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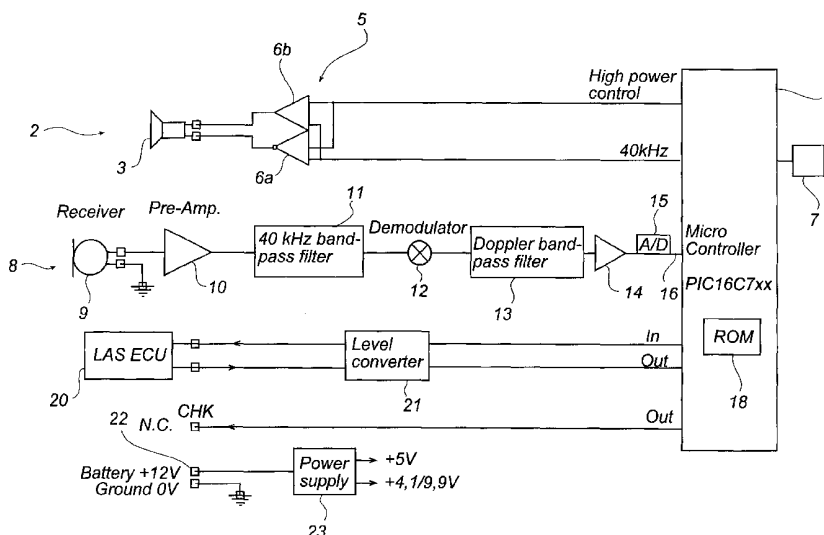
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(54) Title: INTRUSION DETECTOR WITH POWER CONSUMPTION CONTROL AND METHOD FOR INTRUSION DETECTION



(57) Abstract: The present invention relates to an intrusion detector comprising a transmitter (3), arranged to transmit waves into a defined space, a receiver (9), arranged to receive said waves after reflection, detector means (10, 11, 12, 13, 14), connected to said receiver, arranged to detect a signal (16) based on a change in said waves after reflection, said detected signal (16) being representative of any motion in said defined space, and signal processing means (18), arranged to process said detected signal (16) in order to securely determine if an intrusion has occurred. The intrusion detector is characterized in that the transmitter (3) has a variable output power, and that a control unit (1) is arranged to determine any change in said detected signal (16), and to increase said output power of the transmitter (3) in response to such change. The invention also relates to a method for performing such intrusion detection.

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INTRUSION DETECTOR WITH POWER CONSUMPTION CONTROL AND  
METHOD FOR INTRUSION DETECTION

Technical field of the invention

The present invention relates to an intrusion detector with power consumption control, and more specifically to a vehicle intrusion detector of the type  
5 based on Doppler effects on transmitted ultrasonic waves.

The invention also relates to a method for intrusion detection.

Technical background

10 It is a well-known problem in intrusion detectors, especially in vehicle intrusion detectors, to avoid unwanted false alarms. Not only are they a disturbance to people in the neighborhood and risk to discharge the power source, but they also tend to raise a common  
15 acceptance to active alarms, thereby decreasing the discouraging effect of alarms on potential burglars.

Detectors based on transmission of waves in e.g. the interior of a car have been developed. Typically, these systems receive the waves reflected from the interior  
20 surroundings, demodulate them, pass them through a band pass filter, integrate the band-passed signal, and compare the result with a predefined threshold value. If the threshold is exceeded, a signal is passed to a unit responsible for giving off an alarm. The waves are often  
25 ultrasonic sound waves or microwaves, and the demodulation performed is often based on the Doppler effect.

In order to improve this technique, US 5,856,778 discloses a vehicle intrusion detector of this type,  
30 which in addition includes an envelope detecting circuit for determining the level of the received ultrasonic signal. Only if this level exceeds a second predefined threshold value is an alarm generated.

However, a second problem with intrusion alarms, especially in a vehicle or any other location where power is a scarce resource, is the power consumption. A vehicle alarm is active only when the vehicle is parked and  
5 turned off, making it completely dependent upon the available battery power. Especially if the vehicle is parked during a longer period, it is crucial that the power consumption is minimized, as the vehicle otherwise will be difficult to start.

10 In a detector according to US 5,856,778, this problem is in conflict with the first problem, as the accuracy of the alarm is dependent on a relatively strong ultrasonic wave transmitter. To overcome the excessive power consumption, the supersonic transmitter is driven  
15 intermittently. However, this approach is not free from problems. First, the ability of the detector to detect any intrusion is forcefully reduced, as it only is active during part of the time. During the inactive, or intermittent, periods, the detector is "blind", and  
20 intrusions, although short, may occur unnoticed. Secondly, the output frequency of the supersonic transmitter is unstabilized in the beginning of each active period, making it difficult to stabilize the detection operation of the detector. There is thus an  
25 increased risk of obtaining a false alarm caused by this unstable period occurring in each active period.

This second problem has been solved by the teachings of US 5,483,219, which discloses a device that  
30 invalidates the signal from the integrating circuit during a short period of each active period. However, this is not a completely satisfactory solution, and it does not in any way improve the partial "blindness" of the detector.

The overall problem for intrusion detectors is thus  
35 to combine a high detection level, good signal quality, and low power consumption.

Summary of the invention

The object of the present invention is to provide an intrusion detector that overcomes the above problems, and makes it possible to continuously detect intrusions and  
5 at the same time reduces power consumption.

A further object is to provide a vehicle intrusion detector with continuous transmission of waves having satisfactorily low power consumption.

These and other objects are achieved by a detector  
10 according to claim 1 and a method according to claim 14.

When using a detector according to the invention, waves are transmitted into a defined space, and reflected back to the receiver (sensor), and the reflected waves are processed to obtain a signal corresponding to any  
15 change caused by motion in the space. The output power of the transmitter is variable, and a microcontroller (MCU) is arranged to increase the output power in response to a change in said signal.

This arrangement makes it possible to avoid driving  
20 the transmitter with a high power output, unless a signal representative of motion in the vehicle has been detected. This in turn allows for the power consumption to be lowered considerably, without losing the continuous transmission of waves into the space.

25 According to a preferred embodiment, the detector comprises signal processing means, arranged to process said detected signal in order to securely determine if an intrusion has occurred. This processing can be of any suitable type, possibly of a previously known kind, and  
30 typically is dependent on a satisfactory signal/noise-ratio in order to perform the analysis.

During normal functioning, when no motion is detected, the transmitter output power is controlled to a low level. A detection of a change in the reflected waves  
35 thus results in a very weak signal, that cannot be securely analyzed in order to eliminate false alarms. As soon as the detected signal implies that any motion is

present in the vehicle, and the transmitter output is increased by the MCU, this results in a significantly stronger detected signal, so that the signal/noise-ratio is increased considerably. This makes it possible to use advanced detection algorithms, and the detected signal can be analyzed in order to securely determine whether or not the detected change results from an intrusion.

Even if extreme weather conditions or traffic noise result in high signal levels, the resulting detected signals can be identified and removed by advanced algorithms without any significant increase in power consumption.

To further decrease power consumption, the signal processing means can be deactivated during periods of low power transmission. The control unit is then arranged to activate said processing means only when a change in said detected signal is determined, that is when the output power is increased.

One preferred way of embodying the output power control is to let the control unit raise the output power of the transmitter to a higher output level when said detected signal exceeds a predefined threshold.

Preferably, the control unit is then arranged to reset the output power of the transmitter to a lower output level after a predetermined period of time without any intrusion detection. Each time the detected signal exceeds the threshold, the intrusion detector will then be put in an alert condition, with a higher output power, and a significantly increased possibility of identifying intrusions. If the detector signal increase is found to be a "false" alarm, and no intrusion can be securely determined, the output power will be reset again, thereby effectively reducing power consumption.

The waves that are transmitted into the defined space can be any type of waves that can be carried by the medium filling the space. In the normal case of an air-

filled space, possible wave types include sound waves and electromagnetic waves (e.g. microwaves or IR-waves).

In one embodiment of the invention, primarily intended for use in a vehicle, the waves are ultrasonic waves, which have the advantage of an even distribution in the vehicle, and at the same time being confined by the vehicle walls and windows. Also, at least compared to microwaves, ultrasonic waves have a lower frequency, facilitating detection of any change in the reflected waves caused by an intrusion.

In the case of microwaves, the transmitter generates a well-defined wave field, making good detection possible in defined areas. An advantage with using microwaves is that the detector is undisturbed by air movements, for example caused by an open window. On the other hand, the wave field must be carefully adjusted within the space, as otherwise movements outside a window can be unintentionally detected.

As mentioned, IR-waves is another possible wave form. Care has to be taken to the fact that IR-waves are more sensitive to temperature changes and light phenomena typically introduced through the windows of a vehicle.

The signal detected by the detector means in the reflected waves can be of different types, as the detection can be based on various types of phenomena occurring in the reflected wave field.

In one embodiment of the invention the detection is based on the Doppler effect. This technique is commonly known in intrusion detectors, in vehicles as well as in other types of movement detectors, and can be utilized with ultrasonic waves as well as with electromagnetic waves. An advantage of using the Doppler effect is that the geometric form of the space is less influential on the result, which is advantageous in e.g. a vehicle, with typically a complex geometry. When using the Doppler effect in connection to microwaves, the detection can be based on pulse Doppler effect.

The detection of the Doppler signal can be performed with an envelope demodulator. The envelope of the reflected waves has the advantage of being phase- and frequency independent, i.e. synchronization is not crucial. This in turn results in a greater freedom when placing the detector in the space, e.g. a vehicle passenger compartment, which is convenient especially in vehicle intrusion detectors, as it makes a more compact design possible.

10 Instead of Doppler effect, a time discriminating detection can be performed. In the case of microwaves, a combination of these techniques can be performed, for example used in the pulse Doppler radar.

The detector according to the invention is primarily intended for the interior of a vehicle, such as a personal car, van, truck etc, but could in principle be adjusted to any type of alarm system where low power consumption is desired.

#### 20 Brief description of the drawings

A currently preferred embodiment of the present invention will now be described in more detail, with reference to the accompanying drawings.

Fig 1 is a block diagram of a vehicle intrusion system according to a preferred embodiment of the present invention.

Fig 2 is a schematic view of a personal car equipped with an intrusion detector according to the invention.

Fig 3 is a flow diagram of the function of the micro controller unit in fig 1.

#### Detailed description of the preferred embodiment

The embodiment of the invention which will be described in the following is related to a vehicle intrusion detector, where the Doppler effect on reflected ultrasonic waves is used to determine if an intrusion occurs. However, as was mentioned above, the invention is

equally applicable in several other types of intrusion detectors.

Referring now to fig 1, the function of the intrusion detector is controlled by a micro controller unit (MCU) 1, for example a PIC16-series processor.

Beginning with the transmitter side 2, a transmitter 3 is arranged to generate ultrasonic waves of a well-defined frequency. The transmitter 3 is driven by a drive unit 5, which supplies the transmitter 3 with a continuous 40 kHz square wave. This frequency is suitable for air filled compartments. The drive unit 5 comprises two buffers 6a, 6b, which each can deliver a voltage of different levels. One of the buffer outputs 6a is inverted, making it possible to supply the transmitter 2 with a voltage that is twice the voltage of each buffer 6a, 6b. The MCU 1 controls the voltage output of each buffer, and also controls the buffer thresholds, making it possible to selectively deactivate one or both buffers. Additionally, the MCU 1 supplies the drive unit 5 with an oscillating signal from an external oscillating circuit 7.

Turning now to the receiver side 8, a receiver 9 in the form of a piezoelectric microphone is arranged to receive the ultrasonic waves generated by the transmitter, after reflection against the interior walls and objects of the vehicle. The received signal is supplied to a low-noise amplifier (pre-amp) 10, in turn connected to a second order band pass filter 11 with a center frequency corresponding to the chosen transmitting frequency (in the present example 40 kHz).

The band passed signal is then supplied to an envelope demodulator 12, and further to a very sharp Doppler band pass filter 13, preferably a fourth order band pass filter with cut off frequencies at around 30 Hz and 300 Hz. Modulated signals in this range are typically representative of motion in the vehicle, and result from a Doppler effect on the reflected ultrasonic waves.

Before the Doppler signal is supplied to the MCU 1, it is amplified by an end-amp 14 to reach a desired signal/noise-ratio, and A/D converted 15. Finally, the signal 16 is supplied to the MCU 1.

5 The MCU 1 is further provided with signal processing means, in the form of software loaded into the ROM 18, arranged to perform signal processing on the signal 16, in order to securely determine whether the signal 16 represents an intrusion into the vehicle. The algorithms  
10 employed in this processing can be of various types, and do not form part of the subject matter of this application.

The different levels of output power are chosen so that a higher level results in a detected signal 16  
15 strong enough for the desired signal processing, while a lower level only results in a detected signal 16 strong enough for alerting the MCU 1. It is to be noted that when the transmitter is provided with the lower power level, the signal 16 is too weak for any satisfactory  
20 signal processing.

In one example of this construction, the MCU 1 controls the voltage level to 4,1 V or 9,9 V. Theoretically, this allows four different voltage levels being supplied to the transmitter: 4,1 V (one buffer  
25 active, 4,1 V power supply), 8,2 V (both buffers active, 4,1 V power supply), 9,9 V (one buffer active, 9,9 V power supply), 19,8 V (both buffers active, 9,9 V power supply). Normally, only the lowest and highest output levels are used (4,1 v and 19,8 V respectively). This  
30 relation, where the higher level is approximately five times higher than the lower level, has been found satisfactory, but should not be seen as a restriction on the present invention.

In addition to the transmitting and receiving sides  
35 2, 8, the MCU 1 is connected to the alarm system of the vehicle 20 through a level converter 21. Thus any

detected intrusion can easily be communicated to the alarm system 20.

Power is supplied by the vehicle battery 22, connected to a power supply unit 23. The power supply unit delivers stabilized voltage to the different components, in order to achieve highest possible signal quality.

The placement of the transmitter 3 and receiver 9 in a vehicle 25 is illustrated in fig 2. The transmitter 3 is located substantially centered in the ceiling, being directed to emit waves towards the back of the vehicle. The receiver 9 is located in the ceiling just above the windshield, being directed to receive waves reflected from the back of the vehicle. Of course, a different placement is possible, and the best placement depends on the specific vehicle and the chosen transmitter/receiver.

According to the invention, the MCU 1 controls the output power of the transmitter in response to the signal delivered by the receiving side 8. This control is performed by a program loaded into the ROM 18 of the MCU 1. The flow chart of fig 3 describes the program.

First, in step 30, the signal 16 is compared to a pre-defined threshold value. The comparison is performed continuously until the threshold is exceeded, or, of course, the intrusion detector is deactivated.

When the threshold is exceeded, the program control continues to step 32, where the transmitter output level is increased to the higher level (19,8 V). This results in a significantly stronger signal 16.

In step 34 a timer is reset, thereby marking the beginning of a time-limited loop, comprising steps 36, 38, 40 and 42. The first of these steps, step 36, is the signal processing analysis mentioned above. As the transmitting power now has been increased, it is possible to make advanced calculations based on the signal 16, and thereby to accurately determine whether an intrusion has occurred (step 38). When an intrusion is identified, an

alarm is activated in step 40, by communicating with the alarm system 20.

If, in step 38, no intrusion is found, the time-limited loop continues through step 42, until a  
5 predefined time has passed, for example 1 second. When the time limit has been passed, step 42 directs the program control to step 44, where the transmitter output level is decreased back to the lower level (4,1 V).  
10 Finally, the program control returns to step 30, and awaits a new high detected signal 16.

With a detector according to the described embodiment, the power consumption can be reduced considerably. Although determination of intrusion is performed at an output voltage level around 20 V,  
15 securing a satisfactory signal processing, the transmitter is driven at an output voltage level around 4 V during a completely dominating part of the time.

If a vehicle is parked over night, say 10 hours (=36000 s), and whether conditions and passing traffic  
20 causes 100 detected Doppler changes in the reflected ultrasonic waves (=100 s of high output), this means that the higher output level only is employed during 1/360 of the night. The implications in terms of power reduction are of course easily understood.

25 The present invention should not be considered as being limited to the above-described preferred embodiment, but rather includes all possible variations covered by the scope defined by the appended claims.

## CLAIMS

1. Intrusion detector comprising  
a transmitter (3), arranged to transmit waves into a  
defined space,  
5 a receiver (9), arranged to receive said waves after  
reflection,  
detector means (10, 11, 12, 13, 14), connected to  
said receiver, arranged to detect a signal (16) based on  
a change in said waves after reflection, said detected  
10 signal (16) being representative of any motion in said  
defined space,  
characterized in that the transmitter (3) has a  
variable output power, and that a control unit (1) is  
arranged to determine any change in said detected signal  
15 (16), and to increase said output power of the  
transmitter (3) in response to such change.
2. Intrusion detector according to claim 1,  
further comprising signal processing means (1), arranged  
to process said detected signal (16) in order to securely  
20 determine if an intrusion has occurred.
3. Intrusion detector according to claim 2,  
wherein said control unit (1) is arranged to activate  
said processing means (18) only when said output power is  
increased.
- 25 4. Intrusion detector according to any of the  
preceding claims, wherein said control unit (1) is  
arranged to control the output power of the transmitter  
(3) to a higher output level when said detected signal  
(16) exceeds a predefined threshold value.
- 30 5. Intrusion detector according to claim 4,  
wherein said control unit (1) is arranged to reset the  
output power of the transmitter (3) to a lower output  
level after a predetermined period of time without any  
intrusion detection.
- 35 6. Intrusion detector according to any of claims 1  
- 5, wherein said waves are ultrasonic waves.

7. Intrusion detector according to any of claims 1 - 5, wherein said waves are electromagnetic waves.

8. Intrusion detector according to one of claims 1-7, wherein said detector means (10, 11, 12, 13, 14) are  
5 arranged to detect a Doppler signal, based on a Doppler effect on said waves.

9. Intrusion detector according to claim 8, wherein said detector means include an envelope demodulator (12).

10 10. Intrusion detector according to one of claims 1-7, wherein said detector means are arranged to detect a time discriminated signal, based on time discrimination of said waves.

11. Intrusion detector according to any of the  
15 preceding claims, wherein said transmitter (3) is powered by a drive unit (5) connected to a voltage supply (23) and to an oscillating circuit (7), said drive unit thereby providing a square wave signal output with an amplitude level depending on the output level of said  
20 voltage supply (23).

12. Intrusion detector according to claim 11, said drive unit (5) comprising two synchronized square wave signal outputs (6a, 6b), one (6a) of which is connected to an inverter, said transmitter (3) being connected to  
25 the resultant of said signal outputs.

13. Vehicle (25) provided with an intrusion detector according to any of the preceding claims.

14. Method for intrusion detection, comprising the steps of  
30 transmitting waves into a defined space,  
receiving said waves after reflection,  
performing a detection of a signal based on a change of said waves after reflection, said reflected signal being representative of any motion in said defined space,  
35 said method being characterized by the steps of controlling an output power of the wave

transmission, and increasing said output power (step 32) in response to a change in said detected signal.

15       15. Method according to claim 14, further including the step (36) of signal processing the detected signal, in order to securely determine if an intrusion has occurred.

16. Method according to claim 15, wherein the signal processing (step 36) only is performed when said output power is increased.

10       17. Method according to claim 14-16, wherein said output power is increased to a higher output level when said detected signal exceeds (step 30) a pre-defined threshold value.

15       18. Method according to claim 17, further including the step (44) of resetting the output power of the transmitter to a lower output level after a predetermined period of time without any intrusion detection (step 38, 42).

20       19. Method according to claim 14-18, wherein said waves are ultrasonic waves.

20. Method according to claim 14-18, wherein said waves are electromagnetic waves.

21. Method according to claim 14-20, wherein said detection is based on a Doppler effect on said waves.

25       22. Method according to claim 14-20, wherein said detection is based on time discrimination of said waves

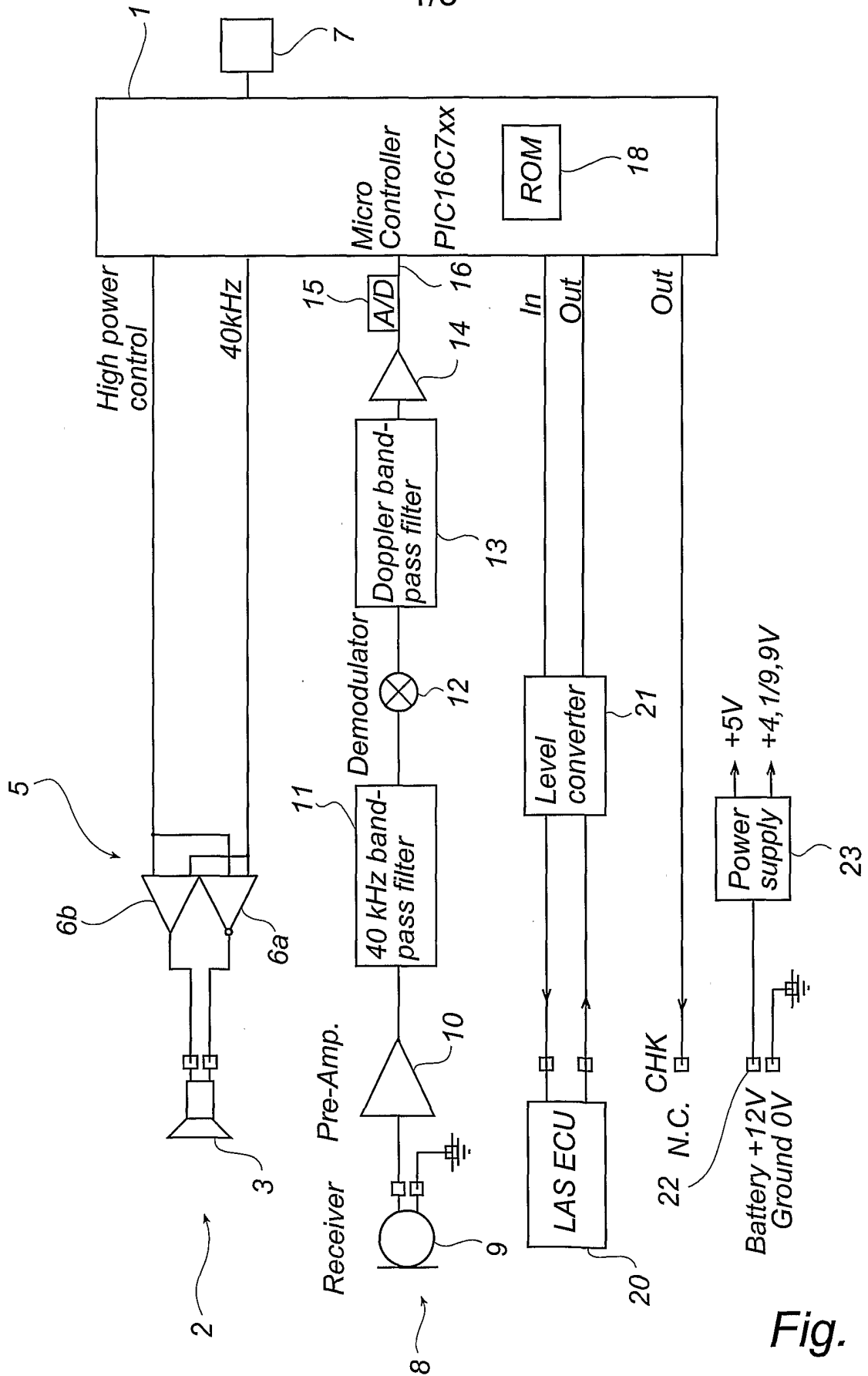


Fig. 1

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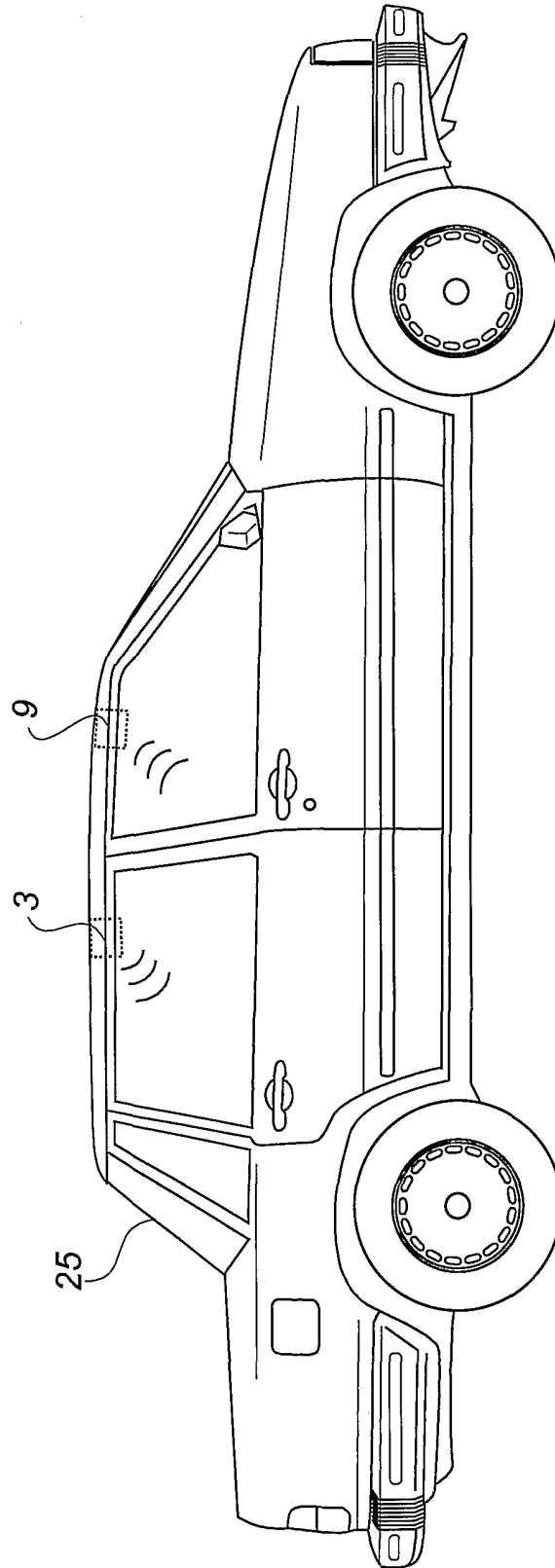


Fig. 2

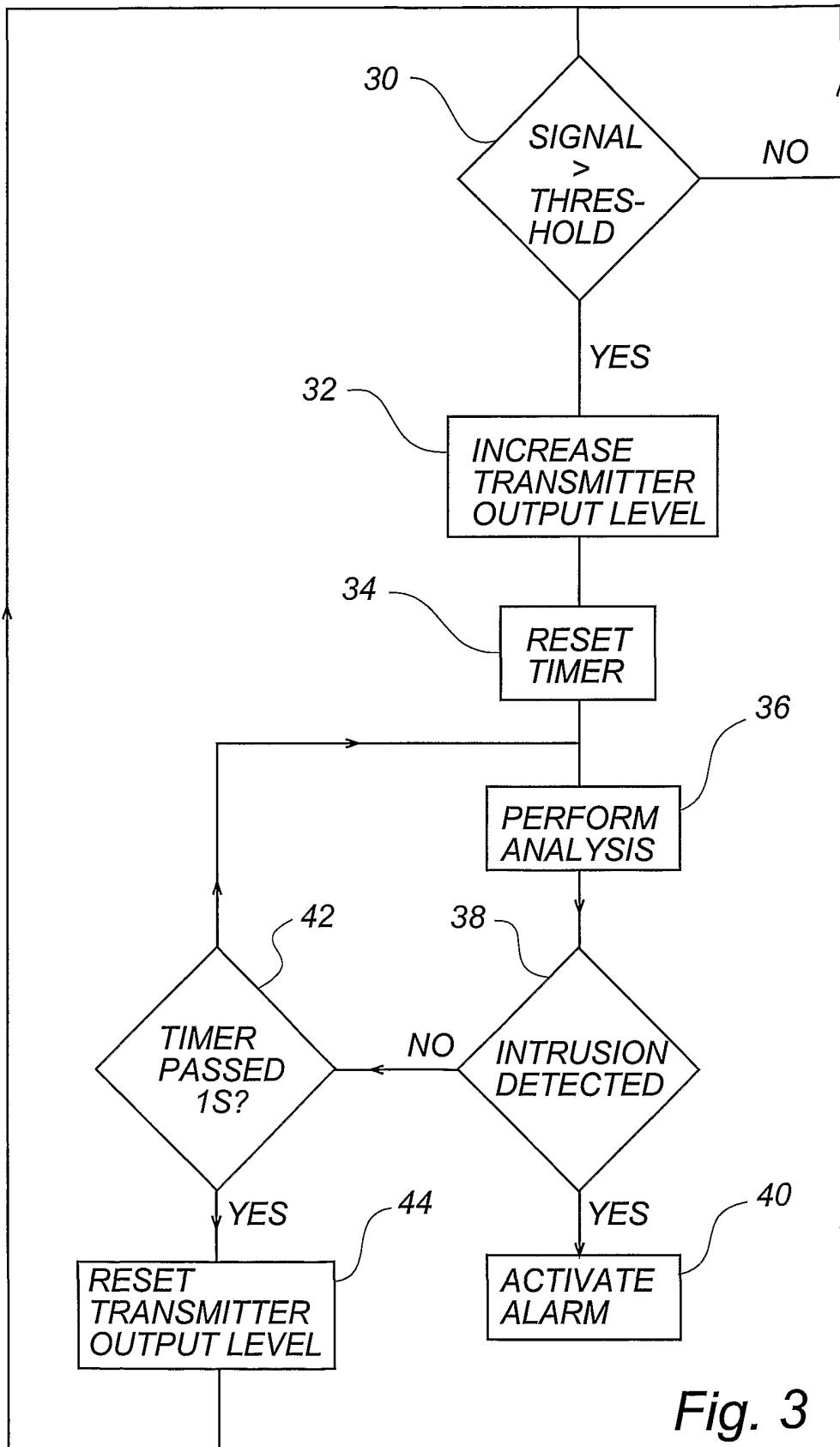


Fig. 3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01128

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B60R 25/10, G01S 15/04

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)

IPC7: B60R

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)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5483219 A (H.AOKI ET AL), 9 January 1996 (09.01.96), abstract --	1-22
A	US 5506567 A (G.BICHLMAIER ET AL), 9 April 1996 (09.04.96), abstract --	1-22
A	DE 19521511 C1 (F+G MEGAMOS SICHERHEITSELEKTRONIK GMBH), 20 February 1997 (20.02.97), abstract -- -----	1-22

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

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

27/12/00

International application No.

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Patent document cited in search report			Publication date	Patent family member(s)		Publication date
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				JP	6144159 A	24/05/94
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