(54) **AN ADJUSTABLE RESONATOR ASSEMBLY AND A METHOD FOR REDUCING ACOUSTIC EMISSIONS IN A GAS FLOW SYSTEM**

(57)   An adjustable resonator assembly, comprising a resonator cavity having a neck area with a neck opening configurable to be in fluid communication with a conduit through which a gaseous material can flow, a resonator adjustment structure configured to move from a first position in which the structure closes the neck area when flow of the gaseous material is absent to a second position in which the structure opens the neck area by a predetermined degree in presence of a flow of the gaseous material and a bias mechanism configured to exert a force onto the resonator adjustment structure so as to move the resonator adjustment structure to the first position.
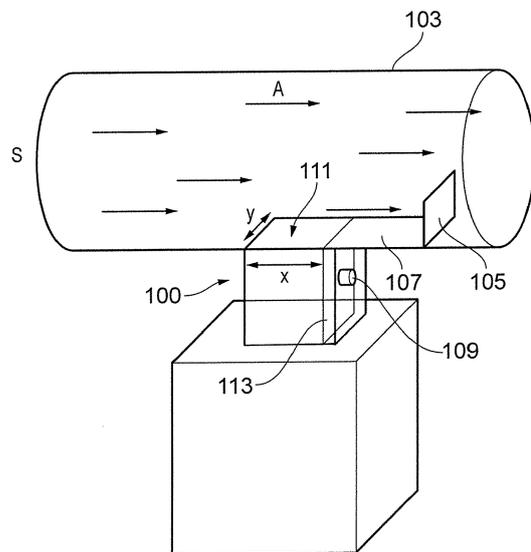

FIG. 1

EP 3 156 664 A1

Description

TECHNICAL FIELD

5   **[0001]**   Aspects relate, in general, to an adjustable resonator assembly and a method for reducing acoustic emissions in a gas flow system.

BACKGROUND

10   **[0002]**   Many airflow systems such as fans, impellors and vehicle exhausts are accompanied, in use, by loud acoustic emissions. The acoustic emissions of these airflow systems often have a dynamic peak acoustic frequency which tends to increase with the air flow. This effect can be observed with a fan where the acoustic pitch of the fan increases as it spins faster and the air flow increases, or in a car where the engine's acoustic pitch increases and will produce more exhaust gases (and therefore airflow) as the revolutions of the car's engine increases.

15   **[0003]**   These acoustic emissions are generally undesirable. In order to reduce the acoustic emissions active or passive systems can be used. For example, in an active attenuation system, signal processing can be used to adjust a sound attenuation system. Active solutions are expensive and require constant power as they are typically electronic systems.

[0004]   In passive systems, no processing is used. For example, acoustic emissions can be absorbed using a material such as acoustic foam. Acoustic foam is highly effective at high frequencies of around 1000hz and above, but has little

20   dampening properties at low frequencies. Acoustic foam is also very bulky and can be heavy.

SUMMARY

[0005]   According to an example, there is provided an adjustable resonator assembly, comprising a resonator cavity

25   having a neck area with a neck opening configurable to be in fluid communication with a conduit through which a gaseous material can flow, a resonator adjustment structure configured to move from a first position in which the structure closes the neck area when flow of the gaseous material is absent to a second position in which the structure opens the neck area by a predetermined degree in presence of a flow of the gaseous material and a bias mechanism configured to exert a force onto the resonator adjustment structure so as to move the resonator adjustment structure to the first position.

30   **[0006]**   In the second position, the resonator cavity has a selected neck area, whereby to cause the resonator cavity to act as a Helmholtz chamber. The bias mechanism can be a spring with a preselected spring constant. The resonator adjustment structure can comprise a plate or flap configured to extend radially inwardly into the conduit. The plate can be arranged on an extension portion or flap attached to a side wall portion or flap. The size of the neck opening can be varied between the first position and the second position. The resonator adjustment structure can be biased using a

35   spring having a preselected spring constant whereby to provide a spring compression force equal to a drag force of the resonator adjustment structure when exposed to the flow of the gaseous material.

[0007]   According to an example, there is provided a method for reducing acoustic emissions in a gas flow system, the method comprising modifying the area of a neck opening of and the volume of a resonator cavity exposed to a gas flow of the system whereby to match a peak acoustic frequency emitted by the gas flow system to the resonant frequency of the resonator cavity by varying the neck area of the cavity using a resonator adjustment structure. The method can

40   further include biasing the resonator adjustment structure in a first configuration in which the area of the neck opening of the resonator cavity is substantially zero. The resonator adjustment structure can be exposed to a gas flow of the system. The resonator adjustment structure can be biased using a spring, the method further comprising selecting a spring with a spring constant whereby to provide a spring compression force equal to a drag force of the exposed

45   resonator adjustment structure. The area of the neck can be modified by adjusting the neck opening of the resonator cavity using an extension portion attached or otherwise arranged on a movable side wall portion of the cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

50   **[0008]**   Embodiments will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of a resonator assembly according to an example;

55   Figure 2 is a graph showing how the resonance of the cavity is matched with the peak acoustic frequency produced by a fan according to an example; and

Figure 3 is a representation showing a proof of concept setup for a fixed Helmholtz resonator according to an example.

DESCRIPTION

[0009] Example embodiments are described below in sufficient detail to enable those of ordinary skill in the art to embody and implement the systems and processes herein described. It is important to understand that embodiments can be provided in many alternate forms and should not be construed as limited to the examples set forth herein.

[0010] Accordingly, while embodiments can be modified in various ways and take on various alternative forms, specific embodiments thereof are shown in the drawings and described in detail below as examples. There is no intent to limit to the particular forms disclosed. On the contrary, all modifications, equivalents, and alternatives falling within the scope of the appended claims should be included. Elements of the example embodiments are consistently denoted by the same reference numerals throughout the drawings and detailed description where appropriate.

[0011] The terminology used herein to describe embodiments is not intended to limit the scope. The articles "a," "an," and "the" are singular in that they have a single referent, however the use of the singular form in the present document should not preclude the presence of more than one referent. In other words, elements referred to in the singular can number one or more, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including," when used herein, specify the presence of stated features, items, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, items, steps, operations, elements, components, and/or groups thereof.

[0012] Unless otherwise defined, all terms (including technical and scientific terms) used herein are to be interpreted as is customary in the art. It will be further understood that terms in common usage should also be interpreted as is customary in the relevant art and not in an idealized or overly formal sense unless expressly so defined herein.

[0013] In order to compensate for the peak frequency being emitted by a gas flow system, a resonator cavity or chamber such as a Helmholtz cavity can be used. A Helmholtz cavity is defined by a volume of air with a neck. If the neck is in fluid communication with an air or gas flow this allows the system to resonate due to the change of pressure. This phenomenon can be observed by blowing across the top of a bottle for example - the sound you hear is the Helmholtz resonance. The resonant frequency of a Helmholtz chamber is governed by the volume of the cavity and the neck size, that is, the neck area of the cavity that is open to the airflow.

[0014] When coupled to the side of a pipe or conduit (for example) with sound propagating through, a Helmholtz chamber can attenuate the sound almost completely at any frequency range due to destructive interference when the acoustic frequency matches the resonance of the Helmholtz chamber. By dynamically/actively varying the parameters of the Helmholtz chamber the resonant frequency of the chamber can be made to match the peak acoustic frequency of the source.

[0015] Semi-passive solutions are known in which a Helmholtz cavity can be fitted with a moving wall and piston etc. that is controlled using active means, such as a motor. Active sensing and processing of the sound spectrum is performed in order to be able to adjust the parameters of the Helmholtz cavity in order to cancel out or reduce acoustic emissions. Such systems are typically, as a result of the active components, rather bulky and complicated, and require power and processing capabilities to be able to function.

[0016] According to an example, an adjustable resonator assembly is provided that uses the airflow (or flow of other gaseous material) from a source to passively change a neck width, and thus the neck area, of a resonator cavity in the form of a Helmholtz resonator so as to vary the attenuation frequency to follow the corresponding changing acoustic frequency from the source. No active signal processing and manipulation is needed since all dynamic properties come directly from the airflow making the assembly totally passive. That is, an air or gas flow present in a conduit is used in order to adjust the dimensions of a resonator cavity.

[0017] Figure 1 is a schematic representation of an adjustable resonator assembly according to an example. The assembly comprises a resonator cavity 100 configurable to be in fluid communication with a conduit 103 through which air or another gaseous material can flow. A resonator adjustment structure 105 is provided that is connected to a movable top portion 107 of the resonator cavity 100. The resonator adjustment structure 105 extends outside of the resonator cavity 100. A mechanism 109 to bias the resonator adjustment structure 105 in a first configuration in which the neck area I I 1 the resonator cavity 100 is substantially zero is provided. In an example, the mechanism 109 is a spring having a preselected spring constant.

[0018] As will be explained in more detail below, the resonator adjustment structure 105 is configured to modify the position of the top portion 107 in the presence of an air or gaseous material flow within the conduit 103. Changing the position of the top portion 107 modifies the neck area 111 of the cavity 100. Furthermore, the top portion 107 is connected to a movable side wall portion 113. As the position of this portion changes, the volume of the cavity changes. Accordingly, the resonant frequency of the cavity 100 can be modified.

[0019] The airflow A from a source S is therefore used to passively change the neck width x of cavity 100, whereby to vary the attenuation frequency in order to follow the corresponding changing acoustic frequency from the source S. This requires no additional active signal processing and manipulation, all dynamic properties come directly from the airflow A making it totally passive. That is, according to an example, a drag plate used to modify the properties of a

resonator cavity has a step-like form (figure 1) with one flap 105 inside the flow conduit 103 and another flap 107 covering the opening of the neck 111 and a third flap 113 being in contact with the spring 109. As the flow within the conduit 103 increases, the force of the flow drags the upper flap 105 which thereby opens the neck 111 and compresses the spring 109 at the same time while the spring constantly pushes in the opposite direction against the flap 113.

[0020]   According to an example, the attenuation frequency of the resonator cavity 100 can be calculated using:

- The compression value (e.g. the spring constant) of the mechanism 109;
- The drag force experienced by the resonator adjustment structure 105; and
- The Helmholtz chamber resonance of the cavity 100.

[0021]   The following nomenclature is used hereinafter:

Symbol	SI Units	Meaning
A_D	m^2	Drag Surface Area
A_f	m^2	Area of flow pipe
A_H	m^2	Area of Helmholtz Chamber Neck Opening
C_D	-	Drag Coefficient
F_D	N	Drag Force
f_f	Hz	Fan Peak Acoustic Frequency
f_H	Hz	Helmholtz Resonant Frequency
F_s	N	Spring Compression Force
k	$N\,m^{-1}$	Spring Constant
L	m	Length (Height) of Helmholtz Neck.
N	Hz	Fan Speed
n	-	Number of Blades on Fan
q	$m^3 s^{-1}$	Flow
V_0	m^3	Helmholtz Volume
x	m	Spring Compression Movement (depth)
y	m	Non variable neck dimension. (Width)
V_a	$m\,s^{-1}$	Air Velocity
V_S	ms^{-1}	Speed of Sound
ρ	$kg\,m^{-3}$	Air Density

[0022]   The spring compression force of the mechanism 109 can be set equal to the drag force of the resonator adjustment structure 105 given by the respective equations:

$$F_s = kx, \quad F_D = \frac{1}{2}\rho v_a^{\,2} C_D A_D$$

in order to provide:

$$kx = \frac{1}{2}\rho v_a^{\,2} C_D A_D \qquad\qquad (I)$$

[0023]   This can then combined with the Helmholtz Chamber resonant frequency equation, where the neck area (A_H) 111 consists of 2 dimensions, x and y, as shown in figure 1, where:

$$f_H = \frac{v_S}{2\pi} \sqrt{\frac{A_H}{V_0 L}}$$

and therefore:

$$f_H = \frac{v_S}{2\pi} \sqrt{\frac{xy}{V_0 L}} \qquad (2)$$

[0024] The value of x can then be substituted between equations 1 and 2 to give the air velocity dependent equation for the Helmholtz resonance, as shown below in equation 3:

$$f_H = \frac{v_s}{2\pi} \sqrt{\frac{\frac{1}{2}\rho v_a^2 C_D A_D y}{V_0 L k}} \qquad (3)$$

[0025] Equation 3 is universal to all air flow sources and, to make use of it, the resonant frequency can be matched to the peak frequency being emitted by the air flow source on a case specific basis.

[0026] Consider the example of a fan. The fan affinity laws state that the air flow produced by a fan is directly proportional to its speed (when the fan diameter is held constant). Accordingly:

$$\frac{q_1}{q_2} = \frac{N_1}{N_2}$$

where $q = vA$

[0027] Accordingly, $q \propto N$, and so, if the constant of proportionality is known (the increase in flow for every extra 1 hertz of frequency of rotation), then the flow can be calculated for all speeds of the fan.

[0028] The peak acoustic frequency of fan blades can be calculated by the product of the fan's speed and the number of blades:

$$f_f = Nn$$

[0029] The dimensions and properties of the Helmholtz generator and spring setup can therefore be tuned to match the peak acoustic frequency of the fan.

[0030] A representative set of variables for the case of a fan, can be as follows:

Spring constant (Nm)	10
Conduit Radius (mm)	25
Initial Neck width (x, mm)	0
Height of neck (L, mm)	15
Depth of neck (y, mm)	17
Radius of Helmholtz volume (mm)	25
Length of volume (mm)	49
No. fan blades	7
Height of adjustment structure (mm)	15
Fan Speed Flow Relationship (cm^3/(s.Hz))	440

[0031] Figure 2 is a graph showing how the resonance of the cavity is matched with the peak acoustic frequency produced by a fan according to an example, using the above parameters. Modifications could be made to produce

predictions for other situations such as internal combustion engines and air compressors for example.

[0032] In the case of a fan, the assumptions that are made are as follows:

- The drag coefficient for the drag surface is 2.0 to represent a 2D flat plane
- Fan blade diameter remains constant (no expansion)
- The adjustment structure is in the form of a drag plate which is the same depth as the Helmholtz neck
- The moving drag plate mechanism has no effect on the Helmholtz resonance relationship
- Effective Length of the neck is the length of neck (no end effects)
- Air density and speed of sound are standard sea level atmospheric values

[0033] Figure 3 is a representation showing a proof of concept setup for a fixed Helmholtz resonator apparatus 300 according to an example. Tones were played through the speaker 301 at the rear and when the frequency matched the resonant frequency predicted by the Helmholtz resonance equation, the sound leaving the tube 303 dropped to near silent. This could be heard in contrast without the effects of the Helmholtz resonance attenuation by covering the opening of the resonator 305 with a thin material.

[0034] The present inventions can be embodied in other specific apparatus and/or methods. The described embodiments are to be considered in all respects as illustrative and not restrictive. In particular, the scope of the invention is indicated by the appended claims rather than by the description and figures herein. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. An adjustable resonator assembly, comprising:

   a resonator cavity having a neck area with a neck opening configurable to be in fluid communication with a conduit through which a gaseous material can flow;
   a resonator adjustment structure configured to move from a first position in which the structure closes the neck area when flow of the gaseous material is absent to a second position in which the structure opens the neck area by a predetermined degree in the presence of a flow of the gaseous material; and
   a bias mechanism configured to exert a force onto the resonator adjustment structure so as to move the resonator adjustment structure to the first position.

2. An adjustable resonator assembly as claimed in claim 1, wherein, in the second position, the resonator cavity has a selected neck area, whereby to cause the resonator cavity to act as a Helmholtz chamber.

3. An adjustable resonator assembly as claimed in claim 1 or 2, wherein the bias mechanism is a spring with a preselected spring constant.

4. An adjustable resonator assembly as claimed in any preceding claim, wherein the resonator adjustment structure comprises a plate configured to extend radially inwardly into the conduit.

5. An adjustable resonator assembly as claimed in claim 4, wherein the plate is arranged on an extension portion attached to a side wall portion.

6. An adjustable resonator assembly as claimed in any preceding claim, wherein the size of the neck opening is variable between the first position and the second position.

7. An adjustable resonator assembly as claimed in any preceding claim, wherein the resonator adjustment structure is biased using a spring having a preselected spring constant whereby to provide a spring compression force equal to a drag force of the resonator adjustment structure when exposed to the flow of the gaseous material.

8. A method for reducing acoustic emissions in a gas flow system, the method comprising:

   modifying the area of a neck opening of and the volume of a resonator cavity exposed to a gas flow of the system whereby to match a peak acoustic frequency emitted by the gas flow system to the resonant frequency of the resonator cavity by varying the neck area of the cavity using a resonator adjustment structure.

9. A method as claimed in claim 8, further including biasing the resonator adjustment structure in a first configuration in which the area of the neck opening of the resonator cavity is substantially zero.

10. A method as claimed in claim 8 or 9, further comprising exposing the resonator adjustment structure to a gas flow of the system.

11. A method as claimed in any of claims 8 to 10, wherein the resonator adjustment structure is biased using a spring, the method further comprising selecting a spring with a spring constant whereby to provide a spring compression force equal to a drag force of the exposed resonator adjustment structure.

12. A method as claimed in any of claims 8 to 11, wherein modifying the area of the neck further comprises:

    adjusting the neck opening of the resonator cavity using an extension portion attached or otherwise arranged on a side wall portion of the cavity.

Amended claims in accordance with Rule 137(2) EPC.

1. An adjustable resonator assembly, comprising:

    a resonator cavity (100) having a neck area (111) with a neck opening configurable to be in fluid communication with a conduit (103) through which a gaseous material can flow;
    a resonator adjustment structure comprising a plate (105) configured to extend radially inwardly into the conduit (103), the resonator adjustment structure configured to use the flow of gaseous material in the conduit (103) to passively change a width of the neck opening, wherein the resonator adjustment structure is configured to move from a first position in which the structure closes the neck area when flow of the gaseous material is absent to a second position in which the structure opens the neck area by a predetermined degree in the presence of a flow of the gaseous material; and
    a bias mechanism (109) configured to exert a force onto the resonator adjustment structure so as to move the resonator adjustment structure to the first position.

2. An adjustable resonator assembly as claimed in claim 1, wherein, in the second position, the resonator cavity (100) has a selected neck area, whereby to cause the resonator cavity to act as a Helmholtz chamber.

3. An adjustable resonator assembly as claimed in claim 1 or 2, wherein the bias mechanism (109) is a spring with a preselected spring constant.

4. An adjustable resonator assembly as claimed in any preceding claim, wherein the plate (105) is arranged on an extension portion (107) attached to a side wall portion (113).

5. An adjustable resonator assembly as claimed in any preceding claim, wherein the size of the neck opening is variable between the first position and the second position.

6. An adjustable resonator assembly as claimed in any preceding claim, wherein the resonator adjustment structure is biased using a spring having a preselected spring constant whereby to provide a spring compression force equal to a drag force of the resonator adjustment structure when exposed to the flow of the gaseous material.

7. A method for reducing acoustic emissions in a gas flow system, the method comprising:

    modifying the area of a neck opening of and the volume of a resonator cavity (100) exposed to a gas flow of the system whereby to match a peak acoustic frequency emitted by the gas flow system to the resonant frequency of the resonator cavity by varying the neck area of the cavity using a resonator adjustment structure comprising a plate (105) extending radially inwardly into a conduit (103) of the system, the resonator adjustment structure configured to use the flow of gaseous material in the conduit (103) to passively change a width of the neck opening.

8. A method as claimed in claim 7, further including biasing the resonator adjustment structure in a first configuration in which the area of the neck opening of the resonator cavity is substantially zero.

9. A method as claimed in claim 7 or 8, further comprising exposing the resonator adjustment structure to a gas flow of the system.

10. A method as claimed in any of claims 7 to 9, wherein the resonator adjustment structure is biased using a spring, the method further comprising selecting a spring with a spring constant whereby to provide a spring compression force equal to a drag force of the exposed resonator adjustment structure.

11. A method as claimed in any of claims 7 to 10, wherein modifying the area of the neck further comprises:

adjusting the neck opening of the resonator cavity using an extension portion attached or otherwise arranged on a side wall portion of the cavity.
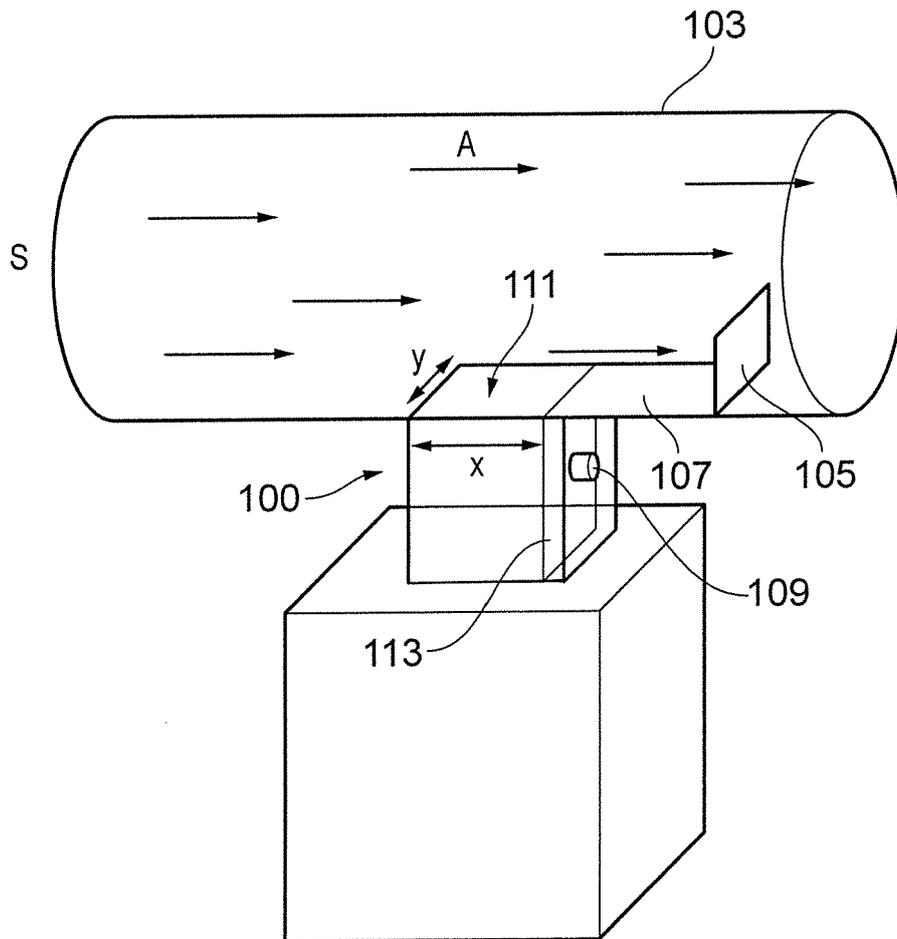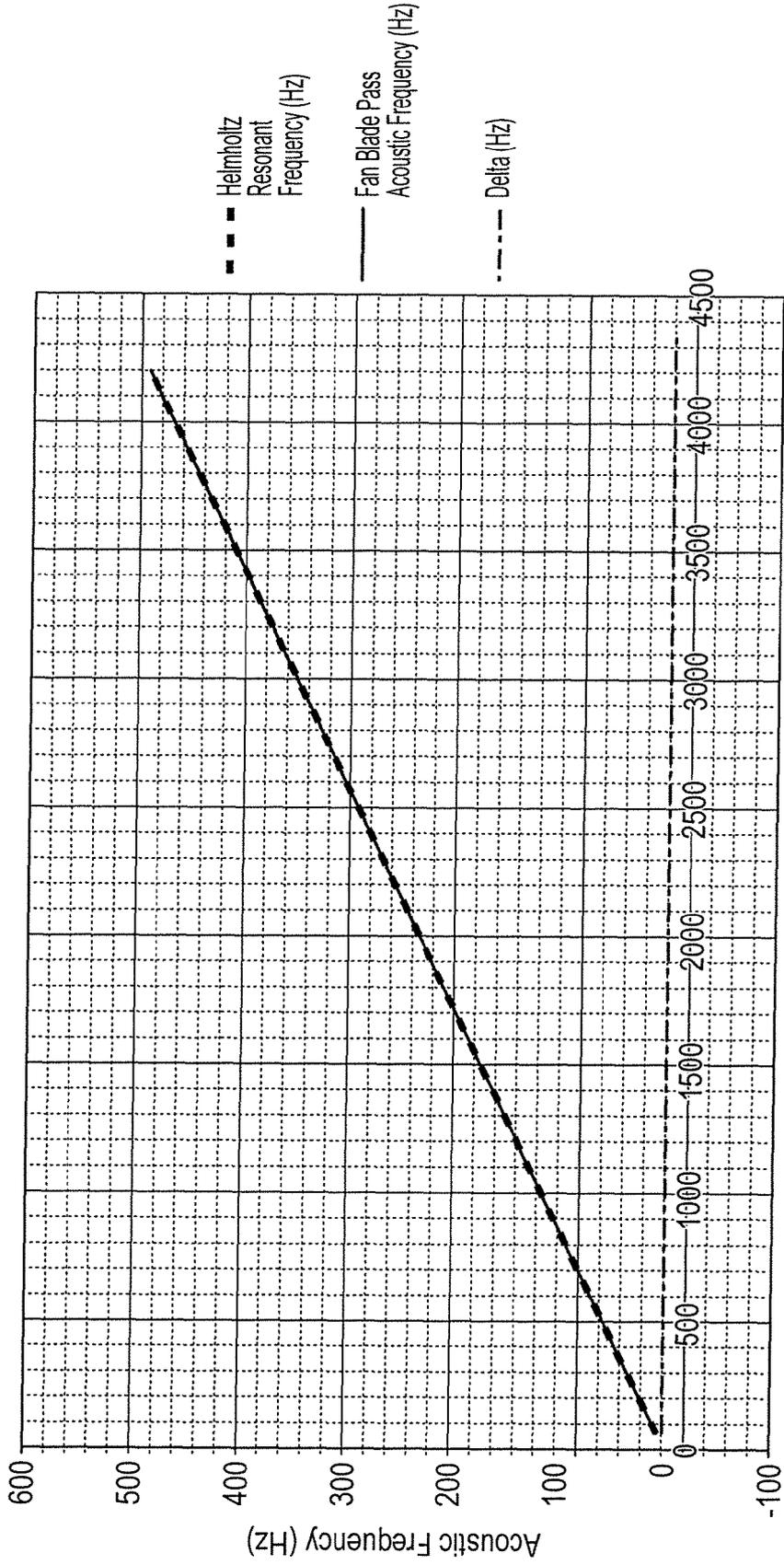
FIG. 1

FIG. 2

300

301

303

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FIG. 3

Europäisches Patentamt

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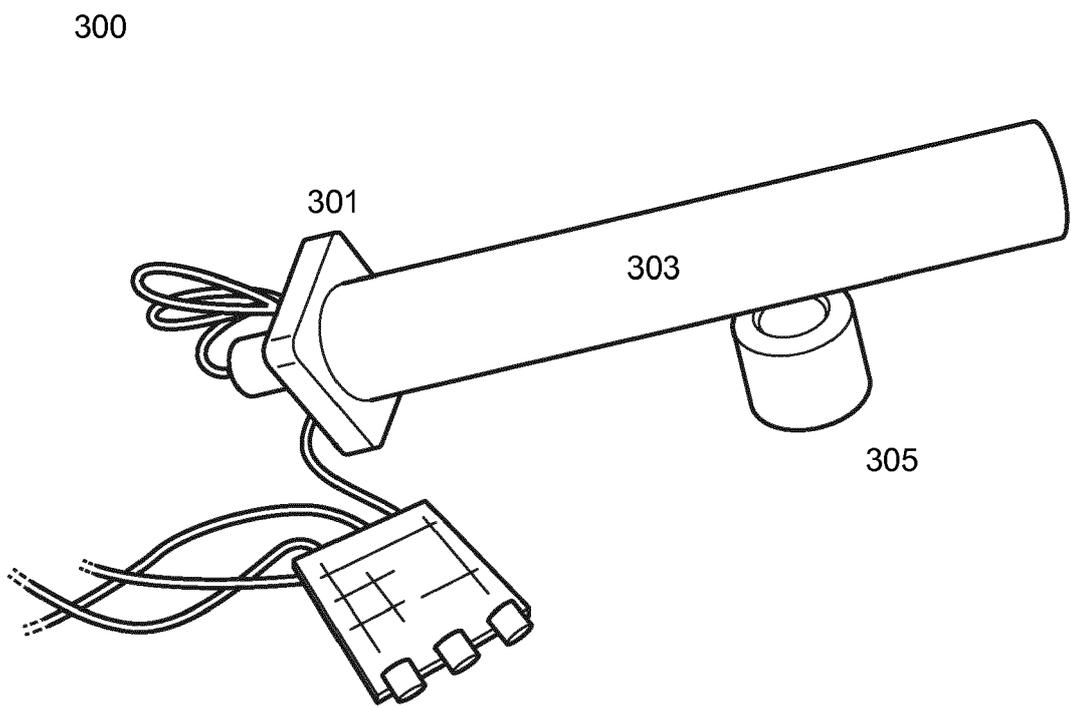
EUROPEAN SEARCH REPORT

Application Number

EP 15 30 6615

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11 April 2016	Gombert, Ralf

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ANNEX TO THE EUROPEAN SEARCH REPORT
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