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(54) **POWER EXTRACTING DEVICE AND METHOD OF USE THEREOF**

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(51) **Int. Cl.**
H01R 3/00 (2006.01)

(52) **U.S. Cl.** **439/489**; 439/620.03; 439/913

(58) **Field of Classification Search** 439/489, 439/578, 913, 620.03; 340/635, 656, 687
See application file for complete search history.

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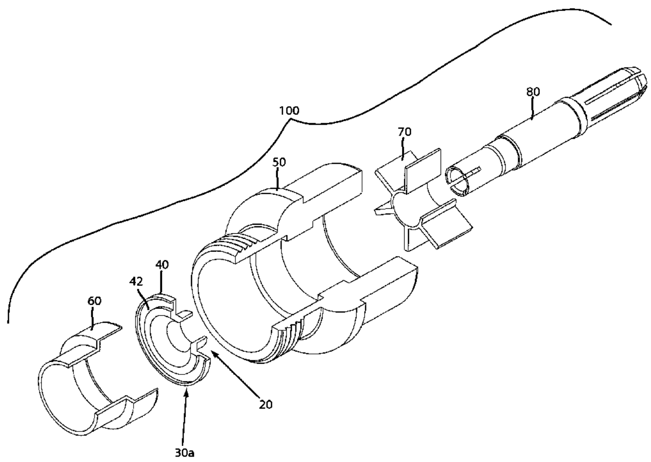
(57) **ABSTRACT**

A structure is provided. The structure includes a signal retrieval circuit formed within a disk located within a coaxial cable connector. The signal retrieval circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector. The signal retrieval circuit is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector. The energy signal is configured to apply power to an electrical device located within the coaxial cable connector. The structure may additionally form a sensing circuit with a status output component. The sensor circuit may be configured to sense physical parameters such as those related to a condition of the electrical signal flowing through the connector or a presence of moisture within the connector.

30 Claims, 11 Drawing Sheets



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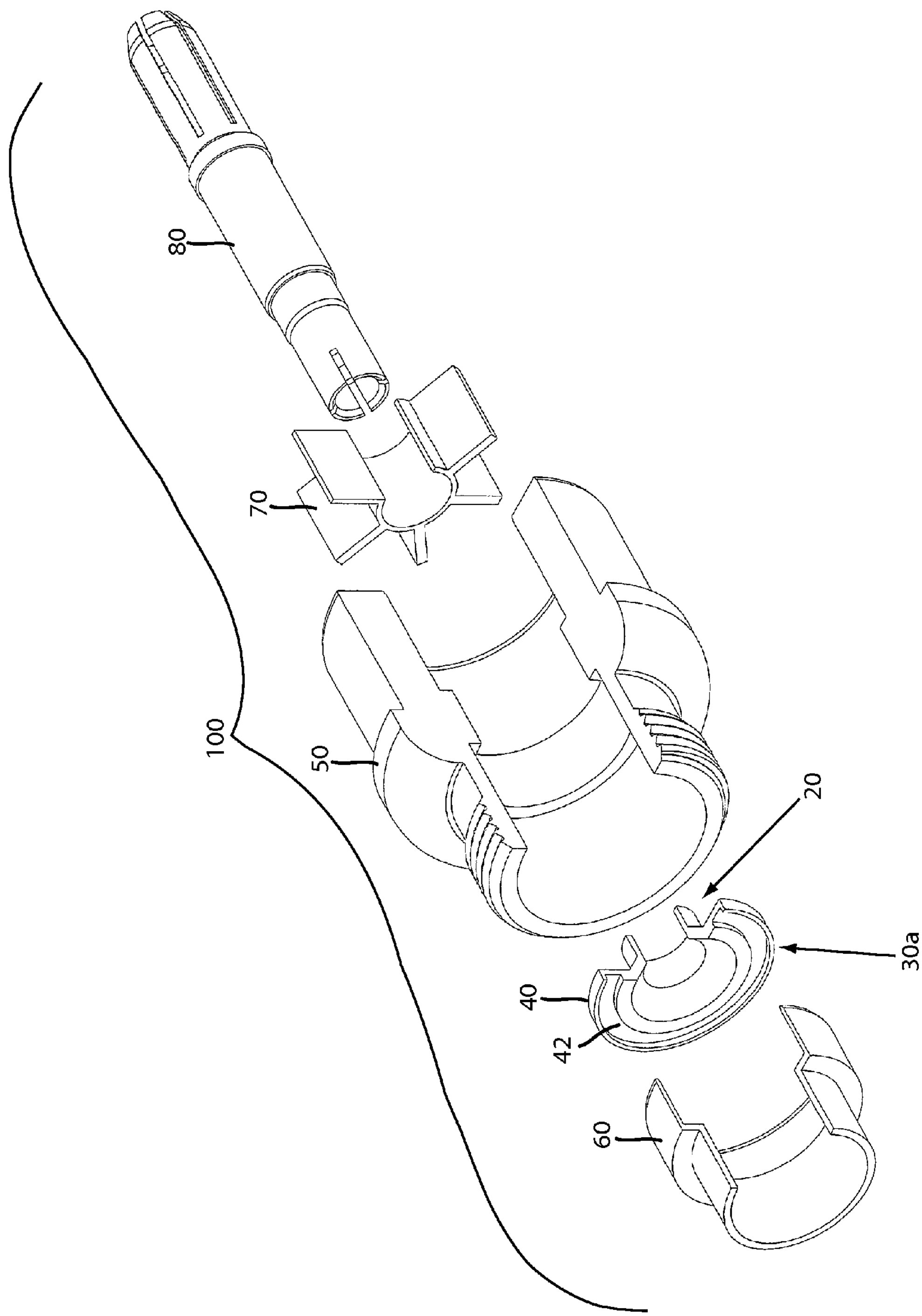


FIG. 1

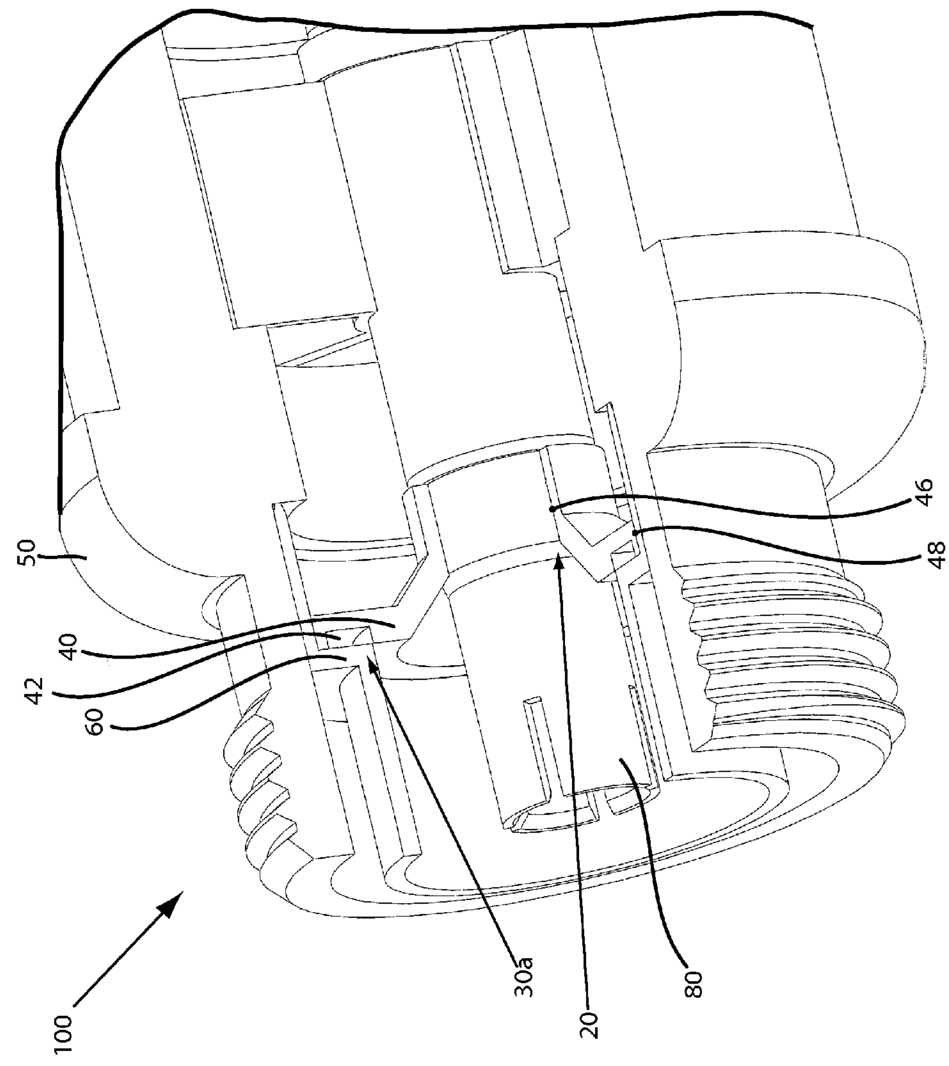


FIG. 2

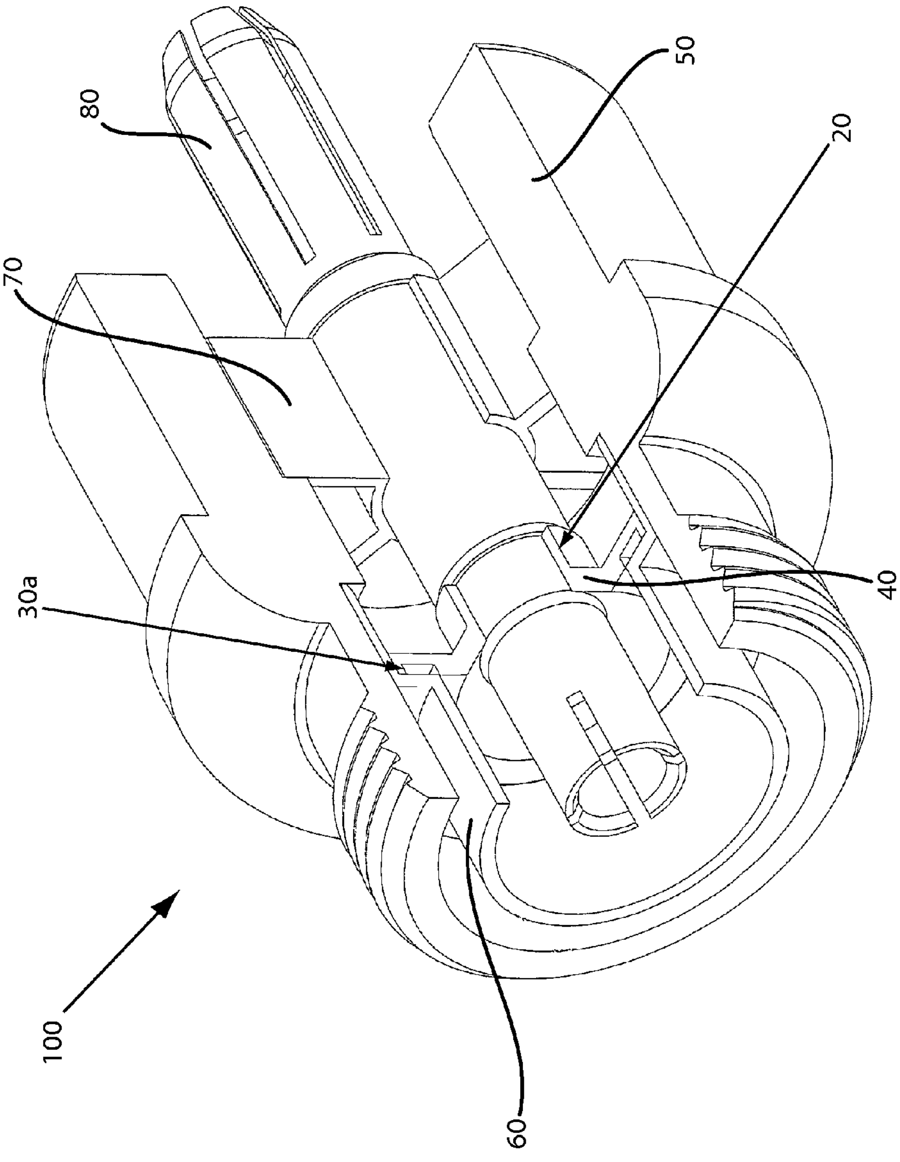


FIG. 3

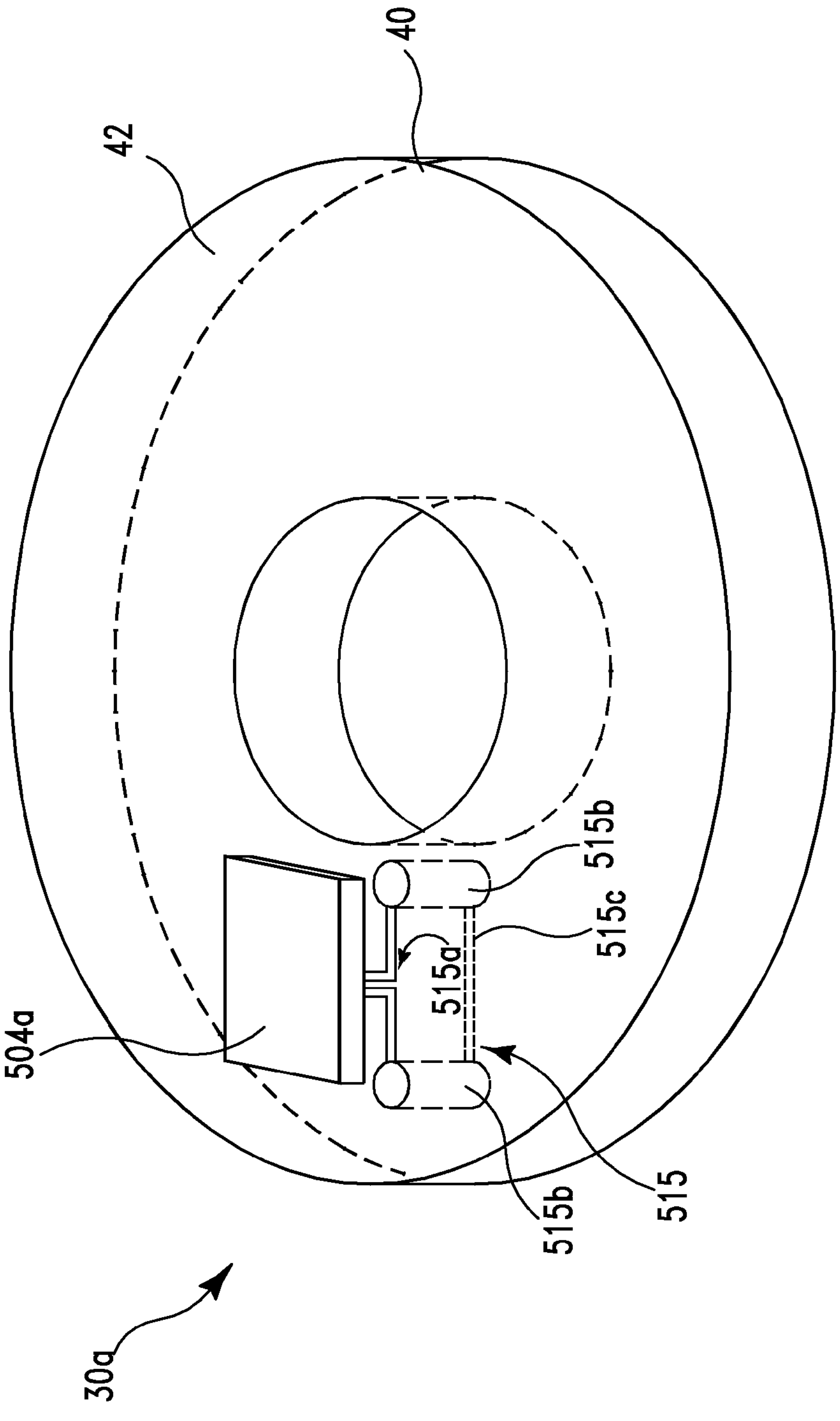
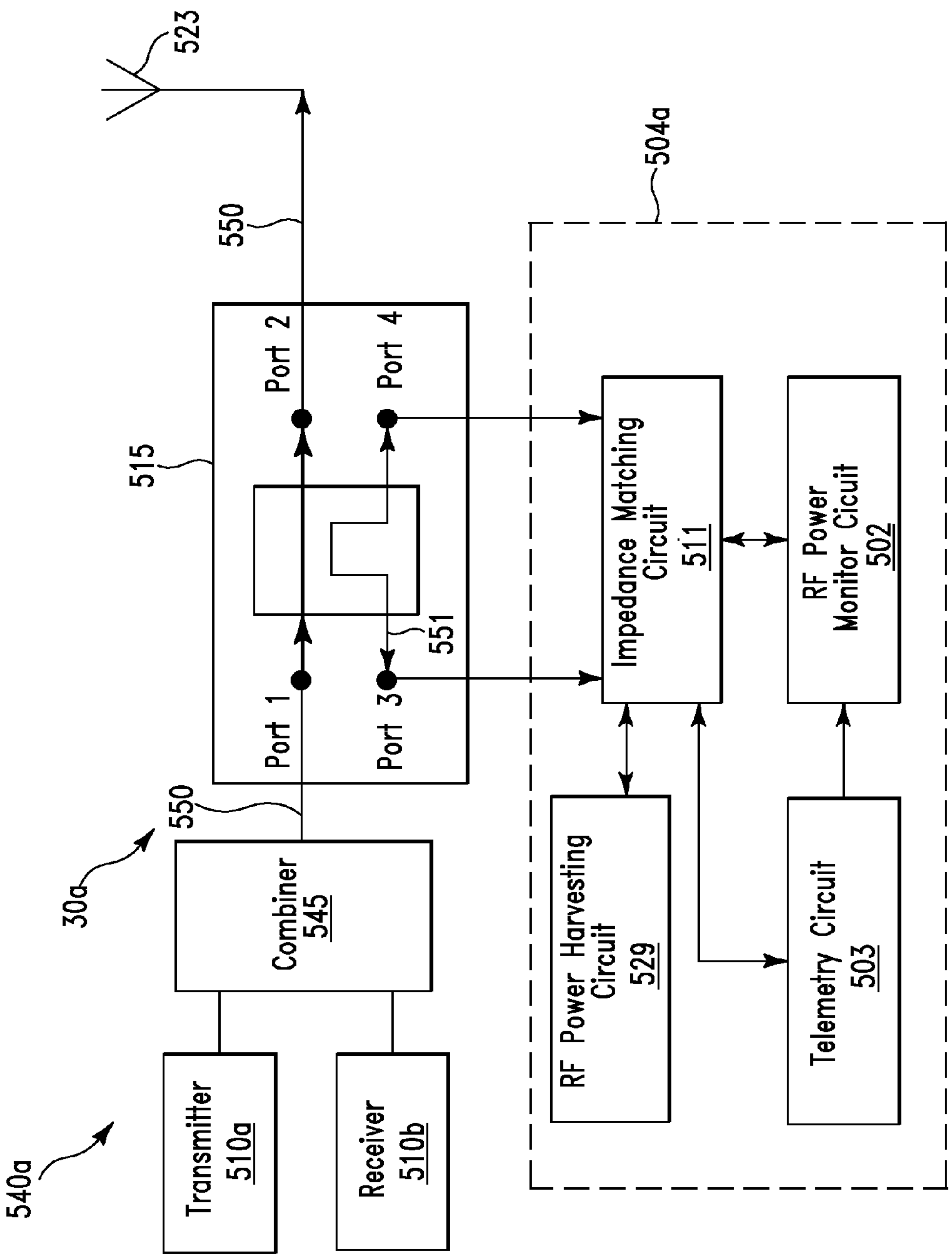


FIG. 4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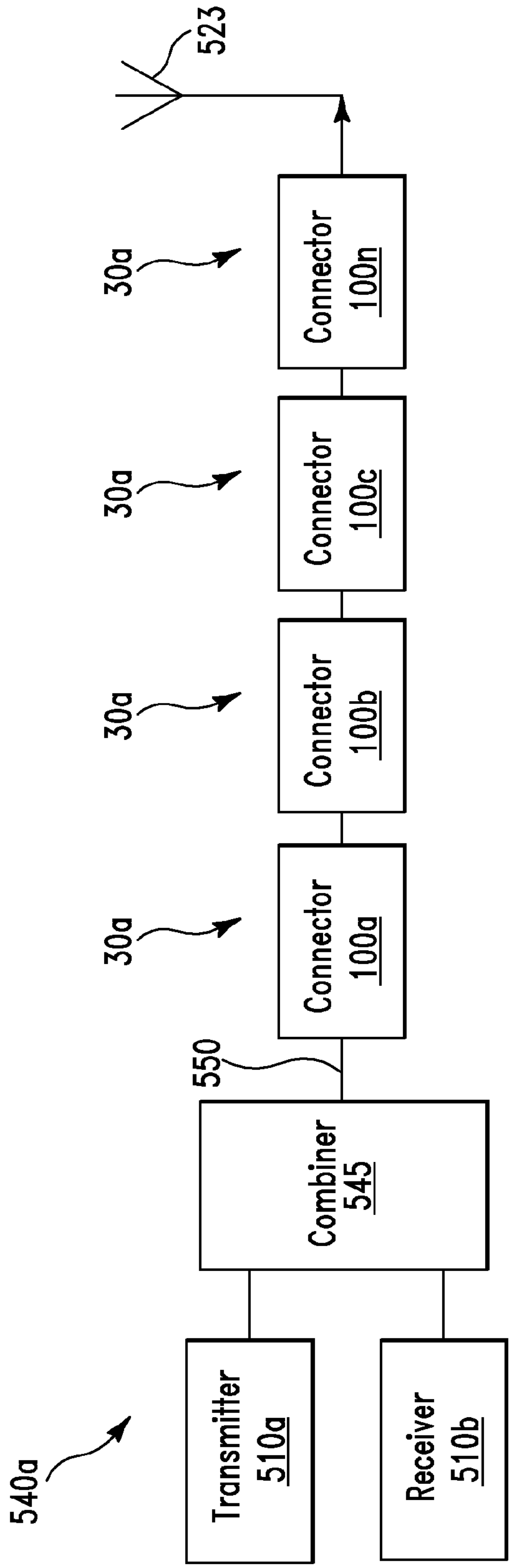
550
515
Port 2
Port 4
Port 1
Port 3
551
550
30a
Combiner
545
540a
Transmitter
510a
Receiver
510b
504a
Impedance Matching
Circuit
511
RF Power
Monitor Cicuit
502
RF Power Harvesting
Circuit
529
Telemetry Circuit
503

FIG. 5A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30a
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100n
30a
Connector
100c
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Connector
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Transmitter
510a
Receiver
510b

FIG. 5B

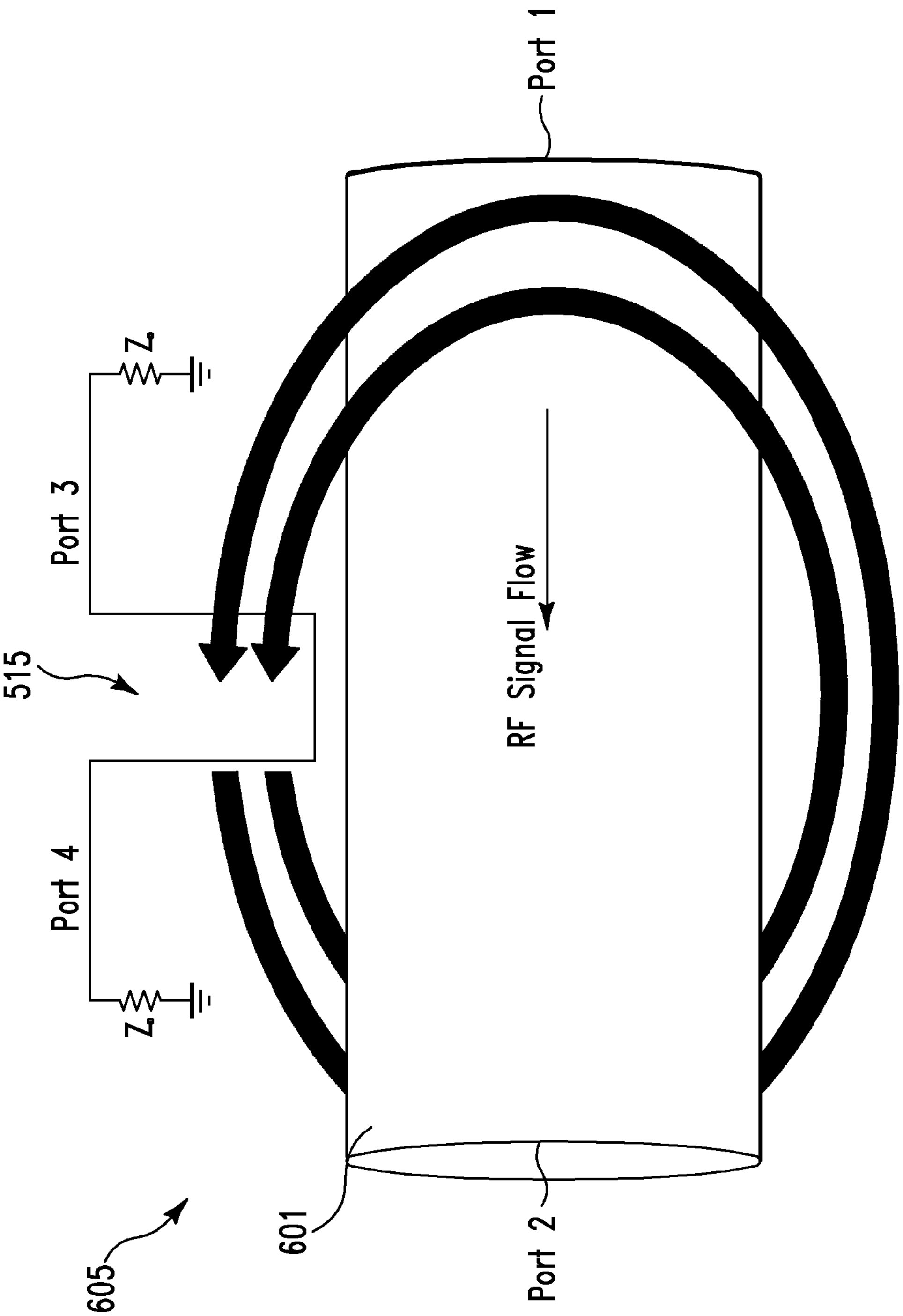


FIG. 6

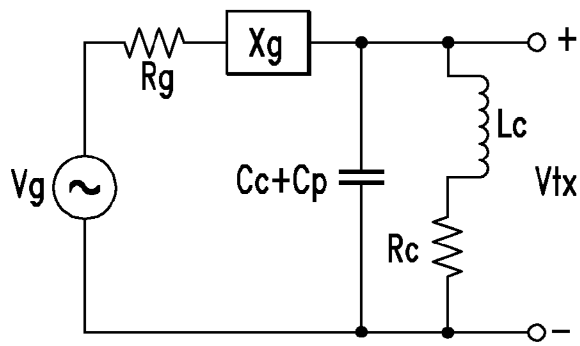


FIG. 7A

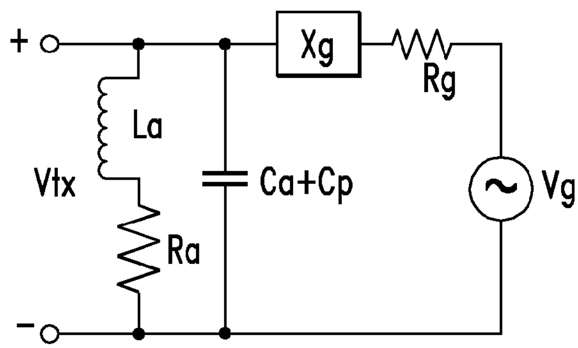


FIG. 7B

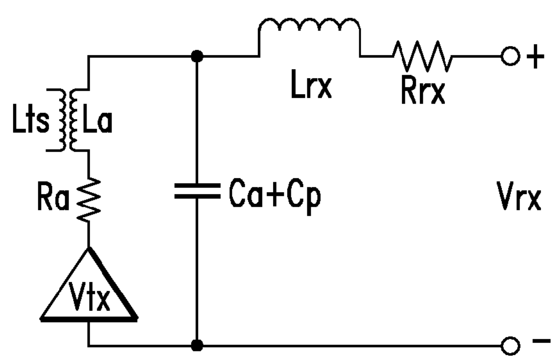


FIG. 7C

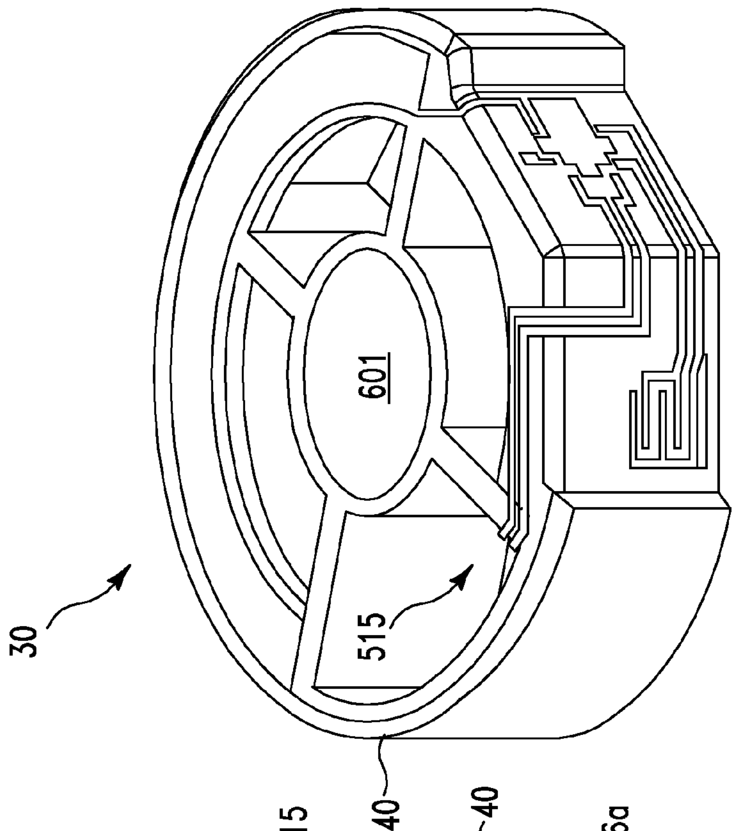


FIG. 8B

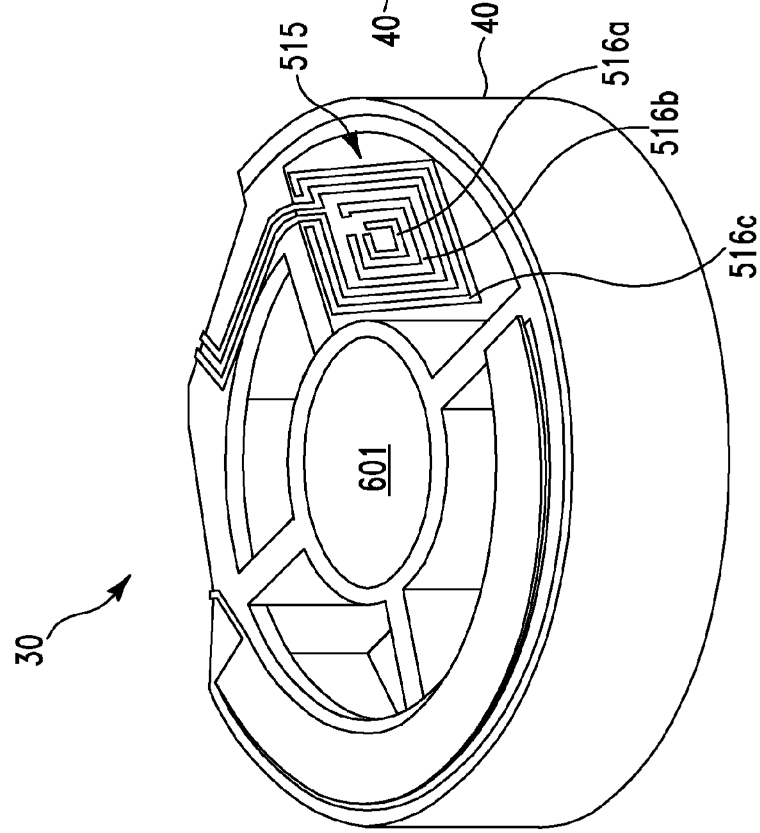
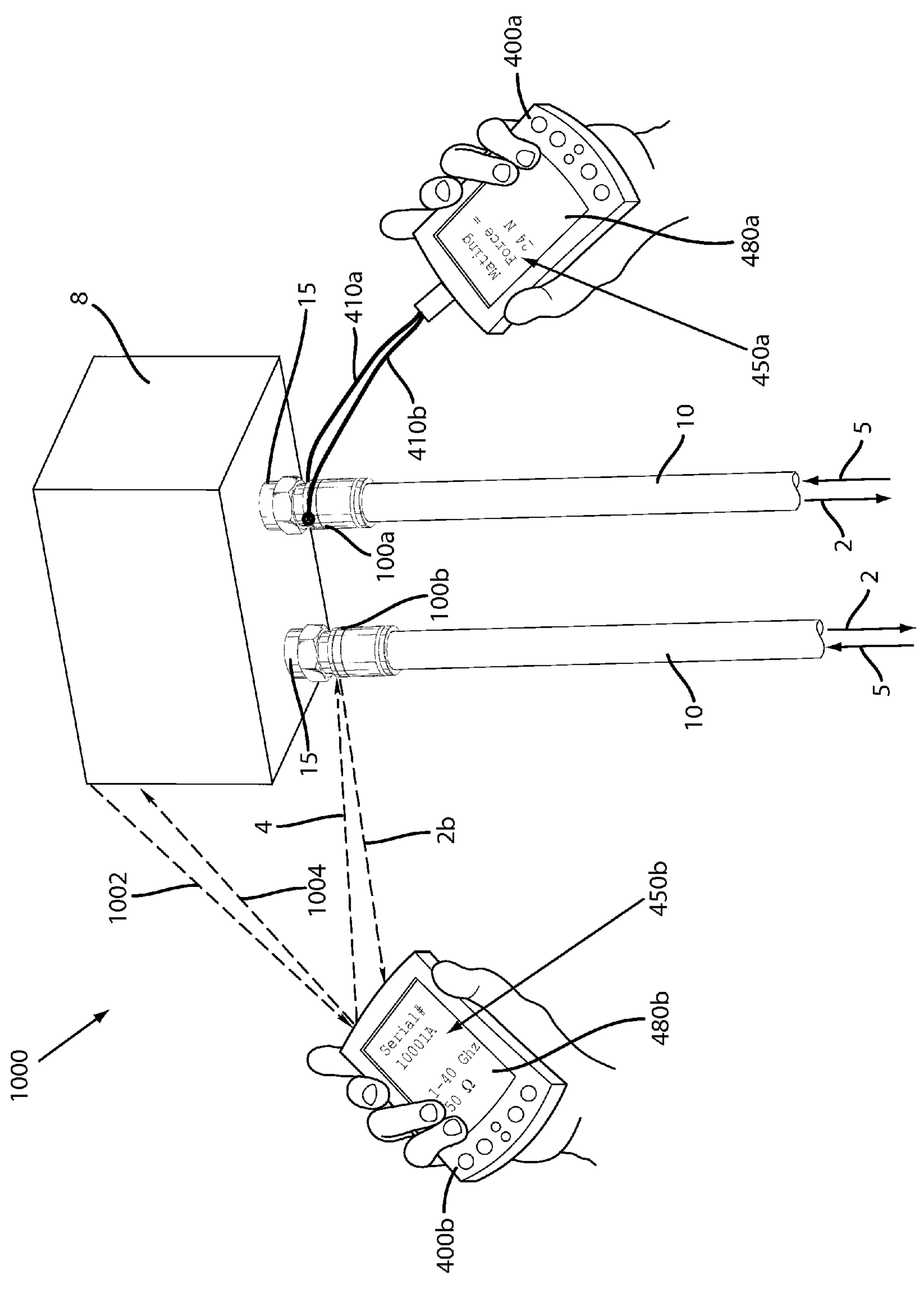


FIG. 8A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2

FIG. 9

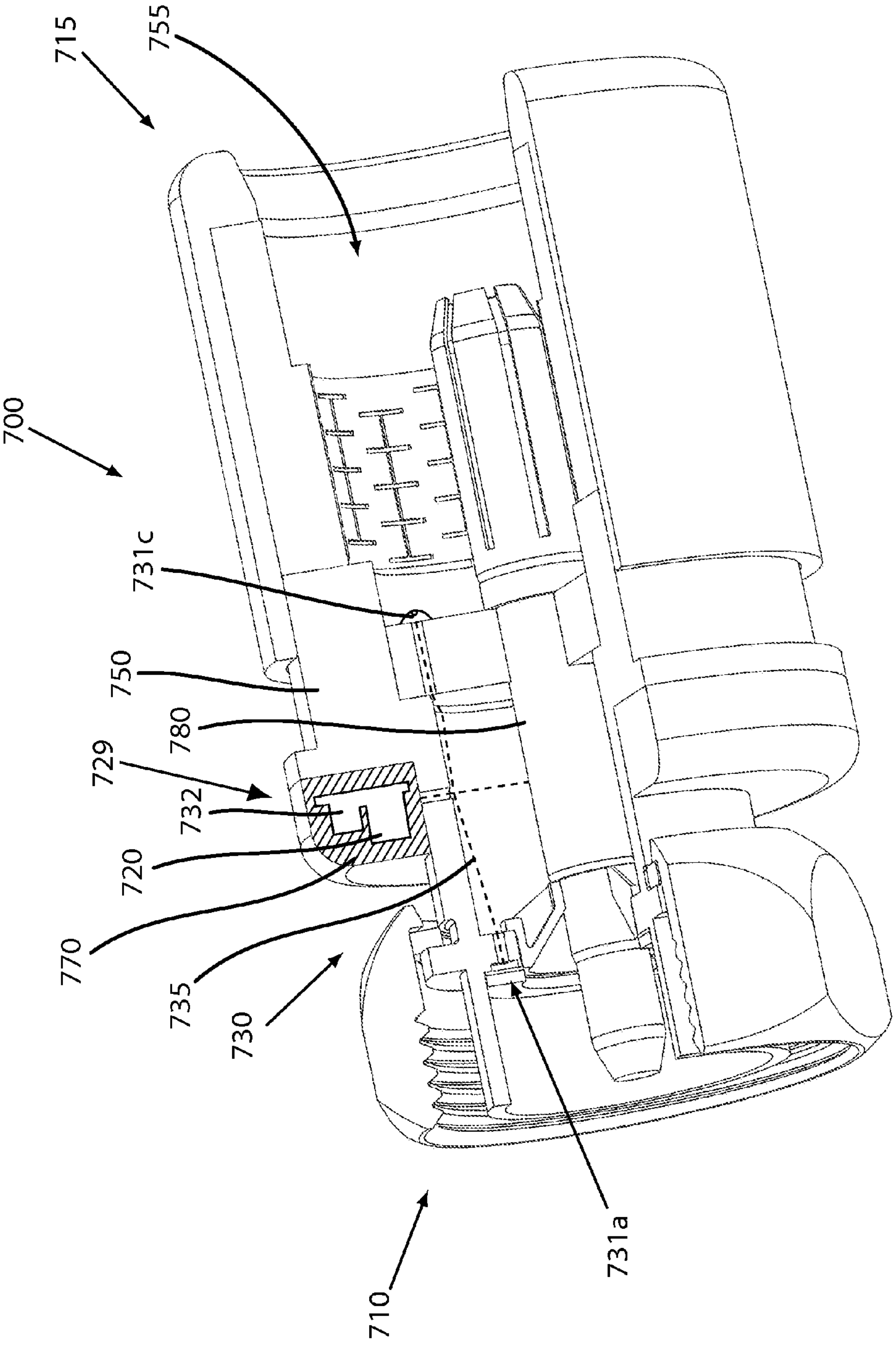

FIG. 10

POWER EXTRACTING DEVICE AND METHOD OF USE THEREOF

RELATED APPLICATIONS

This application is a continuation-in-part of and claims priority from co-pending U.S. application Ser. No. 12/960,592 filed on Dec. 6, 2010, and entitled EMBEDDED COUPLER DEVICE AND METHOD OF USE THEREOF, which is continuation-in-part of U.S. application Ser. No. 12/271,999 filed Nov. 17, 2008, now U.S. Pat. No. 7,850,482 issued on Dec. 14, 2010, and entitled COAXIAL CONNECTOR WITH INTEGRATED MATING FORCE SENSOR AND METHOD OF USE THEREOF.

FIELD OF TECHNOLOGY

The present invention relates generally to coaxial cable connectors. More particularly, the present invention relates to a coaxial cable connector and related methodology for harvesting power from a radio frequency signal flowing through the coaxial cable connector connected to an RF port.

BACKGROUND

Cable communications have become an increasingly prevalent form of electromagnetic information exchange and coaxial cables are common conduits for transmission of electromagnetic communications. Many communications devices are designed to be connectable to coaxial cables. Accordingly, there are several coaxial cable connectors commonly provided to facilitate connection of coaxial cables to each other and or to various communications devices.

It is important for a coaxial cable connector to facilitate an accurate, durable, and reliable connection so that cable communications may be exchanged properly. Thus, it is often important to ascertain whether a cable connector is properly connected. However, typical means and methods of ascertaining proper connection status are cumbersome and often involve costly procedures involving detection devices remote to the connector or physical, invasive inspection on-site. Hence, there exists a need for a coaxial cable connector that is configured to maintain proper connection performance, by the connector itself sensing the status of various physical parameters related to the connection of the connector, and by communicating the sensed physical parameter status through an output component of the connector. The instant invention addresses the abovementioned deficiencies and provides numerous other advantages.

SUMMARY

The present invention provides an apparatus for use with coaxial cable connections that offers improved reliability.

A first aspect of the present invention provides a structure comprising: a disk structure located within a coaxial cable connector; and a signal retrieval circuit formed within the disk structure, wherein the signal retrieval circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector, wherein the signal retrieval circuit is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector, and wherein the energy signal is configured to apply power to an electrical device located within the coaxial cable connector.

A second aspect of the present invention provides a structure comprising: a first metallic structure formed within a disk structure, wherein the disk structure is located within a coaxial cable connector, wherein the first metallic structure is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector; and a second metallic structure formed within the disk structure, wherein the second metallic coupler structure is located in a position that is external to the signal path of the electrical signal flowing through the coaxial cable connector, and wherein the first metallic structure in combination with the second metallic structure is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector, and wherein the energy signal is configured to apply power to an electrical device located within the coaxial cable connector.

A third aspect of the present invention provides a structure comprising: a metallic signal retrieval circuit formed within a disk structure located within a coaxial cable connector, wherein the metallic circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector, wherein the metallic signal retrieval circuit is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector; and an electrical device mechanically attached to the disk structure, wherein the energy signal is configured to apply power to the electrical device.

A fourth aspect of the present invention provides a method comprising: providing a signal retrieval circuit formed within the disk structure located within a coaxial cable connector, wherein the signal retrieval circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector; extracting, by the signal retrieval circuit, an energy signal from the electrical signal flowing through the coaxial cable connector; and supplying, by the energy signal, power to an electrical device located within the coaxial cable connector.

The foregoing and other features of the invention will be apparent from the following more particular description of various embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Some of the embodiments of this invention will be described in detail, with reference to the following figures, wherein like designations denote like members, wherein:

FIG. **1** depicts an exploded cut-away perspective view of an embodiment of a coaxial cable connector with a parameter sensing circuit, in accordance with the present invention;

FIG. **2** depicts a close-up cut-away partial perspective view of an embodiment of a coaxial cable connector with a parameter sensing circuit, in accordance with the present invention;

FIG. **3** depicts a cut-away perspective view of an embodiment of an assembled coaxial cable connector with an integrated parameter sensing circuit, in accordance with the present invention;

FIG. **4** depicts a perspective view of an embodiment of the disk structure **40** of FIGS. **1**-**3**, in accordance with the present invention;

FIG. **5**A depicts a schematic block diagram view of an embodiment of a system including the power harvesting and parameter sensing circuit of FIGS. **1**-**4**, in accordance with the present invention;

FIG. **5**B depicts a schematic block diagram view of an embodiment of a system including multiple power harvesting and parameter sensing circuits, in accordance with the present invention;

FIG. **6** depicts a perspective view of an embodiment of a loop coupler device, in accordance with the present invention;

FIGS. **7**A-**7**C depict schematic views of embodiments of the coupler device of FIGS. **1-6**, in accordance with the present invention;

FIGS. **8**A and **8**B depict perspective views of an embodiment of the disc structure comprising the internal power harvesting and parameter sensing circuit of FIGS. **1-6**;

FIG. **9** depicts a perspective view of an embodiment of a physical parameter status/electrical parameter reader, in accordance with the present invention; and

FIG. **10** depicts a side perspective cut-away view of another embodiment of a coaxial cable connector having multiple sensors, in accordance with the present invention.

DETAILED DESCRIPTION

Although certain embodiments of the present invention will be shown and described in detail, it should be understood that various changes and modifications may be made without departing from the scope of the appended claims. The scope of the present invention will in no way be limited to the number of constituting components, the materials thereof, the shapes thereof, the relative arrangement thereof, etc., which are disclosed simply as an example of an embodiment. The features and advantages of the present invention are illustrated in detail in the accompanying drawings, wherein like reference numerals refer to like elements throughout the drawings.

As a preface to the detailed description, it should be noted that, as used in this specification and the appended claims, the singular forms "a", "an" and "the" include plural referents, unless the context clearly dictates otherwise.

It is often desirable to ascertain conditions relative to a coaxial cable connector connection or relative to a signal flowing through a coaxial connector. A condition of a connector connection at a given time, or over a given time period, may comprise a physical parameter status relative to a connected coaxial cable connector. A physical parameter status is an ascertainable physical state relative to the connection of the coaxial cable connector, wherein the physical parameter status may be used to help identify whether a connector connection performs accurately. A condition of a signal flowing through a connector at a given time, or over a given time period, may comprise an electrical parameter of a signal flowing through a coaxial cable connector. An electrical parameter may comprise, among other things, an electrical signal (RF) power level, wherein the electrical signal power level may be used for discovering, troubleshooting and eliminating interference issues in a transmission line (e.g., a transmission line used in a cellular telephone system). Embodiments of a connector **100** of the present invention may be considered "smart", in that the connector **100** itself ascertains physical parameter status pertaining to the connection of the connector **100** to an RF port. Additionally, embodiments of a connector **100** of the present invention may be considered "smart", in that the connector **100** itself: detects; measures a parameter of; and harvests power from an electrical signal (e.g., an RF power level) flowing through a coaxial connector.

Referring to the drawings, FIGS. **1-3** depict cut-away perspective views of an embodiment of a coaxial cable connector **100** with an internal power harvesting (and parameter sensing) circuit **30***a*, in accordance with the present invention. The connector **100** includes a connector body **50**. The connector body **50** comprises a physical structure that houses at least a portion of any internal components of a coaxial cable connector **100**. Accordingly the connector body **50** can accommodate internal positioning of various components, such as a disk structure **40** (e.g., a spacer), an interface sleeve **60**, a spacer **70**, and/or a center conductor contact **80** that may be assembled within the connector **100**. In addition, the connector body **50** may be conductive. The structure of the various component elements included in a connector **100** and the overall structure of the connector **100** may operably vary. However, a governing principle behind the elemental design of all features of a coaxial connector **100** is that the connector **100** should be compatible with common coaxial cable interfaces pertaining to typical coaxial cable communications devices. Accordingly, the structure related to the embodiments of coaxial cable connectors **100** depicted in the various FIGS. **1-11** is intended to be exemplary. Those in the art should appreciate that a connector **100** may include any operable structural design allowing the connector **100** to harvest power from a signal flowing through the connector **100**, sense a condition of a connection of the connector **100** with an interface to an RF port of a common coaxial cable communications device, and report a corresponding connection performance status to a location outside of the connector **100**. Additionally, connector **100** may include any operable structural design allowing the connector **100** to harvest power from, sense, detect, measure, and report a parameter of an electrical signal flowing through connector **100**.

A coaxial cable connector **100** has internal circuitry that may harvest power, sense connection conditions, store data, and/or determine monitorable variables of physical parameter status such as presence of moisture (humidity detection, as by mechanical, electrical, or chemical means), connection tightness (applied mating force existent between mated components), temperature, pressure, amperage, voltage, signal level, signal frequency, impedance, return path activity, connection location (as to where along a particular signal path a connector **100** is connected), service type, installation date, previous service call date, serial number, etc. A connector **100** includes the power harvesting (and parameter sensing) circuit **30***a*. The power harvesting (and parameter sensing) circuit **30***a* may include an embedded coupler device **515***a* and a processing circuit **504***a* that includes, an impedance matching circuit **511**, an RF power monitor circuit **502**, a RF power harvesting circuit **529**, and a telemetry circuit **503** as illustrated and described with respect to FIGS. **4** and **5**. The power harvesting (and parameter sensing) circuit **30***a* may be integrated onto or within typical coaxial cable connector components. The power harvesting (and parameter sensing) circuit **30***a* may be located on/within existing connector structures. For example, a connector **100** may include a component such as a disk structure **40** having a face **42**. The power harvesting (and parameter sensing) circuit **30***a* may be positioned on and/or within the face **42** of the disk structure **40** of the connector **100**. The power harvesting (and parameter sensing) circuit **30***a* is configured to harvest power form an R/F signal flowing through the connector **100**. The power connector **100** when the connector **100** is connected with an interface of a common coaxial cable communications device, such as interface port **15** of receiving box. Moreover, various portions of the circuitry of the power harvesting (and parameter sensing) circuit **30***a* may be fixed onto multiple component elements of a connector **100**.

Power for power harvesting (and parameter sensing) circuit **30***a* (e.g., the processing circuit **504***a*) and/or other powered components of a connector **100** may be provided through retrieving energy from an R/F signal flowing through the center conductor **80**. For instance, traces may be printed on and/or within the disk structure **40** and positioned so that the traces make electrical contact with (i.e., coupled to) the center conductor contact **80** at a location **46** (see FIG. **2**). Contact with the center conductor contact **80** at location **46** facilitates the ability for the power harvesting (and parameter sensing) circuit **30***a* to draw power from the cable signal(s) passing through the center conductor contact **80**. Traces may also be formed and positioned so as to make contact with grounding components. For example, a ground path may extend through a location **48** between the disk structure **40** and the interface sleeve **60**, or any other operably conductive component of the connector **100**. Those in the art should appreciate that a power harvesting (and parameter sensing) circuit **30***a* should be powered in a way that does not significantly disrupt or interfere with electromagnetic communications that may be exchanged through the connector **100**.

With continued reference to the drawings, FIG. **4** depicts a perspective view of an embodiment of the disk structure **40** of FIGS. **1-3**. The disk structure **40** includes internal power harvesting (and parameter sensing) circuit **30***a*. The power harvesting (and parameter sensing) circuit **30***a* includes an embedded coupler device **515** (including wire traces **515***a*, metallic cylindrical structures **515***b* extending from a bottom surface through a top surface **42** of disk structure **40**, and a wire trace **515***c* connecting metallic cylindrical structures **515***b* thereby forming a loop coupler structure) and associated circuitry **504***a* (e.g., including an impedance matching circuit **511**, an RF power monitor circuit **502**, a R/F power harvesting circuit **529**, and a telemetry circuit **503** as schematically illustrated and described with respect to FIG. **5**). Although embedded coupler device **515** is illustrated as cylindrical structures extending from a top surface **42** through a bottom surface of disk structure **40**, note that embedded coupler device **515** may comprise any geometrical shape (e.g., circular, spherical, cubicle, etc). Embedded coupler device **515** may include a directional coupler and/or a loop coupler that harvests power from a radio frequency (RF) signal being transmitted down a transmission line (and through connector **100** of FIGS. **1-3**) and/or optionally extracts a sample of the RF signal. The harvested power may be used to power electronic transducers/sensors for generating data regarding a performance, moisture content, tightness, efficiency, and alarm conditions within the connector **100**. Disk structure **40** provides a surface **42** for implementing a directional coupler. FIG. **4** illustrates an embedded directional coupler (i.e., coupler device **515**) mounted on/within the disc structure **40** located internal to connector **100**. Coupler device **515** harvests energy from an RF signal on the transmission line (e.g., a coaxial cable for an R/F tower). Coupler device **515** additionally provides a real time measurement of RF signal parameters on the transmission line (e.g., a coaxial cable). Disk structure **40** incorporates electronic components (e.g., associated circuitry **504***a* in an integrated circuit such as a signal processor) to harvest the power, condition the sensed parameter signals (i.e., sensed by coupler device **515**), and transmit a status of the connector **100** condition over a telemetry system. Signals sensed by the coupler device **515** may include a magnitude of a voltage for forward and reverse propagating RF waveforms present on a coaxial cable center conductor (e.g., center conductor **80** of FIGS. **1-3**) relative to ground. A geometry and placement of the coupler device **515** on the disc structure **515** determines a calibrated measurement of RF signal parameters such as, among other things, power and voltage standing wave ratio. Coupler device **515** allows for a measurement of forward and reverse propagating RF signals along a transmission line thereby allowing a measurement of a voltage standing wave ratio and impedance mismatch in a cabling system of the transmission line. The disk structure **40** (including the internal power harvesting (and parameter sensing) circuit **30***a*) may be implemented within systems including coaxial cables and RF connectors used in cellular telephone towers. The disk structure **40** made include syndiotactic polystyrene. An electroplated metallurgy may be used (i.e., on/within the disk structure **40**) to form the coupler device **515** and electronic interconnects (e.g., wire traces **515***a*) to the associated circuitry **504***a*. The coupler device **515** may be used in any application internal to a coaxial line to harvest power from RF energy propagating along the center coaxial line. The coupler device **515** may be used to measure directly and in real time, a calibrated sample of forward and reverse voltages of the RF energy. The calibrated sample of the forward and reverse voltages may provide key information regarding the quality of the coaxial cable and connector system. Additionally, a propagated RF signal and key parameters (such as power, voltage standing wave ratio, intersectional cable RF power loss, refection coefficient, insertion loss, etc) may be determined. A coaxial transmission line supports a transmission electron microscopy (TEM) mode electromagnetic wave. TEM mode describes a property of an orthogonal magnetic and electric field for an RF signal. TEM mode allows for an accurate description of the electromagnetic field's frequency behavior. An insertion of an electrically small low coupling magnetic antenna (e.g., coupler device **515**) is used to harvest power from RF signals and measure an integrity of passing RF signals (i.e., using the electromagnetic fields' fundamental RF behavior). Coupler device **515** may be designed at a very low coupling efficiency in order to avoid insertion loss. Harvested power may be used to power an on board data acquisition structure (e.g., associated circuitry **504***a*). Sensed RF signal power may be fed to an on board data acquisition structure (e.g., associated circuitry **504***a*). Data gathered by the associated circuitry **504***a* is reported back to a data gathering device (e.g., transmitter **510***a*, receiver **510***b*, or combiner **545** in FIG. **5**) through the transmission path (i.e., a coaxial cable) or wirelessly.

FIG. **5**A shows schematic block diagram view of an embodiment of a system **540***a* including a power harvesting (and parameter sensing) circuit **30***a* connected between (e.g., via a coaxial cable(s)) an antenna **523** (e.g., on a cellular telephone tower) and a transmitter **510***a* and receiver **510***b* (connected through a combiner **545**). Although system **540***a* of FIG. **5**A only illustrates one power harvesting (and parameter sensing) circuit **30***a* (within a coaxial cable connector), note that system **540***a* may include multiple power harvesting (and parameter sensing) circuits **30***a* (within multiple coaxial cable connectors) located at any position along a main transmission line **550** (i.e., as illustrated with respect to FIG. **5**B). Embodiments of a power harvesting (and parameter sensing) circuit **30***a* may be variably configured to include various electrical components and related circuitry so that a connector **100** can harvest power and measure or determine connection performance by sensing a condition relative to the connection of the connector **100**, wherein knowledge of the sensed condition may be provided as physical parameter status information and used to help identify whether the connection performs accurately. Accordingly, the circuit configuration as schematically depicted in FIG. **5** is provided to exemplify one embodiment of a power harvesting (and parameter sensing) circuit **30***a* that may operate with a connector **100**. Those in the art should recognize that other power harvesting (and parameter sensing) circuit **30***a* configurations may be provided to accomplish the power harvesting and the sensing of physical parameters corresponding to a connector **100** connection. For instance, each block or portion of the power harvesting (and parameter sensing) circuit **30***a* can be individually implemented as an analog or digital circuit.

As schematically depicted, a power harvesting (and parameter sensing) circuit **30***a* may includes an embedded coupler device **515** (e.g., a directional (loop) coupler as illustrated) and associated circuitry **504***a*. A directional coupler couples energy from main transmission line **550** to a coupled line **551**. The associated circuitry **504***a* includes an impedance matching circuit **511**, an RF power monitor circuit **502**, an RF power harvesting circuit, and a telemetry circuit **503**. The transmitter **510***a*, receiver **510***b*, and combiner **545** are connected to the antenna **523** through coupler device **515** (i.e., the transmitter **510***a*, receiver **510***b*, and combiner **545** are connected to port **1** of the coupler device **515** and the antenna is connected to port **2** of the coupler device **515**) via a coaxial cable with connectors. Ports **3** and **4** (of the coupler device **515**) are connected to an impedance matching circuit **511** in order to create matched terminated line impedance (i.e., optimizes a received RF signal). Impedance matching circuit **511** is connected to RF power monitoring circuit **502** and RF power harvesting circuit **529**. The RF power harvesting circuit **529** receives and conditions (e.g., regulates) the harvested power from the coupler device **515**. A conditioned power signal (e.g., a regulated voltage generated by the RF power harvesting circuit) is used to power any on board electronics in the connector. The RF power monitoring circuit **502** receives (from the coupler device **515**) a calibrated sample of forward and reverse voltages (i.e., from the coaxial cable). A propagated RF signal and key parameters (such as power, voltage standing wave ratio, intersectional cable RF power loss, refection coefficient, insertion loss, etc) may be determined (from the forward and reverse voltages) by the power monitoring circuit **502**. The telemetry circuit **503** is connected between the power monitoring circuit **502** and the impedance matching circuit **511**. The telemetry circuit **503** provides protocols and drive circuitry to transmit sensor data (i.e., from coupler device **515**) back to the coaxial line for transmission to a data retrieval system. The receiver **510***b* may include signal reader circuitry for reading and analyzing a propagated RF signal flowing through main transmission line **550**.

FIG. **5**B shows schematic block diagram view of an embodiment of system **540***b* of FIG. **5**A including multiple sensing/processing circuits **30***b* located in multiple coaxial cable connectors **100***a* . . . **100***n* connected between (e.g., via a coaxial cable(s)) antenna **523** (e.g., on a cellular telephone tower) and transmitter **510***a* and receiver **510***b* (connected through a combiner **545**). Each of coaxial cable connectors **100***a* . . . **100***n* (comprising an associated sensing/processing circuit **30***b*) in includes an RF energy sensing/extraction point. The RF energy may be transmitted from an existing RF communication signal or a dedicated RF energy signal dedicated to providing power for each sensing/processing circuit **30***b*.

FIG. **6** depicts a perspective view of an embodiment of the coupler device **515** (e.g., a loop coupler structure) of FIGS. **1-5**. FIG. **6** illustrates a magnetic field **605** established by an AC current through a center conductor **601** (of a coaxial cable) penetrating a suspended loop (e.g., coupler device **515**). Coupler device **515** includes a gap between the center conductor **601** and a substrate to avoid a sparking effect between the center conductor **601** and outer shielding that often occurs under surge conditions. An RF signal passing through the center conductor **601** establishes an azimuthally orbiting magnetic field **605** surrounding the center conductor **601**. A conductive loop structure (e.g., coupler device **515**) that supports a surface that is penetrated by the orbiting magnetic field **605** will induce a current through its windings and induce a voltage (i.e., harvested power) across its terminals dependent upon a termination impedance. The conductive loop structure is constructed to surround an open surface tangent to the azimuthal magnetic field **605** and induce the aforementioned current. End leads of the conductive loop structure emulate a fully connected loop while maintaining electrical separation thereby allowing for a voltage (i.e., for power electronics within the connector **100**) to be developed across terminals (ports **3** and **4**).

FIGS. **7**A-**7**C depict schematic views of an embodiments of the coupler device **515** (e.g., a loop coupler structure) of FIGS. **1-6**. As RF power is passed through a coupling structure (e.g., coupler device **515**) and a coaxial line, the coupling structure will transmit a portion of the RF power as electric and magnetic components inside the coaxial structure thereby inducing a current down the center conductor and establishing a TEM wave inside the coaxial structure. The coaxial line will drive the TEM wave through the open space occupied by the coupling structure and will induce fields that will couple energy into the structures. FIGS. **7**A-**7**C depict a TX of power from the coupling structure to a coaxial line and vice versa.

FIG. **7**A demonstrates a TX lumped circuit model of a coaxial line. Model parameters including a subscript "g" indicate generator parameters. The generator parameters comprise inductive and resistive Thevenin values at an output of the coupling structure to the coaxial line. Model parameters with a subscript "c" describe inductance, capacitance, and resistance of the coaxial line at the point of the coupling structure's placement. Model parameter Cp comprises a parasitic capacitance with non-coaxial metallic structures and is on the order of pF. Vtx comprises a transmission voltage that induces an electric or magnetic field component that excites the coupling structure. The following equations 1 and 2 define power transfer equations for a generator perturbing the coaxial line. Equation 1 expresses a transmission voltage in terms a generator voltage divided down by transmitter impedances.

$$V_{TX} = \frac{V_G}{Z_G + Z_{Cc//(Lc+Rc)}} \quad \text{Equation 1}$$

Equation 2 expresses a transmission power in terms of lumped circuit components.

$$P_{TX} = \frac{1}{2}|I_{TX}|^2 R_C = \frac{1}{2}\frac{|V|^2 R_C}{|Z_G + Z_{Cc//(Lc+Rc)}|^2} \quad \text{Equation 2}$$

FIG. **7**B demonstrates RF power transmitted in a TEM wave along a coaxial line's length. The TEM wave is received by the coupling structure and an induced power is brought through the coupling structure to internal electronics. A frequency dependant reception of the RF power is dictated by the particular impedances caused by the inductive coupling between the conductive structures, the capacitive coupling with the grounded metal shielding, and the mixed coupling with the other metallic traces within the coaxial environment.

FIG. **7**C demonstrates an Irx current source comprising an induced dependant current that varies with the power and frequency of the transmitted signal along the coaxial line. The La, Ra, and Ca elements are intrinsic and coupling impedances of the loop coupler positioned near the coaxial line. Cp comprises a parasitic capacitance due to a surrounding grounded metal connector housing. The Lrx and Rrx elements comprise impedances used to tune the coupling structure for optimum transmission at select frequencies. Vrx comprises a received voltage to internal electronics. Lts is comprises a mutual inductance created from coupling between the coupling structure and a metallic structure used to tune the coupling structure's resistive impedance at a select power transfer frequency.

FIGS. **8**A and **8**B depict perspective views of an embodiment of the disc structure **40** comprising the internal power harvesting (and parameter sensing) circuit **30***a* of FIGS. **1-6**. FIGS. **8**A and **8**B illustrate coupler device **515** mounted to or integrated with disk structure **40**. Coupler device **515** illustrated in FIG. **8**A comprises a loop coupler that includes optional loops **516***a*, **516***b*, and **516***c* for impedance matching, etc.

Referring further to FIGS. **1-8**B and with additional reference to FIG. **9**, embodiments of a coaxial cable connection system **1000** may include a physical parameter status/electrical parameter reader **400** (e.g., transmitter **510***a*, receiver **510***b*, and/or any other signal reading device along cable **550** of FIG. **5**) located externally to the connector **100**. The reader **400** is configured to receive, via a signal processing circuitry (e.g., any of RF power monitor circuit **502**, impedance matching circuit **511**, or telemetry circuit **503** of FIG. **5**) or embedded coupler device **515** (of FIG. **5**), information from the power harvesting (and parameter sensing) circuit **30***a* located within connector **100** or any other connectors along cable(s) **10**. Another embodiment of a reader **400** may be an output signal **2** monitoring device located somewhere along the cable line to which the connector **100** is attached. For example, a physical parameter status may be reported through signal processing circuitry in electrical communication with the center conductor (e.g., center conductor **601** of FIG. **6**) of the cable **10**. Then the reported status may be monitored by an individual or a computer-directed program at the cable-line head end to evaluate the reported physical parameter status and help maintain connection performance. The connector **100** may ascertain connection conditions and may transmit physical parameter status information or an electrical parameter of an electrical signal automatically at regulated time intervals, or may transmit information when polled from a central location, such as the head end (CMTS), via a network using existing technology such as modems, taps, and cable boxes. A reader **400** may be located on a satellite operable to transmit signals to a connector **100**. Alternatively, service technicians could request a status report and read sensed or stored physical parameter status information (or electrical parameter information) onsite at or near a connection location, through wireless hand devices, such as a reader **400***b*, or by direct terminal connections with the connector **100**, such as by a reader **400***a*. Moreover, a service technician could monitor connection performance via transmission over the cable line through other common coaxial communication implements such as taps, set tops, and boxes.

Operation of a connector **100** can be altered through transmitted input signals **5** from the network or by signals transmitted onsite near a connector **100** connection. For example, a service technician may transmit a wireless input signal **4** from a reader **400***b*, wherein the wireless input signal **4** includes a command operable to initiate or modify functionality of the connector **100**. The command of the wireless input signal **4** may be a directive that triggers governing protocol of a control logic unit to execute particular logic operations that control connector **100** functionality. The service technician, for instance, may utilize the reader **400***b* to command the connector **100**, through a wireless input component, to presently sense a connection condition related to current moisture presence, if any, of the connection. Thus the control logic unit **32** may communicate with sensor, which in turn may sense a moisture condition of the connection. The power harvesting (and parameter sensing) circuit **30***a* could then report a real-time physical parameter status related to moisture presence of the connection by dispatching an output signal **2** through an output component (e.g., RF power monitor circuit **502**) and back to the reader **400***b* located outside of the connector **100**. The service technician, following receipt of the moisture monitoring report, could then transmit another input signal **4** communicating a command for the connector **100** to sense and report physical parameter status related to moisture content twice a day at regular intervals for the next six months. Later, an input signal **5** originating from the head end may be received through an input component in electrical communication with the center conductor contact **80** to modify the earlier command from the service technician. The later-received input signal **5** may include a command for the connector **100** to only report a physical parameter status pertaining to moisture once a day and then store the other moisture status report in memory **33** for a period of 20 days.

A coaxial cable connector connection system **1000** may include a reader **400** that is communicatively operable with devices other than a connector **100**. The other devices may have greater memory storage capacity or processor capabilities than the connector **100** and may enhance communication of physical parameter status by the connector **100**. For example, a reader **400** may also be configured to communicate with a coaxial communications device such as a receiving box **8**. The receiving box **8**, or other communications device, may include means for electromagnetic communication exchange with the reader **400**. Moreover, the receiving box **8**, may also include means for receiving and then processing and/or storing an output signal **2** from a connector **100**, such as along a cable line. In a sense, the communications device, such as a receiving box **8**, may be configured to function as a reader **400** being able to communicate with a connector **100**. Hence, the reader-like communications device, such as a receiving box **8**, can communicate with the connector **100** via transmissions received through an input component connected to the center conductor contact **80** of the connector. Additionally, embodiments of a reader-like device, such as a receiving box **8**, may then communicate information received from a connector **100** to another reader **400**. For instance, an output signal **2** may be transmitted from a connector **100** along a cable line to a reader-like receiving box **8** to which the connector is communicatively connected. Then the reader-like receiving box **8** may store physical parameter status information pertaining to the received output signal **2**. Later a user may operate a reader **400** and communicate with the reader-like receiving box **8** sending a transmission **1002** to obtain stored physical parameter status information via a return transmission **1004**.

Alternatively, a user may operate a reader **400** to command a reader-like device, such as a receiving box **8** communicatively connected to a connector **100**, to further command the connector **100** to report a physical parameter status receivable by the reader-like receiving box **8** in the form of an output signal **2**. Thus by sending a command transmission **1002** to the reader-like receiving box **8**, a communicatively connected connector **100** may in turn provide an output signal **2** including physical parameter status information that may be forwarded by the reader-like receiving box **8** to the reader **400** via a transmission **1004**. The coaxial communication device, such as a receiving box **8**, may have an interface, such as an RF port **15**, to which the connector **100** is coupled to form a connection therewith.

Referring to FIGS. **1-9** a coaxial cable connector power harvesting method is described. A coaxial cable connector

100 is provided. The coaxial cable connector **100** has a connector body **50** and a disk structure **40** located within the connector body **50**. Moreover, a power harvesting (and parameter sensing) circuit **30***a* (e.g., comprising the: embedded metallic coupler device **515**, impedance matching circuit **511**, RF power harvesting circuit **529**, RF power monitor circuit **502**, telemetry circuit **503**, and wire traces **515***a* of FIGS. **4** and **5**) is provided, wherein the power harvesting (and parameter sensing) circuit **30***a* is housed within the disk structure **40**. The power harvesting (and parameter sensing) circuit **30***a* has an embedded metallic coupler device **515** configured to harvest power from an RF signal flowing through the connector **100** when connected. In addition, a physical parameter output component (e.g., RF power monitor circuit **502**, telemetry circuit **503**, etc) is in communication with the power harvesting (and parameter sensing) circuit **30***a* to receive physical parameter status information. Further physical parameter status ascertainment methodology includes connecting the connector **100** to an interface, such as RF port **15**, of another connection device, such as a receiving box **8**, to form a connection. Once the connection is formed, physical parameter status information applicable to the connection may be reported, via a signal processing circuit, to facilitate conveyance of the physical parameter status of the connection to a location outside of the connector body **50**.

Referring to the drawings, FIG. **10** depicts a side perspective cut-away view of an embodiment of a coaxial cable connector **700** having a coupler sensor **731***a* (e.g., the embedded metallic coupler device **515** of the internal power harvesting (and parameter sensing) circuit **30***a*) and a humidity sensor **731***c*. The connector **700** includes port connection end **710** and a cable connection end **715**. In addition, the connector **700** includes sensing circuit **730***a* operable with the coupler sensor **731***a* and the humidity sensor or moisture sensor **731***c*. The coupler sensor **731***a* and the humidity sensor **731***c* may be connected to a processor control logic unit **732** operable with an output transmitter **720** through leads, traces, wires, or other electrical conduits depicted as dashed lines **735**. The sensing circuit electrically links the coupler sensor **731***a* and the humidity sensor **731***c* to the processor control logic unit **732** and the output transmitter **729**. For instance, the electrical conduits **735** may electrically tie various components, such as a processor control logic unit **732**, sensors **731***a*, **731***c* and an inner conductor contact **780** together.

The processor control logic unit **732** and the output transmitter **720** may be housed within a weather-proof encasement **770** operable with a portion of the body **750** of the connector **700**. The encasement **770** may be integral with the connector body portion **750** or may be separately joined thereto. The encasement **770** should be designed to protect the processor control logic unit **732** and the output transmitter **720** from potentially harmful or disruptive environmental conditions. The coupler sensor **731***a* and the humidity sensor **731***c* are connected via a sensing circuit **730***a* to the processor control logic unit **732** and the output transmitter **720**.

The coupler sensor **731***a* is located at the port connection end **710** of the connector **700**. When the connector **700** is mated to an interface port, such as port **15** shown in FIG. **9**, a signal level of a signal (or samples of the signal) flowing through the connector **700** may be sensed by the coupler sensor **731***a*.

The humidity sensor **731***c* is located within a cavity **755** of the connector **700**, wherein the cavity **755** extends from the cable connection end **715** of the connector **700**. The moisture sensor **731***c* may be an impedance moisture sensor configured so that the presence of water vapor or liquid water that is in contact with the sensor **731***c* hinders a time-varying electric current flowing through the humidity sensor **731***c*. The humidity sensor **731***c* is in electrical communication with the processor control logic unit **732**, which can read how much impedance is existent in the electrical communication. In addition, the humidity sensor **731***c* can be tuned so that the contact of the sensor with water vapor or liquid water, the greater the greater the measurable impedance. Thus, the humidity sensor **731***c* may detect a variable range or humidity and moisture presence corresponding to an associated range of impedance thereby. Accordingly, the humidity sensor **731***c* can detect the presence of humidity within the cavity **755** when a coaxial cable, such as cable **10** depicted in FIG. **9**, is connected to the cable connection end **715** of the connector **700**.

Power for the sensing circuit **730***a*, processor control unit **732**, output transmitter **720**, coupler sensor **731***a*, and/or the humidity sensor **731***c* of embodiments of the connector **700** depicted in FIG. **10** may be provided through electrical contact with the inner conductor contact **780** (using the aforementioned power harvesting process). For example, the electrical conduits **735** connected to the inner conductor contact **780** may facilitate the ability for various connector **700** components to draw power from the cable signal(s) passing through the inner connector contact **780**. In addition, electrical conduits **735** may be formed and positioned so as to make contact with grounding components of the connector **700**.

While this invention has been described in conjunction with the specific embodiments outlined above, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the invention as set forth above are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims. The claims provide the scope of the coverage of the invention and should not be limited to the specific examples provided herein.

What is claimed is:

1. A structure comprising:

a disk structure located within a coaxial cable connector; and

a signal retrieval circuit formed within the disk structure, wherein the signal retrieval circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector, wherein the signal retrieval circuit is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector, and wherein the energy signal is configured to apply power to an electrical device located within the coaxial cable connector.

2. The structure of claim **1**, further comprising a signal processing circuit mechanically attached to the disk structure, wherein the signal retrieval circuit is configured to sense an RF signal from the electrical signal flowing through the coaxial cable connector, and wherein the signal processing circuit is configured to report a sensed RF signal to a location external to the coaxial cable connector.

3. The structure of claim **2**, wherein the energy signal is configured to apply power to the signal processing circuit.

4. The structure of claim **2**, wherein the signal processing circuit is configured to report a level of the energy signal to said location external to the connector.

5. The structure of claim **1**, wherein the electrical device located within the connector comprises a semiconductor device.

6. The structure of claim **5**, wherein the semiconductor device is mechanically attached to the disk structure.

7. The structure of claim **1**, wherein the disk structure comprises a syndiotactic polystyrene structure comprising a laser direct structuring (LDS) catalyst.

8. The structure of claim **1**, wherein the signal retrieval circuit comprises a metallic structure formed within the disk structure.

9. The structure of claim **8**, wherein the metallic structure is a loop coupling structure.

10. The structure of claim **9**, wherein the loop coupling structure is an antenna.

11. The structure of claim **8**, wherein the metallic structure comprises a first cylindrical structure and a second adjacent cylindrical extending from a bottom surface of the disk structure through a top surface of the disk structure, and wherein the first cylindrical structure in combination with the second cylindrical structure is configured to apply the power to the electrical device located within the coaxial cable connector.

12. The structure of claim **1**, wherein the electrical device located within the connector comprises a sensor device configured to sense a condition of the coaxial cable connector when connected to an RF port.

13. The structure of claim **1**, wherein the energy signal comprises a voltage signal.

14. A structure comprising:

a first metallic structure formed within a disk structure, wherein the disk structure is located within a coaxial cable connector, wherein the first metallic structure is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector; and

a second metallic structure formed within the disk structure, wherein the second metallic coupler structure is located in a position that is external to the signal path of the electrical signal flowing through the coaxial cable connector, and wherein the first metallic structure in combination with the second metallic structure is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector, and wherein the energy signal is configured to apply power to an electrical device located within the coaxial cable connector.

15. The structure of claim **14**, wherein the first metallic structure comprises a first cylindrical structure extending from a bottom surface of the disk structure through a top surface of the disk structure, wherein the second metallic structure comprises a second cylindrical structure extending from the bottom surface of the disk structure through the top surface of the disk structure, and wherein the first cylindrical structure in combination with the second cylindrical structure is configured to apply the power to the electrical device located within the coaxial cable connector.

16. The structure of claim **14**, wherein the first metallic structure in combination with the second metallic structure form a loop coupler.

17. The structure of claim **14**, wherein the electrical device comprises a semiconductor device.

18. A structure comprising:

a metallic signal retrieval circuit formed within a disk structure located within a coaxial cable connector, wherein the metallic circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector, wherein the metallic signal retrieval circuit is configured to extract an energy signal from the electrical signal flowing through the coaxial cable connector; and

an electrical device mechanically attached to the disk structure, wherein the energy signal is configured to apply power to the electrical device.

19. The structure of claim **18**, wherein the metallic signal retrieval circuit comprises a first cylindrical structure extending from a bottom surface of the disk structure through a top surface of the disk structure and a second cylindrical structure extending from the bottom surface of the disk structure through the top surface of the disk structure, and wherein the first cylindrical structure in combination with the second cylindrical structure is configured to apply the power to the electrical device.

20. The structure of claim **18**, wherein the metallic signal retrieval circuit is a loop coupler.

21. The structure of claim **18**, wherein the electrical device comprises a semiconductor device.

22. A method comprising:

providing a signal retrieval circuit formed within the disk structure located within a coaxial cable connector, wherein the signal retrieval circuit is located in a position that is external to a signal path of an electrical signal flowing through the coaxial cable connector;

extracting, by the signal retrieval circuit, an energy signal from the electrical signal flowing through the coaxial cable connector; and

supplying, by the energy signal, power to an electrical device located within the coaxial cable connector.

23. The method of claim **22**, further comprising;

providing a signal processing circuit mechanically attached to the disk structure;

sensing, by the signal retrieval circuit, an RF signal from the electrical signal flowing through the coaxial cable connector; and

reporting, by the status output component, the sensed RF signal to a location external to the coaxial cable connector.

24. The method of claim **23**, further comprising:

applying, by the energy signal, power to the signal processing circuit.

25. The method of claim **23**, further comprising:

reporting, by the signal processing circuit, the sensed RF signal via a wireless output signal transmission.

26. The method of claim **23**, further comprising:

reporting, by the status output component, a level of the energy signal to the location external to the coaxial cable connector.

27. The method of claim **22**, wherein the electrical device located within the connector comprises a semiconductor device.

28. The method of claim **22**, wherein the signal retrieval circuit comprises a metallic structure formed within the disk structure.

29. The method of claim **28**, wherein the metallic structure is coupler.

30. The method of claim **22**, wherein the energy signal comprises a voltage signal.

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