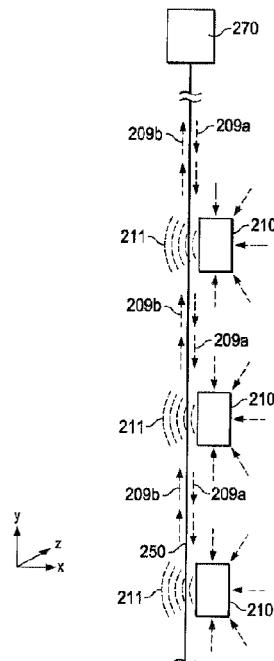




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 (72) **Inventeurs/Inventors:**
THERRIEN, JASON E., US;
JAASKELAINEN, MIKKO, US;
BENJAMIN, SELDON D., US
 (73) **Propriétaire/Owner:**
HALLIBURTON ENERGY SERVICES, INC., US
 (74) **Agent:** PARLEE MCLAWS LLP

(54) **Titre : ATTENUATION DE DOMMAGE DE CABLE PENDANT UNE PERFORATION**
 (54) **Title: MITIGATION OF CABLE DAMAGE DURING PERFORATION**



(57) **Abrégé/Abstract:**

A system and method to minimize the likelihood of cable damage due to downhole operations such as perforating is disclosed. The system includes at least one transducer and at least one orientation device positioned adjacent a cable. A wireless signal from the transducer and/or orientation device is transmitted towards the cable. The wireless signal influences a wired signal transmitted in the cable. The influenced wired signal is used to identify the axial and radial orientation of the cable. The transducer may be secured to a mid-joint collar on the casing string in a portion of the wellbore to be perforated. The transducers are identified and located by the control system and a perforating tool can be adjusted to point away from the cable before firing of the perforating tool.

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- (71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; 3000 N. Sam Houston Parkway E., Houston, Texas 77032-3219 (US).
- (72) Inventors: **THERRIEN, Jason E.**; 1111 Saathoof Dr. apt 706, Cypress, Texas 77429 (US). **JAASKELAINEN, Mikko**; 4011 Bell Hollow Lane, Katy, Texas 77494 (US). **BENJAMIN, Seldon D.**; 5310 White Birch Run, Spring, Texas 77386 (US).
- (74) Agents: **TIDWELL, Mark** et al.; Haynes and Boone, LLP, 2323 Victory Avenue, Suite 700, Dallas, Texas 75219 (US).
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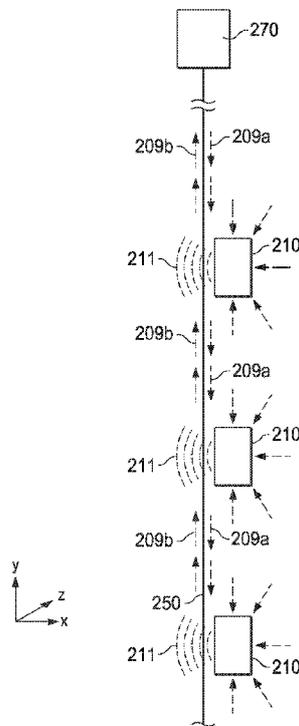


Fig. 6

(57) Abstract: A system and method to minimize the likelihood of cable damage due to downhole operations such as perforating is disclosed. The system includes at least one transducer and at least one orientation device positioned adjacent a cable. A wireless signal from the transducer and/or orientation device is transmitted towards the cable. The wireless signal influences a wired signal transmitted in the cable. The influenced wired signal is used to identify the axial and radial orientation of the cable. The transducer may be secured to a mid-joint collar on the casing string in a portion of the wellbore to be perforated. The transducers are identified and located by the control system and a perforating tool can be adjusted to point away from the cable before firing of the perforating tool.

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MITIGATION OF CABLE DAMAGE DURING PERFORATION

TECHNICAL FIELD

[0001] The present disclosure generally relates to oilfield equipment and, in particular, to downhole tools, drilling and related systems and techniques for completing, servicing, and evaluating wellbores in the earth. More particularly still, the present disclosure relates to systems and methods for locating cables and orienting a downhole tool in relation to the cables.

BACKGROUND

[0002] After drilling the various sections of a subterranean wellbore that traverses a formation, individual lengths of relatively large diameter metal tubulars are typically secured together to form a casing string that is positioned within the wellbore. This casing string increases the integrity of the wellbore and provides a path for producing fluids from the producing intervals to the surface. Conventionally, the casing string is cemented within the wellbore by pumping a cement slurry through the casing and into the annulus between the casing and the formation. To produce fluids into the casing string, hydraulic openings or perforations must be made through the casing string, the cement sheath, and a short distance into the formation.

[0003] Typically, these perforations are created by a perforating tool connected along a tool string that is lowered into the cased wellbore by a tubing string, wireline, slickline, coiled tubing, or other conveyance. Once the perforating tool is properly oriented and positioned in the wellbore adjacent the formation to be perforated, the perforating tool is actuated to create perforations through the casing and cement sheath into the formation.

[0004] It is sometimes desirable to perforate a well in a particular direction. For example, where one or more cables have been permanently deployed downhole adjacent the casing, it is desirable to avoid damaging the cables during perforating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Various embodiments of the present disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. In the drawings, like reference numbers may indicate identical or functionally similar elements. Embodiments are described in detail hereinafter with reference to the accompanying figures, in which:

- [0006] Figure 1 is an elevation view in partial cross section of a land-based well system with a system to mitigate cable damage due to perforating according to an embodiment;
- [0007] Figure 2 is an elevation view in partial cross section of a marine-based well system with a system to mitigate cable damage due to perforating according to an embodiment;
- [0008] Figure 3A is an elevation view in partial cross section of a portion of the well system of Figure 2 utilizing an optic cable to mitigate damage to cables during perforating;
- [0009] Figure 3B is an elevation view in partial cross section of a portion of the well system of Figure 2 utilizing an electric cable to mitigate damage to cables during perforating;
- [00010] Figure 4 is a schematic view of the electro-acoustic transducer package of Figure 3;
- [00011] Figure 5A is a view of a cable support mechanism with an electro-acoustic transducer package according to an embodiment; and
- [00012] Figure 5B is an exploded view of the cable support mechanism of Figure 5A.
- [00013] Figure 5C is an axial view of the cable support mechanism of Figure 5A.
- [00014] Figure 6 is an elevation view of a wellbore having a plurality of EAT sensors deployed adjacent a fiber optic cable.
- [00015] Figure 7 illustrates embodiments of a method for utilizing EAT sensors to determine the axial location and radial position of a cable in a wellbore.

DETAILED DESCRIPTION OF THE DISCLOSURE

[00016] The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the figures is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can

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encompass both an orientation of above and below. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

[00017] Moreover, even though a figure may depict a horizontal wellbore or a vertical wellbore, unless indicated otherwise, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in wellbores having other orientations including, deviated wellbores, multilateral wellbores, or the like. Likewise, unless otherwise noted, even though a figure may depict an offshore operation, it should be understood by those skilled in the art that the apparatus according to the present disclosure is equally well-suited for use in onshore operations and vice-versa.

[00018] Generally, a cable support mechanism for coupling a cable to a casing section of a downhole casing string generally includes first and second collar sections that couple together to form a clamp that extends around a casing section. One of the collars forms a pathway for receipt of a cable when installed on a casing section such that the collars secure the cable to the casing section. Preferably the pathway is axially aligned with the axis of the clamp so that when the clamp is attached to a casing section, the cable is axially aligned with the casing section. Mounted on the clamp adjacent the pathway are an electro-acoustic transducer and a set of the orientation devices, wherein the set comprises a first orientation device and a second orientation device orthogonally oriented with respect to one another. A plurality of cable support mechanisms are axially spaced apart from one another along a casing string thereby securing a cable to the casing string. In other embodiments, the plurality of electro-acoustic transducers and/or sets of orientation devices are mounted directly on the casing string without utilizing cable support mechanisms. In either case, a transmission cable is axially disposed along the casing string. At least one transducer generates a first wireless signal. The wireless signal may be an acoustic signal. A second wired signal is transmitted along the cable based on the first signal. In one or more embodiments, the cable is an optic cable and the second signal is an optic signal generated from a optic signal emitting source. In some embodiments, the second signal is an electric signal generated from a sensor in electrical communication with the cable. In one or more embodiments, the first wireless signal is utilized to generate or alter the second wired signal traveling along the cable in order to establish the location and position of the electro-acoustic transducer in the wellbore. In one or more embodiments, the first acoustic wireless signal causes altered backscattering or reflection of the second wired optic signal, thereby

influencing the second wired optic signal traveling along the cable. Where the electro-acoustic transducer is positioned adjacent the cable, the second signal is utilized to establish the location and position of the wire in the wellbore, thus permitting a perforating tool to be discharged in a direction so as not to damage the cable during firing.

[00019] Turning to Figures 1 and 2, shown is an elevation view in partial cross-section of a wellbore production system 10 utilized to produce hydrocarbons from wellbore 12 extending through various earth strata in an oil and gas formation 14 located below the earth's surface 16. Wellbore 12 may be formed of a single or multiple bores 12a, 12b, . . . 12n (illustrated in Figure 2), extending into the formation 14, and disposed in any orientation, such as the horizontal wellbore 12b illustrated in Figure 2.

[00020] Production system 10 includes a rig or derrick 20. Rig 20 may include a hoisting apparatus 22, a travel block 24, and a swivel 26 for raising and lowering casing, drill pipe, coiled tubing, production tubing, other types of pipe or tubing strings or other types of conveyance vehicles such as wireline, slickline, and the like 30. In Figure 1, conveyance vehicle 30 is a substantially tubular, axially extending drill string formed of a plurality of pipe joints coupled together end-to-end, while in Figure 2, conveyance vehicle 30 is completion tubing supporting a completion assembly as described below. Rig 20 may include a kelly 32, a rotary table 34, and other equipment associated with rotation and/or translation of tubing string 30 within a wellbore 12. For some applications, rig 20 may also include a top drive unit 36.

[00021] Rig 20 may be located proximate to a wellhead 40 as shown in Figure 1, or spaced apart from wellhead 40, such as in the case of an offshore arrangement as shown in Figure 2. One or more pressure control devices 42, such as blowout preventers (BOPs) and other equipment associated with drilling or producing a wellbore may also be provided at wellhead 40 or elsewhere in the system 10.

[00022] For offshore operations, as shown in Figure 2, rig 20 may be mounted on an oil or gas platform 44, such as the offshore platform as illustrated, semi-submersibles, drill ships, and the like (not shown). Although system 10 of Figure 2 is illustrated as being a marine-based production system, system 10 of Figure 2 may be deployed on land. Likewise, although system 10 of Figure 1 is illustrated as being a land-based production system, system 10 of Figure 1 may be deployed offshore. In any event, for marine-based systems, one or more subsea conduits or risers 46 extend from deck 50 of platform 44 to a subsea wellhead

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40. Tubing string 30 extends down from rig 20, through subsea conduit 46 and BOP 42 into wellbore 12.

[00023] A working or service fluid source 52, such as a storage tank or vessel, may supply a working fluid 54 pumped to the upper end of tubing string 30 and flow through tubing string 30. Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, drilling fluid, cementitious slurry, acidizing fluid, liquid water, steam or some other type of fluid.

[00024] Production system 10 may generally be characterized as having a pipe system 58. For purposes of this disclosure, pipe system 58 may include casing, risers, tubing, drill strings, completion or production strings, subs, heads or any other pipes, tubes or equipment that couples or attaches to the foregoing, such as string 30, conduit 46, collars, and joints, as well as the wellbore 12 and laterals in which the pipes, casing and strings may be deployed. In this regard, pipe system 58 may include one or more casing strings 60 that may be cemented in wellbore 12, such as the surface, intermediate and production casings 60 shown in Figure 1. An annulus 63 is formed between the walls of sets of adjacent tubular components, such as concentric casing strings 60 or the exterior of tubing string 30 and the inside wall of wellbore 12 or casing string 60, as the case may be.

[00025] Fluids, cuttings and other debris returning to surface 16 from wellbore 12 are directed by a flow line 118 to storage tanks 54 and/or processing systems 120, such as shakers, centrifuges and the like.

[00026] With respect to Figure 2 where subsurface equipment 56 is illustrated as completion equipment, disposed in a substantially horizontal portion of wellbore 12 with casing system 60 cemented in wellbore 12, which includes casing sections 61 connected with casing connectors or collars 62. A lower completion assembly 82 is disposed in the casing system 60 and includes various tools such as an orientation and alignment subassembly 84, a packer 86, a sand control screen assembly 88, a packer 90, a sand control screen assembly 92, a packer 94, a sand control screen assembly 96 and a packer 98.

[00027] Extending downhole from lower completion assembly 82 is one or more communication cables 100, such as a sensor or electric cable, that passes through packers 86, 90, 94 and is operably associated with one or more electrical devices 102 associated with lower completion assembly 82, such as sensors positioned adjacent casing collars 62, or downhole controllers or actuators used to operate downhole tools or fluid flow control devices. Cable 100 may operate as communication media, to transmit power, or data and the

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like between lower completion assembly 82 and an upper completion assembly 104. Data and other information may be communicated using electrical signals, acoustic signals or other telemetry that can be converted to electrical signals at the rig 20 to, among other things, monitor the conditions of the environment and various tools in lower completion assembly 82 or other tool string.

[00028] In this regard, disposed in wellbore 12 at the lower end of tubing string 30 is an upper completion assembly 104 that includes various tools such as a packer 106, an expansion joint 108, a packer 110, a fluid flow control module 112 and an anchor assembly 114.

[00029] Extending uphole from upper completion assembly 104 are one or more communication cables 116, such as a sensor cable or an electric cable, which extends to the surface 16. Cable 116 may operate as communication media, to transmit power, or data and the like between a surface controller (not shown) and the upper and lower completion assemblies 104, 82, respectively.

[00030] Shown deployed in Figures 1 and 2 is a cable support system 200 to mitigate against damage to a cable (such as cable 100) due to perforating. Shown in Figure 3A is an elevation view in partial cross section of a portion of the well system of Figures 1 and 2 with cable support system 200 installed to mitigate against damage to a cable due to perforation. Also shown in Figure 3A in dashed lines to indicate it is within the interior of casing 30 is a perforating tool 290 supported on deployment vehicle 30. Perforating tool 290 is shown having charges 291. Cable support system 200 comprises at least one electro-acoustic transducer (EAT) package 210, at least one cable support mechanism 220, a sensing cable 250, and a control system 270. Sensing cable 250 may be the same or different than cable 100. In cases, where they are different, the cables are co-located together in the wellbore 12 as described herein. Sensing cable 250 may comprise multiple cables, such as a first optic cable and a second electric cable. In one or more embodiments, control system 270 may be disposed at surface 16 (land-based well system) or platform 44 (marine-based), while in other embodiments, it may be disposed in the wellbore. As shown, cable support system 200 is generally mounted along the exterior of casing string 60. In such embodiments, cement disposed in annulus 63 may encase at least a portion of cable support system 200. In some embodiments, cable support system 200 may include two or more cable support mechanisms 220 axially spaced apart along casing string 60. In one or more embodiments, an EAT package 210 is mounted on each cable support mechanism 220. Cable 250 is secured along

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casing 60 by cable support mechanism 220 and may be disposed to extend between adjacent EAT packages 210.

[00031] Referring now to Figure 4, shown is a schematic view of the EAT package 210. Each EAT package 210 includes a transducer 213 configured to emit a wireless signal 211. Signal 211 is preferably an acoustic signal or a mechanical signal, i.e., vibrations. Each EAT package 210 may further include a sensor 207 and controller 216 to adjust and customize the wireless signal, and a power source 215 to provide power to the various components of EAT package 210 as necessary. Although not limited to a particular type of transducer so long as an acoustic or mechanical signal is generated, in one or more embodiments, transducer 213 is piezoelectric transducer (PZT). Electrically coupled to transducer 213 is sensor 207. As such, electrical responses from sensor 207 may be converted to wireless signal 211 by transducer 213. In this regard, sensor 207 is not limited to a particular type of sensor. In non-limiting examples, sensor 207 may be a temperature sensor, a pressure sensor, geophone, chemical sensor, optical sensor (such as an integrated computational element sensor), load cell, strain gauge, accelerometer, piezoelectric transducer, radiation sensor or the like. In one or more embodiments, transducer 213 also functions as sensor 207. Power source 215 may be local, such as a battery, or external, such as an electrical cable. More particularly, a condition associated with the wellbore, such as temperature, pressure, object orientation, cement curing, may be measured by sensor 207 and converted by transducer 213 (and conditioned by controller 216 as desired) into a wireless signal 211 that may be transmitted as described herein. For example, in some embodiments, transducer 213 may be any electro-acoustic transducer known in the art capable of either directly measuring a characteristic of the wellbore or receiving an electrical signal from a sensor 207, and thereafter generating an acoustic or mechanical signal; controller 216 can be utilized to condition the signal to adjust or customize the signal as necessary. In other words, EAT package 210 is utilized to propagate or emit a frequency modulation (FM) acoustic or amplitude modulation (AM) signal 211. In the present embodiment, each transducer 213 can be configured (such as by controller 216) to emit the same FM signal 211 or a different FM signal 211. In other words, each transducer 213 may be configured to emit a unique signal 211 that is different from the signal 211 emitted from each of the other transducers 213. Power source 215 serves as the energy source for the components of the EAT package 210.

[00032] As will be appreciated below, EAT sensors are particularly useful in fiber optic sensing in which any number of downhole sensors, electronic or fiber optic based, can be

utilized to make 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 cable that is connected to an interrogator that may be located at the surface of a downhole well. EAT sensors can be utilized in a number of different ways depending on the parameter to be determined by the measurement using the EAT sensor. The parameter can include, but is not limited to, a chemical concentration, a pH, a temperature, a vibration, or a pressure. The interrogator may routinely fire optical signal pulses downhole into the optical fiber cable. As the pulses travel down the optical fiber cable back scattered light is generated and is received by the interrogator. The perturbations or strains introduced to the optical fiber cable at the location of the various EAT sensors can alter the back propagation of light and those effected light propagations can then provide data with respect to the signal that generated the perturbations.

[00033] Each EAT package 210 may also include one or more orientation sensors 217, such as accelerometers, geophones or other devices capable of detecting orientation. Orientation sensors 217 may also be powered by power source 215. In the present embodiment as shown in Figure 4, two orientation devices in the form of accelerometers 217a, 217b are shown and oriented orthogonally or 90 degrees apart from each other along X-, and Y- axis for determining the gravitational field and the impact to the different sensors, and to measure seismic signals. In an alternative embodiment, three or more accelerometers 217 may be used. For example, an accelerometer 217 may be oriented in each of the X-, Y- and Z- axis directions relative to one another. In one or more embodiments, orientation sensors 217 may be acoustic sensors oriented to detect an acoustic signal in a select axial direction. For example, orientation devices 217a, 217b may be seismic sensors, each sensor oriented to detect a seismic signal in a direction orthogonal to one another. Similar to transducer 213 and/or sensor 207 response data, accelerometer 217 data may be transmitted by transducer 213 in the form of a first wireless signal 211. In such case, the signal from transducer 213 and/or sensor 207 can be modulated by controller 216 to include accelerometer 217 data. For example, an acoustic signal 211 emanating from transducer 213 may be modulated to include location data from accelerometers 217.

[00034] Each EAT package 210 may also include a locking device 219, such as a cross coupling device, configured to maintain a fixed orientation of the EAT package 210 components relative to the casing string 60 while the casing 60 is run into the wellbore 12.

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[00035] Referring now to Figures 5A and 5B, shown is a cable support mechanism 220 with an EAT package 210 (Figure 5B in exploded view). The cable support mechanism 220 may be any clamping device known in the art for coupling to casing, pipes, or tubing including, but not limited to, clamps, couplings, and collars. In the present embodiment, cable support mechanism 220 is a mid-joint collar and comprises a first collar section 221, a second collar section 231, and a connecting portion 240, which, when joined together on a casing section 61 as described below, form a circular collar about the casing section. In this regard, each of sections 221 and 231, as well as connecting portion 240 may be arcuate in shape so as to form a circle when joined together. Thus, collar sections 221 and 231 may be semi-circular in shape. In any event, each collar section 221, 231 has an upper end 222, 232, respectively, opposite a lower end 223, 233, respectively, a first side 225, 235, respectively, a second side 226, 236, respectively, an outer semi-cylindrical surface 228, 238, respectively, and an inner semi-cylindrical surface 229, 239, respectively. The first side 225 and second side 226 of the first collar section 221 each have protrusions 225a, 226a, respectively; the protrusions 225a, 226a are spaced apart and configured to accept a pin. Similarly, the first side 235 and second side 236 of the second collar section 231 each have protrusions 235a, 236a, respectively; the protrusions 235a, 236a are spaced apart and configured to accept a pin. The connecting portion 240 has an upper end 242 opposite a lower end 243, a first side 245, a second side 246, an outer surface 248, and an inner surface 249. The connecting portion first and second sides 245, 246, respectively, each have protrusions 245a, 246a, respectively, spaced apart and configured to accept a pin.

[00036] The first side 225 of the first semi-circular collar section 221 is coupled to the second side 246 of the connecting portion 240 such that the protrusions 225a of the first semi-circular collar section 221 interlock and align with the protrusions 246a of the connecting portion second side 246. A locking pin 237 inserted through the aligned protrusions 225a, 246a retains the first semi-circular collar section 221 to the connecting portion 240. The second side 236 of the second semi-circular collar section 231 is coupled to the first side 245 of the connecting portion 240 such that the protrusions 236a of the second semi-circular collar section 231 interlock and align with the protrusions 245a of the connecting portion first side 245. A locking pin 227 inserted through the aligned protrusions 236a, 245a retains the second semi-circular collar section 231 to the connecting portion 240. Similarly, the second side 226 of the first semi-circular collar section 221 is coupled to the first side 235 of the second semi-circular collar section 231 such that the protrusions 226a of the first semi-

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circular collar section second side 226 interlock and align with the protrusions 235a of the second semi-circular collar section first side 235. A locking pin 247 inserted through the aligned protrusions 226a, 235a retains the first semi-circular collar section 221 to the second semi-circular collar section 231.

[00037] While EAT package 210 is shown secured to connecting portion 240, it will be appreciated that in other embodiments, cable support mechanism 220 may comprise just two collar sections 221 and 231, which, when jointed together, form a clamp around casing section 61. In such case, EAT package 210 may be carried on one of the collar sections, and that collar section may be configured as described herein, to secure a sensing cable 250 to casing string 60.

[00038] Also illustrated in Figure 5B is perforating tool 290. Perforating tool 290 is oriented so that charges 291 generally point away from cable 250. Specifically, as shown, charges 291 are positioned so that the discharge or blast pattern 293 of perforating tool 290 is oriented away from cable 250.

[00039] Referring again to Figures 1–3, sensing cable 250 extends from the surface 16 (Figure 1) or platform 44 (Figure 2) downhole through the wellhead 40 to the completion. Sensing cable 250 extends through the portion of the wellbore 12 to be perforated and may extend to the lower end of the tubing string 60. Cable 250 may be one of the communication cables 100, 116 or may be an additional or alternate cable. In one or more embodiments, sensing cable 250 is a fiber optic cable, while in one or more other embodiments, sensing cable 250 is an electrical cable. As will be described herein, sensing cable 250 is utilized to “sense” a first signal propagated from EAT package 210 and transmit a second signal based on the sensed first signal. In the case where cable 250 is an electrical cable, as illustrated in Figure 3B, the electrical cable includes sensors 218, such as receivers, capable of detecting electromagnetic signals propagated or emitted by an EAT package 210. The optical fiber cable may be any suitable optical fiber cable known in the art; the electrical cable may be any suitable tube encapsulated conductor (TEC) or other electrical cable known in the art. The one or more optical fiber cables 250 also may be used to monitor various devices and operations including, but not limited to, EAT packages 210, cement curing, perforating, fracturing, injection, fluid inflow, production, and well integrity.

[00040] Referring still to Figures 1 and 2, a control system 270 may be deployed to communicate with sensing cable 250 and function as a source for a signal 209a as described below. In one or more embodiments, control system 270 is disposed at surface 16 or

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platform 44 at a control station 48 and is in communication with cable 250. Where cable 250 is a fiber optic cable, control system 270 may include an interrogator unit (not shown) configured to send optic pulses down the fiber optical cable 250, and process and analyze the resulting return signals. In one or more embodiments, the control system 270 may comprise any distributed acoustic sensing (DAS) system or time-domain interferometry (TDI) system known in the art, although other sensing systems capable of sending pulses and processing and analyzing the resulting signals (optic or otherwise) may be used. In the present embodiment, control system 270 is a DAS system. In other embodiments such as illustrated in Figure 3b, cable 250 is an electrical cable and control system 270 may transmit and receive electrical signals along cable 250. It will be appreciated that in such embodiments, sensors will be distributed along electrical cable 250 which sensors 218 are capable of receiving a propagated signal from EAT package 210 as described herein and transmitting an electrical signal to control system 270 based on the received signal from the EAT package 210.

[00041] Referring now to Figures 3 and 5B and 5C, in one or more embodiments, each EAT package 210 is coupled or attached either directly or indirectly to casing string 60 adjacent cable 250 extending axially along casing string 60. The EAT packages 210 are spaced axially apart along casing string 60. In some embodiments, the cable 250 and EAT packages 210 of system 200 are preferably deployed on the exterior of casing string 60 in annulus 63 between the casing string 60 and the wellbore 12. In one or more embodiments, each EAT package 210 is coupled or attached either directly to casing string 60, while in other embodiments each EAT package 210 is coupled to a mid-joint collar 220, which is installed on casing section 61 to secure cable 250 thereto before the casing section 61 is run in hole to form the casing string 60. In particular, the cable 250 is secured to the outer diameter of casing section 61 by the mid-joint collar 220 such that cable 250 is substantially axially aligned with the longitudinal axis of casing string 60. In this regard, mid-joint collar 220 may include a groove, channel or similar guide 220a through which cable 250 may be run. Guide 220a may be formed or otherwise provide on any part of the mid-joint collar 220 so long as it is adjacent the corresponding EAT package 210. In some embodiments, cable 250 is disposed between the inner surface 249 of the collar connecting portion 240 and the casing section 61. The connecting portion 240 of the mid-joint collar 220 is configured in the form of guide 220a to provide a space or groove to accommodate the cable 250 when the collar 220 is clamped around section 61. In particular, each mid-joint collar 220, positioned

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at approximately the middle of every casing section 61, is generally about thirty to forty feet away from the next adjacent collar 220 carried on the next adjacent casing section 61.

[00042] To further protect the cable 250, Stand-offs or centralizers (not shown) may be used to keep the casing string 60 in the middle of the wellbore 12 and ensure the cable 250 does not get crushed against the formation. Likewise, in addition to the collars 220 as described herein to secure cable 250 at points along casing string 60, cable 250 may also be attached directly to casing collars 62 with an epoxy, clamp, or other mechanical fastener. Coupling the cable 250 to the casing section 61 or casing collars 62 allows the location and orientation of the cable 250 to be known in relation to the casing section 61 or casing collars 62.

[00043] EAT packages 210 are positioned on mid-joint collar 220 so as to be proximate the cable 250 and to propagate a signal in the direction of the cable 250. EAT packages may be carried on each collar 220 or may be spaced apart at certain increments; for example, the EAT packages 210 may be placed on every fifth or every tenth mid-joint collar 220. In the present embodiment, EAT packages 210 are spaced apart approximately every tenth to fifteenth mid-joint collar 220 such that each EAT package 210 is approximately 300–500 feet away from the next subsequent or previous EAT package 210. In other embodiments, EAT packages 210 may be spaced closer together or farther apart. In other embodiments, the EAT packages 210 may be secured to different portions of the casing string 60 including, but not limited to, clamps or casing collars 62 or adhered directly on a casing section 61 or integrally formed as part of a casing section 61.

[00044] Referring again to Figure 5B, the EAT package 210 is mounted to mid-joint collar 220 by any attachment mechanism known in the art including, but not limited to: an adhesive, weld, clamp or other mechanical fastener. In an alternative embodiment, the EAT package 210 may be attached to cable 250 and casing 60 with a similar mechanical fastener. In a preferred embodiment, the EAT package 210 is disposed on the outer surface of the casing collar 62 proximate the cable 250 to be protected during the perforating process. The EAT package 210 may be attached to any surface of the mid-joint collar 220, including but not limited to outer semi-circular surface 228, 238 on the first or second collar section, respectively, or a surface 248, 249 of the connecting portion 240. In the present embodiment, EAT package 210 is disposed on outer surface 248 of connecting portion 240 at location 210a; however, in other embodiments, the EAT package 210 may be disposed on outer semi-cylindrical surface 228 proximate first side 225 of first semi-cylindrical collar section 221, or

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on outer semi-cylindrical surface 238 proximate second side 236 of second semi-cylindrical collar section 231. In further embodiments, the EAT package 210 may instead be attached to a centralizer (not shown), which is then coupled to the casing section 61 proximate the cable 250. Coupling the EAT package 210 to the mid-joint collar 220 or casing section 61 allows the location and orientation of the EAT package 210 components (transducer 213, accelerometers 217a, 217b) to be known in relation to the collar 220 or section 61, and further allows the location and orientation of the EAT package 210 components to be known in relation to the cable 250. Further, by having multiple EAT packages 210 disposed along the length of the sensing cable 250, the orientation of the cable 250 can be determined at any point along the casing string 60.

[00045] Further, in a preferred embodiment and regardless of the portion of the casing string 60 on which the EAT package 210 and cable 250 are attached, the EAT package 210 is adjacent or in proximity to the sensing cable 250 to minimize attenuation of any wireless signals 211 from the EAT package 210 transmitted in the direction of the sensing cable 250. In addition, the locking device 219 configured to maintain the position and orientation of the EAT package 210 components relative to the mid-joint collar 220, and consequently to the casing section 61, while the casing string 60 is run into the wellbore 12. Further, the mid joint collar 220 maintains the position and orientation of the sensing cable 250 as the casing string 60 is run in.

[00046] Figure 6 illustrates a plurality of EAT packages 210 distributed in an axial spaced apart orientation in a wellbore 12. As shown, cable 250 extends along the wellbore extending from control system 270. Cable 250 is positioned to be adjacent on EAT package 210 as described above. In operation, various data is converted by EAT package 210 into a wireless signal 211. In one or more embodiments, the wireless signal 211 may be an acoustic signal transmitting data. The data may include data from sensors 213 and/or accelerometers 217. The wireless signal 211 is transmitted in the direction of cable 250. In one or more embodiments, a wired signal 209a is transmitted down wellbore 12 by control system 270. For example, wired signal 209a may be an optic signal. As the downgoing wired signal 209a encounters the wireless signal 211, wired signal 209a (or a portion thereof) is altered (such as altering the backscattering and/or reflected optic signal) and directed back uphole as return wired signal 209b. Utilizing the return wired signal 209b, control system 270 can determine the axial location and radial orientation of EAT package cable 250, then the radial orientation of cable 250 at that axial location can be determined.

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[00047] In an exemplary embodiment and as illustrated in Figure 7, with continuing reference to Figures 1-6, a method 300 of ascertaining the location of cable 250 in a wellbore 12 is described. The method 300 may be utilized for any operation where knowledge of the radial position of cable 250 at a particular axial depth is required, but method 300 is particularly useful for perforating operations in order to ensure that cable 250 is not damaged during discharge of a perforating gun.

[00048] In any event, in a first step 302, the casing string 60 with the EAT packages 210 and sensing cable 250 is installed in wellbore 12. The EAT packages 210 may be attached directly to a casing section 61 that makes up casing string 60, or may be secured to casing section 61 utilizing a mechanical device, such as cable support mechanisms 220. In any case, the EAT packages 210 are positioned adjacent to cable 250 extending axially along a casing section 61. To the extent a cable support mechanism 220 is utilized, the cable support mechanism 220 may be utilized to clamp or otherwise secure cable 250 to casing section 61 while also supporting EAT package 210 so that it is positioned adjacent cable 250. The EAT packages 210 include a transducer 213 and may contain one or more accelerometers 217. In one or more embodiments, EAT packages 210 and cable 250 are deployed along the exterior of a casing string 60, which casing string 60 is cemented in place within wellbore 12.

[00049] In step 304, a wireless signal 211 is generated from one or more EAT packages 210 and transmitted towards cable 250. Because of the proximity of the EAT packages 210 to cable 250, the transmission need not be focused, but may be omni-directional. The wireless signal 211 may include transducer 213 and/or sensor 207 response data as well as accelerometer 217 data. The transducer 213 and/or sensor 207 response data may reflect a particular condition of the wellbore 12, such as pressure, temperature, etc. The accelerometer 217 data reflects a location in wellbore 12. In one or more embodiments, the wireless signal 211 is an acoustic signal generated from transducer 213, while in other embodiments, the wireless signal 211 is a mechanical signal, such as vibrations, generated from transducer 213. In one or more embodiments, the wireless signal 211 from transducer 213 may be altered or conditioned by controller 216 to include location data from accelerometers 217.

[00050] In step 306, the transmitted wireless signal 211 is utilized to generate a separate wired signal, such as signal 209b, in cable 250. In one or more embodiments, this separate wired signal may be generated locally, such as by a sensor 218. In one or more embodiments, this separate wired signal may be a signal transmitted down cable 250 that is altered locally upon encountering the wireless signal 211. For example, with respect to the

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latter, the backscattering of the separate wired signal 209a transmitted downhole along cable 250 may be locally altered by the presence of a signal such as signal 211 transmitted from adjacent transducer 213. More particularly, in embodiments utilizing a sensor 210, the sensor 210 may sense the wireless signal 211 and generate a signal 209b on cable 250 that is transmitted back to control system 270. In embodiments utilizing a signal originating from control system 270, the signal may be an optic signal transmitted down cable 250; while the return signal may be altered backscatter or reflected optic signal 209b, the return signal 209b being altered when the wireless acoustic signal 211 impinges upon cable 250. With regard to signal 209b, persons of skill in the art will appreciate that in a typical distributed acoustic sensing (DAS) system, normal scattering or reflection of a signal occurs at sites along the length of the optic fiber and changes in the distance between the scattering or reflection sites in the optical fiber are measured to make a particular determination. In the system of the disclosure, the normal scattered or reflected signal is altered by the signal 211 from the transducer 213 because the signal 211 (in the form of acoustic energy or mechanical vibrations) causes small strain and vibration on the optic fiber at the scattering or reflection sites. The wireless signal 211 from the transducer 213 modulates vibrations onto the fiber and cause changes in the optical path for the back scattered or reflected light, and this changes the intensity and/or phase of the optical signal. This is then decoded at the surface.

[00051] In step 308, wired return signal 209b may be utilized to determine the axial location and radial position of the transducer 213 that generated the wireless signal 211. Since the transducer 213 is co-located with or positioned adjacent cable 250, this location and position data of transducer 213, in turn, permits the radial position of cable 250 disposed along casing section 61 to be determined.

[00052] In step 310, an operation in wellbore 12 can be carried out based on the determined radial position of the cable. Since the radial position of the cable has been determined, such an operation may be carried out so as to ensure that damage to cable 250 is minimized. In this regard, a tool may be oriented (either at the surface or once axially positioned) so as not to damage the cable during the operation. Likewise, a tool that is axially positioned may have its orientation altered to ensure the cable is not damaged during the operation. The disclosure is not limited to a particular operation, but has been found to be most useful in operations that require the casing string 60 to be breached, such as by cutting, perforating, milling, severing or the like. Thus, in some embodiments, the operation may be perforating operations, while in other embodiments the operation may be milling operations.

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As will be appreciated, where the casing is breached, it is desirable to carry out such operations so as not to damage cable 250. Thus, the location of the breach may be adjusted to ensure that cable 250 is not damaged. For example, a perforating tool may be operated so that the charges discharge in a direction away from cable 250. Likewise, the position of a window in milling operations may be selected so as to be spaced apart from cable 250 about the radius of casing string 60.

[00053] Steps 302-310 are reflected in the following procedure cementing and perforation procedure. During deployment, initial EAT sensor responses, i.e., first wireless signals generated from EAT package 210, can be monitored, such as by propagating a second, different signal 209a along cable 250 utilizing control system 270 and monitoring the effect of the first wireless signal on the second wired signal 209a. Cement may be pumped down the inside of casing string 60 and pushed down by a wiper plug into the annulus 63 to cement the casing string 60 and cable 250 in place. EAT sensor responses may also be monitored as the cement is pumped down the casing string 60 and up the annulus 63 and, and additionally or alternatively, while the cement is curing. In particular, the control system 270 can monitor the cement while being pumped down the casing 60 by detecting the impact on the second, wired signal 209a transmitted along cable 250 by control system 270 of the first wireless signal from EAT package 210 resulting from the vibration and noise of the cement on the EAT package 210. In one or more embodiments, the second wired signal is an optic signal and the first wireless signal disrupts the second signal. Such disruption may alter the backscattered optical signal or have a similar impact on the second signal 209a, thus altering the second signal and resulting in modulation of the wired return signal 209b. EAT package 210 responses may be monitored in this way prior to, during, and after pumping the cement down the casing string 60. The control system 270 receives the disrupted or backscattered second signal 209b and interprets it to determine the gravitational field of each EAT package 210, from which the location and orientation can be determined. Once the cement has set, a perforating operations may be initiated and EAT packages 210 responses can continue to be monitored before, during, and after the perforating operations.

[00054] More specifically, data from the second signal 209b transmitted to control system 270 along cable 250 based on the first signal's impact on the second signal's 209a backscattered or reflected light is utilized by control system 270 to determine the gravitational field and, subsequently, the position and orientation of each EAT package 210. Because of the proximity of the co-located cable 250 to the EAT packages 210, the location,

i.e., the axial depth and radial position, of the cable 250 in wellbore 12 can be determined. As a service tool, such as perforating tool 250, is lowered into the well, the service tool can then be axially positioned and radially oriented relative to the location of cable 250. For example, the axial position and radial orientation of the perforating tool 290 can be tracked and correlated with the location of the EAT packages 210 to ensure that discharge of the perforating tool 290 is in a direction that will minimize the likelihood of damage to cable 250. Referring again to Figure 3, in one or more embodiments where a perforating tool 290 is deployed, an additional transducer 214 may be coupled to the perforating tool 290 in a similar manner as the transducer 213 are coupled to the mid-joint collars 220. Transducer 214 may be an electro-acoustic transducer as well. As previously described, the transducers 213, 214 may be configured to emit unique wireless signals or the same wireless signal; the wireless signals disrupt or trigger the wired signal in sensing cable 250, which disruption or triggered signal is transmitted back to the control system 270 (Figure 1 and 2). Persons of skill in the art will appreciate that the use of unique signals (as opposed to the same frequency signal) would allow the depth of each EAT package 210 to be determined without the need to count collars 62. In addition to the signal from transducer 213, electrical signals from the accelerometers 217 are converted to an acoustic signal and the acoustic signal may also be transmitted as a wireless signal towards the sensing cable 250. Signal polarity combined with gravity-induced sensor signals (e.g., from accelerometers 217) allows positive orientation identification.

[00055] Referring still to Figure 3, the control system 270 interprets data from the return second, wired signal resulting from the first wireless signal(s) arising from transducer 213, 214 and accelerometers 217 in order to identify and determine the gravitational field and, subsequently, the orientation of EAT packages 210 and, thus, the positioning of cable 250 in the annulus 63. To perforate the casing string 60, a perforating tool 290 connected along a tool string is lowered into the wellbore 12 by a conveyance vehicle such as a wireline 30. During run in, active pinging of the transducer 214 disposed on the perforating tool 290 provides an indication of the perforating tool's 290 location as it travels down the casing string 60. Utilizing the position of the transducers 213 outside the casing string 60 and the transducer 214 on the perforating tool 290 in real-time as the perforating tool is run in, the operator can make adjustments to change in the orientation of the perforating tool 290 to ensure tool 290 during deployment is oriented away from the cable 250 as tool 290 is run in, i.e., the charges of tool 290 are positioned so that an accidental discharge during deployment

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will not damage cable 250. Once tool 290 has been lowered to the desired axial depth, after any necessary adjustments are made to ensure the perforating tool 290 is oriented so as to have a blast patten direction away from cable 250, the perforating tool 290 is activated and the casing 60 is perforated. The real-time orientation information also allows the operator to maneuver subsequent guns in the tool string to remain correctly oriented away from cable 250.

[00056] In some embodiments, perforating tool 290 may be tracked in the wellbore 12 utilizing the control system 270 and cable 250 based on the acoustic signal the perforating tool 290 generates as it is moved down the casing 60. In some embodiments, perforating charges 291 (see Figure 5b) from the perforating tool 290 may be used as a seismic source, and the accelerometers 217 may be used to sense seismic signals returning from the formation 14. In particular, the transducer 213 and accelerometers 217 can detect the orientation of the perforations when the perforating tool 290 discharges into the formation 14, which results in seismic vibrations that the transducer 213 and accelerometers 217 can detect and then convey to the control system 270 utilizing the first wireless and second wired signals as described above. This information may be used for seismic imaging both in-well and cross-well, if multiple wells are instrumented.

[00057] It should be noted that if the mid-joint collar 220 were installed on the casing section 61 upside down and then run into the wellbore 12, the location of the cable 250 may be incorrectly interpreted, which could result in damage to the cable during a perforating operation. For example, if one transducer 213 is orthogonally disposed at +90 degrees relative to the axis of the cable 250, another transducer 213 is orthogonally disposed at -90 degrees relative to the axis of the cable 250, and the mid-joint collar 220 is installed on casing section 61 upside down or backwards, then the identification of the cable location would be off by 180 degrees. To minimize the likelihood of such errors, mid-joint collar 220 may include a mechanical feature 247, such as a tab, shoulder, extension, aperture, slot or similar mechanism that engages the mid-joint collar 220 in such a way that requires the collar to be oriented upright. In one or more embodiments, mechanical feature 247 is a locking pin 247 used to retain the first semi-circular collar section 221 to the second semi-circular collar section 231 and may be configured to only fit in aligned protrusions 226a, 235a from the upper end 222, 232, *see* Figure 5B. An orientation-specific locking pin would impede any mid-joint collars 220 from being installed upside down and, consequently, minimize the likelihood of inaccurate data regarding the cable's 250 location.

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[00058] In another embodiment, transducer 213 may be utilized to determine whether the mid-joint collar 220, and thus the transducer 213, is installed upside down. In particular, the transducer 213 can be utilized to discern its own orientation relative to the surface 16 (*i.e.*, the transducer 213 can be configured to measure which way is up), and can either store that information or emit a signal indicating the transducer 213 is installed upside down. Having the additional information of each transducer's 213 orientation when processing and interpreting data from the transducer 213 and accelerometers 217 would allow corrections to be made, as necessary, and minimize inaccurate orientation determinations.

[00059] In embodiments, the transducer 213 can be turned off and on, to conserve power source 219. This also has the effect of reducing noise. For example, the transducer 213 may be configured to allow communication with a downhole tool, which instructs the transducer 213 to power down or to a lower power state (*i.e.*, the transducer 213 can remain "on" but cease transmitting an acoustic frequency). Alternatively, the transducer 213 may be programmed to operate for a predetermined period of time (*i.e.*, one week) and then go dormant for a certain period of time before it cycles back on with the transducer 213 moving between power states for set intervals until the power source 219 expires. Thus, a first power state may be "on" while a second power state may be "off". Or alternatively, a first power state may be full power, while a second power state may be dormant or minimal power. In a further alternative, the transducer 213 may switch from one power state to another after the perforating tool 290 has been fired.

[00060] While the use of the EAT packages 210 to ascertain positioning and orientation of cable 250 has been specifically described for use in perforating operations, it will be appreciated that the foregoing method may be used to ascertain the positioning and orientation of cable 250 for any downhole operations, and as such, is not limited to perforating operations. Thus, in some embodiments, tool 290 can be any downhole tool, and is not limited to a perforating tool.

[00061] Thus, a cable support mechanism for coupling a cable to a casing section of a downhole casing string has been described. Embodiments of the cable support mechanism may generally include a first collar section; a second collar section coupled to the first collar section; a connecting portion coupled to the first and second halves; and a transducer coupled to one of the first collar section, the second collar section, and the connecting portion. Other embodiments of a cable support mechanism may generally include a first collar section; a second collar section coupled to the first collar section; a transducer coupled to one of the

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collar sections; a set of the orientation devices coupled to one of the collar sections adjacent the transducer, wherein the set comprises a first orientation device and a second orientation device orthogonally oriented with respect to one another. Still yet other embodiments of the cable support mechanism may generally include a first collar section; a second collar section coupled to the first collar section; and a transducer coupled to one of the first collar section or second collar sections. Likewise, a system for perforating a casing string in a wellbore in a direction away from a cable deployed along the casing string has been described. Embodiments of the perforating system may generally include an elongated casing string; a first cable deployed along the casing string; a plurality of spaced apart transducers, each transducer coupled to the casing string adjacent the first cable; a plurality of orientation devices disposed proximate the plurality of transducers; and a control system in communication with the first cable.

[00062] For any of the foregoing embodiments, a cable support mechanism may include any one of the following elements, alone or in combination with each other:

At least one orientation device disposed adjacent the transducer.

The control system comprises a signal source coupled to the first cable.

At least one sensor electrically coupled to the transducer.

The transducer is an electro-acoustic transducer.

The transducer is a piezoelectric transducer.

The transducer is selected from the group consisting of an acoustic transducer and a mechanical transducer.

A fiber optic cable disposed adjacent the transducer; and a control system in optical communication with the fiber optic cable.

The cable support mechanism engages the fiber optic cable, wherein the transducer and the orientation device are disposed on the cable support mechanism in a select position and orientation proximate the fiber optic cable.

A first orientation device and a second orientation device, each orientation device adjacent the transducer and each orientation device oriented to measure in a direction orthogonal to one another.

The transducer includes an electromagnetic signal transmitter.

A power source in electrical communication with the transducer.

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A locking device securing the transducer and the at least one orientation device to the cable support mechanism in a fixed position and orientation relative to each other.

A clamping device that couples the first cable and fiber optic cable to the casing string.

A second cable adjacent the first cable, wherein the first cable is a fiber optic cable and the control system is in optical communication with the fiber optic cable.

A plurality of clamping devices, wherein each clamping device comprises a first collar section and a second collar section secured to one another so as to extend completely around the casing string, each clamping device carrying one of the transducers and a set of the orientation devices, wherein the set comprises a first orientation device and a second orientation device orthogonally oriented with respect to one another.

The clamping device further comprises a connecting portion, the connecting portion forming a guide along which the first and second cables run, wherein the transducer and set of orientation devices for the clamping device are carried on the connecting portion adjacent the cable.

The first cable is an electrical cable, the system further comprising a plurality of sensing devices, each sensing device configured to detect a signal emitted by an transducer and each orientation device adjacent the transducer.

A connecting portion attached to each of the first and second collar sections so as to form a clamping device, the connecting portion forming an axial cable guide for receipt of a cable, wherein the transducer and set of orientation devices are carried on the connecting portion adjacent the cable guide.

The orientation device is selected from the group consisting of accelerometers and seismic sensors.

A cable guide adjacent the transducer.

[00063] Thus, a method for detecting the orientation of a cable in a wellbore has been described. Embodiments of the method include coupling at least one transducer and one orientation device to a casing section; coupling a cable to the casing section proximate the at least one transducer and the at least one orientation device; deploying the casing section in a wellbore; transmitting a first signal from the at least one transducer towards the cable; propagating a second signal down the cable; altering the second signal based on the first

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signal; and utilizing the altered signal to determine the orientation of the cable in the wellbore at the casing section. Other embodiments of the method include deploying a plurality of transducers in a wellbore, the transducers axially spaced apart from one another along a portion of the wellbore; utilizing a transducer to measure a condition of the wellbore and transmit an acoustic signal in the direction of an optic cable; propagating an optic signal along the optic cable; and identifying the location of the transducer in a wellbore based on the backscattering of the propagating optic signal by the acoustic signal. Still yet other embodiments of the method may include propagating an optic signal along an optic cable; utilizing a transducer to generate an acoustic signal at an axial location in the wellbore; altering the optic signal with the acoustic signal at the axial location in the wellbore; and utilizing the altered signal to determine the axial location of the transducer. Likewise, embodiments of the method may include deploying a plurality of transducers in a wellbore, the transducers axially spaced apart from one another along a portion of the length of a wellbore; utilizing a transducer to measure a condition of the wellbore and transmit a wireless signal in the direction of a cable deployed adjacent the transducer; influencing a wired signal transmitted in the cable based on the wireless signal; and identifying the location of the transducer in a wellbore based on the influenced signal. Other embodiments of the method may include deploying a plurality of transducers in a wellbore, the transducers axially spaced apart from one another adjacent a cable extending along a length of the wellbore; transmitting a first signal from at least one transducer towards the cable; propagating a second signal down the cable; altering the second signal based on the first signal; and utilizing the altered signal to determine the orientation of the cable in the wellbore at the casing section.

[00064] For the foregoing embodiments, the method may include any one of the following steps, alone or in combination with each other:

Sensing a condition of a wellbore and transmitting an electrical signal to a transducer based on the sensed condition.

Fixing the position and orientation of the at least one transducer and orientation device and cable to the casing section with a locking device.

The second signal is an optical signal and the first signal is an acoustic or mechanical signal.

The second signal is an electrical signal and the first signal is an acoustic or mechanical signal and the electrical signal is altered by a sensor adjacent the transducer.

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Orienting a perforating tool in the wellbore in based on the determined orientation of the cable; and discharging the perforating tool in a direction away from the cable.

Connecting portion attached to each of the first and second collar sections so as to form a clamping device, the connecting portion forming an axial cable guide for receipt of a cable, wherein the transducer and set of orientation devices are carried on the connecting portion adjacent the cable guide.

Deploying comprises positioning each transducer adjacent a first cable; identifying the position of the first cable in the wellbore at a given point based on the location of the transducer; and discharging a perforating tool based on the identified position of the first cable.

Modulating the acoustic signal to include radial location data.

Altering comprises changing the backscattered optic signal.

Influencing comprises changing the backscattered optic signal transmitted in the cable based on an acoustic signal transmitted from the transducer.

The orientation device is selected from the group consisting of accelerometers and seismic sensors.

Utilizing the discharging from the perforating tool as a seismic source; propagating a seismic signal into the formation; and detecting a reflected seismic signal with the at least one transducer, wherein the at least one transducer is an electro-acoustic transducer.

Propagating a seismic signal in a formation and utilizing the transducer to detect the seismic signal.

Propagating a seismic signal in a formation and utilizing the transducer to detect the seismic signal.

Generating the seismic signal from outside the wellbore.

Generating the seismic signal from within the wellbore.

Generating the seismic signal from within the wellbore by firing a perforating tool.

[00065] Although various embodiments and methods have been shown and described, the disclosure is not limited to such embodiments and methods and will be understood to include all modifications and variations as would be apparent to one skilled in the art. Therefore, it should be understood that the disclosure is not intended to be limited to the particular forms

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disclosed; rather, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

CLAIMS

1. A cable support mechanism for coupling a cable to a casing section of a downhole casing string, the cable support mechanism comprising:
 - a first collar section;
 - a second collar section coupled to the first collar section; and
 - a transducer coupled to one of the first collar section and the second collar section.
2. The cable support mechanism of claim 1, further comprising at least one orientation device disposed adjacent the transducer.
3. The cable support mechanism of claim 2, further comprising
 - a fiber optic cable disposed adjacent the transducer; and
 - a control system in optical communication with the fiber optic cable.
4. The cable support mechanism of claim 1, wherein the transducer is selected from the group consisting of an acoustic transducer and a mechanical transducer.
5. The cable support mechanism of claim 1, further comprising a first orientation device and a second orientation device, each orientation device adjacent the transducer and each orientation device oriented to measure in a direction orthogonal to one another.
6. The cable support mechanism of claim 5, further comprising a sensor electrically coupled to the transducer.
7. The cable support mechanism of claim 6, further comprising a cable guide adjacent the transducer.
8. The cable support mechanism of claim 7, further comprising a locking device securing the transducer and the orientation devices to the cable support mechanism in a fixed position and orientation relative to each other.
9. A system for perforating a casing string in a wellbore in a direction away from a cable deployed along the casing string, the system comprising:
 - an elongated casing string;

a first cable deployed along the casing string;
a plurality of spaced apart transducers deployed along the casing string, each transducer coupled to the casing string adjacent the first cable;
a plurality of orientation devices disposed proximate the plurality of transducers;
and
a control system in communication with the first cable.

10. The system of claim 9, further comprising a clamping device that couples the first cable to the casing string.
11. The system of claim 10, further comprising a second cable adjacent the first cable, wherein the first cable is a fiber optic cable and the control system is in optical communication with the fiber optic cable.
12. The system of claim 11, further comprising a plurality of clamping devices, wherein each clamping device comprises a first collar section and a second collar section secured to one another so as to extend completely around the casing string, each clamping device carrying one of the transducers and a set of the orientation devices, wherein the set comprises a first orientation device and a second orientation device orthogonally oriented with respect to one another.
13. The system of claim 12, wherein the clamping device further comprises a connecting portion, the connecting portion forming a guide along which the first and second cables run, wherein the transducer and set of orientation devices for the clamping device are carried on the connecting portion adjacent the cable.
14. The system of claim 9, wherein the first cable is an electrical cable, the system further comprising a plurality of sensing devices, each sensing device configured to detect a wireless signal emitted by a transducer and each orientation device adjacent the transducer.

15. A method for detecting the orientation of a cable in a wellbore, the method comprising:
 - deploying a plurality of transducers in a wellbore, the transducers axially spaced apart from one another adjacent a cable extending along a length of the wellbore;
 - transmitting a first signal from at least one transducer towards the cable;
 - propagating a second signal down the cable;
 - altering the second signal based on the first signal; and
 - utilizing the altered signal to determine the orientation of the cable in the wellbore at a casing section.
16. The method of claim 15, wherein deploying comprises positioning each transducer adjacent a first cable; identifying the position of the first cable in the wellbore at a given point based on the location of the transducer; and discharging a perforating tool based on the identified position of the first cable.
17. The method of claim 15, wherein the first signal is an acoustic signal and the second signal is an optic signal.
18. The method of claim 15, further comprising, modulating the first signal to include location data.
19. The method of claim 15, wherein altering comprises changing the backscattered optic signal.
20. The method of claim 16, further comprising utilizing the discharging from the perforating tool as a seismic source; propagating a seismic signal into a formation; and detecting a reflected seismic signal with the at least one transducer.
21. The method of claim 15, further comprising propagating a seismic signal in a formation and utilizing the transducer to detect the seismic signal.

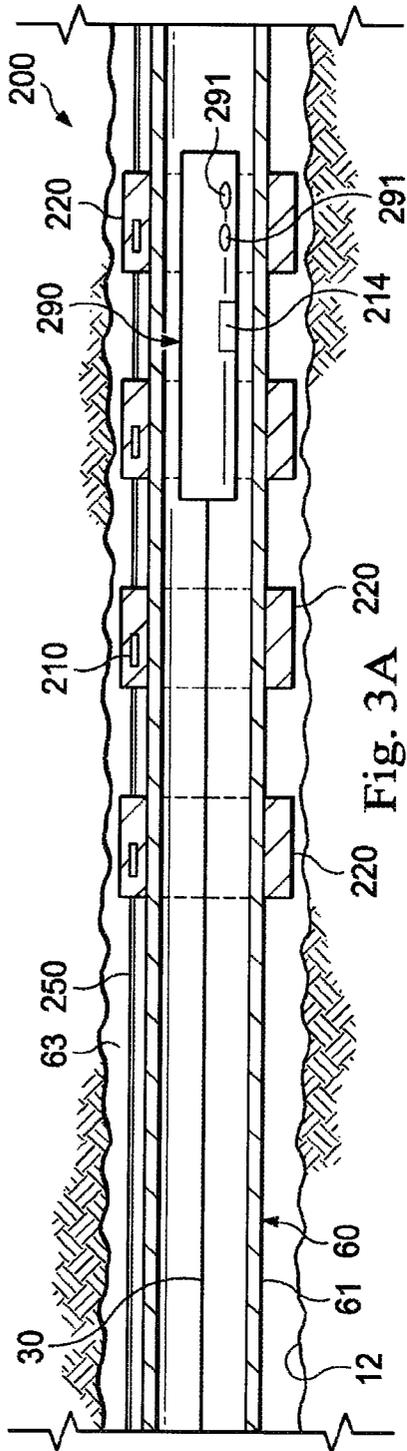


Fig. 3A 220

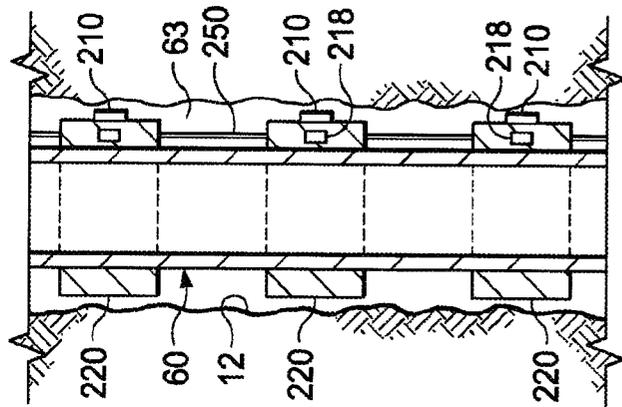


Fig. 3B

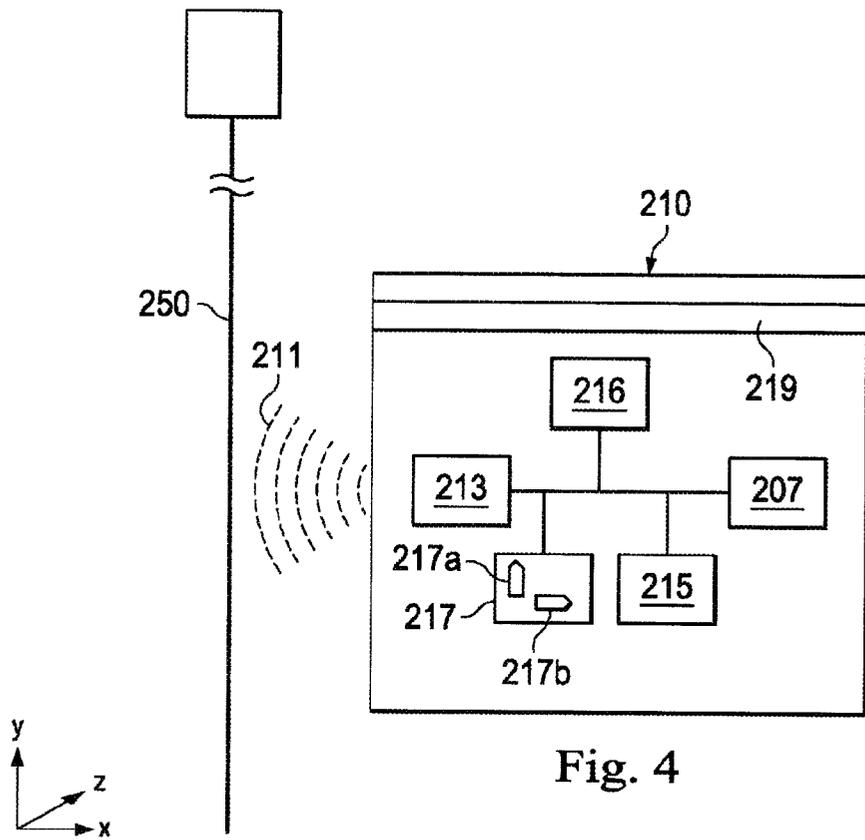


Fig. 4

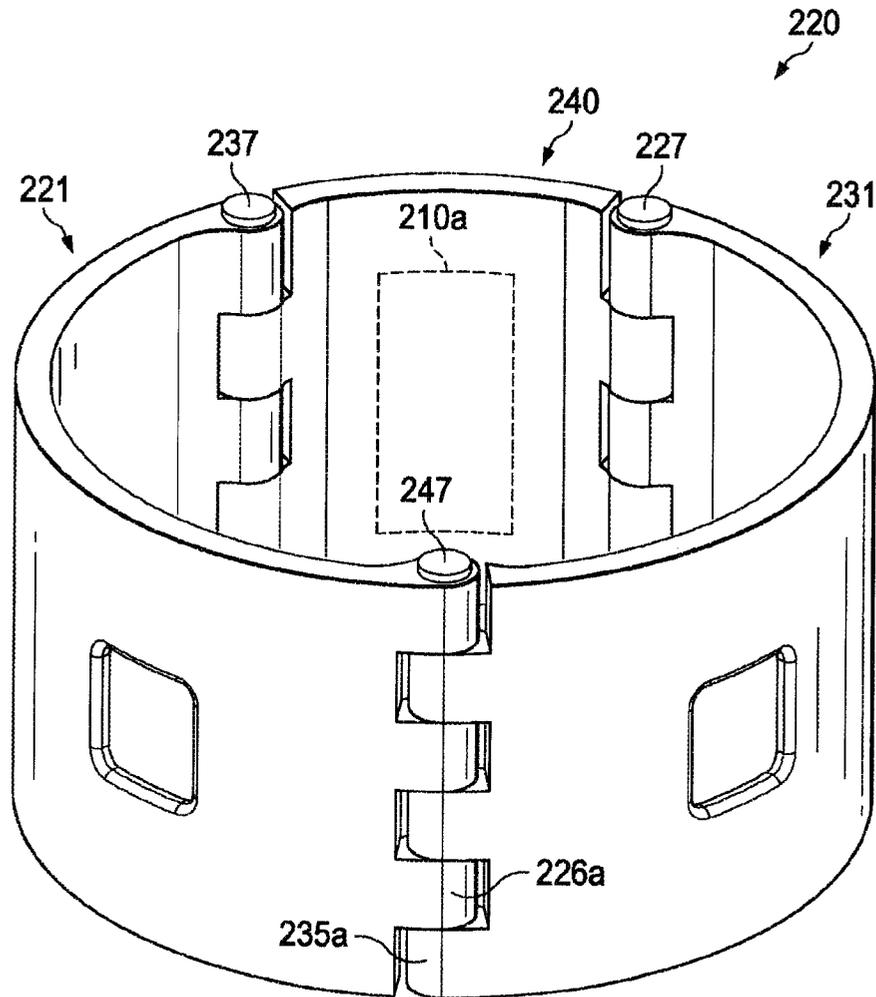


Fig. 5A

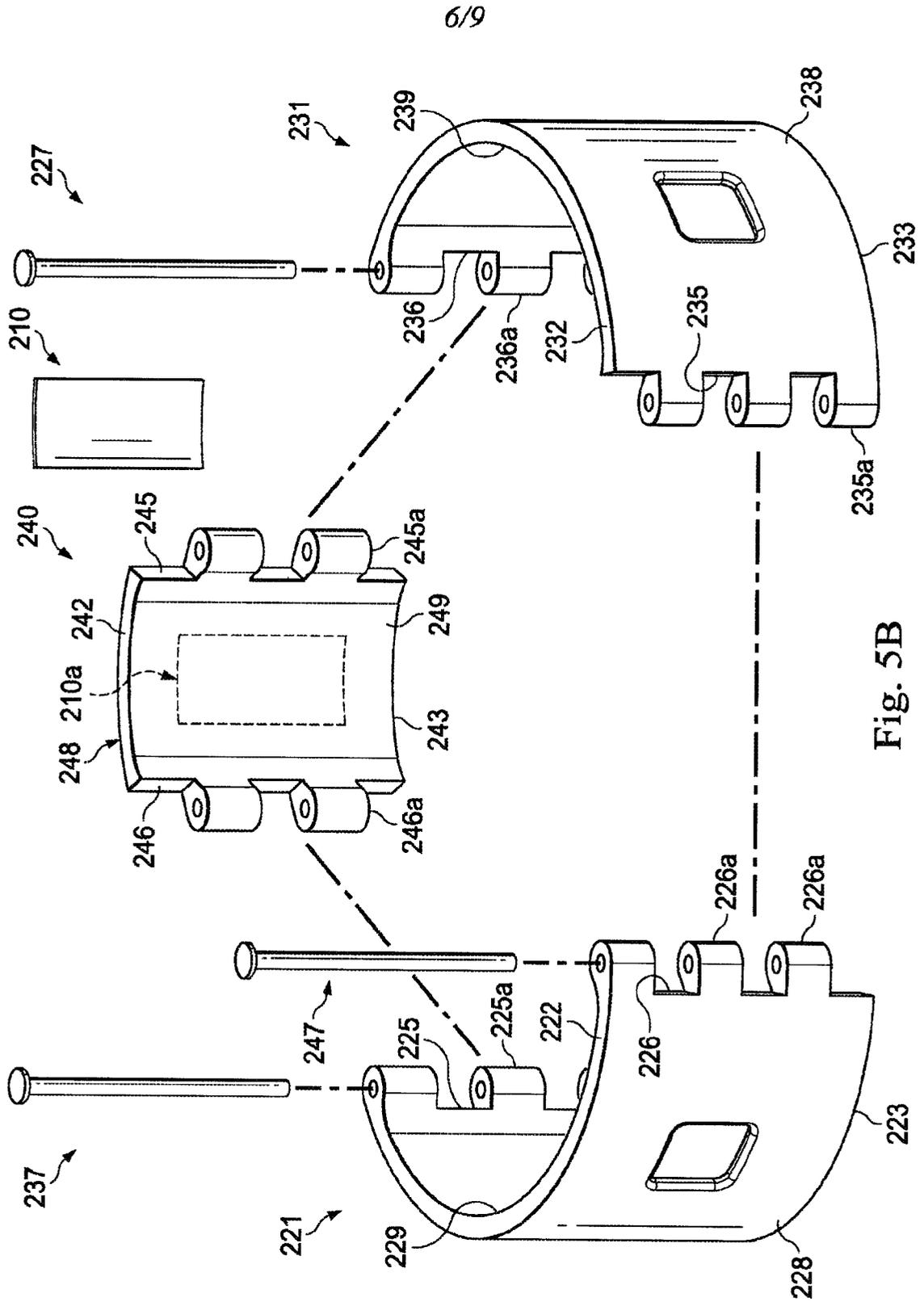


Fig. 5B

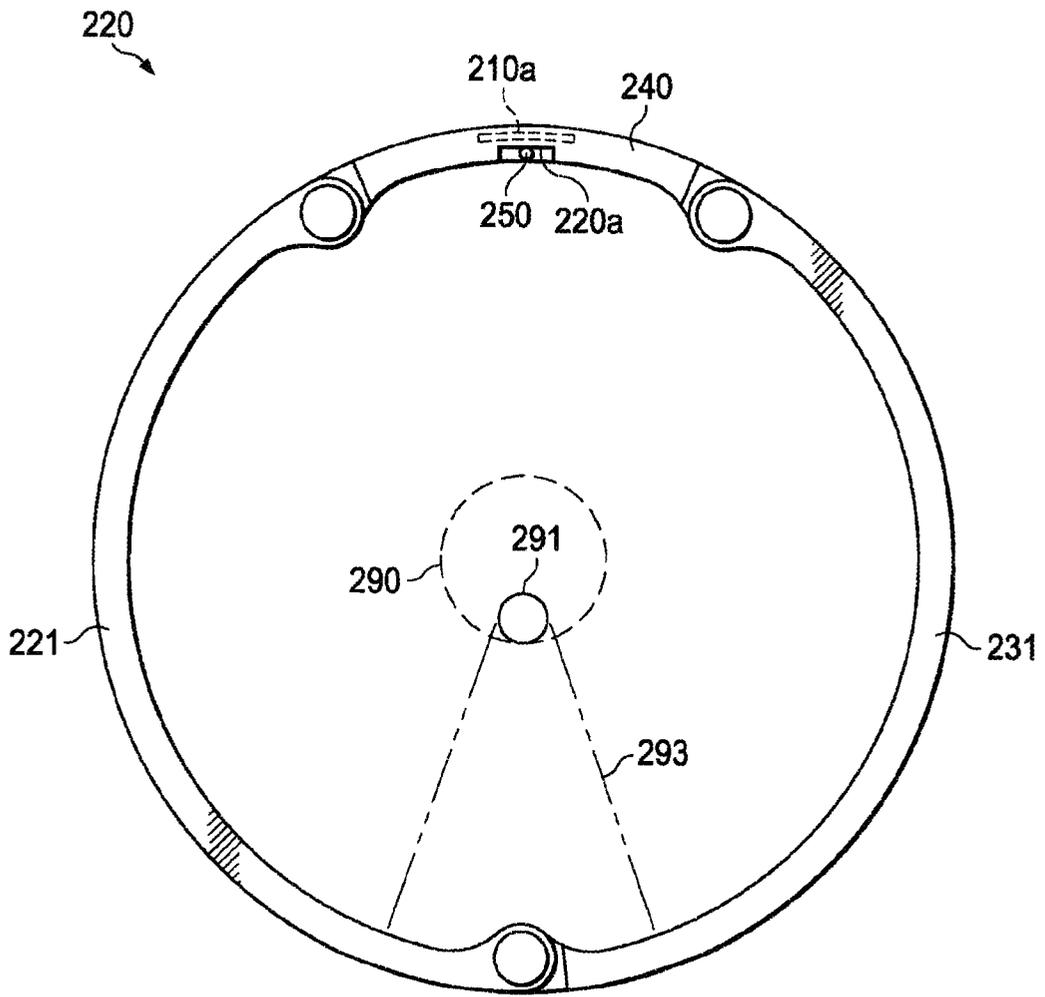


Fig. 5C

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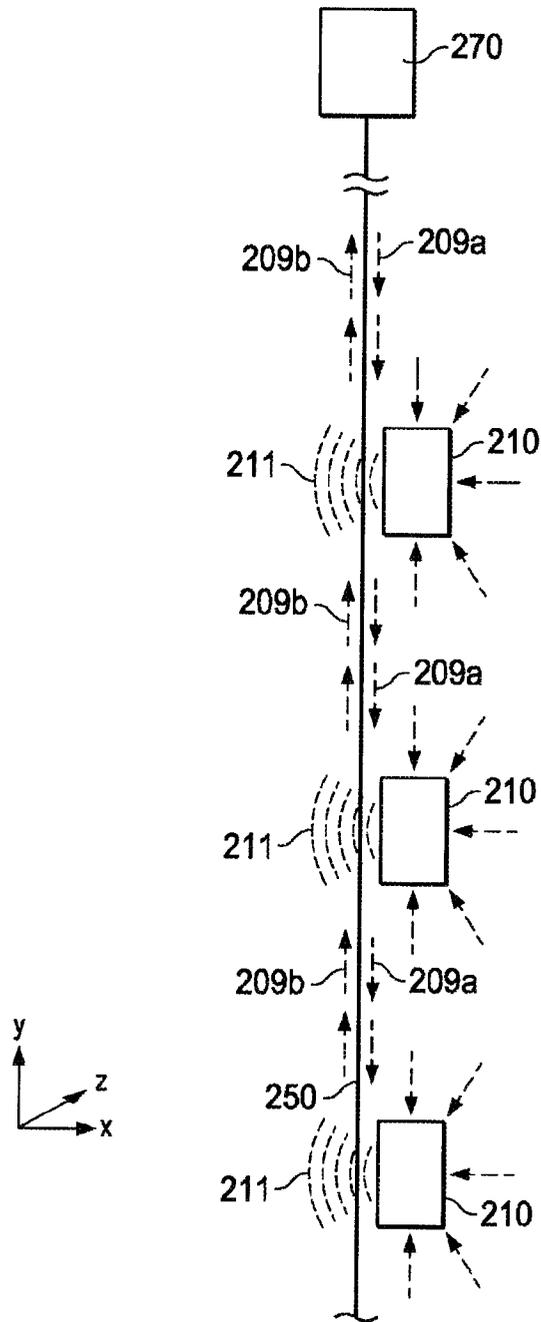


Fig. 6

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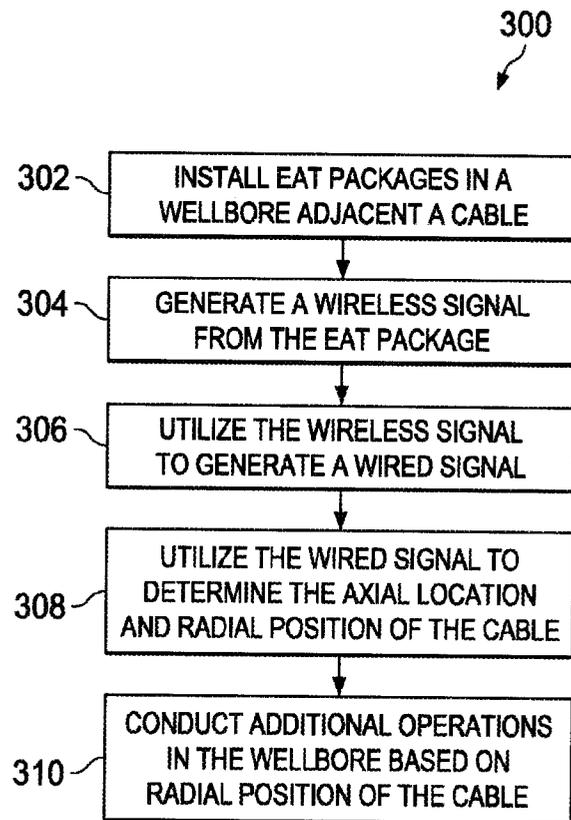


Fig. 7

