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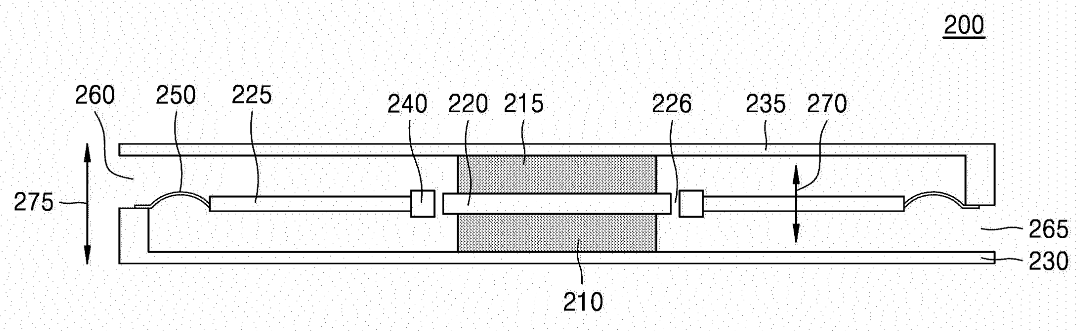
(54) SPEAKER INCLUDING ULTRA-THIN TRANSDUCER

(57) Provided is a speaker including a transducer.

The speaker includes: a diaphragm with a hole; a voice coil arranged at least partially in the hole; and a column structure arranged at least partially in the voice coil. The voice coil has a ring shape with an outer horizontal width and an inner horizontal width, and the outer horizontal width is equal to or less than the first horizontal width of the hole.

FIG. 2A



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Description

TECHNICAL FIELD

[0001] One or more embodiments of the present disclosure generally relate to a speaker, and more particularly, to a speaker including a slim acoustic transducer that has a diaphragm including a hole.

BACKGROUND ART

[0002] Televisions, notebook computers, and mobile phones have increasingly smaller thicknesses, but there is still demand for better sound quality (for example, more lower pitched tone output). To produce low-frequency sound (for example, bass), loudspeakers need to move a lot of air, which may be achieved by having large surface areas or by the large movement of diaphragms. Large surface areas of thin transducers are prone to bending or rocking, and thus, distortion and other mechanical issues occur.

[0003] Often, it is not possible to expose diaphragms. Instead, the sound needs to be radiated through narrow slots, which increase the total built heights (thicknesses) of acoustic modules. Advantages of slots loading transducers include avoiding being touched and also include minimizing interference with industrial design. However, slots loading thin transducers are more prone to rocking because the acoustic load on diaphragms is asymmetric.

DESCRIPTION OF EMBODIMENTS

TECHNICAL PROBLEM

[0004] Example embodiments of the present disclosure provide a speaker including a slim transducer with a diaphragm including a hole.

SOLUTION TO PROBL

[0005] According to an aspect of the present disclosure, a speaker includes a transducer, wherein the transducer includes: a diaphragm including a hole with a first horizontal width; a voice coil arranged at least partially in the hole; and a column structure arranged at least partially in the voice coil.

[0006] A shape of the voice coil may be a ring shape with an outer horizontal width and an inner horizontal width, and the outer horizontal width may be equal to or less than the first horizontal width of the hole.

[0007] A shape of the voice coil may be a ring shape with an outer horizontal width and an inner horizontal width, and a second horizontal width of the column structure may be equal to or less than the inner horizontal width of the ring shape.

[0008] The column structure may include: an upper magnet; a middle plate arranged below the upper magnet; and a lower magnet arranged below the middle plate.

[0009] The upper magnet may be configured to apply an upper magnetic field to the voice coil; the lower magnet may be configured to a lower magnetic field to the voice coil; and the middle plate may be configured to guide at least one of the upper magnetic field or the lower magnetic field toward the voice coil.

[0010] The speaker may further include a top plate above the upper magnet, and the top plate may be configured to assist in directing at least a portion of the upper magnetic field toward the voice coil.

[0011] The speaker may further include at least one magnetic flux coupled to the top plate.

[0012] The speaker may further include a bottom plate below the lower magnet, and the bottom plate may be configured to assist in directing at least a portion of the lower magnetic field toward the voice coil.

[0013] The speaker may further include at least one magnetic flux coupled to the bottom plate.

[0014] Each of the upper magnet and the lower magnet may include neodymium, and the middle plate may include low-carbon steel.

[0015] A vertical axis with respect to the diaphragm may be at the center of the hole, and the speaker may further include: a top plate arranged above the upper magnet and centered on the vertical axis, the top plate being configured to assist in directing at least a portion of the upper magnetic field toward the voice coil; and a bottom plate arranged below the lower magnet and centered on the vertical axis, the bottom plate being configured to assist in directing at least a portion of the lower magnetic field toward the voice coil.

[0016] Each of the hole and the voice coil may be in a circular shape, and the column structure may be in a cylindrical shape.

[0017] The first horizontal width may be a diameter of the circular shape.

[0018] The speaker may further include a suspension attached to the diaphragm, and the suspension may include at least one of an inner suspension or an outer suspension.

[0019] The speaker may further include a lubricant arranged between the voice coil and the column structure.

[0020] The lubricant may include at least one of a ferrofluid or grease.

[0021] The diaphragm may be in one of a planar shape, a concave shape, or a convex shape.

[0022] The diaphragm may include structural foam.

[0023] A vertical axis with respect to the diaphragm may be at the center of the hole, and the ring shape may be centered on the vertical axis.

[0024] The column structure may be centered on the vertical axis.

ADVANTAGEOUS EFFECTS OF DISCLOSURE

[0025] A speaker including a transducer, according to an example embodiment of the present disclosure, may have a slim structure. A transducer according to an example embodiment of the present disclosure may improve sound quality by reducing distortion.

BRIEF DESCRIPTION OF DRAWINGS

[0026]

FIG. 1 illustrates a cross-sectional view of a flat micro-speaker according to a comparison example.

FIG. 2A illustrates a cross-sectional view of an example ultra-thin transducer according to an embodiment of the present disclosure.

FIG. 2B illustrates a cross-sectional view of an ultra-thin transducer showing an example magnetic flux, according to an example embodiment of the present disclosure.

FIG. 3 is a cross-sectional view of a slot-loaded ultra-thin transducer showing top venting and bottom venting, according to an example embodiment of the present disclosure.

FIG. 4 is a cross-sectional view of a slot-loaded ultra-thin transducer showing asymmetric pressure on a diaphragm causing rocking motion, according to an example embodiment of the present disclosure.

FIGS. 5A to 5G respectively illustrate plan views of slot-loaded ultra-thin transducers with various airflow venting, according to an embodiment of the present disclosure.

FIG. 6 illustrates a graph of the propensity for rocking motion versus frequency for the examples in FIGS. 5A to 5G, according to an example embodiment of the present disclosure.

FIG. 7 illustrates a graph of the propensity for sound pressure level (SPL) versus frequency for the examples in FIGS. 5A to 5G, according to an example embodiment of the present disclosure.

FIG. 8A is a cross-sectional view of an ultra-thin transducer with a planar diaphragm, according to an example embodiment of the present disclosure.

FIG. 8B is a cross-sectional view of an ultra-thin transducer with a convex angled diaphragm, according to an example embodiment of the present disclosure.

FIG. 8C is a cross-sectional view of an ultra-thin transducer with a concave angled diaphragm, according to an example embodiment of the present disclosure.

FIG. 8D is a cross-sectional view of an ultra-thin transducer with a planar diaphragm and an outer suspension, according to an example embodiment of the present disclosure.

FIG. 8E is a cross-sectional view of an ultra-thin transducer with a structural diaphragm and an outer suspension, according to an example embodiment of the present disclosure.

FIG. 8F is a cross-sectional view of an ultra-thin transducer with an alternative-shaped voice coil, a structural diaphragm, and an outer suspension, according to an example embodiment of the present disclosure.

FIG. 8G is a cross-sectional view of an ultra-thin transducer with another alternative-shaped voice coil, a structural diaphragm, and an outer suspension, according to an example embodiment of the present disclosure.

FIG. 8H is a cross-sectional view of an ultra-thin transducer with a planar diaphragm and an inner suspension, according to an example embodiment of the present disclosure.

FIG. 8I is a cross-sectional view of an ultra-thin transducer, which has a planar diaphragm, a top plate, and a bottom plate and is configured for slot radiation, according to an example embodiment of the present disclosure.

FIG. 8J is a cross-sectional view of an ultra-thin transducer with a planar diaphragm and a ferrofluid seal, according to an example embodiment of the present disclosure.

FIG. 8K is a cross-sectional view of an ultra-thin transducer with a planar diaphragm and a grease seal, according to an example embodiment of the present disclosure.

FIG. 8L is a cross-sectional view of an ultra-thin transducer with a planar diaphragm, a top plate, and a bottom plate, according to an example embodiment of the present disclosure.

FIG. 8M is a cross-sectional view of an ultra-thin transducer with a planar diaphragm, a perforated top plate, and a perforated bottom plate, according to an example embodiment of the present disclosure.

FIG. 8N is a cross-sectional view of an ultra-thin transducer, which has a planar diaphragm and is configured for slot radiation, according to an example embodiment of the present disclosure.

FIG. 8O is a cross-sectional view of an ultra-thin transducer, which has a planar diaphragm, a top plate, and a bottom plate and is configured for slot radiation, according to an example embodiment of the present disclosure.

FIG. 9A is a cross-sectional view of a transducer, which has a planar diaphragm and is configured for slot radiation, according to the related art.

FIG. 9B is a cross-sectional view of an ultra-thin transducer, which has a planar diaphragm and is configured for slot radiation, according to an example embodiment of the present disclosure.

FIG. 10A is a cross-sectional view of a transducer, which has a planar diaphragm and is configured for direct radiation, according to the related art.

FIG. 10B is a cross-sectional view of an ultra-thin transducer, which has a planar diaphragm and is configured for direct radiation, according to an example embodiment of the present disclosure.

FIG. 11A is a cross-sectional view of an ultra-thin transducer with an inner surround to assist in preventing short circuiting, according to an example embodiment of the present disclosure.

FIG. 11B is a cross-sectional view of an ultra-thin transducer with a pressurizable material to prevent acoustic short circuiting, according to an example embodiment of the present disclosure.

FIG. 11C is a cross-sectional view of an ultra-thin transducer with a ferrofluid seal, according to an example embodiment of the present disclosure.

FIG. 12A is a top perspective view of an ultra-thin transducer with a top plate, according to an example embodiment of the present disclosure.

FIG. 12B is a top perspective view of the ultra-thin transducer of FIG. 12A with the top plate removed, according to an example embodiment of the present disclosure.

FIG. 12C is a cross-sectional view of the ultra-thin transducer of FIGS. 12A and 12B, according to an example embodiment of the present disclosure.

FIG. 13 is a top perspective view of an ultra-thin transducer with a perforated top plate, according to an example embodiment of the present disclosure.

FIG. 14 illustrates an ultra-thin transducer with an elliptical diaphragm, according to an example embodiment of the present disclosure.

MODE OF DISCLOSURE

[0027] The following description is made to describe the general principles of one or more embodiments of the present disclosure and is not meant to limit the inventive concepts claimed herein. In addition, particular features described herein may be used in combination with other described features in each of the various possible combinations and permutations. Unless otherwise specifically defined herein, all terms are to be given their broadest possible interpretation including meanings implied from the specification as well as meanings understood by those of ordinary skill in the art and/or as defined in dictionaries, treatises, and the like.

[0028] One or more embodiments of the present disclosure relate to a speaker including a transducer, and more particularly, to a slim acoustic transducer including a diaphragm with a hole. For example, the hole may be substantially centered on a vertical axis of the diaphragm. For the purpose of description, the terms "loudspeaker," "loudspeaker device," and "loudspeaker system" may be used interchangeably in the specification.

[0029] For the purpose of description, the term "listening position" used herein generally refers to a position of a listener relative to a loudspeaker device.

[0030] For the purpose of description, a diaphragm is a membrane attached to a voice coil, which moves in a magnetic gap, vibrating the diaphragm, and producing sound.

[0031] FIG. 1 illustrates a cross-sectional view of a flat micro-speaker 100 according to a comparison example. The flat micro-speaker 100 includes a magnet 110, a top plate 120, a bottom plate (or frame) 125, a grill (or front cover) 130, a diaphragm 135, and a voice coil 140. A magnet 110 system portion of the flat micro-speaker 100 occupies a significant volume of space and limits the movement of the diaphragm 135 relative to a total built height 150 (acoustic module thickness, including an enclosure). A peak-to-peak displacement 155 of the diaphragm may be less than 40 % of the total thickness. A magnetic flux 160 is formed between the magnet 110 and the voice coil 140.

[0032] FIG. 2A illustrates a cross-sectional view of an ultra-thin transducer 200 according to an example embodiment of the present disclosure. In some embodiments of the present disclosure, the transducer 200 includes a lower (or bottom) magnet 210 (for example, ring-shaped, circular-shaped, cylindrical-shaped, or the like), a middle plate 220 (for example, ring-shaped, circular-shaped, cylindrical-shaped, or the like), an upper (or top) magnet 215 (for example, ring-shaped, circular-shaped, cylindrical-shaped, or the like), and a voice coil 240 (for example, ring-shaped, circular-shaped, elliptical-shaped, or the like). In some embodiments of the present disclosure, a magnet system may be arranged at least partially within an inner perimeter of the voice coil 240. The magnet system may have a column structure substantially centered on a vertical axis. The column structure may have a horizontal width that is equal to or less than an inner horizontal width of a structure shape of the voice coil 240. The column structure may include an upper magnet 215, a middle plate 220 arranged below the upper magnet 215, and a lower magnet 210 arranged below the middle plate 220. The magnet system minimizes a space from the movement of the diaphragm 225. In some embodiments of the present disclosure, each of the lower magnet 210 and the upper magnet 215 may include a rare earth magnetic material such as neodymium (Nd), neodymium iron boron (NdFeB), or samarium cobalt. In some embodiments of the present disclosure, the middle plate 220 may be made of low-carbon steel, soft magnetic steel, or a material similar thereto. In some embodiments of the present disclosure, the diaphragm 225 may include at least one of paper, polypropylene (PP), polyether ether ketone (PEEK), polycarbonate (PC), polyethylene terephthalate (PET), silk, glass fibers, carbon fibers, titanium, aluminum, an aluminum-magnesium alloy, nickel, or beryllium.

[0033] In some embodiments of the present disclosure, a top plate of the column structure may have a ring shape substantially centered on the vertical axis. The top plate may be the top magnet 215, which assists in directing at least some of an upper magnetic field substantially parallel to the vertical axis away from the voice coil 240. A bottom plate of the column structure may be substantially centered on the vertical axis. The bottom plate may include the lower magnet 210, which assists in directing at least some of a lower magnetic field substantially parallel to a horizontal axis adjacent to the vertical axis away from the voice coil 240. The lower magnet 210 may be, for example, a magnet ring. In some embodiments of the present disclosure, an enclosure including a lower frame 230 and an upper frame 235 (for example, low-carbon steel, soft magnetic steel, plastic, aluminum, or the like) may be twice a magnetic return path. In some embodiments of the present disclosure, a peak-to-peak displacement 270 may be greater than 50 % of a total thickness 275.

[0034] In one or more embodiments of the present disclosure, the diaphragm 225 may include or be connected to an outer suspension 250 (for example, a torus or the like). The transducer 200 may include a slot or vent 260 for radiating sound waves outside of the transducer 200 to a listening environment, and a slot or vent 265 for venting to an internal speaker volume. In some embodiments of the present disclosure, the top and bottom plates of the column structure may be a portion of a frame (that is, the lower frame 230 and the upper frame 235).

[0035] In some embodiments of the present disclosure, the diaphragm 225 may include a hole (or space, opening, or the like) 226. The hole 226 may be substantially centered on a vertical axis with respect to the diaphragm 225. The hole 226 may have a horizontal width. The voice coil 240 may be arranged at least partially in the hole 226. The voice coil 240 may have a shape (for example, a ring shape, a circular shape, an elliptical shape, or the like) that is substantially centered on the vertical axis of the diaphragm 225. The voice coil 240 may have an outer horizontal width and an inner horizontal width, where the outer horizontal width may be less than or equal to the horizontal width of the hole 226.

[0036] In some embodiments of the present disclosure, the magnet system produces a low-frequency output in an extremely thin form factor. The transducer 200 may optimize a stack-up topology for a maximum displacement. According to some embodiments of the present disclosure, the enclosure is a functional portion of the design of the transducer 200. In some embodiments of the present disclosure, the magnet system (or motor) of the transducer 200 is located in the center of the diaphragm 225 (not below the diaphragm as in designs according to the related art), providing a thin design with an increased range of movement. In some cases, there is no yoke/gap (direct magnetic return path), which increases a range of movement of the diaphragm 225 by using a fringe field of the magnet system. The transducer 200 also improves the symmetry of electromagnetic force and inductance during an in-/out-stroke. In some embodiments of the present disclosure, the transducer 200 provides a symmetric magnet layout, which improves sound quality by reducing distortion.

[0037] In some embodiments of the present disclosure, the transducer 200 may include a steel housing used for a magnetic return path on both sides of the column structure (no additional thickness required for the enclosure). The diaphragm 225 may be mounted at the center of the voice coil 240, and this improves the symmetry of the in-/out-stroke. In addition, this may also reduce or eliminate a former (bobbin) used in existing transducer designs. Further, a strategically arranged air vent of the transducer 200 may reduce vibration modes of the diaphragm 225, and this reduces distortion and a possibility for the voice coil 240 to rub against the magnet system structure. In some embodiments of the present disclosure, the transducer 200 may be implemented in devices and microelectronic equipment, such as mobile phones, camcorders, personal digital assistants (PDAs), digital cameras, notebook computers, televisions (TVs), digital versatile disks (DVDs), and the like.

[0038] FIG. 2B illustrates a cross-sectional view of an example ultra-thin transducer 200 showing an example magnetic flux 280, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the lower magnet 210 and the upper magnet 215 have opposite polarities to each other to increase the magnetic flux 280 at an edge of a pole plate. The voice coil 240 and the magnet system structure may be located in the center of the diaphragm 225. The magnet system may be centrally located in a driver, and a symmetric motor design may reduce even-order harmonic distortion.

[0039] FIG. 3 illustrates a cross-sectional view of an example slot-loaded ultra-thin transducer 200 showing upper slot 260 and lower slot 265 venting, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 200 discharges air straight to a listening environment from the upper slot 260 and discharges air straight to an internal speaker volume 320 from the lower slot 265.

[0040] FIG. 4 illustrates a cross-sectional view of the example slot-loaded ultra-thin transducer 200 showing asymmetric pressure (indicated by arrows 410 and 411) on the diaphragm 225 causing rocking motion, according to some embodiments of the present disclosure. Although slot loading of a transducer has advantages, slot loading of a thin transducer is likely to cause a vibration because the acoustic load on a diaphragm is asymmetric. This may cause distortion and also cause a voice coil to rub against a magnet structure. In some embodiments of the present disclosure, the transducer 200 provides a venting structure optimized to minimize the asymmetry of the acoustic load on the diaphragm 225, and this may mitigate issues related to slot loading of a planar transducer (for example, the flat micro-speaker 100 in FIG. 1) of the comparison example, which makes rocking likely to occur due to the asymmetric acoustic load on the diaphragm.

[0041] A transducer may exhibit symmetric behavior for an instroke and an outstroke. It is better that the electromagnetic force of the voice coil, coil inductance, and suspension stiffness are as symmetric as possible at remaining positions. Existing slim transducer designs sacrifice symmetry for a slim form factor. Some embodiments of the present disclosure may have perfect symmetry for the electromagnetic force and coil inductance.

[0042] FIGS. 5A to 5G respectively illustrate plan views of example slot-loaded ultra-thin transducers with various air-flow venting, according to some embodiments of the present disclosure. FIG. 5A illustrates a plan view of the slot-loaded transducer 200 and the internal speaker volume 320 in a TV device 510, according to approaches of the related art. The transducer 200 includes an elliptical diaphragm 520. As shown by looking down at the transducer 200, the voice coil 240 surrounds a magnet system. The transducer 200 discharges air straight to a listening environment (for example, a room or the like) from the upper slot 260 (see FIGS. 2A and 2B) across the entire front of the transducer 200. The transducer 200 also discharges air for air flow to the internal speaker volume 320 from the lower slot 265 (FIGS. 2A and 2B).

[0043] FIG. 5B illustrates a plan view of the example slot-loaded ultra-thin transducer 200 with lateral exit slots 540 and 541 for air flow-venting, and the internal speaker volume 320 of the TV device 510, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, improved air venting for the slot-loaded transducer 200 forces air venting through the lateral exit slots 540 and 541, and this improves the asymmetry of the diaphragm 225 (FIGS. 2A and 2B). In some embodiments of the present disclosure, the transducer 200 includes an optimum configuration of upper and lower walls (and exit slots 530 and 531 along with a slot venting to the internal speaker volume 320) that minimize the amount of rocking exhibited by the diaphragm 225.

[0044] FIG. 5C illustrates a plan view of the example slot-loaded ultra-slim transducer 200 with front-open airflow venting, according to some embodiments of the present disclosure. FIG. 5D illustrates a plan view of the slot-loaded ultra-slim transducer 200 with air flow in the rear-center and sides to the internal speaker volume 320, according to some embodiments of the present disclosure. FIG. 5E illustrates a plan view of the example slot-loaded ultra-slim transducer 200 with front sides air-flow venting to a listening environment, according to some embodiments of the present disclosure. FIG. 5F illustrates a plan view of the example slot-loaded ultra-slim transducer 200 with rear-center air-flow venting to the internal speaker volume 320, according to some embodiments of the present disclosure. FIG. 5G illustrates a plan view of the example slot-loaded ultra-slim transducer 200 with back-sides air-flow venting to the internal speaker volume 320, according to some embodiments of the present disclosure.

[0045] FIG. 6 illustrates a graph 600 of the propensity for rocking motion 610 versus frequency 615 for the examples in FIGS. 5A to 5G. A curve 620 corresponds to the front-sides venting with the back-center venting; a curve 621 corresponds to the front-sides venting with the back-sides and center venting; a curve 622 corresponds to the front-sides venting with the back-center venting; a curve 623 corresponds to the front venting with the back-sides and center venting; a curve 624 corresponds to the front-sides venting with the back-sides venting; and a curve 625 corresponds to the front venting with the back-sides venting. As can be seen in the graph 600, the minimum propensity for rocking is achieved by the following configurations (less is better): front open (see FIG. 5A) with back-center open (and sides closed) (see FIG. 5F) (the case of 620), and front-sides open (see FIG. 5B) with back-center and sides open (see FIG. 5D) (the case of 621).

[0046] FIG. 7 illustrates a graph 700 of sound pressure level (SPL) 710 versus frequency 715 for the examples in FIGS. 5A to 5G, according to some embodiments of the present disclosure. A curve 720 corresponds to the front venting with the back-sides and center venting; a curve 721 corresponds to the front-sides venting with the back-sides and center venting; a curve 722 corresponds to the front venting with the back-center venting; a curve 723 corresponds to the front-sides venting with the back-center venting; a curve 724 corresponds to the front venting with the back-sides venting; and a curve 725 corresponds to the front-sides venting with the back-sides venting. As shown, the highest output occurs by the following configurations (more is better): front venting (see FIG. 5C) with back-center and sides venting (see FIG. 5D) (the case of 720), and front-sides venting (see FIG. 5B) with back-center and sides venting (see FIG. 5D) (the case of 721).

[0047] FIG. 8A illustrates a cross-sectional view of an example ultra-thin transducer 800 with a planar diaphragm 820, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 800 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the planar diaphragm 820, and a structure (or frame) 830. In some example embodiments of the present disclosure, the structure 830 may include low-carbon steel, soft magnetic steel, plastic, aluminum, or the like.

[0048] FIG. 8B illustrates a cross-sectional view of an example ultra-thin transducer 801 with a convex angled diaphragm 821, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 801 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the convex angled diaphragm 821, and the structure (or frame) 830.

[0049] FIG. 8C illustrates a cross-sectional view of an example ultra-thin transducer 802 with a concave angled diaphragm 822, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 802 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the concave angled diaphragm 821, and the structure (or frame) 830.

[0050] FIG. 8D illustrates a cross-sectional view of an example ultra-thin transducer 803 with the planar diaphragm 820 and an outer suspension (for example, a torus or the like) 840, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 803 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the planar diaphragm 820, the outer suspension 840, and the structure (or frame) 830.

[0051] FIG. 8E illustrates a cross-sectional view of an example ultra-thin transducer 804 with a structural diaphragm 850 and the outer suspension 840, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 804 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the structural diaphragm 850, the outer suspension 840, and the structure (or frame) 830. In some embodiments of the present disclosure, the structural diaphragm 850 may be made of structural foam or the like.

[0052] FIG. 8F illustrates a cross-sectional view of an example ultra-thin transducer 805 with the alternative-shaped voice coil 241, the structural diaphragm 850, and the outer suspension 840, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 805 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 241, the structural diaphragm 850, the outer suspension 840, and the structure (or frame) 830. In some embodiments of the present disclosure, the voice coil 240 has a different overall shape from the voice coil 240 (FIG. 2A) in that the shape of the voice coil 240 may be asymmetric or semi-asymmetric (for example, a reduction in dimension, angled, a change in thickness, a change in width/height, or the like).

[0053] FIG. 8G illustrates a cross-sectional view of an example ultra-thin transducer 806 with the other alternative-shaped voice coil 242, the structural diaphragm 850, and the outer suspension 840, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 806 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 241, the structural diaphragm 850, the outer suspension 840, and the structure (or frame) 830. In some embodiments of the present disclosure, the voice coil 242 has a different overall shape from the voice coil 240 (FIG. 2A) and the voice coil 241 (FIG. 8F) in that the shape of the voice coil 242 may be another asymmetric or semi-asymmetric shape (for example, a reduction in dimension, angled, a change in thickness, a change in width/height, or the like).

[0054] FIG. 8H illustrates a cross-sectional view of an example ultra-thin transducer 807 with the planar diaphragm 820 and an inner suspension 860, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 807 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the inner suspension 860, and the structure (or frame) 830. In some embodiments of the present disclosure, the inner suspension 860 may be a foam suspension, a poly-foam suspension, or the like.

[0055] FIG. 8I illustrates a cross-sectional view of an example ultra-thin transducer 808, which has the planar diaphragm 820, a top plate 865, and a back plate 866 and is configured for slot radiation, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 808 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the top plate 865, and the back plate 866. In some embodiments of the present disclosure, the slot or vent 260 radiates sound waves to a listening environment (for example, a room or the like), and the slot or vent 265 radiates sound waves internally to the speaker volume. In some embodiments of the present disclosure, each of the top plate 865 and the back plate 866 may be made of low-carbon steel, soft magnetic steel, or the like.

[0056] FIG. 8J illustrates a cross-sectional view of an example ultra-thin transducer 809 with the planar diaphragm 820 and a ferrofluid seal 841, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 809 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the ferrofluid seal 841, and the structure (or frame) 830. The ferrofluid seal 841 uses a response of a magnetic field to an applied magnetic field of a magnet system of the transducer 809. A ferrofluid may function as a liquid O-ring. The ferrofluid seal 841 allows the transducer 809 to more efficiently function with an improved audio response and improved power handling. Audio ferrofluids are based on two types of carrier liquids, synthetic hydrocarbons and esters. Both oils exhibit extremely low volatility and thermal stability. Saturation magnetization (a maximum value of a magnetic moment per unit volume when all domains are aligned) is determined by properties of a suspended magnetic material and by the volumetric load of the material. Physical and chemical properties such as density and viscosity correspond closely to those of the carrier liquid.

[0057] FIG. 8K illustrates a cross-sectional view of an example ultra-thin transducer 810 with the planar diaphragm 820 and a grease seal 842, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 810 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the grease seal 842, and the structure (or frame) 830. In some embodiments of the present disclosure, the grease seal 842 may be of a grease sealing compound type such as grease seal compounds including silicones.

[0058] FIG. 8L illustrates a cross-sectional view of another example ultra-thin transducer 811 with the planar diaphragm 820, a top plate 871, and a back plate 870, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 811 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the top plate 871, the back plate 870, and the structure (or frame) 830. In some embodiments of the present disclosure, each of the top plate

871 and the back plate 870 may include low-carbon steel, soft carbon steel, or the like. In some embodiments of the present disclosure, the back plate 870 may be formed separately from or integrally with the structure (or frame) 830.

[0059] FIG. 8L illustrates a cross-sectional view of an example ultra-thin transducer 812 with the planar diaphragm 820, a perforated top plate 871/872/873, and a perforated back plate 870/874, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 812 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the top plate 871/872/873 (see FIG. 13), and the back plate 870/874. In some embodiments of the present disclosure, each of the top plate 871/872/873 and the back plate 870/874 may be made of low-carbon steel, soft magnetic steel, or the like, portions of the top plate 873 and the back plate 874 may be perforated to allow sound to radiate to a listening environment and a speaker enclosure, and other portions of the top plate 870 and the back plate 871 may be solid to maximize the flux near the voice coil 240. Although the ultra-thin transducer 812 is shown for direct radiation of sound (as opposed to slot radiation), some embodiments of the present disclosure may include a combination of slot radiation and direct radiation.

[0060] FIG. 8N illustrates a cross-sectional view of an example ultra-thin transducer 813, which has the planar diaphragm 820 and is configured for slot radiation, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 813 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, and a frame 880. In some embodiments of the present disclosure, the slot or vent 260 radiates sound waves to a listening environment (for example, a room or the like), and the slot or vent 265 radiates sound waves internally to a speaker volume. In some embodiments of the present disclosure, the frame 880 may be made of low-carbon steel, soft magnetic steel, plastic, aluminum, or the like.

[0061] FIG. 8O illustrates a cross-sectional view of an example ultra-thin transducer 814 with the planar diaphragm 820, the top plate 871, and the back plate 870, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 814 includes the lower magnet 210, the upper magnet 215, the middle plate 220, the voice coil 240, the diaphragm 820, the back plate 870, the top plate 871, and a structure (or frame) 811. The slot or vent 260 radiates sound waves to a listening environment (for example, a room or the like), and the slot or vent 265 radiates sound waves internally into a speaker volume. In some embodiments of the present disclosure, the frame 881 may be made of low-carbon steel, soft magnetic steel, plastic, aluminum, or the like. In some embodiments of the present disclosure, the back plate 870 and the top plate 871 may be formed separately from or integrally with the structure (or frame) 881.

[0062] FIG. 9A illustrates a cross-sectional view of an example transducer 900 according to the related art, which has a planar diaphragm and is configured for slot radiation. The transducer 900 includes a top portion having a width 920 of 1 mm, connection portions respectively having a width 930 of 2 mm and a width 940 of 6 mm, and a bottom portion having a width 950 of 1 mm. The total thickness of the transducer 900 is 10 mm, and the transducer 900 has a peak displacement of 2 mm.

[0063] FIG. 9A illustrates a cross-sectional view of an example ultra-thin transducer 950, which has a planar diaphragm and is configured for slot radiation, according to some embodiments of the present disclosure. The transducer 950 includes a voice coil 960 (for example, similar to the voice coil 240 in FIG. 2A), a frame 970, and an inner suspension 980 (for example, similar to the inner suspension 860 in FIG. 8H), the frame 970 including a top portion having a width 921 of 1 mm, connection portions respectively having a width 931 of 2 mm and a width 941 of 4 mm, and a bottom portion having a width 951 of 1 mm. The total thickness of the transducer 950 is 8 mm, and the transducer 950 has a peak displacement of 2 mm. The transducer 950 has a total thickness which is 20 % (that is, 2 mm) less than that of the transducer 900.

[0064] FIG. 10A illustrates a cross-sectional view of an example ultra-thin transducer 1000, which has a planar diaphragm and is configured for slot radiation, according to the related art. The transducer 1000 has a peak displacement 1020 of 1 mm and includes a top portion having and a width 1025 of 1 mm, a connection portion having a width 1030 of 2 mm, and a bottom portion 1010 having a width 1035 of 1 mm. The total thickness is 5 mm.

[0065] FIG. 10B illustrates a cross-sectional view of an example ultra-thin transducer 1050, which has a planar diaphragm and is configured for direct radiation, according to some embodiments of the present disclosure. The transducer 1050 includes a voice coil 1060 (for example, similar to the voice coil 240 in FIG. 2A) and an inner suspension 1080 (similar to the inner suspension 860 in FIG. 8H), together with a top portion having a width 1026 of 10 mm, a connection portion having a width 1031 of 2 mm, and a bottom portion having a width 1036 of 1 mm. The transducer 1050 has a total thickness of 4 mm and a peak displacement of 1 mm. The transducer 1050 has a total thickness which is 20 % (that is, 2 mm) less than that of the transducer 1000.

[0066] FIG. 11A illustrates a cross-sectional view of an example ultra-thin transducer 1100 with an inner surround 1120 to prevent short circuiting, according to some embodiments of the present disclosure. When a diaphragm moves forward, the diaphragm compresses air in front thereof while the medium is sparse at the opposite end. This causes a phase difference of 180°. At low frequencies, the diaphragm moves slowly such that air moves from one side to the other side and balances a difference in pressure. This produces a low-frequency air flow but no sound (acoustic short circuiting). In some embodiments of the present disclosure, the addition of the inner surround 1120 assists to prevent the occurrence of acoustic short circuiting. The inner surround 1120 may be made of foal, rubber, or the like.

[0067] FIG. 11B illustrates a cross-sectional view of an example ultra-thin transducer 1101 with a compressible material 1130 to prevent acoustic short circuiting, according to some embodiments of the present disclosure. In an embodiment of the present disclosure, the compressible material 1130 may include compressible foam or a material similar thereto. In some embodiments of the present disclosure, the addition of the compressible material 1130 assists to prevent the occurrence of acoustic short circuiting.

[0068] FIG. 11C illustrates a cross-sectional view of an example ultra-thin transducer 1102 with the ferrofluid seal 841 (see FIG. 8J), according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the addition of the ferrofluid seal 841 may assist to prevent the occurrence of acoustic short circuiting and may also reduce the propensity for rocking.

[0069] FIG. 12A illustrates a top perspective view of an example ultra-thin transducer 1200 with a top plate 1220, according to some embodiments of the present disclosure. The transducer 1220 includes a frame 1210 for supporting and mounting the transducer 1200. FIG. 12B illustrates a top perspective view of the example ultra-thin transducer 1200 of FIG. 12A with the top plate 1220 removed, according to some embodiments of the present disclosure. As shown, the transducer 1200 includes a magnet system including the upper magnet 215, the voice coil 240, and a diaphragm 1230 (for example, similar to the diaphragm 520 in FIG. 5A). FIG. 12C illustrates a cross-sectional view of the example ultra-thin transducer 1200 of FIGS. 12A and 12B, according to some embodiments of the present disclosure.

[0070] FIG. 13 illustrates a cross-sectional view of an example ultra-thin transducer 1300 with a perforated top plate 1310, according to some embodiments of the present disclosure. In some embodiments of the present disclosure, the transducer 1300 includes a magnet system (see FIG. 2A), the voice coil 240, and a diaphragm 1320. In some embodiments of the present disclosure, sound waves radiate out through perforations of the top plate 1310. The diaphragm 1320 has a circular or elliptical shape.

[0071] FIG. 14 illustrates a plan view of another example ultra-thin transducer 1400 with an elliptical diaphragm 1410, according to some embodiments of the present disclosure. It should be noted that various diaphragm shapes, such as different sized circular shapes, elliptical shapes, and the like, may be employed.

[0072] References in the claims to an element in the singular is not intended to mean "one and only" unless explicitly so stated, but rather "one or more". All structural and functional equivalents to the elements of the above-described example embodiments, which are currently known or later come to be known to those of ordinary skill in the art, are intended to be encompassed by the present claims. No claim element herein is to be construed under the provisions of pre-AIA 35 U.S.C. section 112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or "step for".

[0073] The terminology used herein is for describing particular embodiments of the present disclosure only and is not intended to limit the present disclosure. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be understood that the terms "comprises" and/or "comprising", when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0074] The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the embodiments of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the present disclosure.

[0075] Although the embodiments of the present disclosure have been described with reference to certain versions thereof, other versions are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions included herein.

Claims

1. A speaker comprising a transducer, wherein the transducer comprises:

   a diaphragm comprising a hole with a first horizontal width;
   a voice coil arranged at least partially in the hole; and
   a column structure arranged at least partially in the voice coil.

2. The speaker of claim 1, wherein a shape of the voice coil is a ring shape with an outer horizontal width and an inner horizontal width, and the outer horizontal width is equal to or less than the first horizontal width of the hole.

3. The speaker of claim 1, wherein a shape of the voice coil is a ring shape with an outer horizontal width and

an inner horizontal width, and a second horizontal width of the column structure is equal to or less than the inner horizontal width of the ring shape.

4. The speaker of claim 1, wherein the column structure comprises:

an upper magnet;
a middle plate arranged below the upper magnet; and
a lower magnet arranged below the middle plate.

5. The speaker of claim 1, wherein the upper magnet is configured to apply an upper magnetic field to the voice coil;

the lower magnet is configured to apply a lower magnetic field to the voice coil; and
the middle plate is configured to guide at least one of the upper magnetic field or the lower magnetic field toward the voice coil.

6. The speaker of claim 4, further comprising:
a top plate above the upper magnet, wherein the top plate is configured to assist in directing at least a portion of the upper magnetic field toward the voice coil.

7. The speaker of claim 4, further comprising:
a bottom plate below the lower magnet, wherein the bottom plate is configured to assist in directing at least a portion of the lower magnetic field toward the voice coil.

8. The speaker of claim 4, wherein each of the upper magnet and the lower magnet comprises neodymium; and
the middle plate comprises low-carbon steel.

9. The speaker of claim 4, wherein a vertical axis with respect to the diaphragm is at a center of the hole;

the speaker further comprises a top plate arranged above the upper magnet and centered on the vertical axis, the top plate being configured to assist in directing at least a portion of the upper magnetic field toward the voice coil; and
the speaker further comprises a bottom plate arranged below the lower magnet and centered on the vertical axis, the bottom plate being configured to assist in directing at least a portion of the lower magnetic field toward the voice coil.

10. The speaker of claim 1, further comprising a suspension attached to the diaphragm,
wherein the suspension comprises at least one of an inner suspension or an outer suspension.

11. The speaker of claim 1, further comprising:
a lubricant arranged between the voice coil and the column structure.

12. The speaker of claim 11, wherein the lubricant comprises at least one of a ferrofluid or grease.

13. The speaker of claim 1, wherein the diaphragm comprises structural foam.

14. The speaker of claim 1, wherein a vertical axis with respect to the diaphragm is at a center of the hole, and the ring shape is centered on the vertical axis.

15. The speaker of claim 14, wherein the column structure is centered on the vertical axis.

FIG. 1

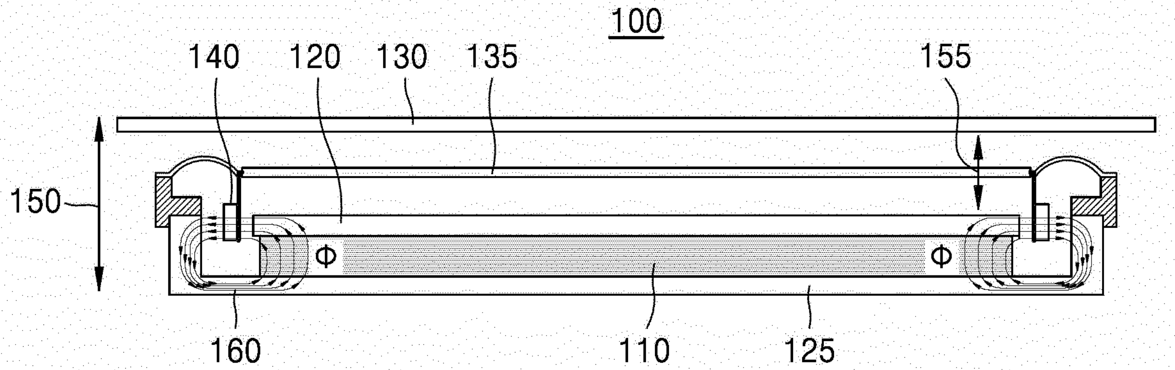


FIG. 2A

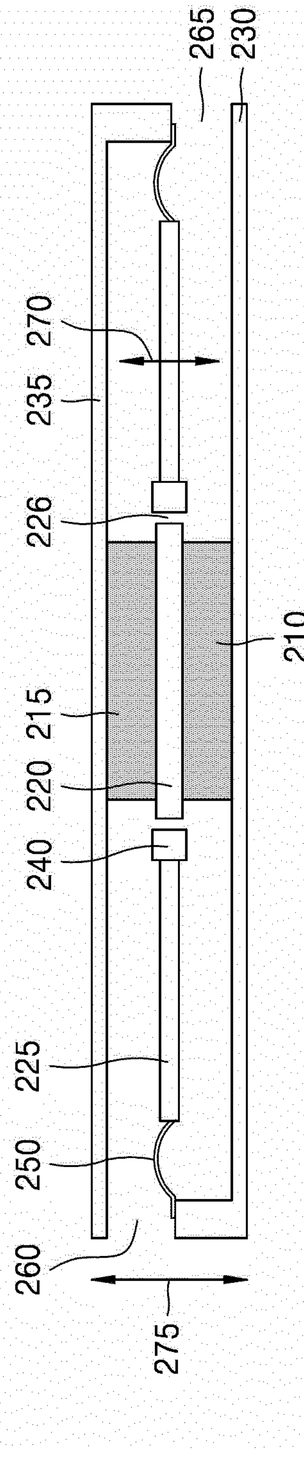


FIG. 2B

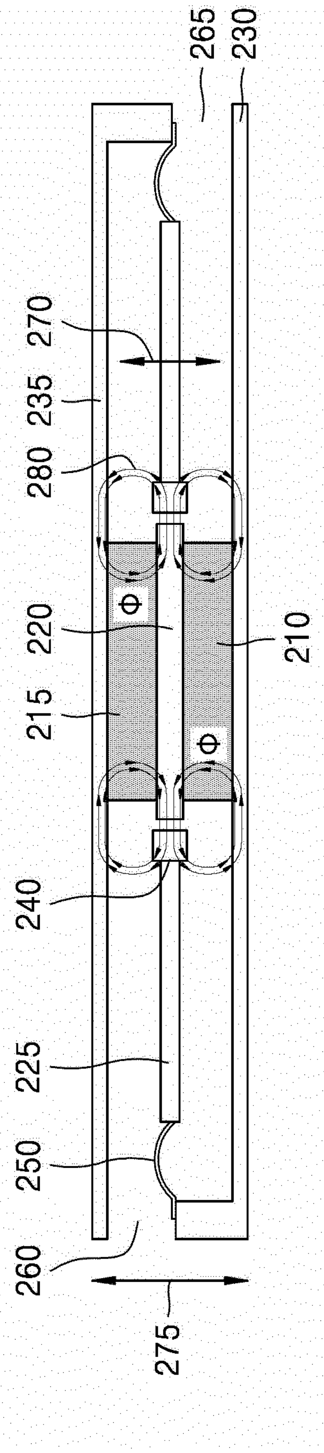


FIG. 3

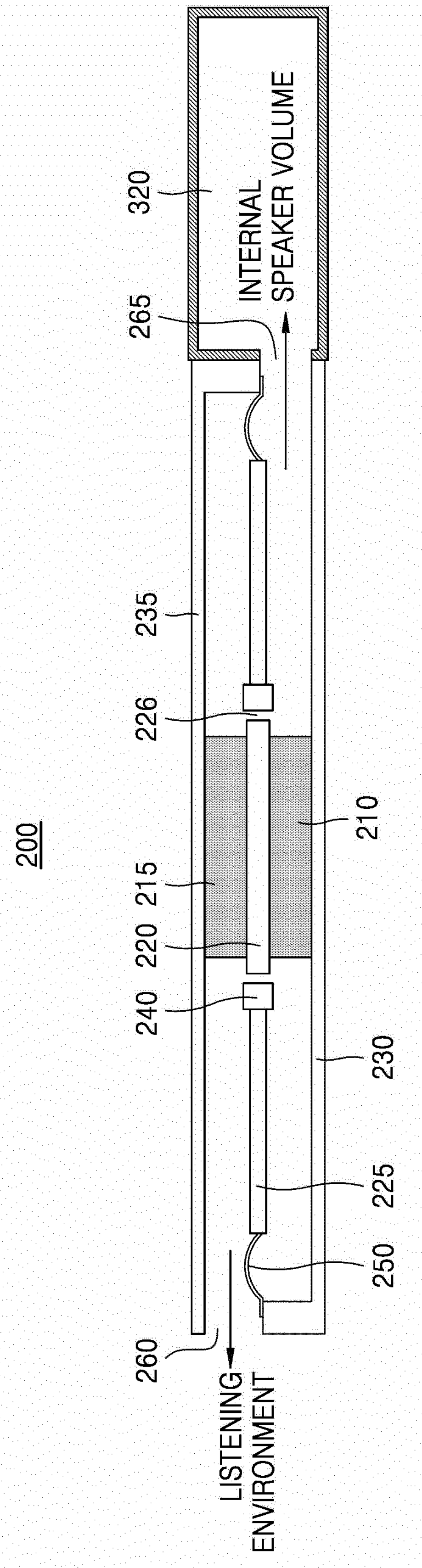

200
320
INTERNAL
SPEAKER VOLUME
265
235
226
210
215
220
240
230
225
250
260
LISTENING
ENVIRONMENT

FIG. 4

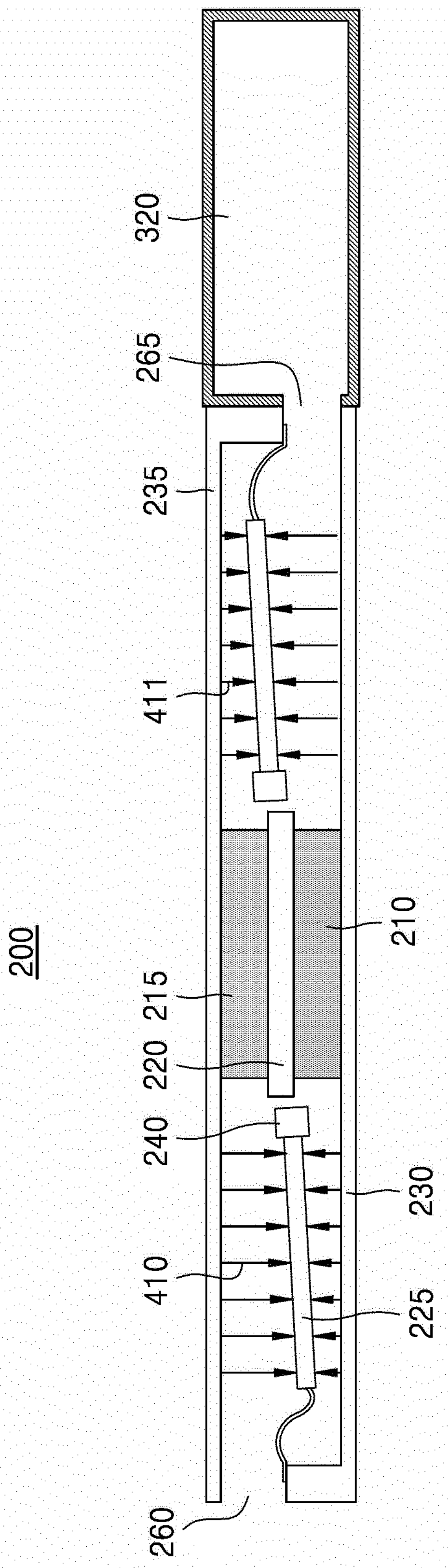


FIG. 5A

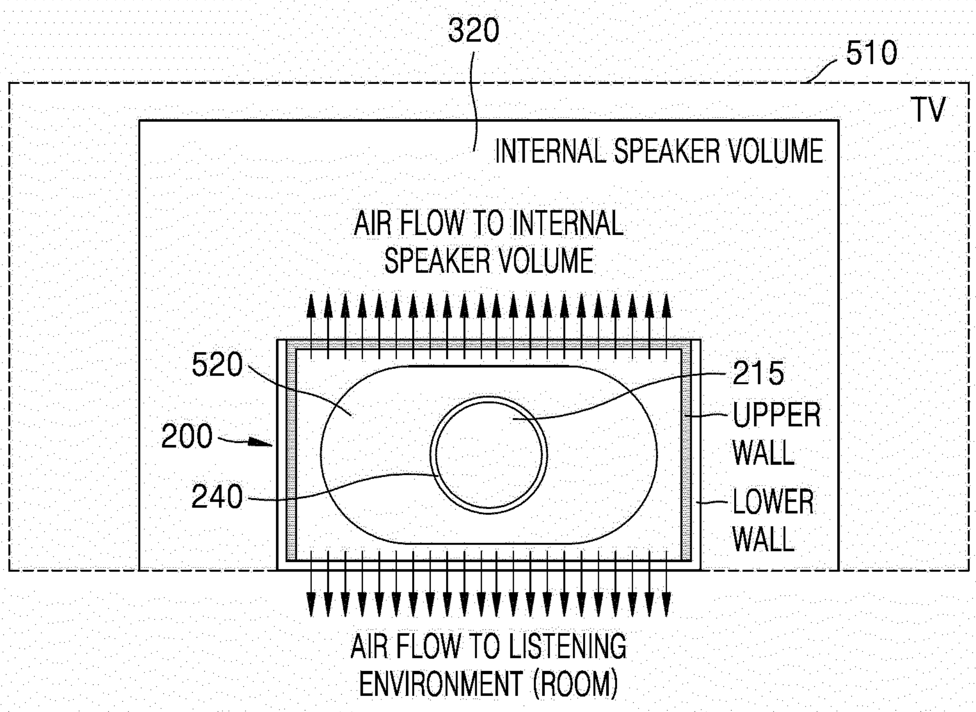

320
510
TV
INTERNAL SPEAKER VOLUME
AIR FLOW TO INTERNAL
SPEAKER VOLUME
520
215
UPPER
WALL
200
240
LOWER
WALL
AIR FLOW TO LISTENING
ENVIRONMENT (ROOM)

FIG. 5B

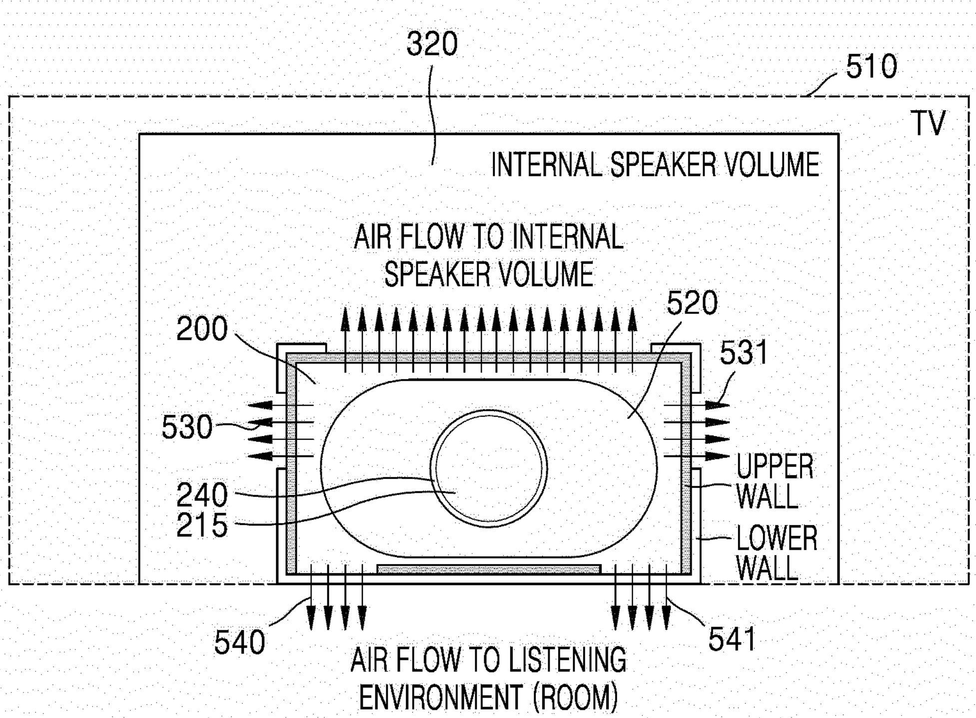

320
510
TV
INTERNAL SPEAKER VOLUME
AIR FLOW TO INTERNAL SPEAKER VOLUME
200
520
531
530
240
215
UPPER WALL
LOWER WALL
540
541
AIR FLOW TO LISTENING ENVIRONMENT (ROOM)

FIG. 5C

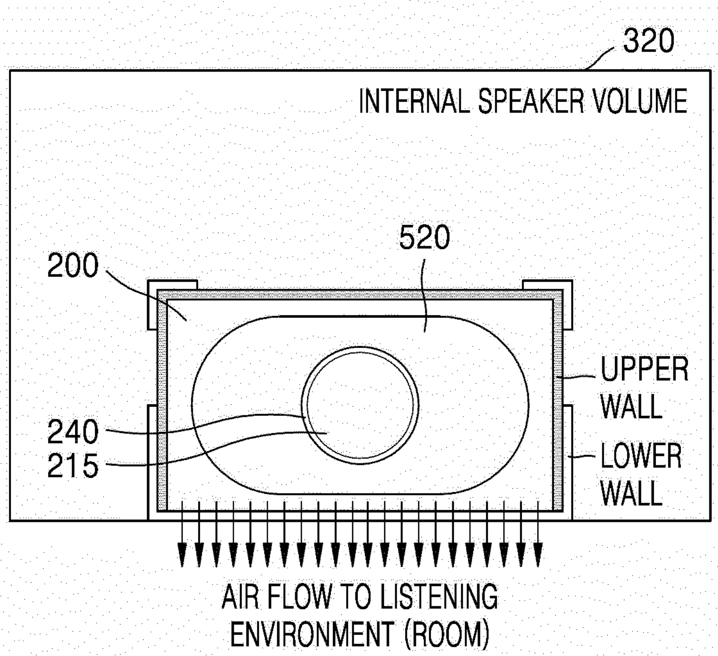

320
INTERNAL SPEAKER VOLUME
520
200
UPPER
WALL
240
215
LOWER
WALL
AIR FLOW TO LISTENING
ENVIRONMENT (ROOM)

FIG. 5D

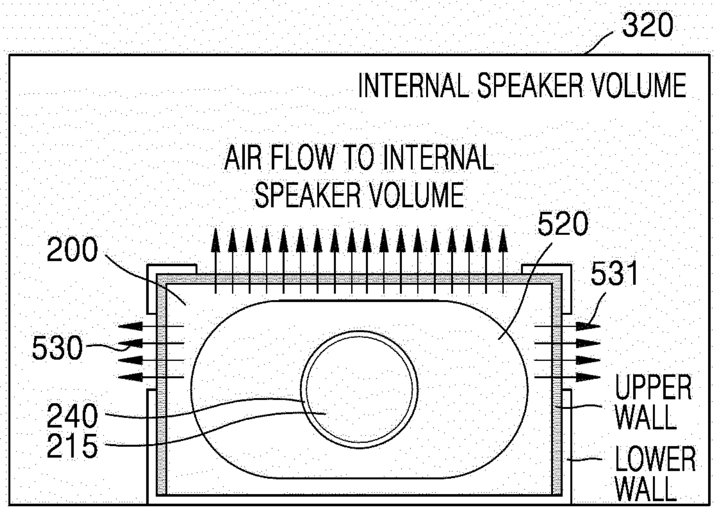

320
INTERNAL SPEAKER VOLUME
AIR FLOW TO INTERNAL
SPEAKER VOLUME
200
520
531
530
240
215
UPPER
WALL
LOWER
WALL

FIG. 5E

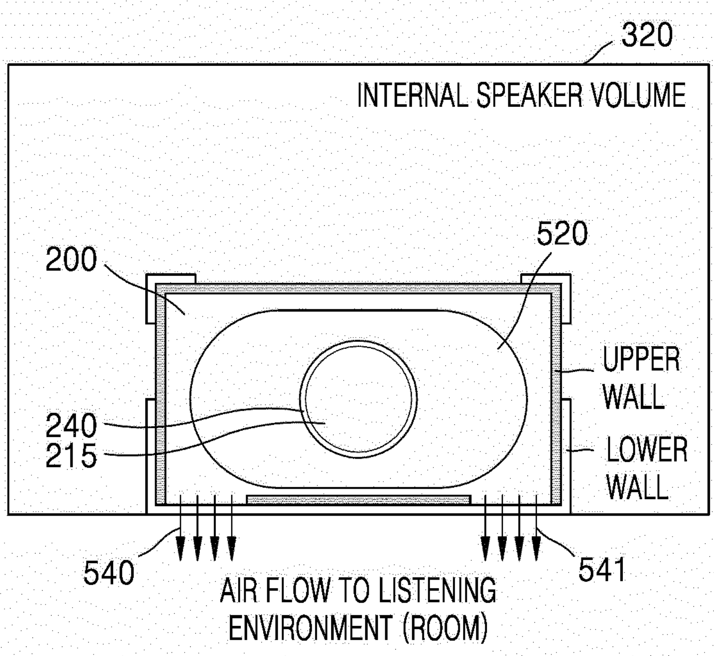

320
INTERNAL SPEAKER VOLUME
520
200
UPPER WALL
240
215
LOWER WALL
540
541
AIR FLOW TO LISTENING ENVIRONMENT (ROOM)

FIG. 5F

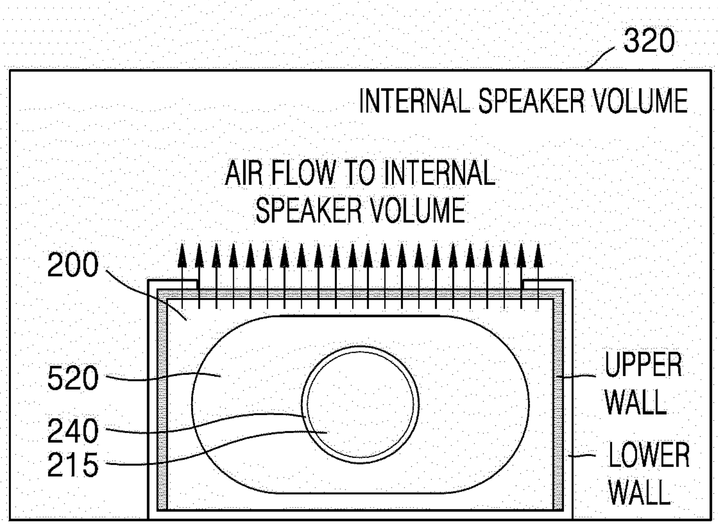

320
INTERNAL SPEAKER VOLUME
AIR FLOW TO INTERNAL
SPEAKER VOLUME
200
520
240
215
UPPER
WALL
LOWER
WALL

FIG. 5G

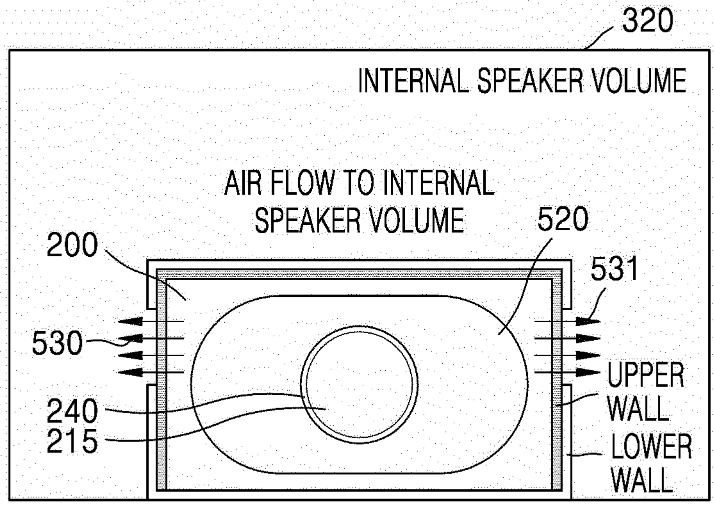

320
INTERNAL SPEAKER VOLUME
AIR FLOW TO INTERNAL SPEAKER VOLUME
200
520
531
530
UPPER WALL
240
215
LOWER WALL

FIG. 6

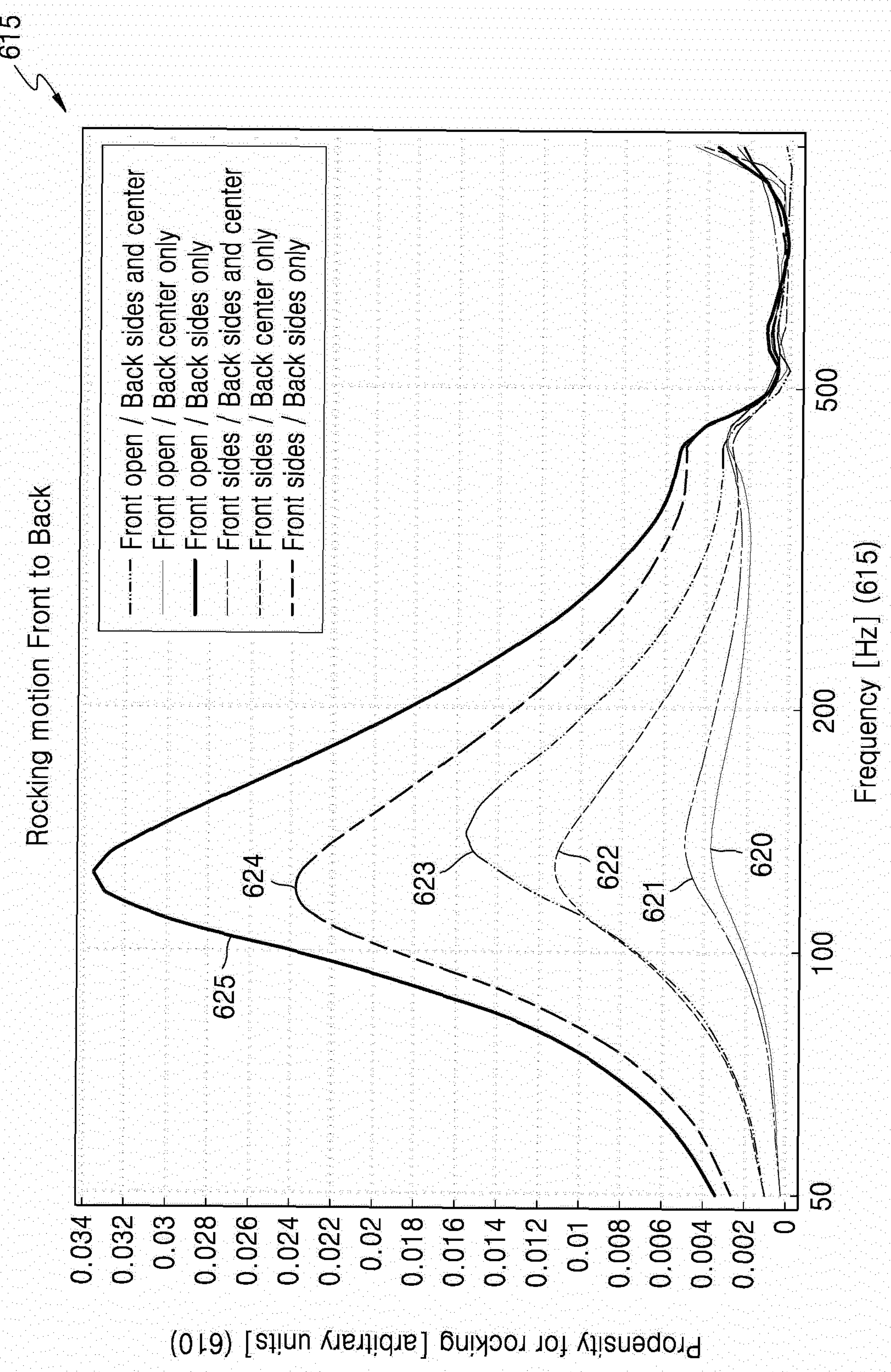

615
Rocking motion Front to Back
Front open / Back sides and center
Front open / Back center only
Front open / Back sides only
Front sides / Back sides and center
Front sides / Back center only
Front sides / Back sides only
625
624
623
622
621
620
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
50
100
200
500
Frequency [Hz] (615)
Propensity for rocking [arbitrary units] (610)

FIG. 7

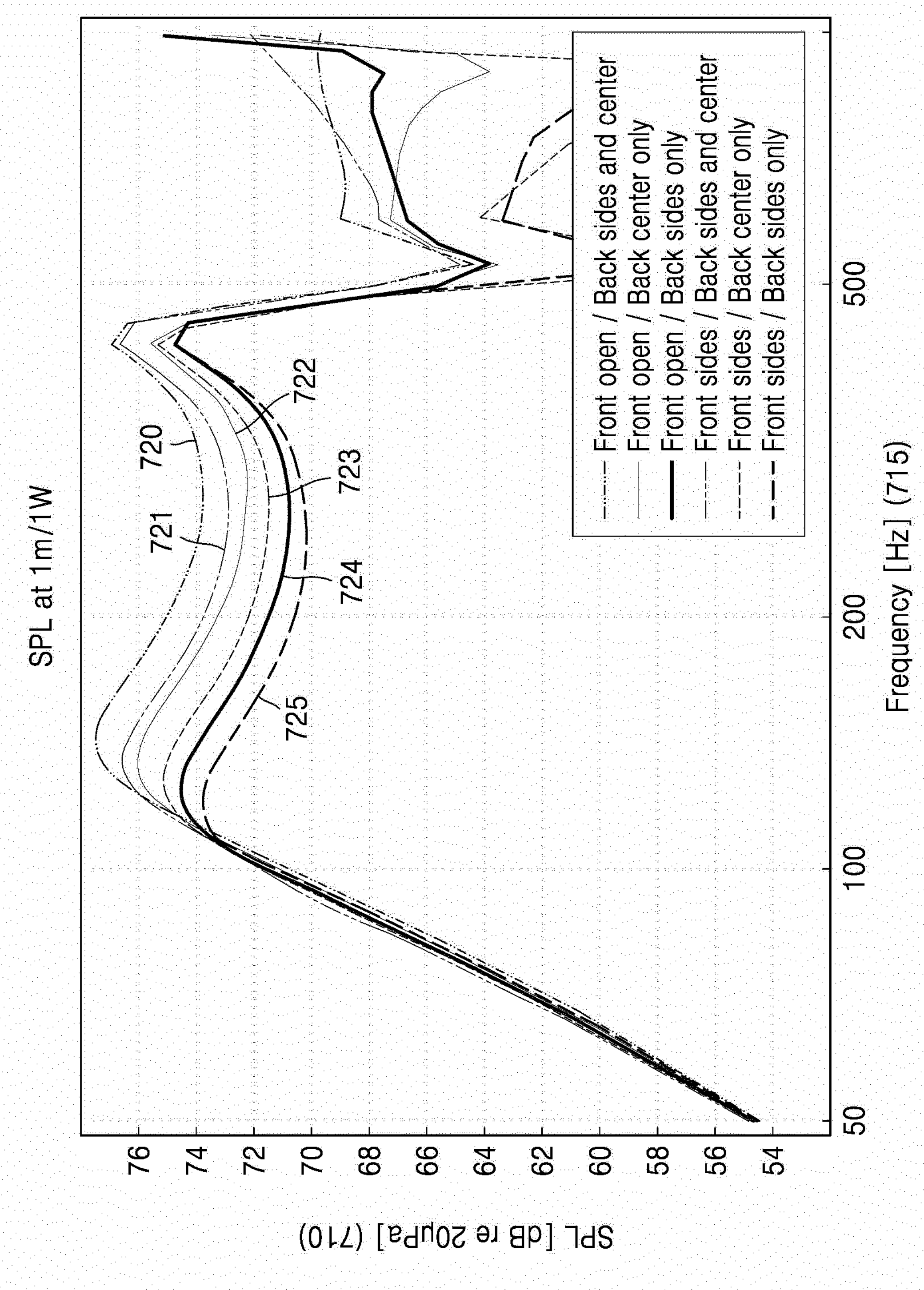

SPL at 1m/1W
SPL [dB re 20μPa] (710)
Frequency [Hz] (715)
720
721
722
723
724
725
Front open / Back sides and center
Front open / Back center only
Front open / Back sides only
Front sides / Back sides and center
Front sides / Back center only
Front sides / Back sides only

FIG. 8A

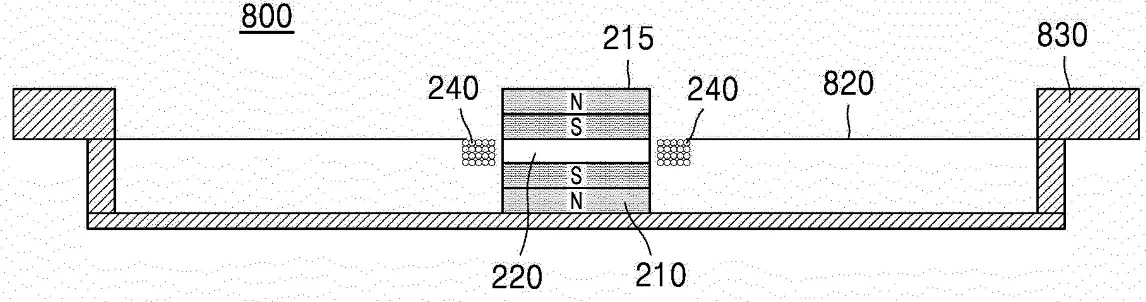


FIG. 8B

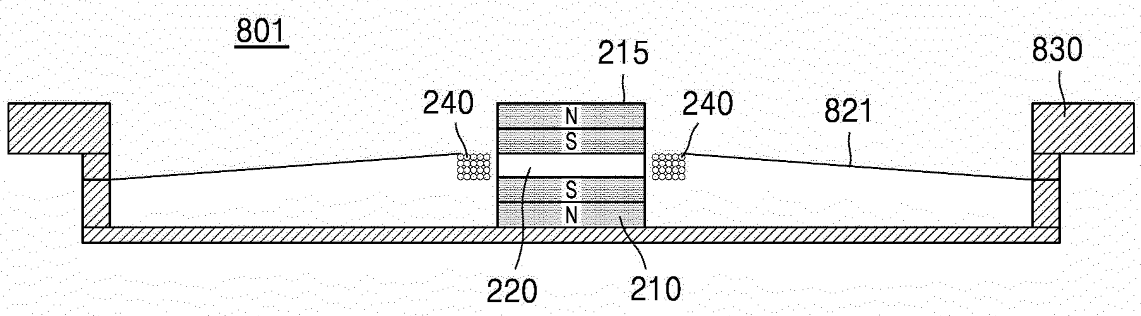


FIG. 8C

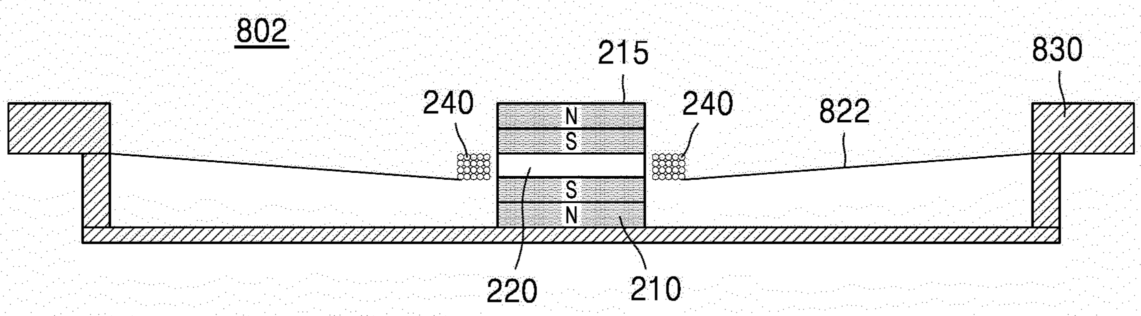


FIG. 8D

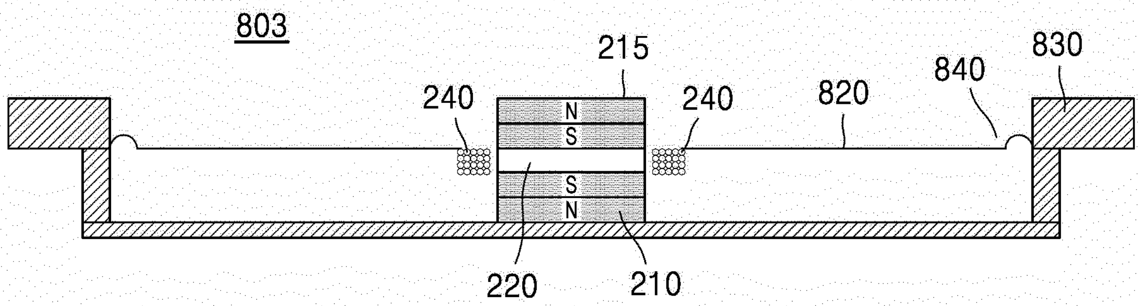


FIG. 8E

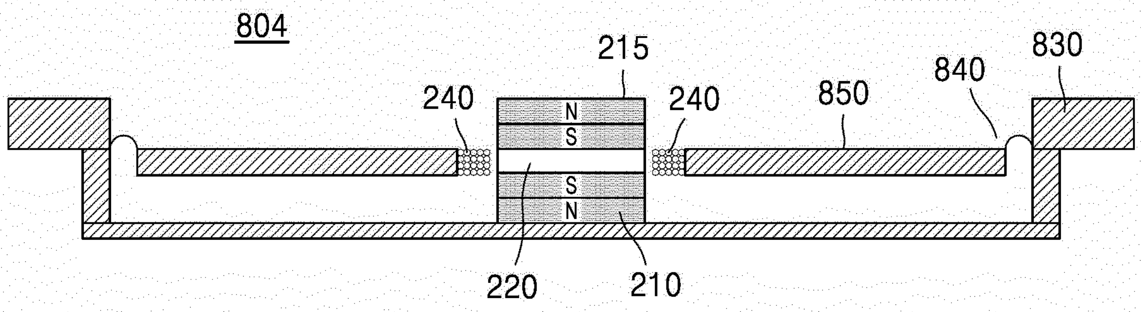


FIG. 8F

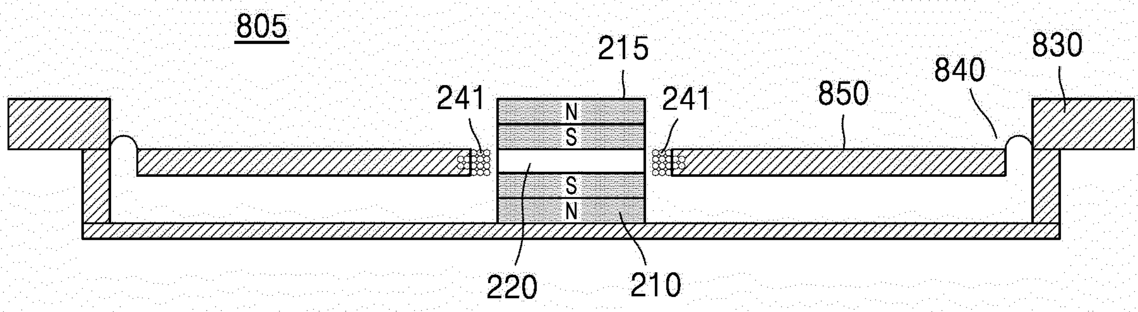


FIG. 8G

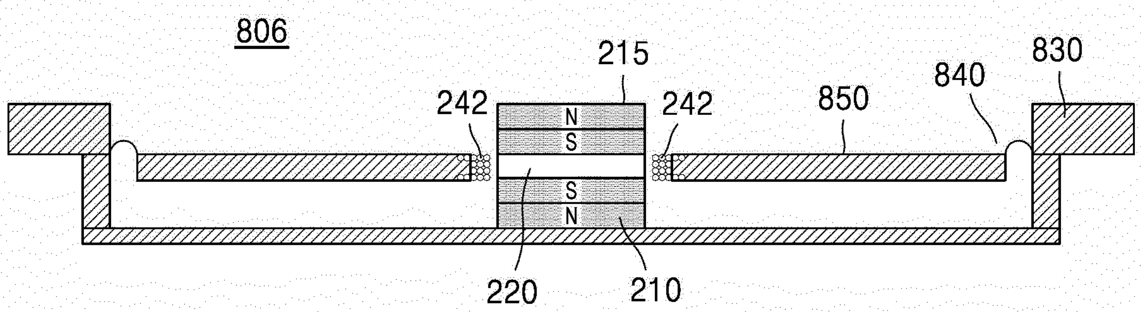


FIG. 8H

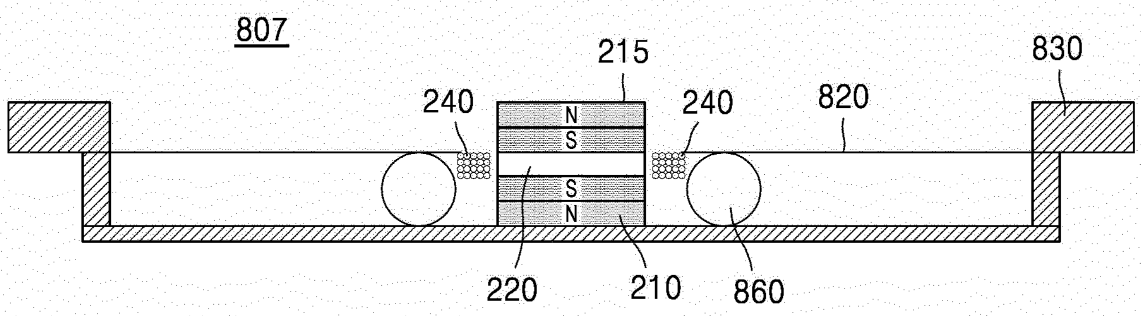


FIG. 8I

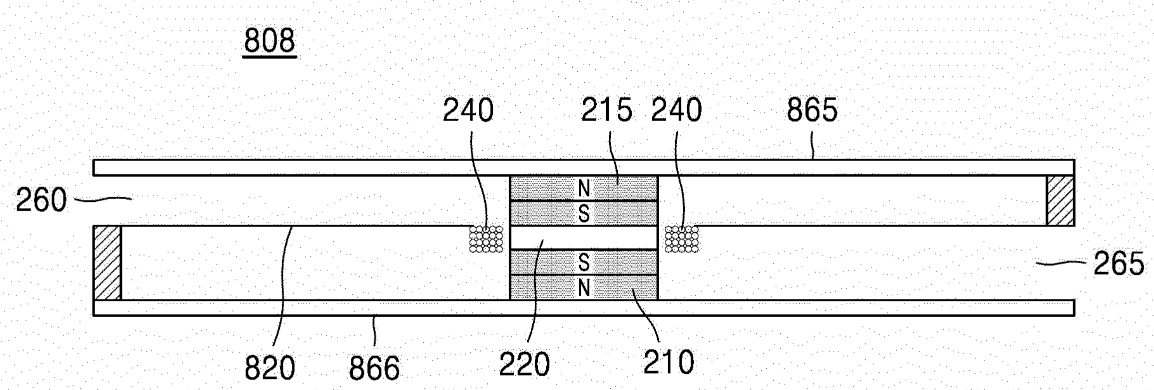


FIG. 8J

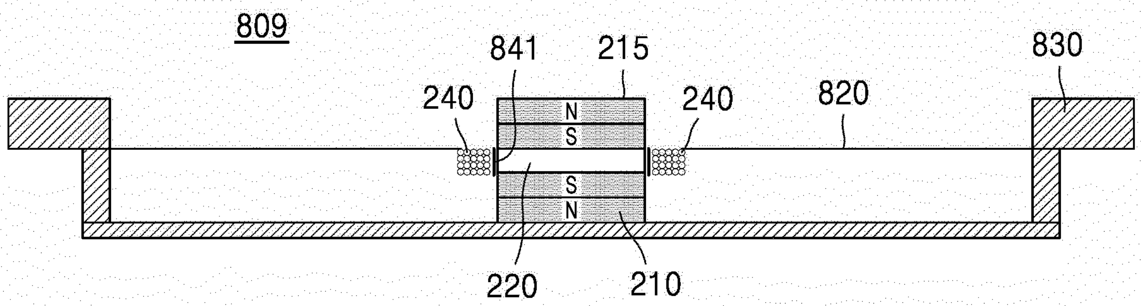


FIG. 8K

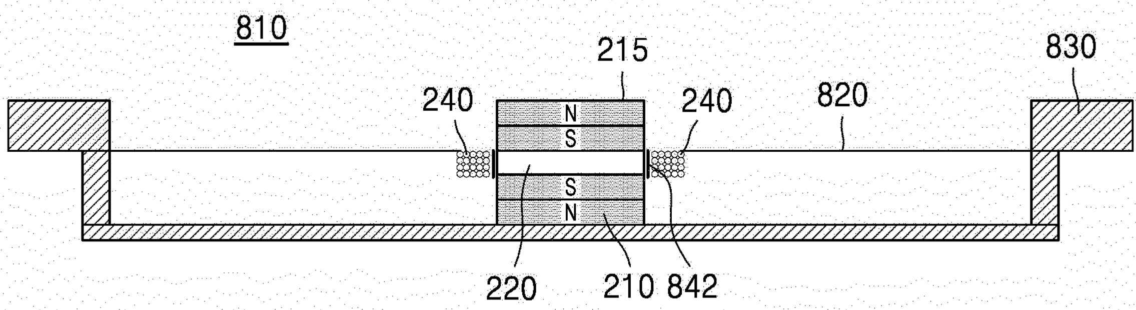


FIG. 8L

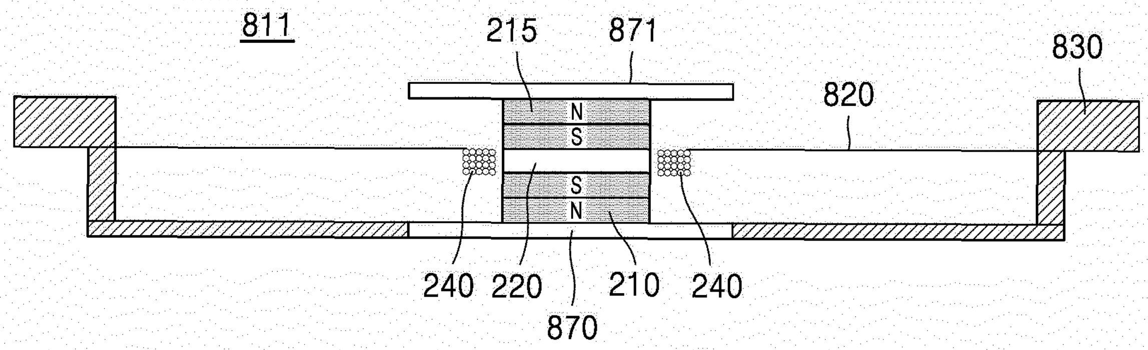


FIG. 8M

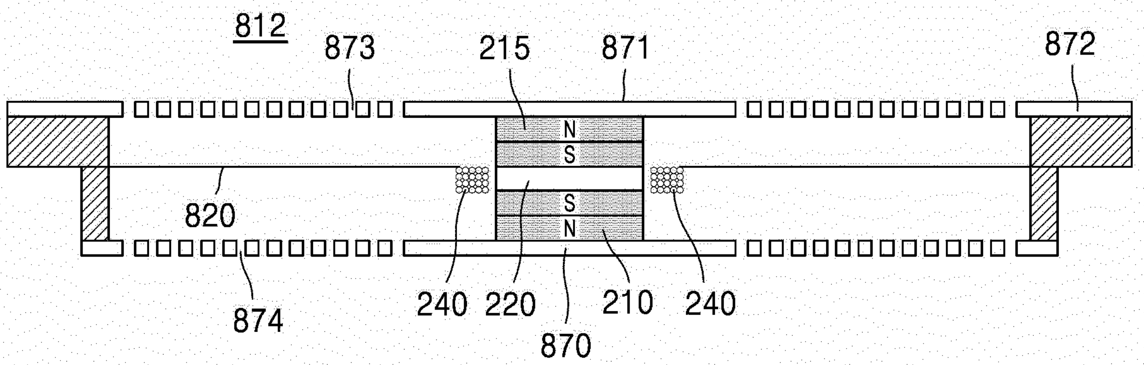


FIG. 8N

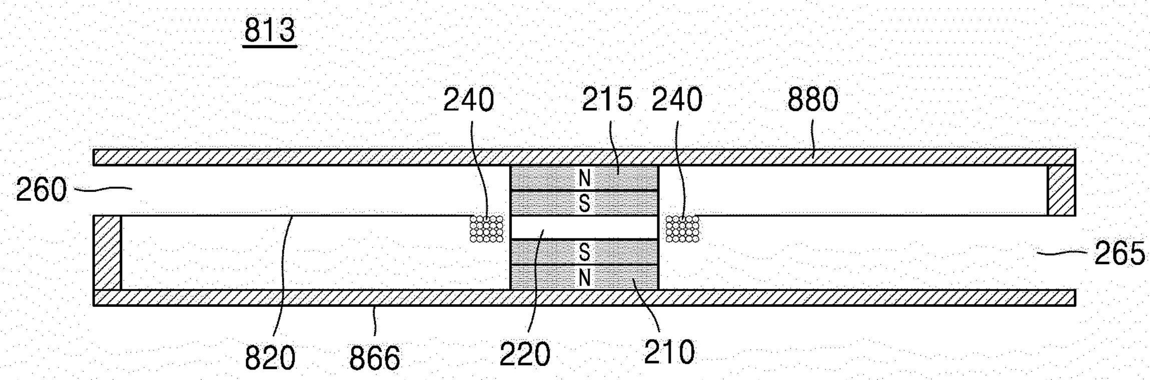


FIG. 80

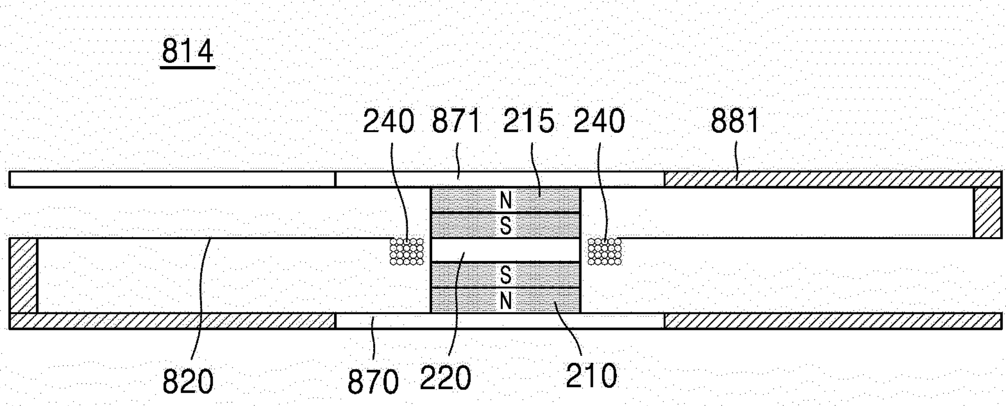


FIG. 9A

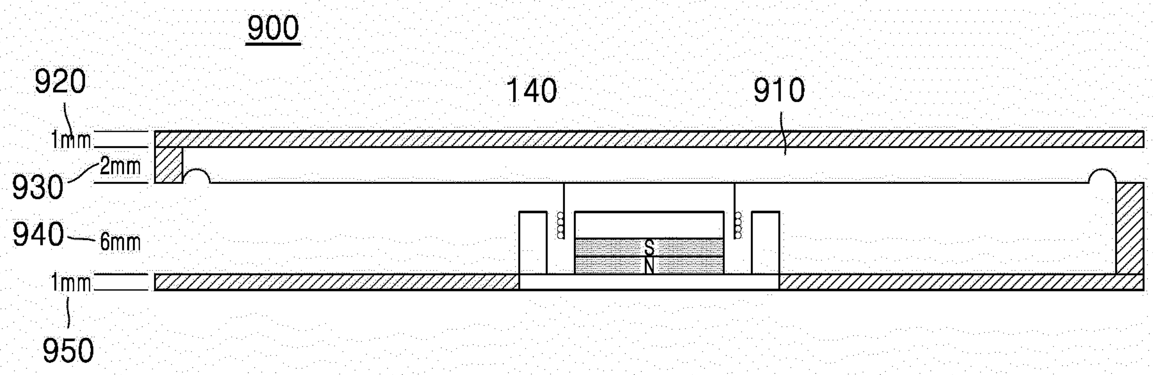


FIG. 9B

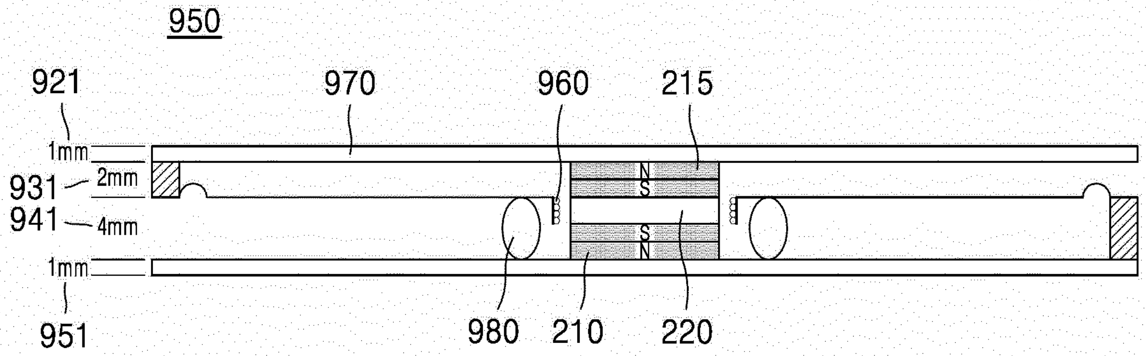


FIG. 10A

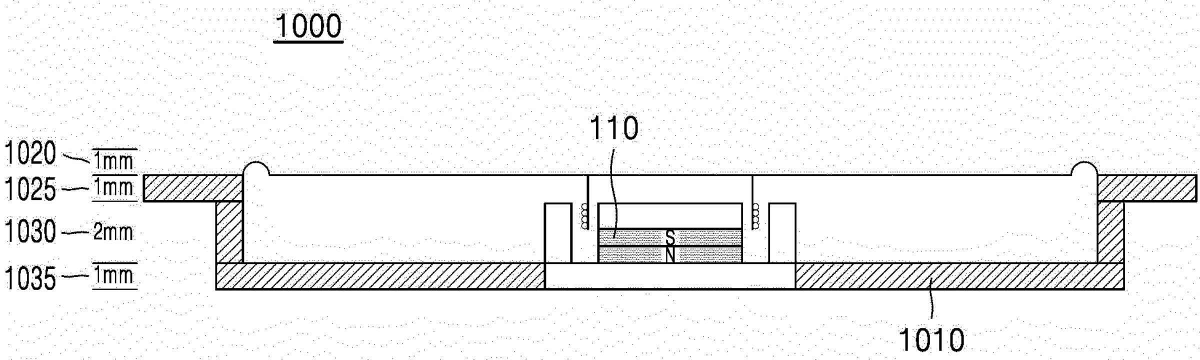


FIG. 10B

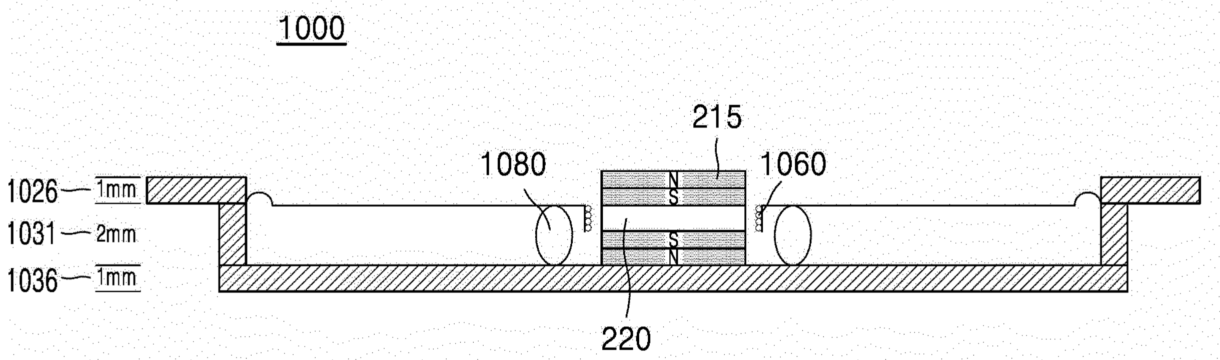


FIG. 11A

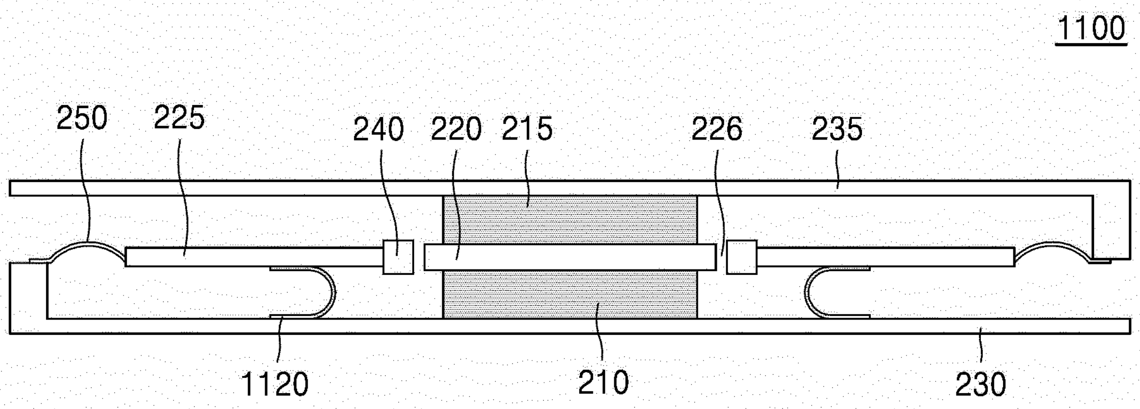


FIG. 11B

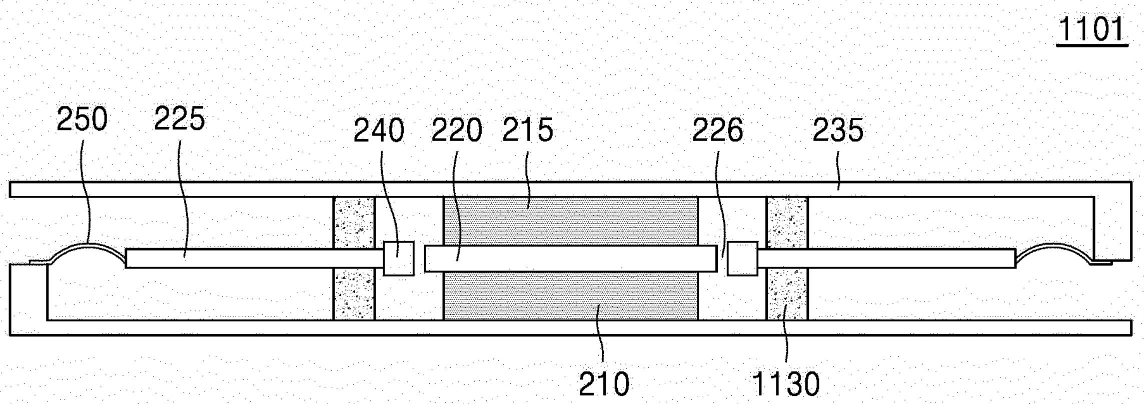


FIG. 11C

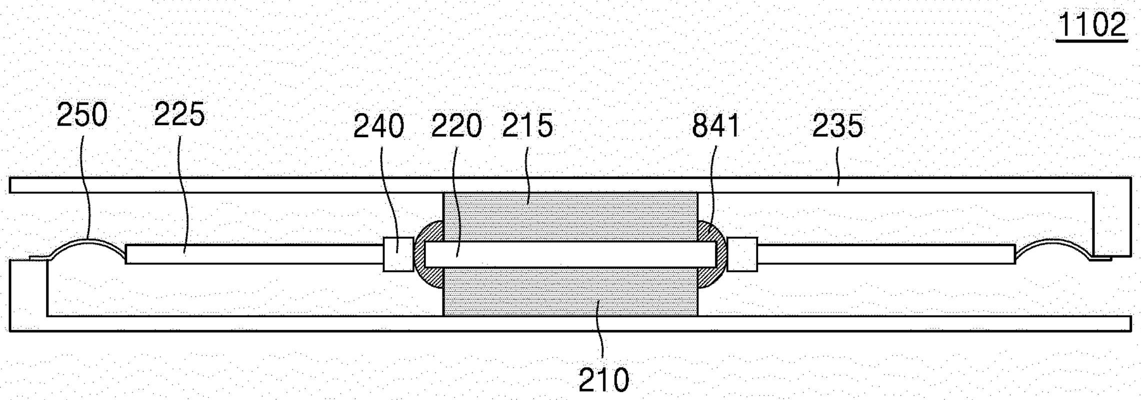


FIG. 12A

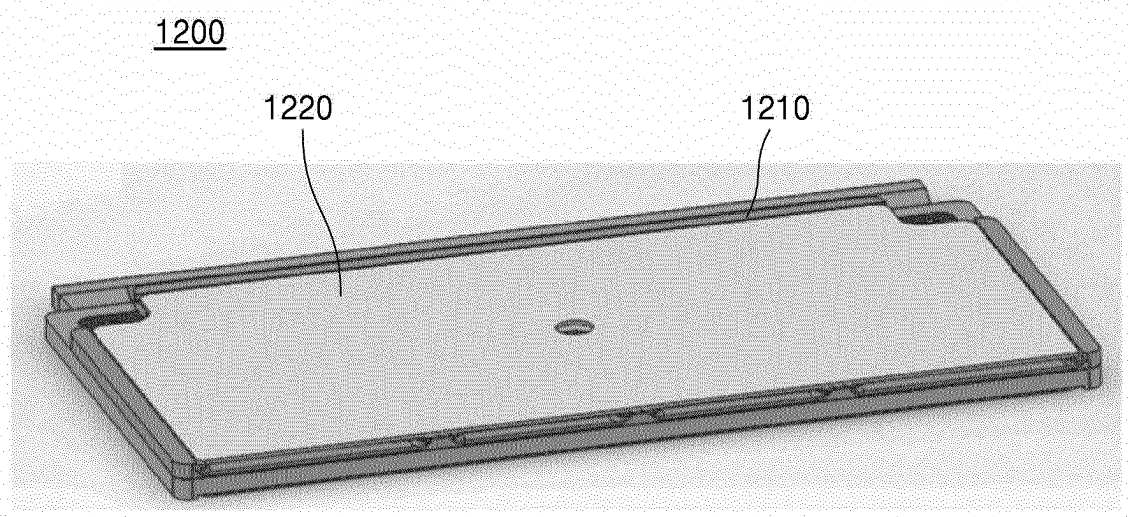


FIG. 12B

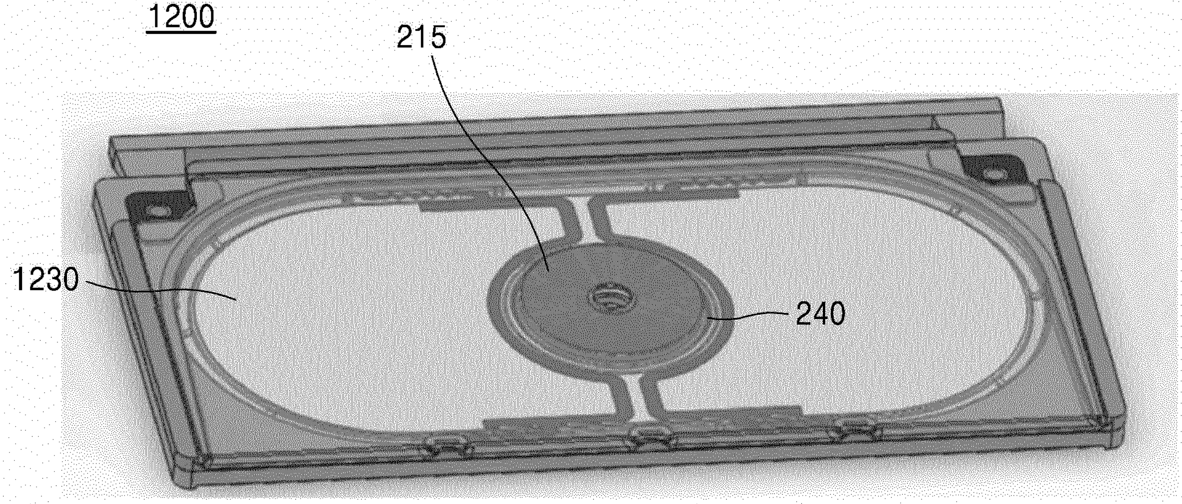


FIG. 12C

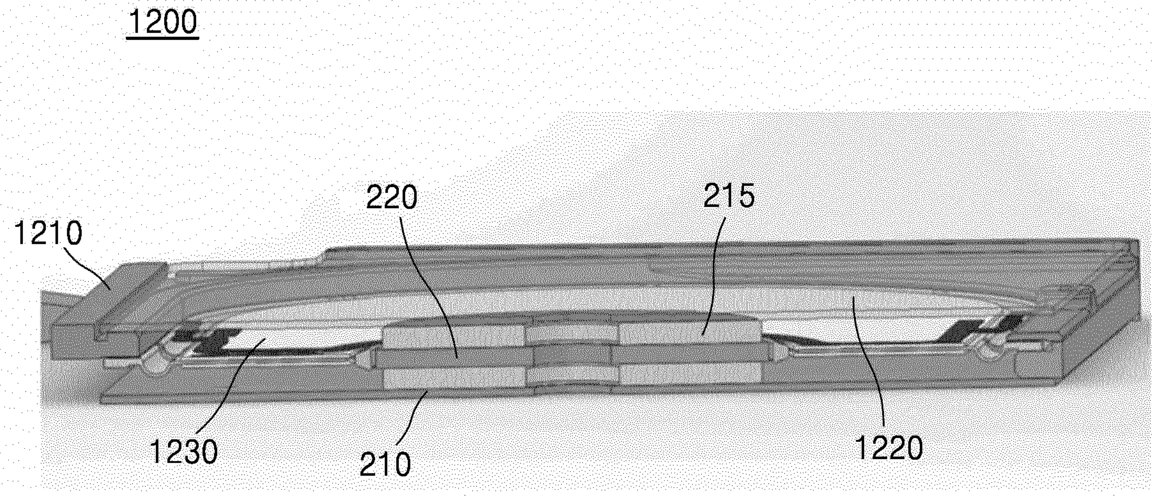


FIG. 13

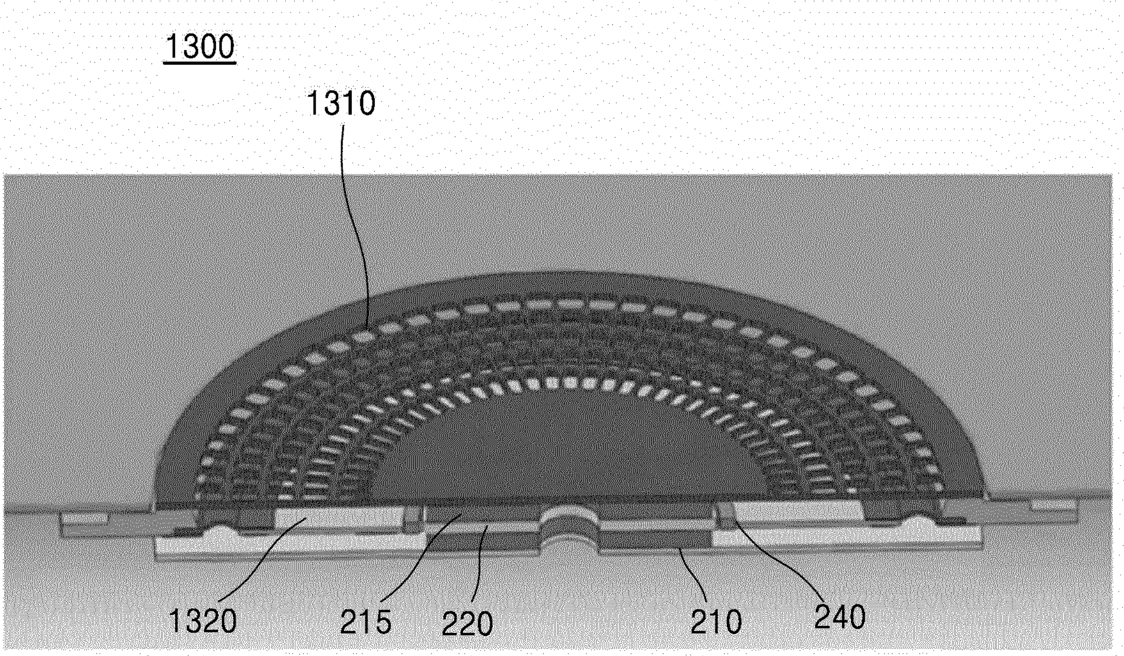
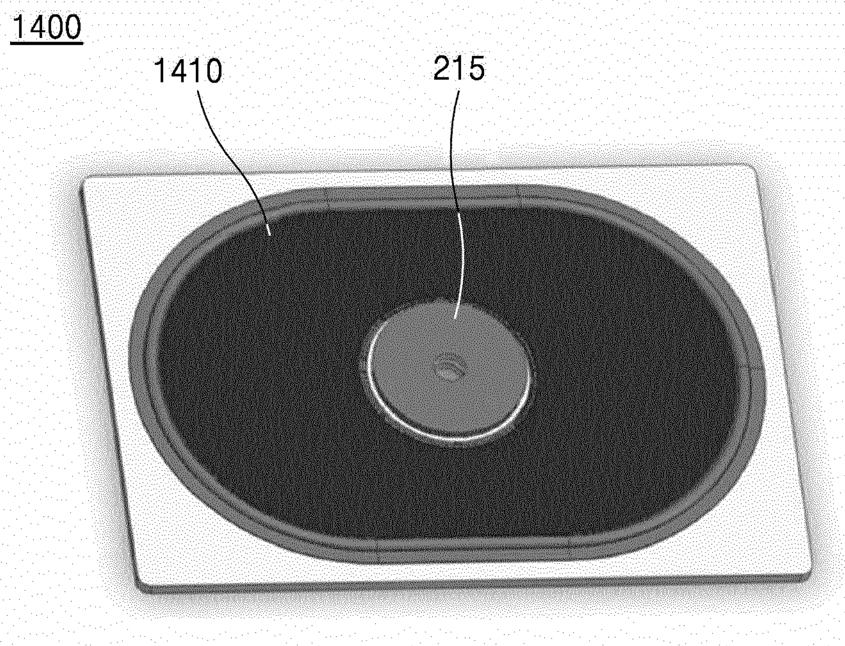


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2020/001659

A. CLASSIFICATION OF SUBJECT MATTER

H04R 9/06(2006.01)i, H04R 9/04(2006.01)i, H01F 1/057(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 9/06; H04R 7/00; H04R 7/02; H04R 7/04; H04R 7/12; H04R 9/02; H04R 9/04; H01F 1/057

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: IPC as above
Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: speaker, diaphragm, coil, magnet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2011-0038883 A (ESTEC CORPORATION) 15 April 2011 See paragraphs [0021]-[0031] and figures 2-3.	1-3,10,14-15
Y		4-5,8,11-13
A		6-7,9
Y	JP 2009-044357 A (ONKYO CORP.) 26 February 2009 See paragraphs [0043]-[0049]and figures 7-8.	4-5,8
Y	JP 2000-059884 A (FOSTER ELECTRIC CO., LTD.) 25 February 2000 See paragraphs [0007]-[0008] and figure 1.	11-12
Y	JP 2005-223806 A (PIONEER ELECTRONIC CORP. et al.) 18 August 2005 See paragraphs [0023]-[0025] and figure 1.	13
A	US 2007-0125591 A1 (SAHYOUN, Joseph Yaacoub) 07 June 2007 See paragraphs [0103]-[0136] and figures 7-31.	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 JUNE 2020 (10.06.2020)	**10 JUNE 2020 (10.06.2020)**

Name and mailing address of the ISA/KR	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2020/001659

Patent document cited in search report	Publication date	Patent family member	Publication date
KR 10-2011-0038883 A	15/04/2011	KR 10-1046005 B1	01/07/2011
JP 2009-044357 A	26/02/2009	JP 4952930 B2	13/06/2012
JP 2000-059884 A	25/02/2000	None	
JP 2005-223806 A	18/08/2005	None	
US 2007-0125591 A1	07/06/2007	AU 2003-217250 A1	02/09/2003
		AU 2003-217250 B2	19/07/2007
		CA 2474493 A1	07/08/2003
		CA 2474493 C	22/12/2009
		CN 1625917 A	08/06/2005
		EP 1024678 A2	02/08/2000
		EP 1024678 A3	26/05/2004
		EP 1470734 A2	27/10/2004
		JP 2005-536079 A	24/11/2005
		JP 4377243 B2	02/12/2009
		TW 200302671 A	01/08/2003
		TW I245575 B	11/12/2005
		US 2002-0121403 A1	05/09/2002
		US 2003-0015369 A1	23/01/2003
		US 2004-0188174 A1	30/09/2004
		US 2004-0188175 A1	30/09/2004
		US 2004-0195039 A1	07/10/2004
		US 6044925 A	04/04/2000
		US 6460651 B1	08/10/2002
		US 6626263 B2	30/09/2003
		US 6675931 B2	13/01/2004
		US 6863152 B1	08/03/2005
		US 7185735 B2	06/03/2007
		US 7225895 B2	05/06/2007
		US 7360626 B2	22/04/2008
		WO 03-065760 A2	07/08/2003
		WO 03-065760 A3	31/12/2003
		WO 2005-079266 A2	01/09/2005
		WO 2005-079266 A3	01/06/2006

Form PCT/ISA/210 (patent family annex) (January 2015)