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“Communication unit in a mining machine”

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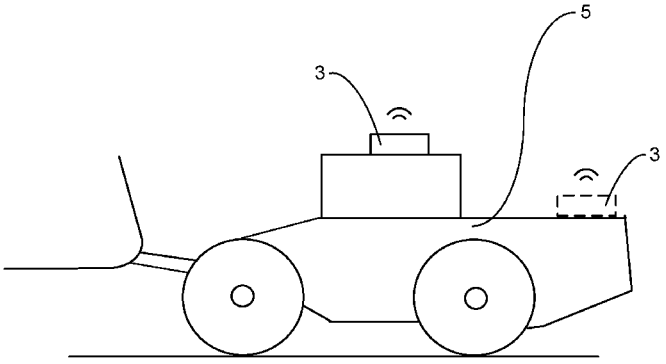

Fig 4

(57) Abstract: The present invention relates to a communication unit (3) in an at least partially remotely controlled mining machine (5). The invention also comprises an at least partially remotely controlled mining machine (5) comprising such a communication unit and a method for remote control of an at least partially remotely controlled mining machine. Said communication unit (3) in an at least partly controlled mining machine is adapted for transferring remote control information between a machine operator and a control system in the mining machine via one or more access points in a wireless communication system in a mine. The communication unit (3) further comprises a radio unit and two or more antennas provided in a space defined by an enclosing protective housing. Said two or more antennas are directional antennas. The radio unit is adapted for data communication with the control system of the machine via one or more data links.

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Communication unit in a mining machine

TECHNICAL FIELD

The present invention relates to a communication unit in an at least partially remotely controlled mining machine. The invention also relates to an at least partially remotely controlled mining machine comprising such a communication unit and a method for remote control of an at least partially remotely controlled mining machine.

BACKGROUND

Underground mines typically include extensive underground tunnel systems. A mine gallery or mine tunnel is a tunnel used to reach an ore in a rock during mining. The mine galleries extend in the direction of the mine deposit in the rock; a mine usually includes a combination of mine tunnels extending in an essentially horizontal direction, tunnels extending in an angled direction to the horizontal plane and mine shafts extending in a vertical direction.

Modern underground mine tunnels are usually quite spacious in order to allow transportation by heavy machinery and trucks; such as drilling, loading and transport machinery and vehicles. Such machinery and vehicles are to an increasing extent unmanned, or more accurately remotely controlled by an operator working in a control room at a distance from the place where the actual mining is performed. Remote control of mining machines brings about a number of advantages, not the least with regard to safety and security, since remote control allows reducing the working staff in the mine tunnels.

Remote control of mining machinery is enabled using wireless communication based on the standard IEEE 802.11, more commonly known as Wi-Fi. The operation of the mining machinery requires that the wireless communication can be maintained reliably. Dropped contact between the machine and an operator station implies a production loss as well as a security risk.

An important component for reliable radio communication with a mobile, remote mining machine is the antenna system used in the mobile device for receiving a signal transmitted from the infrastructure of a wireless communication system. The wireless communication

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system transmits and receives signals from the mobile device via one or more access points. A communication link to an access point may also include communication via several mining machines in a multi-hop or ad-hoc communication system. Most movable mining machines, such as drilling machines and loading machines, comprise movable parts that move in relation to the fixed antennas of the antenna system. These movable parts have a major impact on radio conditions and, depending on position, have a significant negative impact on the receive and transmit capability of the radio system. It is possible to improve reception of the radio signal transmitted from an access point by arranging several receive antennas on the mining machinery. The use of multiple receive antennas, so-called antenna diversity, implies that the transmitted signals are received in multiple versions through respective antennas. A signal sent from an access point located in a mine tunnel, will be reflected and phase shifted on the way to the receiver. The signal will arrive at the receiver via multiple paths with different strength. In an antenna system where multiple antennas are combined, this ratio can be used for improved communication. The location and angle of the antenna at the reception point affect which of the signal paths in the mine tunnel that provides the strongest signal strength. Using multiple antennas it is possible to select signals from different signalling pathways at every moment to select the best signal.

In contemporary mining machinery, two or more antennas are arranged at different positions on a surface of the machinery. Two or more omnidirectional antennas are connected to one or more radio modules using coaxial cables.

A problem with this solution is that the antenna wiring may cause unnecessary losses and attenuation of the signal. Another problem with the present solution is that the mining machine further comprises a number of movable parts which are at risk of being exposed to such mechanical stress that the communication between the antenna and adhering radio module is affected. Another problem with the present solution is the relatively complex mounting required when one or more radio modules are to be mounted at different positions in the mining machinery.

SUMMARY OF THE INVENTION

The inventor has realized that there is a need for a more robust communication solution that is better adapted to the special conditions prevailing in the mining environment. It is an

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advantage of at least one embodiment of the present invention to provide a wireless communication unit for use in an at least partially remotely controlled mining machine, which communication solution reduces the above mentioned problems and deficiencies in prior art communication solutions and provides for more reliable and robust remote control of mining machines.

Another advantage of at least one embodiment is to provide a wireless communication unit in an at least partially remotely controlled mining machine, which unit is easy to install on various types of mining machines and is easy to replace in case of error in the radio communication unit.

Another advantage of at least one embodiment of the invention is to reduce cable losses during transfer of antenna signal from the antenna to the receiver.

These advantages are provided through a communication unit in an at least partially remotely controlled mining machine, as disclosed in claim 1, a mining machine comprising a communication unit as disclosed in claim 10 and a method for remote control of an at least partially remotely controlled mining machine as disclosed in claim 12.

According to an aspect of the invention, a communication unit is arranged in an at least partially remotely controlled mining machine, which communication unit is arranged to transfer control information for remote control between an operator and a control system of the at least partially remotely controlled mining machine. The control information for remote control is arranged to be transferred to the communication unit via one or more access points in a wireless communication system in a mine. The communication unit comprises a radio unit and two or more antennas, provided in a space defined by an enclosing protective housing. Said two or more antennas are directional antennas. The radio unit is adapted for data communication with the control system of the mining machine, the mining machine at least in part being remotely controlled via one or more data links.

The new design solution for a communication unit in an at least partially remotely controlled mining machine provides a communication solution with advantages with regard to antenna diversity, low cable loss and a solution that is less vulnerable to mechanical impact and the special conditions prevailing in a mining environment.

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According to an aspect of the invention, the data links between the communication unit the control system of the mining machine are wireless.

Wireless data links between the communication unit and the control unit implies that the cabling associated with the communication unit may be further reduced, which is advantageous when mounted on a mining machine with a plurality of movable parts and complicated patterns of operation.

According to an aspect of the invention, the communication unit is adapted for mounting at a position on a body surface of the mining machine.

The mounting on the body surface of the mining machine provides the advantage that the mounting of the communication unit is very simple to perform, for example on site in the mine. Furthermore, this aspect of the invention also provides the advantage that the communication units are eligible for retrofit on mining machines already in use on site in a mine or that the communication units easily may be replaced when working less satisfactorily.

According to a further aspect of the invention, the directional antennas of the communication unit are directed with antenna lobe directions facing away from one another.

By selecting directional antennas with narrow antenna lobes and directing these in relation to one another to avoid overlapping antenna lobes, it is possible to achieve a compact, integrated solution for a communication unit.

According to another aspect of the invention, the directional antennas are patch antennas, each comprising two antenna elements. A power splitter is provided between each directional antenna and the radio unit.

This type of antennas provides the advantage of being rugged and, due to the circuit board structure, may easily be integrated in a communication unit. Furthermore, these antenna provide very good electrical properties.

According to a further aspect of the invention, the communication unit is adapted for operation in underground mining.

The antenna design is particularly well suited for the multipath distribution conditions that are prevailing in underground tunnels, i.e. mines for underground operation, where the position

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of the communication unit on the mining machine and the antenna of the communication unit are adaptable to the radio distribution from an access point in the mine tunnel.

According to another aspect of the invention, the communication unit further includes a positioning system adapted for wireless positioning of the mining machine.

Integration of a positioning system in the communication unit provides an even more compact unit comprising all communication equipment required for safe remote control of the mining machine.

According to an aspect of the invention, the positioning system is integrated with the radio unit and the positioning is arranged to be performed based on a distance to one or more access points in the wireless communication system and information on the mine tunnel where the mining machine is arranged to operate.

According to an aspect of the invention, the communication unit is arranged for remote control of an at least partially autonomous mining machine and in that control commands received in the communication unit have priority over control commands generated in the at least partially autonomous mining machine.

Another embodiment of the invention relates to a mining machine comprising a communication unit according to said aspects.

According to another aspect of the invention, the position for mounting the communication unit on the body of the mining machine is dependent on a pattern of operation of one or more controllable, movable parts of the mining machine.

Thereby, mounting is adapted to the field of operation/functionality of the mining machine so that the placement of the communication unit is adapted to the movable parts of the mining machine and a pattern of operation of the mining machine. The position is selected such that the direction of the antennas of the communication unit are optimized to the infrastructure represented by the access points of the wireless communication system. The mounting position for the communication unit on a mine loader will be different from that of a drilling machine.

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Another embodiment of the invention relates to method in a communication unit for remote control of an at least partially remotely controlled mining machine. The communication unit comprises a radio unit and two or more antennas. The method comprises to receive control information in the communication unit via two or more antennas that are arranged to be accommodated in a space defined by a housing that also comprises the radio unit and one or more power splitters. The control information for remote control is originated by a machine operator and is communicated via wireless transmission between the communication unit and one or more access points in a wireless communication system in a mine. The method further comprises to send the control information for remote control to the control system of the at least partially remotely controlled mining machine via a data link from the communication unit to the control system.

According to an aspect of the invention, the method further comprises to send control related information from the communication unit to the machine operator, which control related information comprises visual recordings from one or more cameras on the mining machine.

The control related information facilitates remote control of the mining machine by providing feedback to the machine operator with regard to the mining machine and its surroundings.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more comprehensive understanding of the present invention and additional purposes and advantages of the invention, a detailed description is provided below that should be read together with the accompanying drawings. Like numbers in the drawings refer to like elements throughout.

Figure 1 schematically illustrates wireless communication between a mining machine and access points in a wireless communication system in an underground mine;

Figure 2 schematically illustrates a block diagram for a radio communication unit in accordance with an embodiment of the invention;

Figure 3 schematically illustrates an embodiment of a communication unit seen in perspective view;

Figure 4 schematically illustrates a mining machine comprising a radio communication unit according to an embodiment of the invention and

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Figure 5 is a flow chart illustrating method steps for a method performed in a communication unit for remote control of a mining machine.

DETAILED DESCRIPTION

Figure 1 schematically illustrates wireless communication between the mining machines 5 and access points of a wireless communication system 1 in an underground mine. As illustrated in the figure, the underground mine tunnels in modern mining are designed for the movement of heavy mining machines 5, such as drilling, loading and transport machinery and vehicles. Mining operations are also characterized by an increasingly high degree of automation, such as remote control or autonomous/semi-autonomous operation of mining machines 5. Remote control and semi-autonomous operation takes place from the central operator stations in a control room at a distance from the place where the mining work is underway. For remote control of mining machines 5, wireless communication via access points 7 is used, for example based on the IEEE 802.11 standard, more commonly known as WiFi. For wireless remote control to be achieved in a reliable manner, it is important that a reliable signal transmission can be effected between the management station and the controlled mining machine 5. The wireless transmission from the communication unit to the access node, may be performed by a communications link established directly between the communication unit in a mining machine and an access node. It is also possible to establish an ad-hoc network between the mining machines so that communication from a mining machine to an access node is in a multi-hop scenario where two or more communication units are arranged to communicate with each other and where one of the communication units may be an aggregating function for connecting to the wireless WiFi network.

An important component for reliable radio communication with a mobile, remote mining machine 5 is the antenna used in the mobile device to receive the transmitted signal. A problem associated with many mining machines 5, such as drilling machines and loading machines, is that they comprise bulky moving metal parts which move relative to the fixed antennas. These metal parts have a major impact on radio conditions and depending on the position, have a significant negative impact on a receive and transmit capability of a radio unit 5.

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Figure 2 schematically illustrates a block diagram of a communication unit 3 according to an embodiment of the invention. The communication unit 3 is arranged to transmit remote control information from a machine operator to a control system of the mining machine, but also to feedback information from the control system or other components of the mining machine 5 to the operator. The communication unit 3 is to be used for remote control of mining machines, but is also suitable for communication with the mining machine 5 when operated autonomously or semi-autonomously. Autonomous or semi-autonomous operation requires the existence of a communication link between the operator and the mining machine, whereby the operator can take over control of the machine in cases where the conditions for autonomous operation are impaired, for example when there are significant deviations from ordinary operating conditions.

The illustrated communication device comprises two directional antennas 13, arranged at a distance from each other in the communication unit. The antennas 13 are arranged to receive and send information via access points to the mine's wireless communication systems such as communication based on WiFi. Communication can take place via an access point 7 to the WiFi network, but the communication unit can also be adapted for connection to several access points in the network, or as previously mentioned to other communication units in the network. The use of multiple antennas, so-called antenna diversity, implies that it is possible to receive multiple versions of the transmitted signal through multiple antennas. A signal sent from an access point located in a mine tunnel will be reflected and phase shifted on the way to the receiver. The signal will arrive at the receiver via multiple paths with different strength. In an antenna system where multiple antennas are combined, this may be used to improve communication. The location and the angel of the antenna during reception provide an influence on which of the signal paths that provide the strongest signal. With multiple antennas it is possible to pick up signals from different signal paths and at every instance select the signal that is the best.

According to one aspect of the invention, the antennas 13 are patch antennas each comprising two antenna elements. As illustrated in Figure 2, the directional antennas 13 are positioned at a distance from each other in the communication unit. Directional antennas 13 are also given such a direction that the antenna lobes for each antenna 13 essentially has an apart-directional propagation facing away from one another. In one aspect of the invention,

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distance and direction of the directional antennas 13 are adapted to substantially match the multipath conditions in a mine tunnel in an underground mine, where the radio waves are subject of reflection and phase shift when tunnelled, extending in the tunnel, between the transmitter and receiver. By the choice of sharp directional antennas 13, a communication unit 3 is achieved whose size is small relative to a mining machine 5 on which the communication unit is to be mounted.

According to one aspect of the invention, the communication unit 3 further comprises at least one power splitter 11 coupled to a respective patch antenna and adapted to the frequency band of the wireless communication system 1, e.g. ISM 2.4 GHz. The power splitter is used to determine what/which signals that should be carried on from the antenna elements. A radio unit 9 in the communication unit 3 comprises conventional radio components such as transceiver, memory and processor. The radio unit is further adapted for data communication with the control system of the mining machine 5 via one or more data links. Directional antennas 13, the power splitters 11 and the radio unit 9 are physically interconnected in the communication unit 3 via cables, such as coaxial cables. The radio unit 9 processes the communication unit 3 of the received signals and provides one or more control signals on the one or more data links to the control system of the mining machine 5.

Figure 3 schematically illustrates a physical embodiment of the communication unit 3 in a perspective view. In the illustrated embodiment, the components illustrated in the block diagram are surrounded by a protective housing 15. The protective housing defines a space in which said components are housed. Figure 3 shows an embodiment of such a protective housing 15 comprising a combination of a box-shaped space and antenna covers. The box-shaped space formed by a bottom section 17b and a lid 17a mountable on this bottom section defines the box-shaped space. The protective housing 15 further comprises two or more antenna covers 19 mounted along the side of the bottom section 17b of the box shaped space so that each antenna is protected by an antenna cover 19. The antenna covers 19 along with the illustrated bottom section 17b and the lid 17a form the surrounding protective housing 15 which define a space in which the radio unit, the power splitters and the two or more antennas are contained. The bottom section 17b and the lid 17a may preferably be formed of metal, while the antenna housings are formed of a plastic material or other material with minimal impact to transmission or reception of radio waves. Other realizations of a

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surrounding housing are of course also possible and the invention is not limited to the illustrated exemplary embodiment. The illustrated embodiment is realized with dimensions 25x25x14 cm. Other dimensions are also within the scope of the invention, but the structural solution is based on that the communication unit has a relatively small volume, which means that a side/diameter of the surrounding housing is of the order of 5-50 cm, while the height of the communication unit is in the order of 5-30cm. The small size of the communication unit is important since this allows installation on many different types of remotely controlled mining machines regardless of their form or function.

The inventive communication unit 3 preferably comprises a plurality of fasteners 21 for fastening the communication unit to the mining machine. Such fasteners 21 preferably consist of brackets that are connected to the communication unit via screw or rivet joints. Said brackets then provides the conditions for assembly of the communication unit on a body surface of the mining machine. Other types of fasteners are of course also within scope of the invention, such as a rail or profile along a longitudinal direction of the communication unit and where the communication device attaches to a rail with a corresponding profile that is arranged at a desired position on the body surface of the mining machine. The fasteners 21 can also be magnetic for magnetic attachment of the communication unit to the body surface of the mining machine 5.

The schematic illustrations of the communication unit 3 do not include connections to and from the communication unit. Such is assumed, of course, for connection of the communication unit 3 to the mining machine 5. The communication unit is equipped with one or more data ports and a connection for the power supply. Each data port is connected to the vehicle control system via data cable. According to an aspect of the invention, data transfer from the communication unit to the control system of the vehicle may be performed via wireless communication.

In one aspect of the invention, the communication unit 3 shown in figure 2 further comprises a positioning system adapted for wireless positioning of the mining machine 5. Such a positioning system may be a separate component in the communication unit 3 (not illustrated), but may also be part of the radio unit 9. According to another aspect of the invention, the wireless communication system 1 is used for positioning of the mining machine

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5 so that the positioning system is integrated with the radio unit and position determination is performed based on the distance to one or more access points in the wireless communication system 1 together with information on a mine tunnel where the machine is adapted to work. Positioning in underground mines may be problematic since there is a lack of contact with generally accessible communication solutions. Instead, known reference points in the mine are used for positioning. By providing for positioning in the communication unit 3, remote control as well as autonomous operation of the mining machine may be facilitated and improved.

As previously mentioned, secure communication solutions are an important aspect also during autonomous operation of a mining machine 5. In case of unforeseen events that the autonomous systems is not equipped to handle, the control commands received in the communication unit are given precedence to control commands generated in an autonomous mode for the mining machine.

Figure 4 schematically illustrates a mining machine 5 comprising a communication unit 3. As illustrated in the figure, it is also possible to equip the mining machine with several communication units 3. A further communication unit 3 is indicated with dashed lines in the figure. The communication unit 3 is mounted at a predetermined position on the mining machine 5. The predetermined position is such a position on the body of the mining machine where the best radio conditions have been assessed to prevail for the communication unit based on the moving parts that are part of the mining machine 5 and the pattern of operation of the mining machine 5. When in use in mining machines 5 comprising multiple movable parts moving in all directions in relation to the mining machine, a solution mounting a plurality of communication units 3 on the mining machine may be suitable. The position for mounting the communication unit 3 on the mining machine is appropriately determined by testing the radio conditions when the mining machine is in operation, for example a position where a position of free sight is to be guaranteed or expected between the communication unit 13 and the antennas/access points of the wireless communication system. When an appropriate position has been found for a mining machine 5 of a certain type, markings may be provided on the mining machine 5 to indicate this position, e.g. using pre-drilled holes for receiving fasteners for the communication unit 3. Other types of position markings are of course also possible, for example indications in the paint work of the body surface of the mining machine

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5. The ability to test and predict the positioning of a communication device for various types of mining equipment is an important advantage of the invention. By adapting the position of the communication unit 3 to the working method and patterns of operation of specific mining machines 5, adequate radio performance is achieved even for mining machines 5 that require high radio performance, such as forklifts and loaders.

Figure 5 schematically illustrates a flowchart of a method performed in a communication device for remote control of an at least partially remotely controlled mining machine. The communication unit is assumed to comprise a radio unit and two or more antennas.

According to one aspect of the invention, the method comprises an optional step S51 where the communication unit transmits information associated with control of the machine to a management station in a control centre with information relating to the mining machine and the surrounding environment for this. Information associated with control of the machine may be provided in the form of video recordings form one or more cameras on the mining machine. The information is used by the operator of an operator station when remotely controlling the mining machine.

In accordance with a basic embodiment of the method performed in the communication device, the method comprises receiving in the communication unit S52 wireless remote control information over the two or more antennas, which are arranged to be comprised in a space defined by a housing that also comprises the radio unit and any power splitters. Remote control information is derived from a machine operator and is communicated through wireless communication between the communication unit and one or more access points in a wireless communication system in a mine.

In a next step S53, the communication unit transmits a data signal extracted from the received remote control signal to the control system of the mining machine via a data link from the communication unit to the control system.

Thus, the inventive communication unit is, according to an aspect of the invention arranged for two-way communication with an operator station.

The foregoing description of preferred embodiments of the present invention has been provided for the purpose of illustration and description. It is not intended to be exhaustive or

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to limit the invention to the variants described. Obviously, many modifications and variations are apparent to those skilled in the art. The embodiments were chosen and described to best explain the principles of the invention for various embodiments and with the various modifications disclosed for the intended use.

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CLAIMS

1. A communication unit arranged in an at least partially remotely controlled mining machine, which communication unit is arranged to transfer control information for remote control between an operator and a control system of said mining machine via a wireless communication system in a mine and which communication unit comprises a radio unit and two or more antennas, **characterized in** that the radio unit and said two or more antennas are comprised in a space defined by an enclosing protective housing, that said two or more antennas are directional antennas; and that the radio unit is arranged for data communication with the control system of said mining machine by means of one or more data links.

2. The communication unit of claim 1, **characterized in** that said one or more data links are wireless.

3. The communication unit of claim 1 or 2, **characterized in** that the communication unit is adapted for mounting at a position on a body surface of the mining machine.

4. The communication unit of any one of claims 1 to 3, **characterized in** that the directional antennas are directed with antenna lobe directions facing away from one another.

5. The communication unit of any one of the preceding claims, **characterized in** that the directional antennas are patch antennas each comprising two antenna elements and in that a power splitter is provided between each directional antenna and the radio unit.

6. The communication unit of any one of the preceding claims, **characterized in** that the communication unit is adapted for operation in underground mining.

7. The communication unit of any one of the preceding claims, **characterized in** that the communication unit further comprises a positioning system adapted for wireless positioning of the mining machine.

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8. The communication unit of claim 7, **characterized in** that the positioning system is integrated with the radio unit and the positioning is arranged to be performed based on a distance to one or more access points in the wireless communication system and information on the mine tunnel where the mining machine is arranged to operate.

9. The communication unit of any one of the preceding claims, **characterized in** that the communication unit is adapted for communication with an at least to a part autonomously operating mining machine.

10. A mining machine, **characterized in** that it comprises the communication unit of any one of claims 1 to 9.

11. The mining machine of claim 10, **characterized in** that the position for mounting the communication unit on the body of the mining machine is dependent on a pattern of operation of one or more controllable, movable parts of the mining machine.

12. A method performed in a communication unit arranged in an at least partially remotely controlled mining machine, for remote control of the at least partially remotely controlled mining machine, which communication unit comprises a radio unit and two or more antennas, the method comprising:
    - receiving wireless remote control information in the communication unit via said two or more antennas adapted to be comprised in a space defined by a housing and also comprising the radio unit, which remote control is derived from a machine operator and is communicated by means of wireless communication between the communication unit and the one or more access points of a mine; and
    - transmitting received remote control information to the at least partially remotely controlled mining machine, via a data link from the communication unit to a control system of said mining machine.

13. The method of claim 12, further comprising:

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- sending control related information from the communication unit to the machine operator, the control related information comprising video recordings from one or more cameras on the mining machine.

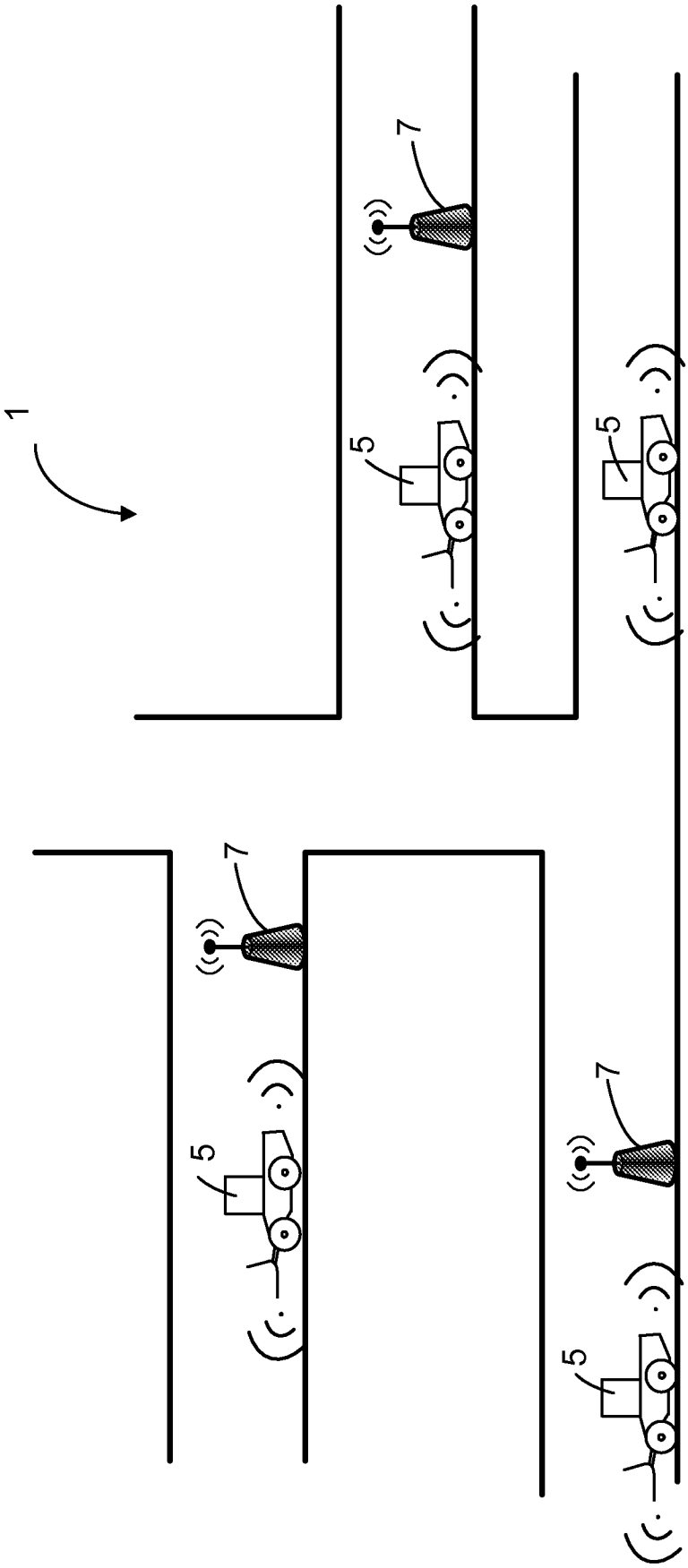

Fig 1

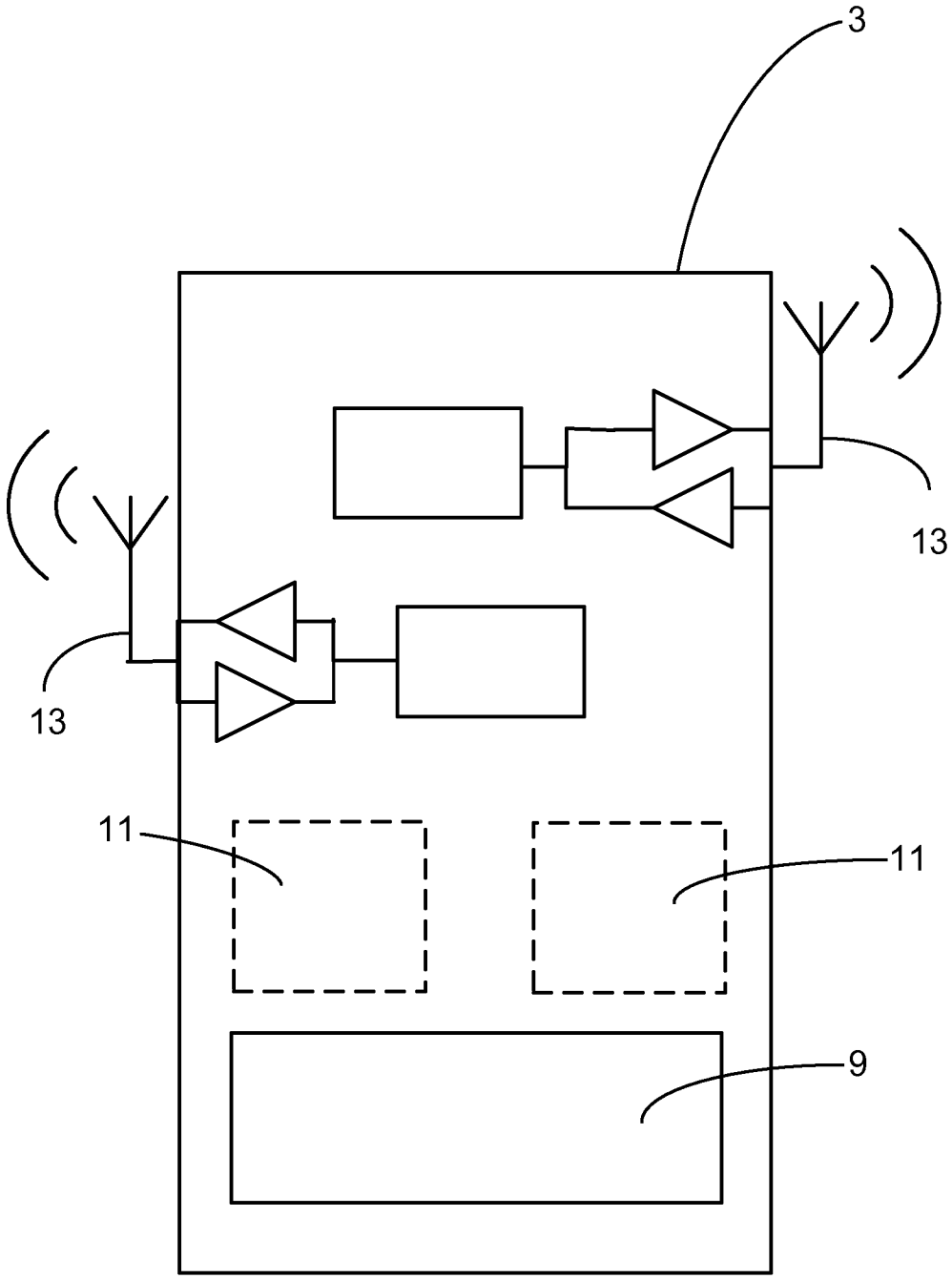

Fig 2

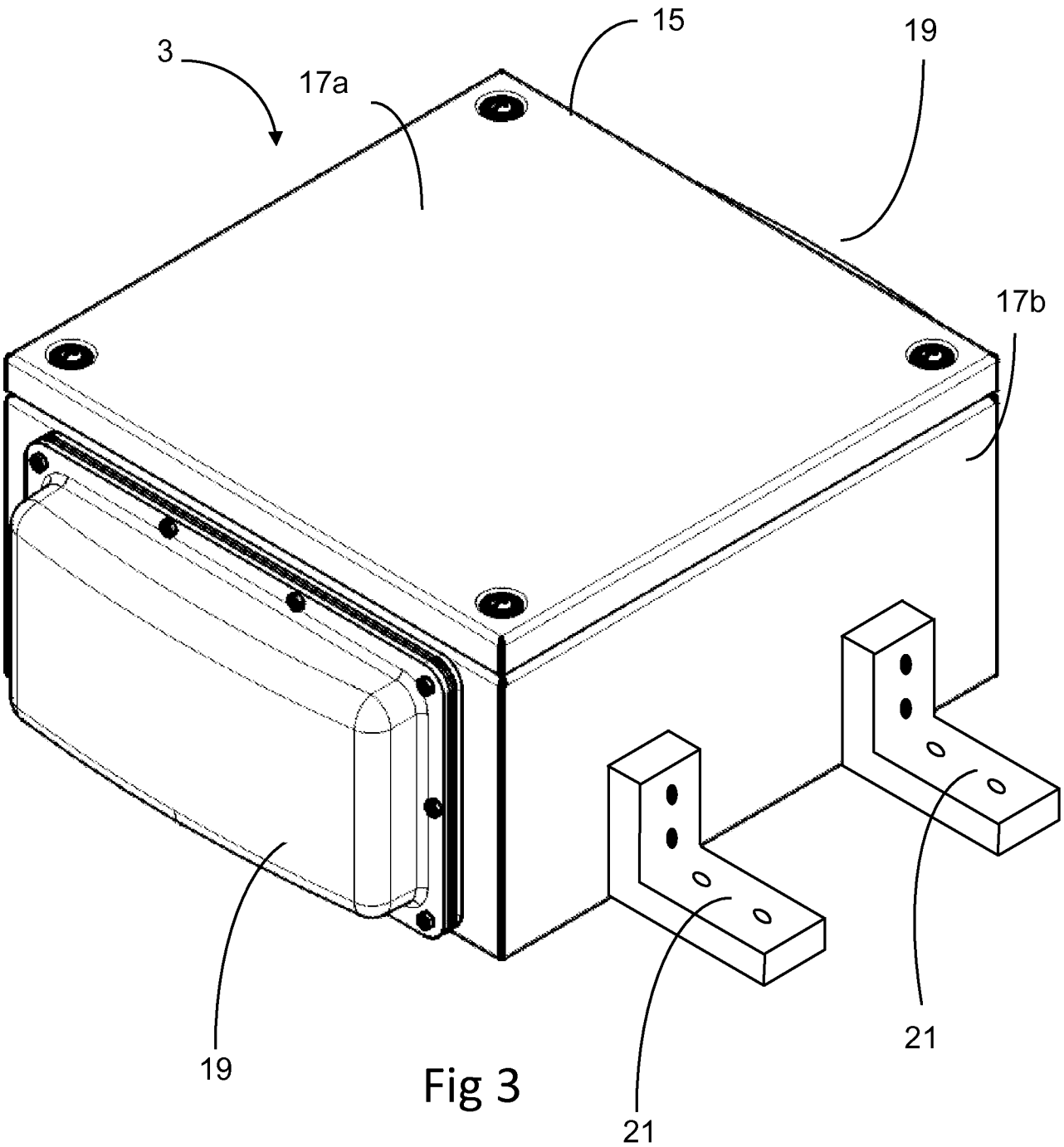

Fig 3

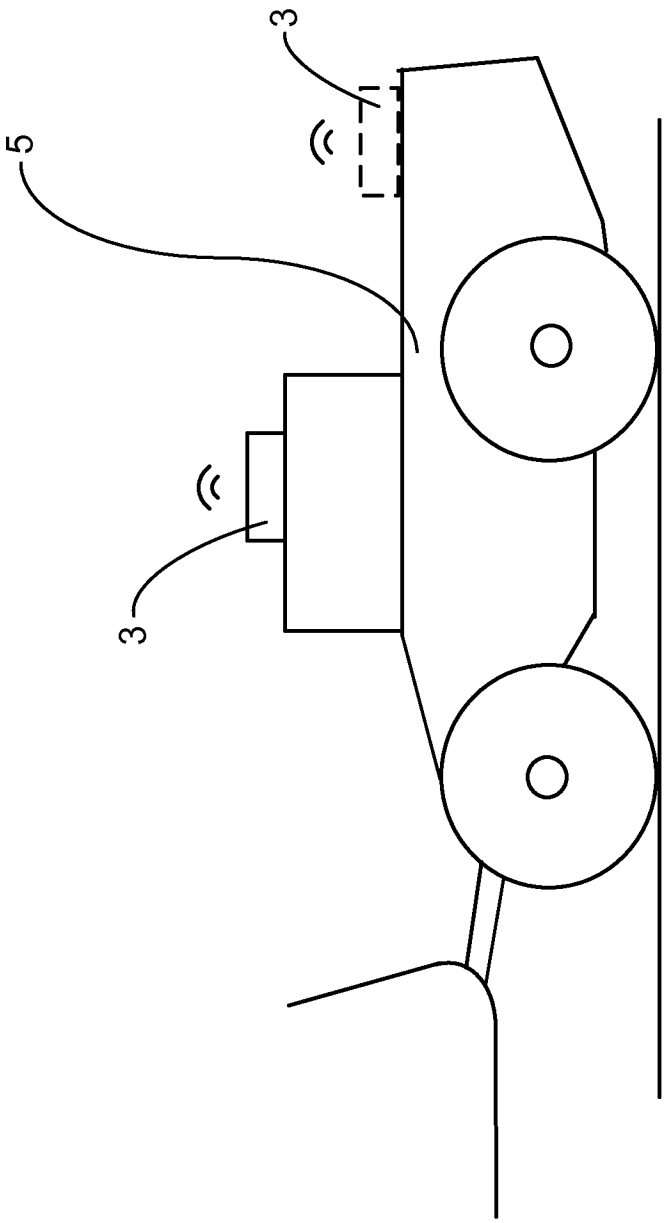

Fig 4

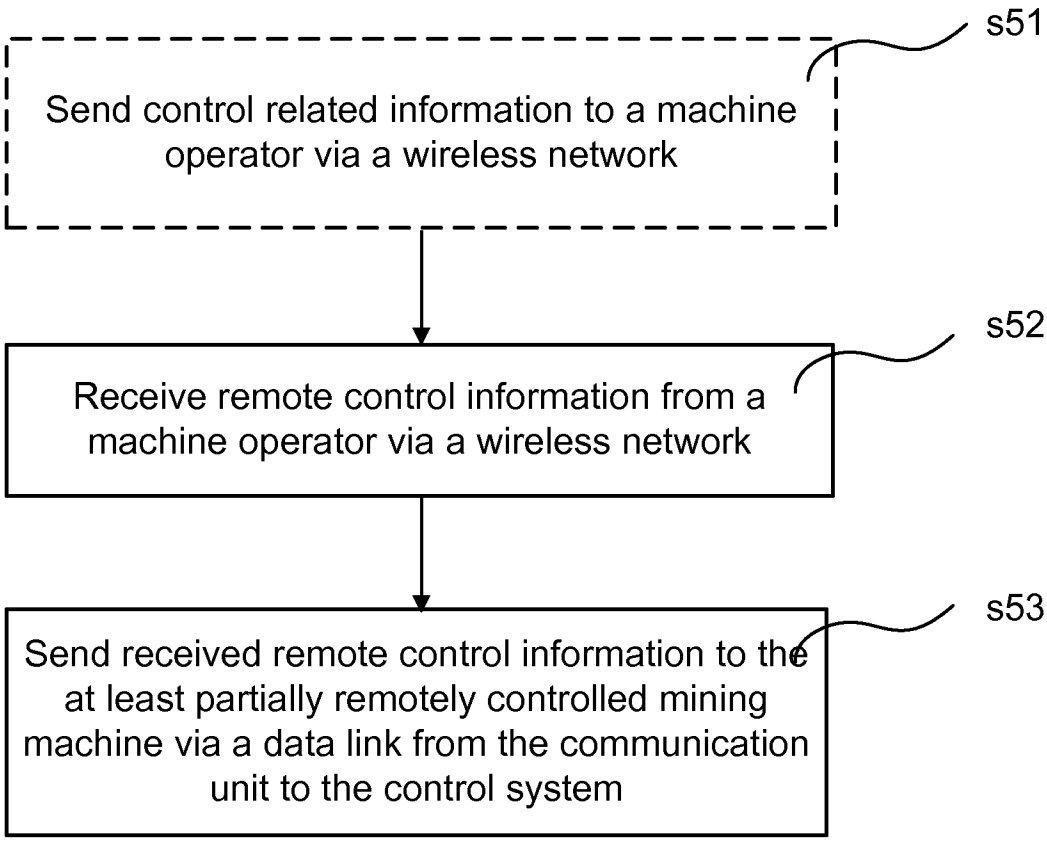
s51
Send control related information to a machine operator via a wireless network
s52
Receive remote control information from a machine operator via a wireless network
s53
Send received remote control information to the at least partially remotely controlled mining machine via a data link from the communication unit to the control system

Fig 5