Title: CAPACITIVE SENSOR SYSTEM

Abstract: Capacitive sensor system for a vehicle, comprising a chassis earth, a signal generator, a signal detector and a processing unit, the signal generator being adapted to generating a sensor signal with a frequency and an amplitude applied between the chassis earth and a virtual external earth. The system comprises an earth antenna adapted to serving as the virtual external earth, electrically connected to the signal generator and so disposed on the vehicle that it is electrically insulated from the chassis earth, has a predetermined size and is situated a predetermined distance from the ground surface. The signal detector is adapted to detecting and determining a measure of the voltage potential between the chassis earth and the virtual external earth, and to generating and conveying to the processing unit a measurement signal based thereon, and the processing unit is adapted to processing the measurement signal and to conveying the processed measurement signal to an alarm system which is adapted to generating one or more alarm signals on the basis of the processed measurement signal.
Title
Capacitive sensor system

Field of the invention
The present invention relates to a capacitive sensor system according to the preamble of the independent claim.

Background to the invention
Breaking into and theft from trucks, trailers and semitrailers has now become a substantial problem due to the relatively unprotected way in which valuable goods are currently transported by road. Such thefts and break-ins cause substantial costs to hauliers and insurance companies. They also contribute to drivers feeling unsafe when sleeping in trucks. Locking systems and alarm systems are commonly used to protect vehicles from break-ins and thefts but today's systems have limitations which make it difficult to achieve satisfactory protection.

The current solution of shell protection for trucks is usually based on the cab's doors and hatches being monitored by the alarm system. In certain cases the cargo space door is also covered by this monitoring, and the shell protection solution detects intrusions when any of the cab's doors or hatches is opened. This is a common solution currently offered by Scania and other truck manufacturers.

A disadvantage observable in many of the shell protections available for trucks is that these protections are often not suited to monitoring of trailers or semitrailers or need expensive adaptations to enable them to do so. Moreover, these systems are often not suitable for use on buses. For monitoring of trailers and semitrailers there is currently no good solution, since tractor units often change trailers and semitrailers. The problem is that all of the trailers and semitrailers need to be equipped with sensors for the monitoring and that they have to be integrated with the tractor unit's monitoring system. A known solution to the problem is referred to in WO-2008/1210141 which relates to a monitoring and communication system for a vehicle, particularly for a long vehicle. Lamp units on the vehicle, e.g. warning lamps and position lamps, are provided with monitoring sensors
and communication units to wirelessly convey output signals from the sensors to a central unit. Each sensor defines a monitoring zone for detection of objects or movements within the monitoring zone. The sensors may for example be ultrasound sensors, Doppler sensors or radar sensors. WO-2008/121041 refers to solving the problem of how the sensors for monitoring a vehicle communicate with one another, particularly in the case of long vehicles, and this solution involves using a wireless network which may be supplemented by further lamp units situated, for example, on semitrailers. A disadvantage of the solution according to WO-2008/121041 is that it is relatively expensive in that components and technology need adapting to the tractor unit's monitoring system.

US-2006/0250230 refers to a method for operation of a monitoring and alarm device for parked vehicles. The device comprises a sensor unit for determining the distance between the vehicle and an approaching object within an active zone, and a reaction device which is connected to a control unit and is activated when the object comes close to the vehicle. The active zone is divided into at least an outer first subzone and an inner second subzone. The reaction device is activated progressively with regard to quantity, type, density and/or sequence in the first subzone as compared with its activation with regard to quantity, type, density and/or sequence in the second subzone.

US-2007/0205775 refers to a device for capacitive determination of the location of an object by a plurality of capacitive probes distributed on a surface and intended to determine the location of the object relative to the surface. According to this device, each probe is connected to a voltage source via coupling capacitances and can be supplied with a supply voltage, and an evaluation device is provided and is connected to the probes to convert the probe signals to an output signal which serves as a measure of the location of the object.

A capacitive proximity sensor is within a category of sensors called proximity sensors which detect objects without touching them. Examples of other proximity sensors are photoelectric and inductive proximity sensors. The capacitive proximity sensor detects objects on the basis of their dielectric properties and has many areas of application which utilise this characteristic.
The main component of a capacitive proximity sensor is a capacitor plate, i.e. half of a capacitor.

In simplified terms, a capacitor comprises two conductive plates separated by dielectric material. A voltage difference applied to these plates creates an electrical field across the dielectric material. This electrical field stores the electrical charges, and if the energy source is switched off the electrical field will collapse and release its energy in the form of a voltage which drops asymptotically towards zero from its initial level.

The capacitor’s ability to store charges is called capacitance and is measured in farads, the amount of which depends on the cross-sectional area of the capacitor plates, the distance between them, and the dielectric constant of the dielectric material. Water has a very high dielectric constant of about 80, whereas air has a low constant of about 1. Most materials have constants between these values.

A capacitive sensor is thus half of a capacitor, i.e. a capacitor plate. An object passing in front of the plate serves both as the second capacitor plate and as the dielectric material, and the capacitive sensor measures the capacitance resulting from this situation. Any such object whose dielectric constant differs from the constant for air can be detected, at least at short distances. A measuring device may then be provided to measure the change in the capacitance and may have predetermined threshold values set, e.g. based on the distance between the object and the plate.

A typical application of capacitive sensors is in the food industry where it is desired to detect whether a food container is full.

A capacitive proximity sensor can detect an object on the basis of the object’s ability to become electrically charged. Since even non-conductive materials may become electrically charged, all objects can be detected with this type of sensor.

Figure 1 depicts schematically an example of a capacitive sensor device comprising an oscillator to which a DC voltage is applied and which delivers an AC current to a capacitor plate via a current sensor. The capacitor plate may retain a charge since, when a plate has been charged positively, negative charges are attracted to the second plate,
making it possible for still more positive charge to be supplied to the first plate. Provided that both plates are present and are close to one another, it is very difficult to cause one of them to carry a large charge.

The capacitive sensor thus comprises only one of the plates and the AC current can only supply current to, or carry current away from, this plate if there is in the vicinity another plate which may have an opposite charge. The object to be detected serves as the second plate. If the object is close enough to the sensor plate to be affected by the latter's charge, it will acquire an opposite charge, and current can be supplied to, and be carried away, from the sensor plate and be measurable by the current sensor.

When capacitive sensors are used to detect objects round a vehicle, some of the disadvantages of these sensors are less important, e.g. the fact that they are not directionally sensitive. A practical system will have many sensors distributed at regular intervals along the outside of the vehicle. This means that there will always be a sensor near to the object, with the result that a relatively limited reach will be sufficient and an object can always be located by the sensor, and the location for the sensor, which detects the object. The lack of directional sensitivity is actually desirable in making it possible to detect objects which are between sensors and very close to the vehicle.

Owing to the lack of directional sensitivity, the capacitive sensor measures a certain capacitance from objects in the surroundings which are always present and are therefore irrelevant. When the sensor is fitted on a vehicle, it detects the vehicle itself and the external earth. Unknown objects are detected as an increase in this background capacitance. However, at a distance of one metre, the change in capacitance is smaller by a number of powers of ten, and far smaller than the background capacitance. This background capacitance has to be determined so that it can be subtracted from the measurement.

Since the background capacitance is substantial relative to the capacitance of the object and is also subject to drift, it is far simpler to use the sensor for detecting the change in the surroundings than to detect the absolute presence or absence of an unknown object. The
magnitude of the change in the background capacitance depends on how stable the surroundings are.

In a mode of use which detects change, the sensor is not to be regarded as a detector of presence but rather as a detector of change of presence.

A disadvantage of the alarm systems currently in use is that they are relatively complicated and expensive to adapt to a vehicle to which various different semitrailers might be coupled. Moreover, current systems are often difficult to install on buses because of varying numbers of doors, storage hatches etc., resulting in expensive installations.

The object of the present invention is to propose a sensor system which is simple and inexpensive to install both on trucks and on buses and which in particular needs no extra adaptation when a semitrailer is coupled to a truck.

Summary of the invention
The above objects are achieved with the invention defined by the independent claim.

Preferred embodiments are defined by the dependent claims.

The invention relates to a device for shell protection for vehicles with or without trailers/semitrailers. The invention uses a capacitive sensor system which makes it possible to detect intrusions within a zone which the sensor creates round the vehicle. The sensor system is connected to the vehicle's monitoring system which provides alarms by means, for example, of light or sound or via telematics. This technology protects the whole vehicle along with any trailer or semitrailer.

The present invention achieves enhanced shell protection for tractor units with any trailers or semitrailers. Coupling a semitrailer to a tractor unit increases the capacitance, but since the sensor system calibrates itself automatically, by the semitrailer also being connected to the tractor unit's chassis earth, it will adapt itself automatically if a semitrailer is coupled.
The capacitive sensor system makes it possible to provide a warning signal which is adaptable to the degree of intrusion. It is also possible to retrofit the system together with existing monitoring systems. The system is also applicable on other vehicles, e.g. buses, and on, for example, mobile electric power plants and is simpler and therefore less expensive than many of today's systems, since the number of sensors can be reduced.

In simplified terms, the way the system works is that any person coming close to the truck or the semitrailer will contribute to an increased capacitance relative to the ground. The result is a change, an increase, in the voltage split between the chassis earth and the virtual earth and a consequent change in the measurement signal.

Brief description of the drawings
Figure 1 depicts schematically an example of a capacitive sensor device.
Figure 2 is a schematic diagram of a truck with semitrailer on which the present invention is implemented.
Figure 3 is a block diagram of the capacitive sensor system according to the present invention.
Figure 4 is a diagram illustrating measurement signals according to the present invention.

Detailed description of preferred embodiments of the invention
Figure 2 is a schematic diagram of a truck with semitrailer on which the present invention is implemented. The capacitive sensor system comprises a signal generator, a signal detector and a processing unit, jointly designated as ref. 1, connected to a chassis earth 2 which is any earth point on the vehicle's chassis, and to a virtual external earth 3 via an earth antenna 4.

The earth antenna 4 is for example a plate or cable situated close to the ground (the external earth).

According to an embodiment, the earth antenna 4 in the form of a plate is fastened under the fuel tank in such a way that it is galvanically insulated from the tank, e.g. by a rubber mat or the like. The size of the antenna in this form has to be at least about 1 m² to
achieve desired sensitivity for the system, particularly when implemented on a truck with
semitrailer. It would also be possible to use the fuel tank itself as the antenna, provided
that it is galvanically separated from the chassis and that its size and distance from the
ground are sufficient. It would also be possible for there to be other fastening points, e.g.
under the silencer or on some other suitable position under the vehicle.

The output signal from the processing unit is a reference value generated by measuring the
potential difference $AV$ between the chassis earth 2 and the external earth 3. The potential
of the chassis earth changes when an object 5 (e.g. a person) comes close to any part
which is connected to the chassis earth. By detecting the potential difference and how it
changes, it is thus possible to detect whether an object is in the vicinity of the vehicle. The
nearer the object is, the greater becomes the potential difference, making it possible to
detect a degree of intrusion, i.e. how close to the vehicle the object is.

As a coupled trailer or semitrailer is electrically connected to the vehicle's chassis, the
chassis earth will also cater for the trailer/semitrailer. The potential difference will
therefore also be affected by an object which comes close to the trailer/semitrailer.

The sensor system then communicates the intrusion, e.g. electrically or wirelessly, to the
vehicle's monitoring system 6, which triggers an alarm appropriate to the situation
detected.

With reference to Figure 3, which is a block diagram schematically illustrating the
capacitive sensor system for a vehicle according to the present invention, the sensor
system comprises a chassis earth, a signal generator, a signal detector and a processing
unit.

The signal generator is adapted to generating a sensor signal with a frequency and an
amplitude applied between the chassis earth 2 and a virtual external earth 3. The sensor
signal is preferably at a frequency within the range 2-20 kHz, e.g. about 10 kHz, and an
amplitude within the range 2-20 V, e.g. about 10 V. For the measurement to be made with
as good a signal-to-noise ratio as possible, it involves, according to a preferred
embodiment, so-called frequency hopping technology, i.e. frequency change according to a specific pattern.

The system further comprises an earth antenna 4 adapted to serving as the virtual external earth 3 and electrically connected to the signal generator. The earth antenna 4 is so disposed on the vehicle as to be electrically insulated from the chassis earth. The antenna is of predetermined size and situated a predetermined distance from the ground surface.

The chassis earth has a capacitance for the truck of the order of several nF, and the same for the semitrailer, whereas the antenna plate (earth antenna 4) may have a capacitance to the ground of the order of two powers of ten less, i.e. of the order of 10 pF (0.01 nF). The earth antenna 4 should preferably have a capacitance to the ground which is as large as possible.

According to a preferred embodiment, the earth antenna is adapted to being fitted on the underside of the vehicle and comprises for example a metal plate with a planar surface, this being essential, which is fitted horizontally on the underside of the vehicle, e.g. on the underside of its fuel tank. Other locations on the underside of the vehicle are of course also possible. The earth antenna may also comprise a plurality of plates electrically connected together. According to a further embodiment the earth antenna takes the form of at least a portion, or the whole, of the vehicle's fuel tank. It is of course a requirement that the portion, or the whole, of the tank is insulated from the chassis earth.

As mentioned above, the earth antenna has a surface of at least 1 m² and preferably about 1.5 m².

The shape of the earth antenna is of little significance, but the surface which it exhibits and its distance from the ground are significant. The larger the plate and the nearer to the ground it is situated, the greater the capacitance (earth connection). It is desirable to have as large a capacitance between the earth antenna 4 and reference earth (external earth) as possible.
The dimensioning of the antenna depends on the smallest permissible difference in capacitance between chassis earth and "antenna earth" (virtual external earth). A size of plate which provides good results for a truck with semitrailer is about 0.8 x 1.6 m.

According to another embodiment, the earth antenna takes the form of an electrically insulated cable so arranged that the effective surface results in a capacitance corresponding to that of a metal plate.

The earth antenna is adapted to being situated a predetermined distance within the range of 0.3-0.8 m from the ground surface and is further provided with an electrically insulating layer, e.g. a rubber mat, on the side which faces towards the vehicle chassis when the antenna is fitted on the vehicle. The distance between the plate (the earth antenna 4) and the fuel tank is preferably of the order of about 10 mm and the antenna is insulated by, for instance, a rubber mat or rubber spacers. What is important here is that the plate is galvanically separate from the tank and that measures are adopted to prevent creep currents between tank and plate. The electrically insulating layer may, but need not, protect both sides of the plate.

The size of the antenna, and the distance to the ground surface, is such that the resulting capacitance (C1 in Figure 3) relative to the ground surface (external earth) is normally approximately two powers of ten less than the resulting capacitance between the vehicle chassis and the ground surface (C2 in Figure 3). When an object, e.g. a person, comes close to the vehicle, the capacitance C2 will decrease.

The signal detector is adapted to detecting and determining a measure of the voltage potential between the chassis earth and the external virtual earth and to generating and conveying to the processing unit a measurement signal based thereon.

The processing unit is adapted to processing the measurement signal and transmitting the processed measurement signal to an alarm system which is adapted to comparing it with one or more threshold levels and generating one or more alarm signals on the basis of these comparisons. The alarm signals may be lamp signals, e.g. headlamps or interior
lighting which switch on, acoustic signals, e.g. a siren or the vehicle's horn, or signalling to an external alarm centre, e.g. via the mobile network.

According to one embodiment, the processing unit processes the measurement signal by determining the derivative for the measurement signal, and according to another embodiment the processing unit processes the measurement signal by generating an absolute value for the measurement signal. According to further another embodiment, the processing unit processes the measurement signal by amplifying it and generating an absolute value for the measurement signal. According to one embodiment, the processing unit processes the measurement signal by determining the derivative for the change in the measurement signal. More complicated forms of processing of the measurement signal are also possible, e.g. the difference in level between two different sliding mean values for the measurement signal may be determined, viz. a slow one which adapts to external circumstances and a fast one which is the measurement signal itself. These are processed by means of various signal processing algorithms to obtain a usable signal. Examples of measurement signals with slow and fast sliding mean values appear in Figure 4. For the signal with a slow sliding mean value (continuous line) the measurement is typically made with values detected during one or more seconds. In the case of a fast sliding mean value (broken line) the measurement is made during one or more milliseconds up to 50 ms. In the diagram, the difference in amplitude (A) is indicated by a double arrow, and the derivative for each signal. Comparing the difference in amplitude and/or the difference in derivative at the same point in time with appropriate threshold values results in rapid and reliable detection.

The general case is that the relative change in capacitance between chassis earth and antenna earth (virtual external earth) is used.

The present invention is not confined to the preferred embodiments described above. Sundry alternatives, modifications and equivalents may be used. The above embodiments are therefore not to be regarded as limiting the invention's protective scope defined by the attached claims.
Claims

1. A capacitive sensor system for a vehicle, comprising a chassis earth (2), a signal generator (1), a signal detector (1) and a processing unit (1), the signal generator (1) being adapted to generating a sensor signal with a frequency and an amplitude applied between the chassis earth (2) and a virtual external earth (3), characterised in that the system comprises an earth antenna (4) adapted to serving as the virtual external earth (3), electrically connected to the signal generator (1) and so disposed on the vehicle that it is electrically insulated from the chassis earth (2), has a predetermined size and is situated a predetermined distance from the ground surface, the signal detector (1) is adapted to detecting and determining a measure of the voltage between the chassis earth (2) and the virtual external earth (3), and to generating and conveying to the processing unit (1) a measurement signal based thereon, and the processing unit (1) is adapted to processing the measurement signal and to conveying the processed measurement signal to an alarm system (6) which is adapted to generating one or more alarm signals on the basis of the processed measurement signal.

2. A device according to claim 1, in which the processing unit (1) processes the measurement signal by determining the derivative of the measurement signal.

3. A device according to claim 1, in which the processing unit (1) processes the measurement signal by generating an absolute value of the measurement signal.

4. A device according to any one of the foregoing claims, in which the alarm system (6) is adapted to comparing the processed measurement signal with one or more threshold levels and to generating one or more alarm signals on the basis of that comparison.

5. A device according to any one of the foregoing claims, in which the earth antenna (4) comprises a metal plate with a planar surface which is fitted horizontally on the underside of the vehicle.
6. A device according to any one of the foregoing claims, in which the earth antenna (4) is adapted to be fitted on the underside of the vehicle.

7. A device according to any one of the foregoing claims, in which the earth antenna (4) is adapted to be fitted on the underside of the vehicle's fuel tank.

8. A device according to any one of claims 1-5, in which the earth antenna (4) takes the form of at least part of the vehicle's fuel tank.

9. A device according to any one of the foregoing claims, in which the earth antenna (4) is adapted to being situated a predetermined distance within the range 0.3-0.8 m from the ground surface.

10. A device according to any one of the foregoing claims, in which the earth antenna (4) has a surface of at least 1 m².

11. A device according to any one of the foregoing claims, in which the earth antenna (4) is provided with an electrically insulating layer situated on its side which faces towards the vehicle chassis when the earth antenna (4) is fitted on the vehicle.

12. A device according to claim 1, in which the earth antenna has a surface size such that the resulting capacitance relative to the ground surface is normally approximately two powers of ten less than the resulting capacitance between the vehicle chassis and the ground surface.

13. A device according to claim 1, in which the earth antenna takes the form of an electrically insulated cable.

14. A device according to any one of the foregoing claims, in which the signal generator (1) is adapted to generating a sensor signal with a frequency within the range 2-20 kHz and an amplitude within the range 2-20 V.
15. A device according to claim 14, in which the signal generator is adapted to generating a sensor signal with a frequency of 10 kHz and an amplitude of 10 V.
INTERNATIONAL SEARCH REPORT

International application No. PCT/SE2011/050695

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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: B60R, G08B, H03K

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

SE, DK, FI, NO classes as above

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>A</td>
<td>US 20070205775 A1 (VOELKEL HARDI ET AL), 6 September 2007 (2007-09-06); abstract</td>
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Form PCT/ISA/210 (second sheet) (July 2009)
Continuation of: second sheet

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B60R 25/10 (2006.01)
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