US 20120218863A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2012/0218863 A1

(43) Pub. Date: Aug. 30, 2012

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(54) **INGROUND DRILL STRING HOUSING AND METHOD FOR SIGNAL COUPLING**

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(21) Appl. No.: **13/035,833**

(22) Filed: **Feb. 25, 2011**

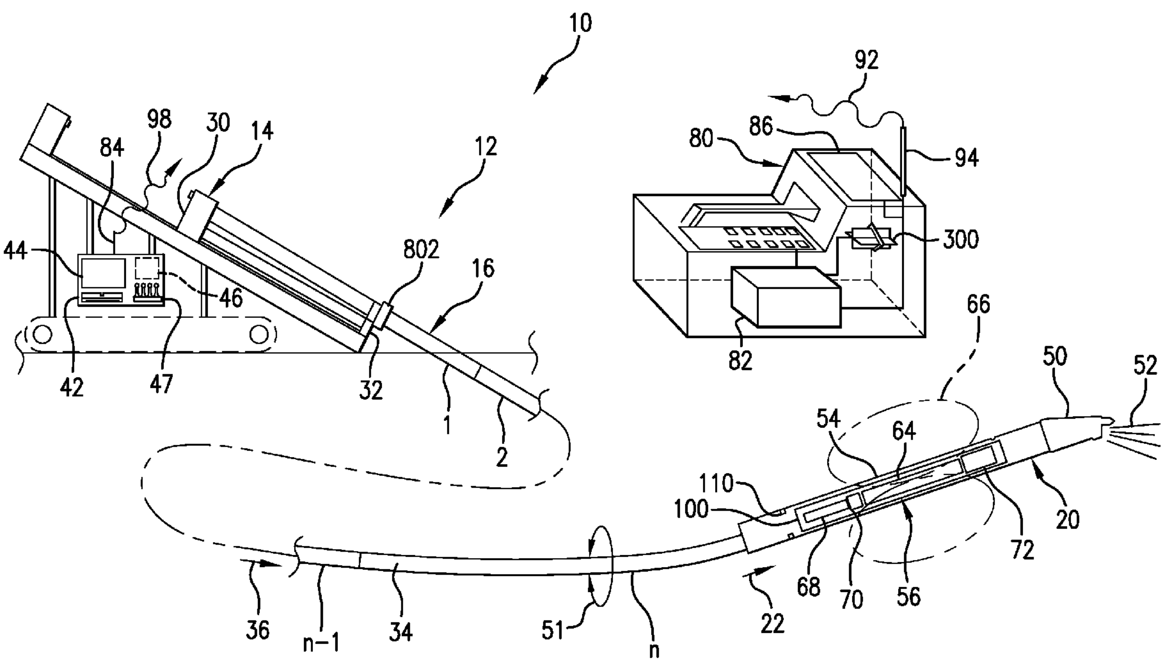
Publication Classification

(51) **Int. Cl.**
E21B 47/16 (2006.01)

(52) **U.S. Cl.** **367/82**

(57) **ABSTRACT**

An inground housing is insertable in at least one joint of a drill string extending from a drill rig. The inground housing supports an electronics assembly for processing a data signal relating to the inground operation and a signal coupling arrangement for transferring the data signal between the electronics assembly and the drill rig by electromagnetically coupling the data signal between the signal coupling arrangement and the drill string such that the data signal is electrically conducted as an electrical data signal along at least a portion of the drill string that extends from the inground housing. In another feature, a current transformer is resiliently supported to isolate the current transformer from mechanical shock and vibration that is produced by an inground operation that is performed using the drill string. In another feature, a drill string repeater is described.



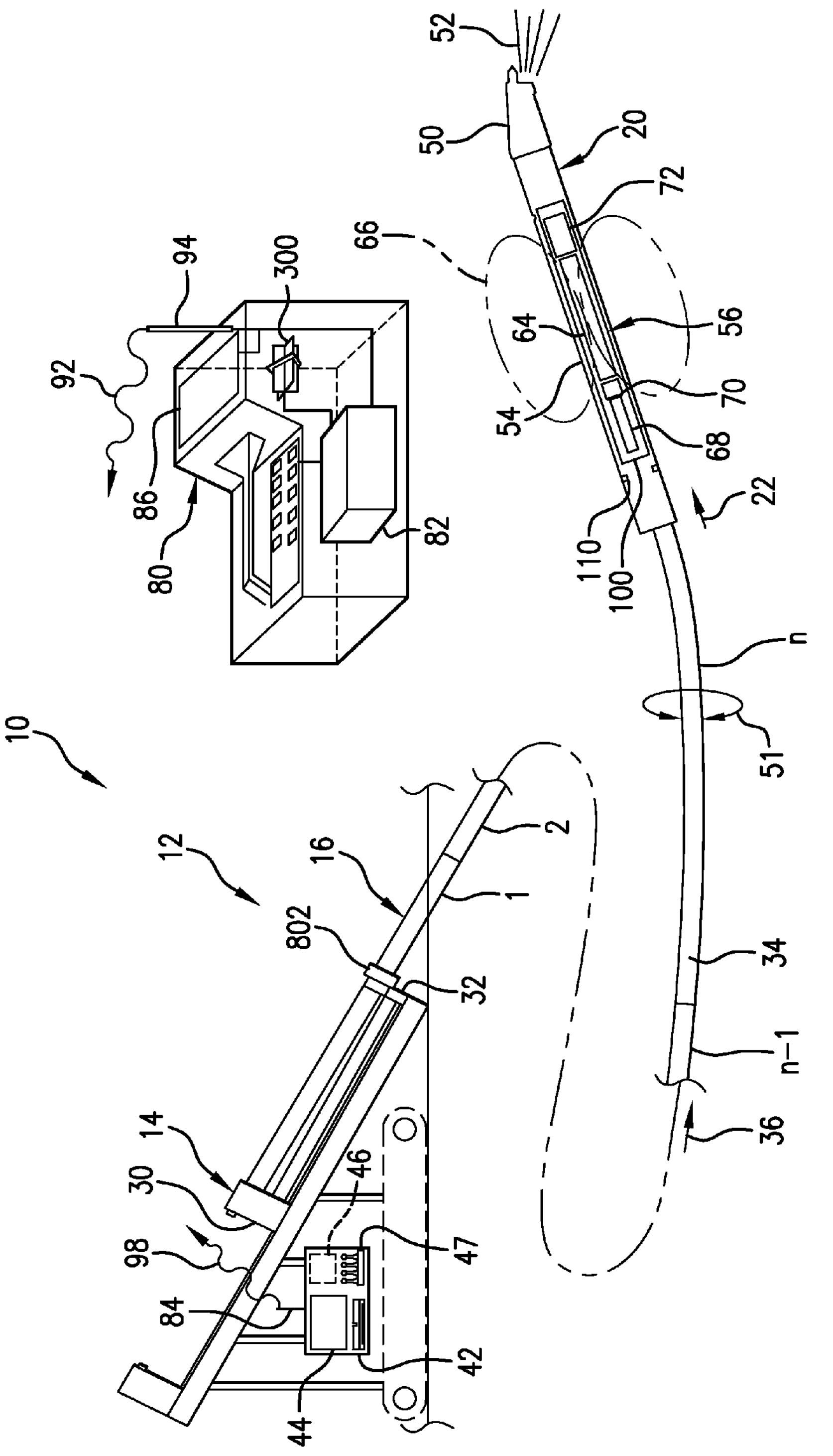

10
12
16
802
32
2
1
14
30
46
98
84
44
42
47
92
94
300
86
80
82
66
64
54
56
70
68
72
50
52
20
22
110
100
n
51
34
n-1
36

FIG. 1

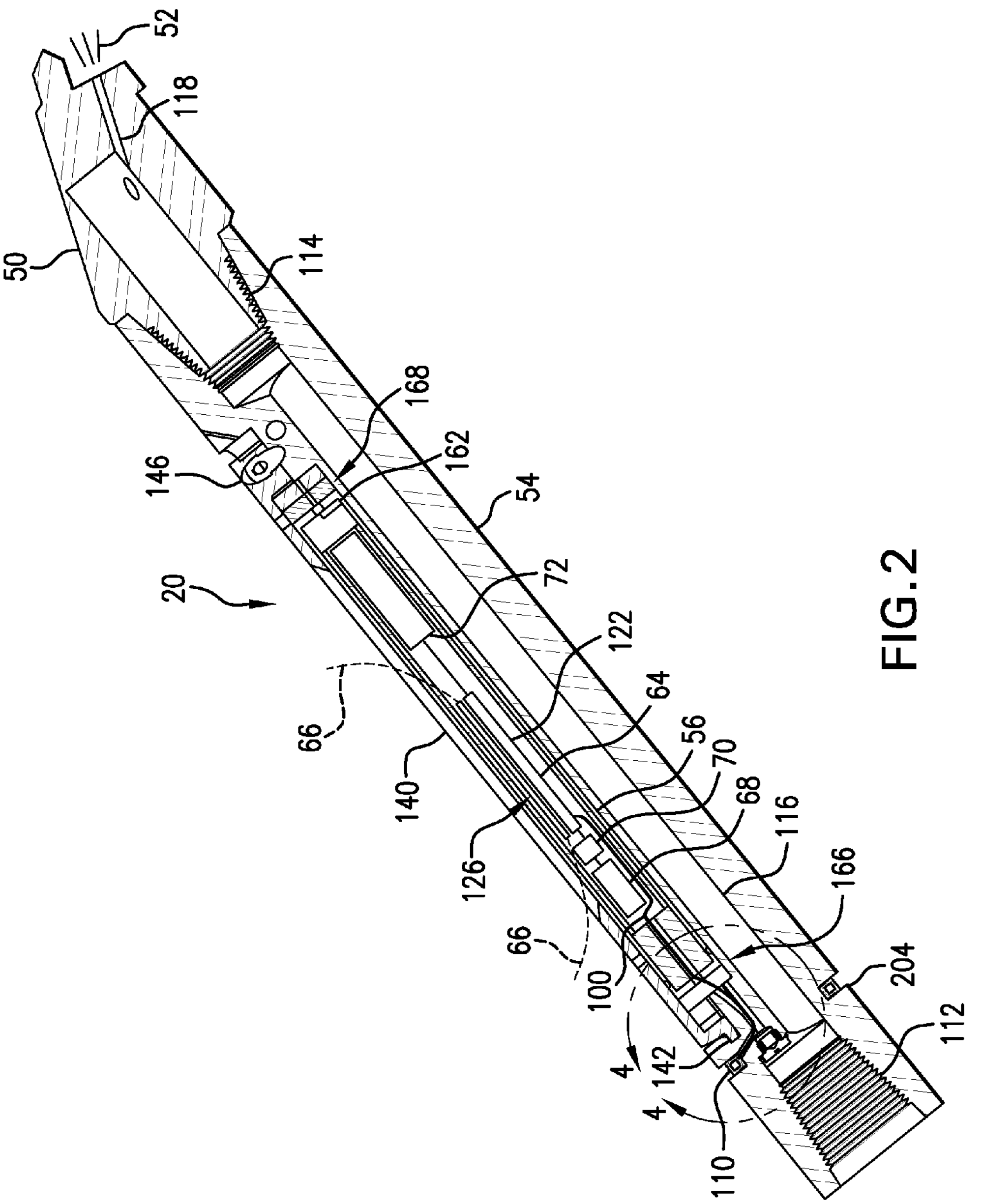

52
118
50
114
168
162
146
54
20
72
122
64
66
56
70
140
68
116
126
166
66
100
204
4
142
112
4
110

FIG. 2

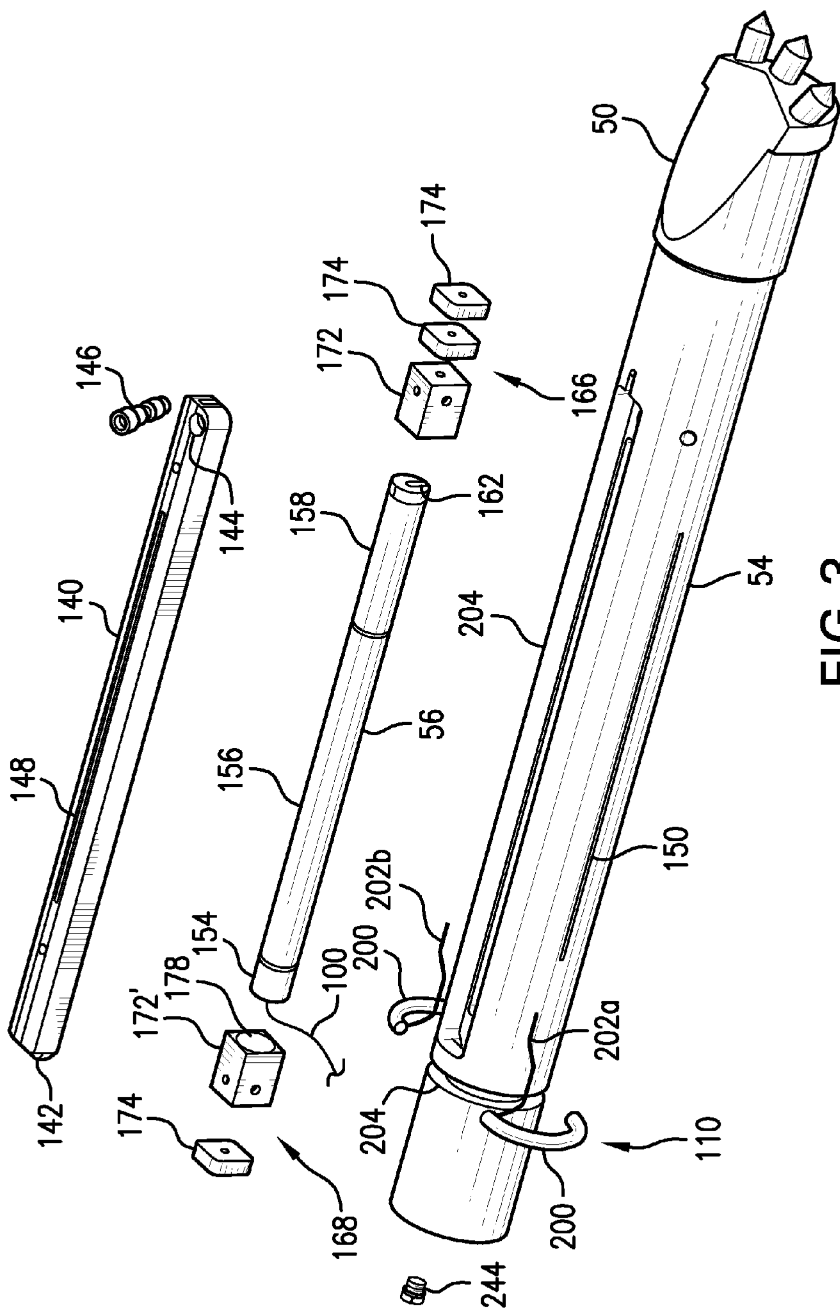

50
174
174
172
166
146
144
140
148
142
162
158
56
156
154
100
178
172'
174
168
204
54
150
202b
200
202a
204
200
110
244

FIG.3

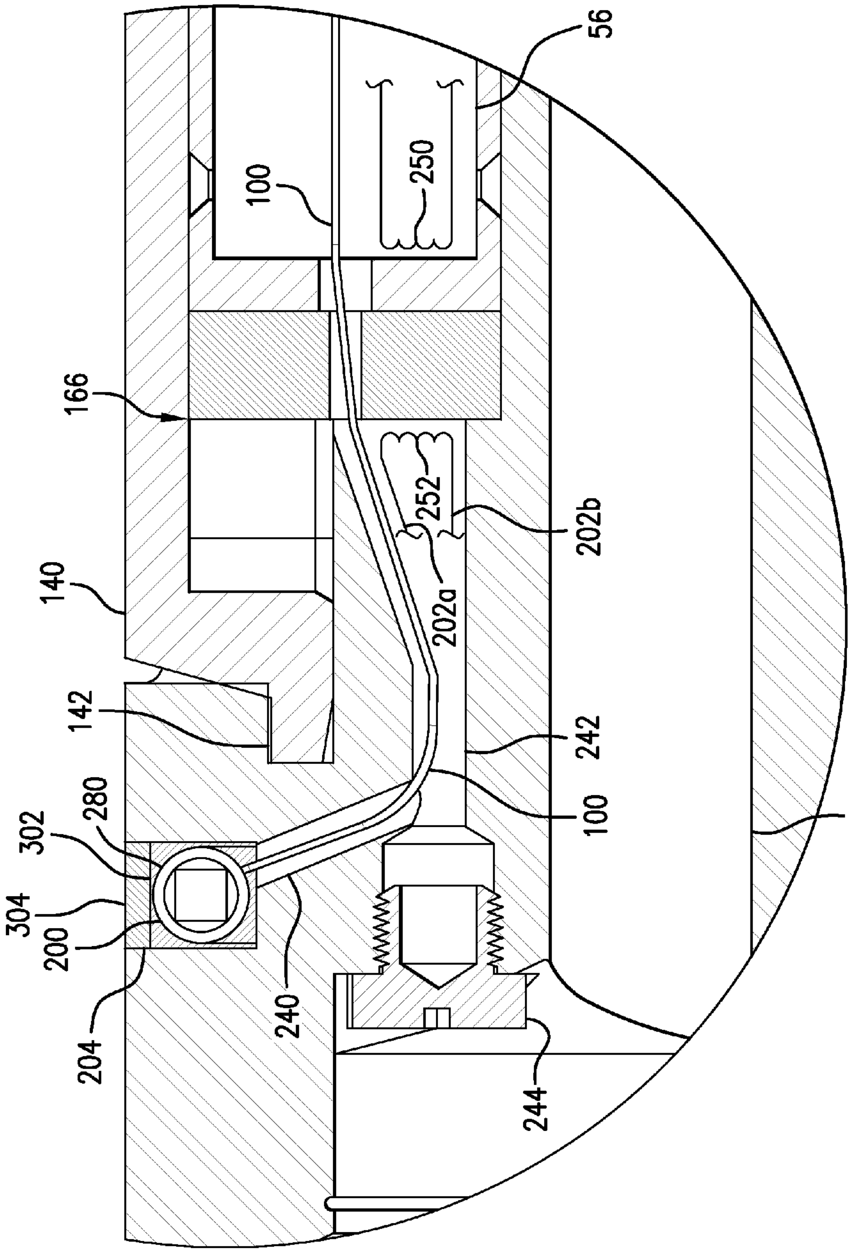

56
250
100
166
252
202b
202a
140
142
242
100
116
280
302
304
200
240
204
244

FIG.4

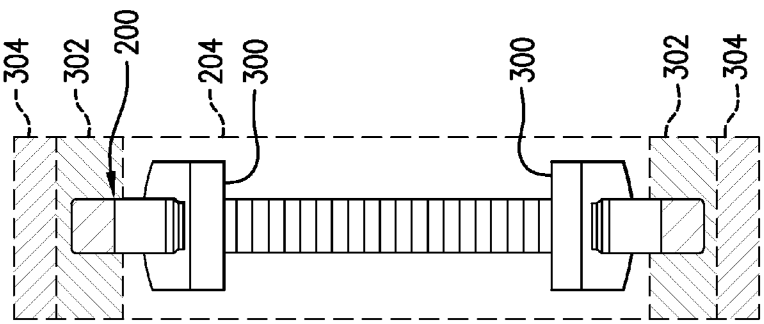


FIG.5

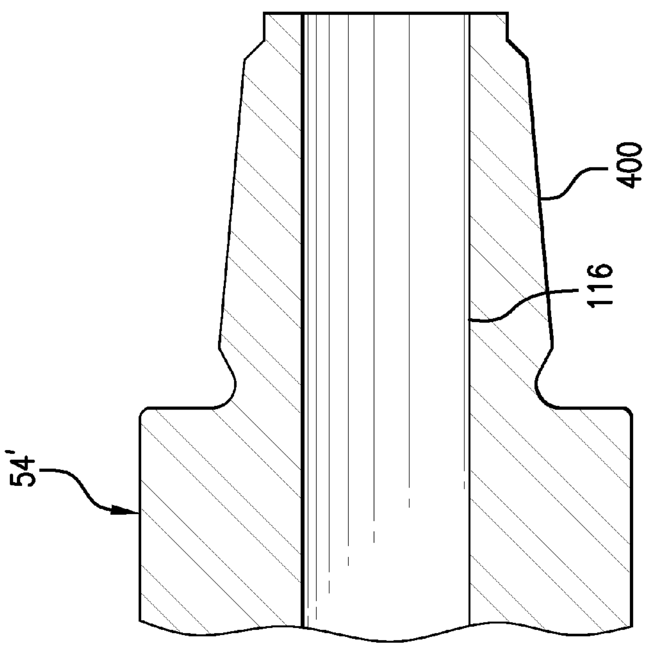


FIG.6

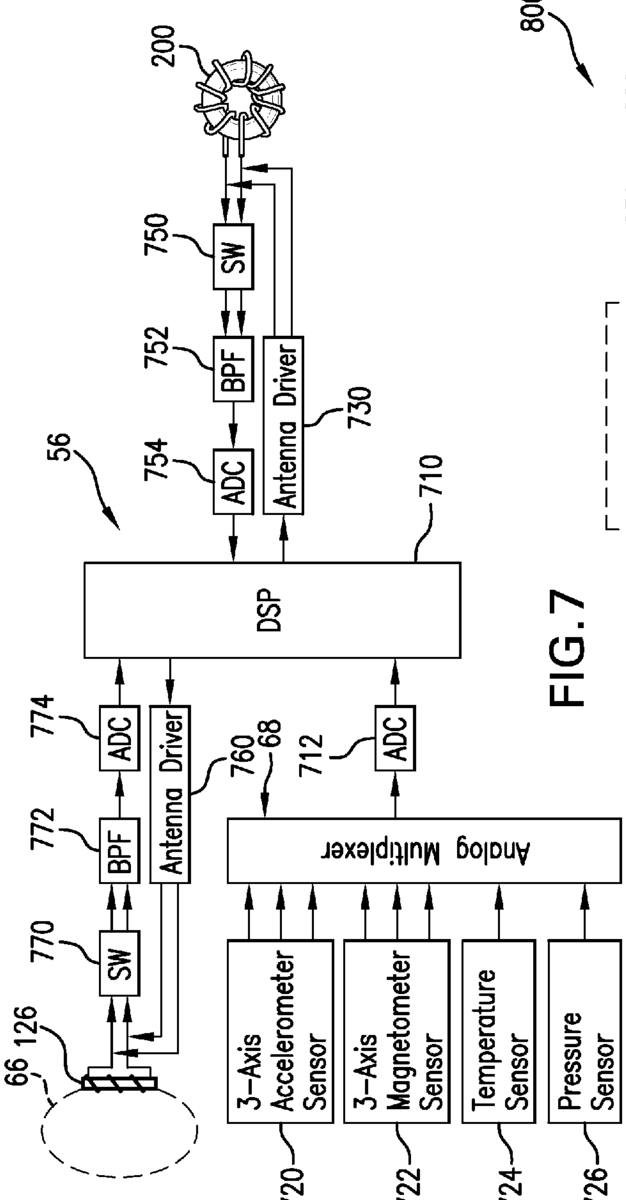

56
200
750
SW
752
BPF
754
ADC
Antenna Driver
730
710
DSP
774
ADC
772
BPF
770
SW
66
126
Antenna Driver
760
68
712
ADC
Analog Multiplexer
3-Axis Accelerometer Sensor
3-Axis Magnetometer Sensor
Temperature Sensor
Pressure Sensor
720
722
724
726

FIG.7

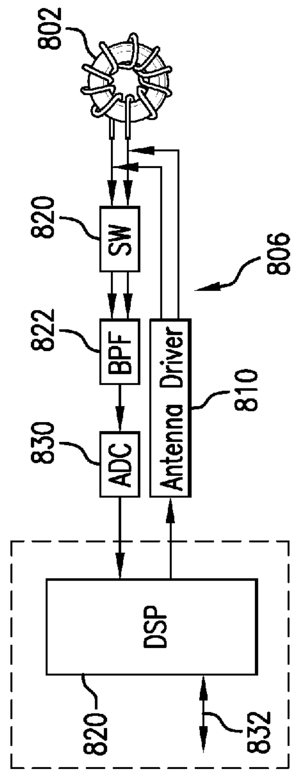

802
800
820
SW
806
822
BPF
830
ADC
Antenna Driver
810
DSP
820
832

FIG.8

INGROUND DRILL STRING HOUSING AND METHOD FOR SIGNAL COUPLING

RELATED APPLICATION

[0001] The present application is related to U.S. patent application Ser. No. ______, (Attorney Docket No. DCI-54) entitled DRILL STRING ADAPTER AND METHOD FOR INGROUND SIGNAL COUPLING, sharing the filing date of the present application and which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] The present application is generally related to inground operations and, more particularly, to a system, apparatus and method for electromagnetically coupling an electrical signal onto an electrically conductive drill string to produce a corresponding electrical signal on the drill string.

[0003] Generally, an inground operation such as, for example, drilling to form a borehole, subsequent reaming of a borehole for purposes of installing a utility line, borehole mapping and the like use an electrically conductive drill string which extends from an above ground drill rig. The prior art includes examples of the use of an electrically conductive drill string as an electrical conductor for serving to electrically conduct a data signal from an inground tool to the drill rig. The surrounding earth itself serves as a signal return path for purposes of detecting the signal at the drill rig. This type of system is often referred to as a measurement while drilling, MWD, system. Applicants recognize, however, that that there remains a need for improvement in MWD systems.

[0004] The foregoing examples of the related art and limitations related therewith are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those of skill in the art upon a reading of the specification and a study of the drawings.

SUMMARY

[0005] The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods which are meant to be exemplary and illustrative, not limiting in scope. In various embodiments, one or more of the above-described problems have been reduced or eliminated, while other embodiments are directed to other improvements.

[0006] Generally, an apparatus and associated method are utilized in a system in which an inground tool is moved through the ground in a region for performing an inground operation. The system includes a drill rig and a drill string which extends between the inground tool and the drill rig and is configured for extension and retraction from the drill rig. The drill string is made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time. In one aspect of the disclosure, an inground housing is removably insertable at one of the joints as the drill string is extended to thereafter form part of the drill string. The inground housing defines a housing cavity that is configured for receiving an electronics assembly that processes a data signal relating to the inground operation. A signal coupling arrangement is supported by the inground housing and configured at least for electrical communication with the electronics assembly when received in the housing cavity and for transferring the data signal between the electronics assembly in the housing cavity and the drill rig at least in part by electromagnetically coupling the data signal between the signal coupling arrangement and the drill string such that the data signal is electrically conducted as an electrical data signal along at least a portion of the drill string that extends from the inground housing and at least some of the electrically conductive drill pipe sections forming said portion of the drill string cooperate as an electrical conductor for carrying the electrical data signal.

[0007] In another aspect of the present disclosure, a repeater is described for use in a system in which an inground tool is moved through the ground in a region for performing an inground operation. The system includes a drill rig and a drill string which extends between the inground tool and the drill rig and is configured for extension and retraction from the drill rig. The drill string is made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time. The repeater includes an inground housing including a housing body that defines a housing cavity and the inground housing is removably insertable at any selected one of the joints as the drill string is extended to thereafter form part of the drill string. The inground housing includes a signal coupling arrangement for providing bidirectional electromagnetic coupling between the inground housing and the drill string for receiving a data signal that is carried by electrical conduction by at least some of the electrically conductive drill pipe sections making up one portion of the drill string by electromagnetically coupling the data signal from the drill string to the inground housing as a received data signal. A repeater electronics package is received in the housing cavity of the inground housing and can be in electrical communication with the signal coupling arrangement for producing a repeater signal based on the received data signal, but which is distinguishable from the received data signal and for providing the repeater signal to the signal coupling arrangement such that the signal coupling arrangement electromagnetically couples the repeater signal back to the drill string for transfer of the repeater signal as another electrical signal along the drill string such that the repeater signal is electrically conducted by at least some of the electrically conductive drill pipe sections making up a different portion of the drill string.

[0008] In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following descriptions.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0009] Exemplary embodiments are illustrated in referenced figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be illustrative rather than limiting.

[0010] FIG. **1** is a diagrammatic view, in elevation, of a system which utilizes an inground housing and signal coupling arrangement of the present disclosure.

[0011] FIG. **2** is a diagrammatic partially cutaway view of one embodiment of the inground housing and signal coupling arrangement of the present disclosure, shown here to illustrate details of its structure.

[0012] FIG. **3** is a diagrammatic exploded view, in perspective, of the embodiment of the inground housing of FIG. **2**, shown here to illustrate details of its structure as well as an electronics package that is receivable in the housing.

[0013] FIG. **4** is a further enlarged fragmentary view, in elevation and partial cross-section, taken within a circle **4-4** in FIG. **2**, shown here to illustrate details at least with respect to electrical connections in the embodiment of FIG. **2** of the inground housing and signal coupling arrangement.

[0014] FIG. **5** is a diagrammatic view, in elevation, of one-half of an overall current transformer that can be used in an embodiment to provide for mechanical shock and vibration isolation of the current transformer from an inground operation using support spacers or donut members.

[0015] FIG. **6** is a diagrammatic view, in cross-section, partially showing another embodiment of an inground housing of the present disclosure including a pin fitting.

[0016] FIG. **7** is a block diagram which illustrates one embodiment of an electronics section that can be used with embodiments of the inground housing of the present disclosure.

[0017] FIG. **8** is a block diagram which illustrates one embodiment of an electronics section that can be used at the drill rig or as part of a drill string repeater in cooperation with the inground housing of the present disclosure.

DETAILED DESCRIPTION

[0018] The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the described embodiments will be readily apparent to those skilled in the art and the generic principles taught herein may be applied to other embodiments. Thus, the present invention is not intended to be limited to the embodiment shown, but is to be accorded the widest scope consistent with the principles and features described herein including modifications and equivalents, as defined within the scope of the appended claims. It is noted that the drawings are not to scale and are diagrammatic in nature in a way that is thought to best illustrate features of interest. Descriptive terminology such as, for example, up, down, upper, lower, left, right and the like may be used with respect to these descriptions, however, this terminology has be adopted with the intent of facilitating the reader's understanding and is not intended as being limiting. Further, the figures are not to scale for purposes of illustrative clarity.

[0019] Turning now to the figures wherein like components are indicated by like reference numbers throughout the various figures, attention is immediately directed to FIG. **1** which is an elevational view that diagrammatically illustrates one embodiment of a horizontal directional drilling system generally indicated by the reference number **10** and produced in accordance with the present disclosure. While the illustrated system shows the invention within the framework of a horizontal directional drilling system and its components for performing an inground boring operation, the invention enjoys equal applicability with respect to other operational procedures including, but not limited to vertical drilling operations, pullback operations for installing utilities, mapping operations and the like.

[0020] FIG. **1** illustrates system **10** operating in a region **12**. System **10** includes a drill rig **14** having a drill string **16** extending therefrom to a boring tool **20**. The drill string can be pushed into the ground to move inground tool **20** at least generally in a forward direction **22** indicated by an arrow. While the present example is framed in terms of the use of a boring tool, it should be appreciated that the discussions apply to any suitable form of inground tool including but not limited to a reaming tool, a tension monitoring tool for use during a pullback operation in which a utility or casing can be installed, a mapping tool for use in mapping the path of the borehole, for example, using an inertial guidance unit and downhole pressure monitoring. In the operation of a boring tool, it is generally desirable to monitor based on the advance of the drill string whereas in other operations such as a pullback operation, monitoring is generally performed responsive to retraction of the drill string.

[0021] With continuing reference to FIG. **1**, drill string **16** is partially shown and is segmented, being made up of a plurality of removably attachable, individual drill pipe sections some of which are indicated as **1**, **2**, n−1 and n, having a section or segment length and a wall thickness. The drill pipe sections may be referred to interchangeably as drill rods having a rod length. During operation of the drill rig, one drill pipe section at a time can be added to the drill string and pushed into the ground by the drill rig using a movable carriage **30** in order to advance the inground tool. Drill rig **14** can include a suitable monitoring arrangement **32** for measuring movement of the drill string into the ground such as is described, for example, in U.S. Pat. No. 6,035,951 (hereinafter the '951 patent), entitled SYSTEMS, ARRANGEMENTS AND ASSOCIATED METHODS FOR TRACKING AND/OR GUIDING AN UNDERGROUND BORING TOOL, which is commonly owned with the present application and hereby incorporated by reference.

[0022] Each drill pipe section defines a through opening **34** (one of which is indicated) extending between opposing ends of the pipe section. The drill pipe sections can be fitted with what are commonly referred to as box and pin fittings such that each end of a given drill pipe section can threadingly engage an adjacent end of another drill pipe section in the drill string in a well known manner. Once the drill pipe sections are engaged to make up the drill string, the through openings of adjacent ones of the drill pipe sections align to form an overall pathway **36** that is indicated by an arrow. Pathway **36** can provide for a pressurized flow of drilling fluid or mud, consistent with the direction of arrow **36**, from the drill rig to the drill head, as will be further described.

[0023] The location of the boring tool within region **12** as well as the underground path followed by the boring tool may be established and displayed at drill rig **14**, for example, on a console **42** using a display **44**. The console can include a processing arrangement **46** and a control actuator arrangement **47**.

[0024] Boring tool **20** can include a drill head **50** having an angled face for use in steering based on roll orientation. That is, the drill head when pushed ahead without rotation will generally be deflected on the basis of the roll orientation of its angled face. On the other hand, the drill head can generally be caused to travel in a straight line by rotating the drill string as it is pushed as indicated by a double headed arrow **51**. Of course, predictable steering is premised upon suitable soil conditions. It is noted that the aforementioned drilling fluid can be emitted as jets **52** under high pressure for purposes of cutting through the ground immediately in front of the drill head as well as providing for cooling and lubrication of the drill head. Boring tool **20** includes an inground housing **54** that receives an electronics package **56**. The inground housing is configured to provide for the flow of drilling fluid to drill head **50** past the electronics package, as will be seen in a subsequent figure. In one embodiment, the electronics package can be cylindrical in configuration and supported within housing **54**. Drill head **50** can include a pin fitting that is received by a box fitting of inground housing **54**. An opposing end of the inground housing can include a box fitting that receives a pin fitting of drill pipe section n which defines a distal, inground end of the drill string. Of course, drill head **50** can be replaced by any suitable inground tool having a pin fitting such as, for example, a reaming tool, a reaming tool in combination with a tension monitoring arrangement, a mapping arrangement or suitable combinations thereof. It is noted that the pipe fittings of the drill head and the inground housing are generally the corresponding box and pin fittings as found on the drill pipe sections of the drill string for facilitating removable attachment of the drill pipe sections to one another in forming the drill string. Thus, inground housing **54** can engage an inground tool such as, for example, drill head **50** having a pin fitting while having an opposing box fitting for removable engagement with the inground/distal end of the drill string. For purposes of inserting inground housing **54** into the drill string, for reasons yet to be described, a box to pin adapter (not shown) can be used in order to adapt box fitting **114** to a pin fitting. It is noted, in this regard, that box to pin fitting adapters are well known in the art. In another embodiment, yet to be described, the inground housing can include a box fitting and an opposing pin fitting.

[0025] Inground electronics package **56** can include a transceiver **64** which, in some embodiments, can transmit a locating signal **66** such as, for example, a dipole locating signal, although this is not required. In some embodiments, transceiver **64** can receive an electromagnetic signal that is generated by other inground components as will be described at an appropriate point below. The present example will assume that the electromagnetic signal is a locating signal in the form of a dipole signal for descriptive purposes. Accordingly, the electromagnetic signal may be referred to as a locating signal. It should be appreciated that the dipole signal can be modulated like any other electromagnetic signal and that the modulation data is thereafter recoverable from the signal. The locating functionality of the signal depends, at least in part, on the characteristic shape of the flux field and its signal strength rather than its ability to carry modulation. Thus, modulation is not required. Information regarding certain parameters of the boring tool such as, for example, pitch and roll (orientation parameters), temperature and drilling fluid pressure can be measured by a suitable sensor arrangement **68** forming part of the electronics package which may include, for example, a pitch sensor, a roll sensor, a temperature sensor, an AC field sensor for sensing proximity of 50/60 Hz utility lines, a DC magnetic field sensor for sensing yaw orientation and any other sensors that are desired. Electronics package **56** further includes a processor **70** that is interfaced as necessary with sensor arrangement **68** and transceiver **64**. Another sensor that can form part of the sensor arrangement is an accelerometer that is configured for detecting accelerations on one or more axes. Power can be provided by a battery **72**.

[0026] A portable locator **80** can be used to detect electromagnetic signal **66**. One suitable and highly advanced portable locater is described in U.S. Pat. No. 6,496,008, entitled FLUX PLANE LOCATING IN AN UNDERGROUND DRILLING SYSTEM, which is commonly owned with the present application and is incorporated herein by reference in its entirety. As mentioned above, the present descriptions apply to a variety of inground operations and are not intended as being limiting, although the framework of horizontal directional drilling has been employed for descriptive purposes. As discussed above, the electromagnetic signal can carry information including orientation parameters such as, for example, pitch and roll. Other information can also be carried by the electromagnetic signal. Such information can include, by way of example, parameters that can be measured proximate to or internal to the boring tool including temperatures and voltages such as a battery or power supply voltage. Locator **80** includes an electronics package **82**. The electronics package is interfaced for electrical communication with the various components of the locator and can perform data processing. Information of interest can be modulated on electromagnetic signal **66** in any suitable manner and transmitted to locator **80** and/or an antenna **84** at the drill rig, although this is not required. Any suitable form of modulation may be used either currently available or yet to be developed. Examples of currently available and suitable types of modulation include amplitude modulation, frequency modulation, phase modulation and variants thereof. Any parameter of interest in relation to drilling such as, for example, pitch may be displayed on display **44** and/or on a display **86** of locator **80** as recovered from the locating signal. Drill rig **14** can transmit a telemetry signal **98** that can be received by locator **80**. The telemetry components provide for bidirectional signaling between the drill rig and locator **80**. As one example of such signaling, based on status provided by drill rig monitoring unit **32**, the drill rig can transmit an indication that the drill string is in a stationary state because a drill pipe section is being added to or removed from the drill string.

[0027] Still referring to FIG. **1**, an electrical cable **100** can extend from inground electronics package **56** to an electromagnetic signal coupling arrangement **110** such that any sensed value or parameter relating to the operation of the inground tool can be electrically conducted in either direction between the electromagnetic coupling arrangement and the electronics package on this cable. One of ordinary skill in the art will appreciate that what is commonly referred to as a "wire-in-pipe" can be used to transfer signals to the drill rig. The term wire-in-pipe refers to an electrical cable/conductor that is housed within interior passageway **36** that is formed by the drill string. In accordance with the present disclosure, however, cable **100** extends only to electromagnetic signal coupling arrangement **110**, as will be further described immediately hereinafter.

[0028] Attention is now directed to FIG. **2** in conjunction with FIG. **1**. FIG. **2** is a diagrammatic partially cutaway view which illustrates one embodiment of boring tool **20** in further detail. In particular, the boring tool includes inground housing **54** which forms box fittings **112** and **114** at each of its opposing ends. Box fitting **112** is configured for engaging the distal end of drill string **16** while box fitting **114** is configured for receiving drill head **50**. It should be appreciated that, in other embodiments, either one or both of these box fittings can be replaced by a pin fitting depending on a particular application. The inground housing can be formed from any suitable material such as, for example, from nonmagnetic alloys including nonmagnetic stainless steels and from magnetic alloys such as, for example, **4140**, **4142**, **4340** or any suitable high strength steel. If the inground housing is to include a magnetometer as part of sensor arrangement **68**, the use of a nonmagnetic material for the housing and related components avoids potential field disturbance. A fluid passage **116** extends between box fittings **112** and **114** such that fluid communication is provided from the drill string leading into drill head **50** which defines a passage **118** for emitting fluid jets **52**. Housing **54** defines a housing cavity for receiving electronics package **56**, as will be further described. For the moment, it is sufficient to note that the electronics package is received in an off-centered manner in order to provide sufficient space for fluid passage **116**. In the present embodiment, transceiver **64** is made up of a printed circuit board **122** and a dipole antenna **126** which transmits electromagnetic locating signal **66**. Cable **100** can be routed from electromagnetic signal coupling arrangement **110** to printed circuit board **122** for purposes of sending data to the signal coupling arrangement and/or receiving data from the electromagnetic signal coupling arrangement. In some embodiments, transceiver **64** can be replaced by a transmitter that is configured for providing signals to the coupling arrangement without the need for receiver functionality. Further, in some embodiments, transmission of locating signal **66** is optional along with associated features of the inground housing, yet to be described. Electrical connections are formed between the various components as needed, but have not been individually designated in FIG. **2** for purposes of illustrative clarity.

[0029] Turning now to FIG. **3** in conjunction with FIG. **2**, the former is an exploded perspective view of boring tool **20**, shown here for illustrating further details with respect to its structure. In particular, inground housing **54** is configured for receiving a cover **140** above the electronics package in the view of FIG. **2**. As seen in the latter figure, a tab **142** extends from one end of the cover to be received in a notch which is defined by the inground housing. An opposite end of the cover defines an opening **144** for receiving a fastener **146** such that the fastener can threadingly engaged the inground housing in an installed condition of the cover. It should be appreciated that any suitable expedient can be used to install the cover on the inground housing. Cover **140** defines a slot **148** that is configured for enhancing the emission of the locating signal while one or more additional slots **150** can be defined by the inground housing for the same purpose. In this regard, such slots are not needed in embodiments that do not utilize locating signal **66**. FIG. **3** illustrates details with respect to one embodiment of electronics package **56** wherein a first end cap **154** is received by a cylindrical body **156** which itself can house dipole antenna **126** and printed circuit board **122** of FIG. **2** wherein body **156** is essentially transparent to locating signal **66**. An opposing end of cylindrical body **156** is connected to a battery compartment **158** which receives battery **72** of FIG. **2**. The battery compartment can be metallic and electrically conductive. Any suitable battery cell or cells can be used to make up the battery such as, for example, a pair of standard C size battery cells. A second end cap **160** is received on the free end of the battery compartment. It should be appreciated that this end cap can define an indexing feature **162** such that the electronics package can be received in a selected orientation within the inground housing. In this way, certain sensor signals such as that of roll orientation can accurately correspond to some selected orientation of the inground housing or inground tool as selectably received in the inground housing to provide selectable orientations in quadrature. The electronics package can be received in the housing first and second spacer arrangements **166** and **168**, respectively, first spacer arrangement **166** includes a first end block **172** that defines a cylindrical recess (not visible) and complementary indexing features (not visible) for being received within indexing slot **162**. First end block **172** can be formed, for example, from thermal plastic. One or more filler spacer blocks **174** can be provided in view of the lengthwise extents of the cavity defined by the inground housing and further in view of the length of electronics package **56**. The filler blocks can be formed, for example, from urethane foam or silicone foam and can be suitably dimensioned. Accordingly, first end spacer block **172** accommodates any one of four user selectable orientations of the electronics package within the cavity of the inground housing. Second spacer arrangement **168**, at the opposite end of the electronics package, can include a second end block **172'** that can be identical to first end block **172** for receiving the opposite end of the electronics package within a cylindrical recess **178**, although complementary indexing features may not be needed. One or more filler blocks **174** can also be positioned adjacent to second end block **172'**, as needed.

[0030] With primary reference to FIG. **3**, electromagnetic signal coupling arrangement **110** includes a current transformer **200** which can be formed using a split core as described in above incorporated co-pending U.S. patent application Ser. No. ______ (Attorney Docket No. DCI-54), entitled DRILL STRING ADAPTER AND METHOD FOR INGROUND SIGNAL COUPLING. The current transformer includes first and second current transformer leads **202***a* and **202***b* which can be connected, for example, in electrical communication with electronics package **56**.

[0031] In one embodiment, the electronics package can include a cable pigtail **100** that is internally electrically connected, for example, to printed circuit board **122** (FIG. **2**). Cable **100** can include either one or two electrical conductors. In one embodiment, cable **100** includes one electrical conductor that is electrically connected, for example, to current transformer lead **202***a*. Current transformer lead **202***b* can be electrically connected to the inground housing which is electrically conductive, for example, using a fastener (not shown) within an annular recess **204** such as an annular groove or slot. At the same time, battery compartment **158** can also be electrically connected to the battery as well as inground housing **54** such that the latter forms part of the electrical circuit to connect current transformer lead **202***b* with the electronics package. In another embodiment, cable **100** can include two conductors such that each one of current transformer leads **202***a* and **202***b* can be electrically connected to one of the cable conductors in electrical communication with electronics package **56**. In this embodiment, the current transformer can be electrically isolated from inground housing **54** and the drill string itself when the electronics package housing is electrically isolated from the inground housing. The split core configuration of the current transformer provides for installation into annular slot or groove **204** that is defined by inground housing **54**, as will be described in further detail immediately hereinafter. Moreover, the above incorporated Application entitled DRILL STRING ADAPTER AND METHOD FOR INGROUND SIGNAL COUPLING, (Attorney Docket No. DCI-54) describes an embodiment in which the current transformer is electrically connected to the drill string by one lead and another embodiment in which the current transformer is completely electrically isolated from the drill string. This isolation can reduce common mode noise that may be coupled onto the drill string, for example, as the result of the presence of 50 Hz or 60 Hz noise in an inground environment.

[0032] Referring to FIG. **4** in conjunction with FIGS. **2** and **3**, FIG. **4** is an enlarged diagrammatic view of a region **4-4** that is shown within a dashed circle in the view of FIG. **2**, shown here to illustrate further details of one embodiment of the apparatus proximate to current transformer **200** and its connection to electronics package **56**. As described above, current transformer **200** is configured for installation in transformer recess or groove **204** that is defined by inground housing **54**. The current transformer includes a coil that is wound upon an annular or toroidal core such that the end portions of the coil can form leads **202***a* and **202***b* of FIG. **3**. In this regard, the core can include any suitable cross-sectional shape such as, for example, rectangular, square and circular. As is also shown in FIG. **2**, the core can be split in order to facilitate installation of the current transformer into transformer groove **204**. It should be appreciated that any suitable current transformer can be used and that the particular current transformer that is described here is not intended as limiting.

[0033] The current transformer can be designed with at least the following in mind:

[0034] a. Shock and vibration. The material selection and construction can provide for withstanding the shock and vibration for the downhole drilling environment.

[0035] b. Magnetic material selection can be based on low core loss at the operating frequency, high flux saturation and mechanical robustness.

[0036] c. High flux saturation of the core can permit a reduction in cross-sectional area of the magnetic core, to provide for increasing the cross-sectional area of the adapter coupling main body for torque and power transmission.

[0037] d. Low inter winding capacitance for high frequency response.

[0038] In view of the foregoing, in one embodiment and by way of non-limiting example, a tape wound core can be used. As will be familiar to one of ordinary skill in the art, such cores are less susceptible to shock and vibration than ferrite cores. Such a tape wound core can be produced using a thin, high magnetic flux saturation tape in order to avoid eddy current losses in the core. In different embodiments, the tape thickness can range from 0.00025" to 0.001". One suitable thickness is 0.0007". The tape wound core can be finished, for example, using powder coating or epoxy coating. In one embodiment, additional vibration and shock protection can be provided for the current transformer and its core based on the manner by which the current transformer is mounted in groove **204**, as will be described at an appropriate point hereinafter.

[0039] One or both of current transformer leads **202***a* and **202***b* (FIG. **3**) can be electrically connected to electronics package **56** by cable **100**, for example, with connections such as crimp connections received in recess **204** adjacent to the current transformer. Cable **100** can be routed through a passage arrangement that is made up of a first passage portion **240** and a second passage portion **242** each of which can be formed, for example, by drilling and/or suitable machining. Passage portion **242** can be configured to receive a plug **244** that can be held in threading engagement, so as to prevent high pressure drilling fluid from entering the passage arrangement. It should be appreciated that any suitable arrangement can be used to provide information coupling between the current transformer and the electronics package including electrical connections and electrical connections in combination with inductive coupling. As an example of the latter embodiment, the electronics package can include a coupling transformer having a first transformer coupling coil **250** that is built-in to the electronics package and a second transformer coupling coil **252** that is connected to current transformer leads **202***a* and **202***b* (or to a cable extending therefrom) and mounted within passage **242**, for example, using a potting compound. In the embodiment using the coupling transformer, components of the electronics package housing and second spacer arrangement **168** can provide for electromagnetic coupling between the subject transformer coils. It should be appreciated that one of ordinary skill in the art can develop many other embodiments in view of the present disclosure while still remaining within the scope of the teachings herein.

[0040] Referring to FIGS. **1-4**, current transformer **200** can use the drill pipe in the manner of a single turn secondary and the surrounding soil to form a complete current path. The primary winding of the current transformer can convert a low current output from the drive electronics to a high current signal on the drill pipe with the drill pipe itself serving as the single turn secondary. Of course, the terms, primary and secondary can be used interchangeably based on the direction of signal coupling and have been applied here for descriptive and non-limiting purposes. The current ratio is proportional to the number of turns on the primary. For example, if the current into the primary is 10 mA rms, the current induced on the drill pipe will be 1000 mA which is one hundred times higher than the input current if the ratio of primary to secondary turns is 100/1. As discussed above, a tape wound core can be encapsulated in an epoxy **280** (FIG. **4**) for added mechanical strength, using any suitable thermal plastic or epoxy. The finished core or toroid can be cut, for example, with a diamond saw into two half cores for installation purposes with the transformer windings applied to each core half. A small gap, for example, of about 0.001" can be formed between the confronting surfaces of the core half ends by bonding a piece of non-magnetic material, such as Mylar®, a strong polyester film between the confronting surfaces, to create a magnetic gap. This gap helps to prevent magnetic saturation of the core. As is well known in the art, the cross-section of the core can be determined by the frequency, flux density, number of turns of magnet wire (for example, an insulated copper wire), saturation flux density and applied voltage to the current transformer. With frequency from a few kilohertz to a hundred kilohertz, the cross-section, by way of example, can be approximately 0.2" by 0.2" for a square-shaped cross-sectional embodiment. In some embodiments, the current transformer can be shock mounted in the annular groove, as will be further described at one or more points hereinafter.

[0041] Assembly of one embodiment can proceed, for example, by installing current transformer **200** into annular groove **204**. Cable **100** can be extended into through passages **240** and **242** from the electronics package to the current transformer. Electrical connections can be made between the current transformer leads and cable **100**, for example, using crimp connections or any other suitable connections. It should be appreciated that the current transformer, cylindrical ring and high pressure electrical connector assembly are readily replaceable/repairable in the field.

[0042] Referring to FIG. **5**, one-half of current transformer **200** is shown for purposes of illustrating another embodiment for isolating the current transformer from mechanical shock and vibration. It is noted that edges of annular recess **204** are diagrammatically shown by dashed lines proximate to the current transformer. In particular, current transformer **200** can be shock mounted using any suitable number of donut or spacer members **300**. Three spacer members can be used with a suitable or at least approximately even distribution around the periphery of the current transformer. Each spacer member can define a center aperture for receiving the current transformer. Since the current transformer can be provided in two halves, spacer members **300** can readily be installed on each current transformer half prior to installation of the current transformer into groove **204**. When the current transformer is provided in two halves, each half can support two or more shock mitigation spacer members. The spacer members can have any suitable shape in view of the shape of the current transformer and annular recess into which they are to be received. Moreover, the spacer members can have any suitable arc width in the annular recess. The spacer ring members can be formed from any suitable material such as, for example, a resilient foam material. In one embodiment, a high temperature foam material can be used. Such foam materials, either currently available or yet to be developed, can be resistant to temperatures up to and including 120 degrees Centigrade and can include, by way of example, a silicone foam. As seen in FIGS. **4** and **5**, a potting compound **302** can be used to at least partially fill the entirety of annular recess **204** or spaces between any of spacer members **300** that are used. A separate layer **304** of protective material can be provided outward of potting compound **302** as well as outward from the spacer members in the annular recess. The potting compound can be a soft or resilient potting compound, such as, for example, polyurethane or electronic grade RTV for purposes of providing at least partial mechanical shock and vibration isolation of the current transformer from inground operations. Protective layer **304**, for example, can be an epoxy compound that is harder than the underlying potting compound. Current transformer **200** can be potted in position, as described above, using spacer members **300** as centering devices during application of the resilient potting compound, however, it should be appreciated that the spacer members are not required.

[0043] Accordingly, a shock isolated and mounted current transformer and associated method have been brought to light herein. The housing which supports the current transformer includes a housing body that can be removably insertable at one of the joints of the drill string as the drill string is extended to thereafter form part of the drill string. The housing is configured at least for receiving the current transformer with the current transformer inductively coupled to the drill string. A support arrangement resiliently supports the current transformer on the housing body such that the current transformer is isolated at least to some extent from a mechanical shock and vibration environment to which the housing is subjected responsive to the inground operation. In some cases, a drill pipe section can be configured to support a current transformer in a manner that is consistent with the descriptions above, for example, when the drill pipe section includes a sidewall thickness that is sufficiently thick for purposes of defining a support groove for the current transformer without unduly weakening the drill pipe section. Additionally, a drill pipe section having a sidewall of sufficient thickness can support the electrical connections, passages and assemblies described above with limited or no modification as will be recognized by one having ordinary skill in the art with this overall disclosure in hand.

[0044] Referring to FIG. **6**, in another embodiment, an inground housing **54'**, partially shown, can be configured as essentially identical to inground housing **54**, as described above, except that box fitting **114** (FIG. **2**) is replaced by a pin fitting **400**. It is noted that threads have not been shown in the figure but are well known and understood to be present. Thus, inground housing **54'** can include a box fitting at one end nearest to the current transformer, as seen in FIG. **2**, and pin fitting **400** at the opposing end such that inground housing **54'** can be inserted directly into the drill string in removable engagement with adjacent ones of drill pipe sections or engaging a drill head or other tool having a box fitting.

[0045] FIG. **7** is a block diagram which illustrates one suitable embodiment of electronics package **56**, that can be supported in inground housing **54** or **54'**. The electronics package can include an inground digital signal processor **710** which can facilitate all of the functionality of transceiver **64** and processor **70** of FIGS. **1** and **2**. Sensor arrangement **68** is electrically connected to digital signal processor **710** via an analog to digital converter (ADC) **712**. Any suitable combination of sensors can be provided for a given application and can be selected, for example, from an accelerometer **720**, a magnetometer **722**, a temperature sensor **724** and a pressure sensor **726** which can sense the pressure of drilling fluid. Current transformer **200** can be connected for use in one or both of a transmit mode, in which data is modulated onto the drill string, and a receive mode in which modulated data is recovered from the drill string. For the transmit mode, an antenna driver section **730** is used which is electrically connected between inground digital signal processor **710** and current transformer **200** to drive the antenna. Generally, the data that can be coupled into the drill string can be modulated using a frequency that is different from any frequency that is used to drive antenna **126** (FIG. **2**) that can emit aforedescribed signal **66** (FIG. **1**) in order to avoid interference. When antenna driver **730** is off, an On/Off Switcher (SW) **750** can selectively connect current transformer **200** to a band pass filter (BPF) **752** having a center frequency that corresponds to the center frequency of the data signal that is received from the drill string. BPF **752** is, in turn, connected to an analog to digital converter (ADC) **754** which is itself connected to digital signal processing section **710**. Recovery of the modulated data in the digital signal processing section can be readily configured by one having ordinary skill in the art in view of the particular form of modulation that is employed.

[0046] Still referring to FIG. **7**, dipole antenna **126** can be connected for use in one or both of a transmit mode, in which signal **66** is transmitted into the surrounding earth, and a receive mode in which an electromagnetic signal such as, for example, a signal from a tension monitoring arrangement is received. For the transmit mode, an antenna driver section **760** is used which is electrically connected between inground digital signal processor **710** and dipole antenna **126** to drive the antenna. Again, the frequency of signal **66** will generally be sufficiently different from the frequency of the drill string signal to avoid interference therebetween. When antenna driver **760** is off, an On/Off Switcher (SW) **770** can selectively connect dipole antenna **126** to a band pass filter (BPF)

772 having a center frequency that corresponds to the center frequency of the data signal that is received from the dipole antenna. BPF **772** is, in turn, connected to an analog to digital converter (ADC) **774** which is itself connected to digital signal processing section **710**. Transceiver electronics for the digital signal processing section can be readily configured in many suitable embodiments by one having ordinary skill in the art in view of the particular form or forms of modulation employed and in view of this overall disclosure.

[0047] Referring to FIGS. **1** and **8**, the latter is a block diagram of components that can make up one embodiment of a transceiver arrangement, generally indicated by the reference number **800**, that is coupled to drill string **16**. An aboveground current transformer **802** is positioned, for example, on drill rig **14** for coupling and/or recovering signals to and/or from drill string **16**. Current transformer **802** can be electrically connected for use in one or both of a transmit mode, in which data is modulated onto the drill string, and a receive mode in which modulated data is recovered from the drill string. A transceiver electronics package **806** is connected to the current transformer and can be battery powered. For the transmit mode, an antenna driver section **810** is used which is electrically connected between a digital signal processor **820** and current transformer **802** to drive the current transformer. Again, the data that can be coupled into the drill string can be modulated using a frequency that is different from the frequency that is used to drive dipole antenna **126** (FIG. **2**) in order to avoid interference as well as being different from the frequency at which current transformer **200** (FIG. **7**) couples a signal onto the inground end of the drill string. When antenna driver **810** is off, an On/Off Switcher (SW) **820** can selectively connect current transformer **802** to a band pass filter (BPF) **822** having a center frequency that corresponds to the center frequency of the data signal that is received from the drill string. BPF **822** is, in turn, connected to an analog to digital converter (ADC) **830** which is itself connected to digital signal processing section **820**. It should be appreciated that digital signal processing section **820** and related components can form part of processing arrangement **46** (shown using a dashed line) of the drill rig or be connected thereto on a suitable interface **832**. Transceiver **806** can send commands to the inground tool for a variety of purposes such as, for example, to control transmission power, select a modulation frequency, change data format (e.g., lower the baud rate to increase decoding range) and the like. Transceiver electronics for the digital signal processing section can be readily configured in many suitable embodiments by one having ordinary skill in the art in view of the particular form or forms of modulation employed and in view of this overall disclosure.

[0048] Referring to FIG. **1**, in another embodiment, inground housing **54** or **54'**, along with current transformer **200**, a box to pin adapter (if needed), and transceiver **806** (FIG. **11**) can be inserted as a unit into one of the joints of the drill string to serve in the manner of a repeater, by way of example, 1000 feet from the inground tool. For example, the repeater arrangement can be inserted in the joint formed between drill pipe sections **1** and **2** in FIG. **1**. In any of these embodiments, of course, the repeater/transceiver electronics can be electrically connected to the current transformer of the inground housing in a manner that is consistent with the descriptions above. In order to avoid signal interference, the current transformer can pick up the signal originating from the inground tool at one carrier frequency and the repeater electronics can retransmit the signal up the drill string from the current transformer at a different carrier frequency.

[0049] The foregoing description of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form or forms disclosed, and other embodiments, modifications and variations may be possible in light of the above teachings wherein those of skill in the art will recognize certain modifications, permutations, additions and subcombinations thereof.

What is claimed is:

1. In a system in which an inground tool is moved through the ground in a region for performing an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, an apparatus comprising:

an inground housing that is removably insertable at one of the joints as the drill string is extended to thereafter form part of the drill string and said inground housing defines a housing cavity that is configured for receiving an electronics assembly that processes a data signal relating to the inground operation; and

a signal coupling arrangement supported by the inground housing and configured at least for electrical communication with the electronics assembly when received in the housing cavity and for transferring the data signal between the electronics assembly in the housing cavity and the drill rig at least in part by electromagnetically coupling the data signal between the signal coupling arrangement and the drill string such that the data signal is electrically conducted as an electrical data signal along at least a portion of the drill string that extends from the inground housing and at least some of the electrically conductive drill pipe sections forming said portion of the drill string cooperate as an electrical conductor for carrying the electrical data signal.

2. The apparatus of claim **1** wherein said portion of the drill string extends at least partially from the inground housing to the drill rig such that the signal coupling arrangement couples the data signal between the signal coupling arrangement and said portion of the drill string.

3. The apparatus of claim **1** wherein said signal coupling arrangement is configured for electromagnetically receiving the electrical data signal from said portion of the drill string as the data signal and thereafter electrically transferring the data signal to the electronics assembly such that the apparatus serves as a receiver.

4. The apparatus of claim **1** wherein said signal coupling arrangement is configured for electromagnetically transferring the data signal from said electronics assembly to said portion of the drill string to produce the electrical data signal in the drill string such that the apparatus serves as a transmitter.

5. The apparatus of claim **1** wherein said signal coupling arrangement is configured for bidirectional coupling of the data signal between the electronics assembly and the drill string such that the apparatus serves as a transceiver.

6. The apparatus of claim **1** wherein said signal coupling arrangement includes a current transformer supported by the inground housing and in electrical communication with the electronics package when received in the housing cavity for electromagnetically coupling the data signal between the drill string and said current transformer.

7. The apparatus of claim **6** wherein said inground housing includes an outer surface configuration that defines an annular groove for receiving said current transformer therein.

8. The apparatus of claim **7** further comprising:

a support arrangement for resiliently supporting said current transformer within said annular groove on said inground housing such that the current transformer is isolated at least to some extent from a mechanical shock and vibration environment to which the housing is subjected responsive to said inground operation.

9. The apparatus of claim **8** wherein said support arrangement includes a plurality of resilient spacers that are distributed around a peripheral configuration of the current transformer for supporting the current transformer in the annular groove and a resilient potting compound that is received in said annular groove between said resilient spacers for further supporting the current transformer in said annular recess groove to isolate the current transformer from the mechanical shock and vibration environment.

10. The apparatus of claim **8** wherein said support arrangement includes a resilient potting compound surrounding the current transformer in said annular recess groove to isolate the current transformer from the mechanical shock and vibration environment.

11. The apparatus of claim **1** wherein said electronics package includes a sensor section and the electronics package is configured for producing said data signal responsive to a sensor signal from at least one sensor in the sensor section such that the signal coupling arrangement electromagnetically couples the sensor signal onto the drill string for transfer to the drill rig using at least some of the electrically conductive drill pipe sections as said electrical conductor and said electronics package includes a locating signal antenna for electromagnetically transmitting an electromagnetic locating signal and said inground housing is configured for emanating said electromagnetic signal into the ground surrounding the inground housing.

12. The apparatus of claim **1** wherein each drill pipe section includes a box fitting at one end and a pin fitting at an opposing end and wherein said inground housing includes said box fitting at one end and said pin fitting at an opposite end.

13. The apparatus of claim **12** wherein each drill pipe section defines a through passage to provide for a flow of drilling fluid through the drill string and wherein said inground housing defines an internal passage which provides for said flow of drilling fluid through the inground housing between the box fitting and the pin fitting of the inground housing.

14. The apparatus of claim **1** wherein each drill pipe section includes a box fitting at one end and a pin fitting at an opposing end and wherein said inground housing includes said box fitting at each end and said apparatus includes a box to pin adapter that is removably attached to one of the box fittings of the inground housing to form part of said drill string.

15. The apparatus of claim **14** wherein said signal coupling arrangement is positioned nearest to a selected one of the box fittings of the inground housing and the box to pin adapter is removably attached to the other box fitting at an opposite end of the inground housing from the selected fitting.

16. The apparatus of claim **1** wherein said signal coupling arrangement includes a current transformer supported by the inground housing and in electrical communication with the electronics package when received in the housing cavity for electromagnetically coupling the data signal between the drill string and said current transformer, and the current transformer includes a winding having a first current transformer electrical lead that is electrically connected to the electronics assembly.

17. The apparatus of claim **16** wherein said winding includes a second current transformer lead that is electrically connected to the electronics package such that the first current transformer lead and the second current transformer lead are in electrical isolation from the drill string.

18. The apparatus of claim **16** wherein said electronics assembly includes a case that serves as one electrical terminal for the electronics package and inground housing is configured to cooperate with the case such that the case is electrically coupled to the inground housing and wherein said winding includes a second current transformer lead that is electrically connected to the inground housing for electrical communication with the electronics assembly.

19. In a system in which an inground tool is moved through the ground in a region for performing an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, a method comprising:

arranging an inground housing for removable insertion at one of the joints as the drill string is extended to thereafter form part of the drill string and defining a housing cavity within the inground housing that is configured for receiving an electronics assembly that processes a data signal relating to the inground operation;

supporting a signal coupling arrangement using the inground housing; and

configuring said signal coupling arrangement for electrical communication with the electronics assembly, when received in the housing cavity, and for transferring the data signal between the electronics assembly in the housing cavity and the drill rig at least in part by electromagnetically coupling the data signal between the signal coupling arrangement and the drill string such that the data signal is electrically conducted as an electrical data signal along at least a first portion of the drill string that extends from the inground housing and at least some of the electrically conductive drill pipe sections forming said first portion of the drill string cooperate as an electrical conductor for carrying the electrical data signal.

20. The method of claim **19** wherein said portion of the drill string extends at least partially from the inground housing to the drill rig and the method includes electromagnetically coupling the data signal between the signal coupling arrangement and said portion of the drill string.

21. The method of claim **19** including configuring said signal coupling arrangement for electromagnetically receiving the electrical data signal from said portion of the drill string as the data signal and thereafter electrically transferring the data signal to the electronics assembly such that the electronics assembly serves as a receiver.

22. The method of claim **19** including configuring said signal coupling arrangement for electromagnetically transferring the data signal from said electronics assembly to said portion of the drill string to produce the electrical data signal in the drill string such that the electronics assembly serves as a transmitter.

23. The method of claim **19** including configuring said signal coupling arrangement for bidirectional coupling of the data signal between the electronics assembly and the drill string such that the electronics assembly serves as a transceiver.

24. The method of claim **19** including supporting a current transformer using the inground housing as part of the signal coupling arrangement and electrically connecting the current transformer in communication with the electronics package when received in the housing cavity for electromagnetically coupling the data signal between the drill string and said current transformer.

25. The method of claim **24** wherein said inground housing includes an outer surface configuration and defining an annular recess as part of the outer surface configuration and receiving said current transformer in said annular recess.

26. The method of claim **25** further comprising:

resiliently supporting said current transformer within said annular recess on said inground housing such that the current transformer is isolated at least to some extent from a mechanical shock and vibration environment to which the inground housing is subjected responsive to said inground operation.

27. The method of claim **26** wherein resiliently supporting includes arranging a plurality of resilient spacers in a spaced apart, distributed way around a peripheral configuration of the current transformer for supporting the current transformer in the annular groove and applying a resilient potting compound in said annular recess between said resilient spacers for further supporting the current transformer in said annular groove to isolate the current transformer from the mechanical shock and vibration environment.

28. The method of claim **26** including applying a resilient potting compound in said wherein said support arrangement includes a resilient potting compound in said annular recess to surround the current transformer in said annular recess to isolate the current transformer from the mechanical shock and vibration environment.

29. The method of claim **19** wherein said electronics package includes a sensor section and the electronics assembly is configured for producing said data signal responsive to a sensor signal from at least one sensor in the sensor section such that the signal coupling arrangement electromagnetically couples the sensor signal onto the drill string for transfer to the drill rig using at least some of the electrically conductive drill pipe sections as said electrical conductor and said electronics assembly includes a locating signal antenna for electromagnetically transmitting an electromagnetic locating signal and including configuring said inground housing for emanating said electromagnetic locating signal into the ground surrounding the inground housing.

30. The method of claim **19** wherein each drill pipe section includes a box fitting at one end and a pin fitting at an opposing end and including configuring said inground housing to include said box fitting at one end and said pin fitting at an opposite end.

31. The method of claim **30** wherein each drill pipe section defines a through passage to provide for a flow of drilling fluid through the drill string and including configuring said inground housing to define an internal passage which provides for said flow of drilling fluid through the inground h

32. The method of claim **19** wherein each drill pipe section includes a box fitting at one end and a pin fitting at an opposing end and said method includes configuring said inground housing including said box fitting at each end and providing a box to pin adapter that is removably attachable to one of the box fittings of the inground housing to form part of said drill string.

33. The method of claim **32** including positioning said signal coupling arrangement nearest to a selected one of the box fittings of the inground housing and removably attaching the box to pin adapter to the other box fitting at an opposite end of the inground housing from the selected fitting.

34. The method of claim **19** including supporting a current transformer on said inground housing as part of said signal coupling arrangement and connecting the current transformer in electrical communication with the electronics assembly when received in the housing cavity for electromagnetically coupling the data signal between the drill string.

35. The method of claim **34** wherein said current transformer includes a winding having a first current transformer electrical lead that is electrically connected to the electronics assembly by said connecting.

36. The method of claim **35** wherein said winding includes a second current transformer lead and connecting further includes electrically connecting the second current transformer lead to the electronics assembly such that the first current transformer lead and the second current transformer lead are in electrical isolation from the drill string.

37. The method of claim **35** wherein said electronics assembly includes a case that serves as one electrical terminal for the electronics assembly and connecting includes configuring the inground housing to cooperate with the case such that the case is electrically coupled to said inground housing and wherein said winding includes a second current transformer lead and connecting includes electrically connecting the second current transformer lead to the inground housing for electrical communication with the electronics assembly.

38. A repeater for use in a system in which an inground tool is moved through the ground in a region for performing an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, said repeater comprising:

an inground housing including a housing body that defines a housing cavity and said inground housing is removably insertable at any selected one of the joints as the drill string is extended to thereafter form part of the drill string and said inground housing includes a signal coupling arrangement for providing bidirectional electromagnetic coupling between the inground housing and the drill string for receiving a data signal that is carried by electrical conduction by at least some of the electrically conductive drill pipe sections making up one portion of the drill string by electromagnetically coupling the data signal from the drill string to the inground housing as a received data signal; and

a repeater electronics package received in said housing cavity of the inground housing and which is in electrical communication with the signal coupling arrangement for producing a repeater signal based on the received data signal, but which is distinguishable from the received data signal and for providing the repeater signal to the signal coupling arrangement such that the signal coupling arrangement electromagnetically couples the repeater signal back to the drill string for transfer of the repeater signal as another electrical signal along the drill string such that the repeater signal is electrically conducted by at least some of the electrically conductive drill pipe sections making up a different portion of the drill string.

39. The apparatus of claim **38** wherein said inground housing includes a current transformer in electrical communication with the inground tool for receiving the data signal and electromagnetically coupling the data signal at least onto said portion of the drill string and said coupling adapter further includes an adapter body assembly having an outer surface configuration that defines an annular recess for receiving said current transformer therein.

40. A method for use in a system in which an inground tool is moved through the ground in a region for performing an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, said method comprising:

configuring an inground housing to include a housing body that defines a housing cavity and said inground housing is removably insertable at any selected one of said joints as the drill string is extended to thereafter form part of the drill string and arranging said inground housing to include a signal coupling arrangement for providing bidirectional electromagnetic coupling between the inground housing and the drill string for receiving a data signal that is carried by electrical conduction by at least some of the electrically conductive drill pipe sections making up one portion of the drill string by electromagnetically coupling the data signal from the drill string to the inground housing as a received data signal; and

supporting a repeater electronics package in said housing cavity of the inground housing in electrical communication with the signal coupling arrangement for producing a repeater signal based on the received data signal, but which is distinguishable from the received data signal and providing the repeater signal to the signal coupling arrangement such that the signal coupling arrangement electromagnetically couples the repeater signal back to the drill string for transfer of the repeater signal as another electrical signal along the drill string such that the repeater signal is electrically conducted by at least some of the electrically conductive drill pipe sections making up a different portion of the drill string.

41. The method of claim **40** including configuring the housing body of the inground housing to include a current transformer in electrical communication with the inground tool for receiving the data signal and electromagnetically coupling the data signal at least onto said portion of the drill string and further configuring the housing body to include an outer surface configuration that defines an annular recess for receiving said current transformer therein.

42. In a system in which an inground tool is moved through the ground in a region during an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, an apparatus comprising:

an electronics package that is configured for inground operation;

a current transformer configured for inductively coupled communication with said drill string as part of providing for communication between said electronics package and said drill rig on said drill string by using the drill string as an electrical conductor;

a housing having a housing body that is removably insertable at one of the joints as the drill string is extended to thereafter form part of the drill string and said housing is configured at least for receiving said current transformer with the current transformer inductively coupled to the drill string and said housing defines a housing cavity for receiving said electronics package therein; and

a support arrangement for resiliently supporting said current transformer on said housing body such that the current transformer is isolated at least to some extent from a mechanical shock and vibration environment to which the housing is subjected responsive to said inground operation.

43. In a system in which an inground tool is moved through the ground in a region during an inground operation, said system including a drill rig and a drill string which extends between said inground tool and said drill rig and is configured for extension and retraction from said drill rig, said drill string being made up of a plurality of electrically conductive drill pipe sections, each of which includes a section length and each of which is configured for removable attachment to the inground tool at one joint and to one another at other joints that are formed between adjacent ones of the drill pipe sections such that the drill string includes a plurality of joints to facilitate the extension and retraction of the drill string by one section length at a time, a method comprising:

providing an electronics package that is configured for inground operation;

configuring a current transformer for inductively coupled communication with said drill string as at least part of providing for communication between said electronics package and said drill rig on said drill string by using at least a portion of the drill string as an electrical conductor;

arranging a housing having a housing body for removable insertion at one of the joints as the drill string is extended to thereafter form part of the drill string and configuring said housing at least for receiving said current transformer with the current transformer inductively coupled to the drill string and defining a housing cavity within the housing for receiving said electronics package therein; and

resiliently supporting the current transformer on said housing body for said inductive coupling to the drill string such that the current transformer is isolated at least to some extent from a mechanical shock and vibration environment to which the housing is subjected responsive to said inground operation.

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