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(54) Title: A MINE BOREHOLE SENSOR PROBE

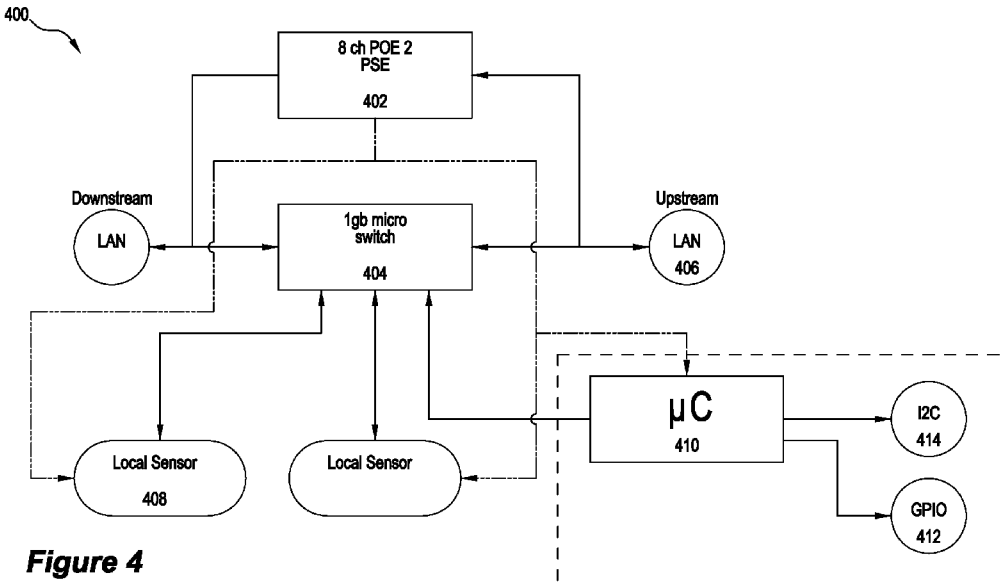

Figure 4

(57) Abstract: The present invention relates to a modular mine hole sensor probe for moving along a mine hole. The probe includes electrical modules for releasably and serially connecting together. Advantageously, the modular probe includes replaceable electrical modules so that interchange can be accomplished easily if damaged or requiring calibration. As improved electrical hardware becomes available, new electrical modules including the hardware may be included in the probe.

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[Continued on next page]

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A MINE BOREHOLE SENSOR PROBE

TECHNICAL FIELD

[0001] The present invention generally relates to a mine borehole sensor probe.

BACKGROUND

[0002] The reference to any prior art in this specification is not, and should not be taken as an acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge.

[0003] Mine borehole sensor probes are used in identification of borehole mineralogy, geometry and other borehole properties.

[0004] A known probe consists of multiple electrical components mounted on one sled. In practice, one or more electrical components may become damaged in the rugged borehole environment or require calibration, thereby undesirably resulting in the probe being out of operation.

[0005] The preferred embodiment provides for an improved mine borehole sensor probe.

SUMMARY OF THE INVENTION

[0006] According to one aspect of the present invention, there is provided a modular mine hole sensor probe for moving along a mine hole, the probe including electrical modules for releasably and serially connecting together.

[0007] Advantageously, the modular probe includes replaceable electrical modules so that interchange can be accomplished easily if damaged or requiring calibration. As improved electrical hardware becomes available, new electrical modules including the hardware may be included in the probe.

[0008] Each pair of adjacent modules may include a connector interface. The connector interface may form a water tight seal.

[0009] The connector interface may include complementary electrical connectors. The connector interface may include an electrical male plug of one module for engaging with an electrical female socket of the other module. The electrical male plugs and female sockets may alternate along the probe.

[00010] The electrical connectors may include a data communications line and/or power line.

[00011] The connector interface may include complementary mechanical connectors. One of the connectors may include an annulus for being received in a well of the other connector. The annulus may be ribbed to impede moisture ingress. The connectors may be axially connected together. The connectors may be locked together. The connectors may alternate along the probe.

[00012] The modules may include an image capture module for capturing images as the probe moves along the hole. The image capture module may include a camera. The image capture module may include a (red, green, blue) RGB sensor for sensing the colour of the material. The image capture module may include a range finder. The range finder may include a microcontroller for Inter-Integrated Circuit (I2C) communication to LAN.

[00013] The modules may include a LiDAR (Light Detection and Ranging) sensor module for providing LiDAR data as the probe moves along the hole.

[00014] The modules may include a controller module for controlling the probe. The controller module may include a cache for caching sensory date from one or more other modules.

[00015] The modules may include an optical module for sensing optical characteristics of the material in which the hole is formed. The optical module may include an optic fibre cable for coupling to a spectroradiometer that senses and scans spectral data as the probe moves along the hole. The optical module may include a wire cable for coupling in communication with a processor. The optical module may include a microcontroller for control of the optic fibre cable.

[00016] Each module may include bussed Power Sourcing Equipment (PSE). Each module may include a bussed switch. Each module may include a LAN bus.

[00017] According to another aspect of the present invention, there is provided a mine hole system including:

the sensor probe; and

a processor for processing probe data from the probe.

[00018] The system may further include an encoder for sensing the depth of the probe moving along the hole. The system may further include at least one winch for winching the probe along the hole. The winch may include at least one winch line coupled to the probe.

[00019] The system may further include a spectroradiometer for providing spectral data as the probe moves along the hole.

[00020] The system may be mobile, preferably carried by a vehicle, so that the probe data may be processed at site of the hole.

[00021] According to another aspect of the present invention, there is provided a method for using a modular mine hole sensor probe for moving along a mine hole, the probe including electrical modules for releasably and serially connecting together, the method involving:

replacing one or more of the electrical modules so that interchange can be accomplished easily if damaged or requiring calibration.

[00022] The method may involve replacing one of the modules with a new module with improved electrical hardware.

[00023] Any of the features described herein can be combined in any combination with any one or more of the other features described herein within the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[00024] Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

[00025] Figure 1 is a rear view of a mine borehole system with a modular mine borehole sensor probe in accordance with an embodiment of the present invention;

[00026] Figure 2 is a side view of the modular mine borehole sensor probe in Figure 1;

[00027] Figures 3A shows end views of adjacent modules of the sensor probe of Figure 2;

[00028] Figures 3B shows end perspective views of the of the adjacent modules of Figure 3A;

[00029] Figures 3C is a side view showing the interconnection of the adjacent modules of Figure 3A; and

[00030] Figure 4 is an electrical circuit of an electrical module of the sensor probe of Figure 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[00031] According to an embodiment of the present invention, there is provided a transportable mine borehole system 100 as shown in Figure 1. The system 100 includes a modular multi-sensor probe 102 for moving along a borehole 104.

[00032] The probe 102 includes four electrical modules 106, 108, 109, 110 for releasably and serially connecting together. Advantageously, the modular probe 102 includes replaceable electrical modules 106, 108, 109, 110 so that interchange can be accomplished easily if any of the modules 106, 108, 109, 110 are damaged or require calibration. As improved electrical hardware becomes available, new electrical modules 106, 108, 109, 110 including the hardware may be substituted in the probe 102. New

modules 106, 108, 109, 110 could add features, reduce the average probe diameter or improve data collection.

[00033] The system 100 also includes a laptop 112 (i.e. processor) for processing the probe data to optionally generate a three-dimensional (3D) model of the borehole 104.

[00034] The system 100 further includes a wireline winch 114 for winching the probe 102 by electrical wire along the borehole 104. The winch 114 includes an encoder for sensing the depth of the probe 104 moving along the borehole 104. The electrical wire cable is in communication between the modules 106, 108, 109, 110 and laptop 112.

[00035] The system 100 further includes a fibre winch 116 for winching the probe 102 by optic fibre cable (fibre winch line) along the borehole 104. Pulleys 118 mounted to a boom 120 are used to feed the optic fibre and wire winch lines.

[00036] The system 100 further includes a spectroradiometer 122, coupled to the optic fibre, for sensing light characteristics and providing associated scanning spectral data as the probe 102 moves up along the borehole 104.

[00037] The mobile system 100 is carried by a four-wheel drive (4WD) vehicle 124, so that the model can be instantaneously generated for analysis at the site of the borehole 104 in the mine.

[00038] Turning to Figure 2, the electrical modules 106, 108, 109, 110 are serially interconnected together, from the head to tail along the probe 102, as follows: optical module 106, controller module 108, LiDAR (Light Detection and Ranging) sensor module 109 and image capture module 110.

[00039] The topmost optical module 106 senses optical characteristics of the material in which the borehole 104 is formed. The optical module 106 includes the optic fibre cable 200, the end of which is located behind a transparent window. The optic fibre cable 200 is coupled to the spectroradiometer 122 that senses and scans spectral data as the probe 102 moves along the borehole 104. The optical module 106 also includes the wire cable 202, and associated electrical connectors, for coupling the laptop 112 in communication with a common electrical bus of the modules 106, 108, 109, 110.

[00040] The next controller module 108 is provided for controlling various functions of the probe 102. The controller module 102 also includes a cache for caching sensory data from one or more other modules 106, 109, 110.

[00041] The next dual LiDAR (Light Detection and Ranging) sensor module 109 is provided for sensing ranges and providing associated borehole topographical range LiDAR data as the probe 102 moves (ascends and/or descends) along the borehole 104.

[00042] Finally, the bottommost image capture (or camera) module 110 is provided for capturing images as the probe 102 moves along the borehole 104. The image capture module 110 includes a downward-pointed camera and a (red, green, blue) RGB sensor for sensing the colour of the material. The image capture module 110 also includes a range finder.

[00043] Turning to Figure 3A and 3B, each pair of adjacent modules (106, 108 or 108,109 or 109, 110) includes an end connector interface 300. The connector interface 300 forms a water tight seal to prevent the ingress of water into the internal module electronics.

[00044] The connector interface 300 includes complementary electrical connectors 302, 304. In particular, the connector interface 300 includes an upstream electrical male plug 302 of one module 106 for engaging with an electrical female socket 304 of the other module 108. Accordingly, the electrical male plugs 302 and female sockets 304 alternate along the probe 102. The electrical connectors 302, 304 include data communications and power lines.

[00045] The connector interface 300 also includes complementary mechanical connectors 306, 308. The downstream mechanical connector 308 includes an annulus for being received in an annular well of the upstream mechanical connector 306. The outside surface of the annulus is ribbed, and/or includes one or more O-rings, to impede moisture ingress.

[00046] Turning to Figure 3C, the mechanical connectors 306, 308 are axially connected by pressing the adjacent modules 106, 108 together. Once pressed together, a locking collar 310 of the upstream mechanical connector 306 is locked downwards

with protrusions 312 of the downstream mechanical connector 308. In locking, an internal lip of the collar 310 is forced over the protrusions 312. The connectors 306, 308 alternate along the probe 102.

[00047] The connector interface 300 provides a mechanism of physically connecting modules that provides a firm connection and satisfies the standard IP69. The modular design interface 300 enables sliding into a shell which provides a smaller profile for avoiding water to impact the internal electronics.

[00048] Figure 4 shows common electrical circuitry 400 of each module 106, 108, 109, 110. The common circuitry 400 includes bussed Power over the Ethernet (POE) Power Sourcing Equipment (PSE) 402. Further, the common circuitry 400 includes a bussed switch 404 for isolating the module from the other modules connected to a local area network (LAN) bus 406. The common circuitry 400 also includes one or more local sensors 408 (e.g. camera, RGB sensor, renge sensor, LiDAR, etc.), dependent upon the module 106, 108, 109, 110.

[00049] The optical module 106 includes a small microcontroller 410 for halo and servo control of the optic fibre cable 200 via a general-purpose input/output (GIPO) 412.

[00050] In the image capture module 110, with range finder, the microcontroller 410 can be used for Inter-Integrated Circuit (I2C) communication 414.

[00051] This common electrical circuitry 400 enables transferring power and data between the probe 102 and the surface, connecting the modules 106, 108, 109, 110 such that data and power transfer is seamless regardless of the number of modules. Each module 106, 108, 109, 110 provides the ability to facilitate communications with modules above and below it in the overall probe 102. Accordingly, the probe 102 provides a method of transferring information from each module to the surface. For example, the electrical circuitry 400 in each module transports RGB information from the lowest module 110, through each module 106, 108, 109, before being sent to the surface.

[00052] A method for using the modular mine borehole sensor probe 02 involves replacing one or more of the electrical modules 106, 108, 109, 110 so that interchange can be accomplished easily if damaged or requiring calibration. The modules 106, 108,

109, 110 may also be upgraded with a new module with improved electrical hardware. Each module is self-contained and changes to one module does not affect the others. The modules 106, 108, 109, 110 are highly configurable and can be of different diameters.

[00053] A person skilled in the art will appreciate that many embodiments and variations can be made without departing from the ambit of the present invention.

[00054] In one embodiment, the modules may include an Inertial Measurement Unit (IMU) module for sensing acceleration, orientation, angular rates, and other gravitational forces and providing associated inertial data as the probe 102 moves along the borehole 104.

[00055] In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. It is to be understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect.

[00056] Reference throughout this specification to 'one embodiment' or 'an embodiment' means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearance of the phrases 'in one embodiment' or 'in an embodiment' in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more combinations.

The claims defining the invention are as follows:

1. A modular mine hole sensor probe for moving along a mine hole, the probe including electrical modules for releasably and serially connecting together.

2. A modular mine hole sensor probe as claimed in claim 1, wherein each pair of adjacent modules includes a connector interface.

3. A modular mine hole sensor probe as claimed in claim 2, wherein the connector interface forms a water tight seal.

4. A modular mine hole sensor probe as claimed in claim 2, wherein the connector interface includes complementary electrical connectors.

5. A modular mine hole sensor probe as claimed in claim 4, wherein the connector interface includes an electrical male plug of one module for engaging with an electrical female socket of the other module.

6. A modular mine hole sensor probe as claimed in claim 5, wherein the electrical male plugs and female sockets alternate along the probe.

7. A modular mine hole sensor probe as claimed in claim 4, wherein the electrical connectors include a data communications line and power line.

8. A modular mine hole sensor probe as claimed in claim 1, wherein each module includes bussed Power Sourcing Equipment (PSE).

9. A modular mine hole sensor probe as claimed in claim 1, wherein each module includes a bussed switch.

10. A modular mine hole sensor probe as claimed in claim 1, wherein each module includes a LAN bus.

11. A modular mine hole sensor probe as claimed in claim 2, wherein the connector interface includes complementary mechanical connectors.

12. A modular mine hole sensor probe as claimed in claim 11, wherein one of the connectors includes an annulus for being received in a well of the other connector.

13. A modular mine hole sensor probe as claimed in claim 12, wherein the annulus is ribbed to impede moisture ingress.

14. A modular mine hole sensor probe as claimed in claim 11, wherein the connectors are axially connected together.

15. A modular mine hole sensor probe as claimed in claim 11, wherein the connectors are locked together.

16. A modular mine hole sensor probe as claimed in claim 11, wherein the connectors alternate along the probe.

17. A modular mine hole sensor probe as claimed in claim 1, wherein the modules include an image capture module for capturing images as the probe moves along the hole.

18. A modular mine hole sensor probe as claimed in claim 17, wherein the image capture module includes a camera.

19. A modular mine hole sensor probe as claimed in claim 17, wherein the image capture module includes a (red, green, blue) RGB sensor for sensing the colour of the material.

20. A modular mine hole sensor probe as claimed in claim 17, wherein the image capture module includes a range finder.

21. A modular mine hole sensor probe as claimed in claim 20, wherein the range finder includes a microcontroller for Inter-Integrated Circuit (I2C) communication to LAN.

22. A modular mine hole sensor probe as claimed in claim 1, wherein the modules include a LiDAR (Light Detection and Ranging) sensor module for providing LiDAR data as the probe moves along the hole.

23. A modular mine hole sensor probe as claimed in claim 1, wherein the modules include a controller module for controlling the probe.

24. A modular mine hole sensor probe as claimed in claim 23, wherein the controller module includes a cache for caching sensory date from one or more other modules.

25. A modular mine hole sensor probe as claimed in claim 1, wherein the modules include an optical module for sensing optical characteristics of the material in which the hole is formed.

26. A modular mine hole sensor probe as claimed in claim 26, wherein the optical module includes an optic fibre cable for coupling to a spectroradiometer that senses and scans spectral data as the probe moves along the hole.

27. A modular mine hole sensor probe as claimed in claim 26, wherein the optical module includes a wire cable for coupling in communication with a processor.

28. A modular mine hole sensor probe as claimed in claim 26, wherein the optical module includes a microcontroller for control of the optic fibre cable.

29. A mine hole system including:
the sensor probe of claim 1; and
a processor for processing probe data from the probe.

30. A system as claimed in claim 29, further including an encoder for sensing the depth of the probe moving along the hole.

31. A system as claimed in claim 29, further including at least one winch for winching the probe along the hole.

32. A system as claimed in claim 29, further including a spectroradiometer for providing spectral data as the probe moves along the hole.

33. A system as claimed in claim 29, being mobile and carried by a vehicle so that the probe data is processed at site of the hole.

34. A method for using a modular mine hole sensor probe for moving along a mine hole, the probe including electrical modules for releasably and serially connecting together, the method involving:

replacing one or more of the electrical modules so that interchange can be accomplished easily if damaged or requiring calibration.

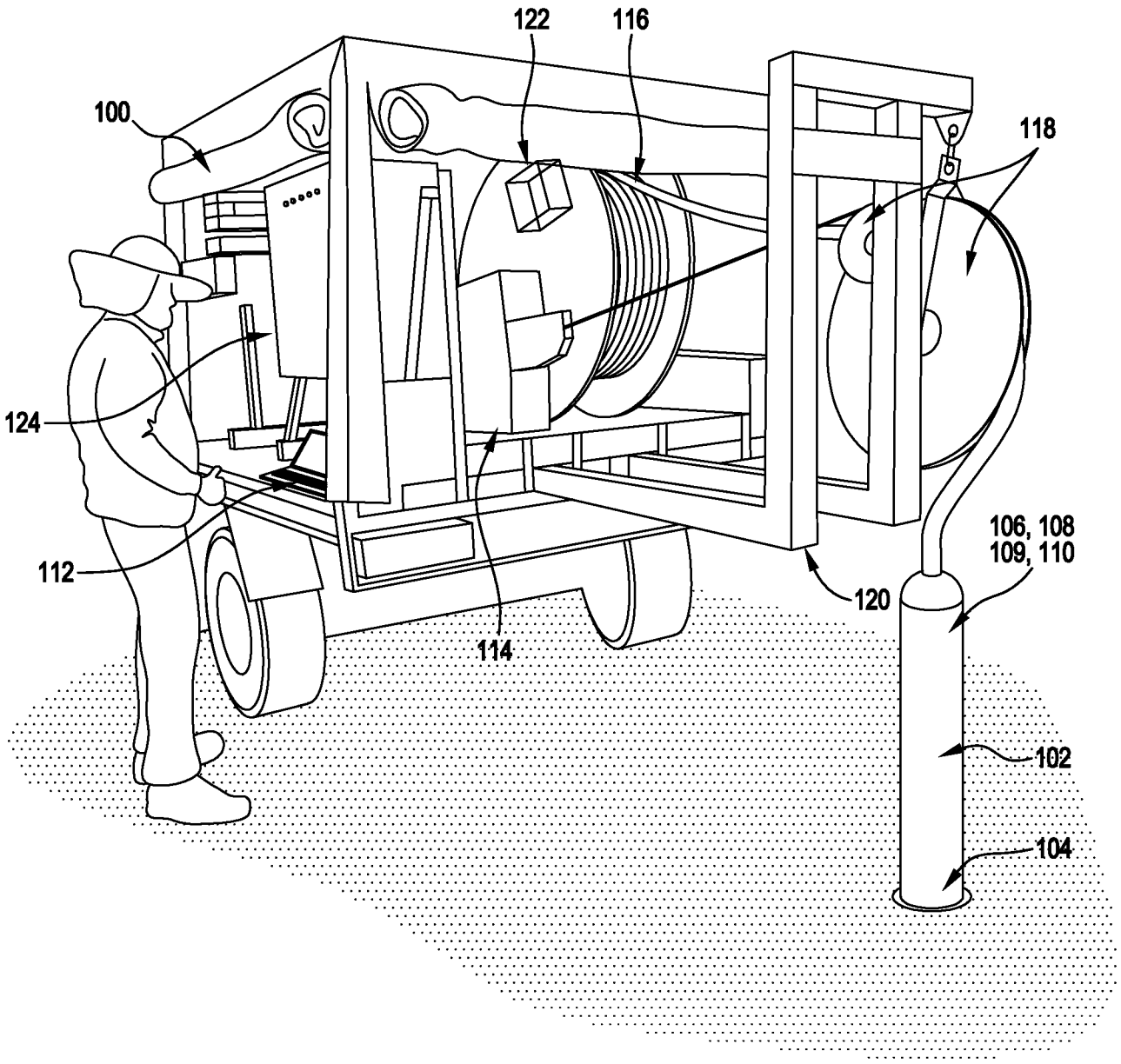


Figure 1

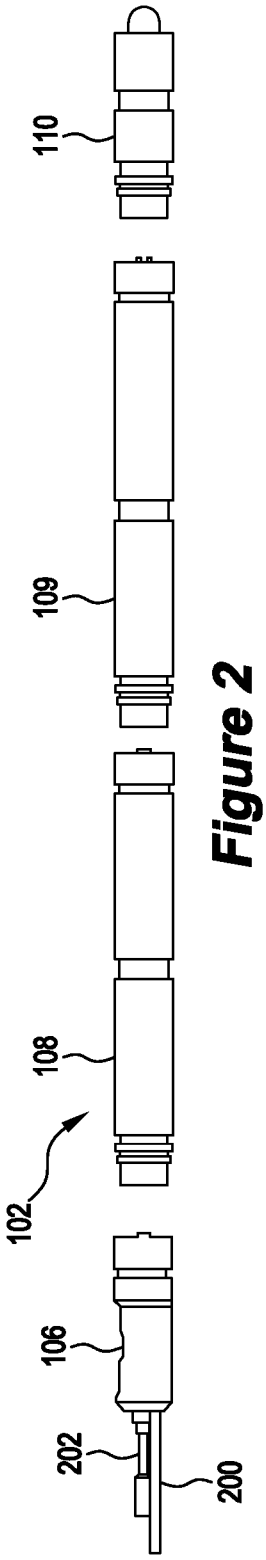


Figure 2

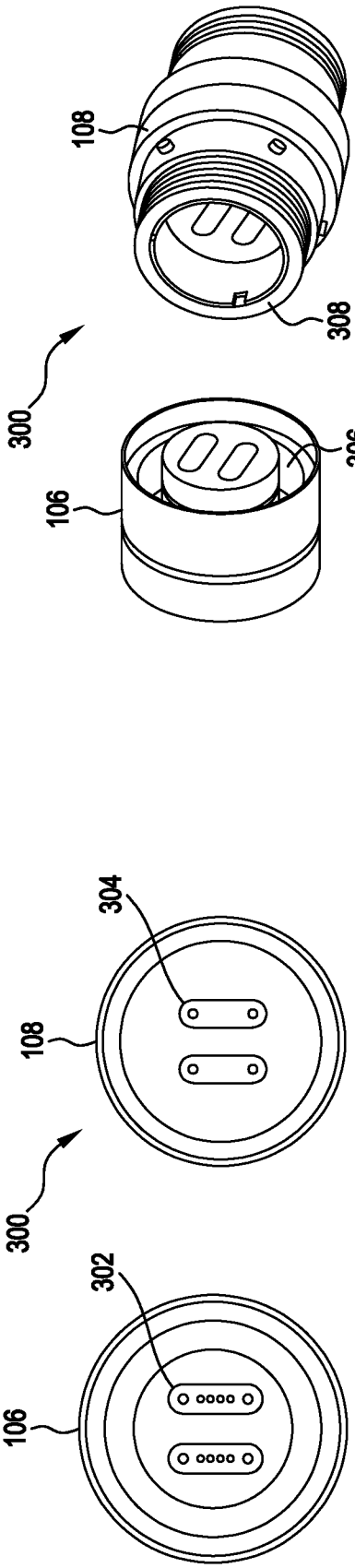


Figure 3A

Figure 3B

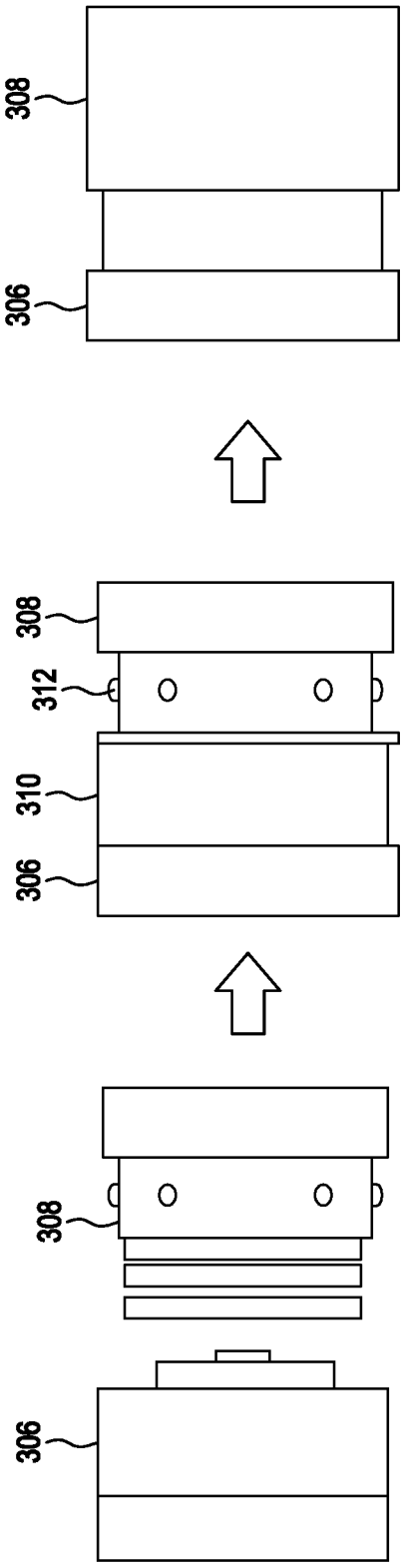
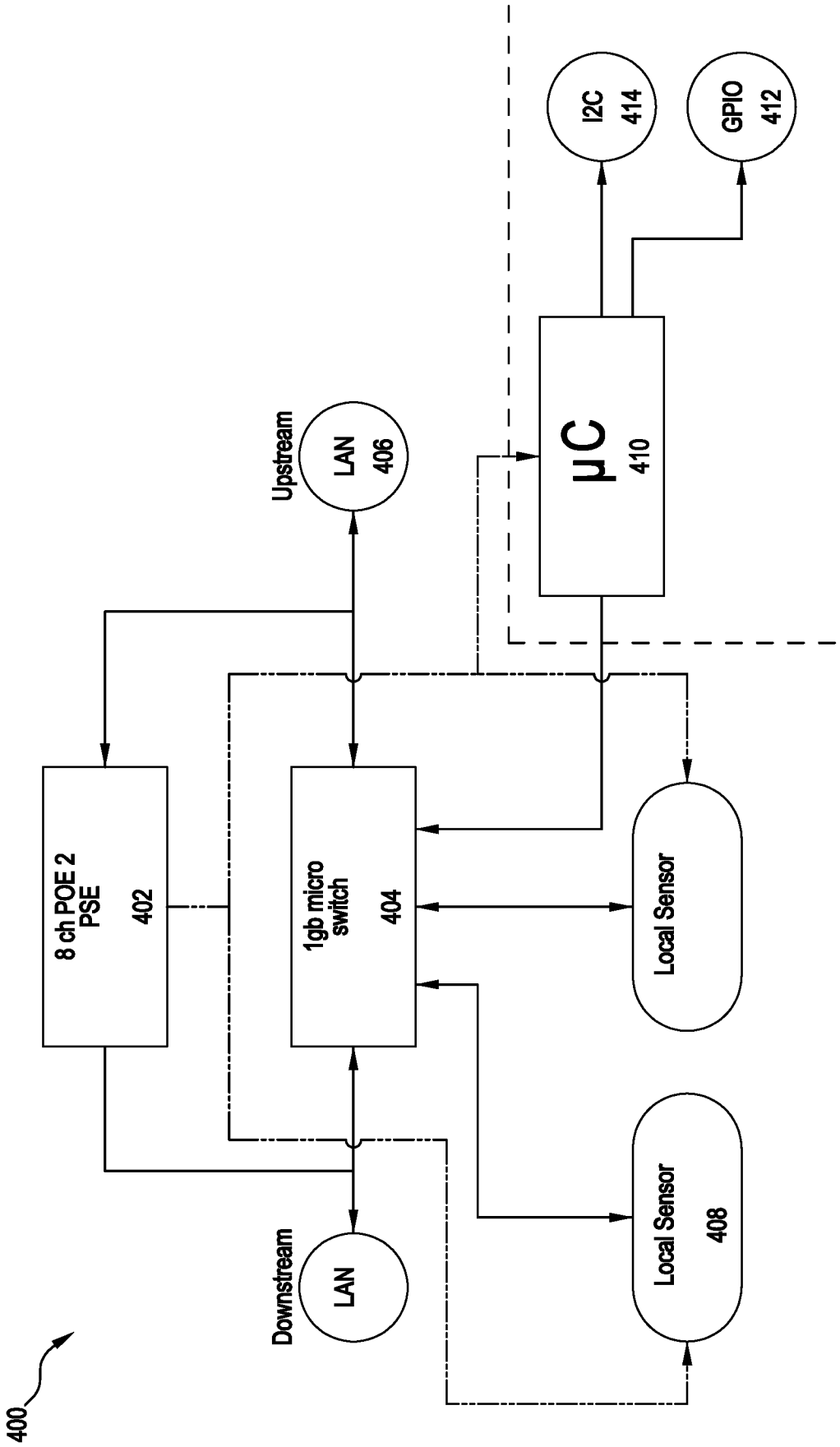


Figure 4


I2C
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Upstream
LAN
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µC
410
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PSE
402
1gb micro
switch
404
Local Sensor
Local Sensor
408
Downstream
LAN
400

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2024/050873

A. CLASSIFICATION OF SUBJECT MATTER

G01V 8/16 (2006.01) ***E21B 47/00 (2012.01)*** ***E21B 47/002 (2012.01)*** ***E21B 47/017 (2012.01)*** ***G01J 3/00 (2006.01)***
G01S 17/89 (2020.01) ***G01V 1/52 (2006.01)*** ***G01V 7/00 (2006.01)*** ***G01V 11/00 (2006.01)*** ***H01R 13/52 (2006.01)***
H01R 13/627 (2006.01) ***H01R 24/58 (2011.01)*** ***H01R 107/00 (2006.01)*** ***H04L 12/10 (2006.01)***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

Database: PATENW (EPODOC, WPIAP, TXTE) with classification marks G01V1/52, G01V11/002, E21B47/00 and keywords vehicle, truck, mount, position, camera, range finder, lidar, optical fibre, water proof, hermetic, and similar terms. **Database:** Private Cluster $Ultracombi (EPODOC, WPIAP) with documents DE19713754, EP1347150, CA2539861, US6942043 and US2023025415 and keywords module, segment, release, interchangeable, adapt, configure and similar terms. **Database:** Google/Google Patents with keywords modular, borehole, sensor, probe.

Applicant/Inventor name searched in Google Patents and internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2024	30 August 2024
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Christopher Hodgson AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61 2 6283 2616

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2024/050873**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/0025415 A1 (REFLEX INSTRUMENTS ASIA PACIFIC PTY LTD) 26 January 2023 Figure 1B, 10-11; Paragraphs 18, 56, 60, 65	1-34
X	DE 19713754 A1 (GLOETZL GES FUER BAUMESTECHNIK et al.) 30 October 1997, Translation sourced from Espacenet. Paragraphs , 6-7, 12-13, 23-24; Claim 6	1-34
X	US 5741962 A (BIRCHAK et al.) 21 April 1998 Figure 1A; Columns 1-2, 9	1-34
X	US 5353637 A (PLUMB et al.) 11 October 1994 Figure 1; Columns 5-6	1-34
X	US 2008/0245570 A1 (PARTOUCHE) 09 October 2008 Abstract; Paragraphs 47, 54-55, 61, 64, 73-74, 78	1-34
X	US 2014/0167767 A1 (HALLIBURTON ENERGY SERVICES, INC.) 19 June 2014 Abstract; Figure ; Paragraphs 21, 24, 30, 43	1-34
X	US 2015/0218936 A1 (PRECISON SYSTEMS INTERNATIONAL IP PTY LTD) 06 August 2015 Abstract; Paragraphs 74-75, 77, 85, 89, 91	1-34
X	US 2023/0073079 A1 (LONGYEAR TM, INC. et al.) 09 March 2023 Figures 2-3; Paragraphs 28-30, 35, 37, 39, 43, 50	1-34
A	US 2019/0346420 A1 (URBAN-GRO, INC.) 14 November 2019 Abstract; Paragraphs 25, 27, 29-30, 32-33	1-34

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2024/050873**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2023/0025415 A1	26 January 2023	US 2023025415 A1	26 Jan 2023
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This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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