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(54) Title: INDUCTIVE CHARGING FOR ELECTRO ACOUSTIC TECHNOLOGY

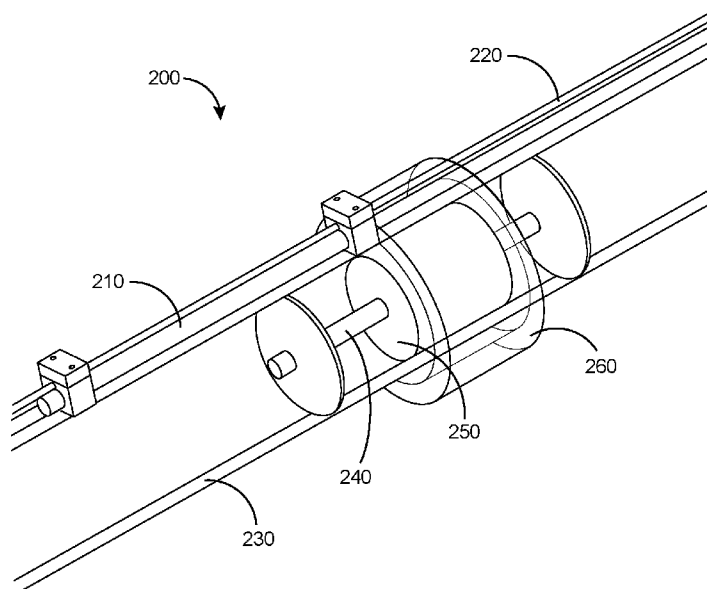


FIG. 3

(57) Abstract: A system and method for enabling inductive charging through downhole casings for electro acoustic technology devices.

Title**Inductive Charging for Electro Acoustic Technology****5 Background**

This disclosure relates generally to systems and methods for enabling inductive charging through downhole casing for Electro acoustic Technology devices.

- 10 Fiber optic distributed sensing systems were developed in the 1980s to replace older measurement systems composed of multiple individual sensors.

- Fiber optic distributed sensing systems are commonly based on Optical
15 Time-Domain Reflectometry (OTDR) and utilizes techniques originally derived from telecommunications cable testing. Today fiber optic distributed sensing systems provides a cost-effective way of obtaining hundreds, or even thousands, of highly accurate, high-resolution measurements and today find widespread acceptance in industries such as oil and gas,
20 electrical power, and process control.

Electro acoustic technology EAT devices represent a new technology that is described later in this disclosure.

- EAT devices may be coupled to a DAS fiber or any other appropriate fiber
25 optic sensing system mounted on the outside of a production casing string. They are either powered by battery or energy harvesting devices or both. However there may be cases where the batteries cannot be charged by energy harvesting – the flow does not create sufficient turbulence for vortex energy harvesting for example. In this case the EAT useful lifespan
30 is limited to the charge in the battery and once depleted, has no further

use. It cannot be retrieved to change out the batteries given that it may be located outside of the tubing and/or casing.

Developments in inductive charging for downhole, has enabled electronic devices to be charged through the casing. This method can be used to
5 charge the sensor behind the casing and also to interrogate the data and bring it back to the surface by wireline.

This approach requires a wireline unit and therefore the data is historical and not real time.

There is a need therefore for means to routinely charge the EAT
10 devices so that they supply their data to the surface continuously in real time.

The systems and methods described herein address this need.

15

Brief Description of the Drawings

5 Figure 1 illustrates the electro acoustic technology (EAT) concept for parameter monitoring.

Figure 2 illustrates a more complete system for utilizing electro acoustic technology in a subsurface well.

10 Figure 3 illustrates a pump down inductive charger and interrogator.

Figure 4 illustrates one embodiment of a wireline inductive charger.

15 Figure 5 illustrates a wireline alternate with multiple induction coil assemblies.

Detailed Description

In the following detailed description, reference is made to accompanying
5 drawings that illustrate embodiments of the present disclosure. These
embodiments are described in sufficient detail to enable a person of
ordinary skill in the art to practice the disclosure without undue
experimentation. It should be understood, however, that the embodiments
and examples described herein are given by way of illustration only, and
10 not by way of limitation. Various substitutions, modifications, additions, and
rearrangements may be made without departing from the spirit of the
present disclosure. Therefore, the description that follows is not to be
taken in a limited sense, and the scope of the present disclosure will be
defined only by the final claims.

15 EAT is able to provide the same data continuously in real time by
transmitting through a fiber optic sensing system like e.g. a DAS fiber to
the surface where the fiber is interrogated. The disclosure described
herein combines inductive charging technology through a casing wall
20 with either pump down EATs which act as untethered charging modules,
or with wireline propelled charging modules. The pump down modules
can be pumped down as required to any location, charge the batteries via
induction, and be returned to the surface by reversing the flow direction.
Multiple EATs can be recharged in a single flow cycle. The pump down
25 EAT battery chargers may also transfer data to the EAT to command the
EAT to perform some task, or update programs, or retrieve data from the
EAT that would not normally be transmitted by DAS, such as diagnostic
information of the state of the electronics or battery.

The wireline based charging modules operate in a similar fashion but use
30 wirelines as the propelling mechanism.

Description of EAT (Electro Acoustic Technology) Sensors

The EAT sensors and EAT sensing technology described in this disclosure
5 is a recently developed technology and has been described in a recently
published PCT application: WO2015020642A1.

EAT Sensors represent a new approach to fiber optic sensing in which any
number of downhole sensors, electronic or fiber optic based, can be utilized
10 to make the basic parameter measurements, but all of the resulting
information is converted at the measurement location into perturbations or
a strain applied to an optical fiber that is connected to an interrogator that
may be located at the surface of a downhole well. The interrogator may
routinely fire optical signal pulses downhole into the optical fiber. As the
15 pulses travel down the optical fiber back scattered light is generated and is
received by the interrogator.

The perturbations or strains introduced to the optical fiber at the location of
the various EAT sensors can alter the back propagation of light and those
20 effected light propagations can then provide data with respect to the signal
that generated the perturbations.

The EAT sensor system can be best understood by reference to Figure 1,
which is an example embodiment of an EAT sensor system. System **100**
25 can include a sensor **105**, a circuit **110** coupled to the sensor **105**, an
actuator **115** coupled to the circuit **110**, and an interrogator **120**. The
sensor **105** is operable to provide a measurement corresponding to a
parameter at a location in a region **102**. The sensor **105** can be realized in
a number of different ways depending on the parameter to be determined
30 by the measurement using the sensor **105**. The parameter can include, but
is not limited to, a chemical concentration, a pH, a temperature, a vibration,
or a pressure. The sensor **105** has the capability of being disposed at a

location in proximity of an optical fiber cable **125**. The sensor **105** can be located downhole at a drilling site with the interrogator **120** at the surface of the drilling site. The drilling site may be terrestrial or sea-based. Components of the system **100** may be disposed outside casing in cement or strapped to a production tube in a permanent installation. Components of the system **100** also may be disposed in a coiled tube that can be pushed through into a horizontal area of operation, or a wire line cable that can be tracted into a wellbore using an electrically driven tractor that pulls the wire line cable into the wellbore, or pumped into a wellbore with fluid that push/pulls a cable into the wellbore. The system **100** may be used with other drilling related arrangements. The circuit **110**, coupled to the sensor **105**, can be structured to be operable to generate a signal correlated to the parameter in response to the measurement by the sensor **105**. The circuit **110** may be integrated with the sensor **105**. For example, a sensing element **107** may be an integral part of the circuit **110** or directly coupled to a component of the circuit **110**. The sensing element **107** may be a diaphragm directly coupled to a component of the circuit **110**.

The actuator **115** can be coupled to the circuit **110** to receive the signal generated in response to the measurement by the sensor **105**. The signal can be a compensated signal, where a compensated signal is a signal having a characteristic that corresponds to the parameter of interest for which variations in one or more other parameters is substantially corrected or removed, or for which the characteristic is isolated to the parameter of interest. The actuator **115** can be integrated with the circuit **110**, integrated with the circuit **110** that is integrated with the sensor **105**, or a separate structure coupled to the circuit **110**.

The actuator **115** can be structured to be operable to generate a perturbation, based on the signal, to an optical fiber cable **125**, that may include one or multiple optical fibers. The actuator **115** can be positioned in proximity to the optical fiber cable **125** at the effective location of the sensor

- 105.** The actuator **115** can be structured to be operable to generate the perturbation to the optical fiber cable **125** with the actuator **115** in contact with the optical fiber cable **125**. The actuator **115** can be structured to be operable to generate the perturbation to the optical fiber cable **125** with the actuator **115** a distance from the optical fiber cable **125**. The actuator **115** may be realized as a non-contact piezoelectric material, which can provide acoustic pressure to the optical fiber cable **125** rather than transferring vibrations by direct contact.
- 10 The optical fiber cable **125** can be perturbed with the optical fiber cable **125** in direct contact with the actuator **115** structured as a vibrator or with the actuator **115** structured having a form of voice coil at a distance away from the optical fiber cable **125**. The perturbation of the optical fiber can be provided as a vibration of the optical fiber cable **125** or a strain induced into
- 15 the optical fiber cable **125**. Other perturbations may be applied such that the characteristics of the optical fiber are altered sufficiently to affect propagation of light in the optical fiber cable **125**. With the effects on the light propagation related to a signal that generates the perturbation, analysis of the effected light propagation can provide data with respect to
- 20 the signal that generates the perturbation.

The interrogator **120** can be structured to interrogate the optical fiber cable **125** to analyze signals propagating in the optical fiber cable **125**. The interrogator **120** can have the capability to couple to the optical fiber cable

25 **125** to receive an optical signal including the effects from the perturbation of the optical fiber cable **125** and to extract a value of the parameter of the measurement in response to receiving the optical signal from the perturbation. In an embodiment, the received signal may be a backscattered optical signal. The interrogator **120** may be structured, for

30 example, to inject a short pulse into the optical fiber cable **125**. An example of a short pulse can include a pulse of 20 nanoseconds long. As the pulse travels down the optical fiber cable **125**, back-scattered light is

generated. Interrogating a location that is one kilometer down the fiber, backscattered light is received after the amount of time it takes to travel one kilometer and then come back one kilometer, which is a round trip time of about ten nanoseconds per meter. The interrogator **120** can include an
5 interferometric arrangement. The interrogator **120** can be structured to measure frequency based on coherent Rayleigh scattering using interferometry, to measure dynamic changes in attenuation, to measure a dynamic shift of Brillouin frequency, or combinations thereof.

10 The interrogator **120** can be arranged with the optical fiber cable **125** to use an optical signal provided to the interrogator **120** from perturbing the optical fiber cable **125** at a location along the optical fiber cable **125**. An arrangement different from using an optical signal backscattered from the perturbation can be utilized. For example, the optical fiber cable **125** can
15 be structured having an arrangement selected from a fiber Bragg grating disposed in the optical fiber in vicinity of the actuator for direct wavelength detection based acoustic sensing, a non-wavelength selective in-line mirror disposed in the optical fiber in vicinity of the actuator, intrinsic Fabry-Perot interferometers as a mode of interrogation from fiber Bragg gratings placed
20 apart in the optical fiber such that each fiber Bragg grating Fabry-Perot cavity is in vicinity of a respective actuator, Fizeau sensors in the optical fiber, a second optical fiber to transmit an optical signal from a perturbation of the optical fiber to a detection unit of the interrogator, or other arrangements to propagate a signal, representative of a measurement, in
25 an optical fiber to an interrogation unit to analyze the signal to extract a value of a parameter that is the subject of the measurement.

The possible advantages from using the above described EAT systems in a variety of configurations may include using a variety of sensors, either
30 electrical or fiber optic based, to measure for example a chemical concentration, a pH, a temperature, or a pressure and using a common optical fiber connected to a surface interrogator to measure perturbation

signals from each EAT sensor location distributed along that common optical fiber and analyzing those signals to extract values of the parameters being measured. The approach can significantly reduce manufacturing complexity, reduce very expensive labor intensive production with expensive equipment like splicers and fiber winders, improve reliability, and widen industry acceptance by allowing the use of sensing technologies of choice.

Figure 2 expands on the use of electro acoustic technology (EAT) sensing systems by illustrating a more complete system. A subsurface well **130** is illustrated, in which a production casing **135** is shown extending through the well. In some applications the production casing may be non-metallic. At the far downhole end of the well an electro acoustic technology sensor assembly **140** is shown. In this example it is shown on the outside of the casing. In some applications the EAT sensor assembly could be within the casing. In many applications there could be multiple EAT sensor assemblies and the technology can easily accommodate that. In close proximity to the EAT sensor assembly shown is a fiber optic cable **145** that is deployed all through the well and back to the surface, then through a wellhead **155**. The fiber optic cable **145** may be clamped to the EAT sensor assembly **140** to ensure good transmission of signals. The fiber optic cable **145** exits through a wellhead exit **165** and is connected using a surface fiber cable **175** within an outdoor cabin or enclosure to a Distributed Acoustic System (DAS) interrogator **185**. The interrogator may then have a laser source **190** that fires interrogation pulses down through the fiber optic cable and receives backscattered light back from the fiber optic cable.

The fiber optic cable **145** may be permanently installed, or in some applications could be attached to some type of logging cable such as wireline or slickline cables. It could also be clamped on tubing inside the casing **135** in some applications.

Coupling of Induction Charging with Electro Acoustic Technology

Figure 3, represented in the numeral **200**, is an illustration of an EAT pump
5 down charger interrogator. An electro acoustic technology assembly **210**,
with an enclosed rechargeable battery is mounted on the outside of a non-
magnetic casing **230** and is in close proximity or clamped to a fiber optic
cable **220** that is in communication back to the surface to a DAS
interrogator system (not shown). A casing induction coil **260**, installed with
10 each EAT assembly, encircles the casing. The pump down charger
interrogator comprises a pump down induction coil **250** and an electro
acoustic technology pump down charger/interrogator **240**. In this use the
casing **230** should be non-magnetic.

15 The charger/interrogator, in addition to performing a charging function, can
be used to transfer data to the EAT assemblies or to retrieve data from the
EAT assemblies.

In use the pump down modules can be pumped down as required to any
20 location, charge the batteries via induction, and be returned to the surface
by reversing the flow direction. The pump down module could also be
used to power an EAT assembly directly. Multiple EATs can be
recharged in a single flow cycle. The pump down EAT battery chargers
may also transfer data to the EAT to command the EAT to perform some
25 task, or update programs, or retrieve data from the EAT that would not
normally be transmitted by DAS, such as diagnostic information of the
state of the electronics or battery.

The location of the pump-down charge module or later described
wireline conveyed induction coil or a coiled tubing conveyed induction coil
30 (not shown) may be monitored using a DAS system as the induction coil
head will make contact with the inner diameter of the casing or tubing

creating acoustic signatures and/or vibration. This can then be used to coarsely align the induction coil with the EAT device that needs to be charged. Fine alignment may be done by monitoring e.g. a signal transmitted by the EAT once it detects power being fed into the receiving coil on the EAT. This signal could indicate power coupling strength and the induction coil assembly could be moved until a satisfactory charge rate has been achieved. Multiple induction coils may be placed in closed proximity along the length of the induction coil assembly and the system may control which induction coil should be activated to maximize power conversion and to reduce the need to move the induction coil assembly.

Figure 4, represented by the numeral **300**, illustrates a wireline version of an inductive charger. Again an EAT assembly **310**, with an enclosed rechargeable battery, is mounted on the outside of a non-magnetic casing **360** and is clamped also to a fiber optic cable **320** that is in communication back to the surface to a DAS interrogator system (not shown). A casing induction coil **340**, is also installed on the outside of the casing. A wireline charger/interrogator **350** is indicated. The wireline is indicated as **330**. Again, the location of the wireline conveyed induction coil may be monitored using a DAS system as the induction coil head will make contact with the inner diameter of the casing or tubing creating acoustic signatures and/or vibration. This can then be used to coarsely align the induction coil with the EAT device that needs to be charged. Fine alignment may be done by monitoring e.g. a signal transmitted by the EAT once it detects power being fed into the receiving coil on the EAT. This signal could indicate power coupling strength and the induction coil assembly could be moved by the wireline until a satisfactory charge rate has been achieved. Multiple induction coils may be placed in closed proximity along the length of the induction coil assembly and the system may control which induction coil should be activated to maximize power conversion and to reduce the need to move the induction coil assembly.

Figure 5, represented by the numeral **400**, illustrates a multiple induction charging of the type discussed in Figure 3. Multiple EAT assemblies **410**, **430** with enclosed rechargeable batteries are mounted on the outside of a non-magnetic casing and are clamped also to the fiber optic cable **450** that is in communication back to the surface to a DAS interrogator system (not shown). The wireline **470** controls the movement of two wireline charger/interrogators **420**, **440** and two casing induction coils **460**, **480** encircle the casing. Multiple induction coils may be placed in closed proximity along the length of the induction coil assembly and the system may control which induction coil should be activated to maximize power conversion and to reduce the need to move the induction coil assembly.

Multiple induction coil assemblies may be spaced along the wireline, and the spacing between the induction coil assemblies may be aligned with the EAT induction coils. Deployment of multiple induction coils may require the use of a wire-line settable packer depending on the length between the induction coil assemblies.

Similarly, the EAT devices designed to be re-charged using the teachings herein may include a number of induction coils to maximize the harvesting of the power transmitted by the inductive charging module.

The induction coil assembly may also contain sensors for monitoring temperature, pressure, flow and others sensors commonly used in the oil & gas industry.

Although certain embodiments and their advantages have been described herein in detail, it should be understood that various changes, substitutions and alterations could be made without departing from the coverage as defined by the appended claims. Moreover, the potential applications of the disclosed techniques is not intended to be limited to the particular embodiments of the processes, machines, manufactures, means, methods and steps described herein. As a person of ordinary skill in the art will

readily appreciate from this disclosure, other processes, machines, manufactures, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described
5 herein may be utilized. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufactures, means, methods or steps.

Claims

1. A system for enabling inductive charging through downhole casings for electro acoustic technology devices comprising:
 - 5 a. one or more electro acoustic technology assemblies with enclosed rechargeable batteries attached to the outside of non-magnetic downhole casings;
 - b. a casing induction coil attached to the outside of the downhole casing at each electro acoustic technology
10 assembly location;
 - c. a fiber optic cable in close proximity to the electro acoustic technology assemblies and in communication with a surface distributed acoustic fiber optic interrogator;
 - d. a pump down electro acoustic technology charging assembly
15 comprising:
 - i. a pump down charger interrogator and;
 - ii. a pump down induction coil.
2. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 1 wherein
20 the pump down electro acoustic technology charging assembly is used to charge the rechargeable batteries of the one or more electro acoustic technology assemblies.
3. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 1 wherein
25 the pump down electro acoustic technology charging assembly is used to power the one or more electro acoustic technology assemblies.
4. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 2 wherein

the pump down electro acoustic technology charging assembly is further used to transmit to or receive data from to the one or more electro acoustic technology assemblies.

5. A system for enabling inductive charging through downhole casings for electro acoustic technology devices comprising:
- a. One or more electro acoustic technology assemblies with enclosed rechargeable batteries attached to the outside of non-magnetic downhole casings;
 - b. casing induction coils attached to the outside of the downhole casing at each electro acoustic technology assembly location;
 - c. a fiber optic cable in close proximity to the electro acoustic technology assemblies and in communication with a surface distributed acoustic fiber optic interrogator;
 - d. a wireline electro acoustic technology charging assembly comprising:
 - i. a wireline;
 - ii. one or more a wireline charger interrogators; and
 - iii. one or more wireline induction coils.
6. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 5 wherein the pump down electro acoustic technology charging assembly is used to charge the rechargeable batteries of the one or more electro acoustic technology assemblies.
7. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 5 wherein the pump down electro acoustic technology charging assembly is used to power the one or more electro acoustic technology assemblies.

8. The system for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 5 wherein the pump down electro acoustic technology charging assembly is further used to transmit to or receive data from to the electro acoustic technology assemblies.
9. A method for enabling inductive charging through downhole casings for electro acoustic technology devices comprising:
- a. providing one or more electro acoustic technology assemblies with enclosed rechargeable batteries attached to the outside of non-magnetic downhole casings;
 - b. providing casing induction coils attached to the outside of the downhole casing at each electro acoustic technology assembly location;
 - c. providing a fiber optic cable in close proximity to the electro acoustic technology assemblies and in communication with a surface distributed acoustic fiber optic interrogator;
 - d. providing a pump down electro acoustic technology charging assembly into the casing;
10. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 9 further providing inductive charging to the batteries of the one or more electro acoustic technology devices by pumping the pump down electro acoustic technology charging assembly to the location of any of the electro acoustic technology devices requiring charging.
11. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 9 further providing power to power the one or more electro acoustic technology assemblies.

12. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 9 further is providing data transfer between electro acoustic charging assembly and the electro acoustic technology assemblies.
- 5 13. A method for enabling inductive charging through downhole casings for electro acoustic technology devices comprising:
- a. providing one or more electro acoustic technology assemblies with enclosed rechargeable batteries attached to the outside of non-magnetic downhole casings;
 - 10 b. providing casing induction coils attached to the outside of the downhole casing at each electro acoustic technology assembly location;
 - c. providing a fiber optic cable in close proximity to the electro acoustic technology assemblies and in communication with a
15 surface distributed acoustic fiber optic interrogator;
 - d. providing one or more wireline electro acoustic technology charging assemblies comprising:
 - i. a wireline;
 - ii. one or more a wireline charger interrogators; and
 - 20 iii. one or more wireline induction coils.
14. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 13 further providing inductive charging to the batteries of the one or more electro acoustic technology assemblies by pumping the pump down
25 electro acoustic technology charging assembly to the location of any of the electro acoustic technology assemblies requiring charging.
15. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 13 further providing power to power the one or more electro acoustic

technology assemblies by pumping the pump down electro acoustic technology charging assembly to the location of any of the electro acoustic technology assemblies.

- 5 16. The method for enabling inductive charging through downhole casings for electro acoustic technology devices of claim 13 further is providing data transfer between electro acoustic charging assembly and the electro acoustic technology assemblies.

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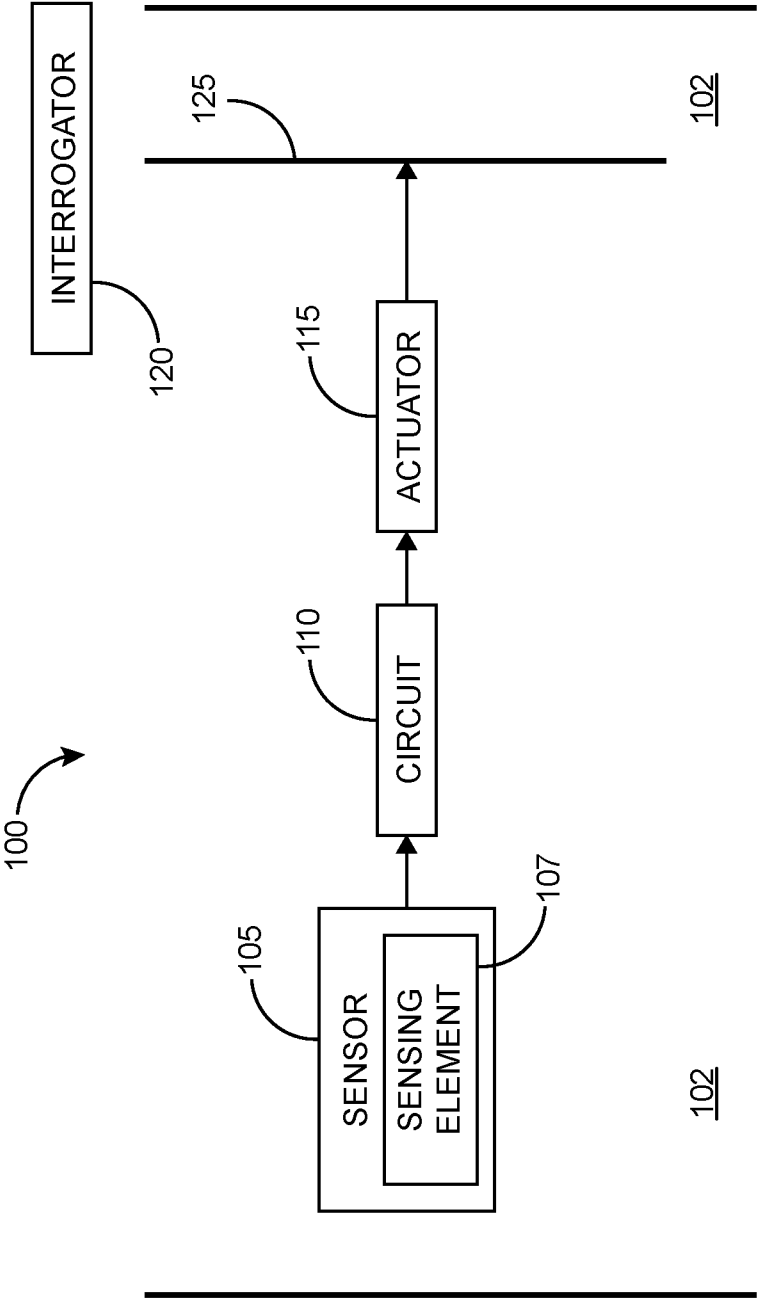


FIG. 1

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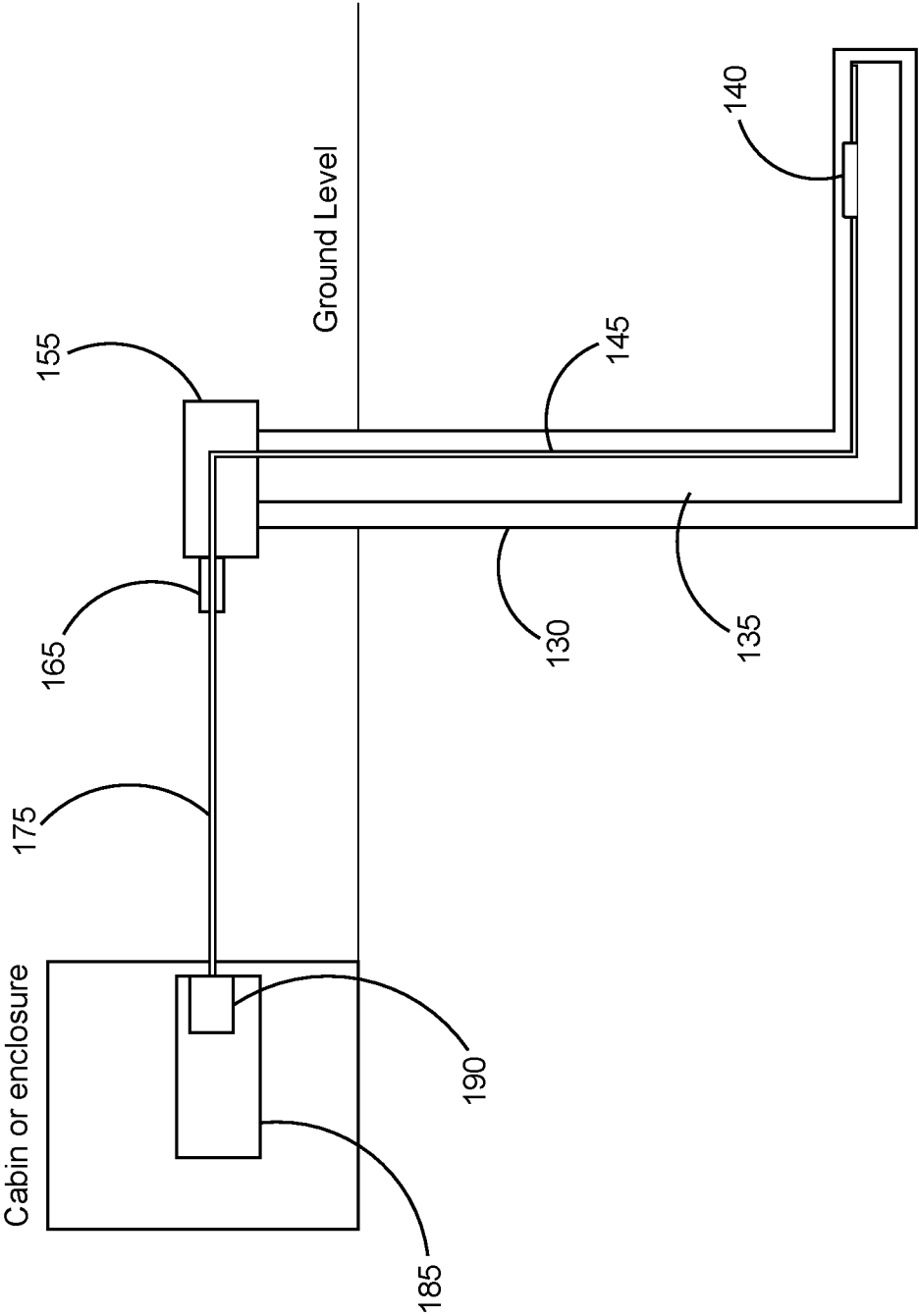


FIG. 2

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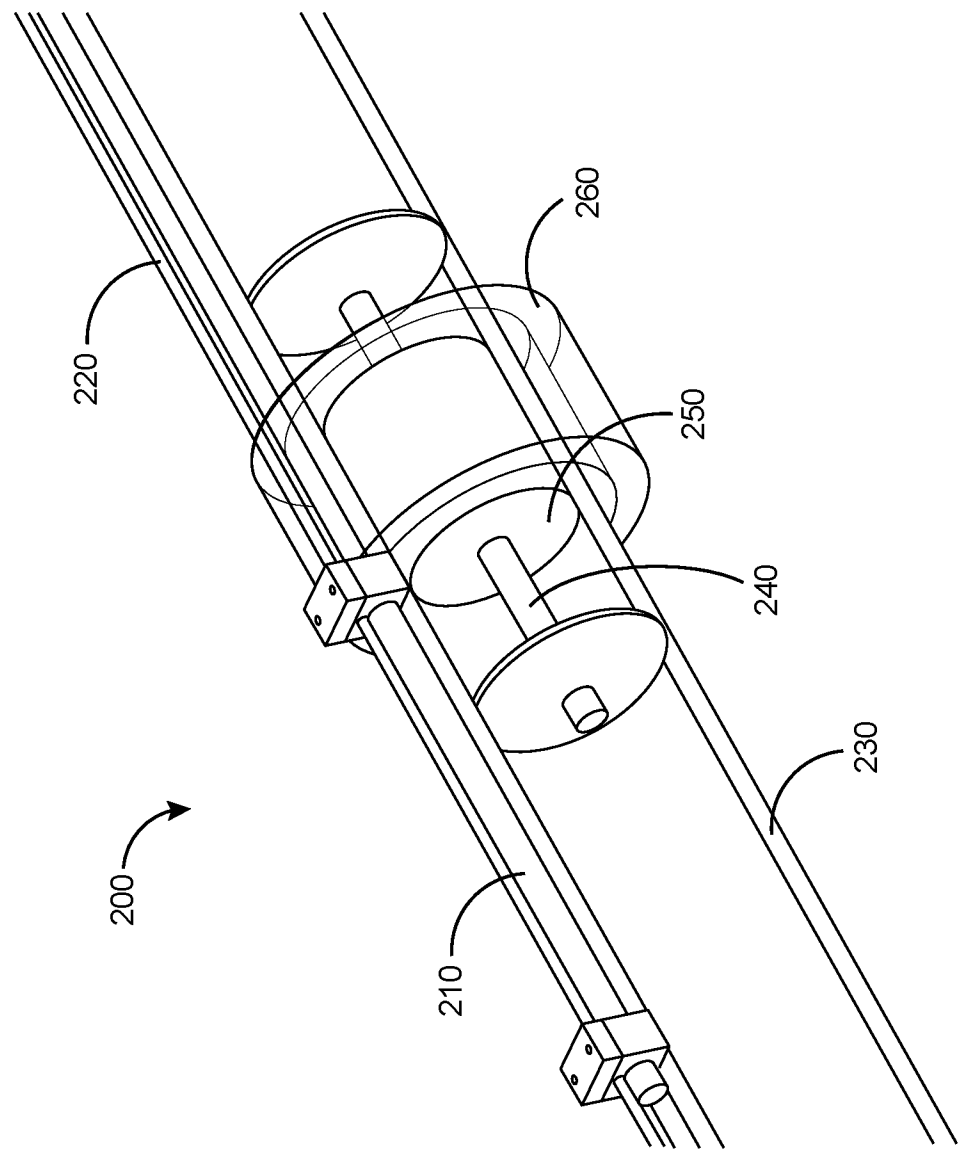


FIG. 3

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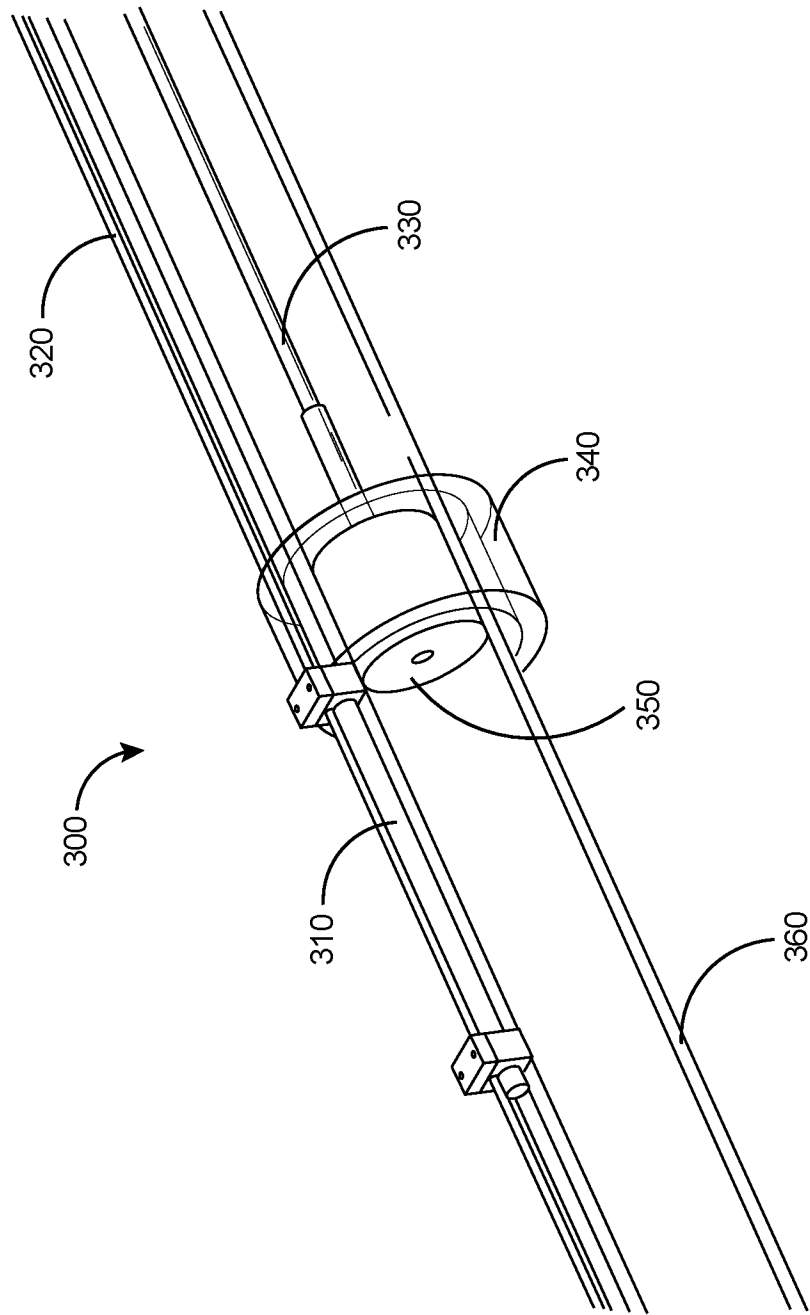


FIG. 4

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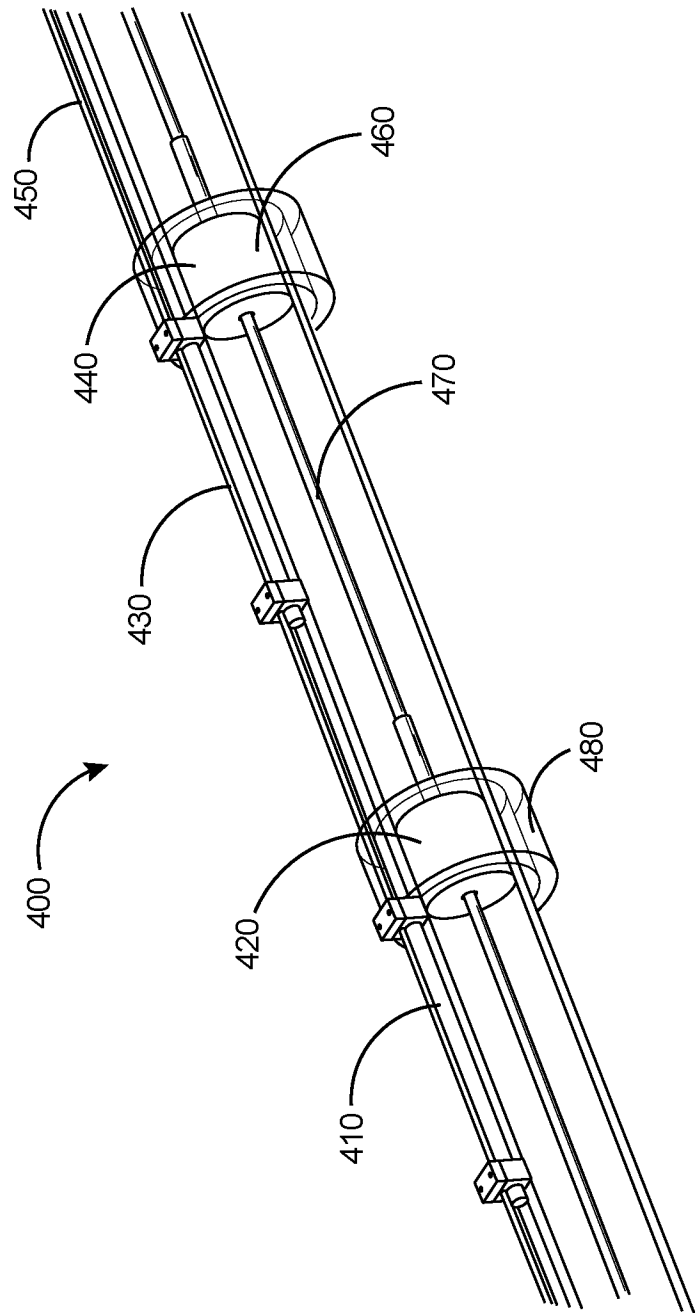


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/065953**A. CLASSIFICATION OF SUBJECT MATTER****H02J 7/00(2006.01)i, H02J 50/00(2016.01)i, G01D 5/353(2006.01)i, H01F 38/14(2006.01)i**

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)

H02J 7/00; H02M 7/217; E21B 47/04; H02J 1/00; E21B 47/00; G08B 13/14; H02J 50/00; G01D 5/353; H01F 38/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: electro acoustic, EAT, charging, induction, coil, power, battery, optical, fiber

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0026978 A1 (JOHN J COOLEY et al.) 31 January 2013 See abstract, claims 1-98 and figure 1.	1-16
Y	US 2009-0174361 A1 (MARK DURON et al.) 09 July 2009 See abstract, paragraphs [0062],[0085], claims 1-18 and figure 2.	1-16
A	WO 86-03800 A1 (HAROLD P. ADAMS, JR.) 03 July 1986 See abstract, claims 1,6 and figures 1-3.	1-16
A	US 2009-0160645 A1 (MARK DURON et al.) 25 June 2009 See abstract, claims 22-25 and figures 5-7.	1-16
A	WO 2004-020789 A2 (SENSOR HIGHWAY LIMITED) 11 March 2004 See abstract, claims 1-63 and figure 2.	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 September 2016 (12.09.2016)

Date of mailing of the international search report

12 September 2016 (12.09.2016)

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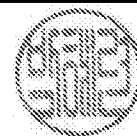
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/065953

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0026978 A1	31/01/2013	CA 2838557 A1 CA 2841171 A1 CA 2843137 A1 CN 104115247 A EA 201490346 A1 EP 2718945 A2 EP 2729948 A2 EP 2737502 A1 EP 2737502 A4 JP 2014-523841 A JP 2014-524146 A JP 2014-531531 A KR 10-2014-0073485 A KR 10-2014-0129283 A US 2015-0002987 A1 WO 2012-170749 A2 WO 2012-170749 A3 WO 2013-009720 A2 WO 2013-009720 A3 WO 2013-016145 A1 WO 2013-126915 A1	13/12/2012 17/01/2013 31/01/2013 22/10/2014 27/02/2015 16/04/2014 14/05/2014 04/06/2014 12/08/2015 18/09/2014 18/09/2014 27/11/2014 16/06/2014 06/11/2014 01/01/2015 13/12/2012 31/01/2013 17/01/2013 14/03/2013 31/01/2013 29/08/2013
US 2009-0174361 A1	09/07/2009	US 8035335 B2	11/10/2011
WO 86-03800 A1	03/07/1986	CN 1016344 B CN 86107566 A EP 0207128 A1 EP 0244459 A1 EP 0244459 B1 JP 62-501223 A KR 10-1987-0700115 A NO 863362 A US 4570718 A US 4728466 A WO 87-02363 A2 ZA 8509644 A	22/04/1992 29/07/1987 07/01/1987 11/11/1987 07/02/1990 14/05/1987 14/03/1987 20/08/1986 18/02/1986 01/03/1988 23/04/1987 29/10/1986
US 2009-0160645 A1	25/06/2009	US 8217757 B2 WO 2009-082619 A1	10/07/2012 02/07/2009
WO 2004-020789 A2	11/03/2004	AU 2003-267555 A1 AU 2003-267555 A8 CA 2439026 A1 CA 2439026 C CN 1723332 A CN 1723332 B GB 2409871 A US 2006-0157239 A1 US 2011-139447 A1	19/03/2004 19/03/2004 29/02/2004 25/11/2008 18/01/2006 27/10/2010 13/07/2005 20/07/2006 16/06/2011

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/065953Patent document
cited in search reportPublication
datePatent family
member(s)Publication
date

US 7900699 B2

08/03/2011

US 8074713 B2

13/12/2011

WO 2004-020789 A3

01/07/2004