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(54) **Title:** INFRARED BARRIER SYSTEMS AND METHODS THEREOF

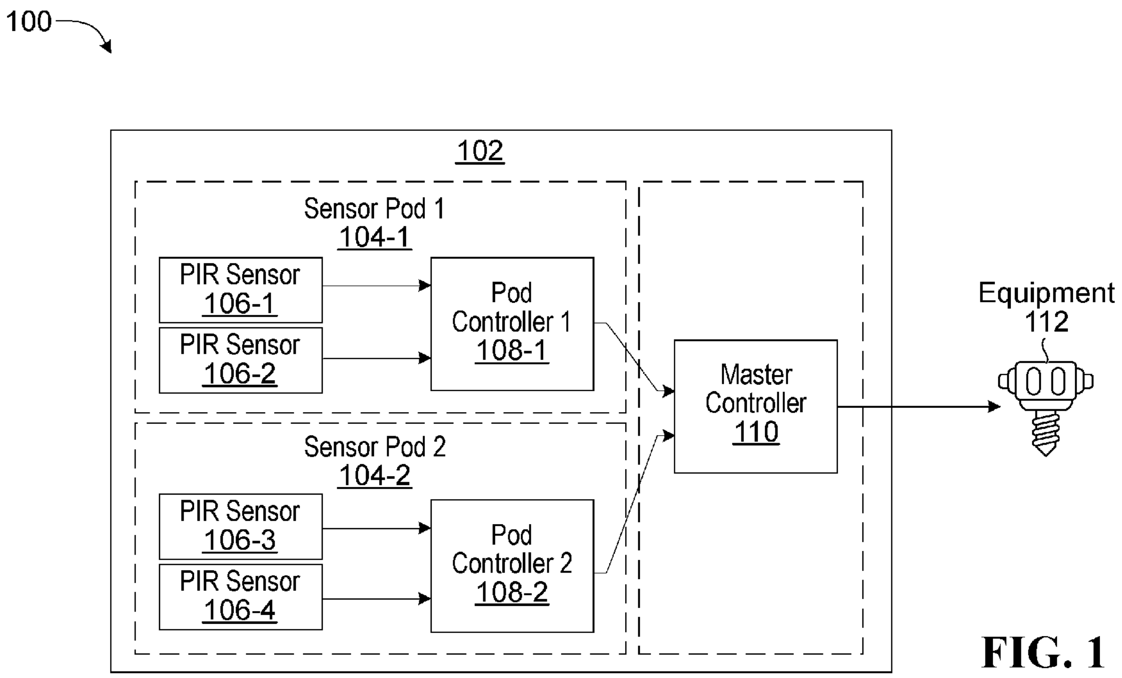

FIG. 1

(57) **Abstract:** The present disclosure relates to infrared barrier systems and methods. The infrared barrier systems may be portable systems or stationary systems. First safety signals are received by a master controller of the infrared barrier system from sensor pods of the infrared barrier system. Each of the sensor pods include passive infrared sensors, and a corresponding pod controller. The first safety signals are continuously monitored. A second safety signal is generated and sent to an equipment. Modified first safety signals are detected from at least one of the sensor pods. The modified first safety signals are indicative of human presence in proximity of the equipment. The second safety signals is modified for the equipment based on the modified first safety signals, the modified second safety signal to cause the equipment to shut down.

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INFRARED BARRIER SYSTEMS AND METHODS THEREOF

Field of the Invention

[001] The present invention relates generally to systems and methods for safeguarding an area, and more particularly, to an infrared barrier system and method that safeguards humans from an area in proximity of an equipment.

Background of the Invention

[002] The following description of related art is intended to provide background information pertaining to the field of the disclosure. This section may include certain aspects of the art that may be related to various features of the present disclosure. However, it should be appreciated that this section be used only to enhance the understanding of the reader with respect to the present disclosure, and not as admissions of prior art.

[003] The techniques of underground mining are always changing; new rules bring new challenges to the work place. In the past, there have been many injuries around “rotating steel” and “rotating equipment.” Early rules required employers to have proper guarding around the rotating equipment, but in the mining industry, rotating steel of a turning rock drill was an exception. Guarding the rotating steel of a turning rock drill was not a requirement, considered impractical, and proper training was required to keep operators safe from the extremely powerful rotating steel of a rock drill. However, proper training was not enough, and injuries kept adding up. Fixed guarding around the rotating steel of an underground drill is impractical due to the frequency that the operator must add or remove drill steel and the complexity that the fixed guarding would require to be operational.

[004] Further, conventional systems and method have introduced several rules and regulations for guarding of the rotating steel. However, the rules and regulations have not been practical, are hard to use, and pose safety risks on its own. Some conventional systems and method use “temporary fence system” around the equipment. Some original equipment manufacturers (OEMs) incorporated electronic devices such as laser curtains to stop the drill from turning if a

human tries to get close to the drill while it is turning. These electronic systems eliminated the need to erect the troublesome fences, but they are only found on certain types of drills. The electronic devices incorporated by the OEMs have issues of their own. The most common type of electronic devices used are lasers, due to the fact that there are many laser type safety devices available. However, laser type systems are not practical to use in these situations, and in some cases cannot be used, because laser systems are largely affected by dust, flying debris, and water spray or anything that disrupts the lasers beam. These system imperfections cause unnecessary equipment stoppage, irritated operators, and slow down production. There are also many types of drills and drilling operations where a laser type system does not work.

[005] Therefore, there is an established need for a solution to at least one of the aforementioned problems. For instance, there is an established need for a system that can operate in an underground environment flawlessly. For example, there is a need for a system that can detect humans or living objects or vehicles in proximity of an equipment placed in the underground environment.

[006] Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with some aspects of the present disclosure as set forth in the remainder of the present application with reference to the drawings.

Summary of the Invention

[007] This section is provided to introduce certain objects and aspects of the present disclosure in a simplified form that are further described below in the detailed description. This summary is not intended to identify the key features or the scope of the claimed subject matter.

[008] In an aspect, the present disclosure relates to a portable infrared barrier device positionable in proximity of an equipment. The portable infrared barrier device includes an enclosure. The enclosure includes one or more sensor pods, each of the one or more sensor pods

including one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod, and a master controller communicatively coupled to the one or more sensor pods and the equipment. The pod controller is configured to generate one or more first safety signals for the master controller. The master controller is configured to monitor the one or more first safety signals received from the pod controllers associated with the one or more sensor pods, and generate and send a second safety signal to the equipment. Each passive infrared sensor is operable to detect a source of infrared radiation in a corresponding detection zone, and generate a detection signal indicative of the detection of the source of infrared radiation. The pod controller associated with the sensor pod is configured to infer human presence in proximity of the equipment based on the detection signals generated by the one or more passive infrared sensors, and modify the one or more first safety signals based on the inference of the human presence in proximity of the equipment. The master controller is configured to detect the modified one or more first safety signals, and modify the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

[009] In some embodiments, the master controller may be configured to determine a fault state associated with the portable infrared barrier device based on continuously monitoring the modified one or more first safety signals from the corresponding pod controller of each of the one or more sensor pods and generate the modified second safety signal based on the fault state associated with the portable infrared barrier device existing for more than a pre-determined time period.

[0010] In some embodiments, the master controller may be communicatively coupled to a relay of the equipment. In some embodiments, the modified second safety signal generated by the master controller may trip the relay to cause the equipment to shut down.

[0011] In some embodiments, the enclosure may include a carbon fibre nylon enclosure.

[0012] In some embodiments, the enclosure may be trapezoidal in shape with the one or more sensor pods placed at center, front, and on each side perpendicular to the front of the enclosure.

[0013] In some embodiments, the enclosure may be guarded by a metal covering, where the metal covering may include aluminium.

[0014] In some embodiments, the portable infrared barrier device may be configured to be coupled to one or more other infrared barrier devices.

[0015] In some embodiments, the one or more other infrared barrier devices may include a stationary infrared barrier device, or another portable infrared barrier device.

[0016] In some embodiments, each of the one or more passive infrared sensors of the sensor pod may have a detection zone that may overlap with a detection zone of at least one other passive infrared sensor of the sensor pod.

[0017] In some embodiments, the detection signal may include a 3.3-volt detection signal indicative of the detection of the source of infrared radiation, each of the one or more first safety signals and the second safety signal may include a 24 volt output switching signal device (OSSD) signal, and each of the modified one or more first safety signals and the modified second safety signal may be a 0 volt signal.

[0018] In some embodiments, the portable infrared barrier device may include a tripod stand, where the enclosure may be mounted on the tripod stand.

[0019] In an aspect, the present disclosure relates to a stationary infrared barrier system for an equipment. The stationary infrared barrier system includes one or more sensor pods mounted on the equipment, each of the one or more sensor pods including one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod, and a master controller communicatively coupled to the one or more sensor pods and the equipment. The pod controller is configured to generate one or more first safety signals for the master controller. The master controller is configured to monitor the one or more first safety signals received from the pod controllers associated with the one or more sensor pods, and generate and send a second safety signal to the equipment. Each passive infrared sensor is operable to detect a source of infrared radiation in a corresponding detection zone, and generate a detection signal indicative of the detection of the source of infrared radiation. The pod controller associated with the sensor pod is configured to infer human presence in proximity of the equipment based on the detection signals generated by the one or more passive infrared sensors, and modify the one or more first safety signals based on the inference of the human presence in proximity of the equipment. The master controller is configured to detect the modified one or more first safety signals, and modify the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

[0020] In some embodiments, the master controller may be configured to determine a fault state associated with the stationary infrared barrier system based on continuously monitoring the modified one or more first safety signals from the corresponding pod controller of each of the one or more sensor pods, and generate the modified second safety signal based on the fault state associated with the stationary infrared barrier system existing for more than a pre-determined time period.

[0021] In some embodiments, the master controller may be communicatively coupled to a relay of the equipment, where the modified second safety signal generated by the master controller may trip the relay to cause the equipment to shut down.

[0022] In some embodiments, the stationary infrared barrier system may be configured to be coupled to one or more other infrared barrier devices or systems.

[0023] In some embodiments, the one or more other infrared barrier devices or systems may include a portable infrared barrier device, or another stationary infrared barrier system.

[0024] In some embodiments, each of the one or more passive infrared sensors of the sensor pod may have a detection zone that may overlap with a detection zone of at least one other passive infrared sensor of the sensor pod.

[0025] In some embodiments, the detection signal may include a 3.3 volt detection signal indicative of the detection of the source of infrared radiation, each of the one or more first safety signals and the second safety signal may include a 24 volt OSSD signal, and each of the modified one or more first safety signals and the modified second safety signal may be a 0 volt signal.

[0026] In an aspect, the present disclosure relates to an infrared barrier method including receiving, by a master controller associated with an infrared barrier device, one or more first safety signals from one or more sensor pods of the infrared barrier device, each of the one or more sensor pods including one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod, and each of the one or more sensor pods in communication with the master controller, continuously monitoring, by the master controller, the received one or more first safety signals, generating and sending, by the master controller, a second safety signal to an equipment, detecting, by the master controller, modified one or more first safety signals from at least one of the one or more sensor pods of the infrared barrier device, the modified one or more first safety signals indicative of human presence in proximity of the equipment, and modifying, by the master controller, the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

[0027] In some embodiments, each of the one or more first safety signals and the second safety signal may include a 24 volt OSSD signal, and each of the modified one or more first safety signals and the modified second safety signal may be a 0 volt signal.

[0028] In another aspect, the present disclosure relates to a non-transitory computer-readable storage medium comprising instructions executable by a processor, the instructions to cause the processor to carry out the functions performed by the disclosed invisible barrier device.

[0029] These and other objects, features, and advantages of the present disclosure will become more readily apparent from the attached drawings and the detailed description of the preferred embodiments, which follow.

Brief Description of the Drawings

[0030] The preferred embodiments of the invention will hereinafter be described in conjunction with the appended drawings provided to illustrate and not to limit the invention, where like designations denote like elements, and in which:

[0031] FIG. 1 shows an example representation for implementing an invisible barrier system, in accordance with embodiments of the present disclosure;

[0032] FIG. 2 shows an example representation of portable invisible barrier systems in proximity of an equipment, in accordance with embodiments of the present disclosure;

[0033] FIG. 3 shows an example representation of a stationary invisible barrier system, in accordance with embodiments of the present disclosure;

[0034] FIG. 4 shows an example representation of detection zones of corresponding passive infrared sensors of invisible barrier systems, in accordance with embodiments of the present disclosure;

[0035] FIG. 5A shows an example functional overview of sensor pods of an invisible barrier system, in accordance with embodiments of the present disclosure;

[0036] FIG. 5B shows an example table showing states of passive infrared sensors and expected outputs, in accordance with embodiments of the present disclosure;

[0037] FIG. 6A shows an example functional overview of a master controller of an invisible barrier system, in accordance with embodiments of the present disclosure;

[0038] FIG. 6B shows an example table showing states of sensor inputs and expected outputs, in accordance with embodiments of the present disclosure;

[0039] FIGs. 7A and 7B show example representations of interconnected invisible barrier systems, in accordance with embodiments of the present disclosure; and

[0040] FIG. 8 shows a flow chart of an example infrared barrier method, in accordance with embodiments of the present disclosure.

[0041] Like reference numerals refer to like parts throughout the several views of the drawings.

Detailed Description

[0042] In the following description, for the purposes of explanation, various specific details are set forth in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent, however, that embodiments of the present disclosure may be practiced without these specific details. Several features described hereafter can each be used independently of one another or with any combination of other features. An individual feature may not address all of the problems discussed above or might address only some of the problems discussed above. Some of the problems discussed above might not be fully addressed by any of the features described herein.

[0043] The ensuing description provides exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the disclosure. Rather, the ensuing description of the exemplary embodiments will provide those skilled in the art with an enabling description for implementing an exemplary embodiment. It should be understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the disclosure as set forth.

[0044] Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits, systems, networks, processes, and other components may be shown as components in block diagram form in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

[0045] Also, it is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed but could have additional blocks not included in a figure. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination can correspond to a return of the function to the calling function or the main function.

[0046] The word “exemplary” and/or “demonstrative” is used herein to mean serving as an example, instance, or illustration. For the avoidance of doubt, the subject matter disclosed herein is not limited by such examples. In addition, any aspect or design described herein as “exemplary” and/or “demonstrative” is not necessarily to be construed as preferred or advantageous over other aspects or designs, nor is it meant to preclude equivalent exemplary structures and techniques known to those of ordinary skill in the art. Furthermore, to the extent that the terms “includes,” “has,” “contains,” and other similar words are used in either the detailed description or the claims, such terms are intended to be inclusive—in a manner similar to the term “comprising” as an open transition word—without precluding any additional or other elements.

[0047] Reference throughout this specification to “one embodiment” or “an embodiment” or “an instance” or “one instance” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Thus, the appearances 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 embodiments.

[0048] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0049] The following detailed description is merely exemplary in nature and is not intended to limit the described embodiments or the application and uses of the described embodiments. As used herein, the word “exemplary” or “illustrative” means “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” or “illustrative” is not necessarily to be construed as preferred or advantageous over other implementations. All of the implementations described below are exemplary implementations provided to enable persons skilled in the art to make or use the embodiments of the disclosure and are not intended to limit the scope of the disclosure, which is defined by the claims. For purposes of description herein, the terms “upper”, “lower”, “left”, “rear”, “right”, “front”, “vertical”, “horizontal”, and derivatives thereof shall relate to the invention as oriented in FIG. 1. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

[0050] In the following description, certain specific details are set forth in order to provide a thorough understanding of various disclosed implementations. However, one skilled in the relevant art will recognize that implementations may be practiced without one or more of these specific details, or with other methods, components, materials, and the like.

[0051] Unless the context requires otherwise, throughout the specification and claims which follow, the word “comprise” and variations thereof, such as, “comprises” and “comprising” are to be construed in an open, inclusive sense that is as “including, but not limited to.”

[0052] As used in this specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the content clearly dictates otherwise. It should also be noted that the term “or” is generally employed in its broadest sense that is as meaning “and/or” unless the content clearly dictates otherwise.

[0053] The headings and Abstract of the disclosure provided herein are for convenience only and do not interpret the scope or meaning of the implementations.

[0054] The various embodiments throughout the disclosure will be explained in more detail with reference to FIGs. 1-8. In particular, shown throughout the figures, the present invention is directed towards an invisible barrier device/system that safeguards an area covered by an equipment.

[0055] FIG. 1 shows an example representation 100 for implementing an invisible barrier system, in accordance with embodiments of the present disclosure.

[0056] Referring to FIG. 1, the example representation 100 includes an invisible/infrared barrier system 102 comprising one or more sensor pods (104-1, 104-2) and a master controller 110. It may be appreciated that “invisible barrier system” and “infrared barrier system” may be used interchangeably throughout the disclosure. In an embodiment, the one or more sensor pods (104-1, 104-2) may include one or more passive infrared (PIR) sensors (106-1, 106-2, 106-3, 106-4). For example, a first sensor pod 104-1 may include one or more PIR sensors (106-1, 106-2), and a second sensor pod 104-2 may include one or more PIR sensors (106-3, 106-4). It may be appreciated that the one or more PIR sensors (106-1, 106-2, 106-3, 106-4) may be individually referred as PIR sensor 106 and collectively referred as the PIR sensors 106. Similarly, the one or more sensor pods (104-1, 104-2) may be referred as the sensor pods 104 or the sensor pods 104. Although two sensor pods (104-1, 104-2) have been depicted in the invisible barrier system 102 in FIG. 1, there may be any number of sensor pods as appropriate within the scope of the present disclosure. Similarly, there may be any number of PIR sensors 106 in each sensor pod 104 within the scope of the present disclosure. In some embodiments, the PIR sensors 106 may be analog sensors or digital sensors. In some embodiments, the PIR sensors 106 may detect humans, and in some embodiments, the PIR sensors 106 may detect direction of travel of the humans.

[0057] Further, as depicted in FIG. 1, each sensor pod (104-1, 104-2) may include a corresponding pod controller (108-1, 108-2). In an embodiment, the pod controllers (108-1, 108-2) may be communicatively coupled to the master controller 110. The master controller 110 may be communicatively coupled to the sensor pods (104-1, 104-2) and an equipment 112. In some embodiments, the equipment 112 may include a rotating steel in an underground drill or mining domain. In some embodiments, the equipment 112 may be any mining equipment. In some embodiments, the equipment 112 may comprise any equipment from which the humans need to be safeguarded.

[0058] In accordance with embodiments of the present disclosure, the invisible barrier system 102 may detect a presence of humans, living objects, or vehicles in proximity of the equipment 112. In some embodiments, the invisible barrier system 102 may cause the equipment 112 to shut down upon detection of the presence of, for example, human within a detection zone of the invisible barrier system 102 (e.g., PIR sensors 106), i.e., in proximity to the equipment 112. In some embodiments, the invisible barrier system 102 may detect direction of travel of the humans, in addition to detecting the presence of humans, based on the combination of sensors and software. Since there are multiple PIR sensors 106, the detection of travel may be possible. Further, if the human is detected entering the front of the equipment 112 or a danger zone, but not detected going back past the equipment 112 or come out of the danger zone, the invisible barrier system 102 may determine that the human is unsafe, and accordingly, the invisible barrier system 102 may not allow reset. In some embodiments, the invisible barrier system 108 may be capable of data logging. For example, data logging may include, but not be limited to, time stamp/date stamp for each event incident, for example, fault state detected at X time X date, human detected at X time X date, human/operators detected entering zone at X time X date, human detected leaving zone at X time X date, system reset/bypassed at X time X date by operator. All these events or incidents may be logged in detail so that they may be referred to in case they are required.

[0059] Referring to FIG. 1, the PIR sensors 106 may be configured to detect a human body heat signature, such that detection zones of each of the PIR sensors 106 may overlap with each other for redundancy in order to identify the presence of the human in proximity of the equipment 112. It may be noted that the invisible barrier system 102 uses the PIR sensors 106 to create an electronic barricade. The PIR sensors 106 may detect motion and self-adjust to changing operating zones around the equipment 112. In an example embodiment, the detection zones of the PIR sensors 106 may be three dimensional (3D) zones spanning 5 meters and may cover an area of 150 degrees horizontally x 35 degrees vertically around the sensor pod 104. In another example embodiment, the detection zones of the PIR sensors 106 may be 3D zones spanning 5 meters and may cover an area of 35 degrees horizontally x 150 degrees vertically around the sensor pod 104. It may be appreciated that these are exemplary embodiments, and other detection zones may be possible. In an example embodiment, the PIR sensors 106 may detect a human even at 16 feet or more. It may be appreciated that the PIR sensors 106 or as such the invisible barrier system 102 may be customized based on requirements on any equipment (e.g., 112) or area, for example, to change angles, zoning, detection distance, or the like.

[0060] In an embodiment, the sensor pods (104-1, 104-2) may be embedded in an enclosure. In an exemplary embodiment, the enclosure may include a 3D carbon fiber nylon enclosure. The invisible barrier system 102 has a safety rating of performance level (PL)-d with 99% diagnostics coverage, which may result from the 3D carbon fiber nylon enclosure. A person of ordinary skill in the art may understand that PL is a value used to define the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions. There are five levels, 'a' – 'e', where 'a' is the higher level of probability of dangerous failure and 'e' is the lowest level of probability of dangerous failure. Accordingly, it may be appreciated that the invisible barrier system 102 has the safety rating of PL-d, because of their constructions (e.g., physical characteristics), operational requirements, specialized software run by the system 102, using the 3D carbon fiber nylon enclosure, etc. In some embodiments, the enclosure may be trapezoidal in shape with the sensor pods (104-1, 104-2) being placed at center, front, and on each side perpendicular to the front of the enclosure. It may be appreciated that this is an illustrative example, and other configurations or arrangements may be possible within the scope of the present disclosure. In some embodiments, the enclosure may be guarded by a metal covering. The metal covering may preferably be of aluminium. However, any other appropriate metal covering may be used within the scope of the present disclosure. It may be noted that the metal covering does not obstruct the detection zone or view of the PIR sensors 106. In an embodiment, the corresponding pod controllers (108-1, 108-2) may also be embedded with the sensor pods (104-1, 104-2) in the enclosure. In some embodiments, the master controller 110 may also be embedded within the same enclosure as the sensor pods (104-1, 104-2) and the pod controllers (108-1, 108-2), as depicted in FIG. 1. In some embodiments, the invisible barrier system 102 may include a display on the back of the unit and light emitting diodes (LEDs) indicating lights that may be mounted inside the enclosure, but may be viewed from outside. The entire invisible barrier system 102 may be potted with epoxy to completely conceal all the internal components, to protect from vibration, moisture, impact, tampering, and reverse engineering, or the like. In some other embodiments, the master controller 110 may be separate from the sensor pods (104-1, 104-2) and the pod controllers (108-1, 108-2), and may be communicatively coupled to the pod controllers (108-1, 108-2). In such embodiments, the invisible barrier system 102 may be a stationary system with the sensor pods (104-1, 104-2) being mounted on the equipment 112, and the master controller 110 being in communication with the sensor pods (104-1, 104-2) and the equipment 112. This will be explained in detail with reference to FIG. 3.

[0061] In some embodiments, the invisible barrier system 102 may be positioned in proximity to the equipment 112, as depicted in FIG. 1, i.e. the invisible barrier system 102 may not be physically attached to the equipment 112. In some embodiments, the invisible barrier system 102 may be installed in underground drill rigs. In some embodiments, the invisible barrier system 102 may be a stand-alone system that may be positionable in proximity to the equipment 112. In an embodiment, the invisible barrier system 102 may be positionable on a tripod stand such that the invisible barrier system 102 may cover a huge 3D area to detect the presence of the human in proximity of the equipment 112. It may be noted that the portable invisible barrier system 102, as discussed herein, may be positionable by an operator or an administrator of the equipment 112, and may be intended to safeguard a dangerous area in proximity to the equipment 112. To this effect, when a human enters a detection zone of any one or more of the PIR sensors 106, the invisible barrier system 102 may detect the presence of the human, and cause the equipment 112 to shut down in order to safeguard the human.

[0062] In an embodiment, the pod controllers (108-1, 108-2) may be configured to evaluate inputs from the PIR sensors 106 and generate one or more first safety signals for the master controller 110. In an embodiment, the PIR sensors 106 may be used in conjunction with a

MOSFET to invert a signal to a normally high signal. When the PIR sensor 106 is in a normal state (i.e., safe state), the signal may be low. When the PIR sensor 106 is triggered, the signal from the PIR sensor 106 may be high, for example, a 3.3V signal. The one or more first safety signals may be pulsed safety output signals, i.e., output switching signal device (OSSD) signals.

[0063] In some embodiments, the master controller 110 may be configured to monitor the one or more first safety signals from the pod controllers (108-1, 108-2). In an example embodiment, the master controller 110 may monitor signals received from up to six PIR sensors 106. The master controller 110 may continuously monitor the one or more first safety signals from the pod controllers (108-1, 108-2). In some embodiments, the master controller 110 may monitor the one or more first safety signals from the pod controllers (108-1, 108-2) at pre-determined time intervals. Further, the master controller 110 may generate a second safety signal based on the received one or more first safety signals from the pod controllers (108-1, 108-2). The master controller 110 may send the second safety signal to the equipment 112. The second safety signal may be the OSSD signal. In some embodiments, the one or more first safety signals and the second safety signal may be 24V OSSD signals. This may indicate that the equipment 112 may continue to function and that the invisible barrier system 102 is in a safe state, i.e. no human, living being, or a vehicle, has been detected in an area covered by the equipment 112. However, as discussed above, the PIR sensors 106 may detect a source of infrared radiation in a corresponding detection zone of the PIR sensor 106 when a human, living being, or the vehicle enters a zone covered by the equipment 112 during an operation of the equipment 112. Based on the detected source of radiation, the PIR sensors 106 may generate a detection signal and send the detection signal to the corresponding pod controller (108-1, 108-2). In an embodiment, the detection signal may be a 3.3V signal indicative of the PIR sensors 106 being triggered. Further, the corresponding pod controller (108-1, 108-2) may infer the presence of the human in proximity of the equipment 112 based on the detection signal received from the PIR sensors 106. Accordingly, the pod controllers (108-1, 108-2) may modify the one or more first safety signals (i.e., 24V OSSD signal) for the master controller 110. For example, the pod controllers (108-1, 108-2) may trip the signal from 24V OSSD signal to a 0V signal. Further, in some embodiments, the master controller 110 may detect the modified one or more first safety signals (i.e., 0V signal), and modify the second safety signal (i.e., 24V OSSD signal) for the equipment 112 based on the modified one or more first safety signals. For example, similar to the pod controllers (108-1, 108-2), the master controller 110 may trip the second safety signal from 24V OSSD signal to a 0V signal. The master controller 110 may send the modified second safety signal to the equipment 112. In particular, by sending the modified second safety signal (i.e., 0V signal), the master controller 110 or as such, the invisible barrier system 102 may indicate that the equipment 112 may need to shut down to safeguard the detected human in proximity of the equipment 112. In an embodiment, the modified second safety signal from the master controller 110 may cause the equipment 112 to shut down for a particular time period or until safe state may be assured, thereby protecting the human. In some embodiments, the invisible barrier system 102 may determine the safe state based on continuously monitoring the area covered by the equipment 112. For example, once the PIR sensors 106 determine that there is no human in the corresponding detection zone, the PIR sensors 106 may indicate the same to the corresponding pod controllers (108-1, 108-2). The pod controller (108-1, 108-2) may then start generating the one or more first safety signals for the master controller 110, and the master controller 110 may generate and send the second safety signal to the equipment 112. This may indicate the equipment 112 that the safe state is assured, and that the equipment 112 may resume operation. In some embodiments, an operator or an administrator may restart the equipment 112 once safe state may be assured.

[0064] In some embodiments, the equipment 112 may include a relay (not shown) such that the master controller 110 may be communicatively coupled to the relay of the equipment 112. In such a scenario, the modified second safety signal generated by the master controller 110 may be sent to the relay. The relay may evaluate these signals received from the master controller 110, such that the modified second safety signal may trip the relay of the equipment 112 causing the equipment 112 to shut down. In an example embodiment, the relay may supply and control the supply of power to the equipment 112 such that the relay may cause the equipment 112 to start, stop, and/or resume. Accordingly, based on receiving the modified second safety signal (i.e., 0V signal) from the master controller 110, the relay may automatically stop the supply of power to the equipment 112, thereby causing the equipment 112 to shut down. In some embodiments, the relay may be used to control any number of things such as, but not limited to, electric prime movers, fuel cut-off solenoids, hydraulic safety valves etc. currently the safety relay controls a set of "block and bleed" type safety valves which in turn may stop hydraulic oil flow to drill motors and other hydraulic controls in the equipment 112. These "block and bleed" type safety valves may be double redundant, and may release all stored energy from a prime mover and provide closed loop feedback of a valve position via inductive proximity switches.

[0065] In some embodiments, instead of a human being detected, there may be a fault with the invisible barrier system 102, and because of this fault, the master controller 110 may send the modified second safety signal, i.e., 0V signal to the equipment 112 to cause the equipment 112 to shut down. For example, the master controller 110 may detect a fault state associated with the invisible barrier system 102 based on continuously monitoring the one or more first safety signals from the pod controllers (108-1, 108-2). The master controller 110, in response to detecting the fault state for more than a pre-determined time period, may generate the modified second safety signal (i.e., 0V signal) for the equipment 112 to cause the equipment 112 to shut down.

[0066] In an example embodiment, the below table 1 gives an overview of environmental conditions and requirements of the invisible barrier system 102.

S.No.	Environmental Condition	Description / Value
1.	Ambient temperature range	-20 degrees C – 40 degrees C
2.	Ambient air pressure	98 kPa – 104 kPa
3.	Ambient humidity	0-95% RH
4.	Moisture/water exposure	Damp/wet
5.	Dust/particulate exposure	Dusty/dirty

Table 1

[0067] Each of the pod controllers 108 and/or the master controller 110 may include a processor and a memory operatively coupled with the processor, such that the processor may enable the pod controllers 108 and/or the master controller 110 to perform the respective functions, as discussed herein. In some embodiments, the processor may be implemented as one or more microprocessors, microcomputers, microcontrollers, edge or fog microcontrollers, digital signal processors, central processing units, logic circuitries, and/or any devices that process data based on operational instructions. Examples of implementations of the processor may be a Graphics Processing Unit (GPU), a Reduced Instruction Set Computing (RISC) processor, an Application-Specific Integrated Circuit (ASIC) processor, a Complex Instruction Set Computing (CISC) processor, a microcontroller, a central processing unit (CPU), and/or a combination thereof. Among other capabilities, the processor may be configured to fetch and execute computer-readable instructions stored in the memory of the pod controllers 108 and/or the master controller 110. The memory may be configured to store one or more computer-readable instructions or routines in a non-transitory computer readable storage medium, which may be fetched and executed to create or share data packets over a network service. The memory may comprise any non-transitory storage device including, for example, volatile memory such as Random-Access Memory (RAM), or non-volatile memory such as Electrically Erasable Programmable Read-only Memory (EPROM), flash memory, and the like. In some examples, the processor may comprise a cloud based or virtualized processing module or functionality. The processor may cooperate with the memory to execute instructions stored in the memory. For example, the processor may execute the instructions stored in memory to perform or control performance of methods, including method (e.g., 800), and the other methods described herein.

[0068] Although FIG. 1 shows example components of the proposed disclosure, in other embodiments, fewer components, different components, differently arranged components, or additional functional components may be implemented than those depicted in FIG. 1.

[0069] FIG. 2 shows an example representation 200 of portable invisible barrier systems in proximity of an equipment, in accordance with embodiments of the present disclosure.

[0070] Referring to FIG. 2, the example representation 200 includes an equipment 202 and a plurality of portable invisible barrier systems (204-1, 204-2, 204-3, 204-4). It may be appreciated that the plurality of invisible barrier systems (204-1-1, 204-2, 204-3, 204-4) may be referred as the plurality of invisible barrier systems 204. Further, it may be appreciated that the equipment 202 and the portable invisible barrier systems 204 may be similar to the respective equipment 112 and the invisible barrier system 102 of FIG. 1 in their functionality, and hence may not be described in detail again for the sake of brevity.

[0071] As depicted in FIG. 2, the invisible barrier system 204 may be positionable on a tripod stand such that the invisible barrier system 204 may cover a huge 3D area, for example, 206 to detect the presence of the human in proximity of the equipment 202. These stand-alone units 204 may be used as one, or multiple units linked together to form a larger system and have detections zones (e.g., 206) that are hundreds of meters apart, if desired. In an exemplary embodiment, there may be up to four invisible barrier systems 204 linked together, as depicted in FIG. 2. In some other embodiments, a portable invisible barrier system 204 may be coupled to a stationary invisible barrier system (depicted in FIG. 3).

[0072] In an embodiment, the plurality of invisible barrier systems 204, as discussed herein, may be positionable by an operator or an administrator of the equipment 202, and may be intended to safeguard a dangerous area 206 in proximity to the equipment 202. To this effect, when a human enters a detection zone of any one or more of PIR sensors (e.g., 106), the invisible barrier system 204 may detect the presence of the human, and cause the equipment 202 to shut down in order to safeguard the human.

[0073] In some embodiments, it may be noted that the invisible barrier systems 204 may be moved quickly to different locations or positions to accommodate for different equipment setups or to avoid interference from other nearby equipment. In an embodiment, the invisible barrier system 204 may guard a break-through point of a long hole drill (i.e., 202). A break-through point may be several hundreds of meters above or below a long hole drill.

[0074] Although the invisible barrier system 204 is shown as being mounted on a tripod stand, it may be appreciated that the invisible barrier system 204 may be mounted elsewhere, based on the application and requirements.

[0075] FIG. 3 shows an example representation 300 of a stationary invisible barrier system, in accordance with embodiments of the present disclosure.

[0076] Referring to FIG. 3, a stationary invisible barrier system may include a master controller 302 in communication with one or more sensor pods (304-1, 304-2) and an equipment 306. In some embodiments, the controller 302 may be mounted on the equipment 306, and connected to the one or more sensor pods (304-1, 304-2) by, for example, cable or wirelessly. It may be appreciated that the master controller 302, the one or more sensor pods (304-1, 304-2), and the equipment 306 may be similar to the respective master controller 110, the one or more sensor pods (104-1, 104-2), and the equipment 112 of FIG. 1 in their functionality, and hence, may not be described in detail again for the sake of brevity. For example, the sensor pods (304-1, 304-2) may include one or more PIR sensors (e.g., 106) and corresponding pod controller (e.g., 108).

[0077] As explained with reference to FIG. 1, the pod controllers may evaluate signals from the PIR sensors to easily detect a presence of a human or a vehicle or any other living object within a detection zone of the corresponding PIR sensor. These signals may then be transformed into one or more first safety signals, i.e., 24V OSSD signals, and transmitted via wire to the master controller 302. In an embodiment, the master controller 302 may include a processor and a memory operatively coupled with the processor, such that the processor may enable the master controller 302 to make critical decisions based on information or signals received from the sensor pods (304-1, 304-2).

[0078] In some embodiments, the master controller 302 may be connected to a relay of the equipment 306, such that the master controller 302 may send second safety signals, i.e., 24V OSSD signals to the relay. The relay may evaluate these second safety signals, and control the equipment 306 based on the second safety signals received from the master controller 302.

[0079] In some embodiments, when the stationary invisible barrier system of FIG. 3 or the portable invisible barrier system of FIG. 1 has tripped due to fault or human detection, the system may be reset by an operator. The master controller 302 or 110 may only provide power to a reset button for the operator to reset the system if all criteria is met. The operator may make the final decision to put the system in run mode. In order to reset the relay of the equipment 306, a reset signal may pass through proximity switches in safety valves before reaching the relay. The reset may only be performed from a first unit in line (if using more than one invisible barrier system and usually located on or at the equipment 306). This ensures that the operator has a visual view of the equipment 306 before resetting the system. The system may not reset if any one unit is tripped if using more than one system linked together. If using multiple systems linked together, the last system in the chain may be the only one that generates the safety signals, i.e., pulsed 24V OSSD signals. These safety signals may be passed through each system until it reaches the relay on the equipment 306 (or 112). Each individual system in the chain may monitor the safety signals, i.e., 24V safety OSSD signals that are passing through it up to the next unit in line. Each system has the ability to break the safety signals that are passing through, which may in turn trip the relay and cause the equipment 306 to shut down. In some embodiments, the systems may determine if they are connected in a system running multiple units or if there is only one unit on its own, and may also determine their position in the chain. This will be further explained with reference to FIGs. 7A and 7B.

[0080] Referring to FIG. 3, the sensor pods (304-1, 304-2) may usually be located on the sides and front of the equipment 306. This machine mounted invisible barrier system may detect a human in a danger area covered by the equipment 306 which may be usually at the front of the equipment 306.

[0081] Although FIG. 3 shows example components of the proposed disclosure, in other embodiments, fewer components, different components, differently arranged components, or additional functional components may be implemented than those depicted in FIG. 3.

[0082] FIG. 4 shows an example representation 400 of detection zones of corresponding PIR sensors of invisible barrier systems, in accordance with embodiments of the present disclosure.

[0083] Referring to FIG. 4, the example representation 400 includes an equipment 402 and one or more PIR sensors (404-1, 404-2, 404-3). It may be appreciated that the equipment 402 and the one or more PIR sensors (404-1, 404-2, 404-3) may be similar to the respective equipment 112 and the one or more PIR sensors 106 of FIG. 1 in their functionality, and hence, may not be described in detail again for the sake of brevity.

[0084] As depicted in FIG. 4, each of the PIR sensors (404-1, 404-2, 404-3) may have their respective detection zones (406-1, 406-2, 406-3). For example, a first PIR sensor 404-1 may have a first detection zone 406-1, a second PIR sensor 404-2 may have a second detection zone 406-2, and a third PIR sensor 404-3 may have a third detection zone 406-3. It may be noted that each of the PIR sensors (404-1, 404-2, 404-3) may be associated with sensors pods (e.g., 104), as depicted in FIG. 1. A detection zone (406-1, 406-2, 406-3) may represent a 3D space in which a human movement or a vehicle movement or any other movement of a living object therein may trigger a detection event at the PIR sensors (404-1, 404-2, 404-3), such that the PIR sensors (404-1, 404-2, 404-3) may generate a detection signal, i.e., 3.3V signals for their corresponding pod controllers (e.g., 108) to indicate presence of movement of a human, as an example.

[0085] In some embodiments, the range or angle of the detection zones (406-1, 406-2, 406-3) may be adjusted by an operator an administrator. For example, as depicted, the detection zones (406-1, 406-2, 406-3) extend out from the PIR sensors (404-1, 404-2, 404-3) at a defined angle.

[0086] Further, as depicted in FIG. 4, the detection zones (406-1, 406-2, 406-3) may be configured to overlap each other at least partially, in order to increase the probability of detection of human in proximity of the equipment 402 and to increase the field of view of the detection zones (406-1, 406-2, 406-3).

[0087] In some embodiments, the PIR sensors (404-1, 404-2, 404-3) may be configured to generate the detection signal when a human enters any detection zone (406-1, 406-2, 406-3). The detection signal may be generated immediately based on the detection of the human within the detection zone (406-1, 406-2, 406-3). Further, the detection signal may be transmitted to the corresponding pod controllers 108, which in turn may generate modified one or more first safety signals (i.e., from 24V OSSD signals to 0V signal) for a master controller (e.g., 110). The master controller 110 may then generate and send a modified second safety signal (i.e., 0V signal) to the equipment 402 to cause the equipment 402 to shut down.

[0088] Although some embodiments have been illustrated herein as having three PIR sensors 404 with corresponding detection zones 406, other embodiments may utilize any number of PIR sensors 404 and/or detection zones 406 within the scope of the present disclosure.

[0089] FIG. 5A shows an example functional overview 500A of sensor pods of an invisible barrier system, in accordance with embodiments of the present disclosure.

[0090] In accordance with embodiments of the present disclosure, an invisible barrier system may include one or more sensor pods (e.g., 104). The one or more sensor pods 104 may include one or more PIR sensors (502-1, 502-2) and a corresponding pod controller 504. It may be appreciated that the one or more PIR sensors (502-1, 502-2) and the pod controller 504 may be similar to the respective one or more PIR sensors 106 and the pod controller 108 of FIG. 1 in their functionality, and hence, may not be described in detail again for the sake of brevity.

[0091] In some embodiments, the pod controller 504 may be configured with a pulse generator and an AND gate. A signal from the PIR sensor (502-1, 502-2) may be low when the PIR sensor (502-1, 502-2) is in its nominal state, i.e., safe state, for example, when there is no detection of any living object within its corresponding detection zone in proximity of an equipment (e.g., 112). A signal from the PIR sensor (502-1, 502-2) may be high when the PIR sensor (502-1, 502-2) is triggered, i.e., when a living object is detected within the corresponding detection zone. For example, the high signal may be a detection signal generated by the PIR sensor (502-1, 502-2). In some embodiments, the detection signal may be a 3.3V signal. In some embodiments, the detection signal may be a 5V signal. Based on the received signals (high or low), the pod controller 504 may generate a corresponding first safety signal for a master controller (e.g., 110). In some embodiments, the pod controller 504 may generate one or more first safety signals, i.e., 24V OSSD signals (506-1, 506-2) based on the low signals received from the PIR sensors (502-1, 502-2), i.e., when the PIR sensors (502-1, 502-2) are in the nominal or safe state. In some other embodiments, the pod controller 504 may modify the one or more first safety signals, i.e., from 24V OSSD signals to 0V signal based on the detection (high) signals received from the PIR sensors (502-1, 502-2) in response to detection of a living object within the corresponding detection zone.

[0092] In an example embodiment, the below table 2 outlines the required parameters and characteristics of the sensor input parameters.

Parameter	Value
Voltage supply	24 VDC
Logical HIGH	11-30 VDC
Logical LOW	(-3)-5 VDC
OSSD pulse frequency	10 Hz
OSSD pulse period	100 ms
OSSD pulse width	1 ms
OSSD pulse duty cycle	99%
OSSD channels	2
Channel offset	2-10 ms

Table 2

[0093] FIG. 5B shows an example table 500B showing states of PIR sensors and expected OSSD outputs, in accordance with embodiments of the present disclosure.

[0094] Referring to FIG. 5B, the table 500B shows states of PIR sensors (502-1, 502-2) with corresponding OSSD outputs (506-1, 506-2). It may be noted that the pod controller (e.g., 504) may not perform any comparison or evaluation between the PIR sensors (502-1, 502-2). The pod controller 504 may use separate redundant circuits (for example, pulse generator and AND gate) to generate each OSSD pulse (506-1, 506-2), one for each respective PIR sensor (502-1, 502-2).

[0095] FIG. 6A shows an example functional overview 600A of a master controller of an invisible barrier system, in accordance with embodiments of the present disclosure.

[0096] In accordance with embodiments of the present disclosure, the invisible barrier system may include one or more sensors pods (602-1, 602-2) and a master controller 604. It may be appreciated that the one or more sensor pods (602-1, 602-2) and the master controller 604 may be similar to the respective one or more sensor pods (104-1, 104-2) and the master controller 110 of FIG. 1 in their functionality, and hence, may not be described in detail again for the sake of brevity.

[0097] In some embodiments, redundant master controllers 604 may evaluate one or more first safety signals (or modified) from the sensor pods (602-1, 602-2) and generate one or more second safety signals (606-1, 606-2). The master controller 604 may include more than one master controller 604. The inputs from the sensor pods (602-1, 602-2) may connect to the master controllers 604 digital inputs. The signal may be stepped down to the required voltage using passive components (e.g., voltage dividing resistor array). The digital inputs of the master controller 604 may be protected using current-limiting resistors and diodes to prevent back-feeding.

[0098] In an example embodiment, the below table 3 outlines the required parameters and characteristics of the master controller input parameters.

Parameter	Value
Voltage supply	24 VDC
Logical HIGH	11-30 VDC
Logical LOW	(-3)-5 VDC
OSSD pulse frequency	10 Hz
OSSD pulse period	100 ms

OSSD pulse width	1 ms
OSSD pulse duty cycle	99%
OSSD input channels	4
OSSD output channels	2
Channel offset	2-10 ms

Table 3

[0099] FIG. 6B shows an example table 600B showing states of OSSD sensor inputs and expected OSSD outputs, in accordance with embodiments of the present disclosure.

[00100] Referring to FIG. 6B, the table 600B shows sensor inputs and outputs. It may be noted that each master controller 604 may monitor each pair of OSSD inputs for discrepancies. A discrepancy fault may be triggered if the discrepancy (high or low) persists for more than a pre-defined time period, for example, for more than 250 ms. In some embodiments, each master controller 604 may monitor each pair of OSSD inputs for shorts between channels. A short fault may be triggered if there are more than, as an example, three overlapping test pulses.

[00101] In some embodiments, the output of the master controller 604 may be a dual-channel OSSD with test pulses. The OSSD pulses may interface to a relay of an equipment (e.g., 112). It may be noted that the master controller 604 may evaluate the OSSD outputs (606-1, 606-2) as a feedback to validate the signals. In an example embodiment, an output fault may be triggered by the master controller 604 if the OSSD output (606-1, 606-2) does not turn on within the pre-defined time period (i.e., 250 ms) of the output being requested to turn on. In another example embodiment, an output fault may be triggered of the OSSD output (606-1, 606-2) does not turn off within the pre-defined time period of the output being requested to turn off.

[00102] FIGs. 7A-7B show example representations (700A, 700B) of invisible barrier systems connected in a chain, in accordance with embodiments of the present disclosure.

[00103] Referring to FIG. 7A, a plurality of invisible barrier systems (704-1, 704-2, 704-3, 704-4) may be coupled with each other in proximity to an equipment 702. It may be appreciated that the plurality of invisible barrier systems (704-1, 704-2, 704-3, 704-4) may be similar to the invisible barrier system 102 of FIG. 1 and/or the invisible barrier system of FIG. 3 in their functionality, i.e., the plurality of invisible barrier systems (704-1, 704-2, 704-3, 704-4) may either be portable systems or stationary systems, as discussed herein.

[00104] As an example, it may be considered that a first invisible barrier system 704-1 may be the farthest system to the equipment 702, and a fourth invisible barrier system 704-4 may be the closest system to the equipment 702. In accordance with embodiments of the present disclosure, if multiple systems are linked together in a chain, as depicted in FIG. 7A, then the farthest system in the chain, i.e., the first invisible barrier system 704-1 or the first system 704-1 may generate safety signals for the equipment 702, such that the first system 704-1 may transmit the generated safety signals, i.e. OSSD signals to a second system 704-2, which in turn may forward the safety signals generated by the first system 704-1 to a third system 704-3. Similarly, the third system 704-3 may forward the safety signals generated by the first system 704-1 to the fourth system 704-4. Likewise, the fourth system 704-4 may forward the safety signals to the equipment 702, thereby indicating that the equipment 702 may continue to function.

[00105] As discussed above, in some embodiments, when a stationary invisible barrier system of FIG. 3 or a portable invisible barrier system of FIG. 1 has tripped due to fault or human detection, the system may be reset by an operator. A master controller 302 or 110 may only provide power to a reset button for an operator to reset the system if all criteria is met. The operator may make the final decision to put the system in run mode. In order to reset a relay of the equipment 702, a reset signal may pass through proximity switches in safety valves before reaching the relay. The reset may only be performed from a first system in line, i.e. the fourth system 704-4. In some embodiments, the system may not reset if any one unit is tripped. If using multiple systems linked together, the last system in the chain, i.e. the first system 704-1 may be the only one that generates the safety signals, i.e., pulsed 24V OSSD signals. These safety signals may be passed through each system until it reaches the relay on the equipment 702. Each individual system in the chain may

monitor the safety signals, i.e., 24V safety OSSD signals that are passing through it up to the next unit in line.

[00106] Referring to FIG. 7B, the first system 704-1 may generate the safety signals for the equipment 702 and transmit to the second system 704-2. Based on continuously monitoring corresponding detection zones, the second system 704-2 may get triggered, and generate a detection signal corresponding to detecting a presence of a human within its corresponding detection zone(s). Based on the detection signal, the second system 704-2 may modify the safety signals generated by the first system 704-1, and send the modified safety signals, i.e. 0V signal to the third system 704-3. Accordingly, the third system 704-3 and the fourth system 704-3 may transmit the modified safety signal, i.e. 0V signal to the equipment 702 or relay of the equipment 702. Therefore, each system has the ability to break the safety signals that are passing through, which may in turn trip the relay and cause the equipment 702 to shut down.

[00107] FIG. 8 shows a flow chart of an example infrared barrier method 800, in accordance with embodiments of the present disclosure. In some embodiments, the blocks of the method 800 may be performed by a master controller (e.g., 110) associated with an infrared barrier system.

[00108] Referring to FIG. 8, at block 802, one or more first safety signals may be received by the master controller 110 from one or more sensor pods (e.g., 104) of an infrared barrier system/device (e.g., of FIG. 1 or FIG. 3). In an embodiment, the one or more sensor pods may include one or more PIR sensors (e.g., 106) and a corresponding pod controller (e.g., 108) associated with the sensor pod. In some embodiments, the one or more sensor pods may be in communication with the master controller. In some embodiments, the one or more sensor pods and the master controller may be enclosed in a single enclosure in a portable invisible barrier system (e.g., FIG. 1). In some other embodiments, the one or more sensor pods may be in communication with the master controller (e.g., FIG. 3).

[00109] At block 804, the one or more first safety signals received from the sensor pods are continuously monitored. Further, at block 806, a second safety signal is be generated and sent to

an equipment (e.g., 112). In some embodiments, the second safety signal may be sent to a relay of the equipment by the master controller 110.

[00110] Referring to FIG. 8, at block 808, modified one or more first safety signals from at least one of the one or more sensor pods are detected. The modified one or more first safety signals may be indicative of, for example, human presence in proximity of the equipment. Further, at block 810, the second safety signal is modified for the equipment based on the modified one or more first safety signals. In some embodiments, the modified second safety signal may cause the equipment to shut down, thereby safeguarding the human. In some embodiments, a fault state associated with the invisible barrier device may be determined based on monitoring the one or more first safety signals from the sensor pods continuously. In such embodiments, the modified second safety signal may be generated by the master controller 110 based on the fault state associated with the invisible barrier device existing for more than a pre-determined time period, for example, 250 ms.

[00111] It may be appreciated that the block shown in FIG. 8 are merely illustrative. Other suitable blocks may be used, if desired. Moreover, the blocks of the method 800 may be performed in any order and may include additional blocks.

[00112] In some embodiment, the methods described herein may be performed using the systems described herein. In addition, it is contemplated that the methods described herein may be performed using systems different than the systems described herein. Moreover, the systems described herein may perform the methods described herein and may perform or execute instructions stored in a non-transitory computer-readable storage medium (CRSM). The CRSM may comprise any electronic, magnetic, optical, or other physical storage device that stores executable instructions. The instructions may comprise instructions to cause a processor to perform or control performance of operations of the proposed methods. It is also contemplated that the systems described herein may perform functions or execute instructions other than those described in relation to the methods and CRSMs described herein.

[00113] Furthermore, the CRSMs described herein may store instructions corresponding to the methods described herein and may store instructions which may be performed or executed by the systems described herein. Furthermore, it is contemplated that the CRSMs described herein may store instructions different than those corresponding to the methods described herein and may store instructions which may be performed by systems other than the systems described herein.

[00114] The methods, systems, and CRSMs described herein may include the features or perform the functions described herein in association with any one or more of the other methods, systems, and CRSMs described herein.

[00115] In some embodiments, the method, methods, or operations described above may be executed or carried out by a computing system including a tangible computer-readable storage medium, also described herein as a storage machine, that holds machine-readable instructions executable by a logic machine (e.g. a processor or programmable control device) to provide, implement, perform, and/or enact the above described methods, processes and/or tasks. When such methods and processes are implemented, the state of the storage machine may be changed to hold different data. For example, the storage machine may include memory devices such as various hard disk drives, CD, or DVD devices. The logic machine may execute machine-readable instructions via one or more physical information and/or logic processing devices. For example, the logic machine may be configured to execute instructions to perform tasks for a computer program. The logic machine may include one or more processors to execute the machine-readable instructions. The computing system may include a display subsystem to display a graphical user interface (GUI) or any visual element of the methods or processes described above. For example, the display subsystem, storage machine, and logic machine may be integrated such that the above method may be executed while visual elements of the disclosed system and/or method are displayed on a display screen for user consumption. The computing system may include an input subsystem that receives user input. The input subsystem may be configured to connect to and receive input from devices such as a mouse, keyboard, or gaming controller. For example, a user input may indicate a request that certain task is to be executed by the computing system, such as requesting the computing system to display any of the above described information or requesting

that the user input updates or modifies existing stored information for processing. A communication subsystem may allow the methods described above to be executed or provided over a computer network. For example, the communication subsystem may be configured to enable the computing system to communicate with a plurality of personal computing devices. The communication subsystem may include wired and/or wireless communication devices to facilitate networked communication. The described methods or processes may be executed, provided, or implemented for a user or one or more computing devices via a computer-program product such as via an API.

[00116] Since many modifications, variations, and changes in detail can be made to the described preferred embodiments of the disclosure, it is intended that all matters in the foregoing description and shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense. Thus, the scope of the invention should be determined by the appended claims and their legal equivalents.

What is claimed is

1. A portable infrared barrier device positionable in proximity of an equipment, the portable infrared barrier device comprising:

an enclosure, comprising:

one or more sensor pods, each of the one or more sensor pods comprising one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod; and

a master controller communicatively coupled to the one or more sensor pods and the equipment,

the pod controller being configured to generate one or more first safety signals for the master controller;

the master controller being configured to:

monitor the one or more first safety signals received from the pod controllers associated with the one or more sensor pods; and

generate and send a second safety signal to the equipment;

each passive infrared sensor being operable to:

detect a source of infrared radiation in a corresponding detection zone; and

generate a detection signal indicative of the detection of the source of infrared radiation;

the pod controller associated with the sensor pod being configured to:

infer human presence in proximity of the equipment based on the detection signals generated by the one or more passive infrared sensors; and

modify the one or more first safety signals based on the inference of the human presence in proximity of the equipment; and

the master controller being configured to:

detect the modified one or more first safety signals; and

modify the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

2. The portable infrared barrier device of claim 1, wherein the master controller is further configured to:

determine a fault state associated with the portable infrared barrier device based on continuously monitoring the modified one or more first safety signals from the corresponding pod controller of each of the one or more sensor pods; and

generate the modified second safety signal based on the fault state associated with the portable infrared barrier device existing for more than a pre-determined time period.

3. The portable infrared barrier device of claim 1, wherein the master controller is communicatively coupled to a relay of the equipment, and wherein the modified second safety signal generated by the master controller is to trip the relay to cause the equipment to shut down.

4. The portable infrared barrier device of claim 1, wherein the enclosure comprises a carbon fibre nylon enclosure.

5. The portable infrared barrier device of claim 1, wherein the enclosure is trapezoidal in shape with the one or more sensor pods placed at center, front, and on each side perpendicular to the front of the enclosure.

6. The portable infrared barrier device claim 1, wherein the enclosure is guarded by a metal covering, and wherein the metal covering comprises aluminium.

7. The portable infrared barrier device of claim 1, wherein the portable infrared barrier device is configured to be coupled to one or more other infrared barrier devices.

8. The portable infrared barrier device of claim 7, wherein the one or more other infrared barrier devices comprise a stationary infrared barrier device, or another portable infrared barrier device.

9. The portable infrared barrier device of claim 1, wherein each of the one or more passive infrared sensors of the sensor pod has a detection zone that overlaps with a detection zone of at least one other passive infrared sensor of the sensor pod.

10. The portable infrared barrier device of claim 1, wherein the detection signal comprises a 3.3 volt detection signal indicative of the detection of the source of infrared radiation, wherein

each of the one or more first safety signals and the second safety signal comprises a 24 volt output switching signal device (OSSD) signal, and wherein each of the modified one or more first safety signals and the modified second safety signal is a 0 volt signal.

11. The portable infrared barrier device of claim 1, further comprising a tripod stand, and wherein the enclosure is mounted on the tripod stand.

12. A stationary infrared barrier system for an equipment, the stationary infrared barrier system comprising:

one or more sensor pods mounted on the equipment, each of the one or more sensor pods comprising one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod; and

a master controller communicatively coupled to the one or more sensor pods and the equipment,

the pod controller being configured to generate one or more first safety signals for the master controller;

the master controller being configured to:

monitor the one or more first safety signals received from the pod controllers associated with the one or more sensor pods; and

generate and send a second safety signal to the equipment;

each passive infrared sensor being operable to:

detect a source of infrared radiation in a corresponding detection zone; and generate a detection signal indicative of the detection of the source of infrared radiation;

the pod controller associated with the sensor pod being configured to:

infer human presence in proximity of the equipment based on the detection signals generated by the one or more passive infrared sensors; and

modify the one or more first safety signals based on the inference of the human presence in proximity of the equipment; and

the master controller being configured to:

detect the modified one or more first safety signals; and

modify the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

13. The stationary infrared barrier system of claim 12, wherein the master controller is further configured to:

determine a fault state associated with the stationary infrared barrier system based on continuously monitoring the modified one or more first safety signals from the corresponding pod controller of each of the one or more sensor pods; and

generate the modified second safety signal based on the fault state associated with the stationary infrared barrier system existing for more than a pre-determined time period.

14. The stationary infrared barrier system of claim 12, wherein the master controller is communicatively coupled to a relay of the equipment, and wherein the modified second safety signal generated by the master controller is to trip the relay to cause the equipment to shut down.

15. The stationary infrared barrier system of claim 12, wherein the stationary infrared barrier system is configured to be coupled to one or more other infrared barrier devices or systems.

16. The stationary infrared barrier system of claim 15, wherein the one or more other infrared barrier devices or systems comprise a portable infrared barrier device, or another stationary infrared barrier system.

17. The stationary infrared barrier system of claim 12, wherein each of the one or more passive infrared sensors of the sensor pod has a detection zone that overlaps with a detection zone of at least one other passive infrared sensor of the sensor pod.

18. The stationary infrared barrier system of claim 12, wherein the detection signal comprises a 3.3 volt detection signal indicative of the detection of the source of infrared radiation, wherein each of the one or more first safety signals and the second safety signal comprises a 24 volt output switching signal device (OSSD) signal, and wherein each of the modified one or more first safety signals and the modified second safety signal is a 0 volt signal.

19. An infrared barrier method, comprising:

receiving, by a master controller associated with an infrared barrier device, one or more first safety signals from one or more sensor pods of the infrared barrier device, each of the one or more sensor pods comprising one or more passive infrared sensors, and a corresponding pod controller associated with the sensor pod, and each of the one or more sensor pods in communication with the master controller;

continuously monitoring, by the master controller, the received one or more first safety signals;

generating and sending, by the master controller, a second safety signal to an equipment;

detecting, by the master controller, modified one or more first safety signals from at least one of the one or more sensor pods of the infrared barrier device, the modified one or more first safety signals indicative of human presence in proximity of the equipment; and

modifying, by the master controller, the second safety signal for the equipment based on the modified one or more first safety signals, the modified second safety signal to cause the equipment to shut down.

20. The infrared barrier method of claim 19, wherein each of the one or more first safety signals and the second safety signal comprises a 24 volt output switching signal device (OSSD) signal, and wherein each of the modified one or more first safety signals and the modified second safety signal is a 0 volt signal.

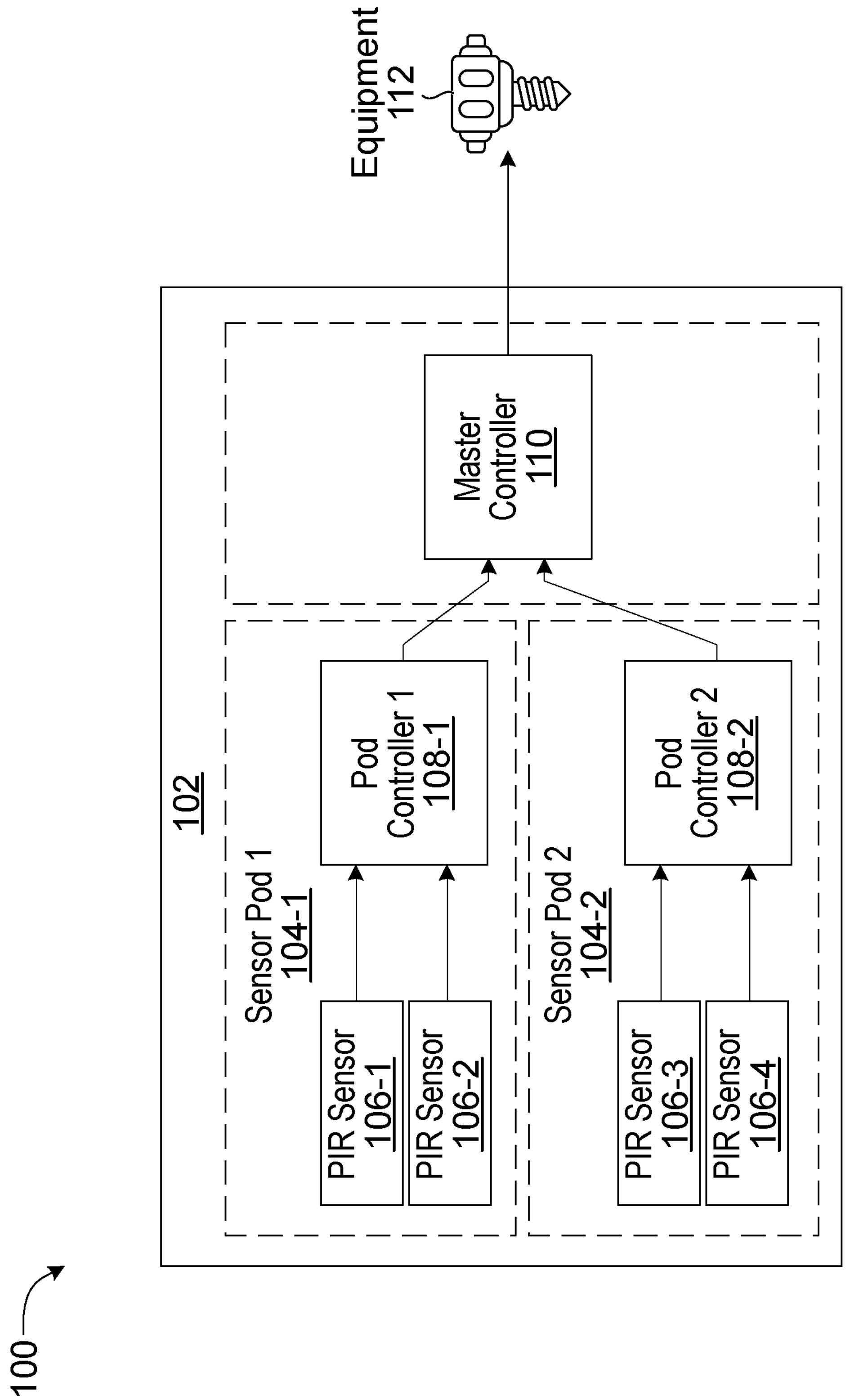

Equipment
112
Master
Controller
110
102
Sensor Pod 1
104-1
Pod
Controller 1
108-1
PIR Sensor
106-1
PIR Sensor
106-2
Sensor Pod 2
104-2
Pod
Controller 2
108-2
PIR Sensor
106-3
PIR Sensor
106-4
100

FIG. 1

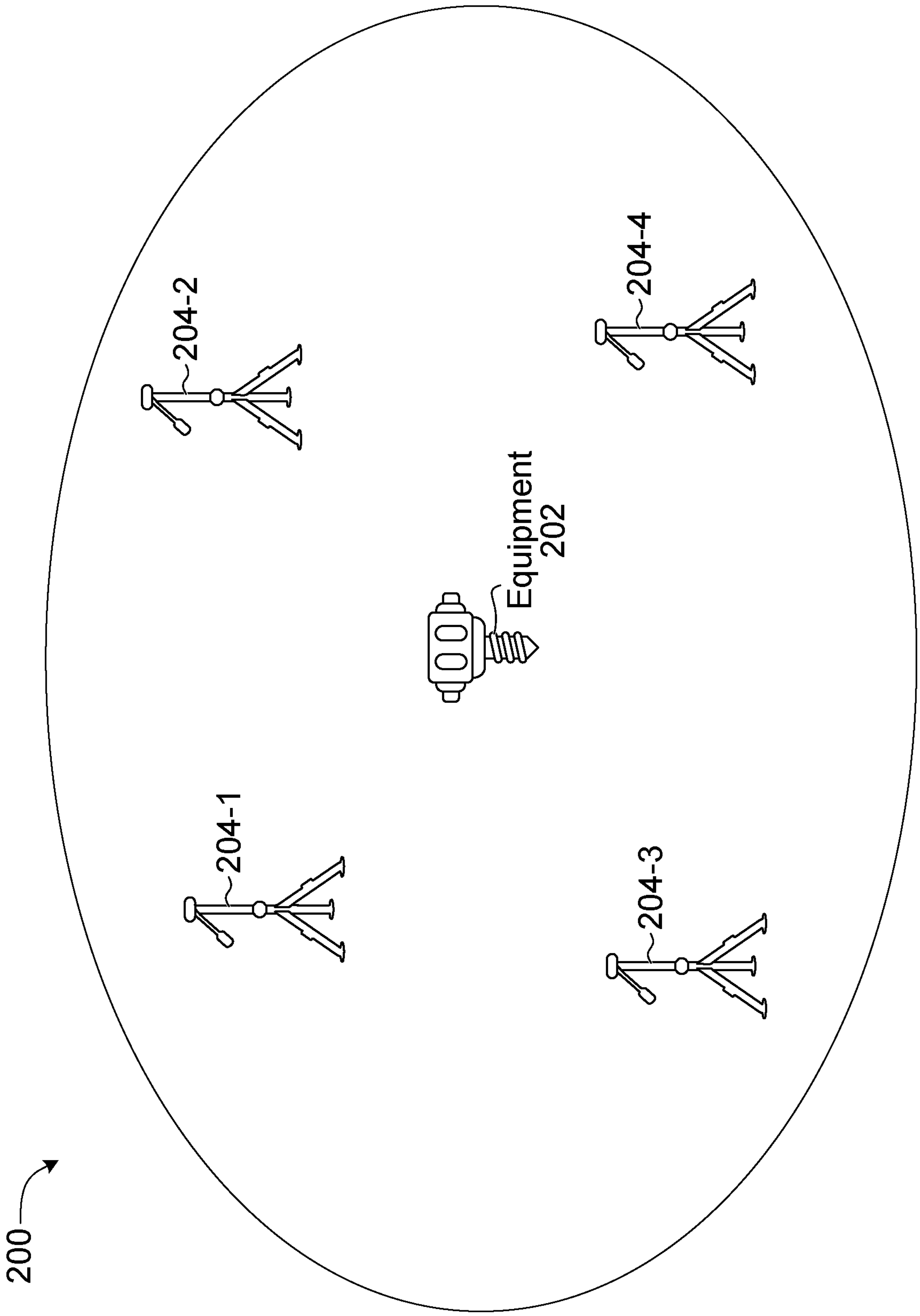


FIG. 2

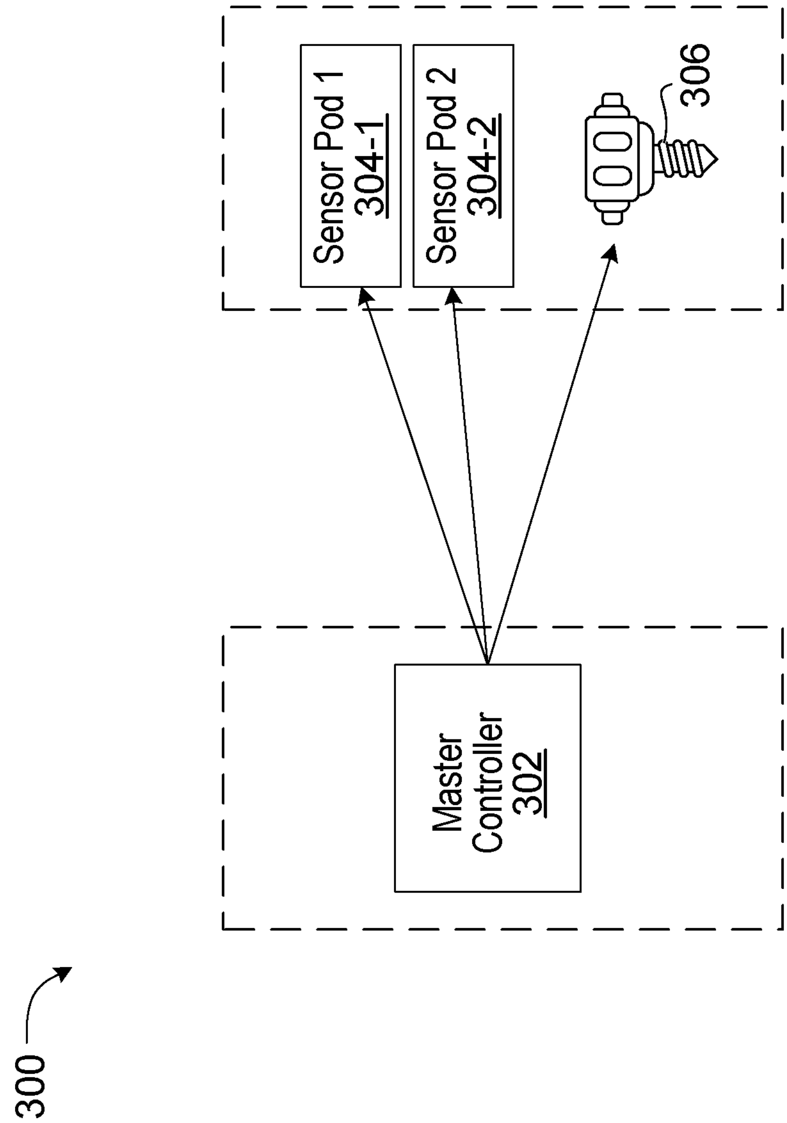

Sensor Pod 1
304-1
Sensor Pod 2
304-2
306
Master Controller
302
300

FIG. 3

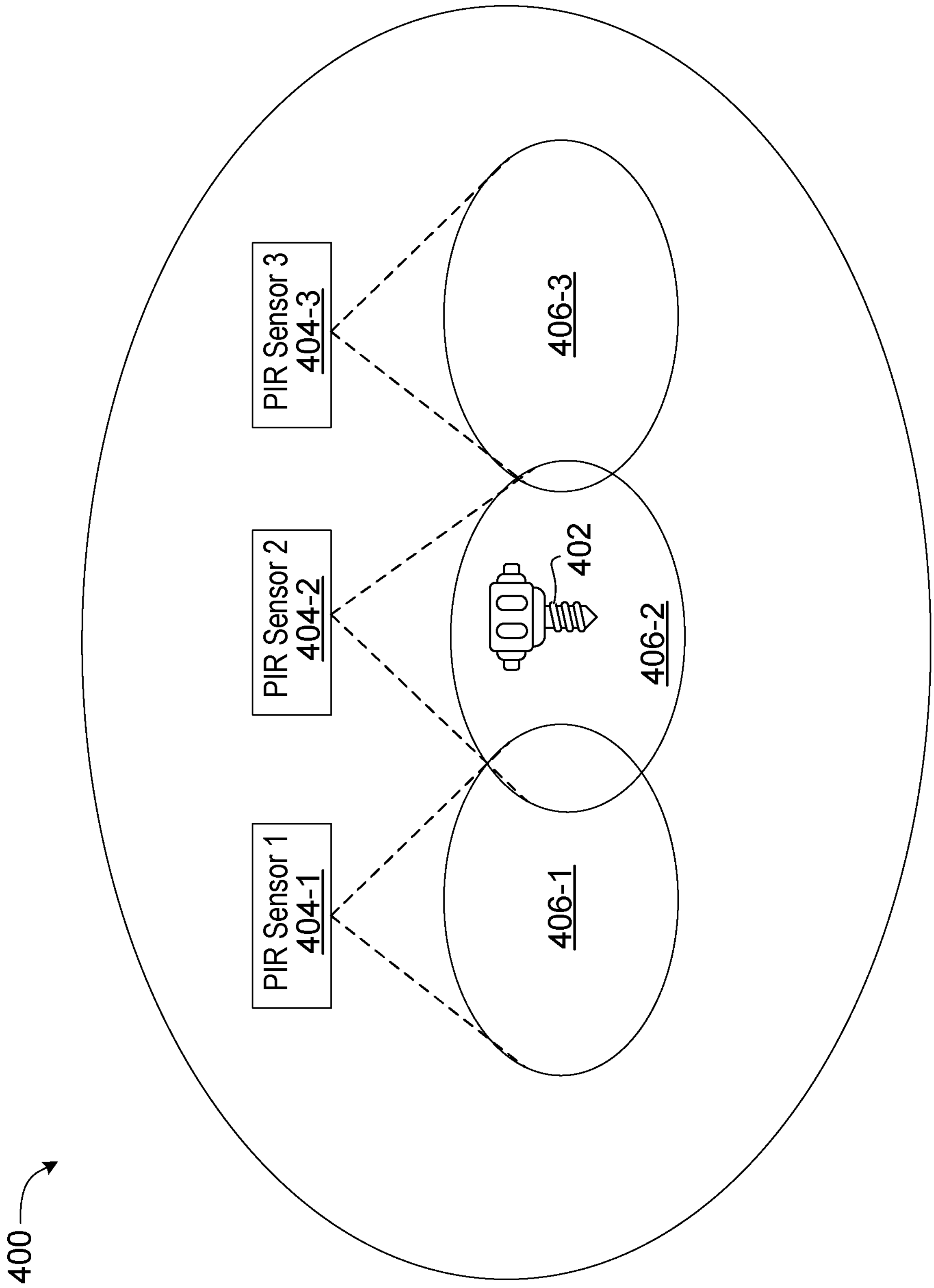

PIR Sensor 3
404-3
PIR Sensor 2
404-2
PIR Sensor 1
404-1
406-3
402
406-2
406-1
400

FIG. 4

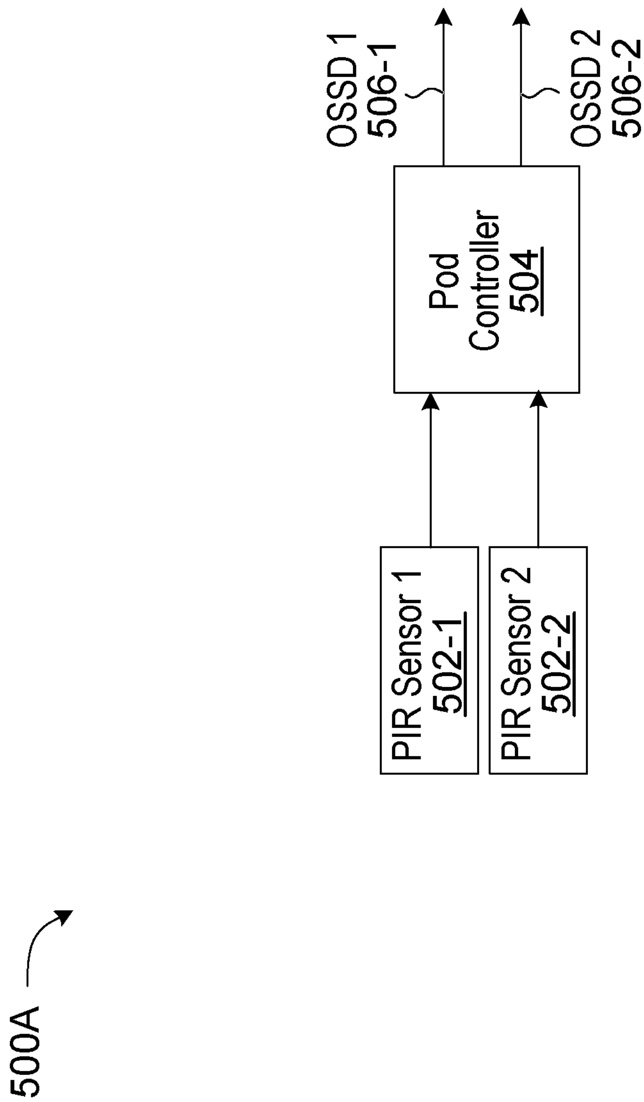

500A
PIR Sensor 1
502-1
PIR Sensor 2
502-2
Pod
Controller
504
OSSD 1
506-1
OSSD 2
506-2

FIG. 5A

500B

State	Vcc	PIR 1	PIR 2	OSSD 1	OSSD 2	Remarks
1	0 VDC	LOW	LOW	LOW	LOW	Power Off
2	24 VDC	LOW	LOW	HIGH	HIGH	Normal Energized State
3	24 VDC	LOW	HIGH	HIGH	LOW	Discrepancy / Detection State
4	24 VDC	HIGH	LOW	LOW	HIGH	Discrepancy / Detection State
5	24 VDC	HIGH	HIGH	LOW	LOW	Detection State

FIG. 5B

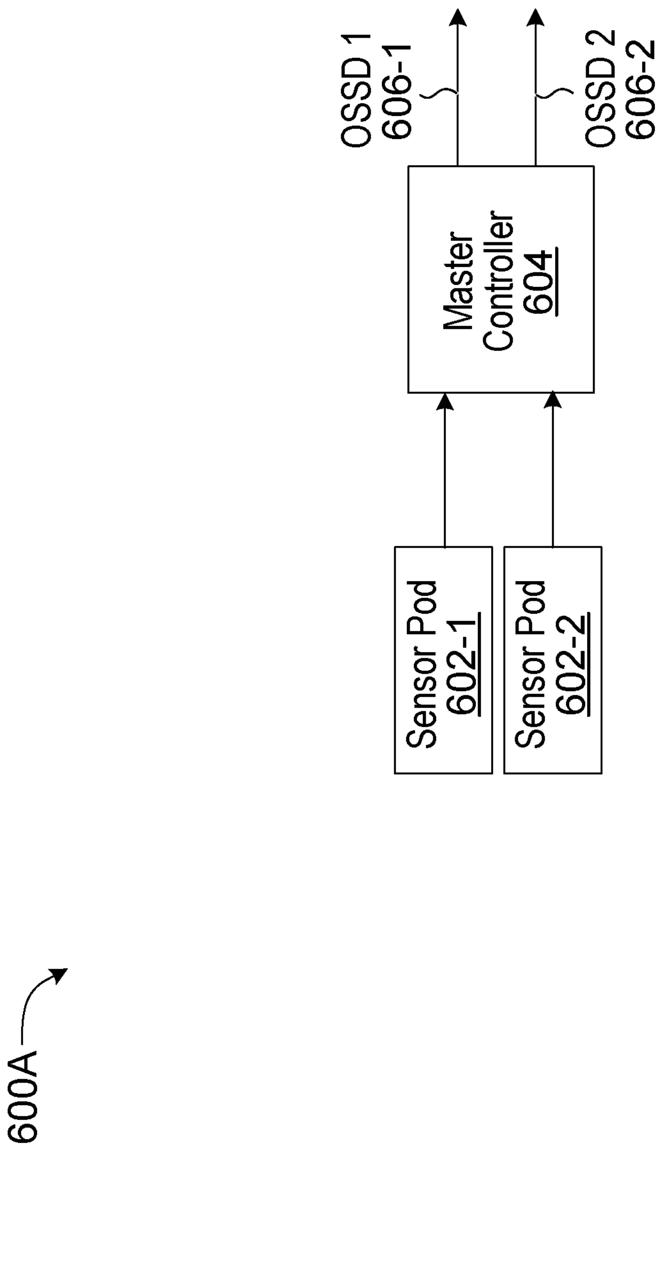

600A
Sensor Pod 602-1
Sensor Pod 602-2
Master Controller 604
OSSD 1 606-1
OSSD 2 606-2

FIG. 6A

600B

State	Vcc	OSSD 1	OSSD 2	OSSD 3	OSSD 4	OSSD Output 1	OSSD Output 2	Remarks
1	0 VDC	LOW	LOW	LOW	LOW	LOW	LOW	Power Off
2	24 VDC	LOW	LOW	LOW	LOW	LOW	LOW	Detection State
3	24 VDC	LOW	HIGH	HIGH	HIGH	LOW	LOW	Input Discrepancy Pod 1 / Detection State
4	24 VDC	HIGH	LOW	HIGH	HIGH	LOW	LOW	Input Discrepancy Pod 1 / Detection State
5	24 VDC	HIGH	HIGH	LOW	HIGH	LOW	LOW	Input Discrepancy Pod 2 / Detection State
6	24 VDC	HIGH	HIGH	HIGH	LOW	LOW	LOW	Input Discrepancy Pod 2 / Detection State
7	24 VDC	HIGH	HIGH	LOW	LOW	LOW	LOW	Detection State Pod 2
8	24 VDC	LOW	LOW	HIGH	HIGH	LOW	LOW	Detection State Pod 1
9	24 VDC	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	Energized State

FIG. 6B

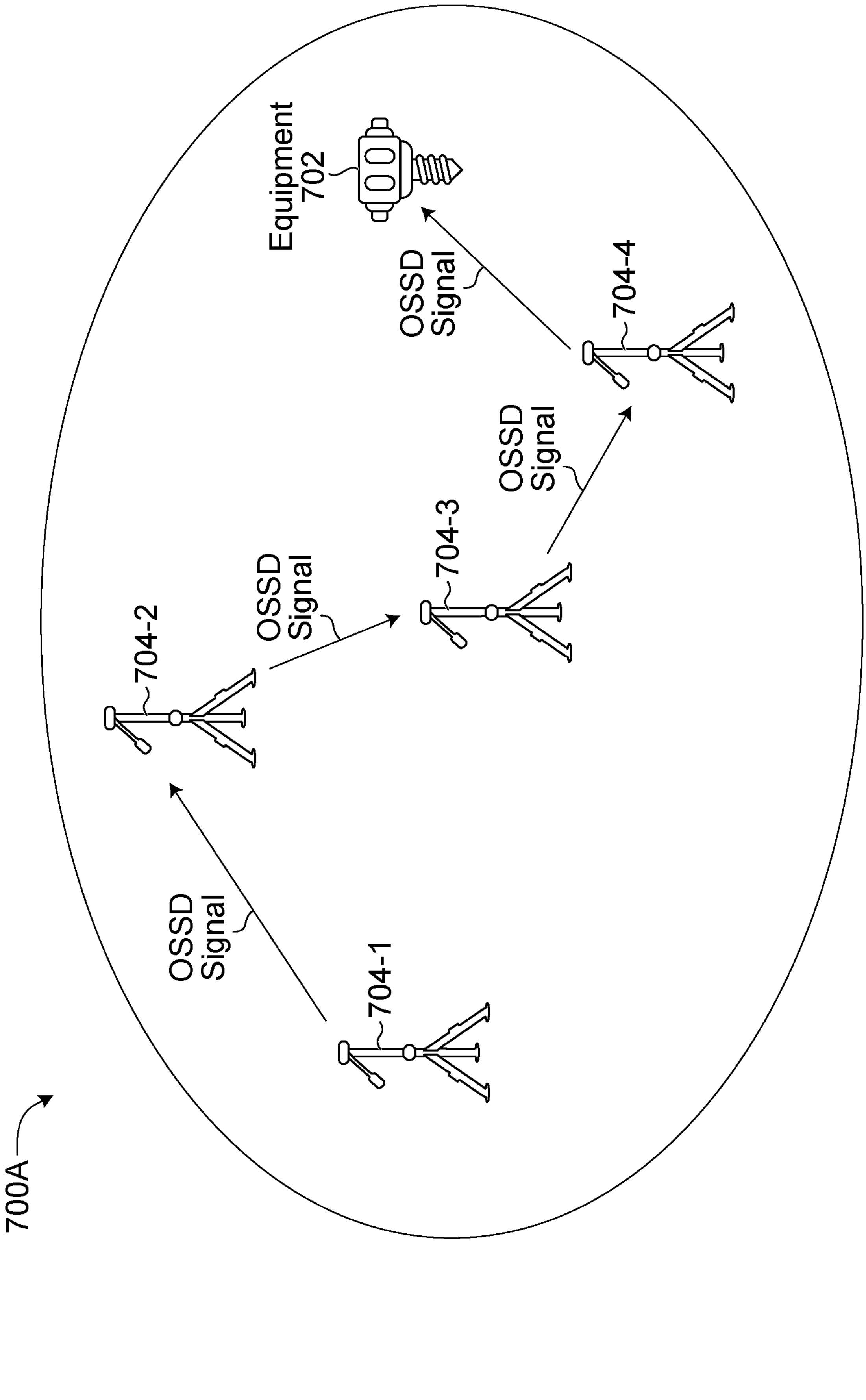
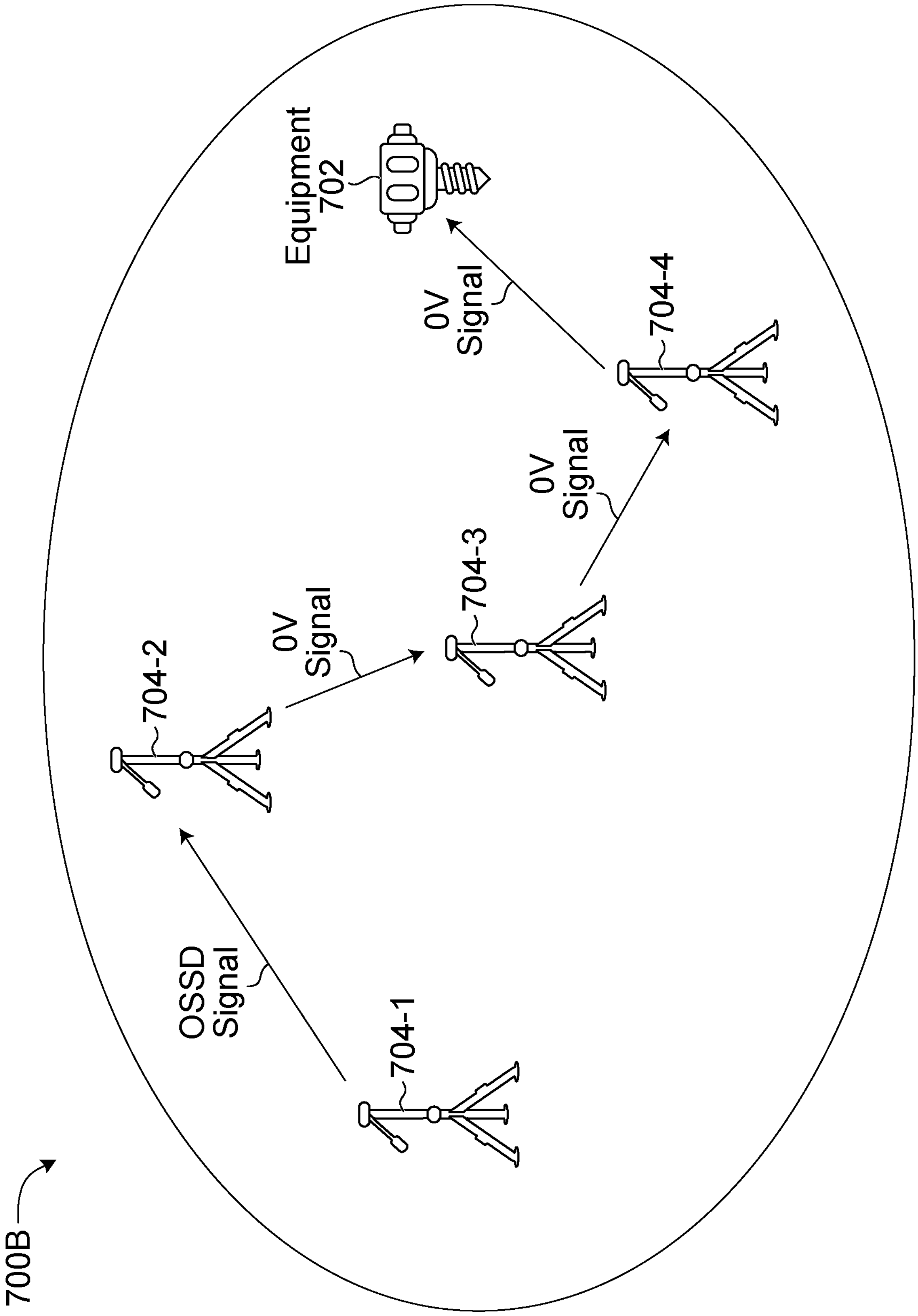

700A
Equipment
702
OSSD
Signal
OSSD
Signal
OSSD
Signal
OSSD
Signal
704-1
704-2
704-3
704-4

FIG. 7A



700B
Equipment
702
0V
Signal
704-4
0V
Signal
704-3
0V
Signal
704-2
OSSD
Signal
704-1

FIG. 7B

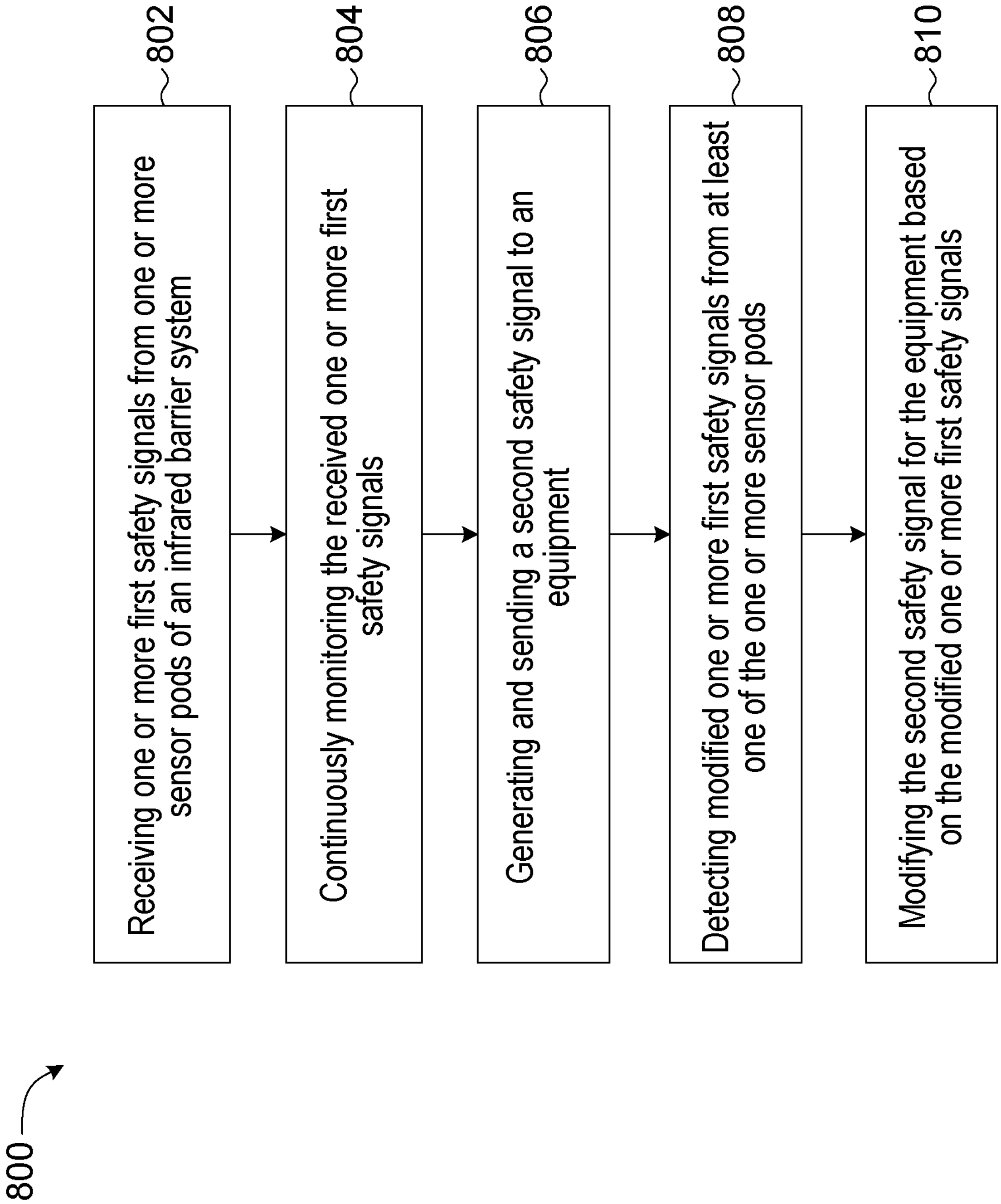

800
802
Receiving one or more first safety signals from one or more sensor pods of an infrared barrier system
804
Continuously monitoring the received one or more first safety signals
806
Generating and sending a second safety signal to an equipment
808
Detecting modified one or more first safety signals from at least one of the one or more sensor pods
810
Modifying the second safety signal for the equipment based on the modified one or more first safety signals

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2023/050808

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***F16P 3/14*** (2006.01) , *G08B 13/19* (2006.01)

CPC: F16P 3/14 (2020.01) , G08B 13/19 (2022.01)

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)
IPC(2006.01) F16P 3/14, G08B 13/19
CPC(2020.01) F16P 3/14, CPC(2022.01) G08B 13/19

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

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

Questel Orbit, Espacenet, Canadian Patent Database
Keywords : infrared, portable, sensor*, safety, signal*, shut down, pod*, capsule*, passive, mount*, enclosure, housing, machine, equipment, human, person, controller

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 10,843,343, B2 (LEE, J.Y. et al.) 24 November 2020 (24-11-2020) *The entire document*	1-20
A	US 7,183,912 B2 (MICKO, E.S.) 27 February 2007 (27-02-2007) *The entire document*	1-20
A	US 5,604, 483 A (GIANGARDELLA, J.J. et al.) 18 February 1997 (18-02-1997) *The entire document*	1-20
A	US 10,909,439 B2 (TOURNOIS, J. et al.) 02 February 2021 (02-02-2021) *The entire document*	1-20

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
12 February 2024 (12-02-2024)	20 February 2024 (20-02-2024)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer

Krystyna Bielunska (819) 639-3299

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		CN109114411B	03 August 2021 (03-08-2021)
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		AU2003291108B2	04 September 2008 (04-09-2008)
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		AU2006238431B2	11 November 2010 (11-11-2010)
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		BRPI0318027B1	13 October 2015 (13-10-2015)
		BRPI0609662A2	20 April 2010 (20-04-2010)
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		CN100565139C	02 December 2009 (02-12-2009)
		CN101167110A	23 April 2008 (23-04-2008)
		CN101167110B	19 May 2010 (19-05-2010)
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		GB2414551A	30 November 2005 (30-11-2005)
		GB2414551B	20 September 2006 (20-09-2006)
		GB0720846D0	05 December 2007 (05-12-2007)
		GB2439882A	09 January 2008 (09-01-2008)
		GB2439882B	11 June 2008 (11-06-2008)
		GB0805980D0	07 May 2008 (07-05-2008)
		GB2445491A	09 July 2008 (09-07-2008)
		GB2445491B	17 September 2008 (17-09-2008)
		HK1112338A1	29 August 2008 (29-08-2008)
		IL168149A	30 November 2010 (30-11-2010)
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		KR101237305B1	27 February 2013 (27-02-2013)
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		US7399970B2	15 July 2008 (15-07-2008)
		US2005236572A1	27 October 2005 (27-10-2005)
		US7755052B2	13 July 2010 (13-07-2010)
		US2008287123A1	20 November 2008 (20-11-2008)
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		CN110161987A	23 August 2019 (23-08-2019)
		EP3528077A1	21 August 2019 (21-08-2019)
		EP3528077B1	07 April 2021 (07-04-2021)
		EP3528077B2	01 November 2023 (01-11-2023)
		JP2019145101A	29 August 2019 (29-08-2019)