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(54) **Title**: MINING MACHINE POSITION TRACKING AND MAPPING

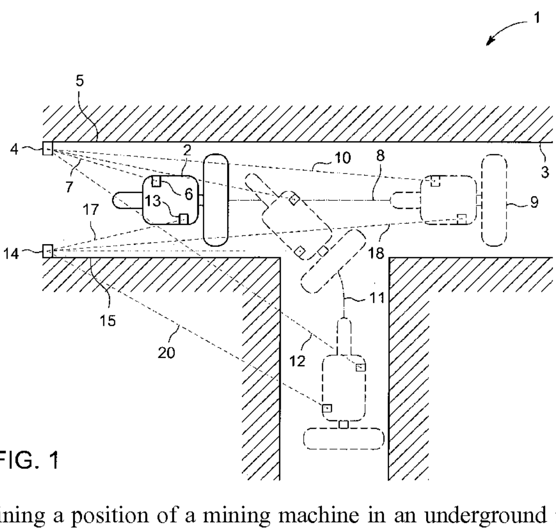

FIG. 1

(57) **Abstract**: A system for determining a position of a mining machine in an underground mine, the system including an emitter unit and a receiver unit, one of the units being positioned in fixed relation to a mine wall and the other unit being mounted relative to the machine, wherein the emitter unit transmits a coded magnetic signal that is received by the receiver unit, the system further including a processor to identify the distance and relative angle between the units based on the received signal. The system utilizes ranging of a through- strata coded low frequency magnetic field for real time and continuous 3-D positioning of the mining machine. The invention also relates to a method of tracking a mining machine and a mining operation.

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MINING MACHINE POSITION TRACKING AND MAPPING

FIELD OF THE INVENTION

[0001] The present invention relates to mining machine tracking and mapping.

BACKGROUND OF THE INVENTION

[0002] In mining operations, it is important to reliably track the position and progress of a mining machine. However, conditions prevalent in underground coal mining make accurate positioning and tracking of a mining machine particularly difficult.

[0003] In a dust free environment, optical theodolites can be used to accurately position equipment using line of sight measurements. However, such devices cannot operate properly in dusty conditions such as found in an underground coal mine. Further, a line of sight measurement may not be available if the mining machine is operating in a side cut and is obscured from view by intervening strata of the mine.

[0004] Indeed, conventional optical and radar tracking systems are both unsuitable for tracking movement of a mining machine if the machine is operating in a side cut in the underground mine as the enveloping strata eliminates any direct optical or radar measurement.

[0005] Obviously, satellite GPS positioning of the machine is not an option in an underground mine.

[0006] Gyroscope and accelerometer based systems are also not suitable as the mining machine may move at a rate that is too slow for these systems to generate accurate positioning data over an extended operational cycle. Inaccuracies may also be introduced due to operational movement of the machine resulting from vibration, shifting, or rolling of the machine as a result of reactionary forces generated through use of equipment such as a cutting boom or the like.

[0007] Accurate and continuous monitoring of the machine position, especially if subject to operational movement, is essential for proper and efficient operation of the machine at a face of the mine and throughout the mining cycle. In the absence of accurate positional information, manual input will be required in order to operate the machine and equipment at the mine face and that exposes an operator to the potentially dangerous and hazardous environment of the mine.

[0008] Existing systems are simply not able to provide such positioning information in the dusty and gassy environment encountered in an underground coal mine.

[0009] Not being able to accurately track progress of the machine during its operational cycle also limits the effectiveness and performance of the entire mining operation, especially if there is no accurate confirmation the machine is travelling on a preselected course. The machine may, for example, be knocked slightly off course due to operational movement and a drilling or cutting operation may then be off trajectory.

[0010] One current process for recording the direction and advancement of a machine is to wait until operation of the machine is halted and the dust is settled, at which time a geometer can make an accurate laser-beam assisted measurement.

[0011] If the machine is off target, a manual steering adjustment can be made and the mining operation recommenced. However, this process of checking the progress of the machine requires manual input and considerable downtime to enable measurements to be taken. If the machine deviates from the required or planned course during operation this may only be discovered after some considerable time delay. In the meantime, the machine could have deviated significantly over the course of the operation cycle.

[0012] It may be desirable to provide a positioning and tracking system suitable for underground mining that differs from existing systems.

BRIEF DESCRIPTION OF THE INVENTION

[0013] In accordance with an embodiment of the present invention, there is provided a system for determining a position of a mining machine in an underground mine, the system comprising: a first emitter unit and a first receiver unit, one of the emitter unit or the receiver unit configured to be positioned in fixed relation to a mine wall and the other of the emitter unit or the receiver unit configured to be mounted relative to the machine, wherein the emitter unit is configured to transmit a coded magnetic signal for receipt by the receiver unit, the system further comprising at least one processor configured to identify a distance and a relative angle between the emitter and receiver units based on the signal as received by the receiver unit.

[0014] In an embodiment, the system further includes a first antenna associated with the receiver unit for transmitting information to the at least one processor relating to the signal as received by the receiver unit.

[0015] In an embodiment, the emitter unit includes a second antenna for receiving the information from the receiver unit such that the emitter and receiver units operate in a closed communications loop.

[0016] In an embodiment, the system further includes multiple second emitter units, wherein each of the first emitter unit and the second emitter units comprises a respective coded magnetic field generator.

[0017] In an embodiment, each of the first and second emitter units includes a pitch and yaw mechanism for mechanical rotation of the respective magnetic field generator.

[0018] In an embodiment, the system further includes an array of the first receiver unit and multiple second receiver units for receiving respective uniquely coded magnetic signals from the first and second emitter units.

[0019] In an embodiment, the emitter units function to provide 3-dimensional positioning information to allow tracking of the machine.

[0020] In an embodiment, the emitter units are mounted on the mining machine.

[0021] In an embodiment, the receiver units are arrayed at predetermined locations through the mine.

[0022] In an embodiment, the system further includes a mapping module for displaying an image and a position of the machine in the mine.

[0023] In an embodiment, the system further includes equipment sensors arranged to feed into the mapping module to enable display of an operational position of one or more components of the machine.

[0024] In an embodiment, the system further includes detectors on the machine, to monitor operational movement of the machine, said operational movement comprising at least one of tilt, roll, or vibration, and the at least one processor is configured to compensate for the operational movement.

[0025] In another aspect, there is provided a method of tracking a mining machine in a mine using signal transmission between at least one emitter unit and at least one receiver unit, wherein one of the emitter unit or the receiver unit is positioned in fixed relation to a mine wall and the other of the emitter unit or the receiver unit is mounted relative to the machine, the method including transmitting a coded magnetic signal from the emitter unit, receiving the signal at the receiver unit, and sending information in relation to the received signal to a processor in order to calculate a range and a relative angle between the emitter and receiver units.

[0026] In an embodiment, the emitter unit provides 3-dimensional position information to allow tracking and mapping of the machine.

[0027] In an embodiment, the coded magnetic signal is transmitted by way of a through-strata coded magnetic field and the range and angle calculated between the units allows relative position of the emitter unit in the mine to be determined in 3-dimensions.

[0028] In an embodiment, peak signal strength detection is used to find the most direct angle between the emitter unit and receiver unit.

[0029] In an embodiment, the information from the receiver unit, resulting from reception of the signal, is sent to the processor via wireless radio link.

[0030] In an embodiment, the information sent over the radio link is received by an antenna of the emitter unit such that the signal transmission, reception, and return sending of the information occurs in a closed communications loop.

[0031] In an embodiment, the at least one receiver unit comprises an array of receiver units, and the position of the mining machine is tracked using the array of receiver units.

[0032] In an embodiment, the at least one emitter unit comprises multiple emitter units mounted to the mining machine, and the method includes generating respective uniquely coded signals from the emitter units so that the signals, received by the receiver units which are respectively associated with the emitter units, are able to be separately identified as originating from the respective emitter units.

[0033] In an embodiment, the tracking is performed continuously to follow movement of the mining machine in real time.

[0034] In another aspect, there is provided a mining operation including tracking a mining machine, in accordance with the method described above, and identifying the position of the mining machine on a displayed map of the mine.

[0035] In an embodiment, the identified position of the mining machine is used to control operation cycles of the mining machine.

[0036] In an embodiment, the mining operation further includes displaying operational positions of components of the mining machine on the displayed map, based on input form equipment sensors on the mining machine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] The invention is described in more detail, by way of non-limiting example only, with reference to the following drawings, in which:

Figure 1 is a schematic top view of mine and a system for determining a position of a mining machine within the mine;

Figure 2 is a diagrammatic representation of a reference unit and emitter unit used in the system; and

Figure 3 is an illustration representing interaction and communication between the reference unit and emitter unit.

DETAILED DESCRIPTION OF THE INVENTION

[0038] Referring firstly to Figure 1, a system 1 is illustrated for tracking a mining machine 2 in a mine 3. The system 1 includes a receiver unit 4, fixed to a wall 5 of the mine 3, and an emitter unit 6 secured relative to the mining machine 2.

[0039] In a reverse configuration, the emitter unit 6 could be mounted to the wall 5 and the receiver unit 4 would then be mounted to the mining machine 2.

[0040] In either case, the emitter unit 6 is designed to emit a low frequency coded magnetic signal. The receiver unit detects the field strength and the pitch and yaw information sent from the emitter unit. The detected relative angle is indicated by bearing line 7.

[0041] The signal from the emitter unit 6 is uniquely coded and is transmitted with a specific yaw and pitch setting, and that effectively provides a characteristic signal profile specific to the emitter unit 6. The signal information received at the receiver unit 4 is sufficient to identify the emitter unit 6 and the range and relative 3-dimensional position of the emitter unit 6. This information is re-transmitted in a closed communications loop back to the emitter unit 6, by radio transmitter, for processing onboard the mining machine.

[0042] By knowing the fixed position of the receiver unit 4 and the relative 3-dimensional position of the emitter unit 6, the system 1 can accurately identify the positions of the machine 2. By continuing to monitor the position of the machine 2, the system 1 provides real time tracking of the machine as it travels through the mine.

[0043] By way of example, as the mining machine 2 travels along a pre-determined main heading 8 to a position indicated by phantom lines 9, the distance and angle between the emitter unit 6 and receiver unit 4 changes. The angular separation between bearing lines 7 and 10 indicates the change in bearing and a change in received signal strength will indicate the change in relative distance between the emitter unit 6 and receiver unit 4. This allows for any change in position of the mining machine 2 to be accurately tracked and continuously monitored in real time.

[0044] Even if the machine 2 travels on a break away heading 11, the relative positioning between emitter unit 6 and receiver unit 4, as indicated by bearing line 12 can be determined as the magnetic signal is a low frequency, through-strata magnetic field and, as such, is not obstructed by the intervening rock or coal strata.

[0045] To obtain more detailed positional information on the location and aspect of the mining machine 2, a second emitter unit 13 can be mounted to the machine 2 at a different location. The second emitter unit 13 can also be configured to transmit a uniquely coded signal specific to the emitter unit 13. In the example shown, the emitter unit 13 is in closed loop communication with a second receiver unit 14 fixed to an opposite side 15 of the mine wall 5. Further receiver units can be added at various predetermined locations along the mine 3, and additional transmitter units can be included, as required, in order to provide an array of units capable of providing highly accurate information in relation to the position of the machine 2 within the mine 3.

[0046] In the example shown, when the position of the mining machine 2 is changed to the location indicated by phantom lines 9, the change in distance and angle of the associated emitter units 6 and 13, as represented by the two sets of bearing lines 7, 10 and 17, 18, will allow the position of the mining machine 2 to be accurately determined. Similarly, if the mining machine travels on a break heading 11 the angle between the emitter units 6, 13, and the associated receiver units 4, 14 will be tracked, as indicated by bearing lines 12, 20. The change in relative angle between the bearing lines 7, 12 and 17, 20 will indicate the mining machine 2 has turned, while the strength of the signal detected by the receiver units 4, 14 will accurately determine the range of the machine 2.

[0047] As may be appreciated then, regardless of whether there is direct line of sight with the mining machine 2 or whether the environment is dusty, the emitter units 6, 13 function as magnetic theodolites, providing 3-dimensional position information to allow accurate and continuous real time tracking of the position and movement of the machine 2 within the mine 3.

[0048] The system 1 shown in Figure 1 is a diagrammatic representation of the location of the mining machine 2 in the mine 3. Such a representation may equally form the basis of a virtual image (that is, an image generated by a computer or other processor-based device on a display screen) of the mine 3 for an onboard operator. Alternatively, the virtual image may be available for viewing and monitoring in a remotely located operations control room. In either case, the system 1 may include a mapping module which shows a 3-dimensional image of the mining machine 2, accurately positioned in a virtual map of the mine 1.

[0049] In embodiments, the mining machine also has various sensors for monitoring the position and operation of onboard equipment and components such as tracks or tires, cutter head, cutter boom, conveyor boom and any moveable parts operated by hydraulic jacks, or the like. Such sensors can also provide input to allow the position and operation of the equipment to be rendered into the same virtual image.

[0050] The mining machine will also have detectors to monitor operational movement of the machine, such as tilt, roll or vibration, and the system 1 is configured to compensate for those movements in determining the distance and relative angle between the emitter and receiver units.

[0051] The mapping function thereby allows for complete oversight of the mining operation during an operational cycle of the machine.

[0052] Referring now to Figure 2, a specific embodiment of the receiver unit 4 and emitter unit 6 is described. However, it should be appreciated any suitable form of electromagnetic transmitter, transducer, or transceiver can be used, as required.

[0053] The emitter unit 6 includes a coded field generator 21, a pitch interface driver 22, and a yaw interface driver 23 to provide a magnetic field generating device 24. The device 24 is rotatable to generate a non-circular uniquely coded magnetic field. The emitter unit 6 also includes a wireless interface 25 and a wireless antenna 26, as well as a microprocessor 27.

[0054] The receiver unit 4 includes a magnetic coded field detector 28 for detecting the magnetic field generated by the emitter unit 6, a battery and interface electronics 29, a microprocessor and interface electronics 30, a wireless interface 31, and a wireless antenna 32.

[0055] The signal interaction between the emitter unit 6 and receiver unit 4 is now described, with reference to Figure 3. The system 1 uses low frequency magnetic ranging. The emitter unit 6 sends two variables, yaw and pitch. The device 24 includes a pitch mechanical assembly 33 and a yaw mechanical assembly 34 holding the coded electromagnetic field generator 21. The device 24 is rotated by the yaw mechanical assembly 34, in a manner similar to rotation of a radar antenna to transmit the uniquely coded signal. The receiver unit 4 identifies the correct signal by way of the unique coding and senses the magnetic field vector that is used to calculate the direction of the magnetic signal. The signal strength is also detected.

[0056] The signal strength and direction information is transmitted from the antenna 32 in a closed loop 19, back to the antenna 26 of emitter unit 6. The relative angle between the emitter unit 6 and the receiver unit 4 is determined with the microprocessor 27 by cross correlating the detected magnetic field vector with the known magnetic field profile produced by the coded field generating device 24. The range of the emitter unit 6 from the receiver unit 4 is determined on the basis of a standard RSSI (received signal strength indicator) measurement or peak signal strength detection, as would be known to a person skilled in the art.

[0057] In any case, the methodology and calculations used to determine the specific 3-dimensional positional relationship between the emitter unit 6 and receiver unit 4 can be varied or modified, as required, as would be apparent to a person skilled in the art, to suit the specific environment and circumstances of the mine 3. Regardless of the specific methodology employed, the detection and ranging of the magnetic signal renders the invention suitable for accurately identifying the location of the mining machine, even through intervening strata, which provides a substantial advantage over the prior art locations techniques.

[0058] Since the invention provides accurate and continuous monitoring and tracking of the mining machine, the cycle of a mining operation does not need to be interrupted to check the position of the machine. Operation cycles can be monitored remotely and planned with accuracy in advance. This assists with general mine management and can be used to generate operational reports used for process optimization, training and simulation.

[0059] The positional information and tracking combined with additional input of the machine sensors to accurately locate the operational positions of various mining equipment and tools means many mining operations can be automated. By feeding in data from operational movement detectors, such as solid-state gravity sensor (MEMS) based pitch and roll detectors, the effect of external movement of the mining machine on the emitter unit 6 can be taken into account and compensated for, to provide an even more accurate mapping and tracking of the mining machine.

[0060] An embodiment of the invention relates to a system for determining a position of a mining machine in an underground mine. The system comprises a first emitter unit and a first receiver unit. (Terms such as "first" and "second" are provided as labels to differentiate elements from one another, and are not meant to necessarily denote an order or placement, or to indicate that an embodiment necessarily includes multiple of said elements.) One of the emitter unit or the receiver unit is configured to be positioned in fixed relation to a mine wall. For example, the emitter unit or receiver unit may be configured to be fixed on the mine wall, including having a housing suitable for a mine environment, e.g., water resistant, dust resistant, shock resistant, or the like, and an attachment assembly, coupled to the housing, for attaching the unit to the wall. The other of the emitter unit or the receiver unit is configured to be mounted relative to the machine. For example, the emitter unit and/or the receiver unit may be configured to be mounted to the machine. This includes the emitter unit and/or the receiver unit being built into the machine, such that the emitter unit and/or the receiver unit is in-effect permanently part of the machine. The emitter unit is configured to transmit a coded magnetic signal for receipt by the receiver unit. The system further comprises at least one processor configured to identify a distance and a relative angle between the emitter and receiver units based on the signal as received by the receiver unit. For example, the processor may be part of the emitter unit, part of the receiver unit, part of the mining machine (e.g., a processor on the mining machine that is also used to control movement or other operations of the mining machine), a processor located in a central mine operations control room, or the like, and/or the various functions may be performed in a distributed manner across multiple such processors.

[0061] In operation, one of the emitter unit or the receiver unit is positioned in fixed relation to a mine wall, e.g., attached to the mine wall. The other of the emitter unit or the receiver unit is mounted relative to the machine, e.g., attached to the machine. The emitter unit transmits a coded magnetic signal, which is received by the receiver unit. Information of the coded magnetic signal as received by the receiver unit is communicated to the at least one processor. The at least one processor identifies a distance and a relative angle between the emitter and receiver units based on the information.

[0062] In another embodiment, the system further comprises a first antenna associated with the receiver unit (e.g., attached to the receiver unit) for transmitting information to the at least one processor relating to the signal as received by the receiver unit.

[0063] In another embodiment, the emitter unit includes a second antenna for receiving the information from the receiver unit, such that the emitter and receiver units operate in a closed communications loop.

[0064] In another embodiment, the system comprises multiple emitter units (e.g., the first emitter unit and plural second emitter units), each with a respective coded magnetic field generator. For example, each emitter unit may include a pitch and yaw mechanism for mechanical rotation of its respective magnetic field generator.

[0065] In another embodiment, the system comprises an array of receiver units (e.g., the first receiver unit and plural second receiver units) for receiving respective uniquely coded magnetic signals from the multiple emitter units.

[0066] In another embodiment of a system for determining a position of a mining machine in an underground mine, the system comprises a first emitter unit, a first receiver unit, and at least one processor. One of the emitter unit or the receiver unit is configured to be positioned in fixed relation to a mine wall. The other of the emitter unit or the receiver unit is configured to be mounted relative to the machine. The emitter unit is configured to transmit a coded magnetic signal for receipt by the receiver unit. In addition to circuitry for transmitting and receiving the coded magnetic signal, the emitter and receiver units further comprise respective antennas and transceivers for RF or other wireless communications. The receiver unit is configured to communicate, using its respective antenna and transceiver, information about the coded magnetic signal as received by the receiver unit. The at least one processor (e.g., which may be part of the emitter unit) is configured to identify a distance and a relative angle between the emitter and receiver units based on the information (about the signal as received by the receiver unit) transmitted by the receiver unit and received by the emitter unit.

[0067] The invention has been described with reference to the location of a mining machine (e.g., a mining vehicle) in a mine, however the principle of using low frequency magnetic field detection is equally applicable for locating any other type of object in any suitable environment.

[0068] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as, an acknowledgement or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

[0069] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

CLAIMS

1. A system for determining a position of a mining machine in an underground mine, the system comprising:

a first emitter unit and a first receiver unit, one of the emitter unit or the receiver unit configured to be positioned in fixed relation to a mine wall and the other of the emitter unit or the receiver unit configured to be mounted relative to the machine, wherein the emitter unit is configured to transmit a coded magnetic signal for receipt by the receiver unit, the system further comprising at least one processor configured to identify a distance and a relative angle between the emitter and receiver units based on the signal as received by the receiver unit.

2. The system of claim 1, further including a first antenna associated with the receiver unit for transmitting information to the at least one processor relating to the signal as received by the receiver unit.

3. The system of claim 2, wherein the emitter unit includes a second antenna for receiving the information from the receiver unit such that the emitter and receiver units operate in a closed communications loop.

4. The system of claim 3, further including multiple second emitter units, wherein each of the first emitter unit and the second emitter units comprises a respective coded magnetic field generator.

5. The system of claim 4, wherein each of the first and second emitter units includes a pitch and yaw mechanism for mechanical rotation of the respective magnetic field generator.

6. The system of claim 4, further including an array of the first receiver unit and multiple second receiver units for receiving respective uniquely coded magnetic signals from the first and second emitter units.

7. The system of claim 6, wherein the emitter units function to provide 3-dimensional positioning information to allow tracking of the machine.

8. The system of claim 7, wherein the emitter units are mounted on the mining machine.

9. The system of claim 8, wherein the receiver units are arrayed at predetermined locations through the mine.

10. The system of claim 1, further including a mapping module for displaying an image and a position of the machine in the mine.

11. The system of claim 10, further including equipment sensors arranged to feed into the mapping module to enable display of an operational position of one or more components of the machine.

12. The system of claim 1, further including detectors on the machine, to monitor operational movement of the machine, said operational movement comprising at least one of tilt, roll, or vibration, and the at least one processor is configured to compensate for the operational movement.

13. A method of tracking a mining machine in a mine using signal transmission between at least one emitter unit and at least one receiver unit, wherein one of the emitter unit or the receiver unit is positioned in fixed relation to a mine wall and the other of the emitter unit or the receiver unit is mounted relative to the machine, the method including transmitting a coded magnetic signal from the emitter unit, receiving the signal at the receiver unit, and sending information in relation to the received signal to a processor in order to calculate a range and a relative angle between the emitter and receiver units.

14. The method of claim 13, wherein the emitter unit provides 3-dimensional position information to allow tracking and mapping of the machine.

15. The method of claim 13, wherein the coded magnetic signal is transmitted by way of a through-strata coded magnetic field and the range and angle calculated between the units allows relative position of the emitter unit in the mine to be determined in 3-dimensions.

16. The method of claim 13, wherein peak signal strength detection is used to find the most direct angle between the emitter unit and receiver unit.

17. The method of claim 13, wherein the information from the receiver unit, resulting from reception of the signal, is sent to the processor via wireless radio link.

18. The method of claim 17, wherein the information sent over the radio link is received by an antenna of the emitter unit such that the signal transmission, reception, and return sending of the information occurs in a closed communications loop.

19. The method of claim 13, wherein the at least one receiver unit comprises an array of receiver units, and the position of the mining machine is tracked using the array of receiver units.

20. The method of claim 19, wherein the at least one emitter unit comprises multiple emitter units mounted to the mining machine, and the method includes generating respective uniquely coded signals from the emitter units so that the signals, received by the receiver units which are respectively associated with the emitter units, are able to be separately identified as originating from the respective emitter units.

21. The method of claim 13, wherein the tracking is performed continuously to follow movement of the mining machine in real time.

22. A mining operation including tracking a mining machine, in accordance with the method defined in claim 13, and identifying the position of the mining machine on a displayed map of the mine.

23. The mining operation of claim 22, wherein the identified position of the mining machine is used to control operation cycles of the mining machine.

24. The mining operation of claim 23, further including displaying operational positions of components of the mining machine on the displayed map, based on input form equipment sensors on the mining machine.

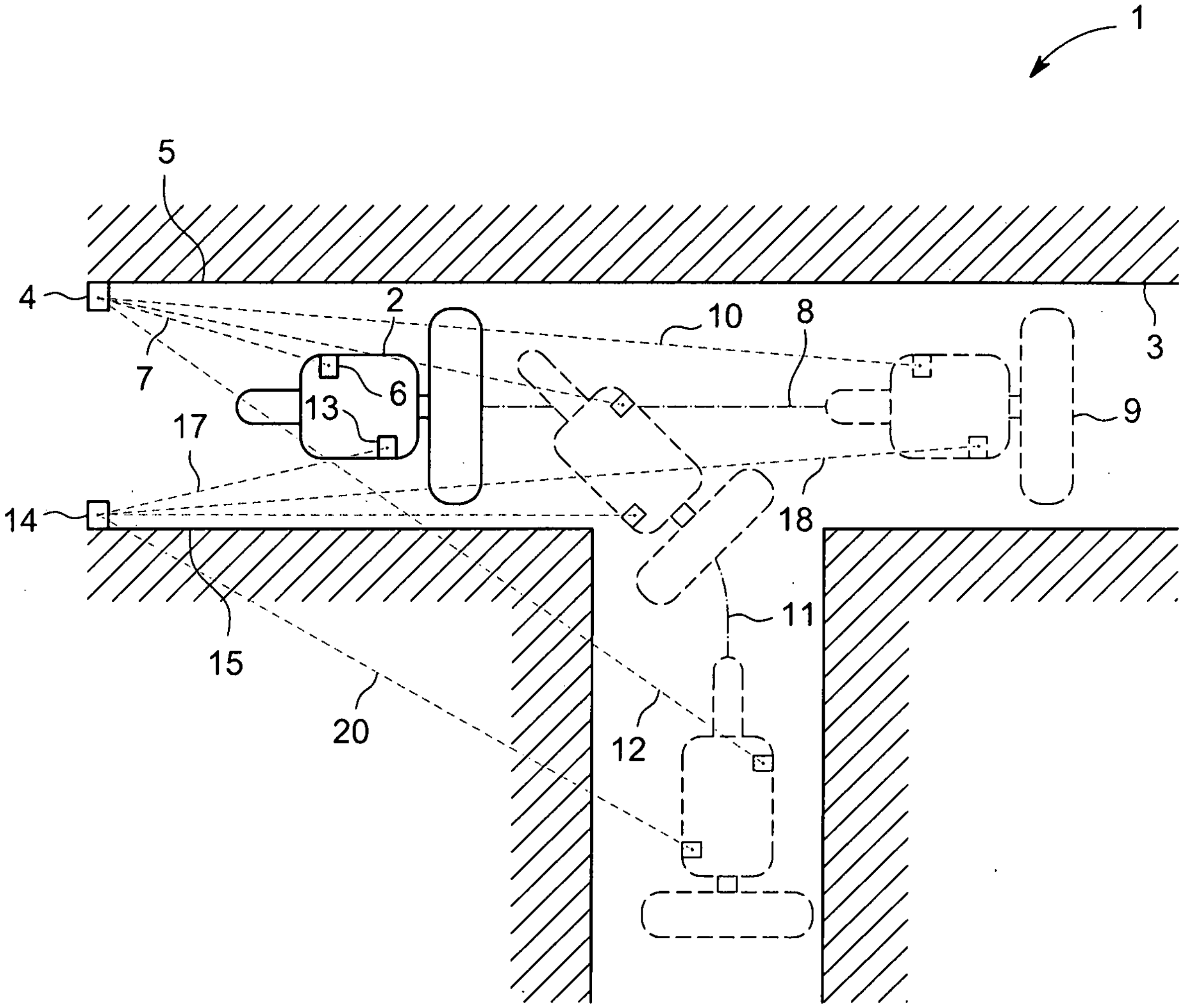

FIG. 1

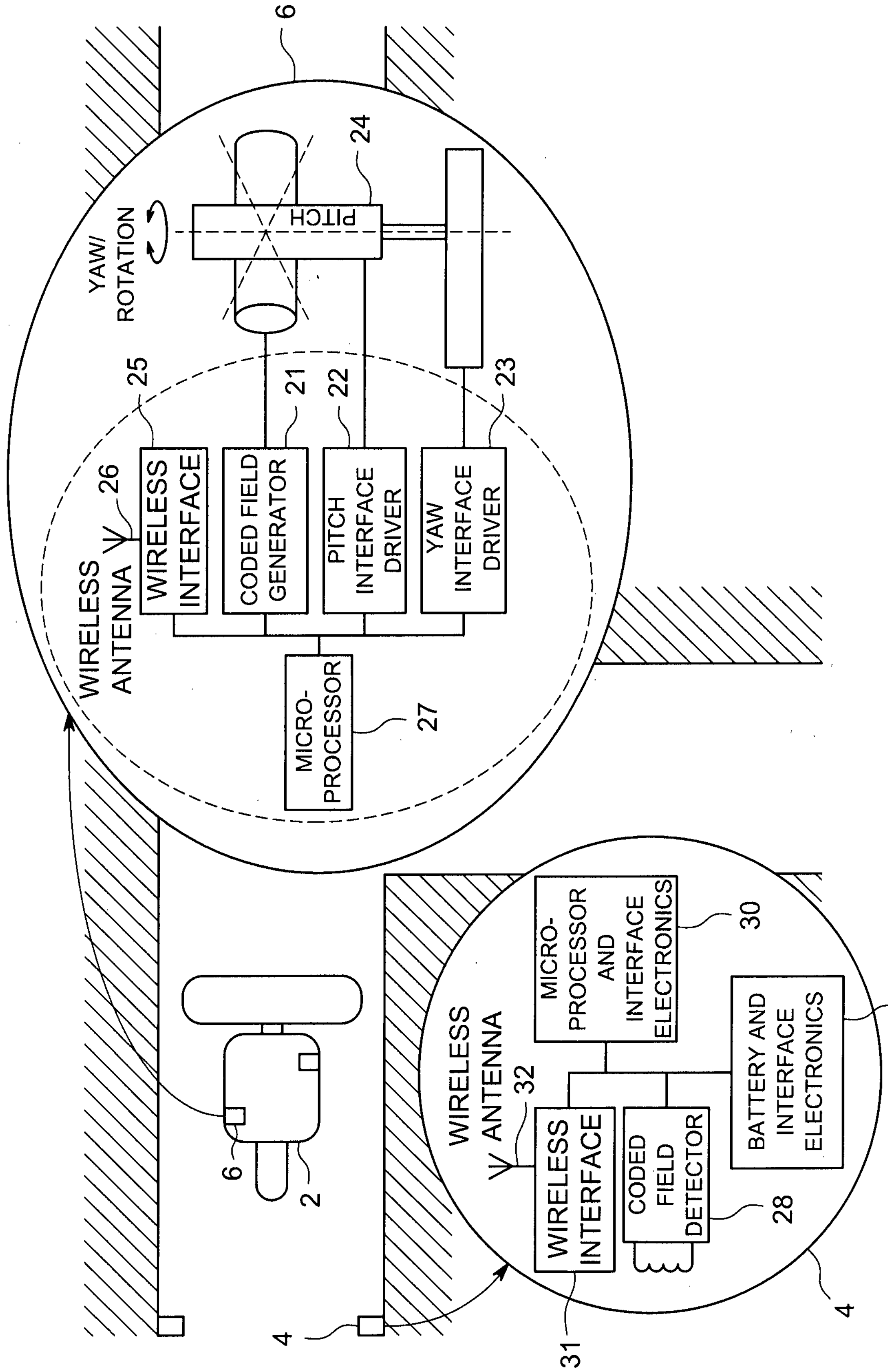
YAW/ ROTATION
PITCH
WIRELESS ANTENNA
WIRELESS INTERFACE
CODED FIELD GENERATOR
PITCH INTERFACE DRIVER
YAW INTERFACE DRIVER
MICRO-PROCESSOR
MICRO-PROCESSOR AND INTERFACE ELECTRONICS
BATTERY AND INTERFACE ELECTRONICS
CODED FIELD DETECTOR
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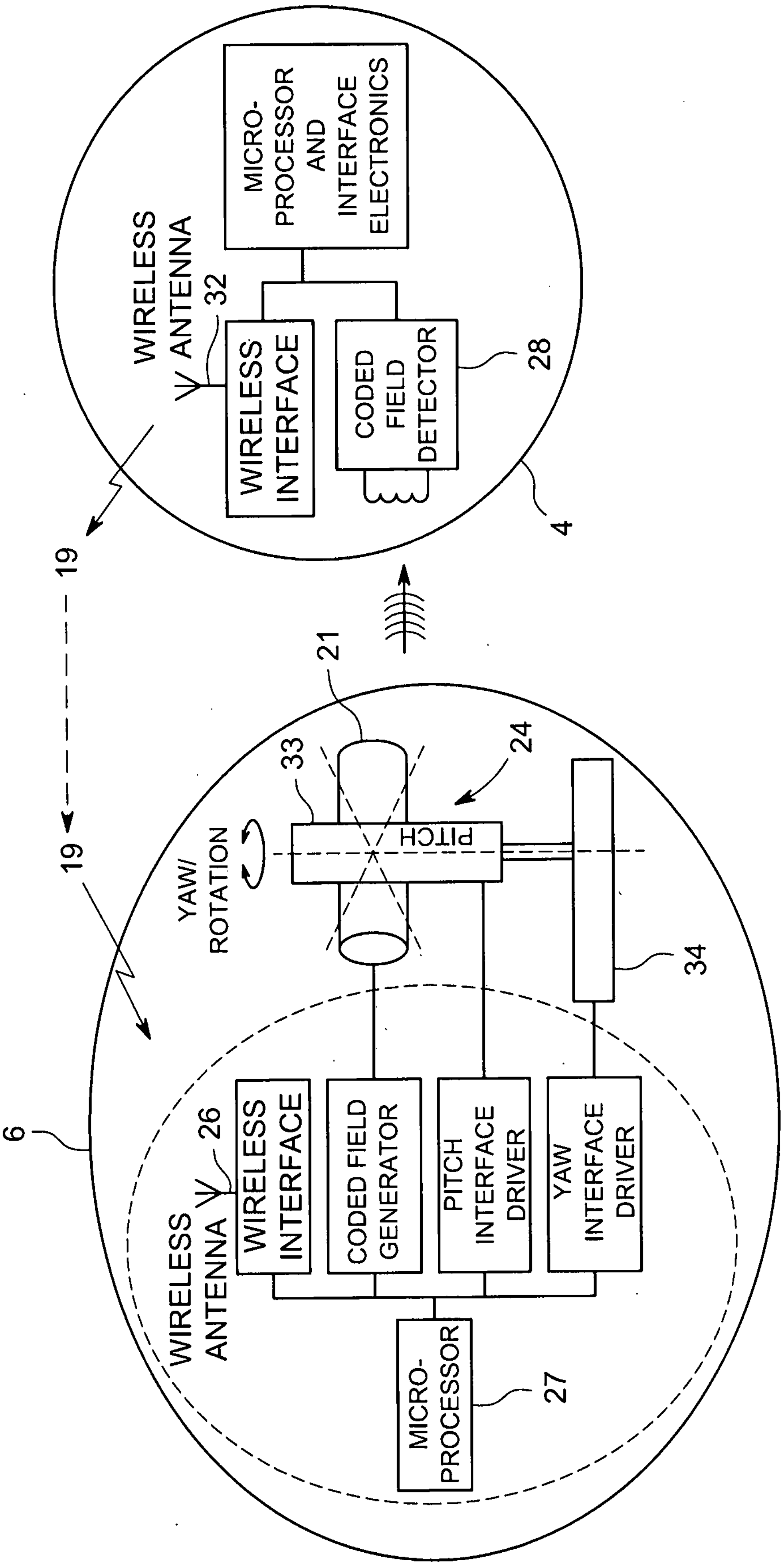
FIG. 2



MICRO-PROCESSOR AND INTERFACE ELECTRONICS
WIRELESS ANTENNA
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WIRELESS INTERFACE
CODED FIELD DETECTOR
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4
19
19
21
33
24
PITCH
YAW/ ROTATION
34
6
26
WIRELESS ANTENNA
WIRELESS INTERFACE
CODED FIELD GENERATOR
PITCH INTERFACE DRIVER
YAW INTERFACE DRIVER
MICRO-PROCESSOR
27

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2014/000302

A. CLASSIFICATION OF SUBJECT MATTER

E21C 35/00(2006.01)i, G01C 21/10(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21C 35/00; B63G 7/02; G01B 7/14; G06F 9/44; G05D 1/00; G01V 3/08; G01C 21/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: position, mining, emitter, receiver, processor, distance and angle

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013-0038320 A1 (FREDERICK, LARRY D.) 14 February 2013 See paragraphs [0021]-[0059]; claim 1; and figure 1.	1-24
A	US 2011-0248706 A1 (DAVIS et al.) 13 October 2011 See paragraphs [0005]-[0014] and claim 1.	1-24
A	US 2012-0286789 A1 (MERCER et al.) 15 November 2012 See paragraphs [0006]-[0007] and claim 1.	1-24
A	US 2010-0312428 A1 (ROBERGE et al.) 09 December 2010 See claims 1,13 and figure 3.	1-24
A	US 6802237 B1 (JONES et al.) 12 October 2004 See claims 1,14.	1-24

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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