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(54) Title: WIND NOISE REDUCTION FILTER

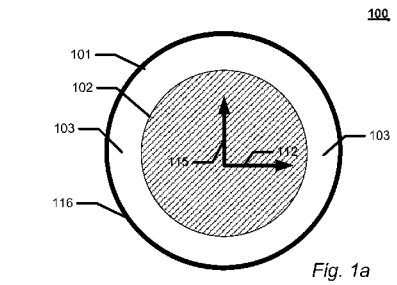

Fig. 1a

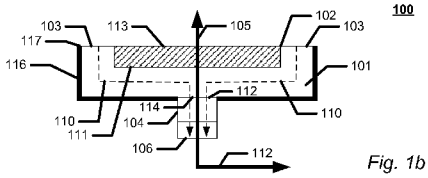

Fig. 1b

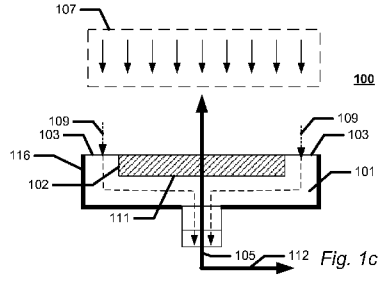

Fig. 1c

(57) Abstract: Disclosed is a noise reduction filter for a microphone, for reducing unwanted wind noise. The noise reduction filter comprises: a first filter element (101) configured to filter out wind noise, and a second filter element (102) made of a second material configured to be impermeable to wind. The second filter element (102) is arranged to prevent a direct sound wave from passing through a second surface (111) of the first filter element (101) into the first filter element (101). The first filter element (101) further comprises at least one sound receiving surface (103) allowing a part (109) of the direct sound wave (107) to directly propagate into the first filter element (101) without first interacting with the second filter element (102).

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Wind noise reduction filter

Field

The present invention relates to filters for a microphone inlet for reducing wind noise, to audio recording devices using such filters and to hearing aid systems using such audio recording devices.

Background

Wind noise is a common problem for microphones. Wind present at the microphone inlet result in turbulence creating an audible noise. This is especially a problem when the microphone is used as part of a hearing aid system as the wind noise will lower speech intelligibility as well as induces stress on the user of the hearing aid device, due to the possible prolonged exposure of the wind noise on the user.

A possible solution to reduce wind noise is to use a porous material positioned in front of the microphone inlet for lowering the wind speed and thereby filtering out wind noise. To achieve an effective filtering effect, the porous material has to have a large size, thus increasing the total size of the microphone.

US31 541 7 1 discloses a noise suppressing filter using a porous material. However, the proposed filter has an undesirable directional sensitivity and increases the size of the microphone.

It remains a problem to provide a filter / audio recording device / hearing aid system capable of efficiently filtering out wind noise.

Summary

According to a first aspect there is provided a noise reduction filter for a microphone for reducing unwanted wind noise, wherein the noise reduction filter comprises:

- a first filter element made of a first material configured to filter out wind noise, wherein said first filter element comprises a first surface configure to be positioned at a first microphone inlet of a first sound tube, the first microphone inlet having a central axis; and
- a second filter element made of a second material configured to be impermeable to wind;

wherein the second filter element is arranged to be positioned at the central axis so that a direct sound wave travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis, is prevented from passing through a second surface of the first filter element into the first filter element without first interacting with second filter element, where the second surface is arranged to be positioned at the central axis, and wherein the first filter element further comprises at least one sound receiving surface allowing a part of the direct sound wave to directly propagate into the first filter element without first interacting with the second filter element.

Consequently, a compact effective noise reduction filter is provided capable of efficiently removing wind noise. By having the second filter element positioned at the central axis, incoming air flow is forced to propagate a longer way through the first filter element, thus increasing the filtering effect. By having a first filter element comprising a sound receiving surface a more uniform directionality pattern is obtained, making the filter more sensitive to directly incoming sound waves.

The first material may be different from the second material. The first material may be air or a porous material. The second material may be a plastic material or a metal material. The first and / or the second filter element may have round shape, a rectangular, or an un-regular shape in a plane spanned by a first axis and a second axis, where the first axis is perpendicular to the central axis, and the second axis is perpendicular to both the first axis and the central axis. The first filter element may interface with the second filter element or may interface with an intermediate element. The second surface of the first filter element may interface with the second filter element. The second surface of the first filter element may face in an opposite direction of the first surface of the first filter element. The second surface of the first filter element may face the second filter element.

The central axis of the first microphone inlet is defined as the axis being perpendicular to the first microphone inlet, and positioned in the centre of the first microphone inlet. If the first sound tube is a straight tube the central axis of the first microphone inlet is also the central axis of the first sound tube. The direct sound wave may be a direct plane wave travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis so that it interacts with the second filter element before it interacts with the first surface of the first filter element.

The first filter element may have a larger widest width than the second filter element in a plane spanned by the first axis and the second axis.

In some embodiments, the material of the first filter element is air.

In some embodiments, the material of the first filter element is a porous material.

Porous materials may comprise internal tortuous paths through out their body. Porous materials may comprise pores whose cavities are connected to one another permitting fluidic communication between the pores.

By using a porous material the wind speed is reduced before it reaches the first microphone inlet. This prevents turbulence to arise at the first microphone inlet.

In some embodiments the porous material is configured to reduce the wind speed, but at the same time being approximately acoustic transparent within frequencies of 100 Hz to 20KHz.

In some embodiments, the second filter element covers a central part of the first filter element, and wherein the at least one sound receiving surface is positioned around at least a part of the periphery of the second filter element.

In some embodiment, the second filter element is positioned in a recess of the first filter element.

The recess may have a depth of 0.1 mm to 1 cm, or 0.2mm to 5mm.

In some embodiment, the second filter element comprises an outer surface facing away from the first surface of the first filter element, wherein the outer surface of the second filter element and the sound receiving surface of the first filter element are positioned in a common plane.

In some embodiments, the noise reduction filter further comprising a third filter element made of a material configured to filter out wind noise, wherein said third filter element is positioned in front of the first filter element and the second filter element relative to the first microphone inlet, so that the direct

sound wave propagates in said third filter element before interacting with the first filter element and the second filter element.

The third filter element may be made of air or a porous material. The third filter element may interface with the first filter element and/or the second filter element. The third filter element may interface with the sound receiving surface of the first filter element. The third filter element may interface with the outer surface of the second filter element. The third filter element may have a widest width that is larger than the widest width of the second filter element. The third filter element may have a widest width that is wider than the widest width of the first filter element. The third filter element may have a widest width that is wider or equal to the widest width of the first filter element.

In some embodiment, the noise reduction filter further comprises a casing containing at least a part of the first filter element.

The casing may comprise both the first filter element and the second filter element. The casing may further comprise the third filter element. The casing may have an outer rim. The outer rim of the casing may be positioned in a common plane with the outer surface of the second filter element and the sound receiving surface of the first filter element. Alternatively the outer rim of the casing may be positioned in a common plane with an outer surface of the third filter element. The casing may be made of a rigid material providing structural strength to the filter. The material of the casing may be configured to be impermeable to wind.

In some embodiment, the common plane is position in a plane spanned by the first axis and the second axis.

In some embodiment the widest width of the filter is between 1 mm and 10cm, 1 mm and 5 cm, 1mm and 2cm, 2mm and 1 cm, or 3mm and 1cm. In some embodiments, the height of the filter is between 0.2mm and 2cm, 0.5mm and 5mm, or 0.5mm and 3mm.

In some embodiments, the noise reduction filter further comprises a fourth filter element made of a third material configured to filter out wind noise, wherein said fourth filter element comprises a first surface configure to be positioned at a second microphone inlet of a second sound tube the second microphone inlet having a central axis

wherein the noise reduction filter further is configured to prevent the direct sound wave from passing through a second surface of the fourth filter element into the fourth filter element without first interacting with a impermeable filter element being impermeable to wind, where the second surface of the fourth filter element is arranged to be positioned at the central axis of the second microphone inlet, and wherein the fourth filter element further comprises at least one sound receiving surface allowing a part of the direct sound wave to directly propagate into the fourth filter element without first interacting with the impermeable filter element.

In some embodiments, the impermeable filter element is the second filter element.

In some embodiments, the impermeable filter element is a fifth filter element made of a material configured to be impermeable to wind.

In some embodiments, the first filter element, the third filter element and/or the fourth filter element is/are covered by a protective net for protecting the porous material.

The protective net may be made of acoustic transparent material. The protective net may be made of a plastic material. The average mesh size of the protective net may be between 0.02mm and 1mm, or 0.05 mm and 0.5mm.

In some embodiments, the distance between the sound receiving surface of the first filter element and the sound receiving surface of the fourth filter element is larger than the distance between the central axis of the first microphone inlet and the central axis of the second microphone inlet.

According to a second aspect there is provided an audio recording device comprising a first microphone, a noise reduction filter and a first sound tube, wherein the first sound tube have a first microphone inlet at a first end configured to capture audio and the first microphone is positioned at a second end of the first sound tube, the first microphone inlet having a central axis, wherein the noise reduction filter comprises:

- a first filter element made of a first material configured to filter out wind noise, wherein said first filter element comprises a first surface positioned at the first microphone inlet; and
- a second filter element made of a second material configured to be impermeable to wind;

wherein the second filter element is positioned at the central axis so that a direct sound wave travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis, is prevented from passing through a second surface of the first filter element into the first filter element without first interacting with the second filter element, where the second surface is positioned at the central axis, and wherein the first filter element further comprises at least one sound receiving surface allowing a part of the

direct sound wave to directly propagate into the first filter element without first interacting with the second filter element.

In some embodiment, the audio recording device further comprising a second microphone and a second sound tube, wherein the second sound tube have a second microphone inlet at a first end configured to capture audio and the second microphone is positioned at a second end of the second sound tube, the second microphone inlet having a central axis, wherein the noise reduction filter further comprises:

a fourth filter element made of a third material configured to filter out wind noise, wherein said fourth filter element comprises a first surface configure to be positioned at the second microphone inlet

wherein the noise reduction filter further is configured to prevent the direct sound wave from passing through a second surface of the fourth filter element into the fourth filter element without first interacting with a impermeable filter element being impermeable to wind, where the second surface of the fourth filter element is arranged to be positioned at the central axis of the second microphone inlet, and wherein the fourth filter element further comprises at least one sound receiving surface allowing a part of the direct sound wave to directly propagate into the fourth filter element without first interacting with the impermeable filter element.

Consequently, a noise reduction filter is provided capable of reducing unwanted wind noise for two microphones.

The third material may be different from the first material and/or the second material. The third material may be air or a porous material. The third material may be the same material as the first material. The second material may be a plastic material or a metal material. The fourth filter element and /

or the impermeable second filter element may have round shape, a rectangular, or an un-regular shape in a plane spanned by the first axis and the second axis. The fourth filter element may interface with the impermeable filter element or may interface with an intermediate element. The second surface of the fourth filter element may face in an opposite direction of the first surface of the fourth filter element. The second surface of the fourth filter element may face the impermeable filter element.

In some embodiments, the impermeable filter element is the second filter element.

In some embodiments, the impermeable filter element is a fifth filter element made of a material configured to be impermeable to wind.

In some embodiments, the first filter element and the fourth filter element may be arranged with a distance between them so that a sound wave propagating in the first filter element is prevented from directly propagate from the first filter element into the fourth filter element.

Consequently, the signals recorded by the first microphone may be more independent of the signals recorded by the second microphone.

The central axis of the second microphone inlet is defined as the axis being perpendicular to the second microphone inlet, and positioned in the centre of the second microphone inlet. If the second sound tube is a straight tube the central axis of the second microphone inlet is also the central axis of the second sound tube. The direct sound wave may be a direct plane wave travelling towards the second microphone inlet with an incidence angle of zero relative to the central axis so that it interacts with the impermeable filter element before it interacts with the first surface of the fourth filter element.

When two or more audio signals recorded at different spatial positions are available, various signal processing techniques may be used to improve the resulting signal quality. However, it is a requirement that the recorded audio signals are spatial distinct to a certain degree for the signal processing techniques to be effective. This is normally achieved by spacing the two or more microphones apart to achieve a desired spatial distinctiveness of the recorded signals. This will however increase the overall size and resulting complexity of the audio recording device.

In some embodiments, the distance between the sound receiving surface of the first filter element and the sound receiving surface of the fourth filter element is larger than the distance between the central axis of the first microphone inlet and the central axis of the second microphone inlet.

Consequently, the distance between the two microphones may be reduced as the resulting spatial distinctiveness of the recorded signals correspondingly can be increased by moving the sound receiving surface further apart. This enable to overall size and complexity of the sound recording device to be decreased.

The distance between the sound receiving surface of the first filter element and the sound receiving surface of the fourth filter element may be measured from the centre of each sound receiving surface.

In some embodiments, the distance between the centre of the sound receiving surface of the first filter element and the centre of the sound receiving surface of the fourth filter element is at least 10% larger, 20% larger, 30% larger, 40% larger or 50% larger than the distance between the central axis of the first microphone inlet and the central axis of the second microphone inlet.

According to a third aspect there is provided a hearing aid system comprising a hearing aid device configured to be worn at the ear of a user, and an audio recording device, wherein the audio recording device comprises a microphone, a noise reduction filter and a first sound tube, wherein the first sound tube have a first microphone inlet at a first end configured to capture audio and the microphone is positioned at a second end of the first sound tube, the first microphone inlet having a central axis, wherein the noise reduction filter comprises:

- a first filter element made of a first material configured to filter out wind noise, wherein said first filter element comprises a first surface positioned at the first microphone inlet; and
- a second filter element made of a second material configured to prevent a majority of the air flow that is incident on the second filter element;

wherein the second filter element is positioned at the central axis so that an air flow travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis, is prevented from directly blowing through a second surface of the first filter element into the first filter element, where the second surface is positioned at the central axis, and wherein the first filter element further comprises at least one sound receiving surface allowing a part of the direct sound wave to directly propagate from air into the first filter element without first interacting with the second filter element,
wherein the audio recording device is configured to record an audio signal and transmit the recorded audio signal to the hearing aid device.

The present invention relates to different aspects including the wind noise reduction filter, the audio recording device and the hearing aid system described above and in the following, each yielding one or more of the benefits and advantages described in connection with the first mentioned aspect, and each having one or more embodiments corresponding to the

embodiments described in connection with the first mentioned aspect and/or disclosed in the appended claims.

Brief description of the drawings

The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

Fig. 1a-b show an audio recording device comprising a noise reduction filter according to an embodiment of the present invention.

Fig. 1c illustrates how an audio recording device comprising a noise reduction filter according to an embodiment of the present invention interacts with a direct sound wave.

Fig. 2a-b show an audio recording device comprising a noise reduction filter according to an embodiment of the present invention.

Fig. 3a-b show an audio recording device comprising a noise reduction filter according to an embodiment of the present invention.

Fig. 4 shows a hearing aid system according to an embodiment of the present invention.

Fig. 5a-d show side views of audio recording devices having different sound receiving surfaces according to embodiments of the present invention.

Fig. 6a-b show an audio recording device comprising two microphones according to an embodiment of the present invention.

Detailed description

In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced.

Figure 1a-b show an audio recording device 100 comprising a noise reduction filter according to an embodiment of the present invention. Fig. 1a shows a top view of the audio recording device 100 and Fig. 1b shows a side view of the audio recording device 100. The audio recording device 100 comprises a noise reduction filter 101 102, a first sound tube 104, and a microphone 106. The noise reduction filter 101 102 comprises a first filter element 101 made of a first material configured to filter out wind noise and a second filter element 102 made of a second material configured to be impermeable to wind. The first sound tube 104 comprises a first microphone inlet 114 interfacing with a first surface 112 of the first filter element 101, the first microphone inlet 114 having a central axis 105. In this embodiment the first sound tube 104 is a straight tube and the central axis 105 of the first microphone inlet 114 is therefore also the central axis of the first sound tube 104. The second filter element 102 is positioned in a recess in the first filter element 101. The first filter element 101 and the second filter element 102 have a round shape in a plane spanned by the first axis 112 and the second axis 115, where the first axis 112 is perpendicular to the central axis 105 and the second axis 115 is perpendicular to both the first axis 112 and the central axis 105 of the first microphone inlet 114. In this embodiment, both the first filter element 101 and the second filter element 102 are centred on the central axis 105.

The second filter element 102 is positioned at the central axis 105 so that a direct sound wave travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis 105 is prevented from directly passing through a second surface 111 of the first filter element 101 positioned at the central axis 105(without first interacting with the second filter element). The first filter element 101 comprises a sound receiving surface 103 allowing the direct sound wave to directly propagate into the first filter element without first interacting with the second filter element 102. As the second filter element 102 is impermeable to wind, this arrangement

forces an incoming air flow to propagate around the second filter element 102 approximately along the illustrated path 110 in the first filter element 101. This increases the length the incoming air flow has to travel in the first filter element 101 and thereby the filtering effect of the first filter element 101. By having a sound receiving surface 103 not covered by the second filter element 102, a directional uniform sensitivity, a high sensitivity to directly incoming sound waves and a more compact design can be achieved.

The second filter element 102 comprises an outer surface 113 facing away from the first microphone inlet 114. In this embodiment, the outer surface 113, the sound receiving surface 103 and a rim 117 on the casing 116 are positioned in a common plane.

Fig. 1c illustrates how an audio recording device 100 comprising a wind noise reduction filter 101 102 as shown in Fig.1 a-b interacts with a direct sound wave 107. Shown is a direct sound wave 107 propagating towards the first microphone inlet with an incidence angle of zero relative to the central axis 105. The second filter element 102 is arranged to be positioned at the central axis 105 so that the direct sound wave 107 (and a direct airflow) is prevented from passing trough a second surface 111 of the first filter element, without first interacting with the second filter element 102. The sound receiving surface 103 of the first filter element is arranged to allow a part of the direct sound wave 107 to directly propagate into the first filter element without first interacting with the second filter element. This arrangement of the first filter element 101 and the second filter element 102 prevents an airflow from passing straight through the first filter element 101, and forces the airflow the long way around. This increases the effective thickness of the filter and at the same time provides a good directional uniform sensitivity for the microphone 106.

Figs. 2a-b show an audio recording device comprising a noise reduction filter according to an embodiment of the present invention. Fig. 2a shows a top view of the audio recording device 200 and Fig. 2b shows a side view of the audio recording device 200. The audio recording device 200 comprises a noise reduction filter 201 202 220 a first sound tube 204 and a microphone 206. The noise reduction filter 201 202 220 comprises a first filter element 201 made of a first material configured to filter out wind noise, a second filter element 202 made of a second material configured to be impermeable to wind, and a third filter element 220 made of a material configured to filter out wind noise. The first filter element and the third filter element 201 220 may both be made of the same material. The first filter 201 and the third filter element 220 may both be made of air, or they may both be made of a porous material. The first filter element 201 comprises a sound receiving surface 203. In this embodiment the first filter element 201 and the second filter element 202 have a rectangular shape in a plane spanned by a first axis 212 and a second axis 215, where the first axis 212 is perpendicular to the central axis 205 and the second axis 215 is perpendicular to both the first axis 212 and the central axis 205. The third filter element 220 interfaces with the sound receiving surface of the first filter element 203 and an outer surface 213 of the second filter element 202. This arrangement may provide a more effective filter.

Fig. 3a-b show an audio recording device comprising a noise reduction filter according to an embodiment of the present invention. Fig. 3a shows a top view of the audio recording device 300 and Fig. 3b shows a side view of the audio recording device 300. The audio recording device 300 comprises a noise reduction filter 301 302 a first sound tube 304 and a microphone 306. The noise reduction filter 301 302 comprises a first filter element 301 made of a first material configured to filter out wind noise, and a second filter element 302 made of a second material configured to be impermeable to wind. The first filter element 301 comprises a sound receiving surface 303. In this

embodiment the second filter element 302 is protruding from the first filter element 301 .

Fig. 4 shows a hearing aid system according to an embodiment of the present invention. The hearing aid system 400 comprises an audio recording device 401 and a hearing aid device 402. The audio recording device 401 comprises a noise reduction filter 403 a first sound tube 404 and a microphone 405. The audio recording device 401 is configured to record an audio signal and transmit the recorded audio signal to the hearing aid device 402.

Fig. 5a-d show side views of audio recording devices according to an embodiment of the present invention having different sound receiving surfaces according to embodiments of the present invention.

Fig. 5a shows an audio recording device 501 502 according to an embodiment of the present invention, having a sound receiving surface 503 comprising protruding features.

Fig. 5b shows an audio recording device 501 502 according to an embodiment of the present invention, having a concave sound receiving surface 503.

Fig. 5c shows an audio recording device 501 502 according to an embodiment of the present invention, having a convex sound receiving surface 503.

Fig. 5d shows an audio recording device 501 502 according to an embodiment of the present invention, having a jagged sound receiving surface 503.

Fig. 6a-b show an audio recording device comprising two microphones according to an embodiment of the present invention. Fig. 6a shows a side view and Fig. 6b shows a top view. The audio recording device 600 comprises a first microphone 615, a second microphone 616, a first sound tube 613, a second sound tube 614, a noise reduction filter 601 602 603 604, a battery 618 and a casing 617. The first sound tube 613 has a first microphone inlet 611 positioned at a first end configured to capture audio and the first microphone 615 is positioned at a second end of the first sound tube 613. The second sound tube 614 have a second microphone inlet 612 positioned at a first end configured to capture audio and the second microphone 616 is positioned at a second end of the second sound tube 614. The first microphone inlet 611 has a central axis 619 and the second microphone inlet 612 has a central axis 620. The noise reduction filter comprises a first filter element 601 , a second filter element 603, a third filter element 604 and a fourth filter element 602. The first filter element 601 , the third filter element 604 and the fourth filter element 602 is made of a material configured to filter out wind noise e.g. air, or a porous material, etc. The second filter element 603 is made of a material configured to be impermeable to wind. The first filter element comprises a first surface 609 positioned at the first microphone inlet 611, and the fourth filter element 602 comprises a first surface 610 positioned at the second microphone inlet 612. The second filter element is arranged to be positioned at the central axis of both the first microphone inlet 619 and the central axis of the second microphone inlet 620. This positioning prevents a direct sound wave, propagating towards the first microphone inlet 611 and the second microphone inlet 612 with an incident angle of zero relative to the central axis 619 620, from passing directly into the first filter element 601 through a second surface 607 of the first filter element or directly into the fourth filter element 602 through a second surface 608 of the fourth filter element 602, without first interacting with the second filter element 603. The first filter element 601 comprises a sound receiving surface 605 and the fourth filter element comprises a sound

receiving surface 606. The sound receiving surfaces 605 606 allows a part of the direct sound wave to directly propagate into the first filter element 601 / fourth filter element 602 without first interacting with the second filter element 603. The sound receiving surfaces 605 606 have a rectangular shape, and are positioned in a common plane with an outer surface of the second filter element 603. The sound receiving surfaces 605 606 interface with the third filter element 604.The sound receiving surfaces 605 606 are positioned on opposite sides of the second filter element 603. The third filter element 604 comprises an outer surface that have a surface area that is at least 5%, 10%, 25% larger than the combined surface area of the outer surfaces of the second filter element 603, the sound receiving surface of the first filter element 605, and the sound receiving surface of the fourth filter element, 606. This may further reduce turbulence at the microphone inlets 611 612, thereby further reducing wind noise.

When two or more audio signals recorded at different spatial positions are available, various signal processing techniques may be used to improve the resulting signal quality. However, it is a requirement that the recorded audio signals are spatial distinct to a certain degree for the signal processing techniques to be effective. This is normally achieved by spacing the two or more microphones apart to achieve the desired spatial distinctiveness of the recorded signals. This will however increase the overall size and resulting complexity of the audio recording device.

In this embodiment, the sound receiving surfaces 605 606 are positioned so that the distance D2 between the centre of the sound receiving surfaces is larger than the distance between the central axes of the microphone inlets D1.

Consequently, the distance between the two microphone may be reduced as the resulting spatial distinctiveness of the recorded signals correspondingly is

increased by moving the sound receiving surfaces 605 606 further apart. This enable to overall size and complexity of the sound recording device to be decreased.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In particular, it is to be understood that other embodiments may be utilised and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Claims:

1. A noise reduction filter for a microphone 106 for reducing unwanted wind noise, wherein the noise reduction filter comprises:

- a first filter element 101 made of a first material configured to filter out wind noise, wherein said first filter element 101 comprises a first surface 112 configure to be positioned at a first microphone inlet 114 of a first sound tube 104, the first microphone inlet 114 having a central axis 105;
- a second filter element 102 made of a second material configured to be impermeable to wind;
- a third filter element 220 made of a material configured to filter out wind noise, wherein said third filter element 220 is positioned in front of the first filter element 101 and the second filter element 102 relative to the first microphone inlet 114, so that the direct sound wave propagates in said third filter element 220 before interacting with the first filter element 101 and the second filter element 102, and

wherein the second filter element 102 is arranged to be positioned at the central axis 105 so that a direct sound wave 107 travelling towards the first microphone inlet with an incidence angle of zero relative to the central axis 105, is prevented from passing through a second surface 111 of the first filter element 101 into the first filter element 101 without first interacting with second filter element 102, where the second surface 111 is arranged to be positioned at the central axis 105, and wherein the first filter element 101 further comprises at least one sound receiving surface 103 allowing a part 109 of the direct sound wave 107 to directly propagate into the first filter element 101 without first interacting with the second filter element 102.

2. A noise reduction filter according to claim 1, wherein the material of the first filter element 101 is air.

3. A noise reduction filter according to claim 1, wherein the material of the first filter element 101 is a porous material.

4. A noise reduction filter according to any of the previous claims, wherein the second filter element 102 is positioned in a recess of the first filter element 101.

5. A noise reduction filter according to any of claim 1 to 4, wherein the second filter element 102 comprises a outer surface 113 facing away from the first surface 112 of the first filter element 101, wherein the outer surface 113 of the second filter element 102 and the sound receiving surface 103 of the first filter element 101 are positioned in a common plane.

6. A noise reduction filter according to any of claims 1 to 5, wherein the noise reduction filter further comprises a fourth filter element 602 made of a third material configured to filter out wind noise, wherein said fourth filter element 602 comprises a first surface 610 configure to be positioned at a second microphone inlet 612 of a second sound tube 614 the second microphone inlet 612 having a central axis 620

wherein the noise reduction filter further is configured to prevent the direct sound wave from passing through a second surface 608 of the fourth filter element 602 into the fourth filter element 602 without first interacting with an impermeable filter element 603 being impermeable to wind, where the second surface 608 of the fourth filter element 602 is arranged to be positioned at the central axis 620 of the second microphone inlet 612, and wherein the fourth filter element 602 further comprises at least one sound receiving surface 606 allowing a part of the direct sound wave to directly propagate into the fourth filter element 602 without first interacting with the impermeable filter element 602.

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7. A noise reduction filter according to claim 6, wherein the impermeable filter element is the second filter element.

8. A noise reduction filter according to claim 6, wherein the impermeable filter element is a fifth filter element made of a material configured to be impermeable to wind.

9. A noise reduction filter according to any of claims 6 to 8, wherein the distance D2 between the sound receiving surface 605 of the first filter element 601 and the sound receiving surface 606 of the fourth filter element 602 is larger than the distance D1 between the central axis of the first microphone inlet 619 and the central axis of the second microphone inlet 620.

10. An audio recording device comprising a first microphone 106, a noise reduction filter and a first sound tube 104, wherein the first sound tube 104 has a first microphone inlet 114 at a first end configured to capture audio and the first microphone 106 is positioned at a second end of the first sound tube 104, the first microphone inlet 114 having a central axis 105, wherein the noise reduction filter comprises:

- a first filter element 101 made of a first material configured to filter out wind noise, wherein said first filter element 101 comprises a first surface 112 positioned at the first microphone inlet; and
- a second filter element 102 made of a second material configured to be impermeable to wind;

wherein the second filter element 102 is positioned at the central axis 105 so that a direct sound wave 107 travelling towards the first microphone inlet 114 with an incidence angle of zero relative to the central axis 105, is prevented from passing through a second surface 111 of the first filter element into the

first filter element 101 without first interacting with the second filter element 102, where the second surface 111 is positioned at the central axis 105, and wherein the first filter element 101 further comprises at least one sound receiving surface 103 allowing a part 109 of the direct sound wave 107 to directly propagate into the first filter element 101 without first interacting with the second filter element 102.

11. An audio recording device according to claim 10, further comprising a second microphone 616 and a second sound tube 614, wherein the second sound tube 614 has a second microphone inlet 612 at a first end configured to capture audio and the second microphone 616 is positioned at a second end of the second sound tube 614, the second microphone inlet having a central axis 620, wherein the noise reduction filter further comprises:

a fourth filter element 602 made of a third material configured to filter out wind noise, wherein said fourth filter element 602 comprises a first surface 610 configure to be positioned at the second microphone inlet 612

wherein the noise reduction filter further is configured to prevent the direct sound wave from passing through a second surface 608 of the fourth filter element 602 into the fourth filter element 602 without first interacting with a impermeable filter element 603 being impermeable to wind, where the second surface 608 of the fourth filter element 602 is arranged to be positioned at the central axis 620 of the second microphone inlet 612, and wherein the fourth filter element 602 further comprises at least one sound receiving surface 606 allowing a part of the direct sound wave to directly propagate into the fourth filter element 602 without first interacting with the impermeable filter element 603.

12. An audio recording device according to claim 11, wherein the impermeable filter element is the second filter element.

13. An audio recording device according to claim 11, wherein the impermeable filter element is a fifth filter element made of a material configured to be impermeable to wind.

14. An audio recording device according to claim 11 to 13, wherein the distance D2 between the sound receiving surface of the first filter element 605 and the sound receiving surface of the fourth filter element 606 is larger than the distance D1 between the central axis of the first microphone inlet 619 and the central axis of the second microphone inlet 620.

15. A hearing aid system comprising a hearing aid device 402 configured to be worn at the ear of a user, and an audio recording device 401, wherein the audio recording device 401 comprises a microphone 106, a noise reduction filter and a first sound tube 104, wherein the first sound tube 104 have a first microphone inlet 114 at a first end configured to capture audio and the microphone 106 is positioned at a second end of the first sound tube 104, the first microphone inlet 114 having a central axis 105, wherein the noise reduction filter comprises:

- a first filter element 101 made of a first material configured to filter out wind noise, wherein said first filter element 101 comprises a first surface 112 positioned at the first microphone inlet; and
- a second filter element 102 made of a second material configured to be impermeable to wind;

wherein the second filter element 102 is positioned at the central axis 105 so that a direct sound wave 107 travelling towards the first microphone inlet 114 with an incidence angle of zero relative to the central axis 105, is prevented from passing through a second surface 111 of the first filter element into the first filter element 101 without first interacting with the second filter element

102, where the second surface 111 is positioned at the central axis 105, and wherein the first filter element 101 further comprises at least one sound receiving surface 103 allowing a part 109 of the direct sound wave 107 to directly propagate into the first filter element 101 without first interacting with the second filter element 102,

wherein the audio recording device 401 is configured to record an audio signal and transmit the recorded audio signal to the hearing aid device 402.

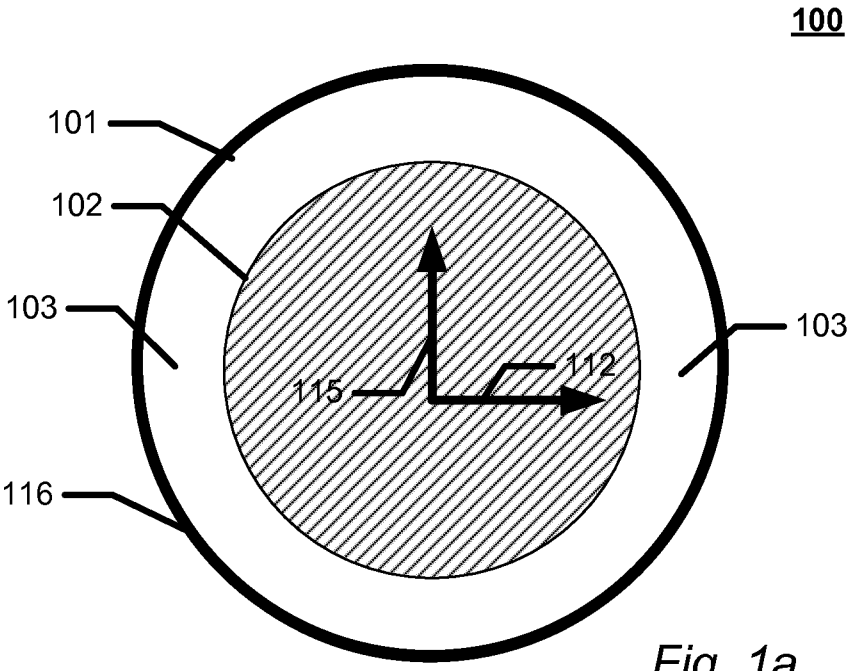

Fig. 1a

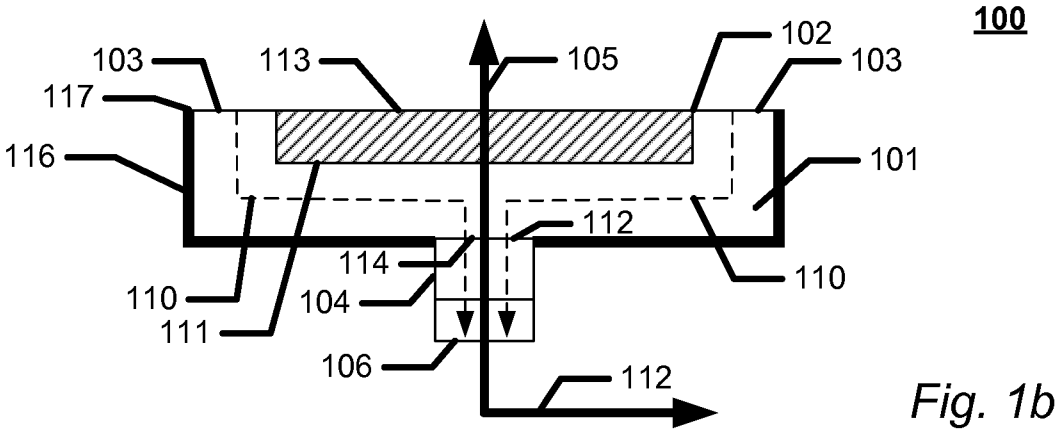

Fig. 1b

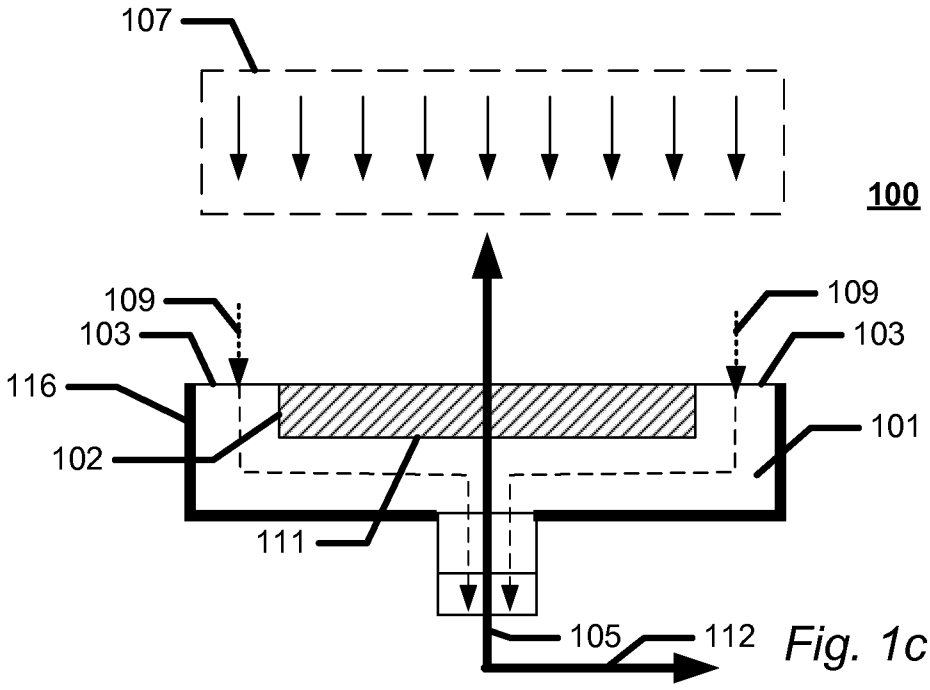

Fig. 1c

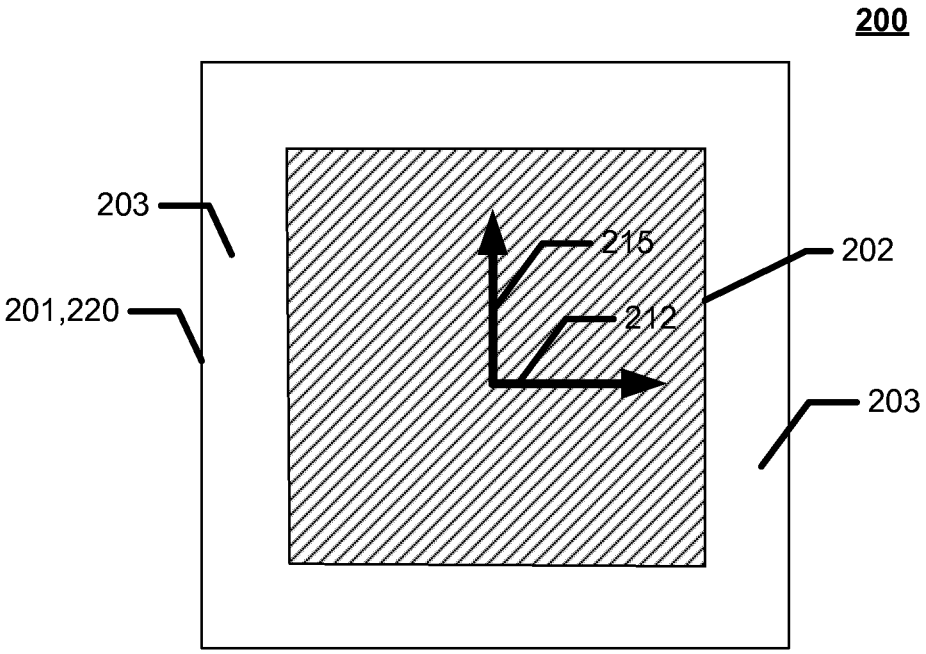
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Fig. 2a

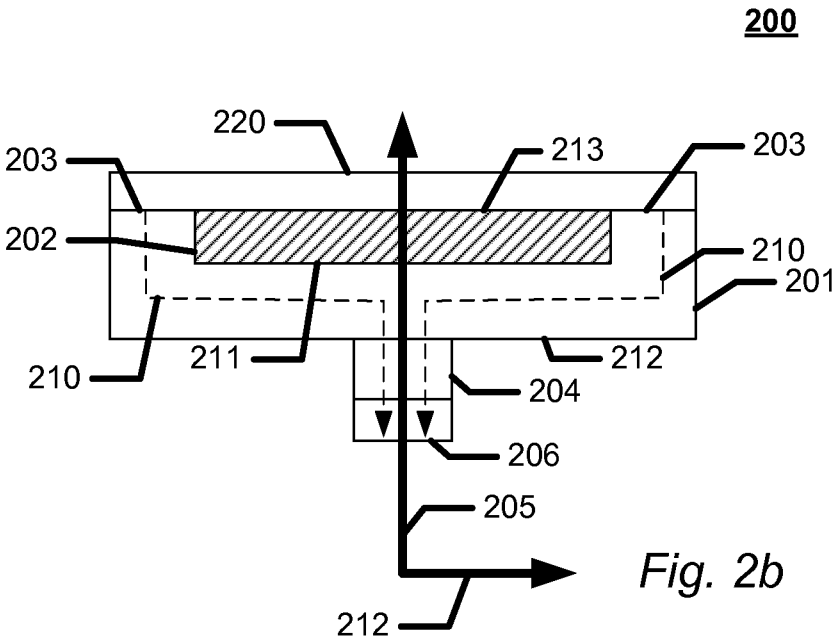
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Fig. 2b

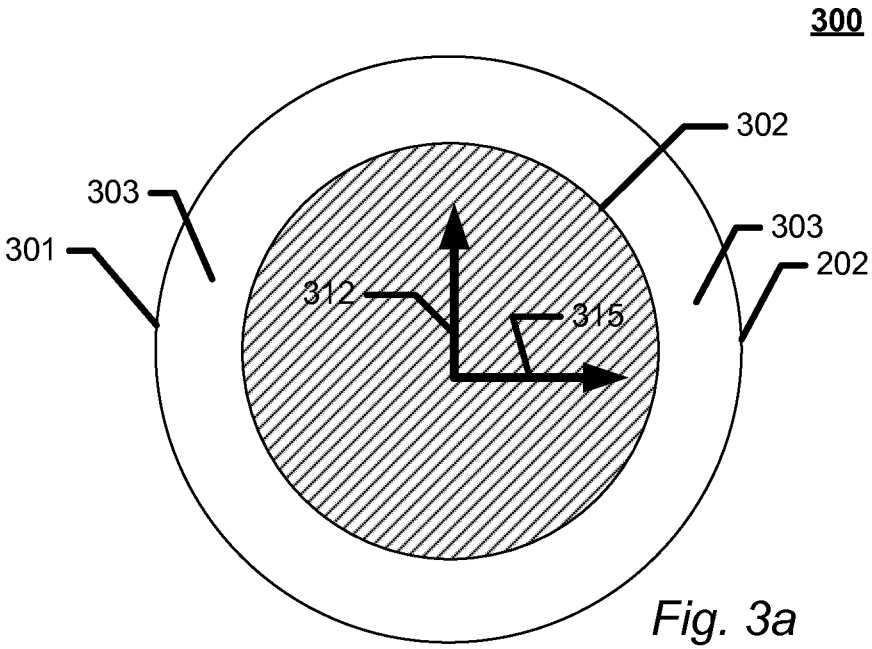

Fig. 3a

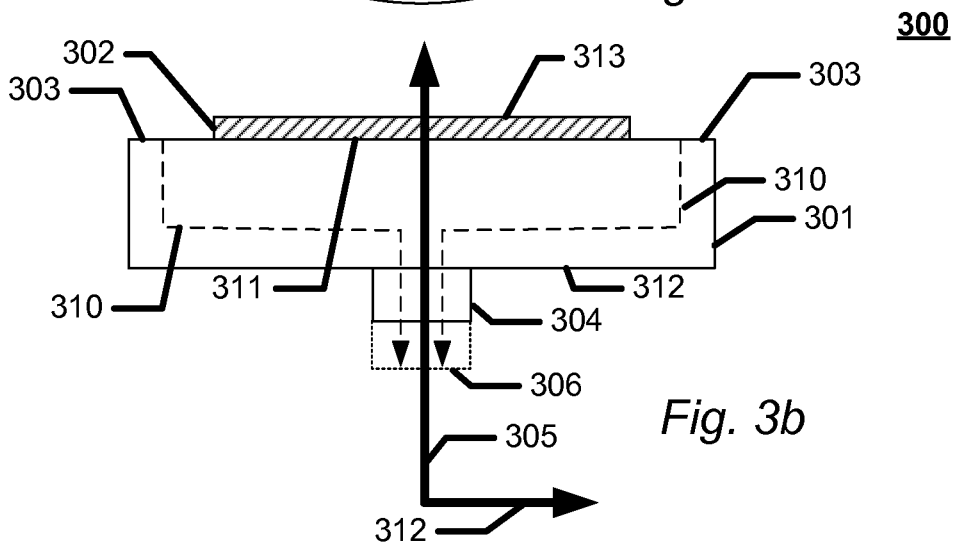

Fig. 3b

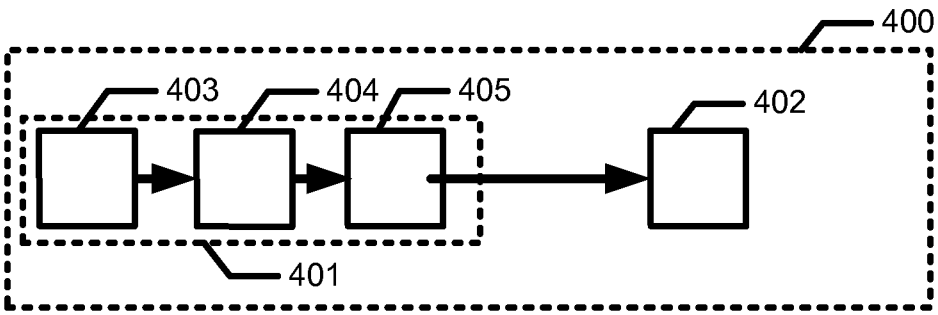

Fig. 4

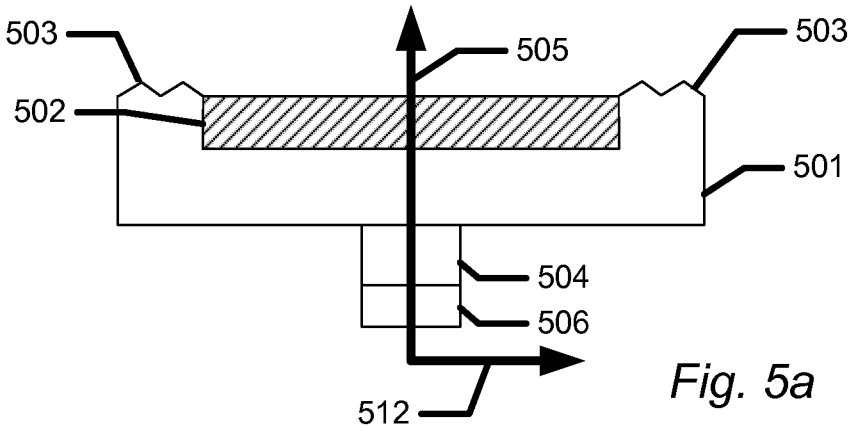

Fig. 5a

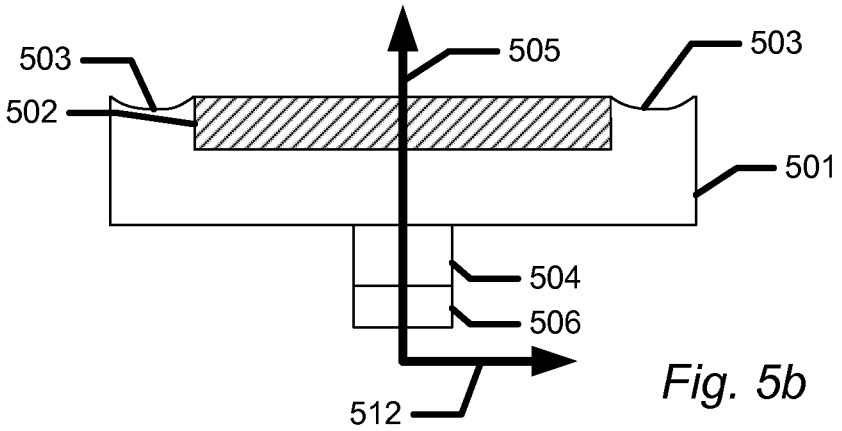

Fig. 5b

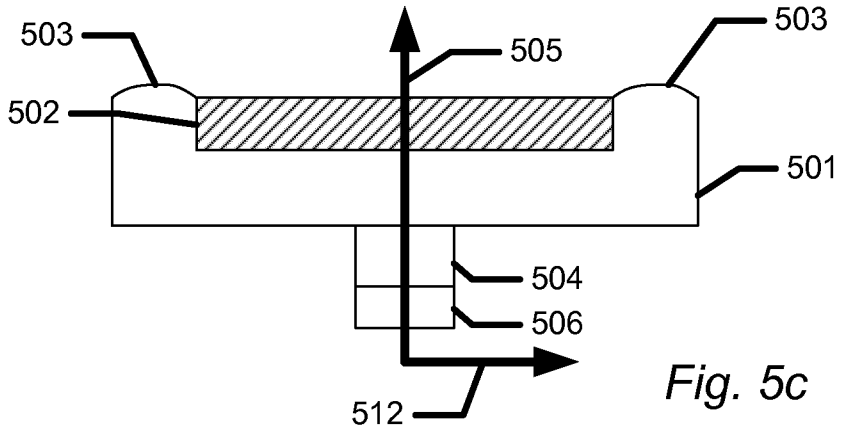

Fig. 5c

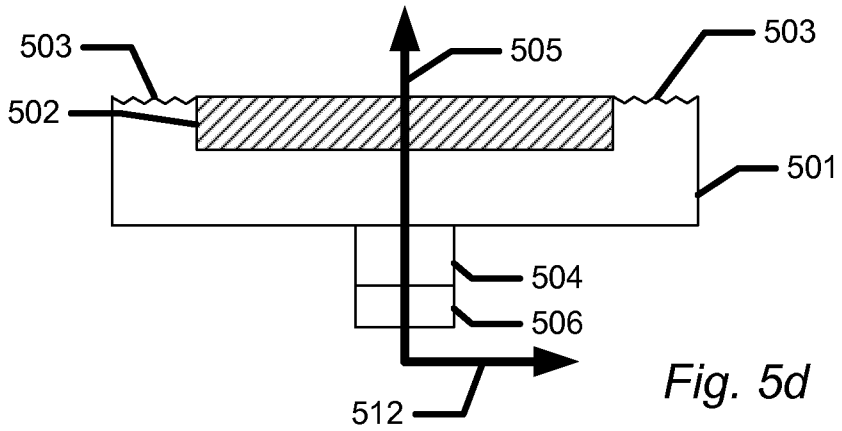

Fig. 5d

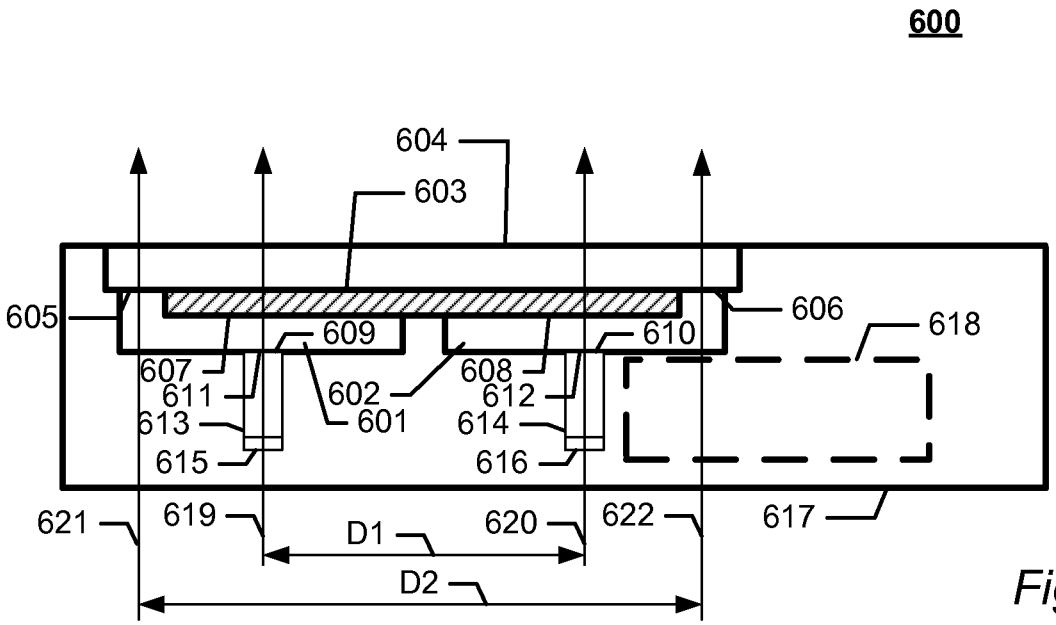
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Fig. 6a

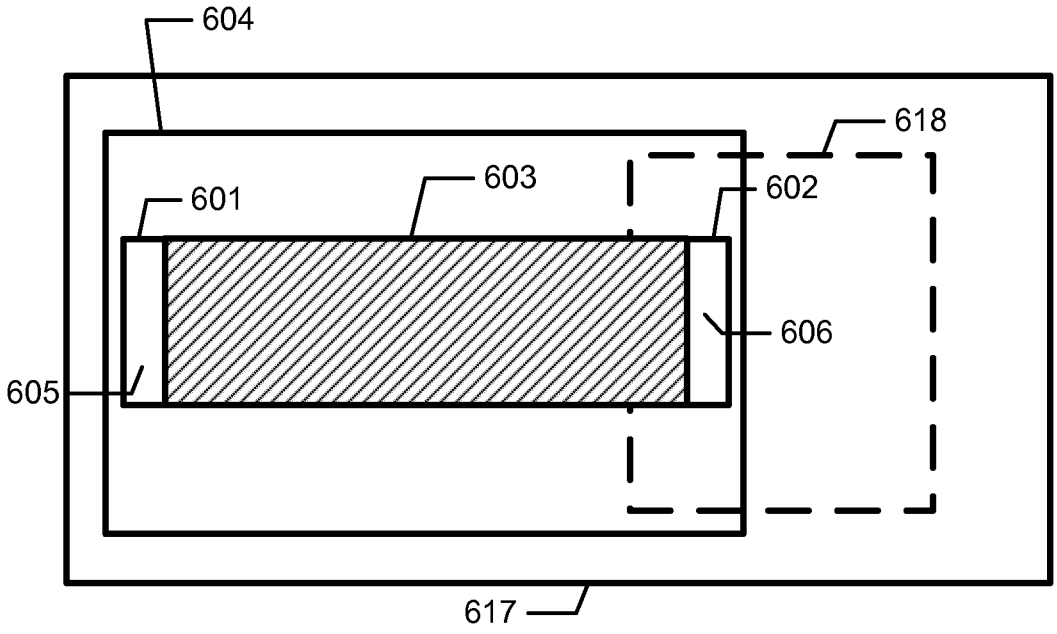
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Fig. 6b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/066998

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04R1/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04R

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal , COMPENDEX, INSPEC, PAJ, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 263 484 A (HISATSUNE YOSHINOBU ET AL) 21 April 1981 (1981-04-21)	10, 13, 15
A	column 2, line 31 - column 3, line 12 figures 1,2	1-9, 11, 12, 14
A	US 3 154 171 A (KNUTSON OLIVER J ET AL) 27 October 1964 (1964-10-27) column 1, line 66 - column 3, line 6 figure 4	1-15
A	EP 1 175 124 A2 (AKG ACOUSTICS GMBH [AT]) 23 January 2002 (2002-01-23) column 3, line 17 - column 4, line 50 figures 1,2	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2012	11/12/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Meiser, Jurgen

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/066998

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