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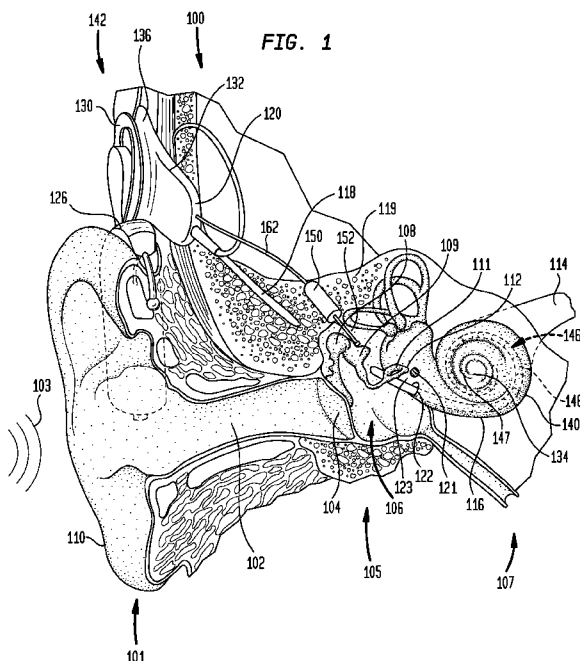
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(54) Title: **IMPLANTABLE SOUND SENSOR FOR HEARING PROSTHESES**



(57) Abstract: A hearing prosthesis is disclosed, the hearing prosthesis comprising an implantable sound sensor comprising: a hermetically sealed biocompatible housing with a membrane on the surface thereof; a coupling mechanism for coupling the membrane to a structure of a recipient's ear that vibrates in response to sound received by the recipient's ear; a vibrational sensor disposed in the housing to detect vibrations of the membrane, and to generate signals representative of the detected vibrations; and a transmitter configured to externally provide the generated signals.

## IMPLANTABLE SOUND SENSOR FOR HEARING PROSTHESES

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is claims priority to U.S. Provisional Application No. 61/061,250, filed June 13, 2008, the entire contents and disclosures of which are hereby incorporated by reference herein.

### BACKGROUND

#### *Field of the Invention*

[0002] The present invention relates generally to implantable sound sensors, and more particularly, to an implantable sound sensor for hearing prostheses.

#### *Related Art*

[0003] Implantable hearing prostheses primarily comprise an implantable stimulator that provides electrical, mechanical, optical or other stimulation to the inner and/or middle ear, and a microphone configured to receive and process external sound and to transform the sound into a signal which is supplied to a sound processor which drives the stimulator. The signal may be electrical, electromagnetic, optical, etc. This signal is encoded by the sound processor which generates a signal for the implantable stimulation device.

[0004] One type of conventional implantable stimulation device, such as a cochlear implant, delivers electrical signals stimulating the auditory nerves by means of electrodes implanted in the cochlea thereby allowing the brain to perceive a hearing sensation resembling the natural hearing sensation normally delivered by the auditory nerve. When the auditory nerve is nonexistent or fails, brainstem stimulation could be applied via an auditory brainstem implant. Another type of implantable stimulation device such as a middle ear implant provides mechanical vibration stimulating the middle or inner ear by means of an actuator.

[0005] In some implantable hearing prostheses, the microphone is also implanted in the recipient. Implantable microphones are conventionally implanted subcutaneously in proximity of the ear. A drawback of subcutaneous microphones is that they are sensitive to body noise which may originate from the circulatory, respiratory, skeletal, digestive or other systems.

## SUMMARY

[0006] In accordance with one embodiment of the present invention, a hearing prosthesis is disclosed, the hearing prosthesis comprising an implantable sound sensor comprising: a hermetically sealed biocompatible housing with a membrane on the surface thereof; a coupling mechanism for coupling the membrane to a structure of a recipient's ear that vibrates in response to sound received by the recipient's ear; a vibrational sensor disposed in the housing to detect vibrations of the membrane, and to generate signals representative of the detected vibrations; and a transmitter configured to externally provide the generated signals.

[0007] In accordance with another embodiment of the present invention, an implantable sound sensor is disclosed, the sound sensor comprising a hermetically sealed biocompatible housing with a membrane on the surface thereof; a coupling mechanism for coupling the membrane to a structure of a recipient's ear that vibrates in response to sound received by the recipient's ear; a vibrational sensor disposed in the housing to detect vibrations of the membrane, and to generate signals representative of the detected vibrations; and a transmitter configured to externally provide the generated signals.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the present invention are described below with reference to the attached drawings, in which:

[0009] FIG. 1 is a perspective view of an exemplary totally implantable cochlear implant, in which embodiments of the present invention may be implemented;

[0010] FIG. 2A is a perspective view of an implantable sound sensor in accordance with embodiments of the present invention;

[0011] FIG. 2B is a longitudinal cross-sectional view of the sound sensor of FIG.2A, illustrating the primary components in a functional block diagram, in accordance with embodiments of the present invention;

[0012] FIG. 3A is a perspective view of an implantable sound sensor in accordance with embodiments of the present invention;

[0013] FIG. 3B is a longitudinal cross-sectional view of the sound sensor of FIG.3A, illustrating the primary components in a functional block diagram, in accordance with embodiments of the present invention;

[0014] FIG. 4A is a flow chart of the operations performed to implant an embodiment of a hearing prosthesis having an embodiment of a sound sensor, in accordance with embodiments of the present invention;

[0015] FIG. 4B is a flow chart of the operations performed to implant another embodiment of a hearing prosthesis having an embodiment of a sound sensor, in accordance with embodiments of the present invention; and

[0016] FIG. 5 is a flow chart of the operations performed during operation of an embodiment of a hearing prosthesis having an embodiment of a sound sensor.

## DETAILED DESCRIPTION

[0017] The present invention is generally directed to an implantable sound sensor configured to detect sound received in a recipient's ear based on vibrations or pressure variations that occur in the natural path followed by acoustic waves in the ear. A hearing prosthesis comprising the implantable sound processor utilizes the detected sound to stimulate the ear.

[0018] Embodiments of the present invention are described herein primarily in connection with one type of implantable hearing prosthesis, namely a totally or fully implantable cochlear prosthesis (commonly referred to as a cochlear prosthetic device, cochlear implant, cochlear device, and the like; simply "cochlear implants" herein). As used herein, a totally implantable cochlear implant refers to an implant that is capable of operating, at least for a period of time, without the need for any external device. It would be appreciated that embodiments of the present invention may also be implemented in a cochlear implant that includes one or more external components. It would be further appreciated that embodiments of the present invention may be implemented in any partially or fully implantable hearing prosthesis now known or later developed, including, but not limited to, acoustic hearing aids, auditory brain stimulators, middle ear mechanical stimulators, hybrid electro-acoustic prosthesis or other prosthesis that electrically, acoustically and/or mechanically stimulate components of the recipient's outer, middle or inner ear.

[0019] FIG. 1 is perspective view of a totally implantable cochlear implant, referred to as cochlear implant 100, implanted in a recipient. The recipient has an outer ear 101, a middle ear 105 and an inner ear 107. Components of outer ear 101, middle ear 105 and inner ear 107 are described below, followed by a description of cochlear implant 100.

[0020] In a fully functional ear, outer ear 101 comprises an auricle 110 and an ear canal 102. An acoustic pressure or sound wave 103 is collected by auricle 110 and channeled into and through ear canal 102. Disposed across the distal end of ear canal 102 is a tympanic membrane 104 which vibrates in response to sound wave 103. This vibration is coupled to oval window or fenestra ovalis 112 through three bones of middle ear 105, collectively referred to as the ossicles 106 and comprising the malleus 108, the incus 109 and the stapes 111. Bones 108, 109 and 111 of middle ear 105 serve to filter and amplify sound wave 103, causing oval window 112 to articulate, or vibrate in response to vibration of tympanic membrane 104. This vibration sets up waves of fluid motion of the perilymph within cochlea 140. Such fluid motion, in turn, activates tiny hair cells (not shown) inside of cochlea 140.

Activation of the hair cells causes appropriate nerve impulses to be generated and transferred through the spiral ganglion cells (not shown) and auditory nerve 114 to the brain (also not shown) where they are perceived as sound.

[0021] As shown, cochlear implant 100 comprises one or more components which are temporarily or permanently implanted in the recipient. Cochlear implant 100 is shown in FIG. 1 with an external device 142 which, as described below, is configured to provide power to the cochlear implant.

[0022] In the illustrative arrangement of FIG. 1, external device 142 may comprise a power source (not shown) disposed in a Behind-The-Ear (BTE) unit 126. External device 142 also includes components of a transcutaneous energy transfer link, referred to as an external energy transfer assembly. The transcutaneous energy transfer link is used to transfer power and/or data to cochlear implant 100. As would be appreciated, various types of energy transfer, such as infrared (IR), electromagnetic, capacitive and inductive transfer, may be used to transfer the power and/or data from external device 142 to cochlear implant 100. In the illustrative embodiments of FIG. 1, the external energy transfer assembly comprises an external coil 130 that forms part of an inductive radio frequency (RF) communication link. External coil 130 is typically a wire antenna coil comprised of multiple turns of electrically insulated single-strand or multi-strand platinum or gold wire. External device 142 also includes a magnet (not shown) positioned within the turns of wire of external coil 130. It should be appreciated that the external device shown in FIG. 1 is merely illustrative, and other external devices may be used with embodiments of the present invention.

[0023] Cochlear implant 100 comprises an internal energy transfer assembly 132 which may be positioned in a recess of the temporal bone adjacent auricle 110 of the recipient. As detailed below, internal energy transfer assembly 132 is a component of the transcutaneous energy transfer link and receives power and/or data from external device 142. In the illustrative embodiment, the energy transfer link comprises an inductive RF link, and internal energy transfer assembly 132 comprises a primary internal coil 136. Internal coil 136 is typically a wire antenna coil comprised of multiple turns of electrically insulated single-strand or multi-strand platinum or gold wire. Positioned substantially within the wire coils is an implantable microphone system (not shown). As described in detail below, the implantable microphone assembly includes a microphone (not shown), and a magnet (also not shown) fixed relative to the internal coil.

[0024] Cochlear implant 100 further comprises a main implantable component 120 and an elongate electrode assembly 118. In embodiments of the present invention, internal energy transfer assembly 132 and main implantable component 120 are hermetically sealed within a biocompatible housing. In embodiments of the present invention, main implantable component 120 includes a sound processing unit (not shown) to convert the sound signals received by the implantable microphone in internal energy transfer assembly 132 to data signals. Main implantable component 120 further includes a stimulator unit (also not shown) which generates electrical stimulation signals based on the data signals. The electrical stimulation signals are delivered to the recipient via elongate electrode assembly 118.

[0025] Elongate electrode assembly 118 has a proximal end connected to main implantable component 120, and a distal end implanted in cochlea 140. Electrode assembly 118 extends from main implantable component 120 to cochlea 140 through mastoid bone 119. In some embodiments electrode assembly 118 may be implanted at least in basal region 116, and sometimes further. For example, electrode assembly 118 may extend towards apical end of cochlea 140, referred to as cochlea apex 134. In certain circumstances, electrode assembly 118 may be inserted into cochlea 140 via a cochleostomy 122. In other circumstances, a cochleostomy may be formed through round window 121, oval window 112, the promontory 123 or through an apical turn 147 of cochlea 140.

[0026] Electrode assembly 118 comprises a longitudinally aligned and distally extending array 146 of electrodes 148, sometimes referred to as electrode array 146 herein, disposed along a length thereof. Although electrode array 146 may be disposed on electrode assembly 118, in most practical applications, electrode array 146 is integrated into electrode assembly 118. As such, electrode array 146 is referred to herein as being disposed in electrode assembly 118. As noted, a stimulator unit generates stimulation signals which are applied by electrodes 148 to cochlea 140, thereby stimulating auditory nerve 114.

[0027] As noted, cochlear implant 100 comprises a totally implantable prosthesis that is capable of operating, at least for a period of time, without the need for external device 142. Therefore, cochlear implant 100 further comprises a rechargeable power source (not shown) that stores power received from external device 142. The power source may comprise, for example, a rechargeable battery. During operation of cochlear implant 100, the power stored by the power source is distributed to the various other implanted components as needed. The power source may be located in main implantable component 120, or disposed in a separate implanted location.

### *Sound Sensor*

[0028] Stimulator 132 receives a signal generated by an implanted sound sensor 150, in this embodiment, via a cable 162. Sound sensor 150 is implanted in a cavity formed in mastoid bone 119 so as to extend, in this embodiment, into the middle ear cavity. Sound sensor 150 is configured to detect sound received in a recipient's ear based on vibrations or pressure variations that occur in the natural path followed by acoustic waves in the ear. In the embodiment illustrated in FIG. 1, this vibrating structure is a structure of middle ear 105, and more specifically, incus 109.

[0029] An embodiment of implantable sound sensor 150 is described next below with reference to FIGS. 2A and 2B, referred to herein as implantable sound sensor 250. Implantable sound sensor 250 comprises a housing 258 having, in this embodiment, a substantially tubular shape. Such tubular shape is preferably cylindrical. The tubular shape can have an elliptical cross section (base). Other shapes, such as prismatic with square, rectangular, or other polygonal cross section can be envisaged as well. However, a cylindrical shape is preferred for ease of implanting and manufacturing.

[0030] Housing 258 is closed at one end 246 by a membrane 248. Membrane 248 is so connected to housing 258 as to seal the one end 246 hermetically. This can be provided by known techniques, such as laser welding, or manufacturing (milling, turning) housing 258 and membrane 248 out of one piece.

[0031] Housing 258 is closed at the opposing end 264, remote from membrane 248, by a closure 260. Closure 260 provides a hermetical seal. Hence, housing 258, membrane 248 and closure 260 form a biocompatible enclosure which is hermetically sealed. The term hermetical refers to impenetrable to air and body fluids, to a degree as suitable for medical implants.

[0032] Membrane 248 is advantageously flexible. It is configured to vibrate. The thickness of the membrane is selected depending on, among others, the material of which it is made and the location of implant. Membrane 248 is preferably made of titanium or a titanium alloy, and housing 258 is preferably made of titanium or a titanium alloy. Other biocompatible materials can be used as well. In alternative embodiments, closure 260 may be manufactured of a biocompatible ceramic material.

[0033] A coupling mechanism 252 is secured to the exterior surface of membrane 248. In the embodiment illustrated in FIGS. 2A and 2B, coupling mechanism 252 comprises an elongate

rod 256 and a bracket 254 disposed on the distal end of the rod. Bracket 254 may take on a variety of configurations depending on which structure of the natural ear the device is to be secured. This is described in further detail below.

[0034] A vibrational sensor 272 such as a microphone is disposed inside housing 258. In embodiments in which vibrational sensor 272 is a microphone, vibrational sensor is a pressure transducer that generates a signal representative of pressure waves in the acoustic spectrum. Microphone 272 is preferably so arranged that the microphone's sensing element is located proximal to membrane 248 with a defined gas layer 275 between the two. The microphone's sensing element is typically a diaphragm.

[0035] Hence, microphone 272 senses vibration of membrane 248. As coupling mechanism 252 vibrates membrane 248, the excitation of the membrane is transmitted to the inside of housing 258, where it is sensed by microphone 272. Microphone 272 may be an electret microphone, such as from Sonion (Denmark) or Knowles (USA). Other types of microphones may be used as well, such as: magnetic, dynamic, piezo-electric, optical, or electro-mechanical.

[0036] In an alternative embodiment, vibrational sensor 272 is an accelerometer suitable for sensing vibrations of membrane 248. In one particular embodiment, vibrational sensor 272 is a micro electromechanical system accelerometer.

[0037] Vibrational sensor 272 is connected to housing 258 by means of a fluid suspension 276, which is preferably made of, or which comprises, silicone. It should be appreciated that in alternative embodiments other mechanisms may be implemented to isolate vibrational sensor 272 from the motion of sound sensor 250.

[0038] Implantable sound sensor 250 further comprises a transmitter for transmitting the signal generated by vibrational sensor 272, either raw or processed, to the exterior of sound sensor 250, such as to an implantable stimulation device or other component of an implantable hearing prosthesis.

[0039] The transmitter may comprise an electronic circuit 270 mounted inside housing 258 and is coupled to microphone 272, e.g. by wires 268. Electronic circuit 270 can be configured to process the signal generated by the microphone 272, e.g. for transmission to an implantable stimulation device.

[0040] Electronic circuit 270 can be configured to convert alternating electrical current (AC) to direct electrical current (DC) and to deliver electrical power to the microphone 272.

Electrical power can be provided from an external source to the implantable device by wires 268 (through AC current). Alternatively, a battery can be provided in the housing 258. In the embodiment illustrated in FIGS. 2A and 2B, the transmission is by electrical signals travelling over electrical conductors. In the specific embodiment shown in FIGS. 2A and 2B, the electrical conductor is wires 268.

[0041] A feed through 266 is preferably provided for passing electrical wires 268 to the exterior of housing 258. Feed through 266 is preferably provided through closure 260. In certain embodiments, feed through 266 is formed in closure 260; in other words, they are unitary.

[0042] Electrical wires 268 may be configured to pass electrical power to implantable device 250. Wires 268 may be configured to transmit the processed microphone signal to the exterior of sound sensor 250. In the latter case, electronic circuit 270 may be configured to modulate the signal on the power wires.

[0043] In an alternative embodiment, the transmission is wireless. In such embodiments the implantable device 250 may be provided with an electromagnetic antenna (not shown).

[0044] The enclosure, formed by housing 258, membrane 248 and closure 260, is preferably filled with an inert gas, such as nitrogen or argon.

[0045] In the embodiment illustrated in FIGS. 1, 2A and 2B, rod 256 is an elongate member suitable for coupling membrane 248 to a vibrating structure of the ear. Alternatively, the implantable device may comprise one or more brackets (in addition to the bracket(s) for fixating the housing 258), for additionally connecting membrane 248 to a structure of the middle or inner ear. In case of the middle ear, said structure can be the tympanic membrane and bracket 254 may be a bracket similar to those used for tympanoplasty; that is, bracket 254 may comprise a disc for coupling to the tympanic membrane and is coupled with a rod to the membrane 12). The structure can be the malleus, the incus, or the stapes. In the latter case, a bracket such as those used for stapedioplasty may be employed, i.e. the bracket comprises a clip for coupling to one of those structures. The structure may be an elliptical window. In case of the inner ear, the structure may then be the elliptical window. The structure may be the circular window. The structure can alternatively be the horizontal canal, the posterior canal or the superior canal. Brackets such as those described in patent application WO 2006/058368, which document is incorporated herein by reference, may also be used. The bracket is preferably coupled to the membrane 248 in the middle thereof. Such

a bracket can influence the dynamics of the membrane. It can be provided to increase membrane sensitivity.

[0046] FIGS. 3A and 3B are perspective and functional block diagrams, respectively, of an alternative embodiment of sound processor 150, referred to herein as sound processor 350. Sound sensor 350 has a membrane 348 with no coupling mechanism to physically couple the membrane to a vibrating structure of the recipient's ear. Rather, sound sensor 350 is configured to implanted so as to be exposed to a natural cavity (or "hollow" organ) of the ear. Such a cavity may be the middle ear cavity, the cochlea or external ear canal. Such cavity is preferably a cavity of the middle ear. The cavity refers to an organ, or part of an organ of the ear, that is filled with a fluid. The fluid can be a liquid. In particular, the fluid is a gas as in the middle ear cavity, or a liquid, as in the cochlea.

[0047] Membrane 348 is sufficiently flexible. It is configured to vibrate due to first pressure variations, which are acoustic waves travelling in the hearing path (in the cavity to which the membrane is exposed). The thickness of the membrane is selected depending on, among others, the material of which it is made and the location of implant. Membrane 348 is preferably made of titanium or a titanium alloy.

[0048] The terms "sound" and "acoustic waves" refer to pressure waves, which can be perceived by the hearing organ of a healthy person or animal (mammal). For mankind, acoustic waves refer to pressure waves falling in a frequency spectrum in the range between about 20 Hz and 20 kHz.

[0049] Implantable sound sensor devices according to certain embodiments of the invention are so construed as to enable a surgeon to surgically implant the implantable sound sensors with ease. This means that the surgical intervention for implanting the implantable sound sensor is preferably limited to drilling a canal from the outside of a patient's head to the location where the distal end of the housing 258, 358 is exposed to the relevant cavity, and coupling mechanism 252 is secured to the desired vibrating structure of the ear. This is then followed by fixation of implantable sound sensor 250, 350. Furthermore, it is desired that the size of the drilled canal be kept as small as possible. In order to solve the above problems, implantable sound sensors according to certain embodiments of the invention have a small aspect ratio as will be identified. In defining the aspect ratio, the following is to be taken into account.

[0050] The length of the implantable device refers to the total size, measured along the axis of the elongate housing, from membrane 248 to, and including, closure 3260. In determining the length of the implantable device, the length of any external wires protruding out of closure 360 are not to be taken into account. The breadth of the implantable sound sensor refers to the diameter of the smallest circle circumscribing a cross section of the implantable device, perpendicular to the axis of the tubular housing.

[0051] The size of the membrane refers to the diameter of the smallest circle circumscribing the membrane in a frontal plane of the membrane. Hence, the aspect ratio of the breadth to the length of the implantable device 250, 350 is smaller than 1. The housing 258, 358 have thus preferably an elongate shape.

[0052] Preferably, the aspect ratio of the breadth to the length of the implantable device 250, 350 is smaller than or equal to 0.75, with aspect ratios smaller than or equal to 0.6 being more preferred and aspect ratios smaller than or equal to 0.45 being particularly preferred.

[0053] Preferably, the size of membrane 248, 348 is smaller than or equal to 9 mm, with a size smaller than or equal to 7 mm being more preferred, a size smaller than or equal to 5 mm being even more preferred, and a size smaller than or equal to 3.5 mm being particularly preferred.

[0054] Preferably, the length of the implantable device 250, 350 is smaller than or equal to 20 mm, with a length smaller than or equal to 15 mm being more preferred and a length smaller than or equal to 12.5 mm being particularly preferred. Such a small aspect ratio device has several benefits. Firstly, surgical operation is significantly eased and the extent of intervention is reduced. Secondly, the small breadth of the implantable device allows full exposure of the membrane in various cavities of the ear, in particular in the middle ear cavity. Furthermore, as the membrane is not skin loaded, the attenuation of acoustic waves arriving at the membrane 248, 348 is reduced, resulting in a smaller membrane needed for an equal sensitivity. Finally, the directionality of the acoustic waves, induced by the outer ear, can be fully exploited.

[0055] Fixation of the implantable device 250, 350 is preferably performed to a bony structure, such as the temporal bone. This can be carried out by brackets 254, 354 which are known in the art. The brackets are configured to be attached to the housing 248, 348 and hence provide mechanical coupling between the housing and said bony structure.

[0056] FIGS. 4A and 4B are flow charts of the operations performed to implant an embodiment of a hearing prosthesis having an embodiment of a sound sensor, in accordance with embodiments of the present invention; FIG. 5 is a flow chart of the operations performed during operation of an embodiment of a hearing prosthesis having an embodiment of a sound sensor.

[0057] At block 404 a hearing prosthesis of the present invention which includes an implantable sound sensor that generates a signal representative of detected vibrations of an element of the recipient's ear caused by the natural processing of sound by the recipient's ear.

[0058] At block 404, a canal is formed such as by drilling from the outside of the patient's head to the middle ear cavity. Insert the implantable device into the canal so as to expose at least the membrane of the implantable device to the middle ear cavity. At block 408 optionally perform a myringotomy to create a passage through the tympanic membrane in order to reduce the attenuation of acoustic waves by the tympanic membrane. This may include inserting a myringotomy prosthesis across the tympanic membrane in order to keep the incision open.

[0059] Then, at block 410, implant the remaining components of the hearing prosthesis prior to, during or after the operations associated with the implantation of the implantable sound sensor.

[0060] Referring to FIG. 4B, the operations are similar other than at block 456 the bracket on the distal end of the rod is secured to the incus.

[0061] FIG. 5 is a flowchart showing the operations performed during normal use of the device. At block 502, the implantable sound sensor generates a signal representative of vibrations or pressure variations which occur in the recipient's ear, and which cause pressure variations within the implantable sound sensor.

[0062] At block 504 the other component(s) of the implantable hearing prosthesis are implanted.

[0063] At block 508 the hearing prosthesis provides stimulation, by the hearing prosthesis, in accordance with the signal generated by the implantable sound sensor.

[0064] Preferably, in the step of fixating the implantable device with a bracket, said cavity is an inner ear cavity. Said structure can then be the elliptical window. Said structure can be the

circular window. Said structure can alternatively be the horizontal canal, the posterior canal or the superior canal.

[0065] According to a preferred embodiment, the housing 11 is of cylindrical shape and has a diameter of about 3.5 – 4 mm. The length of the implantable device is about 10 – 15 mm. This allows to provide an electret microphone, such as a Sonion 8009, having an outer diameter of 2.56 mm and a length of 3 mm. The electronic circuitry for AC-DC conversion can be provided on a board fitting in the housing and having a length not exceeding 3 mm.

[0066] While the foregoing description and drawings represent preferred embodiments of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the present invention.

[0067] All documents, patents, journal articles and other materials cited in the present application are hereby incorporated by reference.

[0068] The invention described and claimed herein is not to be limited in scope by the specific preferred embodiments herein disclosed, since these embodiments are intended as illustrations, and not limitations, of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

## CLAIMS

What is claimed is:

1. A hearing prosthesis comprising:  
an implantable sound sensor comprising:  
a hermetically sealed biocompatible housing with a membrane on the surface thereof;  
a coupling mechanism for coupling the membrane to a structure of a recipient's ear that vibrates in response to sound received by the recipient's ear;  
a vibrational sensor disposed in the housing to detect vibrations of the membrane, and to generate signals representative of the detected vibrations; and  
a transmitter configured to externally provide the generated signals.
2. The hearing prosthesis of claim 1, wherein the vibrational sensor comprises:  
an accelerometer.
3. The hearing prosthesis of claim 1, wherein the vibrational sensor comprises:  
a pressure sensor spaced from the membrane by a defined gas layer.
4. The hearing prosthesis of claim 1, wherein the coupling mechanism comprises:  
an elongate rod having a proximal end connected to the membrane and a distal end;  
and  
a bracket disposed on the distal end of the rod, the bracket configured to securely connect the rod to the vibrating structure of a recipient's ear.
5. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is the tympanic membrane.
6. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is the ossicles.
7. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is the malleus.

8. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is the incus
9. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is the stapes.
10. The hearing prosthesis of claim 1, wherein the vibrating structure of a recipient's ear is an inner ear structure.
11. The hearing prosthesis of claim 1, wherein the hearing prosthesis is elongate having a breadth and a length, with the breadth being less than the length.
12. The hearing prosthesis of claim 11, wherein the aspect ratio of said breadth to said length is less than or equal to approximately 0.75.
13. The hearing prosthesis of claim 11, wherein the length of the implantable device is smaller than or equal to approximately 20 mm.
14. The hearing prosthesis of claim 1, wherein the membrane is circular and has a diameter that is less than or equal to approximately 9 mm.
15. The hearing prosthesis of claim 1, further comprising:  
a suspension of fluid, wherein the vibrational sensor is coupled to the housing via the fluid suspension.
16. The hearing prosthesis of claim 1, wherein the fluid suspension comprises silicone.
17. The hearing prosthesis of claim 1, wherein the housing and the membrane are made of titanium or an alloy comprising titanium.

18. The hearing prosthesis of claim 1, wherein the generated signal is an electric signal, and wherein the transmitter comprises:  
a feed-through for passing at least two wires from a location inside the housing to a location external to the housing.
19. The hearing prosthesis of claim 1, wherein the transmitter comprises:  
an electromagnetic antenna configured for wireless transmission of the generated signal.
20. An implantable sound sensor comprising:  
a hermetically sealed biocompatible housing with a membrane on the surface thereof;  
a coupling mechanism for coupling the membrane to a structure of a recipient's ear that vibrates in response to sound received by the recipient's ear;  
a vibrational sensor disposed in the housing to detect vibrations of the membrane, and to generate signals representative of the detected vibrations; and  
a transmitter configured to externally provide the generated signals.
21. The sound sensor of claim 20, wherein the vibrational sensor comprises:  
an accelerometer.
22. The sound sensor of claim 20, wherein the vibrational sensor comprises:  
a pressure sensor spaced from the membrane by a defined gas layer.
23. The sound sensor of claim 20, wherein the coupling mechanism comprises:  
an elongate rod having a proximal end connected to the membrane and a distal end;  
and  
a bracket disposed on the distal end of the rod, the bracket configured to securely connect the rod to the vibrating structure of a recipient's ear.
24. The sound sensor of claim 20, wherein the vibrating structure of a recipient's ear is the tympanic membrane.
25. The sound sensor of claim 20, wherein the vibrating structure of a recipient's ear is the ossicles.

26. The sound sensor of claim 25, wherein the vibrating structure of a recipient's ear is the malleus.
27. The sound sensor of claim 25, wherein the vibrating structure of a recipient's ear is the incus.
28. The sound sensor of claim 25, wherein the vibrating structure of a recipient's ear is the stapes.
29. The sound sensor of claim 20, wherein the vibrating structure of a recipient's ear is an inner ear structure.
30. The sound sensor of claim 20, wherein the sound sensor is elongate having a breadth and a length, with the breadth being less than the length.
31. The sound sensor of claim 30, wherein the aspect ratio of said breadth to said length is less than or equal to approximately 0.75.
32. The sound sensor of claim 30, wherein the length of the implantable device is smaller than or equal to approximately 20 mm.
33. The sound sensor of claim 20, wherein the membrane is circular and has a diameter that is less than or equal to approximately 9 mm.
34. The sound sensor of claim 20, further comprising:  
a suspension of fluid, wherein the vibrational sensor is coupled to the housing via the fluid suspension.
35. The sound sensor of claim 20, wherein the fluid suspension comprises silicone.
36. The sound sensor of claim 20, wherein the housing and the membrane are made of titanium or an alloy comprising titanium.

38. The sound sensor of claim 20, wherein the generated signal is an electric signal, and wherein the transmitter comprises:

a feed-through for passing at least two wires from a location inside the housing to a location external to the housing.

39. The sound sensor of claim 20, wherein the transmitter comprises:

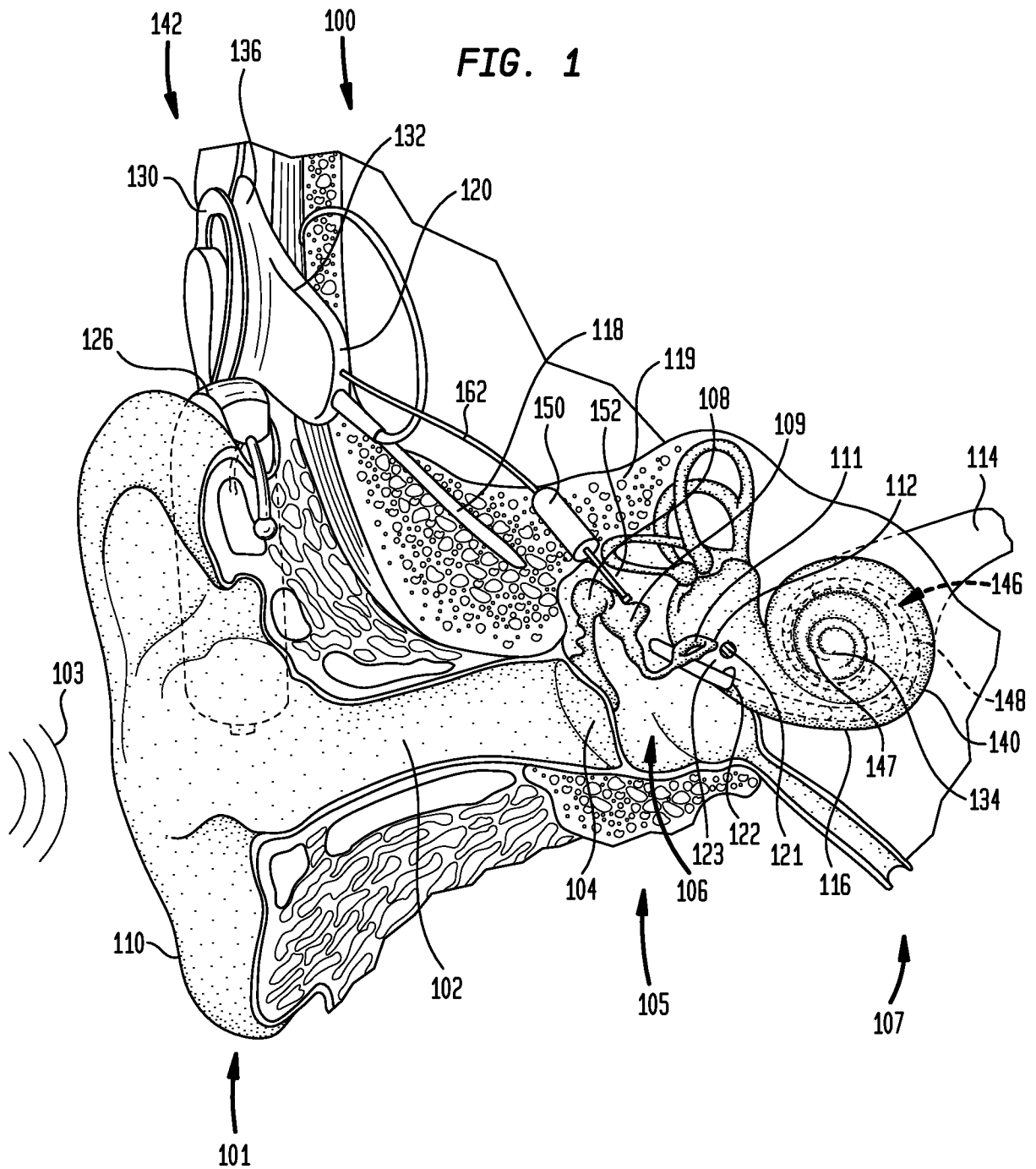
an electromagnetic antenna configured for wireless transmission of the generated signal.

40. The sound sensor of claim 29, wherein the inner ear structure comprises one or more of the group consisting of:

elliptical window;  
circular window;  
horizontal canal;  
posterior canal; and  
superior canal.

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FIG. 1



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**FIG. 2A**

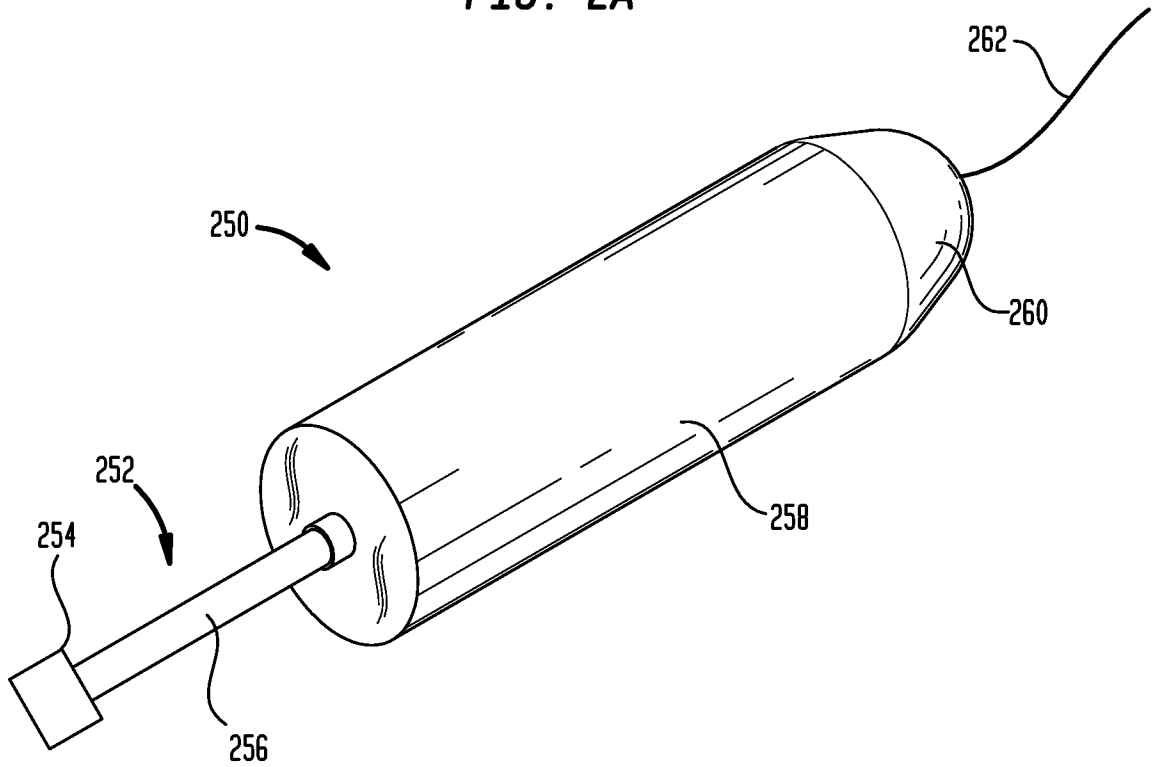
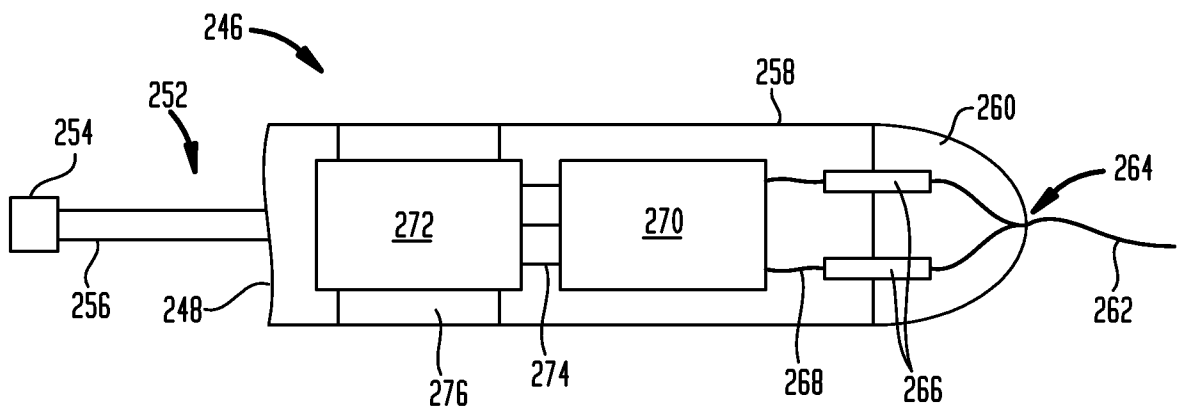


**FIG. 2B**



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**FIG. 3A**

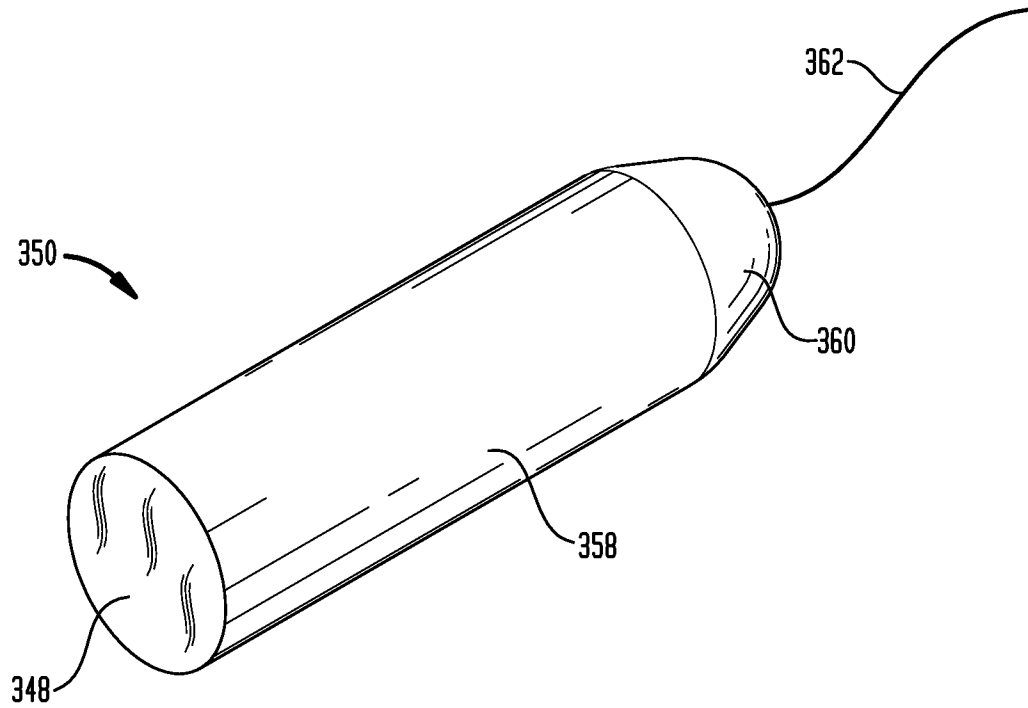
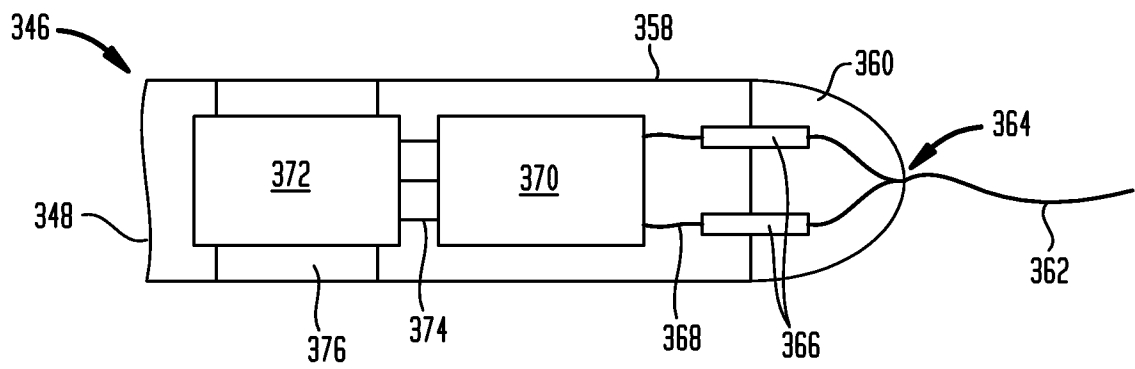


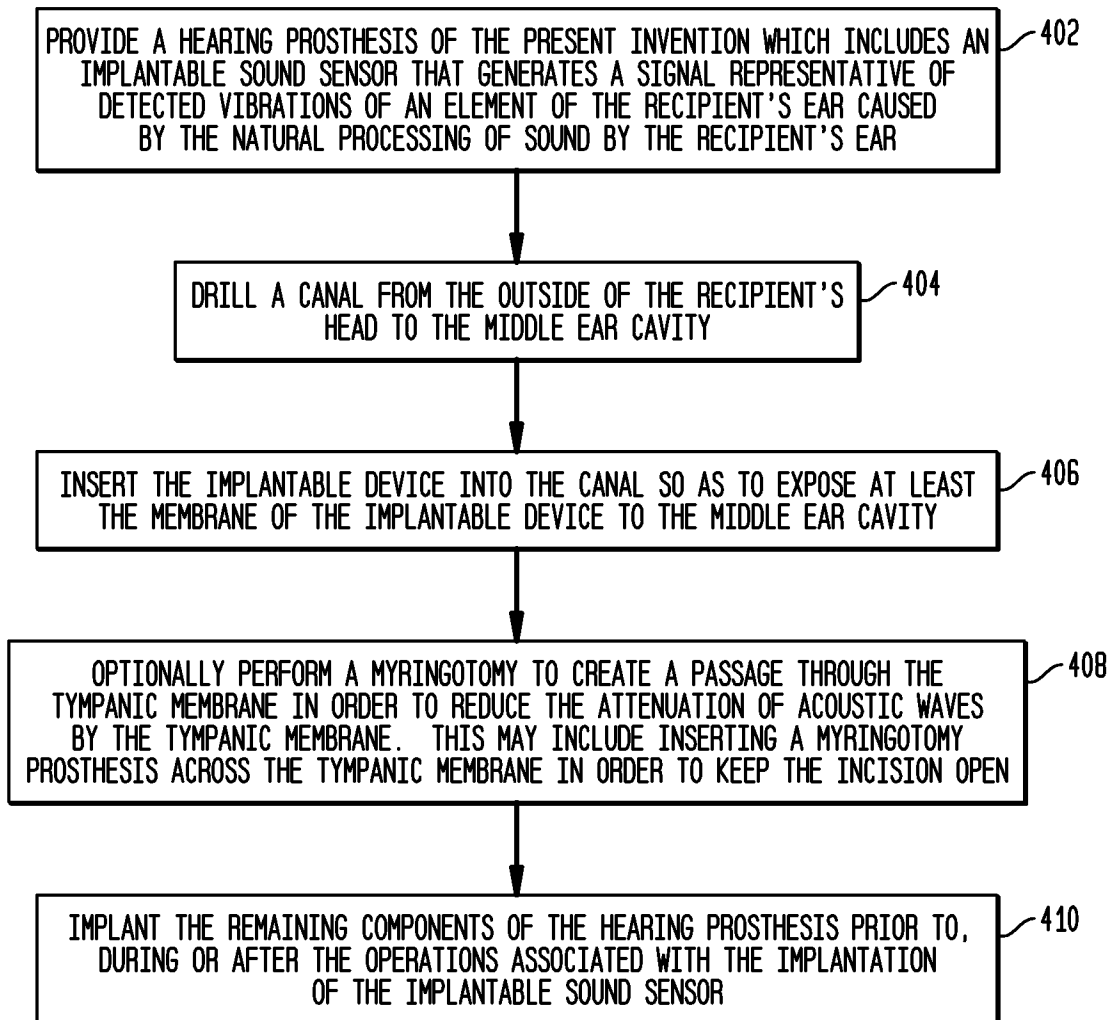
**FIG. 3B**



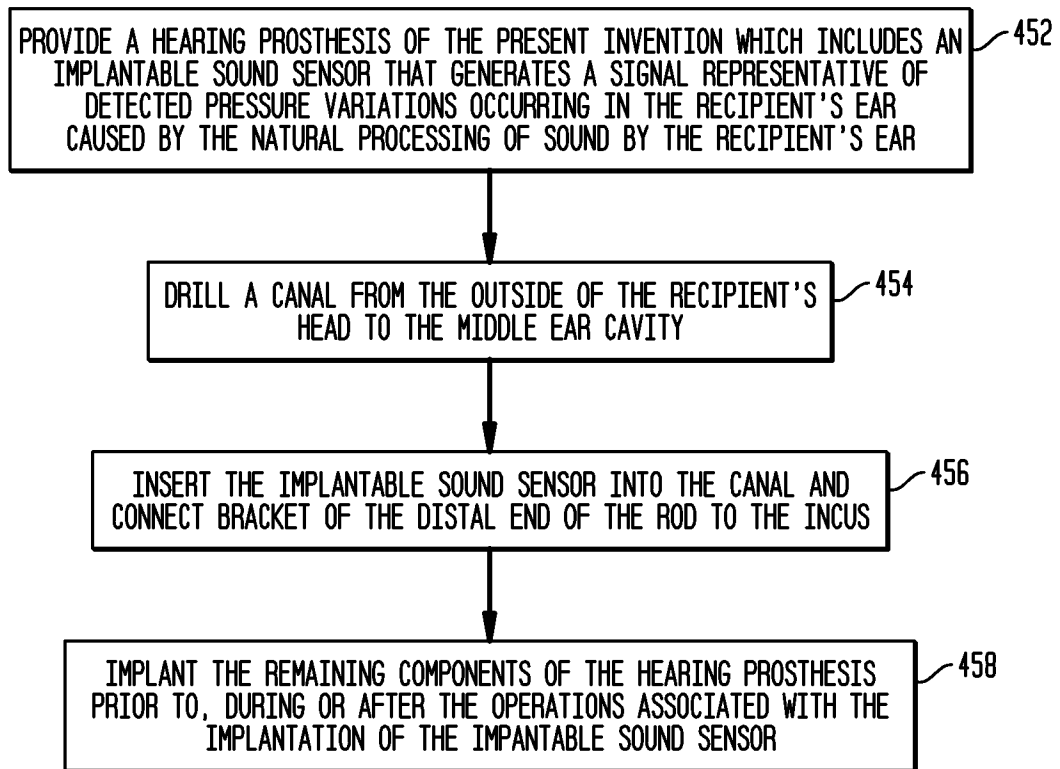
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400

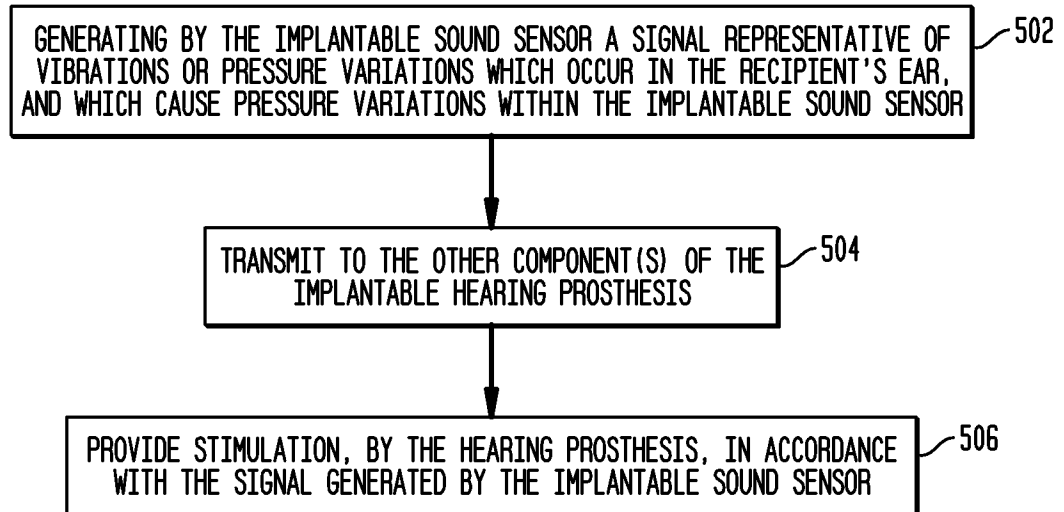
FIG. 4A



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450 **FIG. 4B**

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500 **FIG. 5**

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2009/047422

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61N 1/00 (2009.01)

USPC - 607/56

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)

IPC(8) - A61N 1/00, 1/36; H04R 1/10, 25/00, 25/02, 25/04 (2009.01)

USPC - 607/55, 56, 57

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------|-----------------------|
| Y         | US 5,814,095 A (MULLER et al) 29 September 1998 (29.09.1998) entire document       | 1-36, 38-40           |
| Y         | US 2002/0026091 A1 (LEYSIEFFER) 28 February 2002 (28.02.2002) entire document      | 1-36, 38-40           |
| Y         | US 6,193,645 B1 (KENNEDY) 27 February 2001 (27.02.2001) entire document            | 2, 5, 7, 21, 24, 26   |
| Y         | US 2004/0243212 A1 (DADD et al) 02 December 2004 (02.12.2004) entire document      | 12, 31                |
| Y         | US 2005/0049641 A1 (SHAH et al) 03 March 2005 (03.03.2005) entire document         | 15, 16, 34, 35        |

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

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Date of the actual completion of the international search

21 July 2009

Date of mailing of the international search report

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