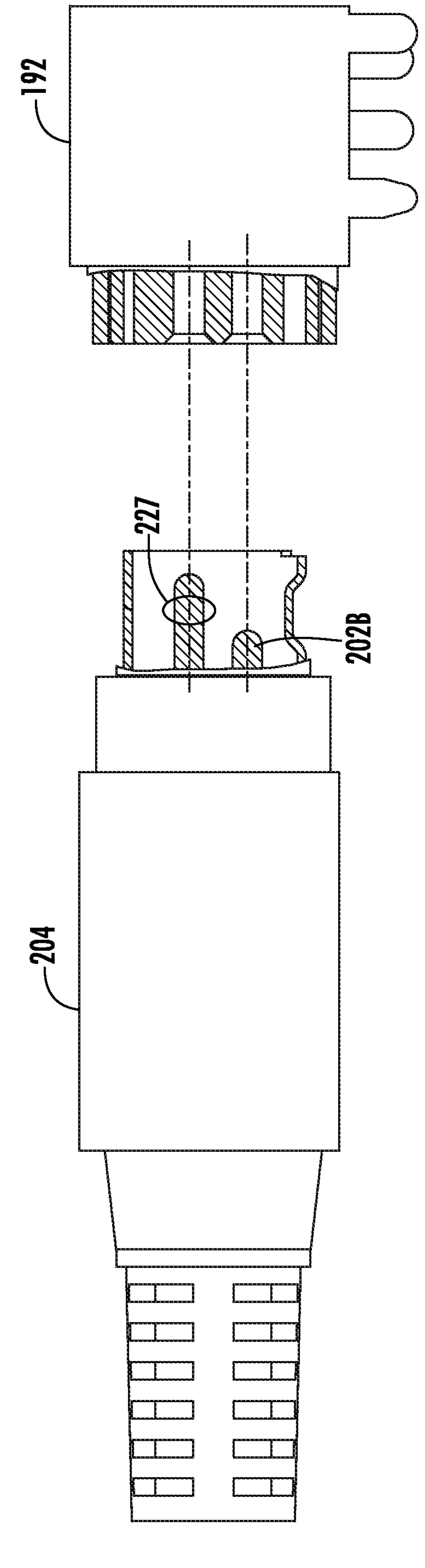


FIG. 13

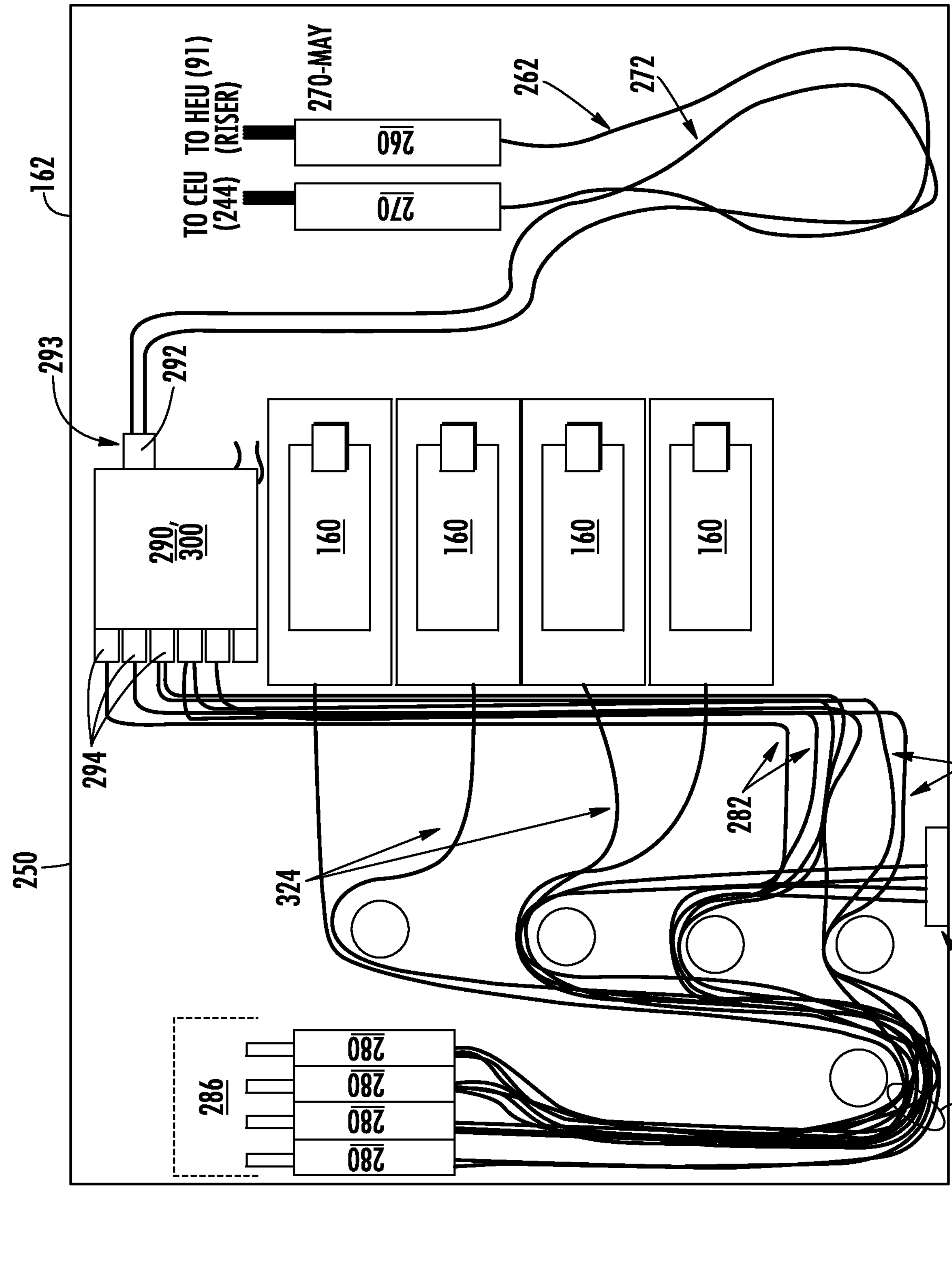

TO CEU
(244)
TO HEU (91)
(RISER)
270-MAY
260
270
262
272
162
293
292
290,
300
160
160
160
160
294
324
282
284
328
326
280
280
280
280
286
250

FIG. 14

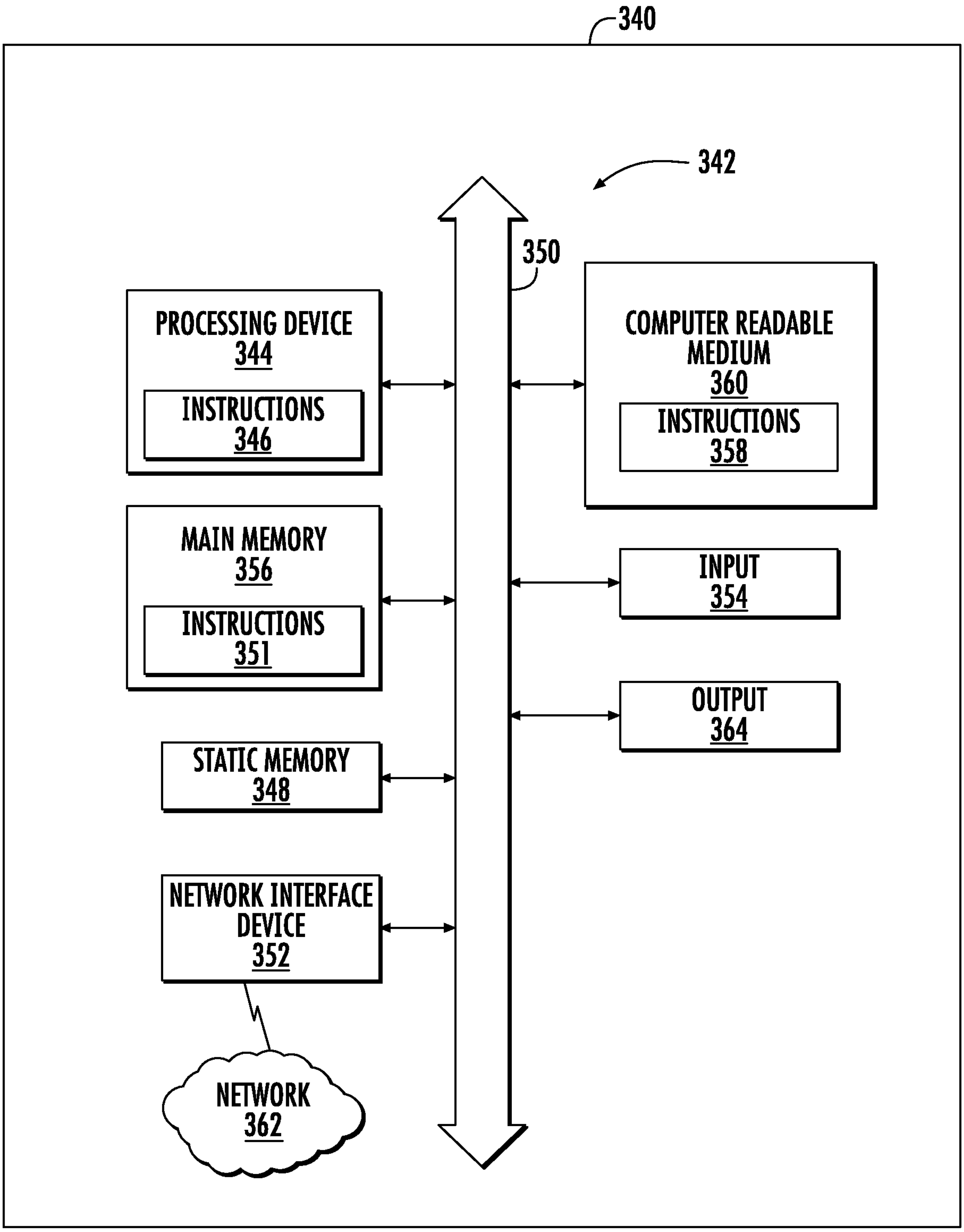

340
342
350
PROCESSING DEVICE
344
INSTRUCTIONS
346
COMPUTER READABLE MEDIUM
360
INSTRUCTIONS
358
MAIN MEMORY
356
INSTRUCTIONS
351
INPUT
354
OUTPUT
364
STATIC MEMORY
348
NETWORK INTERFACE DEVICE
352
NETWORK
362

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/061761

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/10 H04W88/08 H04B10/12 H04B10/00
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)
H04L H04W H04B G05B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/290787 A1 (COX TERRY D [US]) 18 November 2010 (2010-11-18) figures 1,2,3,6 paragraphs [0019], [0020], [0029], [0038], [0039], [0042], [0049] -----	1-45
Y	US 5 436 827 A (GUNN DANIEL D [US] ET AL) 25 July 1995 (1995-07-25) figure 2 sentence 18 - sentence 34 -----	1-45
A	US 2005/226625 A1 (WAKE DAVID [GB] ET AL) 13 October 2005 (2005-10-13) figure 1 paragraphs [0031] - [0036] -----	1-45

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 2012	26/01/2012

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	Nold, Michael

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/061761

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