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(54) **Title:** AN ACOUSTIC STRUCTURE USING A PASSIVE DIAPHRAGM UNIT

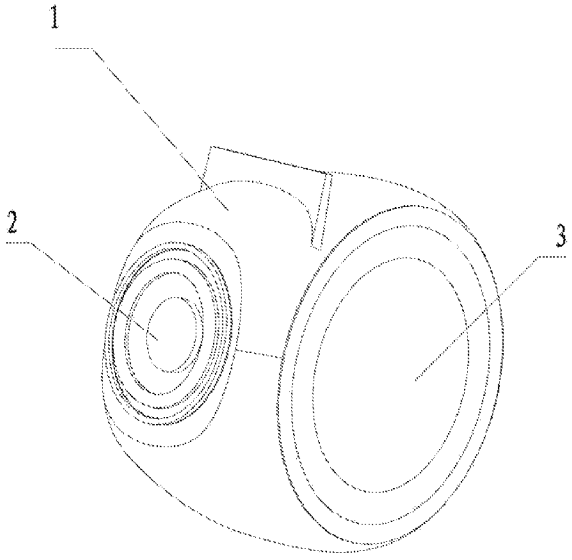

Fig. 1

(57) **Abstract:** The present invention provides an acoustic structure with a passive diaphragm unit comprising: a housing, a speaker unit and at least one passive diaphragm unit. The housing as mentioned above has a closely connected aperture with the speaker unit and the passive diaphragm unit, the passive diaphragm unit as stated above and the cavity inside the housing form an air spring, whose resonant frequency is lower than the resonant frequency of the loudspeaker unit. The cavity in the mentioned housing constitutes the cavity of the speaker unit and the passive diaphragm unit. The ratio of the effective resonant area of the passive diaphragm unit to the effective cone area of the loudspeaker unit is greater than or equal to 3. The present invention provides an acoustic structure using a passive diaphragm unit, such that the passive diaphragm unit forms an independent low-frequency radiation source, thereby expanding the low-frequency response range of the loudspeaker unit through the passive diaphragm unit so that the sensitivity of the entire acoustic

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Declarations under Rule 4.17:

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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— *with international search report (Art. 21(3))*

Description

Title of Invention: AN ACOUSTIC STRUCTURE USING A PASSIVE DIAPHRAGM UNIT

Technical Field

[1] This invention relates to an acoustic structure, and more particularly to an acoustic structure using a passive diaphragm unit.

Technical Background

[2] In the traditional acoustic structure design, the inversion tube or the passive diaphragm unit is often used to reflect the low-frequency radiation wave on the back of the speaker unit and to superimpose the positive phase wave, thereby improving the low-frequency effect. It can be seen that in this structure, both the inverting tube and the passive diaphragm unit are intended to reflect the low-frequency radiation generated by the loudspeaker unit itself. Therefore, the frequency of the emitted low-frequency radiation is determined by the speaker unit. If sensitivity of the speaker unit itself in the low-frequency side is relatively poor, then the overall low-frequency effect of the speaker will not be excellent.

[3] Therefore, the size of the speaker unit must be enlarged in order to improve the overall low-frequency effect of the conventionally designed speaker. The housing volume of the speaker must be increased correspondingly to match size of the speaker unit. Therefore, the improvement of the low-frequency effect leads to the increase of the speaker volume and the increase of the mass. With the modern home simplicity and the need for lightweight mobile devices, the traditional large-volume and heavy speaker is no longer suitable for use in modern living rooms and mobile devices.

The Contents of the Invention

[4] The main technical problem to be solved by the present invention is to provide an acoustic structure using a passive diaphragm unit, such that the passive diaphragm unit forms an independent low-frequency radiation source, thereby expanding the low-frequency response range of the loudspeaker unit through the passive diaphragm unit so that the sensitivity of the entire acoustic structure in the low-frequency range can be greatly enhanced.

[5] In order to solve the above-mentioned technical problems, the present invention provides an acoustic structure using a passive diaphragm unit comprising a housing, a speaker unit and at least one passive diaphragm unit.

[6] The housing as mentioned above has a closely connected aperture with the speaker unit and the passive diaphragm unit, the passive diaphragm unit as stated above and the cavity inside the housing form an air spring, whose resonant frequency is lower than

the resonant frequency of the loudspeaker unit. The air spring is driven by the speaker unit to resonate at its resonant frequency.

[7] The effective vibration area of the passive diaphragm unit is more than 30% of the surface area of the housing; the surface area of the above-mentioned housing refers to the spherical surface area after the box is made equivalent to a sphere.

[8] In a relatively good application: the effective vibration area of the mentioned passive diaphragm unit accounts for 35% of the surface area of the housing.

[9] In a relatively good application: the effective vibration area of the mentioned passive diaphragm unit accounts for 40% of the surface area of the housing.

[10] In a relatively good application: the ratio of the effective resonant area of at least one passive diaphragm unit to the effective cone area of the loudspeaker unit is greater than or equal to 3.

[11] In a relatively good application: the ratio of the effective resonant areas of at least one passive diaphragm unit to the effective cone surface area of the loudspeaker unit is greater than or equal to 4.

[12] In a relatively good application: the ratio of the effective resonant areas of at least one passive diaphragm unit to the effective cone surface area of the loudspeaker unit is greater than or equal to 6, but smaller or equal to 8.

[13] In a relatively good application: the mentioned housing is a polygonal body, the in between surfaces on the side facing the cavity mentioned above has a rod.

[14] In a relatively good application: the projection of the rod mentioned above in the vertical direction is a circular arc shape. the projection of the rod mentioned above in the vertical direction is a circular arc shape.

[15] In a relatively good application: it further comprises a fairing. The fairing as mentioned above is arranged within the resonator and is arranged in a coaxial relation with the stated passive diaphragm unit. There is a through-hole connected to the passive diaphragm unit at the axis of the indicated fairing, the remaining parts separate the passive diaphragm unit from the mentioned resonator.

[16] In a relatively good application: it further comprises a fairing. The mentioned fairing is connected one-to-one to the stated passive diaphragm unit and covers the surface of the passive diaphragm unit, and the fairing is provided with an infusion hole connecting the resonator and the passive diaphragm unit at a symmetrical position.

[17] Compared with the state-of-the-art, the technical proposal of this invention has the following beneficial effects:

[18] 1. This invention provides an acoustic structure using a passive diaphragm unit that breaks through the traditional idea, in which the passive diaphragm unit has replaced the inverted phase structure. Through this bold theory, in which the resonant frequency of the passive diaphragm unit is independent of the volume of the speaker housing, the

effective resonant area of the passive diaphragm unit and the mass of the passive diaphragm unit are increased, making the resonant point of the air spring formed by the passive diaphragm unit and housing lower than the resonant point of the loudspeaker unit. The air spring is driven by the speaker unit to resonate at its resonant frequency, thereby broadening the frequency response range of the loudspeaker, so that the response sensitivity of the entire acoustic structure at the low-frequency side is greatly enhanced. In addition, since the sensitivity of the low-frequency side is strengthened by the passive diaphragm unit, it is only necessary for the speaker unit to have a good intermediate-frequency and high- frequency sensitivity, and a force capable of driving the air spring to resonate so that the speaker unit can be relatively small. The cost is relatively low, the volume of the housing can also be decreased accordingly.

[19] 2. The present invention provides an acoustic structure using a passive diaphragm unit, and since the resonant area of the passive diaphragm unit is large, it is likely to cause resonance unevenness. Given this drawback, a fairing is placed coaxially with the passive diaphragm unit. The periphery of the fairing divides the passive diaphragm unit from the resonator, and there is a through-hole at the axis of the fairing. The airflow inside the resonator after being rectified by the through-hole drives the resonance of the passive diaphragm unit. Because the fairing and the diaphragm unit are coaxially placed, the air pressure and distribution of the airflow out of the fairing is more uniform for the passive diaphragm unit, which can effectively avoid the uneven vibration situation of the passive diaphragm unit.

[20] 3. This invention provides an acoustic structure with a passive diaphragm unit, and since the resonant area of the passive diaphragm unit is relatively large, it is possible to produce a good bass without requiring a large vibration amplitude of the passive diaphragm unit. As such, it is not necessary to make the thickness of the resonator very thick. Therefore it is very suitable for the applications in the tablets, televisions, mobile phones and other products, on which the thickness of the product is critical.

[21] 4. This invention provides an acoustic structure with a passive diaphragm unit, as the passive diaphragm unit is used to expand the low-frequency response range of the loudspeaker unit, the loudspeaker unit only needs to generate the driving force to drive the air spring for resonance, and therefore, it is not necessary to use a large-size loudspeaker unit. It is easier to be designed as a passive speaker, which further enhance the sound quality of the speaker. Besides, the thickness of the passive speaker can be further reduced.

[22] 5. This invention provides an acoustic structure with a passive diaphragm unit, and the housing has a polygonal shape. There is a rod between the sides of the housing, through which the positions of the opposite sides are fixed. As a result, the capacity of the resonator is fixed. Throughout the process of using the speaker, because the

capacity of the housing is constant, there is no loss of sound, and sound staining is also greatly kept under control.

Description of the Attached Figures:

[23] Figure 1 is an external perspective view of the chosen application 1 of the this invention;

[24] Figure 2 is a schematic cross-sectional view of the chosen application 1 of the this invention;

[25] Figure 3 is a frequency response curve of a conventional passive diaphragm speaker compared to the chosen application 1 of the this invention;

[26] Figure 4 is an external perspective view of the chosen application 3 of the this invention;

[27] Figure 5 is a schematic cross-sectional view of the chosen application 3 of the this invention.

Concrete Application Methods

[28] The invention will be further described below with reference to the attached figures and concrete application methods.

[29] Embodiment 1

[30] Referring to Figures 1-2, an acoustic structure with a passive diaphragm unit includes a housing 1, a speaker unit 2 and two passive diaphragm units 3, wherein the size of the passive diaphragm unit 3 is two 2-inch of the passive diaphragm unit. The size of the speaker unit is 1.5 inch. The ratio of the effective resonant surface area of the two passive diaphragm units 3 to the effective cone surface area of the loudspeaker unit is about 3.5.

[31] The housing 1, as mentioned earlier, has a closely connected aperture with the mentioned speaker unit 2 and the passive diaphragm unit 3. In the present application, the housing 1 is cylindrical, and the speaker unit 2 is mounted on the bottom surface of the housing 1, and two passive diaphragm units 3 are located at the side of the housing 1.

[32] The mentioned passive diaphragm unit 3 and the cavity 11 inside the housing form an air spring, whose resonant frequency is lower than the resonant frequency of the speaker unit 2. In order to reduce the resonant frequency of the air spring below the resonant frequency of the speaker unit 2, it is also possible to increase the mass of the passive diaphragm unit while enhancing the surface area of the passive diaphragm unit 3, so that the resonant frequency can be further decreased.

[33] Since the speaker unit 2 only needs to generate a driving force sufficient to push the air spring for resonance, the driving force required for the speaker unit 2 is relatively low, and it is not necessary to use a large loudspeaker unit. For the size of the passive

diaphragm unit 3, the size of the speaker unit 2 is minuscule. Most of the surface area of the entire housing is occupied by the passive diaphragm unit. In this application, the surface area of the passive diaphragm unit 3 accounts for 30% of the surface area of the housing. If a larger passive diaphragm unit 3 is selected, this ratio will be further increased to, for example, 35%, 40%, 45%, 60% and etc. This is entirely different from the design of the traditional speaker, where speaker unit 2 occupies the most surface area of the housing.

[34] The light-colored curve in Figure 3 is the frequency response curve of the speaker with a conventional passive diaphragm. The ratio of the effective resonant areas of the two passive diaphragm units 3 to the effective cone surface area of the loudspeaker unit is less than 2. The dark-coloured curve is the frequency response curve of the speaker in the present application.

[35] As observed from the above Figure, at nearly 300Hz, the frequency response curve of the two speakers intersect. From this point to the low-frequency direction, the sensitivity of the traditional passive diaphragm speaker decreases very fast, at 90Hz, the sensitivity difference between the two speakers reaches a maximum of about 7db. This is an enormous difference. In addition, the traditional passive diaphragm speaker shows another turning point at about 75Hz, where the sensitivity decreases rapidly. In other words, when the frequency is lower than 70Hz, the sensitivity of traditional passive diaphragm speaker is very low, and the bass effect is very limited. The speaker of this application reaches the turning point when it reaches 60 Hz, and it is undoubtedly better in the low-frequency range.

[36] The resonant frequency of the air spring can be further reduced by further increasing the weight of the passive diaphragm unit 3, as the size of the passive diaphragm unit 3 is further increased so that a better low-frequency effect can be achieved. This application will not be further elaborated here. Only corresponding adjustments are required based on the above-described structure for further implementation.

[37] The fairing 4 is also included in this application. The fairing 4 is located inside the cavity 11 and is coaxially arranged with the passive diaphragm unit 3. There is a through-hole 41 at the axis of the mentioned fairing 4 connecting to the passive diaphragm unit 3, and the remaining part isolates the passive diaphragm unit 3 from the mentioned cavity 11.

[38] Since the resonant surface area of the passive diaphragm unit 3 is large, it is likely to cause resonance unevenness. Given this drawback, a fairing 4 located coaxially with the passive diaphragm unit 3 is designed. The periphery of the fairing 4 separates the passive diaphragm unit 3 from the cavity 11, and the airflow inside the cavity 11 can only be rectified by the through-hole 41 to drive the passive diaphragm unit 3 to resonate. As the fairing 4 and the passive diaphragm unit 3 are coaxially placed, the air

pressure and distribution of the airflow from the through-hole 41of the fairing 4 is relatively uniform for the passive diaphragm unit 3, which effectively preventing the vibration of the passive diaphragm unit 3 from becoming uneven.

[39] In addition, since the frequency response in the low-frequency range of the speaker unit 2 is extended by the use of the passive diaphragm unit 3, it is not necessary to use a large-size loudspeaker unit 2. It is easier to be designed as a passive speaker, and the sound quality of the speaker can be further enhanced. The thickness of the passive speaker can be further reduced.

[40] In this application, the ratio of the effective resonant areas of the two passive diaphragm units 3 to the effective cone surface area of the loudspeaker unit is about 3.5. In fact, the ratio can be further increased to such as 4, 6, 8 and etc. With the increase of this ratio, the effect of improving the low frequency becomes more evident.

[41] Embodiment 2

[42] This application differs from the first application in that in the present application, the housing is a polygonal body, and between surfaces on the side facing the cavity mentioned above there is a rod. The projection of the rod mentioned above in the vertical direction is a circular arc shape. Through the rod the positions of the opposite sides are fixed. As a result, the capacity of the resonator is fixed. Throughout the process of using the speaker, because the capacity of the housing is constant, there is no loss of sound, and sound staining is also greatly kept under control.

[43] Embodiment 3

[44] Referring to Figures 4-5, this application differs from application 1 in that an ultra-thin speaker is designed in the present application. Since the resonant area of the passive diaphragm unit 3 is relatively large, it is possible to produce a good bass without generating a large vibration amplitude by the passive diaphragm unit 3, and it is not necessary to make the thickness of the cavity 11 very thick. The thickness of the housing can be made as small as possible, making it ideal for products such as tablets, televisions, and mobile phones, for which the thickness is critical.

[45] Embodiment 4

[46] The present application is different from application 3 in that in this application, the fairing covers the surface of the mentioned passive diaphragm unit. The fairing is designed with an infusion hole connecting the resonator and the passive diaphragm unit at a symmetrical position. The fairing in application 3 needs a particular distance from the passive diaphragm unit so as to ensure that there is sufficient space for the distribution of airflow after passing the through-hole, thereby driving the passive diaphragm unit to vibrate. As a result, this design will occupy part of the resonator thickness, and it is disadvantageous for decreasing the thickness of the housing. With the above structure, the airflow from many infusion holes drives the symmetrical

positions of the passive diaphragm unit simultaneously, to ensure that the force applied by the air pressure to the passive diaphragm unit is uniform, and therefore it is not necessary to separate the fairing far from the passive diaphragm unit. As a result, the size of the housing can be made thinner.

[47] The descriptions above show the intended application methods of this invention, but the scope of the invention is not limited thereto, and any skilled technical personnel in this technological area will be able to make a change or replacement within the disclosed technological scope of this invention. Such changes are to be covered within the protective scope of the present invention. Accordingly, the scope of protection of the present invention should be determined by the framework of the patent claims.

Claims

[Claim 1] The characteristics of an acoustic structure with a passive diaphragm unit include a housing, a speaker unit and at least one passive diaphragm unit.
The housing as mentioned above has a closely connected aperture with the speaker unit and the passive diaphragm unit, the passive diaphragm unit as stated above and the cavity inside the housing form an air spring, whose resonant frequency is lower than the resonant frequency of the loudspeaker unit. The air spring is driven by the speaker unit to resonate at its resonant frequency. The effective vibration area of the passive diaphragm unit is more than 30% of the surface area of the housing; the surface area of the above-mentioned housing refers to the spherical surface area after the box is made equivalent to a sphere.

[Claim 2] An acoustic structure using a passive diaphragm unit according to Patent Claim 1 is characterised in that the effective vibration area of the mentioned passive diaphragm unit accounts for 35% of the surface area of the housing.

[Claim 3] An acoustic structure using a passive diaphragm unit according to Patent Claim 1 is characterised in that the effective vibration area of the mentioned passive diaphragm unit accounts for 40% of the surface area of the housing.

[Claim 4] An acoustic structure using a passive diaphragm unit according to Patent Claim 1 is characterised in that the ratio of the effective resonant areas of at least one passive diaphragm unit to the effective cone surface area of the loudspeaker unit is greater than or equal to 3.

[Claim 5] An acoustic structure using a passive diaphragm unit according to Patent Claim 4 is characterised in that the ratio of the effective resonant areas of at least one passive diaphragm unit to the effective cone surface area of the loudspeaker unit is greater than or equal to 4.

[Claim 6] An acoustic structure using a passive diaphragm unit according to Patent Claim 4 is characterised in that the ratio of the effective resonant areas of at least one passive diaphragm unit to the effective cone surface area of the loudspeaker unit is greater than or equal to 6, but smaller or equal to 8.

[Claim 7] An acoustic structure using a passive diaphragm unit according to Patent Claim 1 is characterised in that the housing is a polygonal body, the in between surfaces on the side facing the cavity mentioned above

has a rod.

[Claim 8] .An acoustic structure using a passive diaphragm unit according to Patent Claim 7 is characterised in that the projection of the rod mentioned above in the vertical direction is a circular arc shape.

[Claim 9] An acoustic structure using a passive diaphragm unit according to any of the Patent Claims 1 to 8 is characterised in that it further comprises a fairing. The fairing as mentioned above is arranged within the resonator and is arranged in a coaxial relation with the stated passive diaphragm unit. There is a through-hole connected to the passive diaphragm unit at the axis of the indicated fairing, the remaining parts separate the passive diaphragm unit from the mentioned resonator.

[Claim 10] An acoustic structure using a passive diaphragm unit according to any of the Patent Claims 1 to 8 is characterised in that it further comprises a fairing. The mentioned fairing is connected one-to-one to the stated passive diaphragm unit and covers the surface of the passive diaphragm unit, and the fairing is provided with an infusion hole connecting the resonator and the passive diaphragm unit at a symmetrical position.

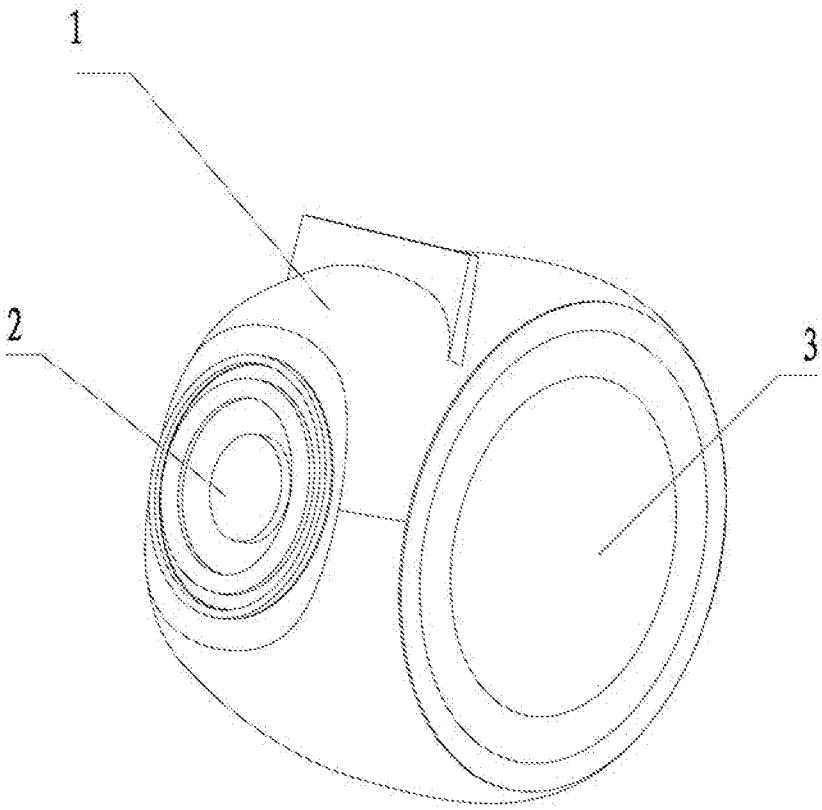

Fig. 1

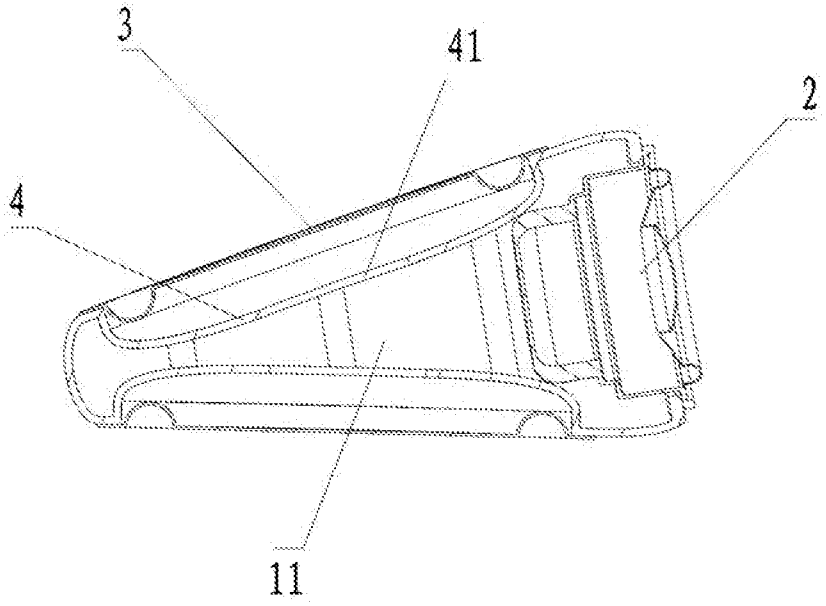

Fig. 2

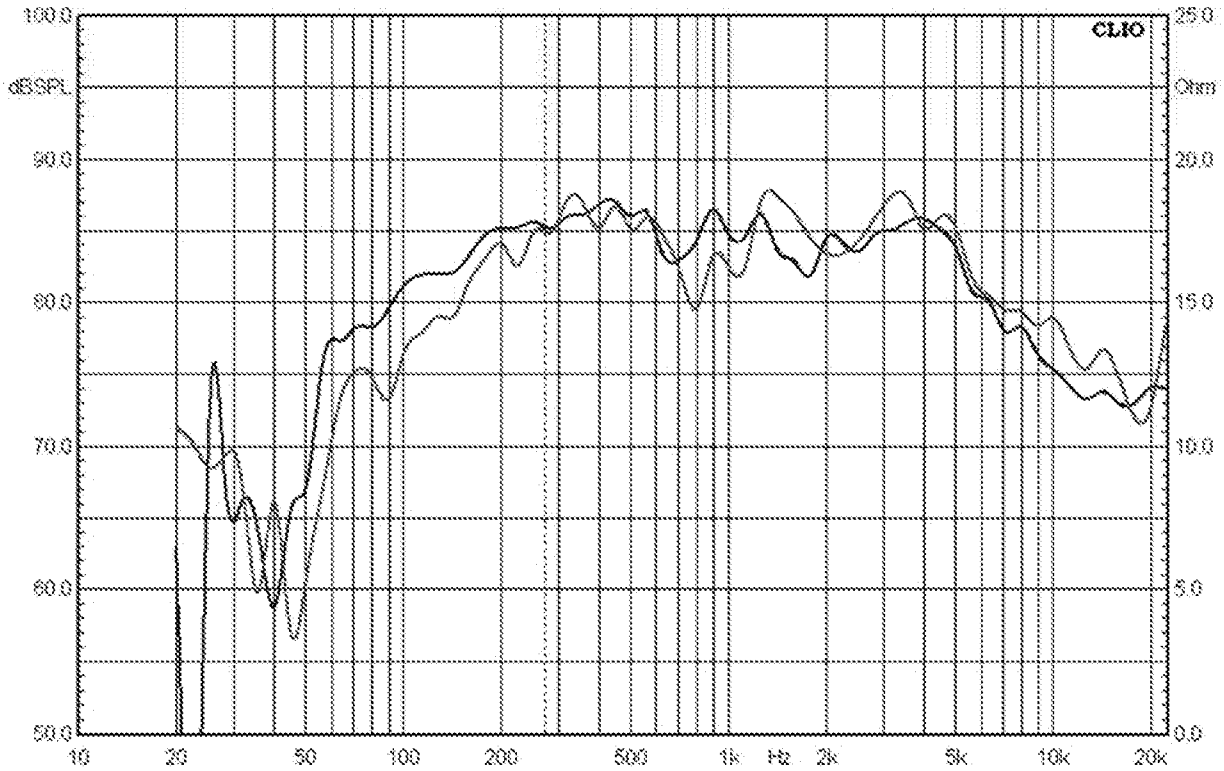
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Fig. 3

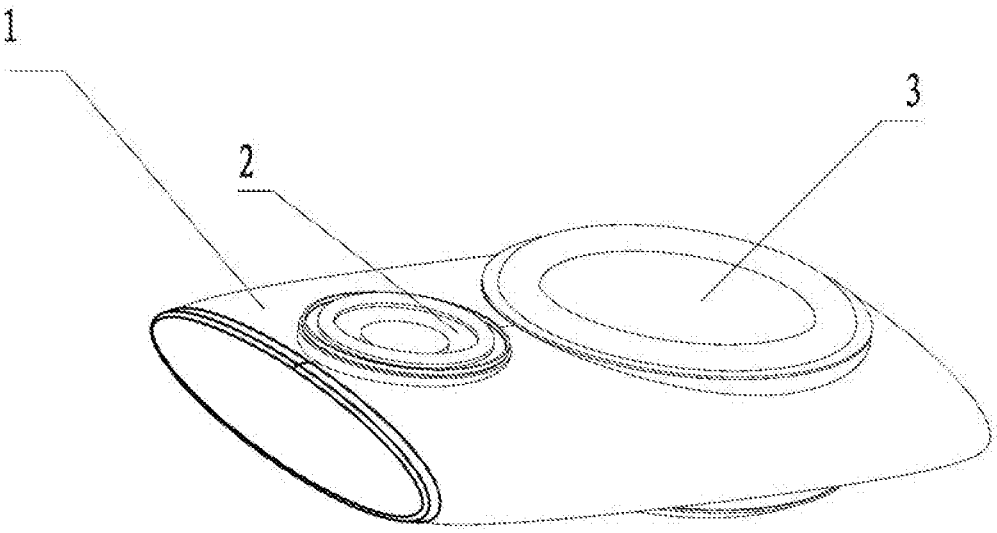

Fig. 4

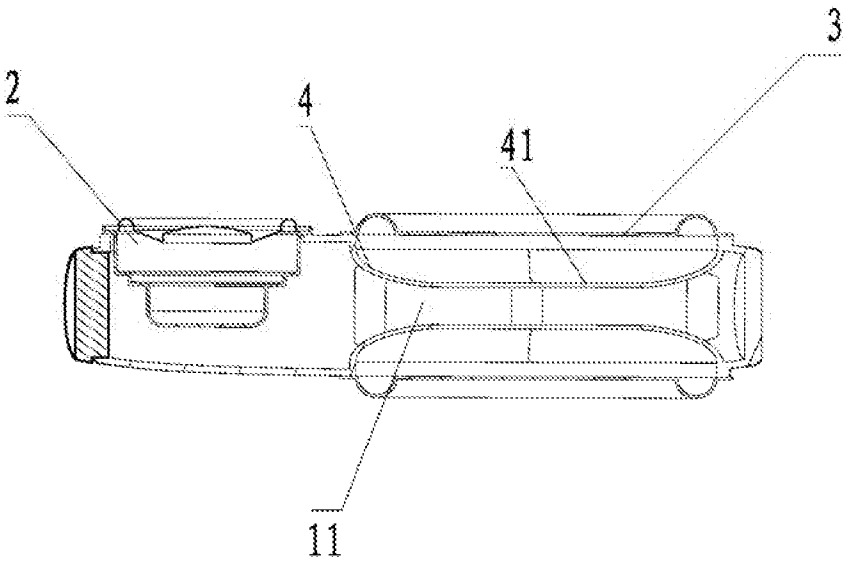

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2017/052901

A. CLASSIFICATION OF SUBJECT MATTER

H04R 7/02(2006.01)i, H04R 1/02(2006.01)i

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 7/02; H04R 1/02; H04R 9/02; H04R 1/00; G10K 13/00; H04R 1/24; H04R 9/06; H05K 5/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: acoustic structure, passive diaphragm, housing, speaker, cavity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2013-100862 A2 (LI, SHIHUANG) 04 July 2013 See pages 3-5 and figure 1.	1-10
Y	US 2012-0014542 A1 (HIROSHI AKINO) 19 January 2012 See paragraphs [0016]-[0034] and figure 5.	1-10
Y	WO 2013-100863 A2 (LI, SHIHUANG) 04 July 2013 See page 4 and figures 1-2.	9-10
A	US 2004-0231911 A1 (ANDREW C. WELKER et al.) 25 November 2004 See paragraphs [0030]-[0036] and figure 1.	1-10
A	US 2011-0158459 A1 (HWANG-MIAW CHEN) 30 June 2011 See paragraph [0013] and figure 1.	1-10

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
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"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
27 July 2017 (27.07.2017)	**28 July 2017 (28.07.2017)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2017/052901

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