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Concept House  
Cardiff Road  
Newport  
South Wales  
NP10 8QQ

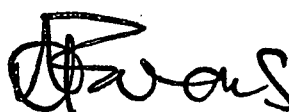
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Concept House  
Cardiff Road  
Newport  
South Wales  
NP10 8QQ

**Application number** GB 0714332.4

1. Your reference	<b>4/8/P14554.GB</b>		
2. Full name, address and postcode of the applicant or of each applicant	<b>Infrasonic Pulse Sensing Ltd</b> <b>Solent House</b> <b>107A Alma Road</b> <b>Portswood</b> <b>Southampton SO14 6UY</b> <b>Hampshire</b> <b>United Kingdom</b> Patents ADP number (if you know it) 09603804001 If the applicant is a corporate body, give the country/state of its incorporation <b>United Kingdom</b>		
3. Title of the invention	<b>INFRASONIC INTRUDER ALARM</b>		
4. Name of your agent (if you have one)	<b>Sanderson &amp; Co.</b>		
"Address for service" to which all correspondence should be sent. This may be in the European Economic area for most applications, but must be in the United Kingdom for any application covered by the warning note below (including the postcode)	<b>Sanderson &amp; Co.</b> <b>34 East Stockwell Street</b> <b>Colchester CO1 1ST</b> <b>Essex</b> <b>United Kingdom</b> Patents ADP number (if you know it) <b>1446001</b>		
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Signature: **Subject: UK, Sanderson & Co., J. Walder**  
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12. Name, e-mail address, telephone, fax and/or mobile number, if any, of a contact point for the applicant

**WALDER, Mr Jeremy**  
**Email: jtw@sandersons.co.uk**  
**Telephone: + 44 1206 571187**  
**Fax: + 44 1206 578164**

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## **INFRASONIC INTRUDER ALARM**

The present invention relates to infrasonic intruder alarms.

Infrasonic intruder alarms work on the principle of detecting changes in infrasonic frequency within a certain area – for example in a building or a room.

5 Infrasonic frequency is defined as sound with a frequency too low to be detected by the human ear and covers sounds from the lower limit of human hearing, from about 16Hz down to 0.001Hz. The infrasonic frequency is detected using a transducer such as a microphone, and is then amplified. Certain events, such as if a window or door is forcefully opened or broken, or if an attempt is made to do  
10 so, cause a change in infrasonic frequency that is detected by the transducer. If this change in frequency is over a certain threshold then the alarm will be triggered.

Figure 1 shows a waveform 10 of voltage plotted against time to illustrate how prior art systems work. During time period 11, the ultrasonic frequency is at  
15 a normal level. During time period 12, an event occurs – in this case a door is opened inwardly. The opening of the door causes a change in infrasonic frequency, which is detected by the transducer and this produces the negative trace during period 12. If the change in amplitude is beyond a predetermined threshold, the alarm is triggered.

20 Known methods of detection, which rely on a predetermined threshold amplitude change about the signal mean, with positive and/or negative deviations being used as a trigger, suffer from a number of shortcomings. The greatest of these is that wind forces on a building cause signal changes of an amplitude greater than those of the predetermined signal detection threshold, causing false

alarms. Such systems are also relatively easy to fool by a knowledgeable intruder. Further, the system must constantly re-calibrate itself in order to compensate for changes in wind. A quiet, calmer period during a period of high wind will leave the property with limited protection until the system re-adjusts.

5       The present invention seeks to address the shortcomings of known systems by applying specific detection techniques so as to qualify a signal sequence as a genuine alarm.

      According to the present invention there is provided an infrasonic intruder alarm system adapted to detect changes in infrasonic frequency in a defined  
10 space comprising:

- a transducer for sensing infrasonic frequency variations, adapted to produce an analogue signal;

- a signal amplifier;

- an analogue to digital converter adapted to convert a portion of the  
15 analogue signal which crosses at least one predetermined threshold into a digital signature;

- a processor adapted to compare the digital signature against known digital signatures, and to trigger an alarm event if the digital signal produced matches a said known signature; and

- alarm means activated by the alarm event.  
20

      As previously discussed, prior art intruder alarms often suffer from false alarms caused by the wind, and other natural events. If the signal being detected is filtered to take account of wind the protection offered by the intruder alarm is diminished. It has been found that certain events, such as the opening or closing

of a door or window, repeated attempts to open the door or window, and the footsteps of an intruder crossing a room produce specific infrasonic frequencies that the apparatus of the present invention is capable of distinguishing from naturally caused fluctuations in infrasonic frequency. When an event causes a  
5 change of infrasonic frequency greater than a pre-determined threshold, a digital signature is produced. A door opening or closing will produce a temporary increase or decrease in localised air pressure, resulting in positive or negative changes in infrasonic frequency. Preferably, therefore, the multiple thresholds may be defined both positive and negative relative to a mean signal.

10 Preferably, the alarm system of the present invention will detect crossings of multiple thresholds, either positive or negative. It has been found that the provision of four thresholds produces digital signatures that can readily distinguish between real and false alarms. These thresholds will preferably be a first positive threshold, a second positive threshold set a value in the range of  
15 from 1-99% of the first positive threshold, a first negative threshold and a second negative threshold set at a value in the range of from 1-99% of the first negative threshold. Preferably, the second positive and second negative thresholds are set at 33% of the first positive and first negative thresholds respectively.

The transducer will pick up many unwanted frequencies, with only  
20 frequencies of between 0.25 Hz and 10Hz generally being of interest. The analogue signal can be filtered and processed before being measured and converted into a digital signal using appropriate sound processing apparatus. Further, certain situations require different sensitivities of alarm system to balance the level of protection with the occurrence of false alarms. Therefore, the

infrasonic intruder alarm system will preferably also include processing equipment including a pre-amplifier, a digital low pass filter, digital high frequency roll off control, automatic background control and a low cut-off filter. These components can be controlled to adjust the sensitivity of the system. The  
5 threshold points may also be adjusted with a threshold trim. The ability to adjust the roll-off frequencies of the sound processing apparatus enables adjustment of the alarm system to better adapt to houses of differing size and construction.

Any suitable alarm means may be used in the present invention. Preferably, the alarm means will, in part at least, comprise an audible signal to  
10 scare off intruders and alert passers by. Further, the alarm means will preferably be linked to a telephone line or ADSL line to notify a predetermined list of persons contained within a certain address book that the alarm has been triggered. For example, the address book may list the police, the homeowner or a neighbour as persons to be contacted. In addition to, or instead of, an ADSL connection, the  
15 present invention will preferably include a GPRS interface to enable use with mobile telephones as an alternative source of alert.

During use, the alarm will system will pick up and analyse a significant quantity of data. Further, although the alarm system will be provided with a table of known digital signatures to compare with incoming signals, it is preferred that  
20 the processor includes an adaptive self-learning protocol to allow self-adjustment. This will enable the alarm system to adapt to recognise patterns of behaviour, such as a pet moving about the building or the movement of people in an adjacent building, without triggering an alarm event.

As well as the ADSL and/or GPRS connection, which sends alerts when



an alarm event is triggered, the alarm system will preferably also send and receive other information through these connections. The processor will preferably contain a data logging protocol capable of storing the information obtained when a threshold is crossed or approached, and sending this information to a central hub connected to a plurality of alarm devices. The information received by the hub will be processed to form a library of events which have been recorded by multiple alarm systems. This information may then be sent to other alarm systems in the form of upgrades, so that the data logging protocol of each alarm system may benefit from the information generated by multiple alarm systems. Further upgrades, such as software upgrades, may also be sent through the ADSL or GPRS connections to the alarm system directly.

The connection to the central hub will also allow other services to connect to the alarm, and information such as electricity and gas meter readings from the building containing the alarm can be sent to the hub for forwarding to respective companies.

Any suitable transducer may be used for the present invention. Preferably however, the transducer will be a microphone. Preferably, the microphone will have a frequency response that extends into the infrasonic frequencies.

The alarm system will preferably have an auxiliary input port to allow additional devices to connect to the alarm system, enabling the alarm system of the present invention to be adapted for use in other applications. For example, additional devices such as health monitors attached to a person may be remotely connected to the alarm system, so that if the person's heart rate falls beneath a certain level, an alarm event will be triggered.

Remote control of the alarm may also be facilitated through the ADSL and GPRS connections. A user will be able, for example, to switch the alarm off when they know a person needs to enter the building without triggering the alarm.

The alarm system may also be connected to other remote controlled devices in the building, such as doors, windows and curtains, which a user will be able to control through the alarm.

A positive increase in the analogue signal detected by the transducer will be caused by a temporary fall in localised air pressure, and a negative increase in analogue signal will be caused by a temporary rise in localised air pressure. The processor will preferably be able to determine which threshold has been crossed, and also whether it was a positive or negative crossing. The sequence of threshold crossing, and the direction of each crossing is important in determining whether an alarm event will occur. To calculate whether or not a sequence suitable to trigger an alarm event has occurred, the processor will preferably assign a different code to each crossing. These codes will preferably be "UP" for a threshold crossing that was caused by a positive change in signal and "DN" for a threshold crossing that caused by a negative change in signal. Due to signal processing and the form of amplification applied, these signals may at any point be inverted.

An alarm event will preferably be triggered when a set sequence of threshold crossings is recorded, as long as the changes occur within a set time period, which will be measured between the two threshold crossings. To differentiate between wanted and unwanted signals, crossings separated beyond a set time period will not count towards triggering an alarm event.

A code for adjacent threshold crossings will be assigned by the processor. These will preferably be referred to as "UP\_UP\_CTR" relating to the time between two successive positive threshold crossings, a "DN\_DN\_CTR" relating to the time between two successive negative threshold crossings, and a  
5 "TOGGLE\_CTR" relating to the time between a negative threshold crossing followed by a positive threshold crossing, or a positive threshold crossing followed by a negative threshold crossing. Previous UP\_UP\_CTR and DN\_DN\_CTR timing sequences are subsequently relabelled "UP\_UP\_2\_CTR" and a "DN\_DN\_2\_CTR" i.e. if a second immediately successive UP\_UP\_CTR  
10 event is detected the first UP\_UP\_CTR will be relabelled UP\_UP\_2\_CTR.

It has been observed that a forceful signal (e.g. from someone trying to break open a door) would produce a sequence of at least four successive timing events. Preferably therefore the alarm event will be triggered after four successive threshold crossings within a set time period.

15 It has also been observed that is not uncommon for the change of direction occurring in a TOGGLE\_CTR event to be a slow transition. Therefore, it is quite likely that a TOGGLE\_CTR will be followed by one or two more TOGGLE\_CTR's. These will preferably be treated as one long TOGGLE\_CTR event rather than a series, and so the timings for each TOGGLE\_CTR will become accumulative.

20 The processor will calculate the time between each threshold crossing. The processor will preferably runs on time units created by a self re-loading loop of 3.2ms, which creates an interrupt. Each time the timer interrupts a counter, assigned the code EVENT\_TMR by the processor, is incremented. The EVENT\_TMR will be enabled if a threshold crossing is detected, and any

subsequent threshold crossing will cause the EVENT\_TMR to increment by one until four EVENT\_TMR's are reached. The event timer will preferably be 8 bits long so the count is inherently limited at 256 iterations, representing a maximum time of about 0.8 seconds. If this time is exceeded then the event is occurring too slowly so the timer will roll over to count zero where it will remain until the next threshold crossing. Although a loop of 3.2ms has been found to provide adequate time for accurate sampling, higher and lower rates are within the scope of the present invention.

Every time an EVENT\_TMR is processed, the value of the analogue signal will preferably be recorded to provide a continuous stream of digitised values representing the history of the signal. These values are used to enhance the data acquired from the threshold crossing. In particular, once the signal has exceeded either the first positive or first negative threshold, the precise value of the signal past that point is unknown. The analogue to digital converter will preferably provide this missing information.

During a TOGGLE\_CTR timing the highest and the lowest measured value from the analogue to digital converter will preferably be identified, and the signal deviation that occurred in that period is then known.

In order that the present invention may be better understood, a preferred embodiment thereof will now be described in detail with reference to the following drawings, in which:

**Figure 1** shows an analogue waveform produced when the main front door of a property is opened with moderate force;

**Figure 2** shows a schematic representation of the intruder alarm system of

the present invention;

**Figure 3** shows an analogue waveform and digital signature produced from said analogue waveform;

**Figure 4** shows a shows analogue waveform and digital signature  
5 produced when a window is opened;

**Figure 5** shows an analogue waveform and digital signature produced by repeated attempts to open a window;

**Figure 6** shows an analogue waveform and digital signature produced by footsteps when an intruder crosses a room;

**Figure 7** shows an analogue waveform and digital signature produced to  
10 demonstrate a wind control system;

Figure 1 refers to prior art devices and has already been discussed in the introduction.

Turning to Figure 2, there is shown an alarm system generally indicated  
15 100, having several components to detect changes in infrasonic frequency within a confined space 101, and to calculate whether the changes are sufficient to trigger an alarm event. These include a microphone 13, adapted to pick up sound within the confined space 101, including frequencies in the infrasonic range. The microphone is connected to a control system 14 and a processor 15.  
20 The control system 14 contains the components which process the signal from the microphone 13 and generate a digital signature. Though not shown here, the control system 14 contains a preamplifier and a low pass filter, a main amplifier, and an analogue to digital converter. The low pass filter removes the high frequency sound that is not required, and the analogue to digital converter

converts the portion of the analogue signal which crosses a predetermined threshold into a digital signal. The processor 15 analyses the digital signal and indicates if a threshold has been passed and allows for the control of the sensitivity of the alarm system 100. If an alarm event is triggered, an audible  
5 alarm 17 will sound. The processor 15 is connected to a central hub 16 via an ADSL and/or GPRS connection, and this will send an alert to designated people 18 within an address book, such as the owner of the property, neighbours or the police.

In use, the microphone 13, control system 14, processor 15 and audible  
10 alarm 17 will be contained within a single unit 19.

As shown in Figure 2, the alarm system 100 is connected to the central hub 16, which is also connected to a plurality of other similar alarm systems 103. The hub 16 contains a database, which includes known digital signatures that cause an alarm event. The hub 16 receives information from the alarm systems  
15 100, 103 via the ADSL or GPRS connections when thresholds are crossed and approached. This information can be used to refine the database of digital signatures. This information is then sent to the alarm systems 100, 102 in the form of upgrades which improve the ability of said alarm systems 100 102 to detect alarm events.

20 The alarm system 100 also includes at least one auxiliary input port 105, to which additional devices 106, 107 can be connected, either by cable 108 or remotely (as shown by dotted line 109). Additional devices 106, 107 include additional alarm systems positioned in outbuildings, or devices which monitor a person's health. In the latter case a fall in the user's heart rate could trigger an

alarm event.

Turning now to Figure 3, there is shown an analogue signal generally indicated 19 and a digital signature, generally indicated 30. The analogue data signal 20 has been amplified and filtered to remove any unwanted frequencies. Line 21 shows the mean signal value of the analogue signal 20. The trace covers a two second period.

There are four predetermined thresholds, and a digital signature will be produced whenever one of these thresholds is crossed. The predetermined positive and negative thresholds are shown wherein line 22 shows the position of the first positive threshold, and line 23 shows the position of the first negative threshold. Line 24 shows the position of a third threshold set at 33% of the value of threshold 22, and line 25, shows the position of a fourth threshold set at 33% of the value of threshold 23. When the analogue signal crosses any of the four threshold points a digital sequence 30 will be generated by the control system 14.

When no threshold is crossed, the digital signature 30 is in position 31. The digital signature 30 drops to point 32 when either threshold 24 or 25 is crossed. The digital signature then drops further to point 33 when either threshold 22 or 23 is crossed. At point 34 on the digital signature the processor within the control system 14 has reported an alarm event derived from the data observed. After an alarm event the alarm 17 will be triggered, and no further digital signature 30 will be recorded.

Figure 3 contains a sequence of threshold crossings that is sufficient to cause an alarm event. Between time span 26 the processor records a DN\_DN\_2\_CTR when the signal drops down below threshold 24 and below

threshold 25 (this would initially have been recorded as DN\_DN\_CTR by the processor). Between time span 27 the processor records a DN\_DN\_CTR caused by the previous negative crossing of threshold 24 and the negative crossing of threshold 23. Between time span 28 the processor records a TOGGLE\_CTR as the signal negatively then positively crosses threshold 23. Finally, between time span 29 the processor records an UP\_UP\_CTR from the previous positive crossing of threshold 23 and the subsequent positive crossing of threshold 25. This sequence triggers an alarm event.

The values obtained from this sequence are recorded in the following table, showing the times between each identified threshold crossing:

<i>Table 1</i>	
Reference	Value (ms)
DN_DN_2_CTR	10
DN_DN_CTR	4
TOGGLE_CTR	24
UP_UP_CTR	3
Sum of the above	41

The values in this sequence were sufficient to cause an alarm event, and the alarm can be configured so different combinations and values will set off the alarm. Different parameters required to cause a trigger will vary according to the type and size of the property being protected.

The sensitivity of the system can be adjusted using digital dual potentiometer chips within the control system 14, which allow digital adjustment of the gain of the microphone 13, and the preamplifier within the control system 14. Potentiometer chips also allow the digital adjustment of the digital low pass



filter in the control system 14 and the roll-off of the main amplifier. Further sensitivity control is provided by the processor within the control system 14 to enable automatic background control and a threshold trim is used to offset the threshold trip points.

5           Figure 4 represents a step change in background level. In this example an alarm event was detected when a window was opened at time 0. However, if the change in infrasound when the window opened at point 40 was insufficient to cause an alarm event, then there are still enough threshold crossings 41, 42, 43, 44 on digital sequence 40 of a certain sequence, within an allowable time frame  
10   to cause an alarm event.

Figure 5 shows an example of an analogue waveform 50 and digital signature 51 caused by repeated cyclic shock activity, in this case caused by attempts to force open a window. In this example, the level of activity is enough to cause an alarm event.

15           Figure 6 shows the analogue waveform 60 and digital signature 60 caused by footsteps on a flexible floor. This type of detection will not generally be applied to buildings such as flats where movement in adjacent properties may be sufficient to trigger an alarm event, and will generally be useful in a detached property with interior wooden floors. An intruder walking across wooden flooring  
20   will have great difficulty in obscuring their steps. In general, once inside a property an intruder will move quickly, and their walking movements will cause digital signatures 62. Signatures 63 in this example show the intruder walking across one room and through a door. As the floor is less flexible at the doorway the signal diminishes and then re-establishes itself on the other side of the

doorway.

Figure 7 shows how the alarm system can be calibrated to control for wind, which has caused prior art alarms to be activated causing a false alarm. There is shown an analogue waveform 70 and a digital signature 71. During the first 27  
5 seconds, the wind control has been switched off to show the effect of a 10mph wind. Although the comparator thresholds have all been passed at some point or other on a repeated basis, no alarm trigger has been generated, as a specific sequence did not occur during an allowable time period.

At about 27.5 seconds into the test the wind control system was activated,  
10 causing a large reduction in the amplitude of the waveform 70. At around 43 seconds a door was opened, causing point 73 on waveform 70 and point 74 on digital signature 71. The wind control has not masked this signal even though it is below the peak amplitudes of the prevailing wind at that time. As can be seen from the digital signature 74, an alarm event occurred.

**CLAIMS**

1. An infrasonic intruder alarm system adapted to detect changes in infrasonic frequency in a defined space comprising:
  - 5 - a transducer for sensing infrasonic frequency variations, adapted to produce an analogue signal;
  - a signal amplifier;
  - an analogue to digital converter adapted to convert a portion of the analogue signal which crosses at least one predetermined threshold into a digital  
10 signature;
  - a processor adapted to compare the digital signature against known digital signatures, and to trigger an alarm event if the digital signal produced matches a said known signature; and
  - alarm means activated by the alarm event.
- 15 2. An infrasonic intruder alarm system as claimed in claim 1 wherein multiple thresholds are provided, at least one threshold being positive and at least one threshold being negative relative to a mean signal.
3. An infrasonic intruder alarm system as claimed in claim 2 wherein there is a first positive threshold, a second positive threshold set at 33% of the first  
20 positive threshold, a first negative threshold and a second negative threshold set at 33% of the first negative threshold.
4. An infrasonic intruder alarm system as claimed in claim 3 wherein the processor can differentiate between a positive and a negative threshold crossing.
5. An infrasonic intruder alarm system as claimed in claim 4 wherein the

processor will assign an "UP" code to positive threshold crossings, and a "DOWN" code to negative threshold crossings.

6. An infrasonic intruder alarm system as claimed in any of claims 3 to 5 wherein the alarm event will be triggered when the analogue signal crosses four  
5 thresholds.

7. An infrasonic intruder alarm system as claimed in any of claims 2 to 6 wherein the time between each threshold crossing is measured.

8. An infrasonic intruder alarm system as claimed in claim 7 wherein if the time between two threshold crossings is above a set time limit, an alarm event  
10 will not be triggered.

9. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the analogue signal is processed to remove unwanted frequencies:

10. An infrasonic intruder alarm system as claimed in any of the preceding  
15 claims which further comprises a pre-amplifier, a digital low pass filter, digital high frequency roll off control, automatic background control and a low cut-off filter.

11. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the sensitivity of the alarm system may be adjusted.

12. An infrasonic intruder alarm system as claimed in any of the preceding  
20 claims wherein the alarm means comprises an audible signal.

13. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the alarm means is coupled to a telephone or ADSL line to notify an address book when an alarm event is triggered.

14. An infrasonic intruder alarm system as claimed in any of the preceding

claims wherein the alarm means is coupled to a GPRS or other mobile phone network to notify an address book when an alarm event is triggered.

15. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the infrasonic intruder alarm system is adapted to be networked  
5 with other infrasonic intruder alarm systems via a central hub.

16. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the infrasonic intruder alarm system further comprises an auxiliary input port to which may be connected one or more secondary devices.

17. An infrasonic intruder alarm system as claimed in claim 16 wherein the  
10 secondary device is one or more health monitors attached to a user.

18. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the transducer is a microphone.

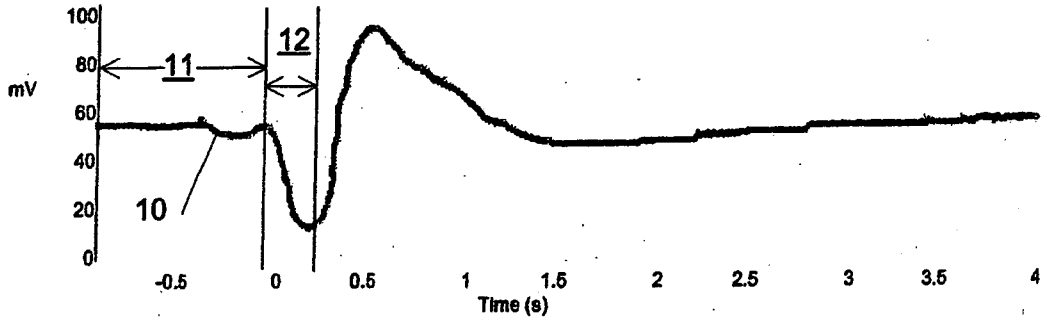
19. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the processor includes an adaptive self learning protocol to allow  
15 self adjustment.

20. An infrasonic intruder alarm system as claimed in any of the preceding claims wherein the processor incorporates a data logging protocol.

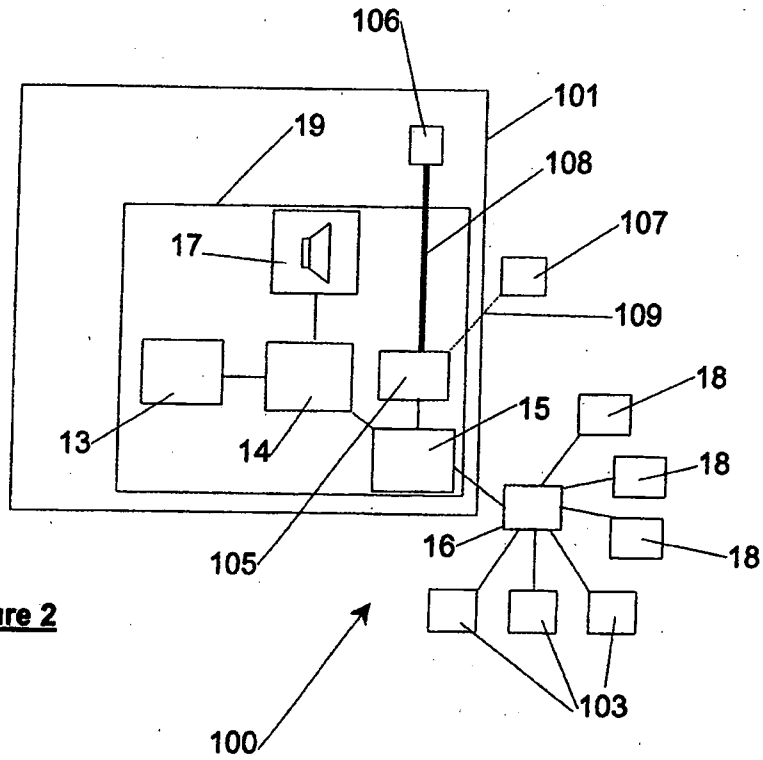
21. An infrasonic intruder alarm system as claimed in claim 20 wherein the data logging protocol can be updated from the Internet.

**ABSTRACT**

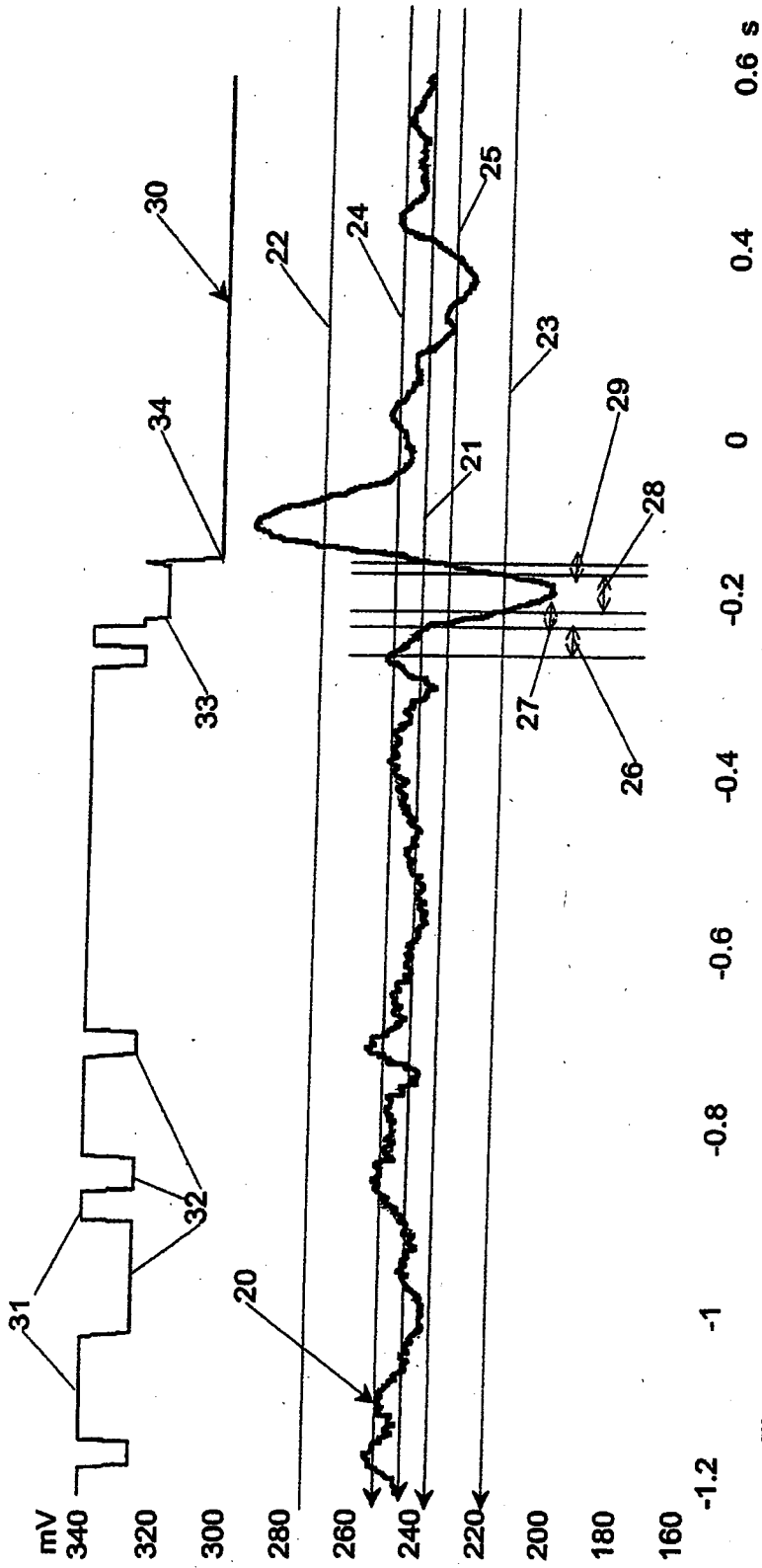
An infrasonic intruder alarm system adapted to detect changes in infrasonic frequency in a defined space. The alarm system comprises a  
5 transducer for sensing infrasonic frequency variations, which is adapted to produce an analogue signal, a signal amplifier, an analogue to digital converter which is adapted to convert a portion of the analogue signal which crosses at least one predetermined threshold into a digital signature, and a processor adapted to compare the digital signature against known digital signatures. An  
10 alarm event is triggered if the digital signal produced matches a known signature, and alarm means are activated by the alarm event.



**Figure 1 (Prior Art)**



**Figure 2**



**Figure 3**



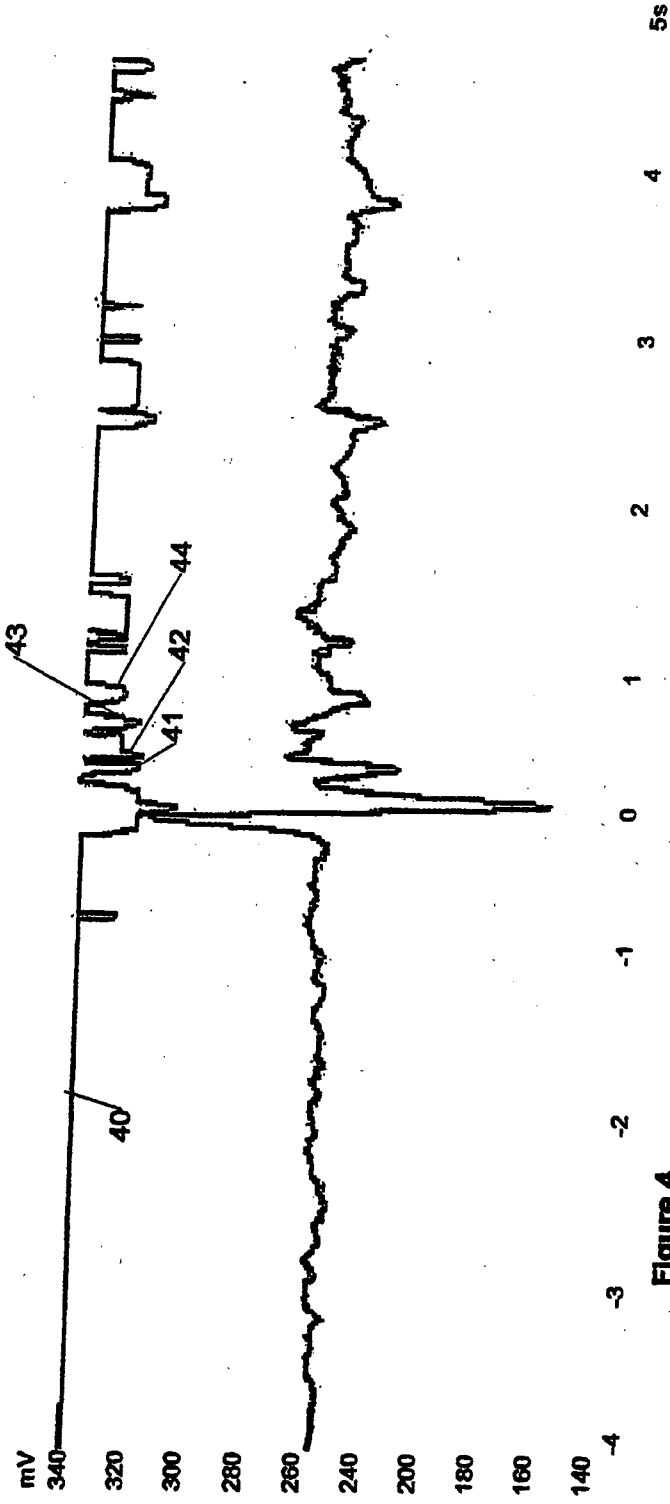
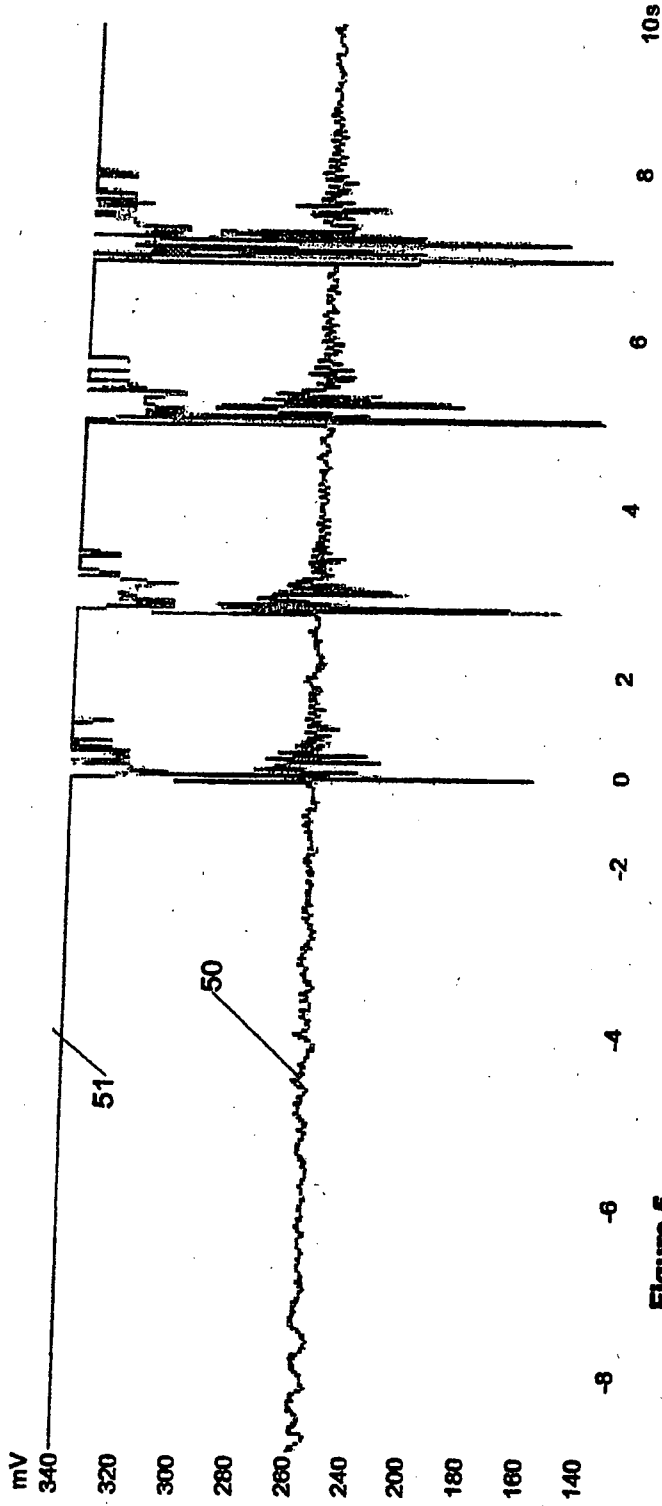
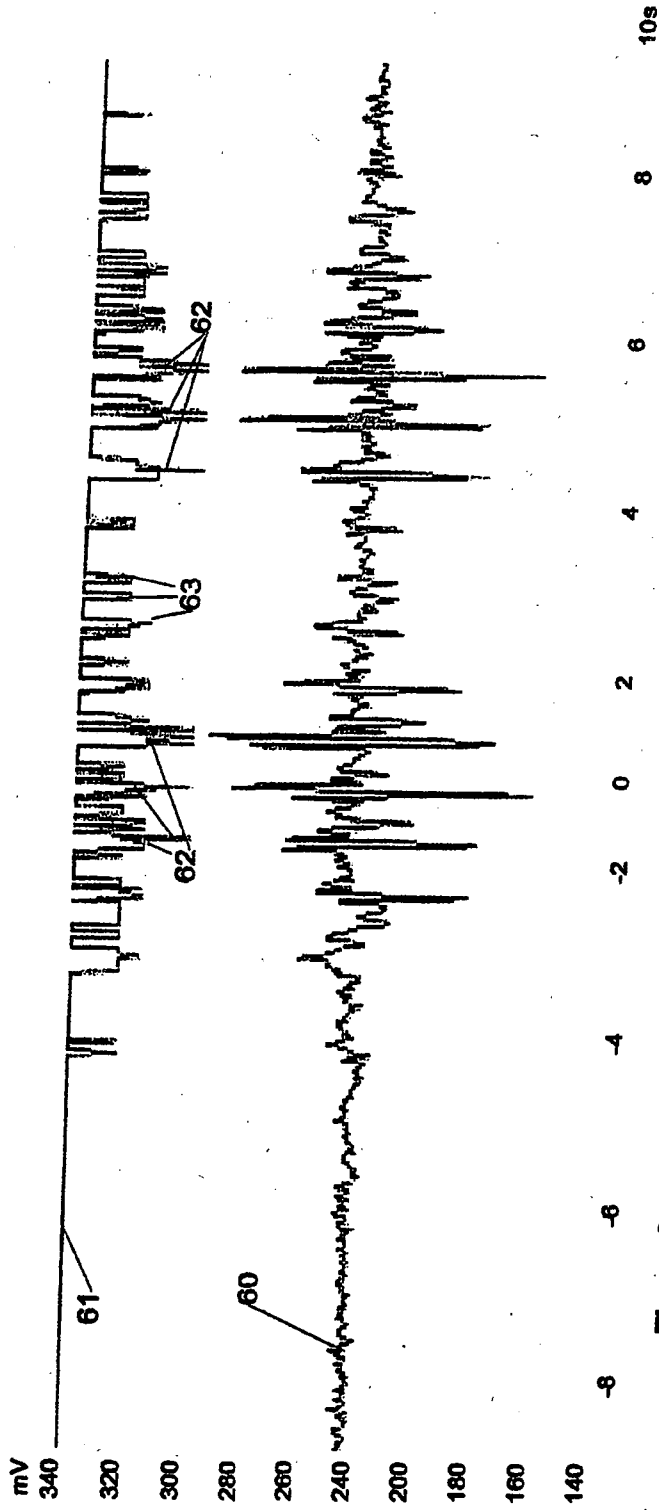


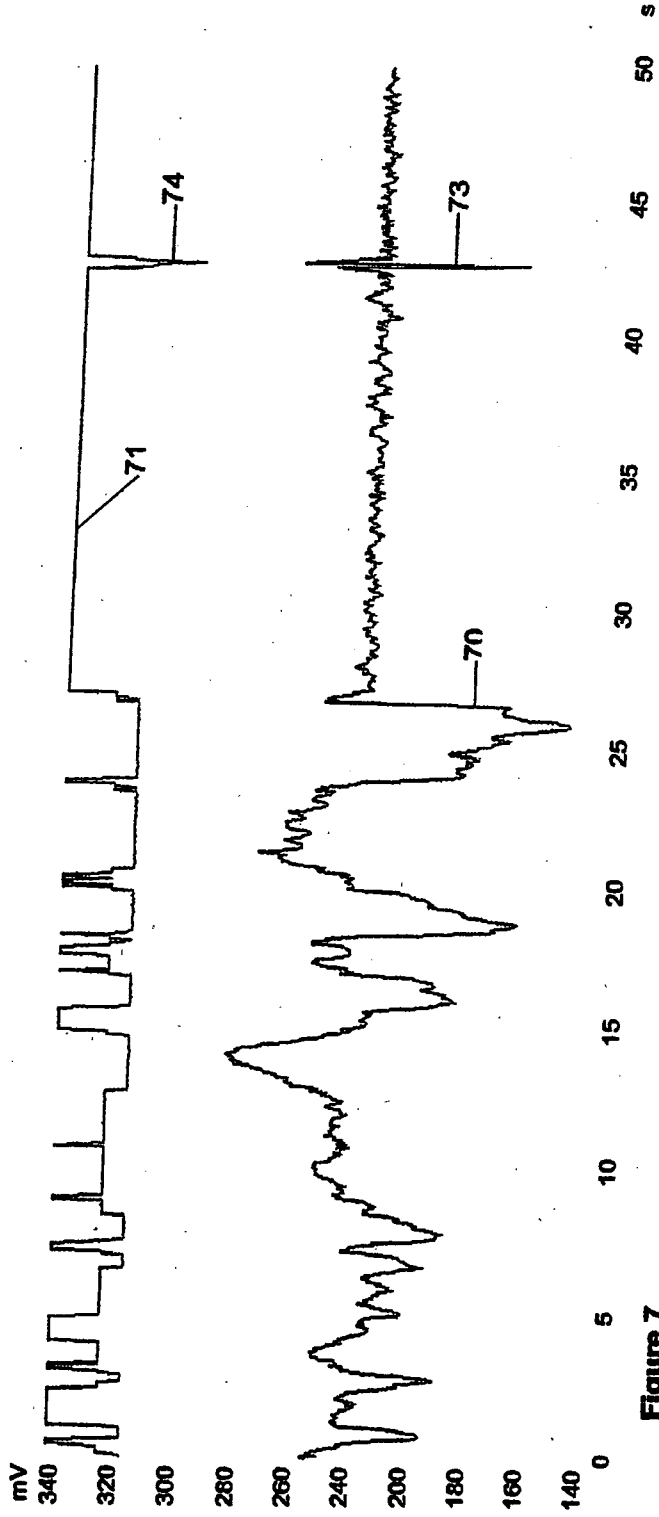
Figure 4



**Figure 5**



**Figure 6**



**Figure 7**