(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 477 629 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.05.2019 Bulletin 2019/18

(51) Int Cl.:
G10K 11/172 *(2006.01)* ***H04R 1/28*** *(2006.01)*

(21) Application number: **17199171.4**

(22) Date of filing: **30.10.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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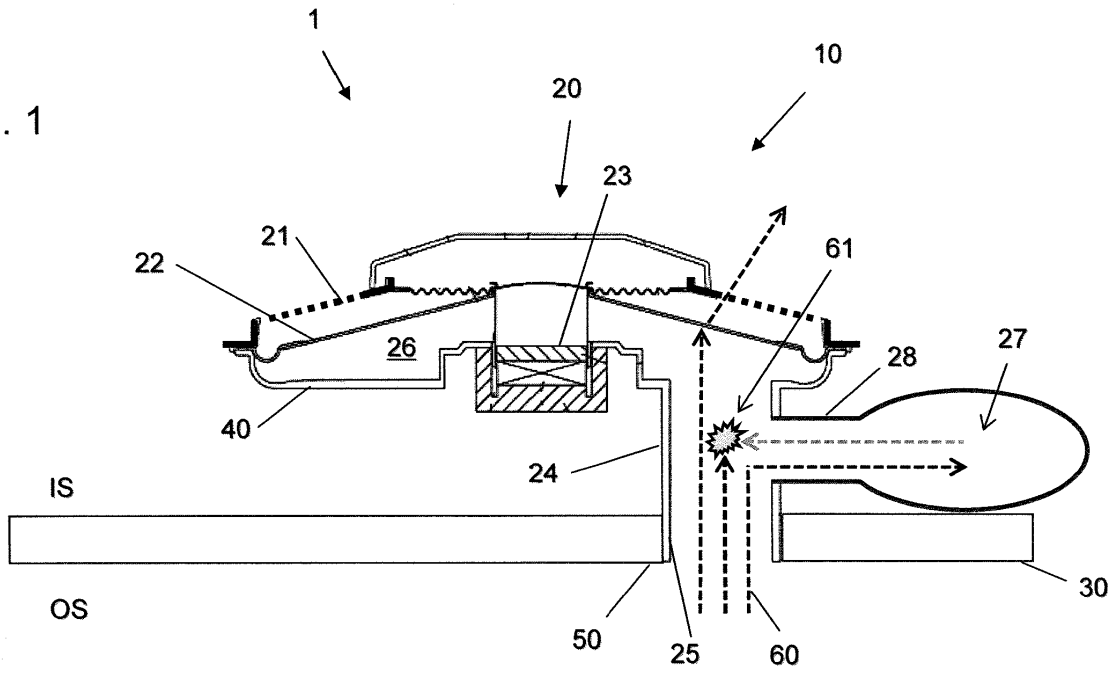
(54) VEHICLE LOUDSPEAKER SYSTEM AND VEHICLE STRUCTURE COMPRISING SUCH LOUDSPEAKER SYSTEM

(57) A vehicle loudspeaker system (10) comprises a loudspeaker device (20) comprising a driver (23) and a diaphragm (22), and which is configured to emit front sound from a first side of the diaphragm (22) to an inner space (IS) of the vehicle. The vehicle loudspeaker system (10) further comprises a communication channel (24) with a first terminal coupled to a back space (26) of the diaphragm facing a second side of the diaphragm (22) opposite the first side, and a second terminal adapted to be coupled to an opening (50) of a partition panel (30) dividing the inner space (IS) from an outside space (OS) of the vehicle for communicating back sound emitted from the second side of the diaphragm (22) to the outside space (OS) of the vehicle. A Helmholtz resonance absorber is configured to attenuate or absorb at least one noise frequency and comprises at least one cavity (27) and at least one connection (28) coupling the at least one cavity (27) with the communication channel (24).

Fig. 1



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Description

[0001] The present invention relates to a vehicle loudspeaker system comprising a loudspeaker device having a driver and a diaphragm, and which is configured to emit front sound from a first side of the diaphragm to an inner space of the vehicle, and comprises a communication channel comprising a first terminal coupled to a back space of the diaphragm facing a second side of the diaphragm opposite the first side, and a second terminal adapted to be coupled to an opening of a partition panel dividing the inner space from an outside space of the vehicle for communicating back sound emitted from the second side of the diaphragm to the outside space of the vehicle.

[0002] In the automotive field, loudspeaker devices are commonly used for providing audio output to listeners situated in vehicles like cars. A loudspeaker device typically employs a magnetic driving unit causing a diaphragm connected to a frame of the loudspeaker device to move back and forth. This vibration creates sound that is produced by the loudspeaker. The frame is commonly enclosed by a housing of the loudspeaker device. When the loudspeaker device is a subwoofer, typically an air communication duct connects an inner space of the housing to an outside space.

[0003] In known arrangements, such loudspeaker device is installed at a vehicle panel (such as part of a vehicle body) which has a separate opening to an outside space of the vehicle. The loudspeaker device comprises a housing including an air volume which is communicated at a backside of the diaphragm through an air communication duct and the opening with the outside space of the vehicle. Such arrangement enables the loudspeaker device to be placed in small locations such as in a vehicle side space adjacent to a vehicle panel or in the rear part near the trunk. For connecting the air communication duct to the outside, an opening needs to be provided in the vehicle panel, which may form part of the vehicle body. Typically, such opening is a dedicated hole in a vehicle structure, such as a vehicle panel, which may cause additional noise to enter the vehicle.

[0004] EP 2 941 011 A1 discloses such a loudspeaker system operated in a subwoofer range which is installed at a wall of a vehicle including a vehicle panel (such as a vehicle body). The loudspeaker device comprises a housing including an air volume which is communicated through an air communication duct with an outside space of the vehicle. The loudspeaker device further comprises a magnetic driving unit and a frame attached to a diaphragm. Such arrangement enables the loudspeaker device to be placed in small locations such as in a vehicle side space adjacent to a vehicle panel. For providing the air communication duct, an opening needs to be provided in the vehicle panel which may be forming part of the vehicle body. Typically, such opening is a dedicated hole in a vehicle structure, such as a vehicle panel. Such subwoofer is smaller in space, however, there is the risk that additional noise emitted from wheels of the vehicle enters into the inner space of the vehicle through the hole in the vehicle structure, which might increase noise inside the vehicle.

[0005] Fig. 6 shows a further arrangement of a loudspeaker device as known in the prior art installed at a vehicle partition panel. It particularly shows an arrangement 100 with a loudspeaker device 200 which is installed at a wall of a vehicle including a vehicle partition panel 300 (such as a vehicle body) which has an opening 500, e.g. of circular shape. The loudspeaker device 200 comprises a frame 201, a diaphragm 202 elastically supported at the frame 201, and a magnetic driving device 203 including a voice coil that provides driving power for operating the diaphragm 202. Front sound is emitted by a front side of the diaphragm 202 towards the inner space IS of the vehicle, whereas the opposing back side of the diaphragm 202 delimits a back space 206 of the diaphragm 202. A duct member forming an air communication duct 501 is connected to the back space 206 of the diaphragm 202 at a back opening of the housing. Accordingly, with vibration of the diaphragm 202 an air volume of the back space 206 is communicated through air communication duct 501 with an outside space OS of the vehicle on the other side of the vehicle partition panel 300 delimiting the outer space, whereas the side of the vehicle partition panel 300 facing the loudspeaker device 200 is delimiting an acoustic space of the vehicle. Such arrangement 100 enables the loudspeaker device 200 to be placed in locations such as in a vehicle side space adjacent to a vehicle panel. For providing the air communication duct 501, an opening 500 needs to be provided in the vehicle panel 300. Accordingly, the arrangement is susceptible to noise 60 entering through the opening 500 and through the duct 501 into the inner space IS of the vehicle. For example, such noise may be generated by wheels of the vehicle when driving.

[0006] DE 198 04 737 A1 discloses a vehicle loudspeaker which has a cone membrane located in a housing and provided with an electromagnetic drive for radiating sound. To seal the loudspeaker on the rear side, a second membrane is located in the housing in sealing fashion. The drive moves both membranes synchronously. However, from a cost perspective, providing a second membrane in the housing in sealing fashion significantly increases the manufacturing costs of such loudspeaker device.

[0007] It is an object of the present invention to provide a vehicle loudspeaker system of the type as mentioned above, which is capable of improving sound quality at a low frequency range while reducing any additional noise entering the vehicle inner space through an opening in a vehicle partition panel preferably at low cost.

[0008] The invention relates to a vehicle loudspeaker system according to the appended claims. Moreover, the invention relates to a vehicle structure and vehicle comprising such vehicle loudspeaker system.

[0009] According to a first aspect, there is disclosed a

vehicle loudspeaker system comprising a loudspeaker device which comprises a driver and a diaphragm, and which is configured to emit front sound from a first side of the diaphragm to an inner space of the vehicle, and a communication channel comprising a first terminal coupled to a back space of the diaphragm facing a second side of the diaphragm opposite the first side, and a second terminal adapted to be coupled to an opening of a partition panel dividing the inner space from an outside space of the vehicle for communicating back sound emitted from the second side of the diaphragm to the outside space of the vehicle. A Helmholtz resonance absorber is provided which is configured to attenuate or absorb at least one noise frequency and comprises at least one cavity and at least one connection coupling the at least one cavity with the communication channel.

[0010] With provision of such Helmholtz resonance absorber (also often called as Helmholtz resonator), it is possible to attenuate or absorb any additional noise entering the vehicle inner space through the opening in the partition panel and through the communication channel while not significantly increasing the dimensions and manufacturing costs of such loudspeaker device. For example, such at least one cavity and at least one connection can efficiently be provided in a housing of the loudspeaker device.

[0011] According to an embodiment, a Helmholtz resonance absorber is provided which is configured to attenuate or absorb at least one noise frequency and comprises a branched air-chamber having at least one cavity and at least one connection, such as a duct, coupled to the communication channel.

[0012] According to an embodiment, such at least one connection may be formed as a duct, such as formed by the wall thickness of an intermediate housing wall between the at least one cavity and the communication channel, or having a longer extension formed as, e.g., a tube. According to another embodiment, the at least one connection may be formed more as a gate, for example, in a thin intermediate housing wall between the at least one cavity and the communication channel. An air volume in the at least one connection may be a part of the total air volume of the Helmholtz resonator and it may work as an air spring, as set out in more detail below.

[0013] Typically, a Helmholtz resonator may be used, the principle of which is known to reduce undesirable low frequency sounds by building a resonator tuned to the problem frequency, thereby attenuating or eliminating it. Generally, a Helmholtz resonator as described herein shall be understood as encompassing, in principle, any resonance absorber arrangement appropriate to attenuate or absorb acoustic noise. Without making claim to be complete and fully accurate, it basically operates according to the principle of an oscillating mass and spring. The impinging noise energy is transferred into oscillation of the mass-spring system. Maximum attenuation or absorption typically occurs in the range of the resonance frequency, so that the resonance frequency is typically set at or near the noise frequency/frequencies to be attenuated or absorbed. The mass can be implemented, in principle, by any medium such as the air enclosed within the connection (particularly when formed as a duct), as in some embodiments of the present implementation, or any other medium such as a membrane, a foil, or a thin plate made of flexible or hard material. The air volume in the cavity behind the connection acts as an air spring. In other embodiments, the air volume in the at least one connection is a part of the total air volume of the Helmholtz resonator and it works as an air spring as well (particularly when formed as a kind of gate). There is no particular delimitation between the different embodiments in this respect. The resonance frequency/frequencies of the Helmholtz resonator can thus be implemented by setting the volume of the one or more connections (or adjusting any other medium) and the volume of the one or more cavities appropriately.

[0014] Preferably, the Helmholtz resonance absorber (or Helmholtz resonator) according to the present invention is configured to attenuate or absorb at least one noise frequency emitted from wheels of the vehicle during driving. Particularly, such noise may be generated by the rolling of the wheels on the street, so that noise to be attenuated or absorbed is preferably noise in a frequency range as generated by the rolling of the wheels. Preferably, the Helmholtz resonance absorber is configured to attenuate or absorb at least one noise frequency which is above a working range of the loudspeaker device. According to an embodiment, the working range of the loudspeaker device is in the subwoofer range, particularly in a range equal to or below approx. 100 Hz.

[0015] According to an embodiment, the loudspeaker device comprises a housing surrounding at least part of the back space of the diaphragm, wherein the Helmholtz resonance absorber is integrated with the housing. In this way, a cost effective manufacturing of the loudspeaker device with such Helmholtz resonator at a reduced cost may be achieved.

[0016] According to an embodiment, the communication channel is formed within the housing and comprises a back port that is connected to the housing. Preferably, such back port may be coupled to the opening in the partition panel, thus achieving a compact arrangement in restricted space in relation to the vehicle partition panel.

[0017] According to one embodiment, the housing comprises at least one chamber in communication with the back space of the diaphragm, and the at least one cavity is coupled to the at least one chamber through the at least one connection. To achieve a compact design, the at least one chamber and the at least one cavity may be arranged such that the at least one cavity surrounds the at least one chamber. According to an embodiment, the at least one chamber and the at least one cavity are arranged concentrically with respect to the diaphragm.

[0018] According to another embodiment, the loudspeaker device further comprises a frame supporting the

diaphragm, and the at least one cavity is attached to at least one part of the frame such that the at least one part of the frame forms at least one side wall of the at least one cavity. Thus, a loudspeaker device with such Helmholtz resonator can be manufactured at a reduced cost.

[0019] According to an embodiment, the at least one part of the frame comprises two diametrically opposed lugs, and the at least one cavity is formed to span an extension between the two diametrically opposed lugs.

[0020] According to a further embodiment, the diaphragm has a cone shape and is supported by an outer circumferential portion of a frame, wherein the concave side of the diaphragm forms the second side of the diaphragm.

[0021] Preferably, the loudspeaker device is configured such that the diaphragm vibrates at a frequency in a sub-woofer frequency range.

[0022] According to another aspect, the invention also relates to a vehicle structure comprising a partition panel dividing an inner space from an outside space of the vehicle, an opening formed in the partition panel, and a vehicle loudspeaker system according to the invention as described herein, wherein the second terminal of the communication channel is coupled to the opening of the partition panel.

[0023] According to an embodiment, the partition panel forms an outer skin portion of a vehicle body.

[0024] According to another aspect, the invention also relates to a vehicle comprising such vehicle structure according to the invention as described herein.

[0025] Aspects and embodiments of the invention will now be described with reference to the drawings, in which:

Fig. 1 shows a vehicle loudspeaker system and a vehicle structure according to an embodiment of the invention,

Fig. 2 shows parts of a vehicle loudspeaker system according to an embodiment of the invention,

Fig. 3 shows a vehicle loudspeaker system according to an embodiment of the invention as depicted in Fig. 2,

Fig. 4 shows parts of and a vehicle loudspeaker system according to a further embodiment of the invention,

Fig. 5 shows different views of a vehicle loudspeaker system according to the embodiment as depicted in Fig. 4,

Fig. 6 shows an arrangement of a loudspeaker device according to the prior art installed at a vehicle partition panel.

[0026] Fig. 1 shows a vehicle loudspeaker system and a vehicle structure according to an embodiment of the invention. A vehicle loudspeaker system 10 comprises a vehicle partition panel 30 that separates an inner space IS and an outer space OS of the vehicle. For example, the inner space IS is a passenger compartment or any other space inside the vehicle chassis. For example, the inner space IS is or has access to a vehicle interior space in which the driver and any passengers are travelling. In the present embodiment, the inner space IS is an acoustic space into which sound is radiated from a loudspeaker device 20. The outer space OS may be an exterior space of the vehicle, or, for example, a trunk or engine compartment with direct or indirect fresh air access. For example, the partition panel 30 forms an outer skin portion of the vehicle body.

[0027] The loudspeaker device 20 is fixed to the vehicle partition panel 30 and comprises a frame 21, a diaphragm 22 elastically supported at the frame, and a driving device 23 (simply designated as driver) that is configured to provide driving power for operating the diaphragm 22. A housing 40 is attached to the frame 21 such that a back space 26 of the diaphragm 22 is enclosed between the diaphragm 22 and the housing 40. The diaphragm 22 is configured to emit front sound from a first side of the diaphragm 22 towards the inner space IS of the vehicle. For example, the loudspeaker device 20 is configured such that the diaphragm 22 vibrates at a frequency in a sub-woofer frequency range. The diaphragm 22 has a cone shape and is supported by an outer circumferential portion of the frame 21, wherein in the present embodiment the concave side of the diaphragm 22 forms a second side of the diaphragm opposite the first side. The back space 26 of the diaphragm 22 faces the second side of the diaphragm 22. A communication channel 24, which is provided in the back part of the loudspeaker device 20, comprises a first terminal coupled to the back space 26 of the diaphragm, and a second terminal coupled to an opening 50 of the partition panel 30 which divides the inner space IS from an outside space OS of the vehicle. With the communication channel 24, back sound emitted from the second side of the diaphragm 22 is communicated to the outside space OS of the vehicle through the communication channel 24 and the opening 50 in partition panel 30. The communication channel 24 comprises as the second terminal a back port 25 which is connected to the opening 50. In the present embodiment, the back port 25 is connected to the housing 40 and preferably is configured to fit into the opening 50 of the partition panel 30.

[0028] In addition, a Helmholtz resonance absorber (or Helmholtz resonator) is provided which is connected to the communication channel 24. Such Helmholtz resonator is schematically shown in Fig. 1 and is formed by one or more cavities 27 and connections 28 which couple(s) the cavity/cavities 27 with the communication channel 24. Particularly, it is configured to attenuate or absorb noise coming from the outside of the vehicle. Specifically, it is configured to attenuate or absorb one or more noise

frequencies emitted from wheels of the vehicle during driving. Preferably, the Helmholtz resonance absorber is configured to attenuate or absorb noise frequencies in a range which is above a working range of the loudspeaker device. According to an embodiment, the working range of the loudspeaker device is in the subwoofer range, particularly in a range equal to or below approx. 100 Hz.

[0029] To this end, the Helmholtz resonator comprises at least one cavity 27 and at least one connection 28 coupling the at least one cavity 27 with the communication channel 24 which function as a Helmholtz resonator in the frequency range of interest. According to some embodiments, the at least one cavity 27 and the at least one connection 28 form a branched air-chamber having at least one cavity 27 and at least one connection 28, such as a duct, coupled to the communication channel 24. For example, the Helmholtz resonator may comprise a cavity 27 and one or more connections 28, or may comprise multiple cavities 27 and one or more connections 28. In principle, any suitable configuration for such Helmholtz resonator may be implemented. The Helmholtz resonator reduces undesirable frequencies of noise 60 penetrating through the communication channel 24, such as in an area 61 schematically shown in Fig. 1, thus building a resonator tuned to one or more noise frequencies, thereby attenuating or eliminating it.

[0030] Fig. 2 shows parts of a vehicle loudspeaker system according to an embodiment of the invention. Fig. 2A shows the core of the loudspeaker device including the frame 21, the diaphragm 22 supported by the frame 21, and the driver 23 for driving the diaphragm. In Fig. 2B, there is shown an embodiment of a housing 40 which is to be attached to the frame 21 on the concave side of the diaphragm 22, so that it encloses a back space of the diaphragm 22 in the concavity of the diaphragm. In principle, another arrangement with housing 40 attached to the frame 21 on the convex side of the diaphragm 22 would also be possible. In the present embodiment, the outer diameter of the housing 40 substantially corresponds to the outer diameter of the frame 21. Fig. 3 shows the assembled vehicle loudspeaker system according to the embodiment as depicted in Fig. 2A and 2B, in which the housing 40 is attached onto the outer diameter of the frame 21. Fig. 3A shows a side view of the loudspeaker system with the back port 25 being arranged concentrically to the diaphragm 22 and driver 23. Fig. 3B shows a cross-sectional view of the loudspeaker system along line A-A in Fig. 3A.

[0031] As shown in Fig. 2B and 3B, the Helmholtz resonator is integrated with the housing 40. Particularly, the communication channel 24 is formed within the housing 40, in the present embodiment is formed by a central inner chamber 41 of the housing 40 enclosing and forming the back port 25. Thus, the chamber 41 is in communication with the back space 26 in the concavity of the diaphragm 22, cf. Fig. 3B. The housing further comprises cavity 27 which surrounds the chamber 41. In this embodiment, the chamber 41 and the cavity 27 are arranged concentrically to the diaphragm 22, the cavity 27 thus forming an outer ring around the central chamber 41. The cavity 27 is divided from the chamber 41 through a ring wall 42. The chamber 41 has a central opening forming the back port 25. The cavity 27 is coupled with chamber 41 through one or more connections 28, e.g. by slots, gates or gaps within the ring wall 42. Any other geometric shape (e.g. rectangular or elliptic) may also be used for cavity 27 and/or chamber 41, or cavity 27 may be subdivided into plural chambers, or more than one cavity may be formed connected through respective one or more connections. The number of connections 28 as well as the length and/or width of the connections 28 may be adjusted to get the desired absorber behaviour.

[0032] For adjusting any resonance frequencies of the Helmholtz resonator, the air volume within the connections 28 may be adjusted by appropriate thickness of the ring wall 42 and diameter of the connections 28. With the arrangement according to Figures 2 and 3, a compact arrangement of a loudspeaker system can be achieved in which noise penetrating through the back port 25 to the inner space of the vehicle can be reduced while the dimensions and manufacturing costs of the loudspeaker system are not significantly increased as the Helmholtz resonator is integrated within the housing 40. Thus, no additional assembly steps are required. To account for any increased dimensions of the housing 40, such as greater diameter of the housing 40 resulting from the provision of cavity 27, the circumferential flange of the frame 21 may be extended, i.e. has a greater width, as shown in Fig. 2A. Preferably, the housing can be manufactured from any suitable material, such as plastics, and sealed with respect to the frame appropriately, which thus advantageously also seals the cavity and connection(s) of the Helmholtz resonator.

[0033] A further embodiment of the invention is now described with reference to Figs. 4 and 5. Specifically, Figs. 4A-4C show various parts of a vehicle loudspeaker system according to this embodiment, wherein Fig. 4A shows the loudspeaker device 20, Figs. 4B and 4C show the housing 40, while Figs. 4D and 4E show an assembled vehicle loudspeaker system. Fig. 5 shows different views of a vehicle loudspeaker system according to this embodiment. Particularly, Fig. 5A shows a side view, Fig. 5B a rear view, Fig. 5C a cross-sectional view along line A-A in Fig. 5B, and Fig. 5D a cross-sectional view along line B-B in Fig. 5B.

[0034] As compared to the first embodiment, the components of the loudspeaker device 20, that is the frame 21, diaphragm 22 and driver 23 are substantially the same or correspond to those as already described with reference to Figs. 1-3, with an exception of frame 21 as described in more detail below. As a difference to the first embodiment as described with reference to Figs. 2-3, the loudspeaker device 20 of the second embodiment comprises a differently formed housing 40 surrounding the back space 26 of the diaphragm 22. Again, similarly as with the previous embodiment, the Helmholtz resona-

tor is integrated with the housing 40.

[0035] Further, similarly as with the previous embodiment, housing 40 is attached to the frame 21 on the concave side of the diaphragm 22, so that it encloses the back space of the diaphragm 22 in the concavity of the diaphragm. In principle, another arrangement with housing 40 attached to the frame 21 on the convex side of the diaphragm 22 would also be possible. The outer diameter of the housing 40 substantially corresponds to the outer diameter of the frame 21. The communication channel 24 schematically shown in Fig. 1 is formed within the housing 40 by a corresponding chamber 41 (cf. Figs. 4E, 5C, 5D) which is in communication with the back space 26 of the diaphragm 22, and its back port 25 is connected to the housing 40. In the present example, the back port 25 is facing downward and is formed like a tube which may be coupled to the opening 50. The housing 40 further forms a cavity 27 which is coupled to the chamber 41 through one or more connections 28, in the present embodiment through two ducts 28. In the present embodiment, the ducts 28 are formed like tubes, as best shown in Fig. 4E. For adjusting any resonance frequencies of the Helmholtz resonator, the air volume within the ducts 28 may be adjusted by any one of appropriate length, geometric shape, and/or diameter of the ducts 28.

[0036] In the present embodiment, the frame 21 comprises at least two opposite parts for attaching the housing, which may be formed by two diametrically opposed lugs or fins 21-1, 21-2. As best shown in Fig. 4A, the lugs 21-1, 21-2 may be part of the frame which are bent upwards to be substantially rectangular to the plane of the diaphragm 22. Any other form and/or attachment of the lugs 21-1, 21-2 may also be used. For example, the lugs 21-1, 21-2 may be separate parts which are attached to the frame, or may be part of the housing 40. Such arrangement may be more cost effective than an arrangement as shown in Fig. 2A with an extended flange of the frame 21 for attaching the housing 40, since the frame 21 can be manufactured with less material (typically metal). Preferably, the housing 40 can be manufactured from any suitable material, such as plastics, and sealed with respect to the frame appropriately, which thus advantageously also seals the cavity and connection(s) of the Helmholtz resonator.

[0037] As best shown in Figs. 4B, 4D, 4E, and 5B, the cavity 27 is formed to span the extension between the two diametrically opposed lugs 21-1, 21-2. Particularly, the cavity 27 is attached to the lugs 21-1, 21-2 of the frame 21 such that the lugs 21-1, 21-2 respectively form a respective side wall of the cavity 27. For example, as shown in Fig. 4E, the lug 21-1 forms the left side wall of cavity 27. With this arrangement, a secure attachment of the housing to the frame 21 can be achieved. Here, the cavity 27 is formed with a rectangular cross-section forming a cuboid. Any other geometric shape may also be used for cavity 27 and/or chamber 41, or cavity 27 may be subdivided into plural chambers, or more than one cavity may be formed connected through respective one or more connections.

[0038] With the arrangement according to Figs. 4 and 5, a compact arrangement of a loudspeaker system can be achieved in which noise penetrating through the back port 25 to the inner space of the vehicle can be reduced while the dimensions and manufacturing costs of the loudspeaker system are not significantly increased as the Helmholtz resonator is integrated within the housing.

Claims

1. A vehicle loudspeaker system (10), comprising

a loudspeaker device (20) comprising a driver (23) and a diaphragm (22), and which is configured to emit front sound from a first side of the diaphragm (22) to an inner space (IS) of the vehicle,

a communication channel (24) comprising a first terminal coupled to a back space (26) of the diaphragm facing a second side of the diaphragm (22) opposite the first side, and a second terminal adapted to be coupled to an opening (50) of a partition panel (30) dividing the inner space (IS) from an outside space (OS) of the vehicle for communicating back sound emitted from the second side of the diaphragm (22) to the outside space (OS) of the vehicle,

characterized by a Helmholtz resonance absorber which is configured to attenuate or absorb at least one noise frequency and comprises at least one cavity (27) and at least one connection (28) coupling the at least one cavity (27) with the communication channel (24).

2. The vehicle loudspeaker system according to claim 1, wherein the loudspeaker device (20) comprises a housing (40) surrounding at least part of the back space (26) of the diaphragm (22), wherein the Helmholtz resonance absorber (27, 28) is integrated with the housing (40).

3. The vehicle loudspeaker system according to claim 2, wherein the communication channel (24) is formed within the housing (40) and comprises a back port (25) that is connected to the housing (40).

4. The vehicle loudspeaker system according to one of claims 2 to 3, wherein the housing (40) comprises at least one chamber (41) in communication with the back space (26) of the diaphragm (22), and the at least one cavity (27) is coupled to the at least one chamber (41) through the at least one connection (28).

5. The vehicle loudspeaker system according to claim 4, wherein the at least one chamber (41) and the at

least one cavity (27) are arranged such that the at least one cavity (27) surrounds the at least one chamber (41).

6. The vehicle loudspeaker system according to claim 5, wherein the at least one chamber (41) and the at least one cavity (27) are arranged concentrically to the diaphragm (22).

7. The vehicle loudspeaker system according to one of claims 1 to 6, wherein the loudspeaker device (20) further comprises a frame (21) supporting the diaphragm (22), and the at least one cavity (27) is attached to at least one part (21-1, 21-2) of the frame (21) such that the at least one part (21-1, 21-2) of the frame forms at least one side wall of the at least one cavity (27).

8. The vehicle loudspeaker system according to claim 7, wherein the at least one part of the frame (21) comprises two diametrically opposed lugs (21-1, 21-2), and the at least one cavity (27) is formed to span an extension between the two diametrically opposed lugs (21-1, 21-2).

9. The vehicle loudspeaker system according to one of claims 1 to 8, wherein the diaphragm (22) has a cone shape and is supported by an outer circumferential portion of a frame (21), wherein the concave side of the diaphragm (22) forms the second side of the diaphragm.

10. The vehicle loudspeaker system according to one of claims 1 to 9, wherein the loudspeaker device (20) is configured such that the diaphragm (22) vibrates at a frequency in a sub-woofer frequency range.

11. The vehicle loudspeaker system according to one of claims 1 to 10, wherein the Helmholtz resonance absorber (27, 28) is configured to attenuate or absorb at least one noise frequency emitted from wheels of the vehicle during driving.

12. A vehicle structure (1), comprising
a partition panel (30) dividing an inner space (IS) from an outside space (OS) of the vehicle,
an opening (50) formed in the partition panel (30), and
a vehicle loudspeaker system (10) according to one of the preceding claims, wherein the second terminal of the communication channel (24) is coupled to the opening (50) of the partition panel (30).

13. The vehicle structure according to claim 12, wherein the partition panel (30) forms an outer skin portion of a vehicle body.

14. A vehicle comprising a vehicle structure (1) according to one of claims 12 to 13.

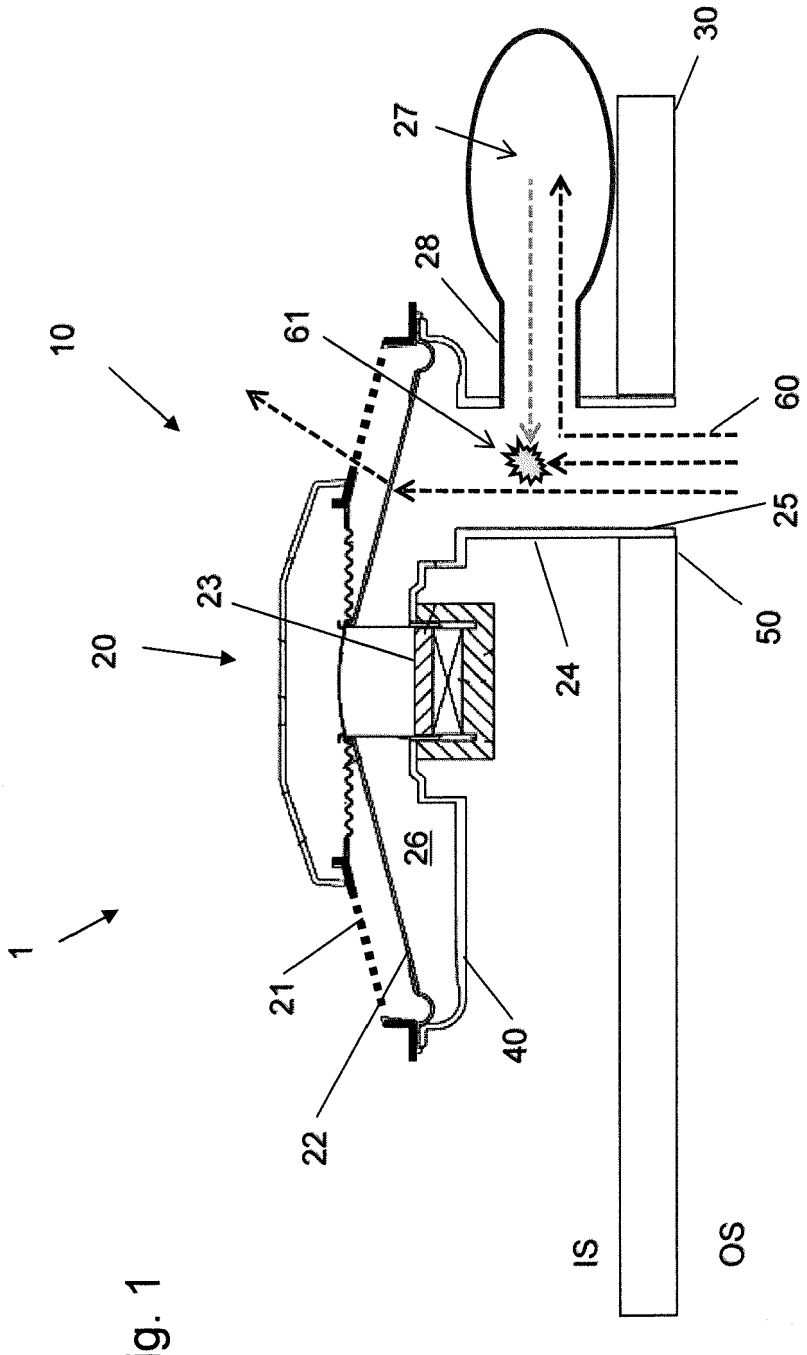


Fig. 1

Fig. 2B

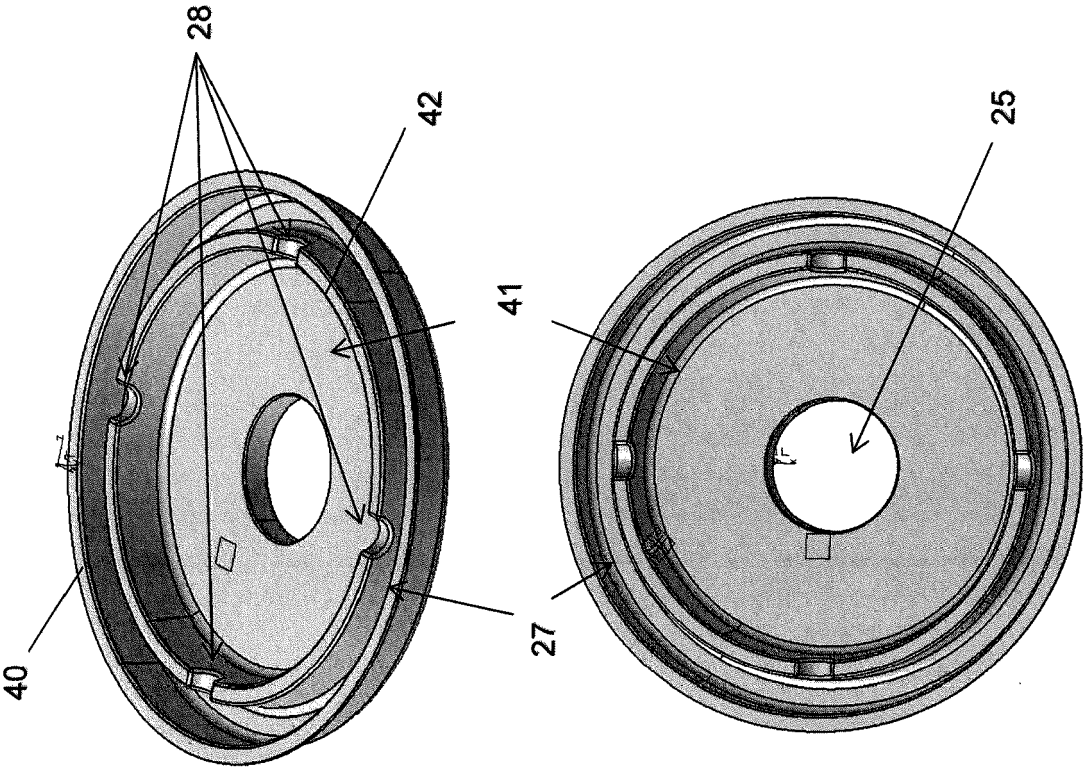


Fig. 2A

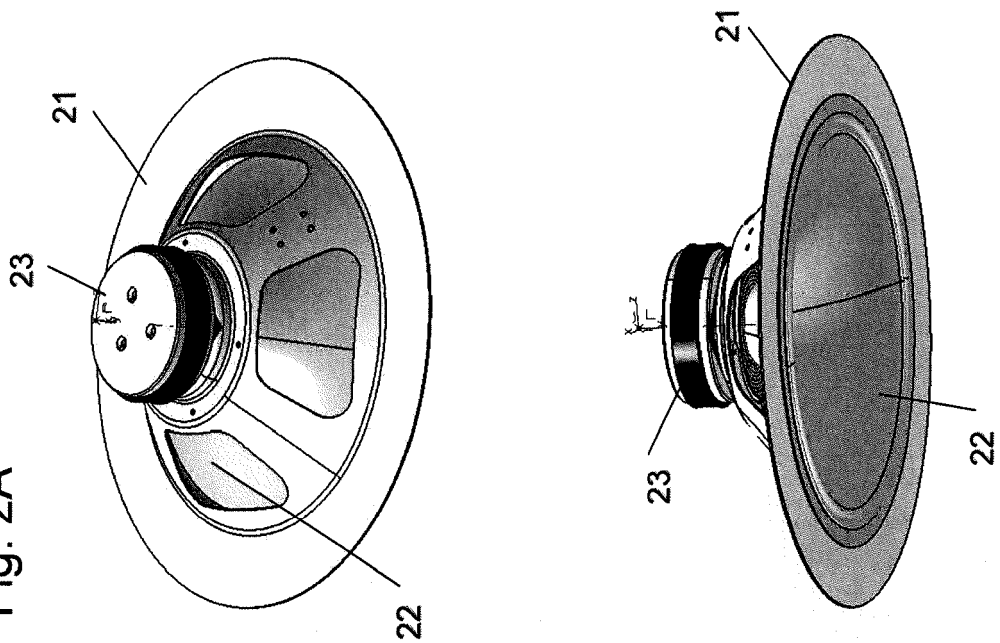


Fig. 3B

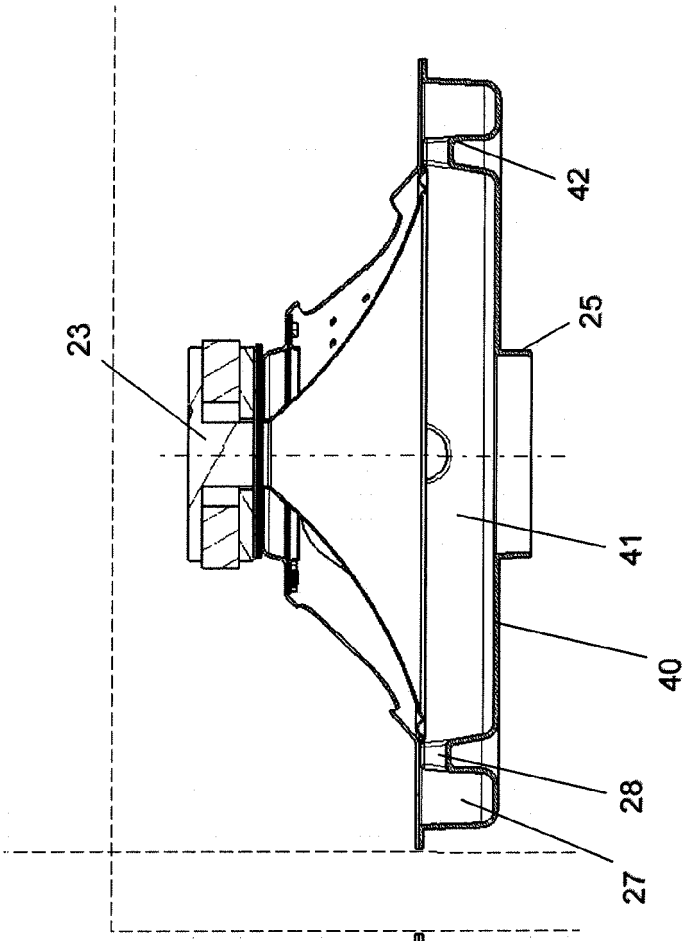
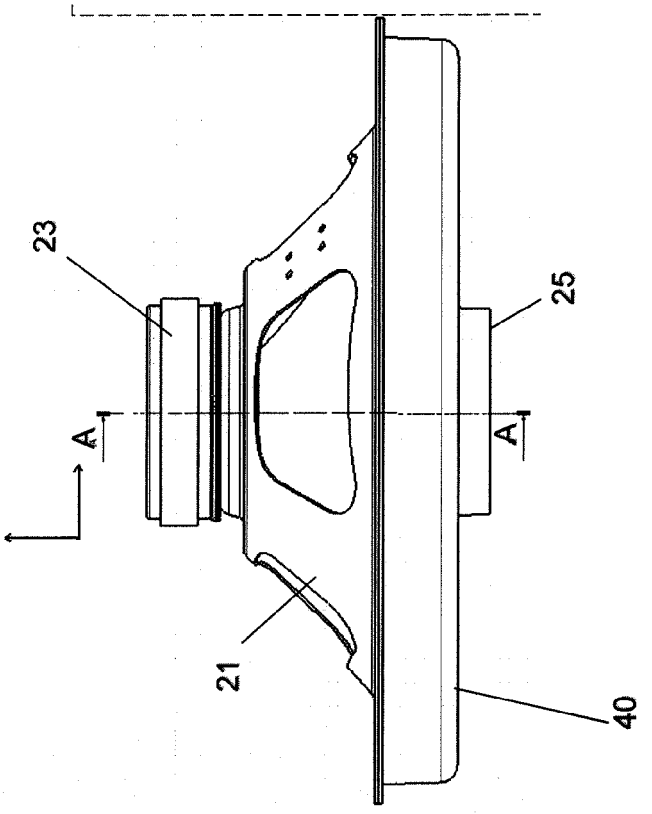


Fig. 3A



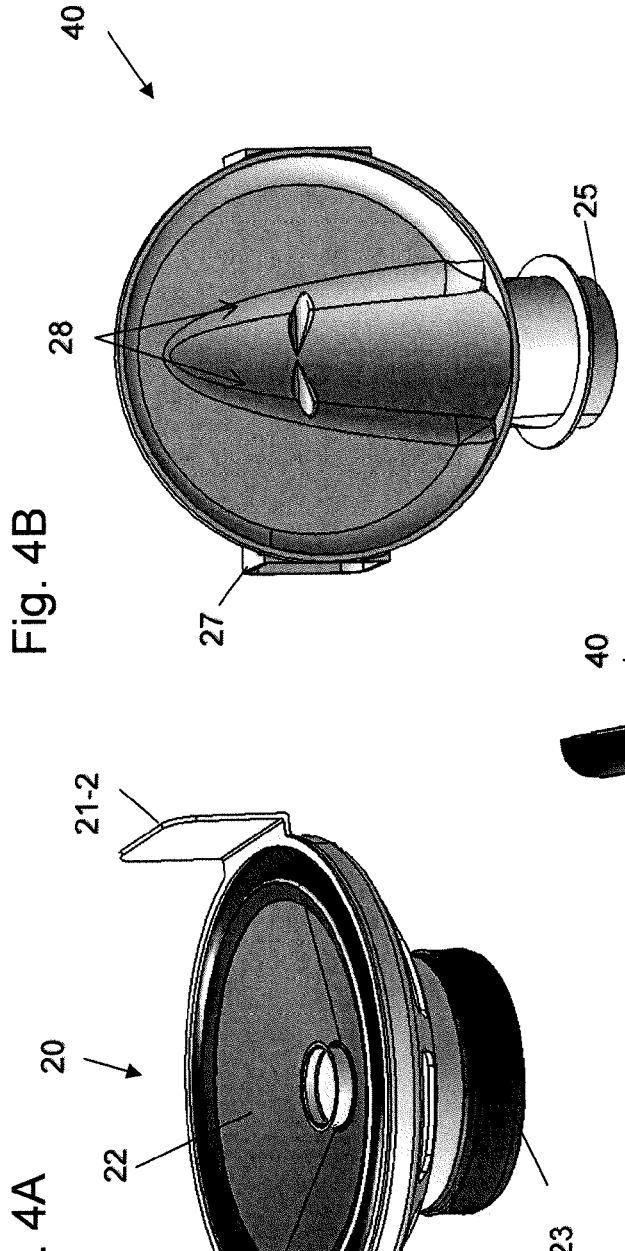


Fig. 4A

Fig. 4B

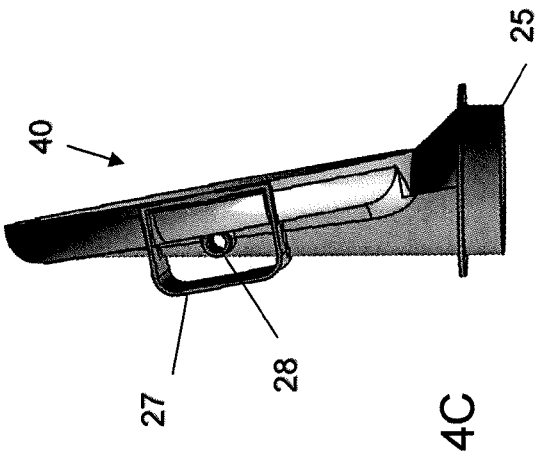


Fig. 4C

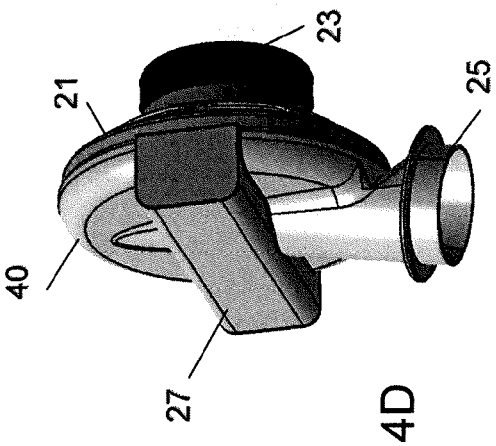


Fig. 4D

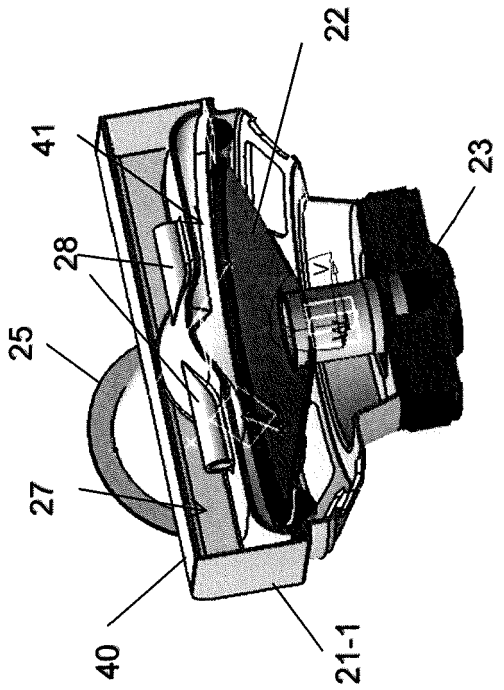


Fig. 4E

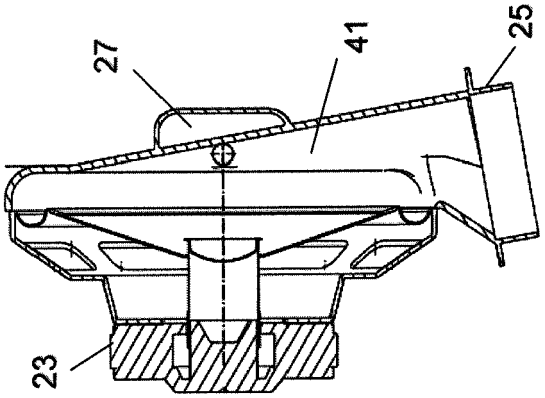


Fig. 5C

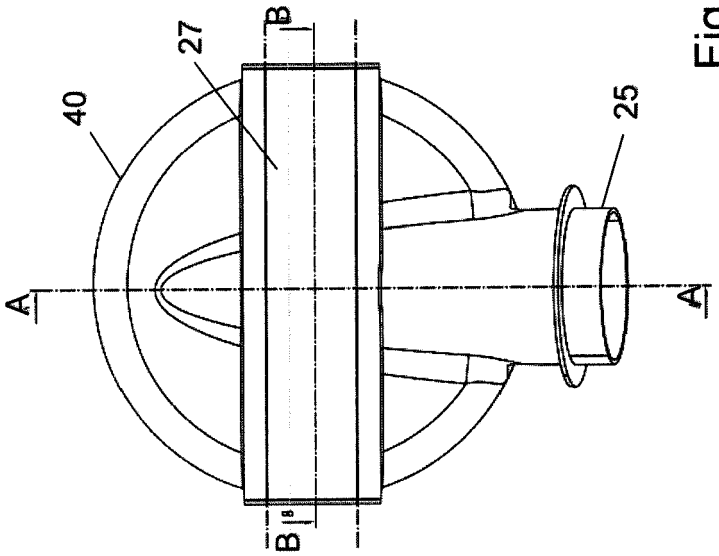


Fig. 5B

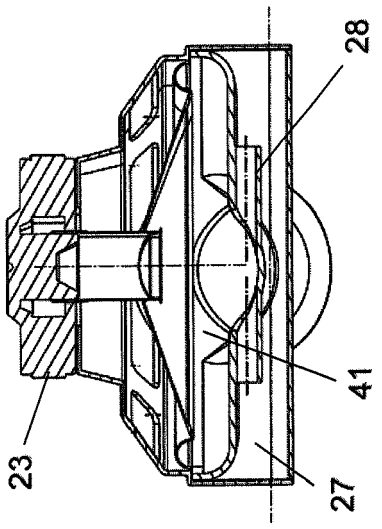


Fig. 5D

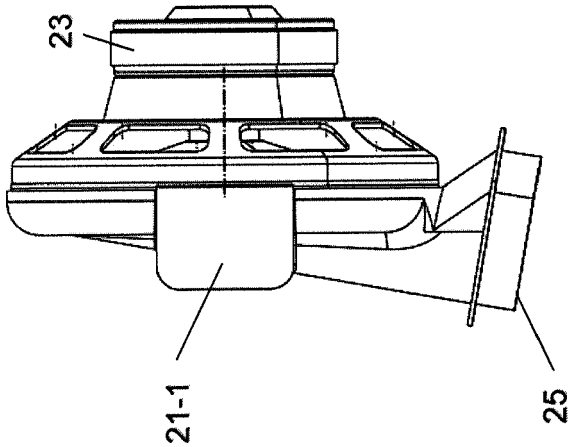


Fig. 5A

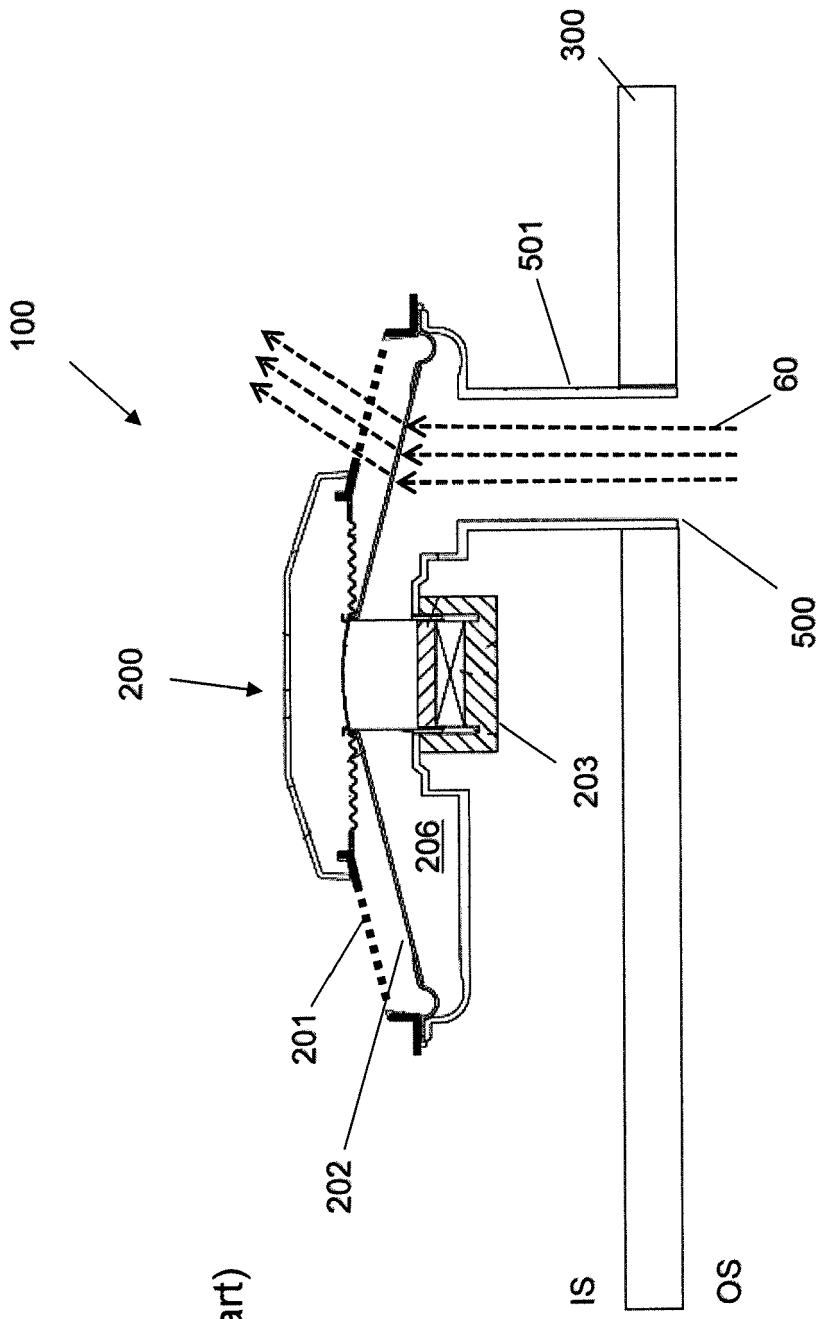


Fig. 6
(Prior art)

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EUROPEAN SEARCH REPORT

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Place of search	Date of completion of the search	Examiner
The Hague	6 April 2018	Carrière, Olivier

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