



(43) International Publication Date
20 August 2015 (20.08.2015)

(51) International Patent Classification:
B66F 9/075 (2006.01)

(21) International Application Number:
PCT/IB2015/051049

(22) International Filing Date:
12 February 2015 (12.02.2015)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
FI2014A000030 12 February 2014 (12.02.2014) IT

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM,

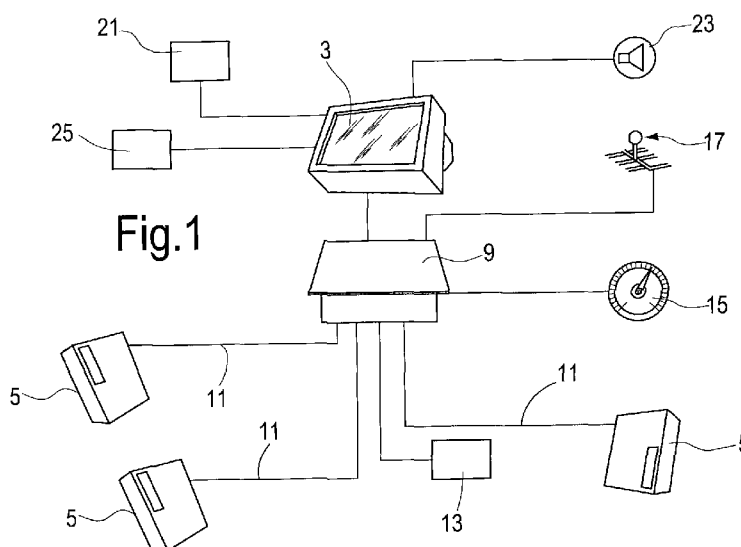
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: SYSTEM FOR PREVENTING COLLISIONS BETWEEN SELF-PROPELLED VEHICLES AND OBSTACLES IN WORKPLACES OR THE LIKE



(57) Abstract: The control system comprises a central control unit (3) associated with one or more sensors (5). The sensors emit an activation signal to actuate responders (DR) arranged within a control volume around a vehicle, aboard which the sensors are installed. When a responder enters the control volume, it is actuated by means of the signal of the sensor and generates an answer that is captured by the sensor (5) and transmitted to the control unit, which generates an alarm. The dimension of the control volumes varies according to the velocity of the self-propelled vehicle.

"SYSTEM FOR PREVENTING COLLISIONS BETWEEN SELF-PROPELLED VEHICLES AND OBSTACLES IN WORKPLACES OR THE LIKE"

DESCRIPTION

FIELD OF THE INVENTION

5 The present invention relates to accident prevention at work. The invention especially relates to improvements to the so-called active safety systems, using for instance RFID technology, to prevent accidents caused by the collision between vehicles or between a vehicle and a person.

10 BACKGROUND TO THE INVENTION

Reduction and prevention of workplace accidents are fundamental in any industry, especially in the sectors where workers are directly into contact with both fixed and self-propelled machines, representing potential risks to people.

15 Accident risks, that can result in severe and permanent damages and injuries, and in some cases even in workers' death, may be posed both by fixed operating machines, for instance provided with movable elements that can harm the workers, such as machine tools, calenders, presses, printing machines and the like, and by self-propelled vehicles, such as trucks, lorries, forklifts, stackers, container cars, lifting machines, earthwork machinery such as scrapers and excavators, or the like.

20 If self-propelled machines or vehicles hit people, many severe damages and injuries can occur, even the death.

 The risk of collision between self-propelled vehicles and operators exists for instance on construction sites, where earthwork machinery and vehicles are used, in harbor areas, in warehouses, in storage areas and the like. Similar problems arise in
25 production plants, for instance foundries, paper mills and the like.

 In case of collision between a vehicle and a person, the passive safety systems, such as for instance protective helmets, safety shoes and boots, harnesses and the like, are not sufficient to avoid serious harms, permanent injuries, and even death.

30 Therefore, so-called active safety systems have been developed for the prevention of workplace accidents. Specifically as regards the prevention of person-vehicle collisions, active systems have been developed using sensors installed on board the vehicles and configured like RFID tag or transponder readers. The operator

wears at least one RFID tag, provided for instance in a helmet, a safety vest, or other mandatory passive safety device. Thanks to the interaction between the sensor and the RFID tag, the operator of the self-propelled vehicle is alerted by a central control unit as a sensor installed on board the vehicle detects the presence of a person within
5 the vehicle motion range.

EP 1209615 discloses a dual-band RFID transponder technology that is particularly effective and is especially targeted at active prevention of workplace accidents. This document, whose content is incorporated in the present description and to which reference should be made for more details, provides a system
10 comprising at least one sensor and one or more dual-band RFID transponders or tags, able to communicate at two different frequency bands without interferences. Both the sensor, or reader, and the transponder, or responder, contain two distinct antennas each. A first antenna on the sensor emits, and a first antenna on the transponder respectively receives, a signal, typically a microwave signal, whose function is to
15 actuate the RFID transponder, that is usually quiescent for energy saving purposes. The transponder is actuated as it enters a limited sensor range or control volume.

A second antenna on the transponder, or responder, and a corresponding second antenna on the sensor allow the transmission between transponder and sensor and/or vice-versa, via a channel, typically a radio-frequency channel, other than the
20 channel of the activation signal for the transponder.

As it is well known, this technology is also applied for active prevention of workplace accidents, especially to prevent collisions between people and vehicles. At least one sensor is provided on board the vehicle, and usually more than one sensor are provided, whilst the operator wears at least one transponder. When the operator
25 enters the range of a sensor arranged on board the vehicle, this sensor actuates the transponder and causes the emission of an alarm signal.

WO2011/141897, whose content is incorporated in the present description and to which reference can be made for further details, discloses an integrated modular active safety system, based upon the use of the dual-band RFID technology
30 described above. This document describes a system, wherein the operator wears a plurality of passive safety systems, each of which is provided with an RFID transponder and which in combination form a so-called PAN (Personal Area Network) or BAN (Body Area Network). At least one of the RFID transponders

functions as a master and communicates with the other network devices. It also interacts with a sensor that can be arranged, for instance, on board a self-propelled vehicle for anti-collision purposes, as described above.

The systems described in the documents mentioned above are very useful tools for accident prevention at work. Their main advantage is to allow a wide range, thanks to the high sensitivity of both the transponder and the sensor.

However, the achievable safety level can be further increased. An object of some embodiments of the present invention is to improve the safety level and the ergonomics of this kind of active safety systems.

10

SUMMARY OF THE INVENTION

According to one aspect, an active safety system for collision avoidance is provided, comprising:

at least one self-propelled vehicle;

15 at least one sensor on board the self-propelled vehicle, configured to detect the presence of at least one responder within a control volume controlled by the sensor;

a central control unit, preferably arranged on board the self-propelled vehicle, with which there is associated said at least one sensor, said control unit being
20 configured to modify the dimension of the control volume according to at least one velocity parameter of the self-propelled vehicle and to generate at least one alarm signal when the responder enters the control volume of the sensor.

As it will be described in greater detail below with reference to some
25 embodiments, the system of the invention allows modulating the sensor range according to the speed of the self-propelled vehicle. In this way, it is possible to adapt, in the best possible way, the sensor range to the different conditions of use, increasing it when the vehicle moves at higher speed and decreasing it when the vehicle moves at lower speed. This correlation between speed and sensor range
30 maximizes the safety levels, avoiding false alarms that usually occur in the traditional systems, when the vehicle moves, for example, very slowly or does not move, while the sensor range is set for higher speed.

Conveniently, the sensors are micro-wave sensors, having the advantage of

being directive and thus allowing an accurate selection of the range thereof.

In practical embodiments, the sensor emits an activation signal at a power variable according to the speed of the self-propelled vehicle. When a responder, installed on another vehicle or on a person, enters the sensor range, whose dimension
5 varies according to the vehicle speed, it is actuated by means of the activation system and emits a response signal. This is received by the sensor and sent to a control unit that, in turn, generates an alarm signal or actuates a safety procedure. As it will be explained below, many supplemental functions can be implemented with this technology, all increasing the system safety.

10 In some embodiments, it is possible to detect the magnitude and direction of velocity of the self-propelled vehicle so as individually to modulate the range, i.e. the control volume, of each individual sensor according to its position on board the vehicle, i.e. according to whether the sensor is directed forward or backward. In this way, the directivity of the microwave sensors is exploited really in an optimal way.

15 According to another aspect, the invention relates to a method for the prevention of collisions between a self-propelled vehicle and at least one obstacle, comprising the steps of:

arranging at least one sensor and one central control unit on board the self-propelled vehicle;

20 modulating the sensor capacity according to at least one velocity parameter of the self-propelled vehicle.

In other embodiments, the sensor range is constant, the power of the activation signal emitted by the sensor varies periodically and contains a datum on the radiated power. When a responder enters the sensor range, the activation signal actuates it and
25 the responder generates a response signal giving a piece of information on the strength of the received activation signal. This datum, or piece of information, is indicative of the detected distance, i.e. the distance between sensor and responder. Through the sensor, the central control unit receives the response from the responder and verifies whether the detected distance is equal to, shorter or longer than a safety
30 distance, defining the dimension of the control volume. In case the detected distance is longer than the safety distance, the responder is considered to be outside the control volume. In case the detected distance is shorter than, or equal to, the safety distance, the responder is considered to be inside the control volume and an alarm

signal is generated.

Practically, as the safety distance, and therefore the dimension of the control volume, varies according to the speed of the self-propelled vehicle, the safety system is essentially adapted to the velocity of the self-propelled vehicle: the higher this velocity, the greater the control volume, and vice-versa.

Features and embodiments are disclosed here below and are further set forth in the appended claims, which form an integral part of the present description. The above brief description sets forth features of the various embodiments of the present invention in order that the detailed description that follows may be better understood and in order that the present contributions to the art may be better appreciated. There are, of course, other features of the invention that will be described hereinafter and which will be set forth in the appended claims. In this respect, before explaining several embodiments of the invention in details, it is understood that the various embodiments of the invention are not limited in their application to the details of the construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which the disclosure is based, may readily be utilized as a basis for designing other structures, methods, and/or systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood based upon the description below of some embodiments, set forth with reference to the accompanying drawings. In the drawings:

Fig. 1 is a functional block diagram of the equipment that can be installed on board a self-propelled vehicle of a system according to the invention;

Fig. 2 is a schematic plan view of different types of industrial vehicles

(forklift, scraper, truck) and the possible arrangement of sensors on board thereof;

Fig. 3 illustrates the effect of the modulation of the sensor range, or control volume, according to the speed of the self-propelled vehicle on which the sensors are arranged;

5 Fig. 4 is a diagram correlating vehicle speed and control volume, i.e. sensor range;

Fig. 5 is a diagram of a signaling monitor associated with a system of sensors installed on board a vehicle;

Fig. 6 shows the monitor of Fig. 5 in a function mode with double alarm
10 level;

Figs. 7 and 8 show data that can be collected through the system according to the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

15 The following detailed description of the exemplary embodiments refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. Additionally, the drawings are not necessarily drawn to scale. Also, the following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims.

20 Reference throughout the specification to "one embodiment" or "an embodiment" or "some embodiments" means that the particular feature, structure or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrase "in one embodiment" or "in an embodiment" or "in some embodiments" in various
25 places throughout the specification is not necessarily referring to the same embodiment(s). Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

A system according to the invention for avoiding collisions and preventing accidents can comprise one or more self-propelled vehicles and one or more
30 responders. Generally speaking, a complete system can comprise a plurality of responders, in a number sufficient for providing all people, accessing an area protected by means of the system described herein, with at least one responder each. In some embodiments, the system also comprises responders arranged on the self-

propelled vehicles, to avoid the collisions between self-propelled vehicles too.

In the present description and the attached claims, "self-propelled vehicle" means any vehicle moving automatically or under the operator's control. In the last case, a central control unit interfacing with one or more sensors on board the self-propelled vehicle can emit an alarm signal for the operator when a responder is detected within the control volume of one of the sensors arranged on board the vehicle. The alarm signal can be a visual, an acoustic, or a mechanical signal (for instance a vibration), or a combination thereof. Instead, in the case of a vehicle moving automatically, the central control unit can cause an automatic action on the vehicle management system (for example through a suitable interface, such as a relay), for instance slowing the vehicle down or stopping it; or it can cause the vehicle to generate an alarm signal by means of a siren or an emergency light. Automatic self-propelled vehicles, such as carriages, bridge cranes, forklifts, etc., are used for instance in industrial plants, warehouses or the like, to transport or transfers items, finished or semi-finished products and the like.

Moreover, the responder can be part of a PAN or BAN as mentioned above. In some embodiments, the responder is installed on a passive safety system, such as a helmet, a safety jacket, a safety boot or other safety device that the operator must wear when he/she enters the area protected by means of the protection system of the invention.

In the present description and in the attached claims, in some cases reference will be made to at least one self-propelled vehicle and at least one responder. However, it should be understood that, in most cases, the system will comprise a vehicle or a fleet of vehicles, equal to or different from one another, and a plurality of responders.

In some embodiments, all the responders are substantially equal to one another. In other embodiments, different categories of responders are provided, according to the use thereof. For instance, as it will be described below with reference to some specific applications, responders may be provided, configured to be worn by the staff working in the area protected by means of the system of the invention, as well as responders configured to be installed on board self-propelled vehicles.

In some advantageous embodiments, each responder is provided with a

unique code. These unique codes can be used to classify the responders according to their use, i.e. according to their installation. For example, each unique code may have a section with a number indicating whether the responder shall be installed on board a vehicle or shall be worn by a person. Alternatively, it is possible to associate a
5 piece of information with each unique code, for instance in a data bank; this piece of information indicates whether this code relates to a responder installed on board a vehicle or to a responder worn by a person.

In this way, it is possible to program the central control units of one, or of each, self-propelled vehicle of the system so as to generate different alarm signals
10 according to whether a responder entering the range is installed on board a vehicle or is worn by a person. In this way the operator of the self-propelled vehicle can detect what kind of risk occurs.

The responder unique identification code may be also used, for example, for control purposes, to differentiate the system behavior, to record events, to limit the
15 access to given areas, or for any other purpose where it is useful or necessary to detect uniquely which responder is in a given position or in a given status with respect to the sensors that are on board the vehicles.

Also each sensor of the system can be identified with a respective unique code. In this way it is possible to associate each detected event with a pair of codes,
20 one identifying the responder and the other one identifying the sensor that has detected the presence of the responder within its range. These pieces of information can be adequately stored to be subsequently processed. In this way it is possible to know, for each responder, which sensor has detected it and therefore in which sector the risk occurred.

25 The teaching upon which the present invention is based can be applied to a variety of sensors and responders. Generally, the sensors are configured to send an activation signal and the responders are configured to be actuated by the activation signal when they are within the volume controlled by a sensor. The actuated responder and the sensor are also configured to exchange information, from the
30 responder to the sensor and vice-versa, if necessary, so that the responder can inform the central control unit associated with the sensor of having entered the sensor range.

In preferred embodiments of the invention sensors are used, formed by, or comprising, a reader or so-called RFID tag illuminator, provided with a preferably

bidirectional transmission system allowing the exchange of data between the sensor and the responder. The responder is preferably an RFID device or tag.

There are particular advantages if the sensor and the responder are dual-band. In this case the sensor uses a band, for instance a microwave frequency band, to
5 actuate a responder entering the range, or control volume, thereof, while another band, for instance a radio frequency, is used for the mono- or preferably bi-directional transmission between the sensor and the responder.

The sensor may be a high directive sensor. In accident and near-miss assessment, this feature of the sensor, together with its unique ID, allows to identify
10 the direction from which the responder or TAG moved towards the sensor.

In some embodiments the responder or TAG emits an alarm signal, which can be heard by the person wearing the responder when it enters the sensor range. In this way, the event is signaled not only to the operator of the self-propelled vehicle (or to the central unit controlling the movement of the self-propelled vehicle, in case of
15 automatic vehicle without driver), but also to the person wearing the responder.

The self-propelled vehicles usable in the system of the invention can be actuated electrically or by means of an internal-combustion engine.

The self-propelled vehicles may move along tracks or guides, or they can freely move, for instance on tired wheels.

20 Within the scope of the present invention, self-propelled vehicle refers also to cranes, bridge cranes or other movable means typically used in industrial environment, on sites or in similar workplaces.

Fig. 1 shows a block diagram of the main components that can be arranged on board a self-propelled vehicle of a system according to the invention.

25 On board a generic self-propelled vehicle there is installed a central control unit 3, that may be provided, for instance, with a microprocessor, input/output ports, one or more mass storage supports, a display or other user interfaces, and other components or drivers, not shown. In some embodiments, communications interfaces may be provided. These interfaces are usually wireless, to allow the vehicle to move
30 freely. However, in some embodiments it is possible to use a wired interface, for instance when the self-propelled vehicle (for example a bridge crane) has a limited movement along a given trajectory. The central control unit 3 is connected to one or more sensors 5. The connection between the central control unit and the sensors can

be a wireless or, preferably, a wired connection, because the central control unit and the sensors take, anyway, a fixed, or only slightly variable, reciprocal position once they have been installed on board the self-propelled vehicle.

In some embodiments, the central control unit 3 is connected to the sensors 5
5 by means of a first wire 7, a hub 9 and a plurality of cables 11 connecting the hub 9 to the individual sensors 5.

The diagram of Fig. 1 shows only three sensors 5; however, it should be understood that the number of sensors can be also different than that illustrated; this number depends, for example, upon the dimension and the shape of the self-
10 propelled vehicle, as well as upon the directivity of the antennas of the individual sensors. The position and the number of the sensors are preferably such as to form an overall control volume surrounding the whole self-propelled vehicle.

In some embodiments, for instance when the self-propelled vehicle has a movable part, such as the excavator bucket, this movable part may be provided with
15 one or more sensors, which are slightly movable with respect to the other sensors carried by the body of the self-propelled vehicle.

The self-propelled vehicle may be also provided with one or more GPS receivers, or other systems for localizing the self-propelled vehicle with respect to a reference network. In Fig. 1, number 13 schematically indicates a GPS receiver,
20 shown just by way of example. In some embodiments, instead of using GPS receivers, the vehicle can use detection systems of a different network, external to the vehicle, for instance provided locally by means of TAGS similar to those used for detecting an obstacle in the vehicle maneuvering area. The receiver(s) can also be used to detect the speed and the position of the self-propelled vehicle, for the
25 purposes that will be better described below. In this way it is possible to determine the velocity, in terms of direction and magnitude of the vector quantity, by means of a reference network outside the vehicle, without it being necessary to interface the system described herein with mechanical, electrical or electronic means with which the vehicle is provided. For instance, by means of the detection system using a
30 network outside the vehicle it is possible to determine the velocity scalar quantity (magnitude), i.e. the speed, based upon the derivative of the displacement detected by means of the external network, without it being necessary to connect the central control unit 3 to a tachometer or other speedometers. With the same data that can be

detected by means of the external reference network it is possible to detect also the direction (of the vector velocity); thus, it is no longer necessary to connect the central control unit 3 with a selector provided on the vehicle, for instance a gear box. This makes it easier to install the equipment of the system described herein on the
5 vehicles of an existing fleet, so as to upgrade them. In some embodiments it can be decided to detect only the scalar quantity, i.e. the speed, and not the direction of the velocity vector. In fact, even if it is preferable to modulate the control volume also according to the direction, as described above, in simpler embodiments it is possible to modulate the control volume only according to the speed, i.e. the velocity
10 magnitude, without taking into account the moving direction of the self-propelled vehicle.

In some embodiments, the self-propelled vehicle may be also provided with a radar system, for instance a Doppler radar, to detect the speed of the self-propelled vehicle even in case there is no external network. This can be useful, for example, in
15 the case of self-propelled vehicles working both outside, where the GPS network is available, and inside, for instance in a warehouse, where the GPS signal could be insufficient or even missing. In this case the Doppler radar detector, or a different speedometer on board the self-propelled vehicle, can be used as a temporary replacement of the GPS system. The Doppler radar can detect not only the speed, but
20 also the vectorial value of the velocity, i.e. its direction and magnitude.

In some embodiments, the central control unit, with which the Doppler radar is associated, is programmed so that, when the vehicle is still, the radar gives an alarm signal as it detects a relative velocity between the vehicle and an obstacle entering the radar range. As the Doppler radar is able to detect, for example, the
25 relative velocity of a person moving within the Doppler radar range, this can be used to send a datum or an alarm signal useful for the operator of the self-propelled vehicle. In some cases, it could be useful to alert the operator when an obstacle, such as a vehicle or especially a person, enters the Doppler radar range; this, in fact, limits the risk of collision in case of a sudden starting of the vehicle.

30 The following situation can thus occur. The self-propelled vehicle is not moving and its sensors are therefore inactive, or they emit at a minimum rate. A person enters the space near the self-propelled vehicle as the operator wants to move the vehicle. The sensors are modulated according to the velocity of the self-propelled

vehicle; therefore, they could send the alarm signal too slowly or too late with respect to the reciprocal position and the relative velocity between self-propelled vehicle and obstacle. The use of a Doppler radar reduces this risk. In some embodiments two or more Doppler radars are used, for instance to monitor the area
5 in front and at the back of the self-propelled vehicle.

In other embodiments, the central control unit 3 is connected to a speedometer of the self-propelled vehicle. For example, the central control interfaces with a tachometer 15. The use of a tachometer, or other speedometer provided on board the self-propelled vehicle, allows to omit the GPS receiver, or to have two
10 distinct systems for measuring the speed of the self-propelled vehicle. In some embodiments, a speedometer is provided, that is autonomous with respect to the vehicle, for instance a Doppler radar system, a magnetic encoder, an ultra-sound system or other suitable system. The use of a speedometer that is autonomous with respect to the vehicle, including a GPS system or a system based upon the use of a
15 different localization network outside the vehicle, allows installing this system on already existing self-propelled vehicles, without the need for connection to the instruments already existing on the vehicle.

In some embodiments, the central control unit 3 interfaces with systems for detecting the movement direction (forward or backward movement). This is
20 schematized in Fig. 1, where the central control unit 3 is connected to a gearbox 17 of the self-propelled vehicle. The direction can be detected also by means of an autonomous measurement system, such as a Doppler radar or an encoder.

Fig. 2 shows schematic plan views of different self-propelled vehicles, on which it is possible to install the set of instruments described above with reference to
25 Fig. 1. The self-propelled vehicles of Fig. 2 are mere examples of the different possibilities of use of the system of the invention. The represented self-propelled vehicles comprise a forklift 1A, an excavator 1B and a semi-trailer truck 1C. The reference numbers 5A, 5B, 5C; 5D, 5E, 5F, 5G, 5H; 5I, 5J, 5K, 5L indicate sensors arranged in different ways on the self-propelled vehicles 1A, 1B, 1C, according to
30 the shape and the dimensions thereof, as well as to the movements they perform. The number and the position of the sensors may also depend upon the directivity of the emitting antenna and therefore upon the shape and dimension of the radiating lobe thereof.

A single system can comprise vehicles of different types, with a different number and a different arrangement of sensors 5. Sensors may also be provided, different from one another in terms of directivity, i.e. of radiating lobe shape. Sensors with different radiating lobes can be installed in different positions on the same vehicle, or on different vehicles.

Fig. 3 shows a plan view of the range, i.e. the control volume, of the sensors 5 in an exemplary arrangement of a generic vehicle 1, for instance an excavator. Reference numbers 5D-5H indicate the sensors. Two sensors 5D, 5E may be arranged in the front area, two sensors 5F, 5H may be arranged in the side area and one sensor 5G may be arranged in the back area.

Each sensor may be provided with a radiating system, for instance a microwave system. The radiating system may comprise suitably configured antenna with a suitable radiating lobe, so that the sensor has the desired directivity. The circuit structure of a sensor 5 may be of the type described in EP1209615.

The distance covered by the signal of the sensor 5, i.e. the sensing range, may be adjusted by means of the central control unit 3, so as to define a given control volume, i.e. a volume arranged in front of the sensor and usually having a given shape according to the configuration of the sensor antenna. The control is performed by electronically modulating the strength of the signal emitted by the sensor. For example, in the case of microwave sensors, the strength of the microwave signal emitted by the sensor antenna is adjusted so as to modulate the distance achieved by the sensor signal and therefore the control volume thereof, i.e. the volume accessing which a responder, reacting to the sensor signal, is detected.

The direction of the control volume may be adjusted by suitably positioning the sensor 5 on board the vehicle 1. For instance, in the illustrated example the two front sensors 5D, 5E are directed so as to generate two radiating lobes directed forward. The illustrated shape of the radiating lobes is just an example thereof, and does not limit the scope of protection of the invention.

It is also possible to provide one or more sensors with a relative movement with respect to the self-propelled vehicle, for instance a scan movement around an axis. An encoder may be provided to detect the instant position, so that the central control unit 3 is able to know the sensor direction at every instant, and, therefore, also the instant a response signal is detected by a responder actuated, i.e. illuminated,

by the activation signal generated by the sensor.

The dimension of the radiating lobes, and, thus, of the control volume, of each individual sensor may be adjusted by regulating the radiated power. The greater the sensor radiated power, the greater the range thereof, i.e. the distance at which the signal can be received, thus the greater the dimension of the radiating lobe.

Fig. 3(A) shows five control volumes indicated with VD, VE, VF, VG, VH, for the five sensors 5D, 5E, 5F, 5G, 5H, respectively. Under the conditions illustrated in Fig. 3(A), the control volumes VD-VH are substantially equal. The distance D achieved by the sensor signal is nearly the same for all the sensors 5D-5H. This is usually the condition where the self-propelled vehicle 1 does not move.

When the vehicle moves forward, the dimension of the control volumes of the sensors 5D-5H can be changed according to the magnitude and, as the case may be, to the direction of velocity. In the illustrated example, both the direction and the magnitude of the vector velocity are detected, and the radiation of each individual sensor 5D-5H is modified so as to optimize their range.

In Figs. 3(B) and 3(C) the self-propelled vehicle 1 is moving forward at different speeds. For example, in Fig. 3(B) the self-propelled vehicle travels at 20 kph, while in Fig. 3(C) it travels at double speed, i.e. 40 kph.

As the speed changes, the radiating lobes, and therefore the control volumes of the sensors 5D-5H, change. Under the operating conditions of Figs. 3(B), the radiating distance D1 of the two front sensors 5D, 5E is increased with respect to the distance D of Fig. 3(A), where the vehicle is not moving. In the illustrated example, the dimension of the control volume of the side and rear sensors is decreased, and is equal to D2. In other embodiments, the dimension of the control volumes of the sensors oriented in the opposite direction with respect to the direction of movement of the self-propelled vehicle can be the same as the dimension in the absence of motion. If the system is provided with means that detect only the magnitude, and not the direction of the velocity, all of the radiating lobes of the sensors 5A-5H change substantially in the same way, i.e. all the lobes increase as the speed increases, and decrease as the speed decreases.

As the speed further increases, as shown in Fig. 3(B), then the radiating power of the front sensors 5D, 5E further increases, so as further to increase the distance achieved by the signal and the volume control dimension, up to the

dimension D3. In the illustrated example, the side and rear sensors 5F-5H have decreased the radiating power and have, consequently, reduced the distance D4 and the volume control.

If an operator, wearing a responder schematically indicated with DR in Fig. 3(B) and Fig. 3(C), is at a certain distance from the self-propelled vehicle 1, he/she is not reached by the radiating lobe of the sensors and, therefore, no alarm signal is generated, when the vehicle travels at low speed (Fig.3(B)). Contrarily, if the operator wearing the responder DR is at the same distance from the vehicle, but the vehicle 1 travels more quickly (Fig. 3(C)), an alarm signal is generated, because the dimension of the radiating lobe of the sensors is greater, due to the greater stopping distance.

In general, the function linking the sensing range - and, thus, the dimension of the control volume (through a change in the radiating power of the activation signal) - to the speed of the self-propelled vehicle is a direct function; in other words, the sensing range, and thus the control volume of the sensors, increases as the speed increases. This link is not necessarily linear.

The link between speed and dimension of the control volume is given by the vehicle stopping distance, measured taking into account the estimated reaction time of the driver (or of the control electronics in case the vehicle is automatic) and the braking distance of the vehicle.

Fig. 4 shows an example of how the sensing range (y-axis) can vary with the speed (x-axis). The numerical values on the x-axis are given just by way of example. Even the illustrated curve is given just by way of example, being understood that it could be different than that shown here. Preferably, the curve is in general a quadratic function, approximately.

Just by way of non-limiting example, Fig. 3 shows, 3 m, 10 m and 25 m as values for the sensing range of the front sensors. The same exemplary data are shown in Fig. 4.

As shown in the example of Fig. 3, when the vehicle moves forward, the sensing range of the sensors directed forward increases, while the sensing range of the sensors directed backwards may decrease.

If the self-propelled vehicle reverses and moves backwards, the situation illustrated in Fig. 3 (D) may occur: the sensing range, and, thus, the control volume,

of the rear sensors 5F-5H increases, while the sensing range of the front sensors decreases, with respect to the range of the stationary vehicle. In other embodiments, the sensing range, and, thus, the control volume, of the front sensors may remain the same as the range of the stationary condition (Fig. 3(A)).

5 The relation between speed of the self-propelled vehicle and dimension of the control volume, i.e. sensor signal strength, may also take into account the operating conditions of the self-propelled vehicle, namely the situation in which it is used. For example, the sensor range may be increased when the self-propelled vehicle works in situations increasing the braking distance (wet road, gravel drive, etc.). In this case,
10 the curve of Fig. 4 becomes steeper as the braking distance increases.

 The relationship between control volume (and, hence, sensor signal strength) and speed can be changed according not only to the road or ground conditions, but also to other conditions of use of the vehicle, such as the load, which may affect the braking distance.

15 In some embodiments, the relation between sensing range and speed can be changed also according to other factors. For example, the sensing range may correlate also with the vehicle position. This latter can be detected using a GPS, or other localization methods (e.g. RFID or encoder or proximity sensors). In this way, the sensing range can be increased, for example, when the vehicle is in an area that is
20 particularly dangerous for the workers.

 Thanks to the adjustment of the sensing range, i.e. of the control volume, of the sensors 5 according to the speed of the self-propelled vehicle, the system is inherently safer and more efficient. In fact, the sensing range is optimized based upon the operating conditions. If the self-propelled vehicle moves slowly, and its
25 stopping distance is therefore reduced, it is sufficient that the sensors detect the responder presence within a smaller range, i.e. within a shorter distance from the self-propelled vehicle. In this way it is possible to avoid false alarms, i.e. alarm conditions for obstacles placed at such a distance that is not dangerous due to the low speed of the self-propelled vehicle. Conversely, when the self-propelled vehicle
30 speed increases, the sensing range is increased, as the stopping distance increases. Adjusting the sensor control volume it is possible to avoid false alarm conditions that - if frequent - can lead to a lower level of attention by the operator of the self-propelled vehicle.

As mentioned above, in simpler embodiments the sensing range, and therefore the control volume, can be adjusted only according to the magnitude, and not according to the direction, of velocity. In this case, all of the sensors 5 increase or decrease the radiated power as a direct function of the velocity magnitude. In this way, it is easier to control the sensor emission and to detect the operating conditions of the self-propelled vehicle, as it is enough to measure the magnitude of velocity, and not the direction thereof. However, in this way the number of false alarms increases, for instance when an operator enters the sensing range of a rear sensor on board the vehicle while this latter is moving forwards, and there is therefore no risk of collision with the operator. If the radiating lobe of the rear sensors has not been decreased, this causes a false alarm.

If the dimension of the control volume of the sensors oriented in the reverse direction with respect to the direction of movement of the vehicle is adjusted so as to be equal to, or lower than, the dimension of the control volume of the stationary vehicle, there are no false alarms due to obstacles that are near the vehicle but in a place from which the vehicle is moving away, and that are not therefore dangerous.

The central control unit 3 may be programmed so as to set a default radiated power, and therefore a default control volume, in case there are no speed data available, for instance due to a failure of the GPS receiver or due to any other reason. In order to maximize the system safety, the default value for the power, and therefore for the control volume, may be the same value set for the vehicle maximum speed.

Fig. 5 schematically illustrates a way in which a collision risk may be represented on a monitor 21, arranged on board the self-propelled vehicle and interfacing with the central control unit 3. Such an alarm situation occurs when at least one of the sensors 5 of the vehicle 1 receives a signal from a responder, which enters the control volume thereof and is therefore "illuminated" by the activation signal that is sent by the sensor and that actuates the quiescent responder. Following the activation, the responder sends a signal to the sensor that, in turn, sends an alarm to the central control unit. The responder may also send data about its own unique ID code; in this way the central control unit 3 is able to identify the operator at risk of collision.

Fig. 5 shows the profile of a generic driver seat S1 of a self-propelled vehicle 1; the seat is surrounded by a series of indicator lamps I5, each of which corresponds

to one of the sensors on board the self-propelled vehicle 1. In the example of Fig. 5, eight indicator lamps I5 are schematically indicated, corresponding to eight sensors 5. The indicator lamps I5 are used for diagnostic purposes. The color of each indicator changes according to the operating condition of the corresponding sensor.

5 For instance: no light means that the sensor is not present or not installed; green color indicates that the sensor is present and works correctly; red color indicates that the sensor is present but does not work correctly. Alternatively, instead of a different color to indicate whether the sensor works correctly or is broken, a light can be used, continuous or flashing respectively.

10 In some embodiments, light sectors SL are arranged around the indicator lamps I5. Each light sector SL can be associated with one or more sensors. Each light sector SL is lit when the sensor, or one of the sensors with which it is associated, detects a TAG or responder within its control volume. In this way, an alarm signal is generated, with which there is associated a datum about the direction along which the

15 sensor and the responder are moving towards each other.

In case different types of responders are provided, namely responders worn by the staff and responders installed on board the vehicles respectively, different signals may be generated on the monitor 21, so that the operator of the self-propelled vehicle is able to understand whether the responder entering the sensing range is on

20 board a vehicle or is worn by a person. This can be useful due to the different vulnerability of the obstacles detected by the system: a second vehicle entering the sensing range of the sensor(s) may pose a risk to damage objects and things, but not people, and can be therefore managed according to a different procedure. Moreover, the central control unit 3 may advantageously store the type of hazard, i.e. of

25 collision risk, for example for statistical purposes, or for lessons learned purposes, to modify the operating conditions, the trajectories of the self-propelled vehicles, the movements of the staff, etcetera, to avoid similar hazards in the future.

In the embodiment schematically illustrated in Fig. 5, a first ring of light sectors SL and a second ring of light sectors SL1 are provided to differentiate the

30 type of collision risks (person-vehicle collision, vehicle-vehicle collision) easily. The sectors of the first ring SL are actuated when the responder is worn by a person. The sectors of the second ring SL1 are actuated when the responder is installed on board a vehicle.

The two rings of light sectors SL and SL1 may also have a different color, for instance red and white respectively, to differentiate clearly and quickly the higher or lower severity of the hazard situation.

In some embodiments the system is able to give different alarm signals according to the distance at which there is the responder detected by the sensor(s). Fig. 6 schematically illustrated two different collision risk signals, wherein a responder is detected by the same sensor but at two different distances, greater in Fig. 6(A) than in Fig. 6(B). These two different situations can be distinguished, for example, by means of a different color of the light signals, by means of different intensity of the signals, by means of a continuous light or a flashing one, by using both an optical and a sound signal, or in any other suitable way.

In some embodiments, an alarm signal at different distances is provided, based upon whether the responder entering the sensing range is installed on board another vehicle or worn by a person. This allows, for example, reducing the alarm signals in case of involvement of only vehicles, wherein a collision has less severe consequences.

In general, it is possible to adopt different solutions when it is necessary to generate alarm signals taking into account the responder distance.

For instance, the sensor may cyclically emit frames of different strength, variable from a minimum to a maximum. The maximum value is suitably determined according to the vehicle speed, based upon the criterion described above, while the minimum value may be constant, i.e. it does not vary according to the vehicle speed.

Each signal frame emitted by the sensor may contain, coded therein, a piece of information on the radiated power. A responder in the sensor range (defined by the distance covered by the signal when the maximum power frame is radiated) answers only if the radiated frame has a sufficient strength to achieve the responder. As the signal received by the responder contains a datum corresponding to the frame radiated strength, the answer from the responder to the sensor may contain, in turn, a datum correlating with the strength of the signal frame, to which the responder has reacted.

For instance, let's assume that the self-propelled vehicle 1 travels at a speed V , such that the sensor 5 emits a signal whose maximum strength is W_n . This signal is practically divided into a series of (two or more) frames, with a strength increasing

from a minimum $W1$ to a maximum Wn , for example three signal frames whose strength is $W1$, $W2$ and Wn , respectively. These frames are repeated cyclically. The frames achieve increasing distances $D1$, $D2$, and Dn . The responders outside the sensing range, i.e. at a distance greater than Dn , are at safety distance, and, thus, they
5 do not generate an alarm situation. Conversely, a responder that is at a distance Dr such that:

$$D1 < Dr < D2$$

is actuated by the signal frame of strength $W2$, but not by the signal frame of strength $W1$. The responder actuated by the signal frame with strength $W2$ sends a response
10 signal to the sensor 5, containing a datum about the fact that the received activation signal is that of the frame whose strength is $W2$. This datum is transmitted to the central control unit 3, that is able to understand that the obstacle corresponding to the responder is within the sensing range of the sensor 5 at a distance comprised between $D1$ and $D2$.

15 The central control unit 3 receives therefore the following information: the code of the responder that has been actuated by the signal emitted by the sensor; the code of the sensor, whose signal has been received by the responder; the strength of the signal that has actuated (i.e. has caused the response from) the responder. Based upon these data, the central control unit 3 can send an alarm signal through the
20 monitor 21, or any other interface, indicating not only the type of responder (installed on a vehicle or worn by a person) but also the distance of the obstacle corresponding to the responder. Alternatively, the central control unit 3 may be programmed to generate or not to generate an alarm according to the type of obstacle that has been detected (vehicle or person) and to the distance: in case of a vehicle, the central
25 control unit generates an alarm only if the distance is equal to, or lower than, a lower threshold; in case of a person, the central control unit always generates an alarm signal, independently of the distance, as the responder enters the sensing range, this being a function of, at least, the vehicle speed.

The visual or light signal on the monitor 21 may be combined with a sound,
30 that can be emitted by means of a sound diffuser 23 or the like (Fig. 1) and that can be adjusted, for example, according to the level of risk. Also this sound signal can be different, according to whether the responder is installed on board a vehicle or is worn by a person.

In some less advantageous embodiments, it is possible to provide only the sound signal. In this case, the sounds can be different according to the area where the detected obstacle is, using, for example, different tones based upon whether the obstacles are in front of or at the back of the vehicle.

5 The central control unit 3 can be also programmed to verify whether a given responder is entering the sensing range of a given sensor for the first time or it remains in this sensing range for some time, emitting two different signals accordingly.

10 In the embodiments described above, the strength of the activation signal emitted by the sensors 5 is adjusted according to the speed (and the direction, as the case may be) of the self-propelled vehicle. In this way, the range of the safety system is adapted to the vehicle speed; therefore, it is possible, on one hand, to avoid the use of an excessive range when the vehicle is not moving or is traveling slowly, and, on the other hand, to increase the sensor range, and therefore the system safety, when
15 the vehicle travels more quickly. In this way it is possible to avoid false alarms or, anyway, too frequent alarm signals that, instead, could occur if, to increase the safety at high speed, a greater range of the activation signal would be used also at low speed or when the vehicle is not moving.

20 In a modified embodiment, the result described above may be achieved by means of a modified management system. The components of the hardware may be the same; therefore, on board a generic self-propelled vehicle 1 the components that are schematized in the block diagram of Fig. 1 are arranged. According to this modified embodiment, the strength of the activation signal emitted by each sensor 5 does not change according to the vehicle speed but can vary, for example, cyclically
25 within a range comprised between a minimum strength W_{min} and a maximum strength W_{max} .

30 To this end, the activation signal may be subdivided into signal frames. Each frame is emitted at a strength comprised between W_{min} and W_{max} , and it may contain a piece of information on the radiated power. If the signal is emitted cyclically, signal frames of gradually increasing strength are emitted repeatedly in the space surrounding the vehicle, each of which contains the piece of information on the strength of the individual frame.

Each responder may be programmed to be activated by the activation signal,

when this signal reaches the responder antenna, and to emit a response signal received by the sensor 5. Moreover, each responder may be programmed to read the piece of information on the strength of the received frame, which is contained in the signal frame that has actuated the responder. The response signal, sent by the responder to the sensor, contains a datum corresponding to the strength of the signal frame, which has actuated the responder. Since the signal strength correlates with the distance at which the signal can be detected, and since sequences of signal frames are emitted very quickly compared to the relative displacement between the vehicle and the obstacles identified by the responders, in practice the strength of the signal detected by the responder correlates with the mutual distance between the responder and the vehicle, or more precisely the sensor which sent the activation signal.

Therefore, when a responder has detected an activation signal and has been actuated thereby, it sends a response signal, the sensor receives the response signal from the responder and transmits, to the central control unit, a piece of information indicating:

- a) that a responder has been detected within the space "illuminated" by the sensor and, thus, at a distance comprised between the minimum and the maximum distance achieved by the signal (minimum distance achieved by the frame W_{min} and maximum distance achieved by the signal W_{max}),
- b) the strength of the activation signal that has actuated the responder, and thus, indirectly, the distance at which there is the responder.

The central unit 3 can be programmed to receive data on the speed of the self-propelled vehicle. These data may indicate only the magnitude, or also the direction of velocity, and can be collected, for example, in one of the ways described above.

The central control unit can be programmed also to generate an alarm signal based upon two parameters:

- i) vehicle speed
- ii) strength of the signal frame received by the responder.

When the distance, corresponding to the strength of the frame that has caused the response signal from the responder, represents a risk for the vehicle instant speed, the central control unit 3 emits an alarm signal based upon an algorithm, or using tabulated values stored in a memory the central control unit 3 can access, or in any other way. Conversely, when the distance, corresponding to the strength of the signal

frame, is greater than a safety distance, corresponding to the vehicle speed, the central control unit does not generate the alarm signal.

In practice, indicating with $W_0, W_1, W_2, W_3, \dots, W_i, W_{i+1}, \dots, W_N$ the increasing strengths of the frames of the activation signal, these strengths correspond to increasing detection distances $d_0, d_1, d_2, d_3, \dots, d_i, d_{i+1}, \dots, d_n$, i.e. increasing distances, from the sensor, at which the signal can be detected by a responder. According to this notation, d_i is the maximum distance at which the signal of strength W_i can be detected. For a given speed V_j of the self-propelled vehicle, the central control unit 3 establishes that the safety distance, and therefore the dimension of the volume control, shall be D_j . This correlation may be fixed or variable, for example depending on the condition of the road (wet/dry) where the vehicle travels, on the load, etc., as already described above.

The central control unit 3 is programmed to emit an alarm signal when a responder DR is detected at a distance d_j that is lower than, or equal to, the safety distance D_j and that corresponds to a radiated power W_j , where D_j is the quantity defining, in this case, the control volume. If the response signal of the responder DR contains data indicating that the strength of the received activation signal is greater than W_j , the central control unit 3 does not generate an alarm signal, as it understands that the responder DR is outside the control volume. Conversely, if the strength of the signal that has actuated the responder is lower than, or equal to, W_j , the central control unit 3 considers it a collision risk and emits an alarm, as it understands that the responder DR is within the control volume having dimension D_j .

Therefore, essentially, in this case again, the range, i.e. the dimension of the control volume, of the safety system is modulated according to the vehicle speed, i.e. an hazard situation is signaled when an obstacle (identified by a responder) is at a distance equal to, or lower than, a safety distance from the self-propelled vehicle, the safety distance not being fixed but rather modulated so as to adapt to the speed and, as the case may be, also to the direction of the self-propelled vehicle.

The vehicle speed can be determined (in terms of vector and/or scalar quantity) using any system and method described above, for example preferably using a reference system with respect to an external network, such as a GPS system. Instead of a GPS system, other types of network can be used, for example with references located along predetermined paths of the self-propelled vehicle, which is

equipped with sensors able to detect the position of the vehicle with respect to said references, and therefore the position of the vehicle in the space where there is the network defined by these references.

In some embodiments, the method of periodic modulating the signal strength, described herein can be used, receiving the signal from the responder that contains the information on the received power, and then comparing the speed value obtained from this signal with a limit value, which can be different for the various sensors, depending on the direction of the vehicle. For example, let's assume that the self-propelled vehicle includes a front sensor and a rear sensor. Both sensors are managed, according to the operating mode described above, by the central control unit 3 so as to generate activation signals of periodically increasing strength, each signal containing information on the radiated power. When a sensor receives a response signal from a responder, the central control unit compares the distance of the responder, that can be extracted from the response signal, with a value of minimum safety distance, which can be different for the front sensor with respect to the rear sensor, according to the direction and the magnitude of velocity. When the self-propelled vehicle is traveling forward, the response signal received by the front sensor will be compared, for example, with a greater value of safety distance (the greater, the higher the speed) than the safety distance associated with the rear sensor. The opposite occurs when the vehicle is reversing.

Briefly, in the first embodiment a control volume is provided, directly defined by the sensor range, that is, by the maximum distance at which the activation signal can be detected, and therefore the strength of the emitted signal, and the control volume varies based upon the speed, directly acting on the maximum sensor power according to the speed of the self-propelled vehicle.

Conversely, in the second embodiment the control volume is indirectly modulated according to the speed of the self-propelled vehicle, namely: the sensor range does not change with respect to the speed, but the responders are considered selectively inside or outside the control volume (and therefore closer or more distant with respect to a safety distance) based upon the strength of the signal that they detect. That is, the control volume is defined by the central control unit 3, rather than by modulating the strength of the signal emitted by the sensor according to the speed. The radiating power of the activation signal is modulated in a repetitive manner and

independently of the speed of the self-propelled vehicle, in order to provide the central control unit with information on the detection distance of the activation signal and, hence, on the distance at which there is the responder with respect to the sensor and the self-propelled vehicle.

5 Currently the first embodiment is preferred, because it allows a higher response speed of the system.

 The alarm condition can be shown, for example, on a monitor in one of the ways described above, possibly distinguishing between the detection of a responder installed on board a vehicle and a responder worn by a person. Different alarm
10 signals may also be provided based upon different safety distances.

 Essentially, in this alternative embodiment the sensors always have the same range, that is, the emission of the activation signal does not depend upon the speed, while the central control unit distinguish between real danger and non-hazardous situation based upon the distance at which the responder has been detected, which
15 distance is determined based upon the strength of the signal frame that has actuated the responder, and upon the speed of the self-propelled vehicle.

 Combined systems, which use both the methods described above, can also be utilized.

 Moreover, the system described herein can be provided with software able to
20 record and store various data during the operation of the self-propelled vehicle. In some embodiments, it is possible to record one or more pieces of information relating to: the position of the vehicle over time; speed of the vehicle over time; detection of responders and, at the same time, storage of the unique identification code of the detected responder and, therefore, of the type thereof (installed on board
25 a vehicle or worn by a person), date and time; unique identification code of the sensor that has detected the responder.

 Figs. 7 and 8 show two different types of tables containing data that can be stored, for example, in a mass memory 25 (see Fig. 1) and transmitted to a control center, for example with a remote query system, or downloaded onto a storage
30 medium such as SD card, flash memory, external hard drive or other means that can interface with the central control unit 3 installed on board the self-propelled vehicle 1. Advantageously, data can be downloaded from the memory by means of a wireless system, which allows to optimize the data management from a mobile vehicle.

The first column of the table of Fig. 7 shows the codes of the responders that have entered the range of sensors of the vehicle. It is possible to distinguish the responders worn by a person, indicated with "Tag", and the responders installed on board vehicles, indicated with "Vehicle", and their unique identification codes. The second column of the table shows the sensor(s) in whose range the responder has been detected. This allows knowing the direction along which the sensor and the responder have moved towards each other. The third column of the table shows the time of the event; the last column shows the date. An additional column (not shown) can contain the speed, detected for example via the GPS system and/or another device, independent or connected to the tachometer of the vehicle (if any).

The table of Fig. 8 shows data similar to the previous ones, also indicating the coordinates (latitude North/South; longitude East/West) identifying the position of the self-propelled vehicle in correspondence of each detection of a responder, as well as the time and date, both local and of the GPS system, used in this example to track the movements of the vehicle.

In the embodiments described herein, reference is made to configurations, wherein on board the self-propelled vehicle one or more sensors in one or more appropriate positions are arranged. The various sensors may have high directivity, i.e. emit according to relatively narrow radiating lobes, so as to provide relatively accurate information on the position of the detected obstacle with respect to the vehicle. All the sensors can be substantially equal.

In other embodiments, sensors can be used, having directivity characteristics different from one other. For example, it is possible to install, in different positions on board the self-propelled vehicle, sensors whose radiating lobes have different shapes, and therefore having different directivity. In other embodiments, it is possible to install, in the same position of the self-propelled vehicle 1, two or more sensors different from one another as regards the radiation features, for example directivity, and/or range, i.e. distance achieved by the signal, or other features. In some embodiments, active and passive sensors can be used in combination on the same vehicle.

In some particularly advantageous configurations, it is possible to install, in each position on the vehicle, two sensors, which emit lobes that differ from each other in shape and dimension. A first sensor may have a radiating lobe of small

dimension and high isotropy. In this case the sensor has low directivity. It can be combined with a second sensor having a narrower and longer radiating lobe. In this case, the sensor case has greater range and higher directivity. The combination of the two sensors results in the combination of two different radiating lobes, and, therefore, results in a control volume of complex shape. The first sensor is capable of detecting a near obstacle, in whatever position it is within the control volume. Therefore, the first sensor has high isotropy. The second sensor is capable of detecting also a far obstacle, but that must be in a narrow volume, i.e. within a limited angle of view of the sensor, which has high directivity and therefore has anisotropic radiation. The combination of sensors with these different characteristics allows particularly interesting results, as the nearest obstacle is easily detected whatever position it has with respect to the self-propelled vehicle.

In general, in the context of the present description and the appended claims, when reference is made to a generic sensor it should be understood that this can also be inclusive of two or more distinct emitting and receiving devices, and therefore of two or more sensors, with directivity and/or isotropy and/or range features different from one another.

While the disclosed embodiments of the subject matter described herein have been shown in the drawings and fully described above with particularity and detail in connection with several exemplary embodiments, it will be apparent to those of ordinary skill in the art that many modifications, changes, and omissions are possible without materially departing from the novel teachings, the principles and concepts set forth herein, and advantages of the subject matter recited in the appended claims. Hence, the proper scope of the disclosed innovations should be determined only by the broadest interpretation of the appended claims so as to encompass all such modifications, changes, and omissions.

CLAIMS

1. An active safety system for collision avoidance comprising:
 - at least one self-propelled vehicle;
 - at least one responder;
 - 5 - at least one sensor, on board the self-propelled vehicle, configured to detect the presence of the responder within a control volume, controlled by the sensor by means of activation signals emitted by the sensor;
 - a central control unit, with which the sensor is associated;wherein the central control unit is configured to modify the dimension of the control
10 volume according to at least one velocity parameter of the self-propelled vehicle and to generate at least one alarm signal when the responder enters the control volume.
2. System according to claim 1, wherein said sensor emits electromagnetic wave activation signals, preferably microwaves signals, at variable power.
- 15 3. System according to claim 2, wherein said sensor emits activation signals at variable power depending on said at least one velocity parameter.
4. System according to one or more of the previous claims, wherein the central control unit is configured to increase or decrease the dimension of the control volume as a direct function of the magnitude of velocity of the self-propelled vehicle.
- 20 5. System according to one or more of the previous claims, wherein the central control unit is configured to increase or decrease the radiated power of said at least one sensor according to said at least one velocity parameter of the self-propelled vehicle.
6. System according to one or more of the previous claims, wherein a
25 plurality of sensors are arranged on board the self-propelled vehicle.
7. System according to one or more of the previous claims, wherein at least one front sensor and one back sensor are arranged on board the self-propelled vehicle.
8. System according to claim 6 or 7, wherein said central control unit is

configured to receive data on the direction and magnitude of velocity of the self-propelled vehicle and wherein the sensors are controlled by the central control unit according to the direction and magnitude of velocity of the self-propelled vehicle.

9. System according to one or more of the previous claims, wherein with
5 the self-propelled vehicle there is associated a system of localization with respect to a reference network outside the self-propelled vehicle, said localization system transmitting said central control unit a datum on the velocity of the self-propelled vehicle, and possibly on the position thereof, the reference network preferably being a GPS network and the localization system preferably comprising a GPS receiver;
10 and wherein the datum on the velocity of the self-propelled vehicle comprises at least one of the following data: a datum on the velocity scalar value; a datum on the velocity direction; a datum on the velocity vector of the self-propelled vehicle.

10. System according to one or more of the previous claims, wherein said central control unit is configured to change the relation between velocity and control
15 volume according to at least one parameter related to the driving conditions of the self-propelled vehicle.

11. System according to one or more of the previous claims, wherein said central control unit is configured to change the relation between velocity and control volume according to at least one of the following parameters: position of the self-propelled vehicle; characteristics of the road surface where the self-propelled vehicle
20 moves; load conditions of the self-propelled vehicle; a generic factor affecting the stopping distance of the self-propelled vehicle.

12. System according to one or more of the previous claims, wherein said central control unit is configured to store at least one of the following pieces of
25 information: path followed by the self-propelled vehicle; velocity of the self-propelled vehicle; position of the self-propelled vehicle; a responder entering the control volume of said at least one sensor; identification data of the responder entering the control volume of said at least one sensor; identification data of the sensor detecting the presence of the responder; identification of the vehicle.

30 13. System according to one or more of the previous claims, comprising a

plurality of said self-propelled vehicles, each of which is equipped with one or more sensors and with a corresponding central control unit.

14. System according to one or more of the previous claims, wherein said central control unit is provided with a wireless connection for downloading data.

5 15. System according to one or more of the previous claims, wherein said at least one sensor is a sensor comprising an emitter, to actuate the responder when it receives the signal from the sensor, and a channel for exchanging data with the responder; wherein said at least one responder is preferably an RFID transmitter, preferably a dual-frequency transmitter.

10 16. System according to one or more of the previous claims, comprising a plurality of responders.

17. System according to one or more of the previous claims, wherein said central control unit is programmed to set a default dimension of the control volume in case there is no available a datum on the velocity of the self-propelled vehicle.

15 18. System according to one or more of the previous claims, comprising at least two groups of responders, the responders of the first group being configured to be worn by people, and the responders of the second group being configured to be arranged on board self-propelled vehicles of said system; wherein the responders are preferably associated with unique codes for verifying, for each responder, whether it
20 belongs to the first group or to the second group; and wherein the central control unit of each self-propelled vehicle is programmed to generate a different alarm depending on whether a responder of the first group or a responder of the second group enters the control volume of said at least one sensor.

19. System according to one or more of the previous claims, wherein said
25 central control unit is programmed to generate a first type of alarm signal when the responder is at a first distance from the vehicle, and a second type of alarm signal when the responder is at a second distance from the vehicle, shorter than the first distance.

20. System according to one or more of the previous claims, wherein said

activation signals comprise signal frames, emitted at variable power and containing information on the radiated power; said at least one responder is programmed to generate a response signal containing information on the strength of a received activation signal; and said central control unit is programmed to manage an alarm
5 signal according to said information on the power of the received activation signal.

21. System according to one or more of the previous claims, wherein the central control unit is programmed: to periodically emit, by means of said sensor, an activation signal at variable powers, said activation signal containing information on the radiated power; and to receive a response signal from a responder, containing a
10 datum on the strength of the activation signal that has caused the answer of the responder, so as to obtain an indication of the distance between sensor and responder.

22. System according to claim 20 or 21, wherein said central control unit is programmed to generate an alarm signal according to the datum on the power of the activation signal and the velocity of the self-propelled vehicle, so that the alarm
15 signal is given when the power of the activation signal corresponds to a distance of detecting the activation signal equal to or lower than a dimension of the control volume corresponding to the velocity of the self-propelled vehicle, control volumes of different dimensions being provided for different speeds of the self-propelled vehicle.

20 23. An active safety system for collision avoidance comprising:
– at least one self-propelled vehicle;
– at least one responder;
– at least one sensor, on board the self-propelled vehicle, able to detect the presence of the responder within a control volume, controlled by the sensor
25 by means of activation signals emitted by the sensor, wherein the activation signals actuate the responder when the responder receives an activation signal, and wherein the responder is configured to generate a response signal when it is actuated by means of an activation signal;
– a central control unit, with which the sensor is associated;
30 wherein: the response signal contains a piece of information that can be associated with the distance between sensor and responder; and the central control unit is

configured to obtain an indication of the distance between sensor and responder based upon the piece of information contained in the response signal.

24. System according to claim 23, wherein the central control unit is configured to generate an alarm signal when the distance between sensor and responder is lower than a safety distance correlating with the advancing velocity of the self-propelled vehicle.

25. System according to claim 23 or 24, wherein: the activation signals comprise signal frames, emitted at variable power and containing information on the radiated power; the response signal contains a piece of information on the power of the received activation signal, said piece of information being the piece of information that can be associated with the distance between sensor and responder; and the central control unit is programmed to obtain an indication of the distance between sensor and responder based upon the piece of information on the power of the activation signal received by the responder.

26. System according to claim 23 or 24, wherein the central control unit is programmed to: periodically emit, by means of said sensor, an activation signal at variable power, said activation signal containing information on the radiated power; wherein the response signal contains a piece of information on the power of the activation signal that caused the answer of the responder, said piece of information being the piece of information that can be associated with the distance between sensor and responder; and the central control unit is programmed to obtain an indication of the distance between sensor and responder based upon the piece of information on the power of the activation signal received by the responder.

27. A method for preventing collisions between a self-propelled vehicle and at least one obstacle with which at least one responder is associated, comprising the steps of:

- arranging at least one sensor on board said self-propelled vehicle, configured to detect the presence of a responder within a control volume controlled by the sensor;
- providing a central control unit for controlling said sensor;
- by means of the sensor, emitting activation signals in said control volume;

- modulating the dimension of the control volume according to at least one velocity parameter of the self-propelled vehicle;
- generating an alarm signal when a responder enters the control volume and is actuated by means of an activation signal of the sensor.

5 28. Method according to claim 27, comprising the step of determining said at least one velocity parameter of the self-propelled vehicle by means of a system for localizing the vehicle with respect to a reference network outside the self-propelled vehicle, wherein the reference network is preferably a GPS network.

29. Method according to claim 27 or 28, wherein said velocity parameter
10 comprises at least one of the following data: a datum on the velocity scalar value, a datum on the velocity direction, a datum on the velocity vector of the self-propelled vehicle.

30. Method according to claim 27, 28, or 29, comprising the steps of:

- by means of said at least one sensor, emitting activation signals at a power that is
15 modulated according to said at least one velocity parameter, the modulation of the power radiated from the sensor determining the dimension of the control volume;
- by means of said activation signal, actuating a responder when the responder is in the control volume;
- 20 - by means of said responder, emitting a response signal towards said sensor.

31. Method according to one or more of claims 27 to 29, comprising the steps of:

- arranging said at least a sensor directed in the direction of forward movement of the self-propelled vehicle;
- 25 - arranging at least a second sensor on board the self-propelled vehicle, the second sensor being directed in the direction of backward movement of the self-propelled vehicle;
- modulating the operation of the sensors according to the magnitude and direction of velocity of the self-propelled vehicle.

30 32. Method according to claim 23 or 31, comprising the steps of:

detecting the speed of the self-propelled vehicle; according to the speed, increasing or decreasing the power of the signal emitted by the sensor.

33. Method according to claim 31 or 32, comprising the steps of:
detecting the magnitude and direction of velocity of the self-propelled vehicle;
5 according to the direction of velocity, increasing or decreasing the power of the emitted signal in a different way for the sensors directed forwards and the sensors directed backwards.

34. Method according to one or more of claims 27 to 33, wherein: the activation signals are emitted at variable power, and contain a datum on the radiated
10 power; a responder, actuated by one of said activation signals, emits a response signal containing at least one datum on the power of the activation signal that has actuated the responder, said power correlating with the distance at which the activation signal is received by the responder.

35. Method according to claim 34; wherein the power radiated from the
15 sensor is independent of the velocity of the self-propelled vehicle; wherein the central control unit compares the distance at which the activation signal is received with a safety distance, said safety distance being modulated according to the velocity of the self-propelled vehicle; and wherein an alarm signal is generated if the distance at which the signal is received is equal to or lower than the safety distance
20 corresponding to the velocity of the self-propelled vehicle.

36. Method according to one or more of claims 27 to 35, comprising the step of storing information on response signals from a responder actuated by means of the activation signal of the sensor.

37. A method for preventing collisions between a self-propelled vehicle
25 and at least one obstacle with which at least one responder is associated, comprising the steps of:

- arranging at least one sensor on board said self-propelled vehicle, configured to detect the presence of a responder within a control volume controlled by the sensor;
- 30 - by means of the sensor, emitting activation signals in said control volume;

- when a responder enters the control volume and is actuated by means of an activation signal of the sensor, generating, through the responder, a response signal containing a piece of information that can be associated with the distance between sensor and responder.

5 38. Method according to claim 37, comprising the step of generating an alarm signal when the distance between sensor and responder, determined based upon the response signal, is lower than a safety distance correlating with the forward velocity of the self-propelled vehicle.

 39. Method according to claim 37 or 38, wherein the activation signals are
10 emitted at variable power, and contain a datum on the radiated power; a responder, actuated by means of one of said activation signals, emits a response signal containing at least one datum on the power of the activation signal that has actuated the responder, said power correlating with the distance at which the activation signal is received by the responder.

15 40. Method according to claim 37, 38, or 39, comprising the steps of: periodically emitting, by means of said sensor, an activation signal at variable power, said activation signal containing information on the radiated power; generating the response signal contains a piece of information on the power of the activation signal that caused the answer of the responder, said piece of information being the piece of
20 information that can be associated with the distance between sensor and responder; obtaining an indication on the distance between sensor and responder based upon the piece of information on the power of the activation signal received by the responder.

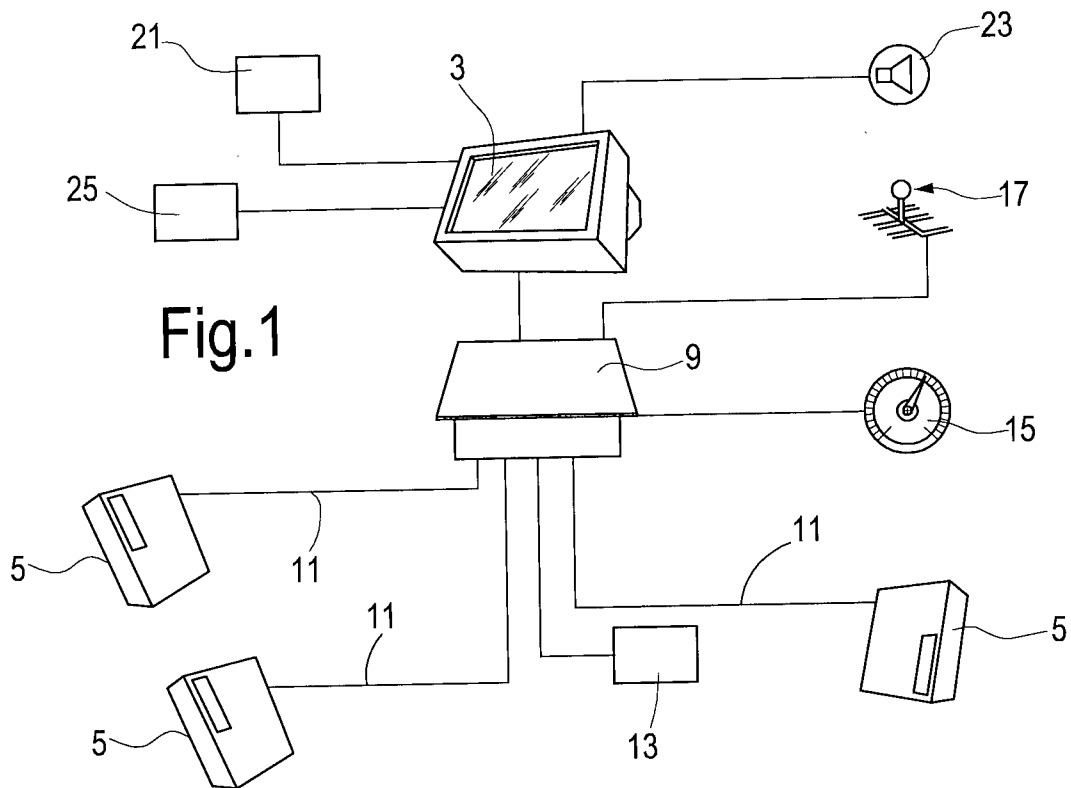
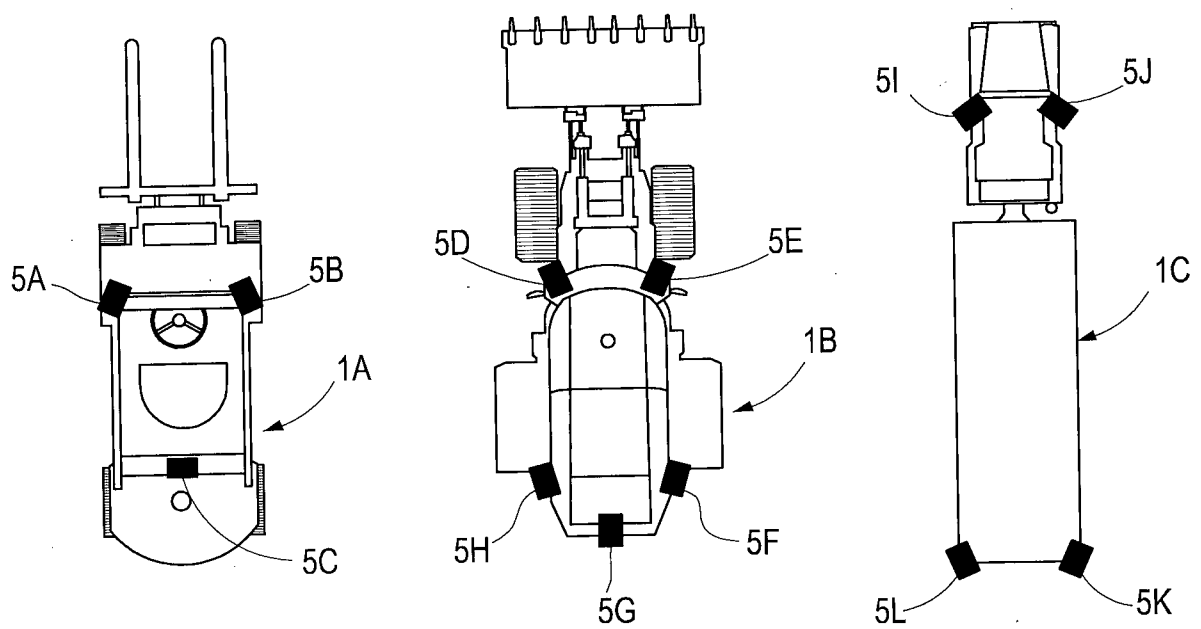
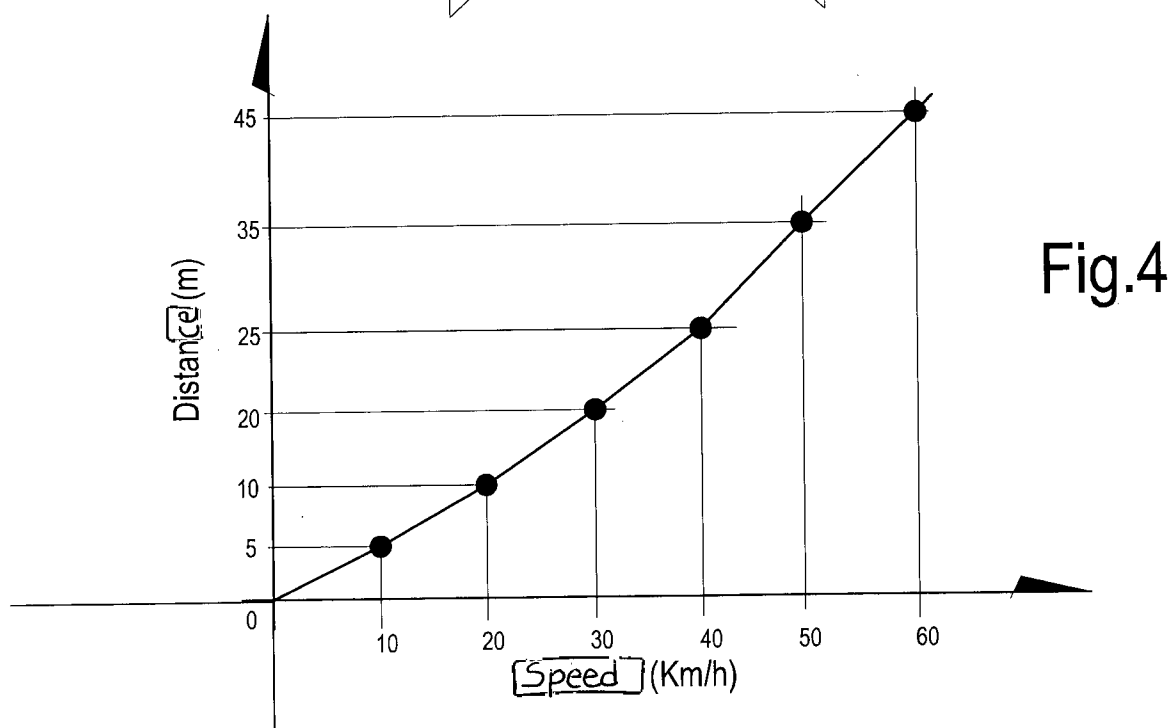
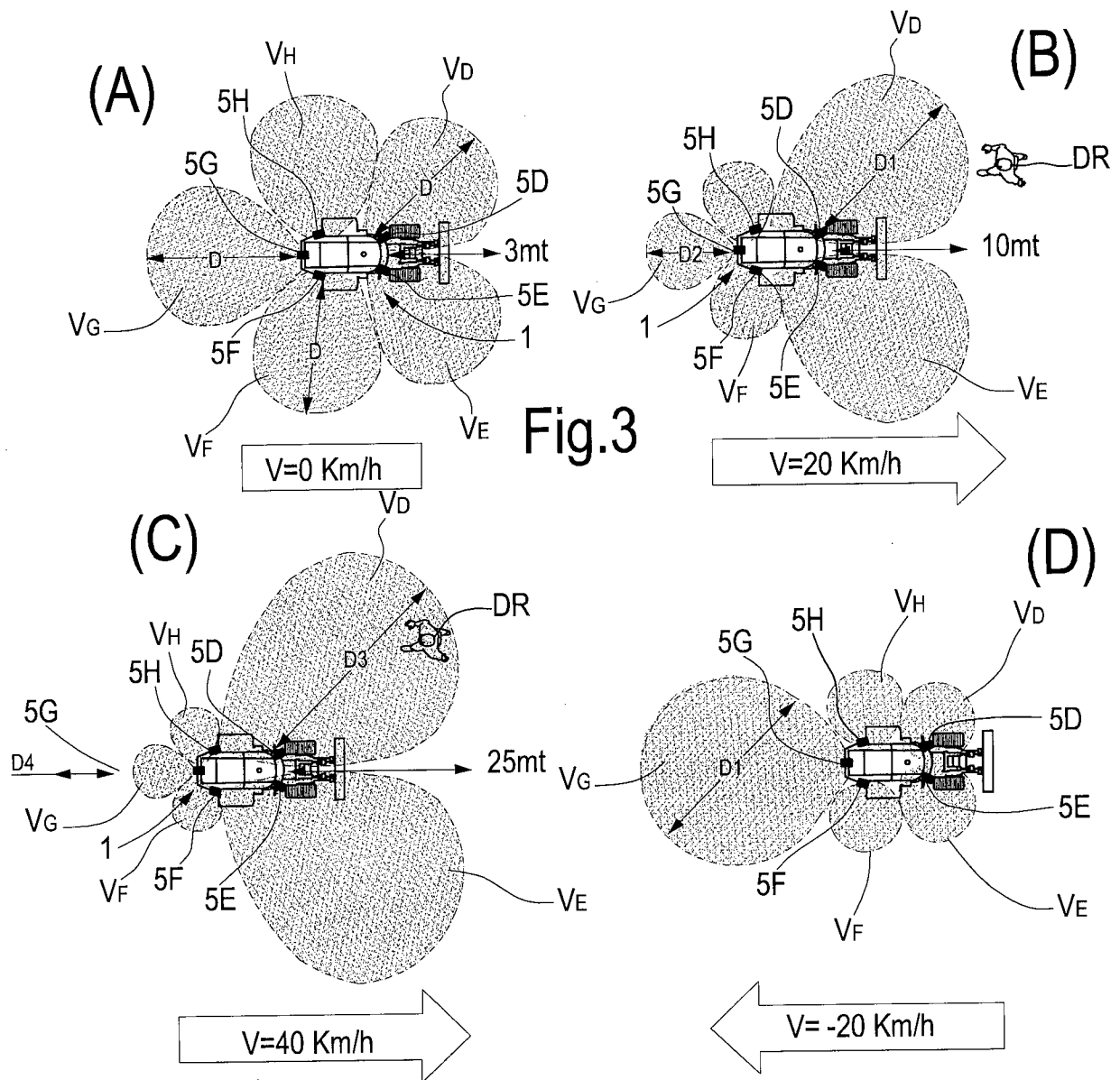


Fig. 2





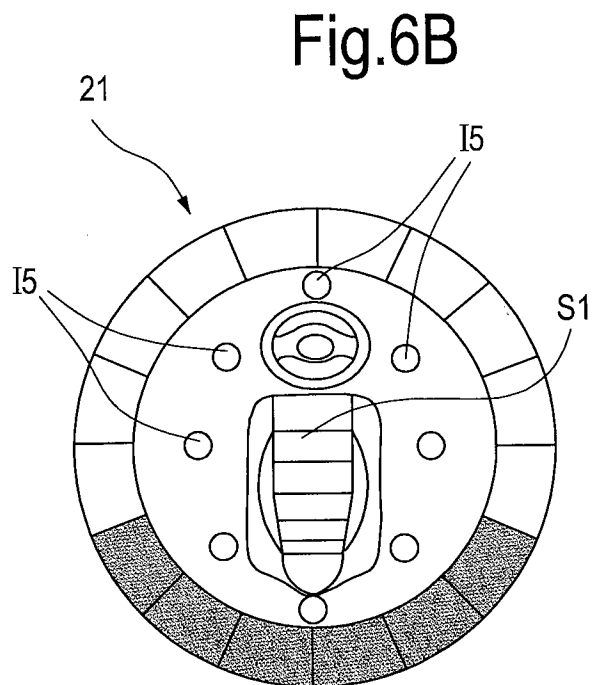
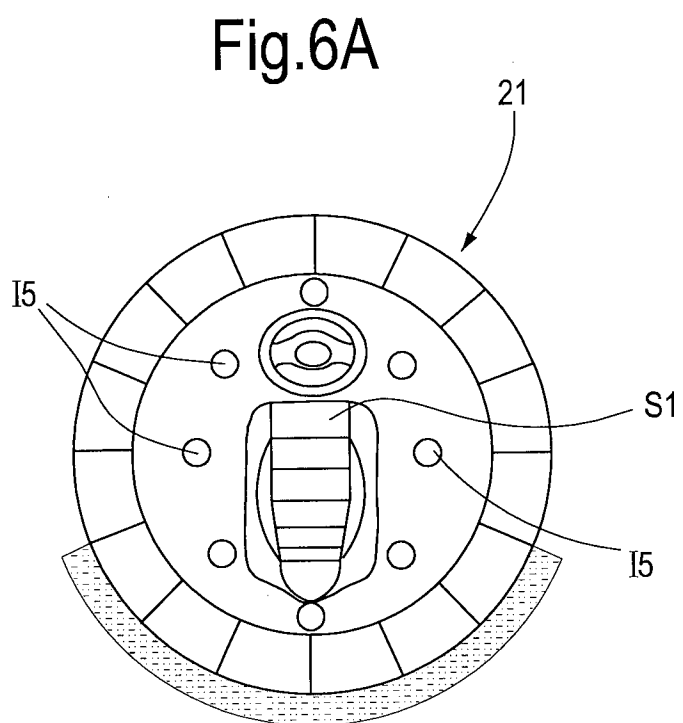
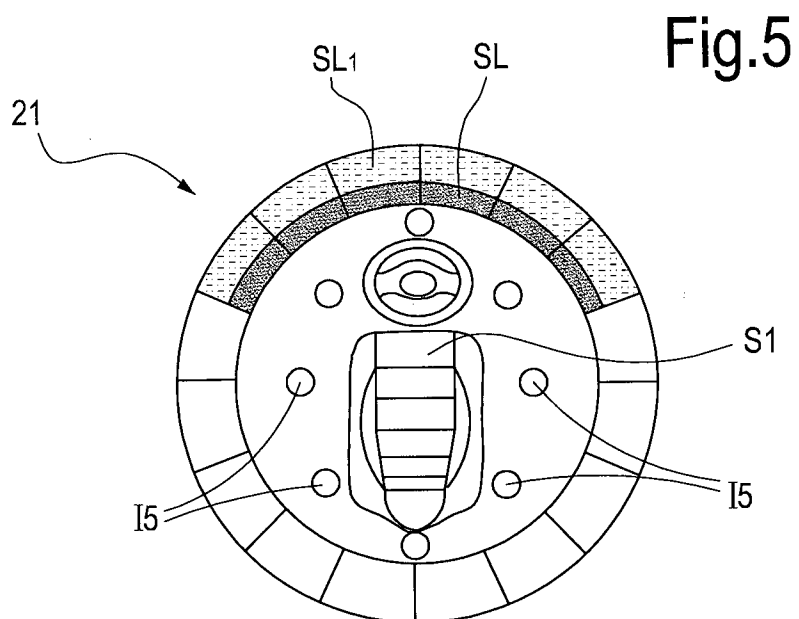


Fig7

Vehicle to vehicle	Tag 25865	Sensors	1	09:33:19.672	11/11/2013
	Vehicle 85	Sensors	1	09:33:19.351	11/11/2013
	Tag 25865	Sensors	1	09:33:19.037	11/11/2013
	Vehicle 85	Sensors	1	09:33:19.037	11/11/2013
Human to vehicle	Vehicle 85	Sensors	1	09:33:18.721	11/11/2013
	Tag 25865	Sensors	1	09:33:18.404	11/11/2013
	Vehicle 85	Sensors	1	09:33:18.403	11/11/2013
	Vehicle 85	Sensors	1	09:33:18.089	11/11/2013
	Tag 25865	Sensors	1	09:33:18.089	11/11/2013
	Tag 25865	Sensors	1	09:33:17.774	11/11/2013

Fig.8

Code Tag	Sensor	ID Operator	Clok &Date local	Latitude	N or S	Longitude	E or W	Clok &Date GPS
0	0	1234	11:00:08.186 20/11/2013	4.345.496.951	N	1.112.639.911	E	10:01:00.000 20/11/2013
0	0	1234	11:00:38.371 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:01:29.000 20/11/2013
0	0	1234	11:01:08.449 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:01:59.000 20/11/2013
25865	1	1234	11:01:38.552 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:29.000 20/11/2013
0	0	1234	11:01:38.591 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:29.000 20/11/2013
25865	1	1234	11:01:38.923 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:29.000 20/11/2013
25865	1	1234	11:01:39.269 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:30.000 20/11/2013
25865	1	1234	11:01:39.619 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:30.000 20/11/2013
25865	1	1234	11:01:40.280 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:31.000 20/11/2013
25865	1	1234	11:01:40.620 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:31.000 20/11/2013
25865	1	1234	11:02:08.733 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:59.000 20/11/2013
0	0	1234	11:02:08.757 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:02:59.000 20/11/2013
25865	1	1234	11:02:09.084 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:03:00.000 20/11/2013
25865	1	1234	11:02:09.438 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:03:00.000 20/11/2013
0	0	1234	11:02:38.939 20/11/2013	4.345.497.842	N	1.112.639.911	E	10:03:29.000 20/11/2013