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(54) ULTRASONIC OBSTACLE DETECTION IN ALARM DEVICES

(57) An alarm device (1) detects smoke and has a housing having a longitudinal axis and containing a sensor and having vents (3) for access by ambient air to the sensor, a signal processing circuit (15) with a processor linked with the sensor, a power supply for the circuit and the sensor. An obstacle detector detects presence of an unwanted obstacle to flow of ambient air to the sensor. The obstacle detector has an ultrasonic transducer (16) mounted to reflect emitted ultrasonic waves in radial directions relative to the longitudinal axis. The guide comprises a dish-shaped guide element (6) mounted to the housing (2) so that a single ultrasonic transducer can emit radially to cover a very large field of view, but also that the guide element (60) can act as a secondary source directing ultrasonic waves axially, and also to direct waves through the vents (3) so that there is immediate and effective detection of inadvertent blocking of the vents by tape. Also, there is in-built determination as to whether the air is stable enough for accurate obstacle detection.

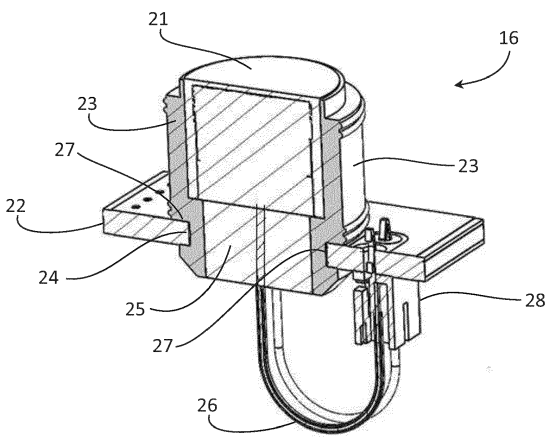

Fig. 6

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Description

Introduction

[0001] The invention relates to static alarm devices such as smoke, heat and/or carbon monoxide (CO) alarm devices.

[0002] The sensing technology of such devices is typically of good quality and is reliable. However, problems can arise due to use of the devices whereby an adequate flow of air to be sensed does not reach the active sensor, for example smoky air not reaching an optical chamber sensor of a smoke alarm device, hot air not reaching a temperature sensor, or air with CO not reaching a CO sensor. This can arise if someone inadvertently puts an obstacle in place, such as for example taping over a vent of a device while painting and decorating, covering over a device with a false ceiling, or placing a large item of furniture close to the device.

[0003] CN20152242292 (Zenner Meters Shanghai Ltd) describes an arrangement of LED detectors to detect obstacles.

[0004] EP2492882 (Hager) describes a smoke alarm with an obstacle detector.

[0005] The invention is directed towards providing enhanced obstacle detection for alarm devices which are suitable to be mounted in static positions to detect a condition of ambient air.

Summary

[0006] We describe an alarm device as set out in the accompanying claims 1 to 15.

[0007] We describe an alarm device to detect a condition of ambient air, the alarm device comprising:

a housing having a longitudinal axis and containing a sensor and having vents for access by ambient air to the sensor,
a signal processing circuit with a processor linked with the sensor,
a power supply for the circuit and the sensor,
an obstacle detector for detecting presence of an unwanted obstacle to flow of ambient air to said sensor.

[0008] Preferably, the obstacle detector comprises:

an ultrasonic transducer mounted in or on the device to have a field of emission outside of the device,
a processor in the circuit and linked with the ultrasonic transducer to monitor ultrasonic return values and process them to determine if any have been reflected by an unwanted obstacle, wherein the processor is configured to generate an alert to indicate presence of such an obstacle which may affect access of ambient air to the sensor through the vents, and
a guide mounted to the housing to reflect emitted ultrasonic waves in radial directions relative to the longitudinal axis.

[0009] The alert may be internal, to prevent proceeding with an obstacle detection test, and/or it may be a user alert such as an audio or visual alert.

[0010] Preferably, the guide comprises a guide element mounted to the housing so that it is spaced-apart from the housing. Preferably, the guide element is mounted by a plurality of pillars. Preferably, the guide element has a first curved surface facing the housing, and said guide element first curved surface may be generally concave.

[0011] Preferably, the housing has a curved surface facing the guide element, and the housing curved surface may be generally convex. Preferably, the guide element is mounted substantially symmetrically to the device longitudinal axis.

[0012] Preferably, the guide element is dish-shaped with a narrower end facing the housing. Preferably, the guide element has a second curved surface facing away from the device housing. Preferably, said second curved surface is generally convex.

[0013] Preferably, the guide element has a thickness and a density to act as a secondary ultrasonic source upon ultrasonic waves being incident on the first surface.

[0014] Preferably, the vents are arranged around at least some of the circumference of the housing with a field of emission of ultrasonic waves guided by the guide. Preferably, at least some of the vents are arranged so that at least some ultrasonic waves pass through the vents.

[0015] Preferably, the vents include vents which are primarily facing radially and vents which at least have a directional component facing axially.

[0016] Preferably, the housing includes a barrier to render application of tape to the vents difficult. The barrier may comprise a barrier element mounted by pillars so that it is spaced apart from at least some vents. The barrier element may be annular.

[0017] Preferably, the barrier comprises a plurality of elements which extend from the housing between vents. Preferably, the ultrasonic transducer is mounted in a resilient cover and said cover engages in an aperture of a substrate which is in turn mounted to the housing.

[0018] Preferably, the resilient cover has a groove which engages a side edge of the substrate aperture. Preferably, the ultrasonic transducer is connected to a conductor on a substrate by a flexible wire link.

[0019] Preferably, the processor is programmed to detect ambient air instability either before or as part of an obstacle detection operation. The processor may be configured to record a return signal amplitude value for each of a plurality of sample points, and to quantify variance across said values, and if said variance exceeds a threshold determine that there is excessive ambient air instability.

[0020] Preferably, the processor is configured to determine a series of difference values for each pair of successive values for a sample point, and to derive a sample point variance value representative of variance for each sample point, and to compare the derived sample point variance value with a threshold. Preferably, the derived sample point variance value is a sum of the difference values for a sample point.

[0021] Preferably, the processor is configured to perform a plurality of scans each with a plurality of sample points, and to determine a multi-scan derived variance value derived from said sample point variance values. Preferably, a multi-scan derived variance value is an average of all sample point variance values.

Detailed Description of the Invention

[0022] The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings in which:

Figs. 1, 2, and 3 are top perspective, top plan and side views respectively of an optical alarm device;

Fig. 4 is a block diagram of the main functional parts of the device;

Fig. 5 is a cut-away perspective view showing the device housing, and Ultrasonic ("US") wave guide element pathways for US waves for obstacle detection, especially in relation to vents for ambient air entry;

Fig. 6 is a cut-away perspective view of an ultrasonic transducer, and Fig. 7 is a perspective view of its mounting PCB in which the transducer is mounted in a manner to minimise transfer of vibration to the PCB and to other components;

Figs. 8 to 11 are diagrams illustrating operation of the obstacle detector in terms of emission of ultrasonic waves;

Figs. 12, 13 and 14 are perspective, side and cut-away views of an alternative alarm device with an obstacle detector; and

Fig. 15 is a table of data from eight consecutive scans, each with 38 sample points captured in still air, for air turbulence detection, Fig. 16 is a plot of the eight scans overlaid using the data from Fig. 15, Fig. 17 is a table of values including processed values, Fig. 18 is a plot showing by interrupted lines the differences in plots of amplitude vs. time where conditions are unstable in terms of air turbulence, and Fig. 19 is a plot of variance across multiple sample points for stable air variance, stable air average variance, unstable air, and unstable air average variance.

[0023] Referring to Figs. 1 to 3 an alarm device 1 comprises a housing having an overall cylindrical shape with a longitudinal axis, and with a base 2 and vents 3 arranged circumferentially around a top part of the device. In this specification the term "top" means the end opposed to the mounting base, even though the device may in practice be mounted on a ceiling with the "top" facing downwardly.

[0024] The device 1 includes an obstacle detector having an ultrasonic ("US") transceiver or "transducer" mounted on a circuit board to emit US waves, which are routed by a guide 4 having pillars 5 supporting a dish-shaped guide element 6. The guide element 6 is mounted centrally around the longitudinal axis of the device. It has curved lower (first) and upper (second) surfaces 10 and 11 respectively. A generally concave lower surface 10 faces the device body 2, and a generally convex surface 11 faces away from the device body 2. The concave surface 10 faces a top generally convex surface 12 of the housing 2 facing the guide element 6.

[0025] The invention is not concerned with the sensing details as they can be of any known type for detecting heat, smoke, or gas which enters the vents 3. In this case the active sensor is a smoke detector with an optical chamber.

[0026] As best shown in Figs. 1, 3, and 5 the vents 3 comprise a ring of circumferentially arranged radial vents 3(a) and, immediately above, a ring of vents 3(b) which are sloped to have a directional component facing radially and a directional component facing axially (parallel to the longitudinal axis). There is a rim 9 over the vents 3, in the form of a ring mounted on pillars 13, spaced apart from the vents 3. In this specification the term axial is intended to mean parallel to the longitudinal axis, which in Fig. 3 is a central vertical line through the centre of the device 1.

[0027] Referring specifically to Figs. 4 and 5 the device 1 has an ultrasonic transducer 16 driven by a driver circuit 17, and is connected to a receiver amplifier circuit 18, in turn connected to a signal processing circuit 15 for delivery of signals to a microprocessor (not shown). In this case the microprocessor is a low power, 8-bit processor.

[0028] As shown in Figs. 5 to 7 the US transducer 16 has a cap 21 housing the active piezo element and being surrounded by a vibration isolator in the form of a rubber sleeve 23 which protrudes downwardly to provide an internal space 25 for flexible leads 26. The isolator 23 has a circumferential groove 27 near its lower end, the groove 27 having a width matching the thickness of a mounting PCB 22. The transducer 16 is mounted in a hole 24 of the PCB 22, with the edge of the hole 24 engaging in the groove 27 of the rubber isolator casing 23.

[0029] As best shown in Fig. 5, the surface of the US transducer 16 is substantially co-planar with the housing surface 12, and this provides for the US waves to be generated at or near the external surface of the housing device body 12. The US waves therefore do not interfere with internal components within the device body, and advantageously the transmission and reception of US waves have clear paths from the on-axis transducer location and reflected from the guide element 6.

[0030] A major advantage of placing the transducer 16 surface substantially flush with the housing surface 12 instead of inside the housing, is that it minimises echo signals caused by the ultrasound waves reflecting off the internal details of the housing. These unwanted signals could cause false detections of objects due to the housing itself and could be randomly increased if turbulent warm air passing through the housing refracts the ultrasound in such a way that more of the sound energy is reflected back to the transducer than during static airflow conditions.

[0031] Also, the mounting arrangement minimises vibration from the US transducer to the PCB 22 by virtue of damping by the sleeve 23. Also, the flexible electrical connector leads 26 provide electrical connection to a terminal 28 mounted on the lower surface of the PCB 22. This further ensures that mechanical vibration is not transmitted to the PCB. This has the effect of reducing signal "ringing" while also reducing stress on electrical joint components, helping to ensure reliability. "Ringing" is a known condition of US transducers, where the generated oscillations continue even after the excitation source has been removed. For detection of near-field objects, ringing should be reduced such that it does not interact with the returning echo signal of interest. For a near object to be correctly detected, the ringing is preferably therefore stopped as soon as possible after excitation.

[0032] The guide element 6, being placed so close to the US source 16 (less than 5 mm) acts as a secondary ultrasonic source upon ultrasonic waves being incident on the first surface 10. This aspect is assisted by the guide element 6 having a thickness of only about 2.8mm, being located just less than 5mm at its closest from the ultrasonic source 16, and being of moulded plastics material (polycarbonate).

[0033] The top surface 11 generally has an overall taper extending proximally towards the housing 12 and radially inwardly to the longitudinal axis (centrally and downwardly as viewed in Fig. 3 for example), and as noted above has locally between its rim and the centre (longitudinal axis) a slight convex shape as viewed in section. The slight convex shape is not essential, but it is preferred that the element 6 has an overall dish shape tapered distally from the housing 12 and radially from the longitudinal axis (upwardly and outwardly as viewed in for example Fig. 3). The lower surface 10 is also tapered generally proximally and radially towards the housing at the longitudinal axis (downwardly and inwardly as viewed for example in Fig. 3). Locally between the element rim and the longitudinal axis the surface 10 has a slight concave shape as viewed in section, but again this is not essential. Again, the overall guide element configuration is dish-shaped.

[0034] Use of the obstacle detector is now described with reference to Figs. 5 and 8 to 11, which are diagrammatic views illustrating paths of US waves emitted by the transducer 16. Advantageously, the US waves propagate radially from the longitudinal axis of the device, out from a space between the guide element 6 lower surface 10 and the housing 2 top surface 12. This wave propagation path includes above and below the rim 9 and through the vents 3(a) and 3(b). Blockage or taping of either the axial or radial vents creates a new surface off which the outgoing US wave can strike, resulting in an echo that is measurable, thereby detecting blockages. This detects for example taping over the vents (which may be inadvertently left in place by a decorator). Also, as shown in Figs. 11 (a) and 11(b) such waves will encounter an obstacle Y parallel with the longitudinal axis, in this case vertical. Upon encountering an obstacle, the waves are reflected back much more quickly than if there were no obstacle. The transducer 16 operates with the receiver amplifier circuit 18 to detect such early reflections in a manner which is well known *per se* in the art.

[0035] The "field of view" for the single transducer 16 therefore includes all radial directions from the device longitudinal axis, allowing detection of obstacles both on the device itself (such as tape) or nearby.

[0036] Moreover, the guide element 6 also acts as a secondary US wave source due to its vibration in response to the waves which are incident on its lower surface 10 facing the transducer 16. This is primarily due to the short distance between the US transducer 16 and the guide element 6 (less than 5mm at its closest, and preferably in the range of 1.5mm to 4mm) and it is also helped by the fact that the guide element is thin enough to vibrate. In this case the thickness of the element is about 2.8mm and it is of plastics (polycarbonate) composition, thereby allowing it to vibrate. This causes US waves to propagate axially from the device, as shown in Figs. 9 to 11. This allows further extension of the field of view, allowing the obstacle detector to detect horizontal obstacles X such as shown in Figs. 10(a) and 10(b). The returning echo signal (Fig. 10(b)) encounters the guide element 6 upon which the vibration is re-transmitted back to the US transducer 16 for detection. The return signal is further enhanced from horizontal obstacles X by way of the angled edge of the outer rim 9 and/or angled vent fins.

[0037] Another advantageous aspect of the device 1 is that by providing vents which face radially and also vents which at least partially face axially there is less chance of all of the vents being accidently taped. This is further improved by virtue of the rim 9, which acts as a spaced-apart barrier to help reduce chances of the vents being taped over such that air entry is completely blocked or blocked to an extent that severely hinders the operation of the alarm.

[0038] With the rim 9 effectively preventing convenient access to the radial and axial vents, tape applied around the circumference of the unit is no longer sufficient to block some or all of the vents from air entry, since there still remains a viable air entry path in the axial direction.

[0039] Referring to Figs. 12 to 14 an alternative device 100 has a housing 102 with a guide 104 akin to the guide 4 of Figs. 1 to 13. In this case there are vents 103 which face both radially and axially. Spacers 130 are arranged to extend generally axially between the vents 103, thereby helping to prevent taping of the vents 103 while also allowing propagation of US waves through and over the vents.

[0040] Another advantageous aspect of the device is that the processor is programmed to detect ambient air changes and turbulence, thereby providing an indication of reliability of the US obstacle detection measurement. An obstacle detection test may be inaccurate if the ambient air is unstable, for example by flowing at an excessive flow rate, and/or rapid changes in air temperature (relative to the steady state temperature of the unit or object under test), by for example a nearby air conditioning unit. Such air flow may render the obstacle detection inaccurate because the relevant changes in air characteristics (temperature, velocity, refractive index) would affect US beam uniformity, signal intensity and propagation time to and from the obstacle. This makes accurate US detection of objects, and also calculation of object distance from echo return time, unreliable.

[0041] In this embodiment the air stability test is integrated with the obstacle detection test, the processor firstly analysing the US return signal values to initially determine if the ambient air is sufficiently stable. If sufficiently stable, the processor proceeds to use the values to determine if there is an obstacle.

[0042] It is also envisaged that the processor may carry out an air stability test as a discrete test to decide whether to carry out an obstacle detection test. For example, the processor may be programmed to carry out an obstacle detection routine once per day, thereby consuming valuable electrical power only for a number of seconds once per day.

[0043] For each obstacle detection test the processor performs a number of ultrasonic scans separated by a small (about 1msec) delay. To reduce the effect of signal noise, the results of the scans are summed and averaged to a single data set upon which obstacle detection logic is performed. Since averaging requires multiple scans, the system uses these multiple scans more advantageously to determine the ambient air stability, thus acting as an indicator of reliability for obstacle detection measurements.

[0044] In each scan, the US transducer is driven with a number of pulses, after which the processor samples and stores the amplitude of the returning signal as a function of time. The processor then performs calculations to quantify the extent of amplitude variation between the same sample points on successive scans. Variance or Standard Deviation across all scans is then calculated for each data point.

[0045] It is useful to, for example, sum or average the variance, or standard deviation values to yield a single value for the entire scan. This value is compared to a threshold to determine if the ambient air properties were stable or unstable during the time of the scans.

[0046] In stable air conditions the variation from measurement to measurement should be small across the full scan, yielding a low average variance value. As instability in the air increases the variance increases. The threshold level is determined empirically, based on acceptable limits of detection and repeatability of the system.

[0047] If the result of the calculation is less than the threshold, the scan is "Stable" and so the average scan is accepted as a valid obstacle detection measurement. If the result is "Unstable", the obstacle detection measurement is not accepted and the measurement should be repeated. This may be repeated at intervals until a valid ("Stable") measurement is obtained.

[0048] Fig. 15 is a table of return signal amplitude values for 6 of the 36 sample points in 8 scans. Each column is a scan and each row contains the return values for a certain sample point across all of the scans. For example, Row 3 of the Fig. 15 table shows the return signal amplitude values for the first sample point for all 8 scans.

[0049] Referring to Fig. 16 variations in amplitude of the return signals is shown.

[0050] To determine the level of variability, the processor measures the absolute difference (or 'delta' in reference to Fig. 15) between a particular sample point return signal value of one scan and the next, comparing each scan to the previous, for all 8 scans (in this case). There may be one column for each delta value across the 8 scans, so therefore 7 columns of delta values, as shown in Fig. 17. The right-hand column of Fig. 17 has the value for the sum of the deltas for each row (i.e. the sum of the seven-delta series of values for each sample point).

[0051] Fig. 18 shows examples of amplitude signals for stable and unstable conditions. The higher and lower amplitudes shown for the unstable condition indicate how the signal can vary relative to the true signal (stable condition) as a result of air instability, caused by, for example, an air-conditioning blower. In this case the amplitude variability occurs rapidly (for example, less than 1 sec), so fast successive scans can therefore measure these variances. This is in contrast to other environmental instability such as room temperature changes which generally occur over minutes or hours and would generally have little effect on the amplitude of the return signal (but may change the echo return time if compensation for temperature is not included).

[0052] Unwanted amplitude variation of a signal is effectively noise, and an alternative approach may be to minimize such noise by averaging the signals. However, if the variation in amplitude is a significant fraction of the true amplitude, then the average signal may be a poor representation of the actual signal. This is especially true if the number of scans or samples is limited by hardware, power consumption or memory, such as with inexpensive 8-bit microcontrollers. Experimentally it was found that averaging of 16 times was insufficient to remove the noise caused by air instability from air conditioning unit and could lead to false detections or misinterpretation of the signals. Hence, the approach of determining and analysing variance is preferred.

[0053] Fig. 19 shows the values of variance represented by arbitrary units. The average variance for stable air is approximately 2 units and that for unstable air is about 10 units. These units allow the processor to have a threshold setting for average variance above which it decides that the air is excessively unstable.

[0054] The following is an example of simplified pseudo code for the turbulence testing performed by the processor.

- Drive transducer with x number of pulses.
- Start sampling via ADC.
- Take 40 samples with time interval of 50μsec (total time of sampling is therefore 2 msec per scan).
- Store samples in array.
- Wait 5 msecs.
- Repeat the above procedure 16 times to yield an array of 16 x 40 samples.
- For each sample point, calculate the absolute difference between each point on successive scans.
- Sum the 16 absolute difference values to yield a single value for each of the 40 sample points. The resulting array is 1 x 40.
- This array can be averaged by dividing each value by 16 or used as is.
- The resulting array can be further simplified to a single value by averaging all samples into one, i.e. sum the 40 sample points and divide by 40.
- This "turbulence" value gives an indication of the average absolute difference across all sample points.
- This single value is compared to an "instability threshold".
- If "turbulence" value > "instability threshold" raise flag to alert system or user, abort obstacle detection.
- If "turbulence" value < "instability threshold", proceed to process the previously stored 16-scan data for purposes of obstacle detection.

[0055] The invention is not limited to the embodiments described but may be varied in construction and detail. For example, even though the US guide provides a wide field of view for the single transducer there may be one or more additional transducers. It is not essential that the top surface or the bottom surface of the guide element be curved as viewed in a plane from the longitudinal axis towards the edge, and if either is curved the shape may be convex or concave between the longitudinal axis and the edge.

Summary Statements

[0056]

1. An alarm device to detect a condition of ambient air, the alarm device comprising:

    a housing (2) having a longitudinal axis and containing a sensor and having vents (3) for access by ambient air to the sensor,
    a signal processing circuit (15) with a processor linked with the sensor,
    a power supply for the circuit and the sensor,
    an obstacle detector for detecting presence of an unwanted obstacle to flow of ambient air to said sensor, the obstacle detector comprising:

        an ultrasonic transducer (16) mounted in or on the device to have a field of emission outside of the device,
        a processor (18, 19) in the circuit (22) and linked with the ultrasonic transducer to monitor ultrasonic return values and process them to determine if any have been reflected by an unwanted obstacle, wherein the processor is configured to generate an alert to indicate presence of such an obstacle which may affect access of ambient air to the sensor through the vents, and
        a guide (4) mounted to the housing to reflect emitted ultrasonic waves in radial directions relative to the longitudinal axis.

2. An alarm device as in 1, wherein the guide comprises a guide element (6) mounted to the housing (2) so that it is spaced-apart from the housing, and the guide element is dish-shaped with a narrower end facing the housing, and the housing has a curved generally convex surface (12) facing the guide element.

3. An alarm device as in 2, wherein the guide element is mounted by a plurality of pillars (5), is mounted substantially symmetrically to the device longitudinal axis, and is spaced from the ultrasonic transducer by less than 5mm.

4. An alarm device as in 3, wherein the guide element has a surface (10) facing the housing which has a concave curve from the longitudinal axis towards the edge of the guide element, and the transducer (16) has a surface which is substantially flush with the housing surface (12).

5. An alarm device as in any preceding, wherein at least some of the vents (3(b)) are arranged so that at least some ultrasonic waves pass through the vents.

6. An alarm device as in 5, wherein the vents include vents (3(a)) which are primarily facing radially and vents (3(b)) which at least have a directional component facing axially.

7. An alarm device as in any preceding, wherein the housing includes a barrier (9) to render application of tape to the vents difficult.

8. An alarm device as in 7, wherein the barrier comprises a barrier element (9) mounted by pillars (13) so that it is spaced apart from at least some vents, and optionally the barrier element is annular.

9. An alarm device as in 7, wherein the barrier comprises a plurality of elements (130) which extend from the housing between vents (103).

10. An alarm device as in any preceding, wherein the ultrasonic transducer is mounted in a resilient cover (23) and said cover engages in an aperture (24) of a substrate (22) which is in turn mounted to the housing.

11. An alarm device as in 10, wherein the resilient cover (23) has a groove (27) which engages a side edge of the substrate aperture, and wherein the ultrasonic transducer is connected to a conductor (28) on a substrate by a flexible wire link (26).

12. An alarm device as in any preceding, wherein the processor (18, 19) is programmed to detect ambient air instability either before or as part of an obstacle detection operation, and wherein the processor is configured to record a return signal amplitude value for each of a plurality of sample points, and to quantify variance across said values, and if said variance exceeds a threshold determine that there is excessive ambient air instability.

13. An alarm device as in 12, wherein the processor (18, 19) is configured to determine a series of difference values for each pair of successive values for a sample point, and to derive a sample point variance value representative of variance for each sample point, and to compare the derived sample point variance value with a threshold.

14. An alarm device as in 13, wherein the derived sample point variance value is a sum of the difference values for a sample point.

15. An alarm device as in any of 12 to 14, wherein the processor (18, 19) is configured to perform a plurality of scans each with a plurality of sample points, and to determine a multi-scan derived variance value derived from said sample point variance values, and wherein a multi-scan derived variance value is an average of all sample point variance values.

Claims

1. An alarm device to detect a condition of ambient air, the alarm device comprising:

    a housing (2) having a longitudinal axis and containing a sensor and having vents (3) for access by ambient air to the sensor,
    a signal processing circuit (15) with a processor linked with the sensor,
    a power supply for the circuit and the sensor,
    an obstacle detector for detecting presence of an unwanted obstacle to flow of ambient air to said sensor, the obstacle detector comprising:

        an ultrasonic transducer (16) mounted in or on the device to have a field of emission outside of the device,
        a processor (18, 19) in the circuit (22) and linked with the ultrasonic transducer to monitor ultrasonic return values and process them to determine if any have been reflected by an unwanted obstacle, wherein the processor is configured to generate an alert to indicate presence of such an obstacle which may affect access of ambient air to the sensor through the vents, and
        a guide (4) mounted to the housing to reflect emitted ultrasonic waves in radial directions relative to the longitudinal axis, and
        wherein the ultrasonic transducer is mounted in a resilient cover (23) and said cover engages in an aperture (24) of a substrate (22) which is in turn mounted to the housing.

2. An alarm device as claimed in claim 1, wherein the guide comprises a guide element (6) mounted to the housing (2) so that it is spaced-apart from the housing.

3. An alarm device as claimed in claim 2, wherein the guide element is dish-shaped with a narrower end facing the housing.

4. An alarm device as claimed in claim 3, wherein the guide element is mounted by a plurality of pillars (5), and is spaced from the ultrasonic transducer by less than 5mm.

5. An alarm device as claimed in claim 4, wherein the guide element has a surface (10) facing the housing which has a concave curve from the longitudinal axis towards the edge of the guide element, and the transducer (16) has a surface which is substantially flush with the housing surface (12).

6. An alarm device as claimed in any preceding claim, wherein at least some of the vents (3(b)) are arranged so that at least some ultrasonic waves pass through the vents.

7. An alarm device as claimed in claim 6, wherein the vents include vents (3(a)) which are primarily facing radially and vents (3(b)) which at least have a directional component facing axially.

8. An alarm device as claimed in any preceding claim, wherein the housing includes a barrier (9) to render application of tape to the vents difficult.

9. An alarm device as claimed in claim 8, wherein the barrier comprises a barrier element (9) mounted by pillars (13) so that it is spaced apart from at least some vents, and optionally the barrier element is annular.

10. An alarm device as claimed in any preceding claim, wherein the resilient cover (23) has a groove (27) which engages a side edge of the substrate aperture.

11. An alarm device as claimed in claim 10, wherein the ultrasonic transducer is connected to a conductor (28) on a substrate by a flexible wire link (26).

12. An alarm device as claimed in any preceding claim, wherein the processor (18, 19) is programmed to detect ambient air instability either before or as part of an obstacle detection operation, and wherein the processor is configured to record a return signal amplitude value for each of a plurality of sample points, and to quantify variance across said values, and if said variance exceeds a threshold determine that there is excessive ambient air instability.

13. An alarm device as claimed in any claim 12, wherein the processor (18, 19) is configured to determine a series of difference values for each pair of successive values for a sample point, and to derive a sample point variance value representative of variance for each sample point, and to compare the derived sample point variance value with a threshold.

14. An alarm device as claimed in claim 13, wherein the derived sample point variance value is a sum of the difference values for a sample point.

15. An alarm device as claimed in any of claims 12 or 14, wherein the processor (18, 19) is configured to perform a plurality of scans each with a plurality of sample points, and to determine a multi-scan derived variance value derived from said sample point variance values, and wherein a multi-scan derived variance value is an average of all sample point variance values.

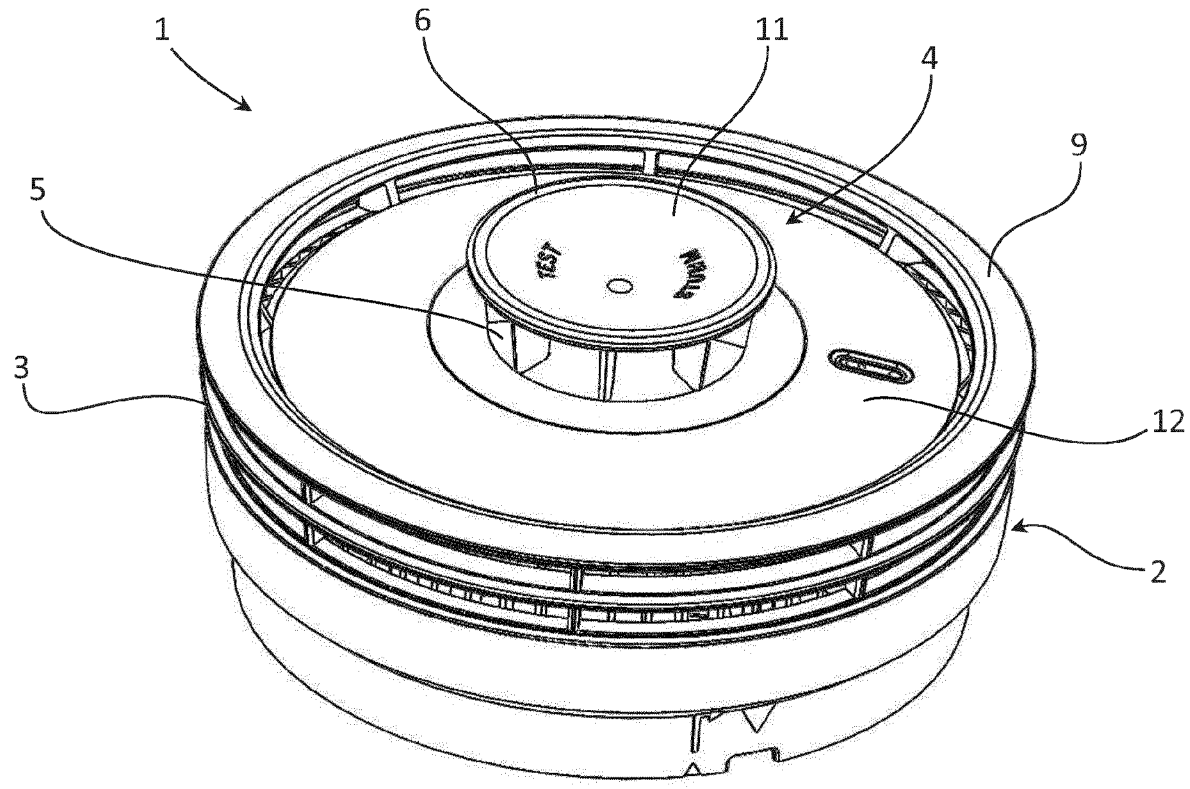

Fig. 1

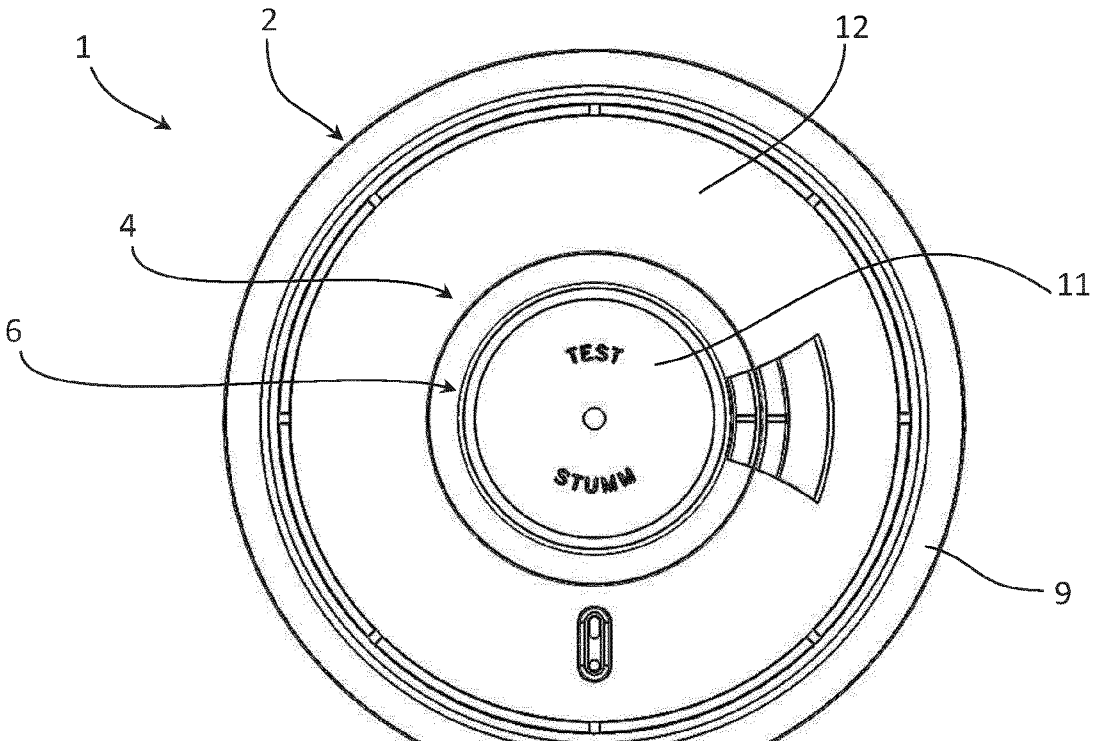

Fig. 2

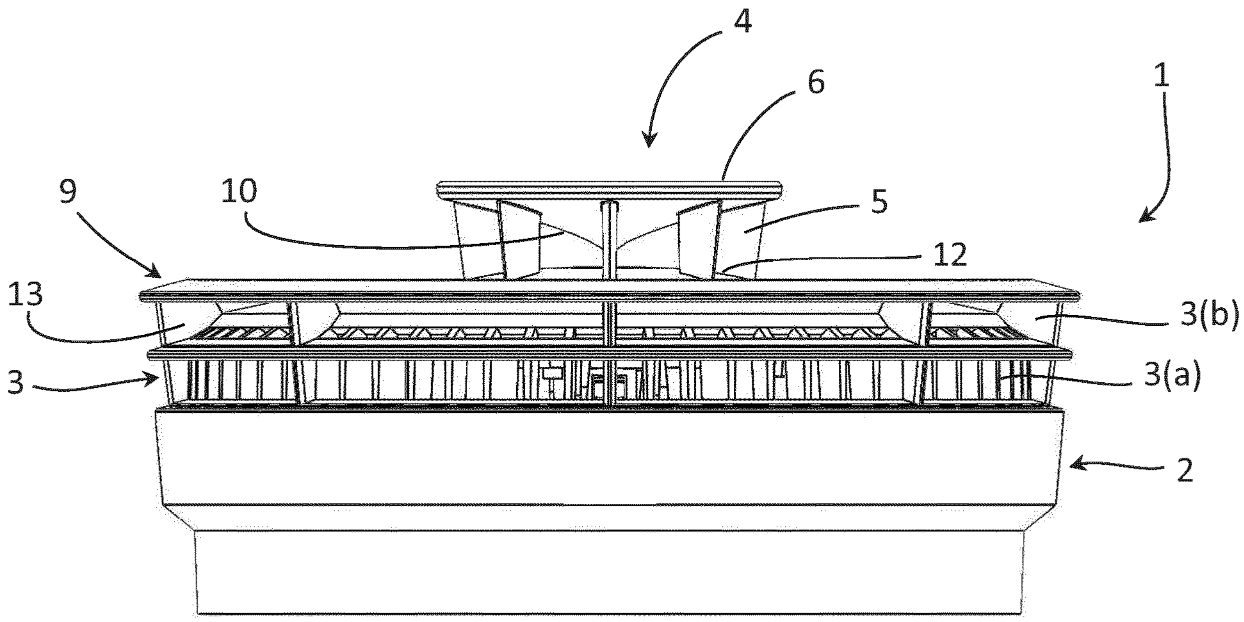
4
6
1
9
10
5
12
13
3(b)
3
3(a)
2

Fig. 3

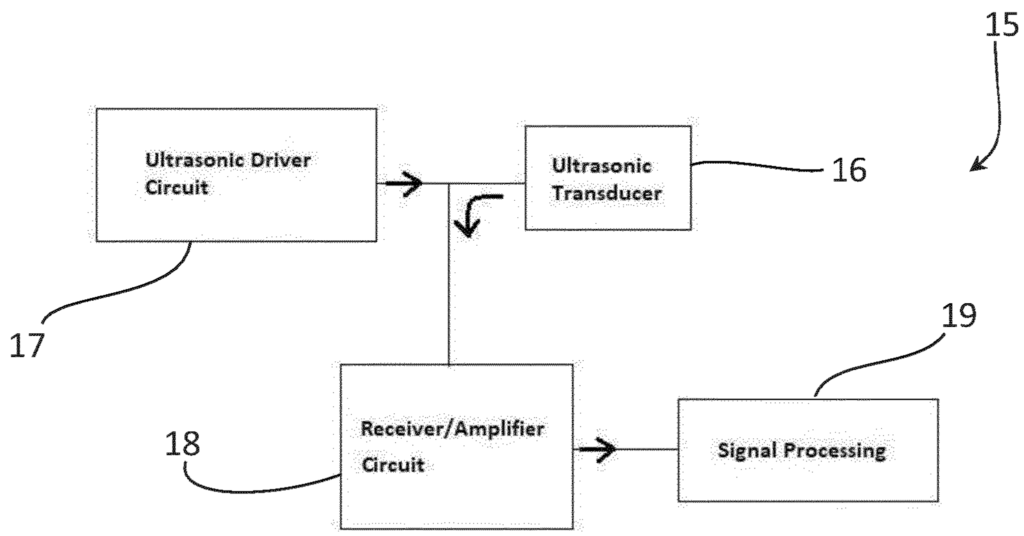
15
Ultrasonic Driver Circuit
Ultrasonic Transducer
16
17
19
18
Receiver/Amplifier Circuit
Signal Processing

Fig. 4

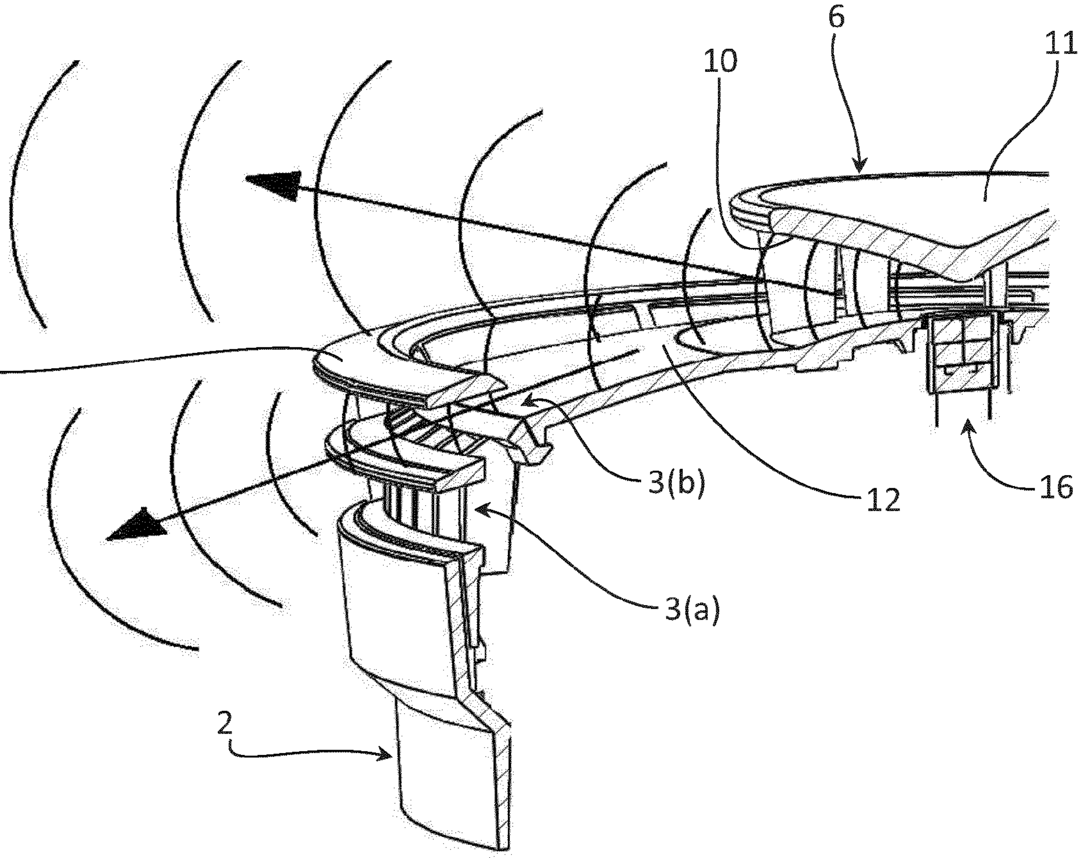

Fig. 5

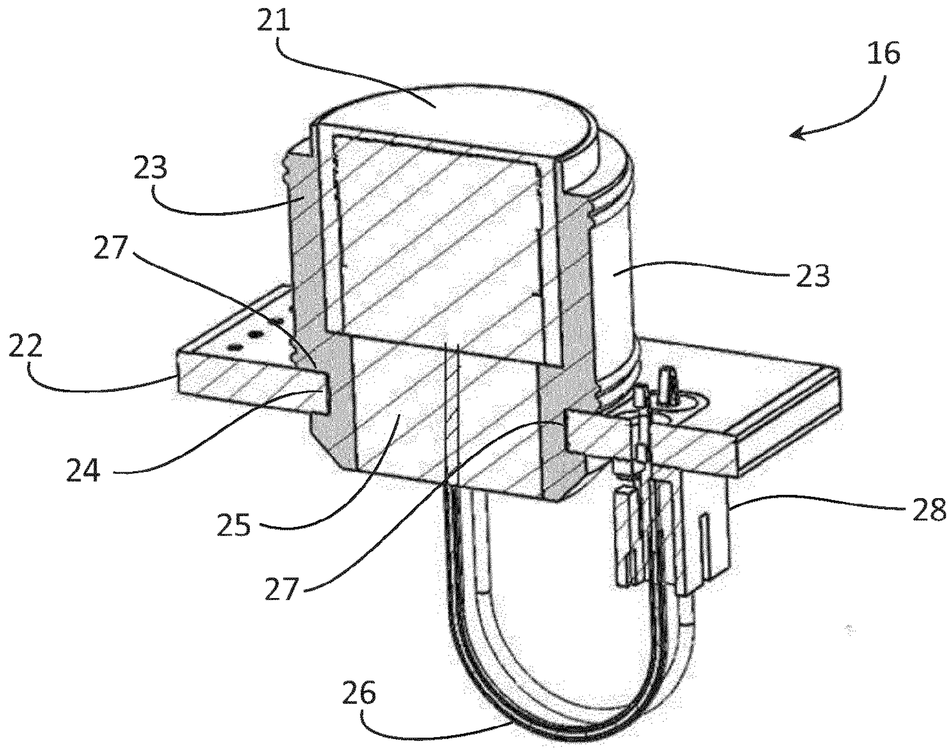

Fig. 6

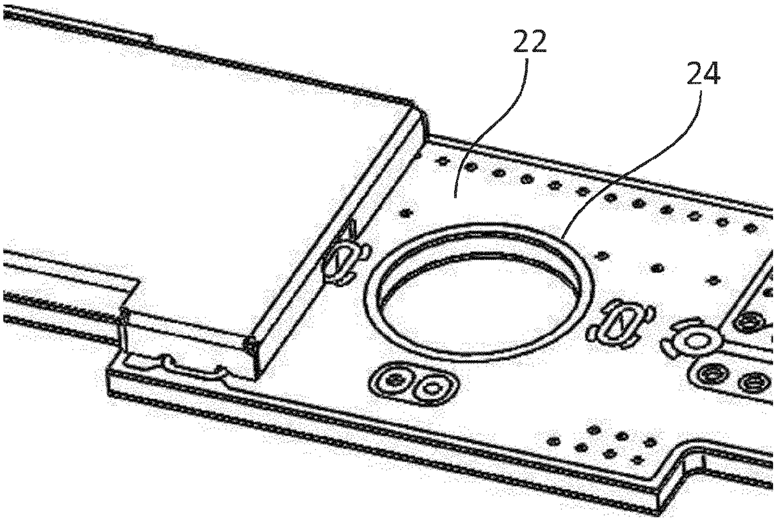

Fig. 7

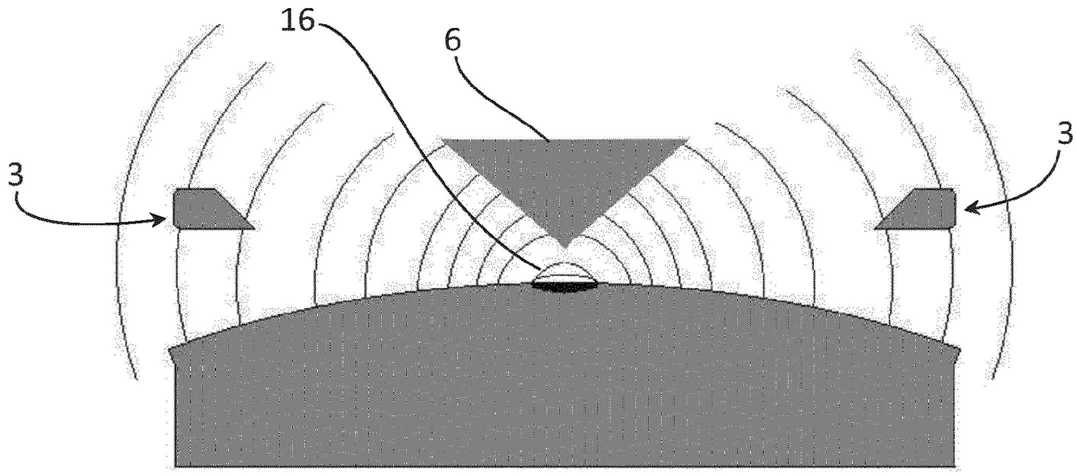

Fig. 8

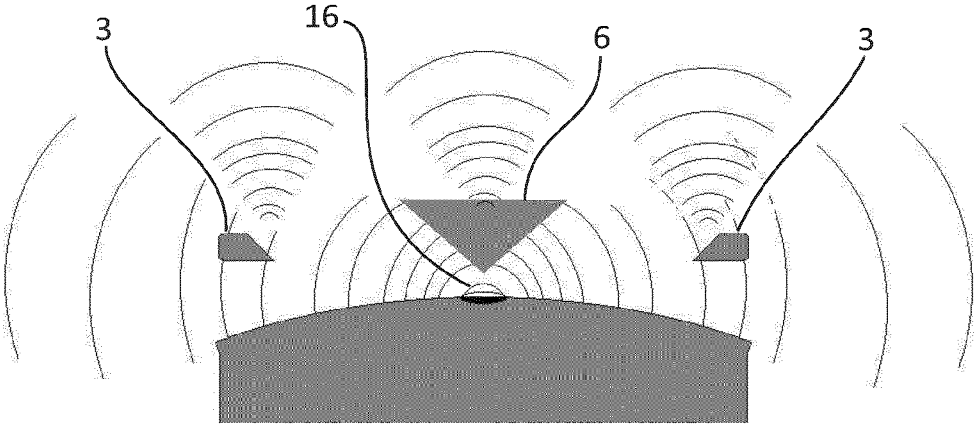

Fig. 9

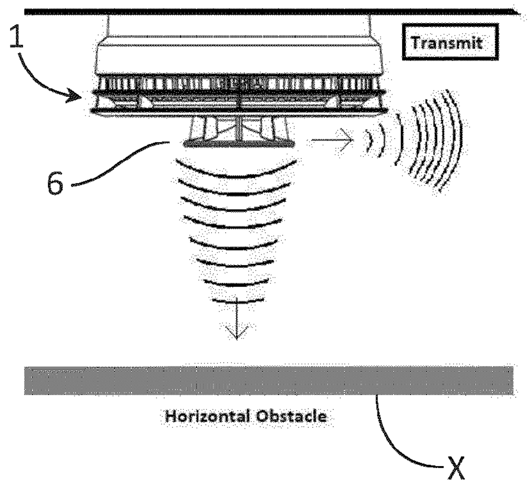

Fig. 10(a)

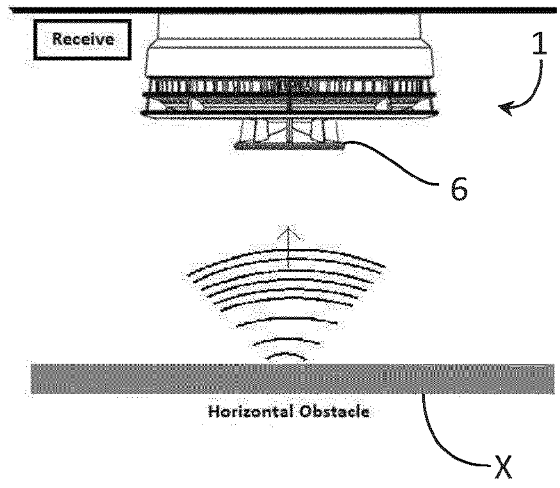

Fig. 10(b)

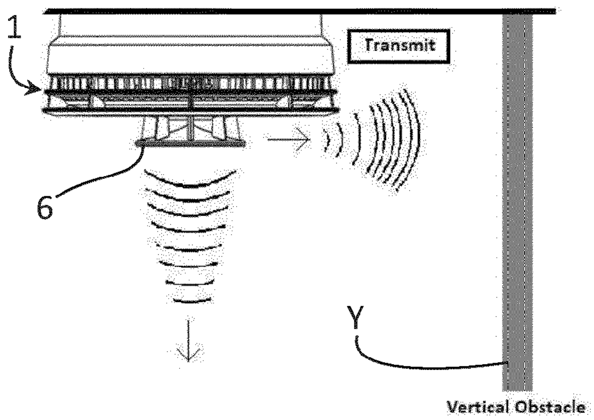

Fig. 11(a)

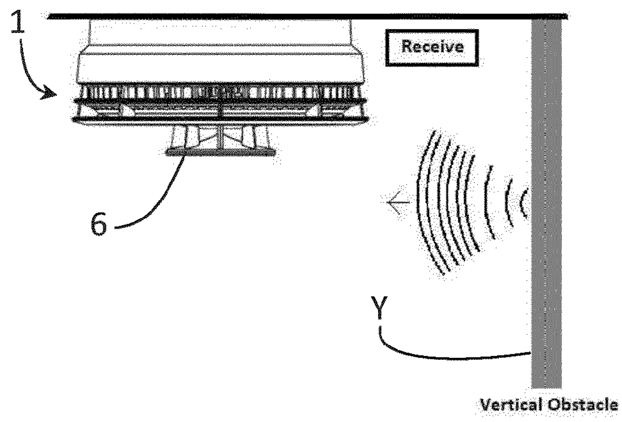

Fig. 11(b)

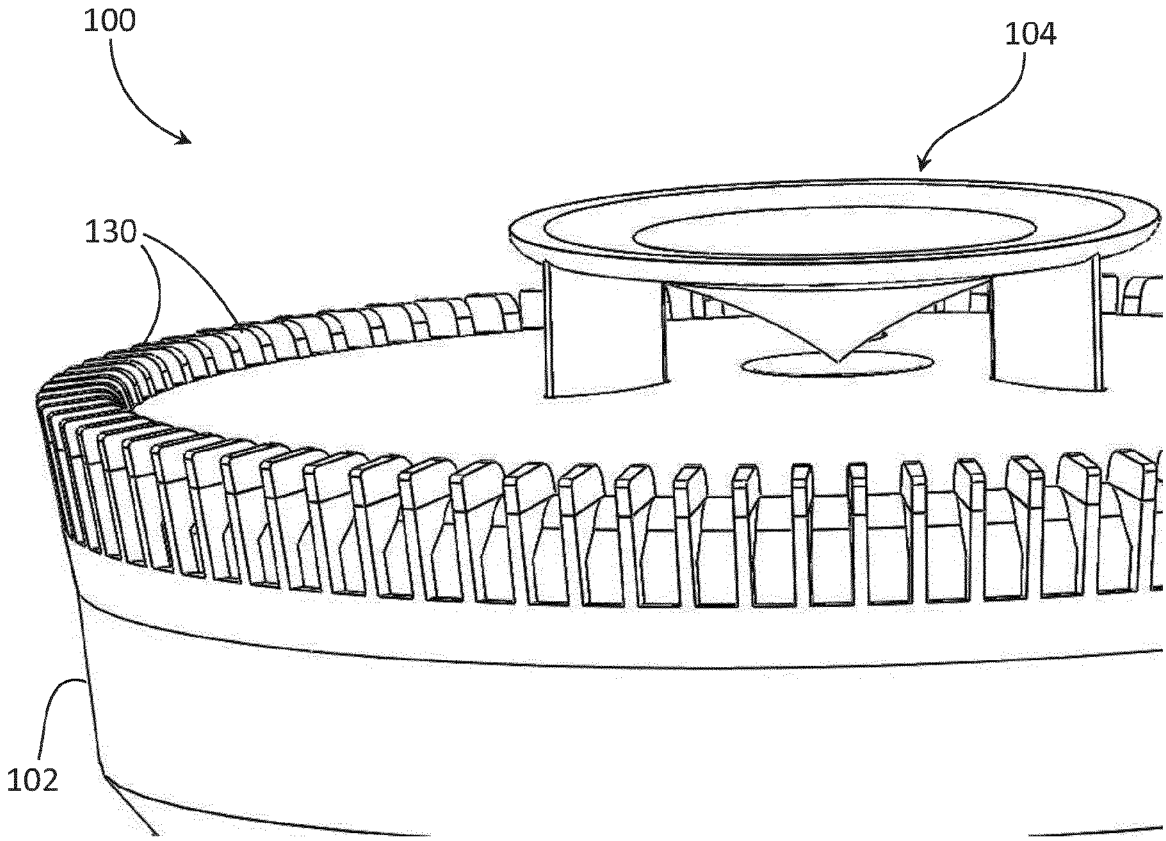

Fig. 12

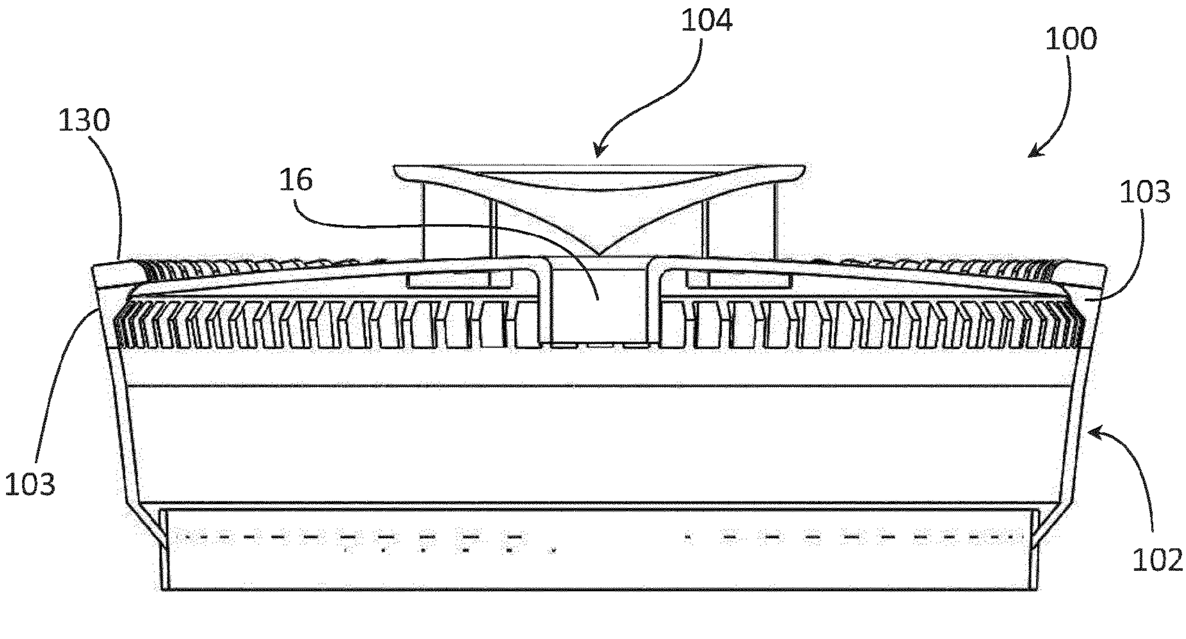

Fig. 13

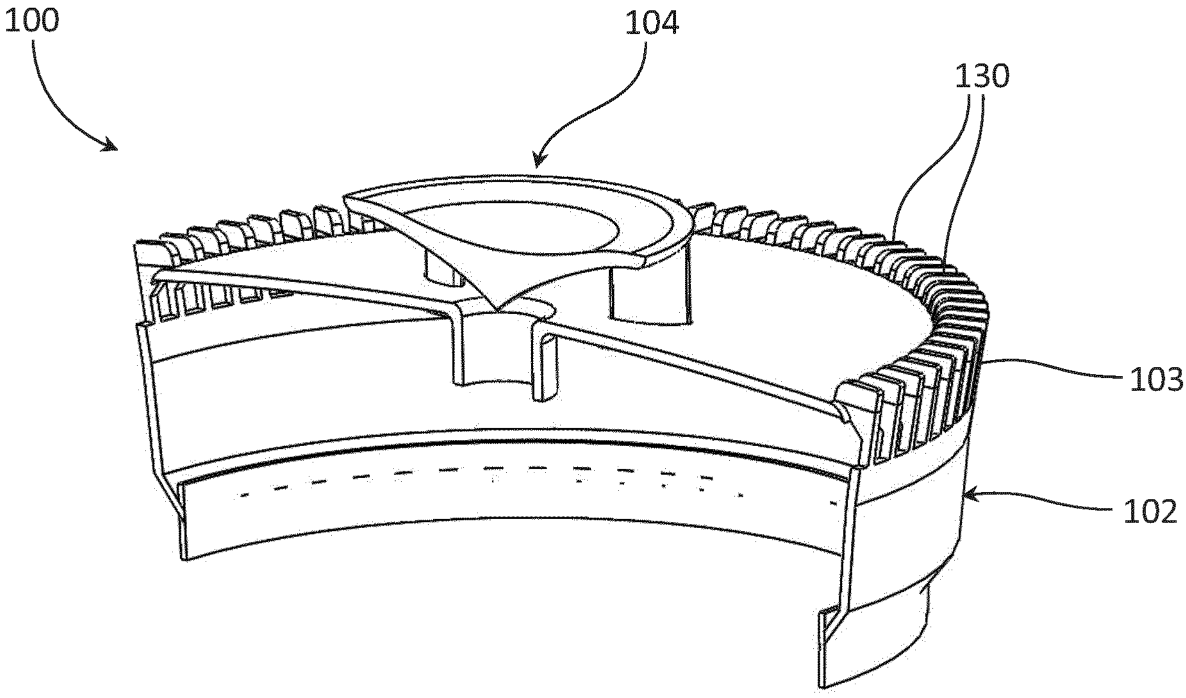

Fig. 14

◿	A	B	C	D	E	F	G	H
1	STILL AIR, same scan repeated 8 times. Each scan has 38 data points							
2	S1	S2	S3	S4	S5	S6	S7	S8
3	4.36[-01	4.38[-01	4.37[-01	4.39[-01	4.38[-01	4.40[-01	4.38[-01	4.38[-01
4	4.58E-01	4.58E-01	4.58E-01	4.56E-01	4.58E-01	4.55E-01	4.58E-01	4.57E-01
5	4.37E-01	4.37E-01	4.37E-01	4.36E-01	4.37E-01	4.36E-01	4.37E-01	4.38E-01
6	4.40E-01	4.41E-01	4.41E-01	4.45E-01	4.42E-01	4.45E-01	4.41E-01	4.43E-01
7	4.40E-01	4.39E-01	4.40E-01	4.35E-01	4.39E-01	4.33E-01	4.39E-01	4.39E-01
8	3.52E-01	3.51E-01	3.52E-01	3.47E-01	3.50E-01	3.46E-01	3.51E-01	3.51E-01

Fig.15

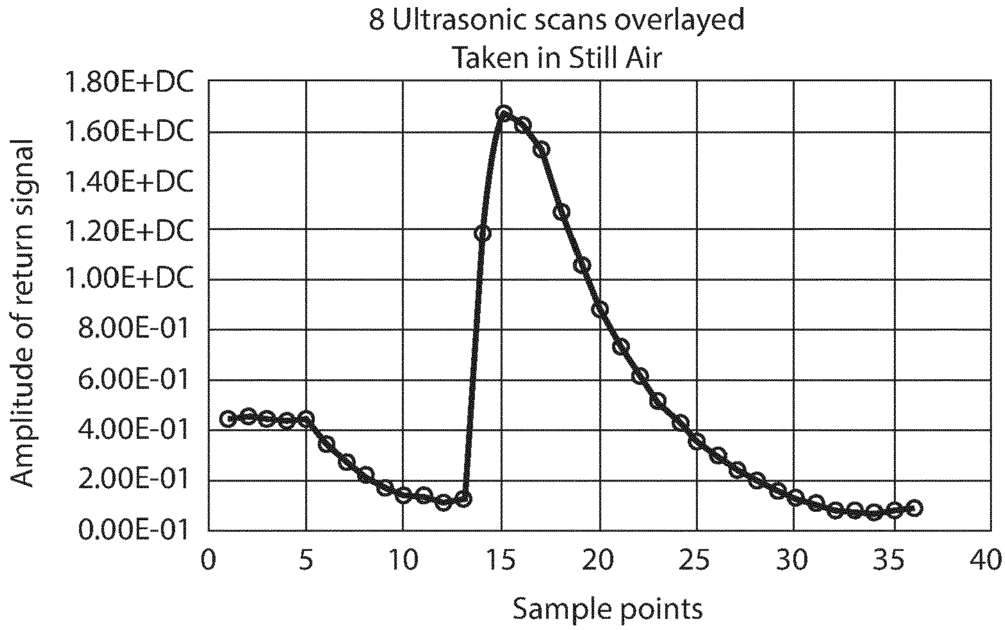

Fig.16

	Still Air Absolute Delta Values:							
	s2-s1	s3-s2	s4-s3	s5-s4	s6-s5	s7-s6	s8-s7	Sum 0f Abs Deltas
1	2.58E 03	9.39E 03	1.80E 03	7.19E 04	1.54E 03	2.14E 03	4.99E 04	1.02E 02
2	2.11E 04	2.01E 04	2.20E 03	1.71E 03	2.93E 03	3.07E 03	4.12E 04	1.07E 02
3	7.29E -04	4.32E-04	6.71E-04	8.63E-01	1.28E-03	9.88E-01	6.04E-04	5.57E-03
4	1.39E-03	3.45E-04	3.91E-03	2.70E-03	2.74E-03	4.03E-03	1.92E-03	1.70E-02
5	1.13E-03	1.27E-03	4.90E-03	3.28E-03	5.38E-03	6.06E-03	5.66E-04	2.26E-02
6	1.29E-03	1.05E-03	4.35E-03	2.69E-03	4.32E-03	5.50E-03	5.18E-04	1.97E-02

Fig.17

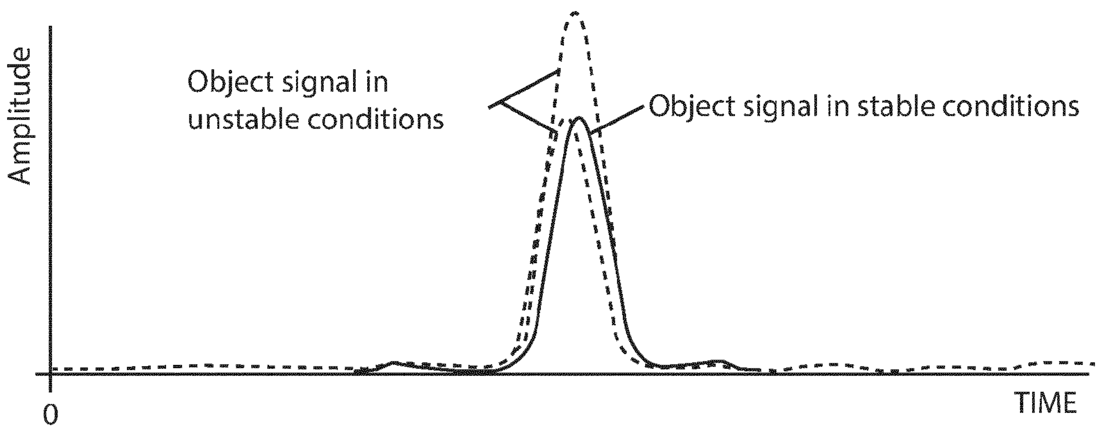
Amplitude
Object signal in unstable conditions
Object signal in stable conditions
0
TIME

Fig.18

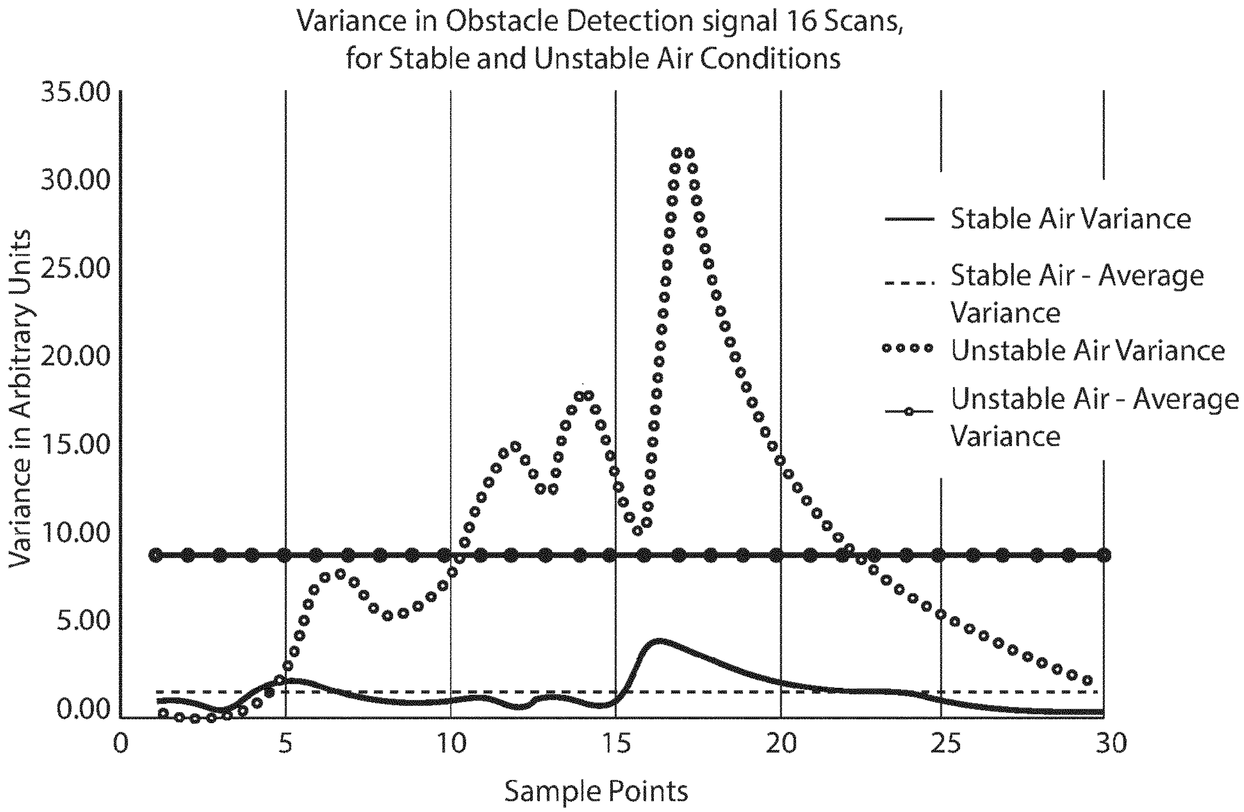
Variance in Obstacle Detection signal 16 Scans, for Stable and Unstable Air Conditions
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Variance in Arbitrary Units
0
5
10
15
20
25
30
Sample Points
Stable Air Variance
Stable Air - Average Variance
Unstable Air Variance
Unstable Air - Average Variance

Fig.19

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 20152242292 **[0003]**
- EP 2492882 A, Hager **[0004]**