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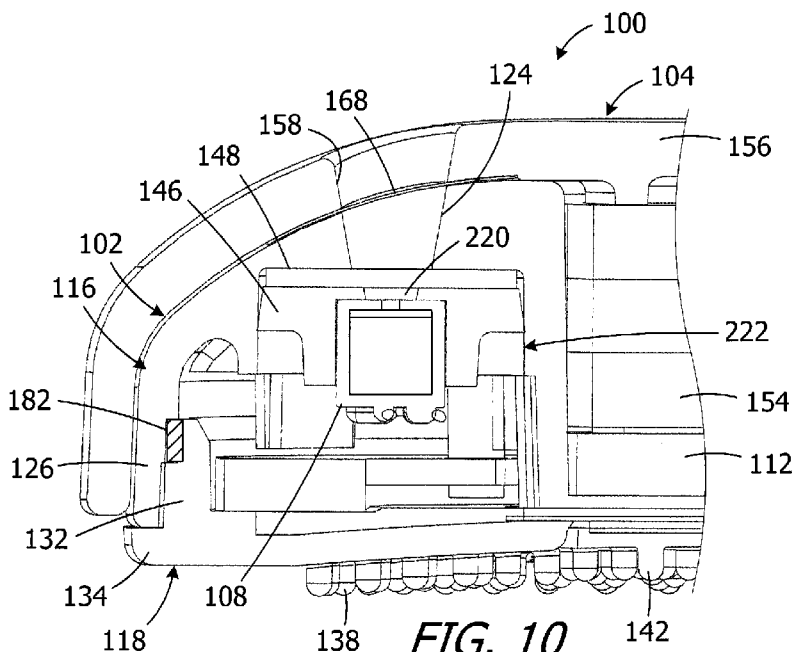
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(54) Title: MOISTURE RESISTANT HEADPIECES AND IMPLANTABLE COCHLEAR STIMULATION SYSTEMS INCLUDING THE SAME



(57) Abstract: Cochlear implant headpieces with improved moisture resistance. The headpiece comprises a housing (102) including a housing microphone aperture (124), a microphone (108) within the housing, a membrane (148) between the housing microphone aperture and the microphone, a cap (104) including a sound port (158) and a shield (168), the cap being removably connectable to the housing and the headpiece being protected from particulate and moisture ingress.

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MOISTURE RESISTANT HEADPIECES AND IMPLANTABLE COCHLEAR STIMULATION SYSTEMS INCLUDING THE SAME

BACKGROUND

1. Field

The present disclosure relates generally to headpieces such as, for example, the headpieces in implantable cochlear stimulation (or “ICS”) systems.

2. Description of the Related Art

ICS systems are used to help the profoundly deaf perceive a sensation of sound by directly exciting the intact auditory nerve with controlled impulses of electrical current. Ambient sound pressure waves are picked up by an externally worn microphone and converted to electrical signals. The electrical signals, in turn, are processed by a sound processor, converted to a pulse sequence having varying pulse widths and/or amplitudes, and transmitted to an implanted receiver circuit of the ICS system. The implanted receiver circuit is connected to an implantable electrode array that has been inserted into the cochlea of the inner ear, and electrical stimulation current is applied to varying electrode combinations to create a perception of sound. A representative ICS system is disclosed in U.S. Patent No. 5,824,022, which is entitled “Cochlear Stimulation System Employing Behind-The-Ear Sound Processor With Remote Control” and incorporated herein by reference in its entirety.

As alluded to above, some ICS systems include an implantable device, a sound processor unit, and a microphone that is in communication with the sound processor unit. The implantable device communicates with the sound processor unit and, to that end, some ICS systems include a headpiece, with a microphone, that is in communication with both the sound processor unit and the implantable device. In one type of ICS system, the sound processor unit is worn behind the ear (a “BTE unit”), while other types of ICS systems have a body worn sound processor unit (or “body worn unit”). The body worn unit, which is larger and heavier than a BTE unit, is typically worn on the user’s belt or carried in the user’s pocket. One example of a conventional body worn unit is the Advanced Bionics Platinum Series body worn unit.

One issue associated with ICS systems is the moisture resistance of the headpiece. In particular, the present inventor has determined that it would be desirable to provide a headpiece that includes a microphone and is capable of being worn during activities such as swimming and bathing where the headpiece may be subjected to submersion in water, splashing and the like. The present inventor has also determined that the moisture resistance features of the headpiece should be configured in such a manner that the acoustic response is not substantially degraded, as compared to an identical microphone that is not within the headpiece.

SUMMARY

A cochlear implant headpiece in accordance with one embodiment of a present invention comprises a housing including a housing microphone aperture, a microphone carried within the housing and associated with the housing microphone aperture, a membrane between the housing microphone aperture and the microphone, and a cap, including a sound port and a shield over the sound port, configured to be positioned on the housing such that the sound port and shield are aligned with the housing microphone aperture. The present inventions also include cochlear stimulation systems with a cochlear implant, a sound processor, and such a headpiece.

A cochlear implant headpiece in accordance with one embodiment of a present invention comprises a housing, including an internal volume and a housing microphone aperture that extends to the internal volume, and a microphone carried within the housing internal volume and aligned with the housing microphone aperture. The internal volume is protected against particulate and moisture ingress to an extent greater than that required by IEC IP67. The present inventions also include cochlear stimulation systems with a cochlear implant, a sound processor, and such a headpiece.

A cochlear implant headpiece in accordance with one embodiment of a present invention comprises a housing, a transmitter, and a connector. The connector includes an electrically conductive barrel, an electrically conductive socket, an electrical insulator between the barrel and the socket, a first seal compressed between the barrel and the insulator, and a second seal

compressed between the socket and the insulator. The present inventions also include cochlear stimulation systems with a cochlear implant, a sound processor, and such a headpiece.

5 A method of manufacturing a cochlear implant headpiece includes calculating the volume of the microphone aperture according to the formula

$$V_{\text{APERTURE}} > (WP_{\text{MAX}}/AP) V_{\text{MIC}} - V_{\text{MIC}}, \text{ where}$$

V_{APERTURE} = microphone aperture volume, WP_{MAX} = water pressure at the predetermined maximum depth, AP = atmospheric pressure, and V_{MIC} = internal microphone volume.

10 The above described and many other features of the present inventions will become apparent as the inventions become better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

15 **BRIEF DESCRIPTION OF THE DRAWINGS**

Detailed descriptions of the exemplary embodiments will be made with reference to the accompanying drawings.

FIG. 1 is a functional block diagram of an ICS system in accordance with one embodiment of a present invention.

20 FIG. 2 is a perspective view of a headpiece in accordance with one embodiment of a present invention.

FIG. 3 is another perspective view of the headpiece illustrated in FIG. 2.

25 FIG. 4 is a perspective view of a portion of the headpiece illustrated in FIG. 2.

FIG. 5 is an exploded view of the headpiece illustrated in FIG. 2.

FIG. 6 is a section view taken along line 6-6 in FIG. 2.

FIG. 7 is a perspective view of a portion of the headpiece illustrated in FIG. 2.

30 FIG. 8 is a section view of a connector in accordance with one embodiment of a present invention.

FIG. 9 is a plan view of a portion of the headpiece illustrated in FIG. 2.

FIG. 10 is a section view taken along line 10-10 in FIG. 2.

FIG. 11 is an enlarged view of a portion of FIG. 10.

FIGS. 12A-12C are diagrammatic representations of the compression of an air column during submersion of a headpiece in accordance with one embodiment of a present invention.

5 FIG. 13 is a graph showing the acoustic response of a headpiece microphone in accordance with one embodiment of a present invention under various test conditions.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

10 The following is a detailed description of the best presently known modes of carrying out the inventions. This description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the inventions.

15 The present inventions have application in a wide variety of systems that provide sound (i.e., either sound or a perception of sound) to the hearing impaired as well as others who require such systems on a situational basis. One example of such a system is an ICS system where an external sound processor communicates with a cochlear implant and, accordingly, the present inventions are discussed in the context of ICS systems. The present inventions are not,
20 however, limited to ICS systems and may be used in combination with other systems for the hearing impaired that currently exist, or are yet to be developed.

 One example of an ICS system is generally represented by reference numeral 10 in FIG. 1. The system 10 includes a headpiece 100, a sound processor 300 and a cochlear implant 400.

25 The exemplary headpiece 100 includes a housing 102 and a removable cap 104, as well as various components, e.g., a RF connector 106, a microphone 108, an antenna (or other transmitter) 110 and a positioning magnet 112, that are carried by the housing. Additional details concerning the headpiece 100 are described below with reference to FIGS. 2-13. For example,
30 the headpiece 100 may be configured such that it possesses particulate and moisture ingress protection that is superior to that represented by the International Electrotechnical Commission (IEC) IP67 rating, yet does not simply place the microphone within a sealed volume or otherwise shield the

microphone in a way that would substantially degrade the acoustic response of the headpiece.

5 The exemplary sound processor 300 includes a housing 302 in which and/or on which various components are supported. Such components may include, but are not limited to, sound processor circuitry 304, a headpiece port
10 306, an auxiliary device port 308 for an auxiliary device such as a mobile phone or a music player, a control panel 310 (including, e.g., a volume knob and program switch), a Euro Plug receptacle 312 (for a Euro Plug such as that associated with the Phonak MLxi FM receiver), and a power supply receptacle
15 314 with electrical contacts 316 and 318 for a removable battery or other removable power supply 320 (e.g., rechargeable and disposable batteries or other electrochemical cells). A power button (not shown) may also be carried on the housing 302. The headpiece port 306 and auxiliary device port 308 may be connected to the sound processor circuitry 304 by way of, for example, a signal
20 splitter/combiner (not shown) such as that found in the Platinum Signal Processor body worn unit from Advanced Bionics.

The headpiece 100 in the exemplary ICS system 10 may be connected to the headpiece port 306 by a cable 114. In at least some implementations, the cable 114 will be configured for forward telemetry and power signals at 49 MHz
25 and back telemetry signals at 10.7 MHz. It should be noted that, in other implementations, communication between a sound processor and a headpiece and/or auxiliary device may be accomplished through wireless communication techniques.

The exemplary cochlear implant 400 includes a housing 402, an antenna 404, an internal processor 406, a cochlear lead 408 with an electrode array, and a positioning magnet (or magnetic material) 410. The transmitter
30 110 and receiver 404 communicate by way of electromagnetic induction, radio frequencies, or any other wireless communication technology. The positioning magnet 112 and positioning magnet (or magnetic material) 410 maintain the position of the headpiece antenna 110 over the cochlear implant antenna 404.

During use, the microphone 108 picks up sound from the environment and converts it into electrical impulses, and the sound processor 300 filters and manipulates the electrical impulses and sends the processed electrical

signals through the cable 114 to the antenna 110. Electrical impulses received from an auxiliary device are processed in essentially the same way. The receiver 404 receives signals from the antenna 110 and sends the signals to the cochlear implant internal processor 406, which modifies the signals and passes them through the cochlear lead 408 to the electrode array. The electrode array may be wound through the cochlea and provides direct electrical stimulation to the auditory nerves inside the cochlea. This provides the user with sensory input that is a representation of external sound waves which were sensed by the microphone 108.

The exemplary sound processor 300 may be carried by the user in a variety of ways. By way of example, but not limitation, the sound processor 300 may be carried in the user's pocket, secured to a belt with a belt clip that is either part of housing 106 or a separate carrier, or placed in a harness that is configured to be worn by a small child.

Turning to FIGS. 2-5, and as noted above, the exemplary headpiece 100 includes a housing 102 and a removable cap 104 that may be secured to the housing. The housing 102 has a main portion 116 and a cover 118 that may be secured to the main portion in the manner described in greater detail below with reference to FIG. 6. The exemplary housing main portion 116 has a top wall 120, a cup 122 for the magnet 112, a housing microphone aperture 124, a side wall 126 with a plurality of latch indentations 128, and a connector tube 130 for the connector 106. The exemplary cover 118 has a side wall 132 and a bottom wall 134 that extends slightly beyond the side wall. The bottom wall 134 includes a plurality of apertures 136 for friction pads 138 that are molded into the bottom wall (note FIG. 6), as well as a recess 140 for a friction pad 142 that is adhered to the bottom wall. The configurations of the housing main portion 116 and cover 118 are such that the inner surface of the main portion side wall 126 abuts the outer surface of the cover side wall 132 and the end of the main portion side wall abuts the cover bottom wall 134 (note FIG. 6) when the housing 102 is in the assembled state.

The exemplary housing 102 has an internal volume 144 (FIG. 5), defined by the main portion 116 and cover 118, in which the microphone 108, a microphone holder 146, a membrane 148 and a printed circuit board (PCB) 150

are positioned. In the illustrated implementation, all of electronic components (with the exception of the microphone 108 and connector 106) are carried on the PCB 150. The connector 106 is positioned in the connector tube 130 such that the connector wires 152 may be connected to the PCB 150 by, for example, solder. The configuration of the connector 106, and the manner in which it is mounted within the connector tube 130, are discussed below with reference to FIGS. 6-8. The microphone holder 146 is positioned in the housing 102 such that the microphone wires 153 may be connected to the PCB 150 by, for example, solder. On the other side of the top wall 120 and outside the internal volume 144, one or more spacers 154 are carried within the cup 122 to hold the magnet 112 in place.

The cap 104 in the illustrated embodiment may be connected to and then removed from the housing 102, i.e., the cap may be removably connected to the housing. As used herein, "removably connected" means that, once connected, the cap 104 will remain on the housing 102 under normal use conditions, but can be removed from the housing without destruction of the housing, the cap and/or the instrumentality that secures the two to one another. Although one exemplary connector configuration is illustrated in FIGS. 2-5, others may be employed. In other implementations, single-use caps may be provided. A "single-use connection" is a connection where, once connected, the cap will remain on the housing under normal use conditions, but can be removed from the housing without damage to the housing. Damage or destruction to the cap and/or the instrumentality that secures the cap to the housing is possible with a single-use connection.

Referring to FIGS. 2-5, the exemplary cap 104 includes a top wall 156 with a sound port 158, a side wall 160 with a plurality of latches 162, and a connector hood 164 with a pair of latches 166. The cap 104 also carries a shield 168 (see also FIGS. 9-11). The respective configurations of the housing 102 and cap 104 allow the cap to be snap fit onto the housing and removed from the housing. In particular, the cap latches 162 will be aligned with the housing latch indentations 128 when the housing 102 and cap 104 are oriented in the manner illustrated in FIG. 5. The distance between the inner surfaces of the hood latches 166 is less than the diameter of the connector tube 130, and the

distance between the hood top inner surface 170 (FIG. 9) is greater than the diameter of the connector tube. The cap 104 is also somewhat flexible. Thus, as the cap 104 is pressed onto the housing 102, the cap side wall 160 and hood 164 will bow outwardly as the latches 162 and 166 slide along the housing side wall 126 and connector cover 130. When the cap 104 reaches the position illustrated in FIGS. 2 and 3, the resilience of the cap will force the latches 162 into the latch recess 128 and the hood latches 166 against the surface of the connector cover 130, thereby latching the cap to the housing 102. The cap 104 may be removed by pulling the cap at the end of the hood 164 in the direction of arrow A.

The exemplary friction pads 138 and 142 facilitate retention of the headpiece in the desired location over hair and sweat. As illustrated in FIG. 6, the friction pads 138 include a base 172 and a plurality of spaced flexible bumps 174. The respective configurations of the apertures 136 and the bases 172 are such that, once the friction pads 138 have been overmolded into the housing cover bottom wall 134, they will be mechanically interlocked with the housing cover 118. The bases 172 also form seals that prevent ingress of particles and moisture through the apertures 136 to a level superior to that represented by the IEC IP67 standard. Referring to FIG. 5, the friction pad 142 includes a base 176 and a plurality of flexible bumps 178. The bumps 174 and 178 define multiple low- and zero-pressure channels that allow blood to flow in nearly every part of the skin and tissue underneath the headpiece 100. The bumps 174 and 178 can also resiliently deform and flex independently, which allows the headpiece 100 to conform to the contour of the skin and to dynamically conform to the skin with minor changes of the skin. Although the exemplary bumps 174 and 178 have a right cylindrical base and a hemispherical tip, other shapes may be employed. By way of example, but not limitation, other bumps may have a conical base and a flat tip, a conical base and a concave tip, a right cylindrical base and a conical tip, a regular pyramidal base extending to a pointed tip, a tapered rectangular base that is truncated to form a flat rectangular tip, or a rectangular base tapering to a wedge-shaped tip.

Suitable materials for the pads 138 and 142 include, but are not limited to, thermoplastic elastomers (TPE) such as SANTOPRENE TPE or

VERSOLLAN TPE, or a silicone rubber such as SILASTIC silicone elastomer. The material may have a durometer of between 20 and 70 Shore A, and may be about 50 Shore A in some embodiments.

5 In the illustrated implementation, the base 176 is secured to the recess 140 in the housing cover bottom wall 134 with adhesive or other suitable instrumentalities. In other implementations, a second magnet (not shown) may be secured to the recess 140 in place of the friction pad 142 for patients that require a higher retention force.

10 Turning to FIG. 7, the exemplary housing main portion 116 includes a plurality of support posts 180. The support posts 180 are used to mount and locate the PCB 150 within the housing.

15 A variety of aspects of the exemplary headpiece 100 contribute to the aforementioned particulate and moisture ingress protection that is superior to that represented by the IEC IP67 standard. For example, and referring to FIG. 6, the housing main portion 116 may be secured to the cover 118 by way of a robust joint 182. Suitable methods of forming the joint 182 include, but are not limited to, ultrasonic welding. Here, the joint 182 is formed from the main portion and cover material and no additional connective instrumentalities (e.g., adhesives) are employed. The joint 182 will prevent ingress of moisture into the
20 internal volume 144 by way of the main portion 116 and cover 118 interface, thereby preventing damage to the PCB 150, at submersion depths of 3.0 m or more.

25 With respect to dimensions, the headpiece 100 may be any size suitable for the intended application. In one exemplary embodiment, and referring to FIG. 2, the length (measured along line 6-6) of the exemplary headpiece 100 may be about 40 mm or less, the width (perpendicular to the length) may be about 35 mm or less, and the height may be about 14 mm or less. The housing 102 and cap 104 may be formed from any suitable materials. By way of example, but not limitation, the housing 102 and cap 104 may be formed from a
30 polycarbonate/polyester compound such as XYLEX polycarbonate/polyester compound.

The connector 106 may also be configured so as to prevent particulate and moisture ingress beyond that required by an IP67 rating and, as discussed

in greater detail below, to at least an IP68 rating. Turning to FIG. 8, the exemplary connector 106 includes a barrel 184, an electrical insulator 186 and a socket 188. The barrel 184 and socket 188 may be formed from suitable electrically conductive materials such as, for example, beryllium copper or brass, while the insulator 186 may be formed from a dielectric material such as, for example, polytetrafluoroethylene (PTFE). The barrel 184 has a cylindrical outer surface and the connector tube 130 has a correspondingly sized inner surface, as shown in FIG. 6. With respect to waterproofing, the connector 106 may be provided with seals between the interfaces between the barrel 184, insulator 186 and socket 188 to prevent ingress of moisture into the internal volume 144 by way of the interfaces between the barrel, insulator and socket. In the illustrated embodiment, a pair of o-ring seals 190 and 192 are compressed between the barrel 184, insulator 186 and socket 188. The insulator 186 and socket 188 are provided with recesses 194, 196 and 198 to accommodate the seals 190 and 192 as well as to control the location and compression of the seals. Suitable materials for the seals 190 and 192 include, but are not limited to, silicone rubber. The compression of the seals 190 and 192 may be such that the thickness is about 10-20% less than the uncompressed diameter, and is about 15% less than the uncompressed diameter in the illustrated embodiment. Connector posts 200 and 202 for wires 152 are also provided. The connector post 202 and associated wire 152 are shown spaced apart from one another in FIG. 7 for clarity.

With respect to assembly of the connector 106 into the housing 102, and referring to FIG. 7, the exemplary housing main portion 116 includes an opening 204 on the inner surface of the side wall 126 that extends into the connector tube 130. During assembly, the connector 106 is pushed into the connector tube 130 through the open end. The opening 204 is then sealed, e.g., with UV activated epoxy (not shown).

Turning to FIGS. 10 and 11, the exemplary microphone 108 includes, among other conventional microphone structures, a housing 206, a diaphragm 208 that provides the acoustic response, an open region 209 behind the diaphragm, and a sound aperture 210. Electrical circuitry (not shown) occupies a portion of the open region 209. The microphone diaphragm 208 is a thin

structure (e.g., about 0.005 inch thick) that includes a small hole 207 which may be, for example, about 15 μm in diameter. The diaphragm hole 207 insures that the pressure is equal on both sides of the microphone diaphragm 208 so that the acoustic response is similar at different barometric conditions. The open region 209 is the volume within the housing 206 not occupied by microphone components. The exemplary microphone holder 146 has a relatively narrow portion 212, a relatively wide portion 214, a recess 216 for the microphone 108, a top surface 218 and a holder aperture 220. The exemplary housing 102 includes a mounting recess 222 in the main portion 116 that is configured to receive the microphone holder 146. The configurations of the housing 102, microphone 108 and microphone holder 146 are such that microphone sound aperture 210 and holder aperture 220 are aligned. The membrane 148 is positioned between the microphone holder top surface 218 and the end wall 224 of the mounting recess 222.

It should be noted here that, in the illustrated embodiment, the headpiece microphone aperture 226 (FIG. 11) consists of the housing microphone aperture 124, the microphone sound aperture 210, the microphone holder aperture 220 and the pores in the cylindrical portion of the membrane 148 that extends from the housing microphone aperture 124 to the holder aperture 220. In other words, there is no wall or other non-porous structure between the environment and the microphone diaphragm 208 that would interfere with sound waves in addition to preventing moisture ingress. The respective configurations of the housing 102 and the cap 104 are such that the housing microphone aperture 124 and the cap sound port 158 are aligned with one another and the shield 168 is positioned therebetween. As such, air, sound and moisture may pass through the cap 104 and into the microphone aperture 226.

Passage of moisture through the hole 207 in the microphone diaphragm 208 and into the interior of the microphone would damage or destroy the microphone 108, while dust and other particulates would degrade the acoustic response. Accordingly, the exemplary headpiece 100 is configured to protect the microphone diaphragm 208 from moisture without adversely effecting the acoustic response of the headpiece.

For example, the exemplary membrane 148 is a hydrophobic membrane that protects against water ingress into the microphone 108 at relatively low pressures, e.g., in the shower, or during submersion at depths up to 0.5 m where the water pressure is about 0.05 bar. Suitable materials for the membrane 148 include, but are not limited to, a hydrophobic-treated polyethylene sheet from Porex Technologies (part no. XM-18505) that is about 0.45 +/- 0.05 mm thick.

The exemplary shield 168 is an acoustic hydrophobic membrane that is configured to prevent dust, soap, oils, and other relatively large particles and drops (i.e. 30 microns or larger) from reaching membrane 148. The shield 168 will not preclude water from reaching the membrane 148 (e.g., during submersion), but will prevent air turbulence between the shield and membrane 148. The significance of turbulence prevention is discussed below. Suitable materials for the shield 168 include, but are not limited to, PETEX hydrophobic acoustic material (part no. 145-27 07-27/16), which is a 1:2 twill weave of PET monofilament fibers. It should also be noted that the shield 168 is a non-permanent, serviceable portion of the headpiece 100 and may be readily removed from the housing 102, along with the cap 104, and replaced as necessary or desired. In the illustrated embodiment, the shield 168 is a permanently secured to the cap 104 with adhesive and the shield will be replaced with the cap. The shield 168 is also robust enough to be cleaned by wiping the shield with a cloth when the cap 104 is removed from the housing.

The exemplary headpiece 100 may also be configured to maintain a column of air over the microphone 108 that will prevent moisture from reaching the microphone diaphragm 208 during submersion of the headpiece up to a predetermined maximum submersion depth (e.g., submersion up to a depth of 3.0 m). The column of air will not, however, interfere with the transmission of sound waves to the microphone diaphragm 208 or otherwise degrade the acoustic response of the headpiece as would positioning a non-porous cover between the microphone and the environment.

More specifically, and referring to FIG. 11, an air column AC extends (prior to submersion) from shield 168, through the housing microphone aperture 124, the pores in the cylindrical portion of the membrane 148 that extends from

the microphone aperture 124 to the microphone holder aperture 220, the microphone holder aperture 220 itself, to the bottom end (in the illustrated orientation) of the internal region 209 of the microphone 108. The air column AC will be compressed by water that passes through the shield 168 when the headpiece 100 is submerged. The amount of compression is a function of the water pressure WP which, in turn, is a function of the submersion depth. The relationship of the respective volumes V_1 (i.e., the volume within of the housing microphone aperture 124 and the pores of the aligned cylindrical portion of the membrane 148), V_2 (i.e., the volume of the microphone sound aperture 210 and microphone holder aperture 220) and V_3 (i.e., the volume of the region 209 behind the microphone diaphragm 208) may be selected such that water will not reach the microphone diaphragm 208 during submersions up to a predetermined depth. The total volume of the air in the air column AC prior to submersion must be such that, when compressed by the water at the predetermined maximum submersion depth, the compressed volume of the air column will be greater than V_3 in order to insure that water does not reach the microphone diaphragm 208. Put another way, volumes V_1 and V_2 together define an aperture volume, which is the portion of the air column AC on the housing side of the microphone diaphragm 208, and the volumetric reduction of the air column may not exceed the aperture volume.

One example of the above-described volumetric relationship is diagrammatically illustrated in FIGS. 12A-12C. The locations of the shield 168, the microphone diaphragm 208 and the microphone holder top surface 218 are shown for perspective. The air column AC is shown in FIG. 12A prior to submersion and exposed to atmospheric pressure AP. The air column AC has an uncompressed volume at atmospheric pressure $V_{AC_{AP}} = V_1 + V_2 + V_3$. After the headpiece 100 has been submerged, water will enter the housing microphone aperture 124 (FIG. 11), pass through the shield 168 and form a water column WC. FIG. 12B shows the air column AC being compressed by the water pressure WP when the headpiece 100 is submerged to a depth that is less than the predetermined maximum depth. The water pressure WP will increase as the depth of the submersion increases. At the predetermined maximum submersion depth, the water pressure WP_{MAX} is such that the volume of the compressed air

column VAC_{COMP} will be slightly greater than volume V_3 (FIG. 11), thereby preventing the water column WC from reaching the microphone diaphragm 208.

The relationship of volumes V_1 , V_2 and V_3 is related Boyle's gas law, which states that the product of gas pressure and gas volume is a constant.

5 Thus,

$$VAC_{AP} \times AP = VAC_{COMP} \times WP_{MAX}; \text{ and}$$

$$VAC_{COMP} = VAC_{AP} \times (AP/WP_{MAX}).$$

10 For example, atmospheric pressure is 100 kPa and water pressure at a depth of 3.0 m is 130 kPa. Thus, for a maximum submersion depth of 3.0 m, $VAC_{COMP} = VAC_{AP} \times (100/130) = (V_1+V_2+V_3)(100/130)$. However, given that VAC_{COMP} should be greater than V_3 in order to prevent damage to the microphone, the equation $(V_1+V_2) > 0.3V_3$ defines the volumetric relationship when the predetermined maximum submersion depth is 3.0 m. The relationship of $(V_1 + V_2)$, which is the aperture volume on the housing side of the microphone diaphragm 208, to V_3 , which is the volume on the other side of the microphone diaphragm, will be different for different maximum submersion depths. Thus, more generally, the equation $(V_1+V_2) > (WP_{MAX}/AP)V_3 - V_3$ defines a volumetric relationship whereby the air column will prevent water from reaching the microphone diaphragm 208.

15 Additionally, for best performance, the air column AC should not be subjected to turbulence during submersion that could result in some of the air escaping from the column and being replaced with water. The shield 168 reduces the likelihood that there will be turbulence sufficient to result in air escape. Alternatively, or in addition, horizontal and/or vertical baffles (not shown) may be provided in the air column AC in some embodiments to further prevent turbulence in the air column.

20 The headpiece described above was also tested under various conditions. Test results, which are presented in graph form in FIG. 13, show that the headpiece 100 provides ingress protection that is superior to the IEC IP67 standard without substantially degrading acoustic response. An IP67 rating indicates that the device is dust-tight and that internal structures are protected against moisture ingress at immersion depths of 15 cm to 1 m for 30 minutes.

30 The acoustic response of a microphone 108 mounted in a headpiece 100 in the manner described above was measured at frequencies ranging from 150

Hz to 10 kHz under a variety of test conditions. The goal prior to testing was no more than +/- 6 dB deviation from a theoretically perfect microphone after being subjected to all test conditions, as shown by the upper limit UL and lower limit LL plots on the graph illustrated in FIG. 13. Headpiece acoustic response, prior to submersion testing, within +/- 6 dB deviation from a theoretically perfect microphone is acoustic response that is not substantially degraded. The ingress of water into the microphone 108 would result in deviation outside this range and, accordingly, it may be assumed that acoustic response within +/- 6 dB deviation from a theoretically perfect microphone indicates that water did not reach the microphone diaphragm 208.

A single headpiece 100 was employed for all of the tests discussed below. Under test condition TC₁, the acoustic response of the microphone 108 in a new, dry headpiece 100 was tested. In other words, test condition TC₁ is simply used to confirm that the microphone 108 is not defective and that the acoustic response of the headpiece is within the acceptable, not substantially degraded, range. For test condition TC₂, which is referred to herein as the "IP68 test," the same headpiece 100 was submerged in water at a depth of 3 m for 30 minutes. The headpiece 100 was then fully dried and the acoustic response of the microphone 108 in the headpiece tested. Test conditions TC₃ to TC₅ simulate the exposure to water and other contaminants that a headpiece 100 could experience over the course of three years, and are substantially tougher than the IP68 test. Test condition TC₃ is representative of the amount of direct exposure to a shower stream that the headpiece will experience, assuming that the wearer takes one shower a day for three years. Here, the headpiece 100 was subjected to 27 cycles of exposure to a direct shower stream. Each cycle consisted of 30 minutes of direct exposure to the shower stream followed by shaking, wiping and full drying (e.g., 1-8 hours in a desiccant dryer). The acoustic response of the microphone 108 in the headpiece 100 was tested after the last cycle. Test condition TC₄ is representative of conditions that would be experienced in a bathtub environment over the course of three years. Here, the headpiece 100 was subjected to 9 cycles of submersion to a depth of 0.05 m in bath water including soap, shampoo and lotion. Each cycle consisted of 1 hour of submersion followed by shaking, wiping and full drying (e.g., 1-8 hours in a

desiccant dryer). The acoustic response of the microphone 108 in the headpiece 100 was tested after the last cycle. Test condition TC₅ is representative of the conditions that could be experienced by a headpiece worn by a person who swims twice a week. Here, the headpiece 100 was subjected to 5 cycles of
5 submersion to a depth of 1.0 m in pool water including chlorine. Each cycle consisted of 30 minutes of submersion followed by shaking, wiping and full drying (e.g., 1-8 hours in a desiccant dryer). The acoustic response of the microphone 108 in the headpiece 100 was tested after the last cycle.

As illustrated in FIG. 13, the acoustic response of the microphone 108 in
10 the headpiece 100 was within the +/- 6 dB deviation range for all test conditions. Thus, these tests show that there was no water ingress into the microphone 108 under test conditions TC₂ to TC₅.

Although the inventions disclosed herein have been described in terms
of the preferred embodiments above, numerous modifications and/or
15 additions to the above-described preferred embodiments would be readily apparent to one skilled in the art. By way of example, but not limitation, the inventions include any combination of the elements from the various species and embodiments disclosed in the specification that are not already described. Additionally, the inventions described herein are also applicable to
20 BTE sound processors. The present inventions also include systems including headpieces in accordance with description above and claims below in combination with a sound processor and/or a cochlear implant. It is intended that the scope of the present inventions extend to all such modifications and/or additions and that the scope of the present inventions is limited solely
25 by the claims set forth below.

I claim:

- 1 1. A cochlear implant headpiece, comprising:
2 a housing including a housing microphone aperture;
3 a microphone carried within the housing and associated with the
4 housing microphone aperture;
5 a membrane between the housing microphone aperture and the
6 microphone; and
7 a cap, including a sound port and a shield over the sound port,
8 configured to be positioned on the housing such that the sound port and
9 shield are aligned with the housing microphone aperture;
10 wherein the housing and cap are configured such that they will
11 be removably connected to one another when the cap is positioned on the
12 housing.
- 1 2. A cochlear implant headpiece as claimed in claim 1, wherein the
2 membrane comprises a hydrophobic membrane.
- 1 3. A cochlear implant headpiece as claimed in claim 2, wherein the
2 hydrophobic membrane is configured to prevent water passage at water
3 pressures up to about 0.05 bar.
- 1 4. A cochlear implant headpiece as claimed in claim 1, wherein the
2 shield is configured to prevent passage of particles that are at least 30
3 microns in diameter.
- 1 5. A cochlear implant headpiece as claimed in claim 4, wherein the
2 shield is configured to allow passage of water.
- 1 6. A cochlear implant headpiece as claimed in claim 1, wherein
2 the housing includes a main portion and a cover secured to one
3 another by a joint formed from material from the main portion and cover.

1 7. A cochlear implant headpiece as claimed in claim 6, wherein the
2 joint comprises an ultrasonic weld.

1 8. A cochlear implant headpiece as claimed in claim 1, further
2 comprising:
3 a magnet carried by the housing.

1 9. A cochlear implant headpiece as claimed in claim 1, wherein
2 the microphone includes a microphone housing, a sound
3 aperture, an open region defining a volume within the microphone housing,
4 and a diaphragm between the sound aperture and the open region;
5 the housing microphone aperture and the microphone sound
6 aperture together define a combined volume; and
7 the combined volume is greater than $(0.3) \times (\text{volume of the}$
8 microphone open region).

1 10. A cochlear implant headpiece as claimed in claim 1, wherein
2 the housing includes a plurality of latch apertures; and
3 the cap includes a plurality of latches.

1 11. A cochlear implant headpiece, comprising:
2 a housing including an internal volume and a housing
3 microphone aperture that extends to the internal volume; and
4 a microphone carried within the housing internal volume and
5 aligned with the housing microphone aperture;
6 wherein the internal volume is protected against particulate and
7 moisture ingress to an extent greater than that required by IEC IP67.

1 12. A cochlear implant headpiece as claimed in claim 11, wherein
2 the internal volume is protected against particulate and moisture ingress to a
3 level of at least IEC IP68.

1 13. A cochlear implant headpiece as claimed in claim 11, further
2 comprising:

3 a cap, including a sound port and a shield over the sound port,
4 configured to be positioned on the housing such that the sound port and
5 shield are aligned with the housing microphone aperture.

1 14. A cochlear implant headpiece as claimed in claim 11, further
2 comprising:

3 a porous hydrophobic membrane between the housing
4 microphone aperture and the microphone.

1 15. A cochlear implant headpiece as claimed in claim 11, wherein
2 the configuration of the housing and microphone is such that the acoustic
3 response of the headpiece is +/- 6 dB deviation from a theoretically perfect
4 microphone.

1 16. A cochlear implant headpiece as claimed in claim 11, wherein
2 the housing microphone aperture is not sealed.

1 17. A connector implant headpiece, comprising:
2 a housing configured to be worn on a user's head;
3 a transmitter carried by the housing; and
4 a connector, carried by the housing and operably connected to
5 the transmitter, including
6 an electrically conductive barrel,
7 an electrically conductive socket,
8 an electrical insulator between the barrel and the socket,
9 a first seal compressed between the barrel and the
10 insulator, and
11 a second seal compressed between the socket and the
12 insulator.

1 18. A cochlear implant headpiece as claimed in claim 17, wherein at
2 least one of the first and second seals comprises an o-ring seal.

1 19. A cochlear implant headpiece as claimed in claim 17, wherein

2 the electrical insulator includes first and second recesses; and
 3 the first and second seals are respectively positioned in the first
 4 and second recesses.

1 20. A cochlear implant headpiece as claimed in claim 17, wherein
 2 the respective configurations of the barrel, socket, insulator, first seal and
 3 second seal are such that the connector prevents particulate and moisture
 4 ingress beyond that required by IEC IP67.

1 21. A cochlear implant headpiece as claimed in claim 17, further
 2 comprising:
 3 a microphone carried by the housing.

1 22. A method of manufacturing a cochlear implant headpiece,
 2 including a microphone aperture and a microphone having an internal volume
 3 mounted adjacent to the microphone aperture, that can be submerged in
 4 water without damage to the microphone to a predetermined maximum depth,
 5 the method comprising the steps of:

6 calculating the volume of the microphone aperture according to
 7 the formula:

$$8 \quad V_{\text{APERTURE}} > (WP_{\text{MAX}}/AP) V_{\text{MIC}} - V_{\text{MIC}}$$

9 where,

10 V_{APERTURE} = microphone aperture volume,

11 WP_{MAX} = water pressure at the predetermined maximum
 12 depth,

13 AP = atmospheric pressure, and

14 V_{MIC} = internal microphone volume; and

15 forming a microphone aperture of the calculated size.

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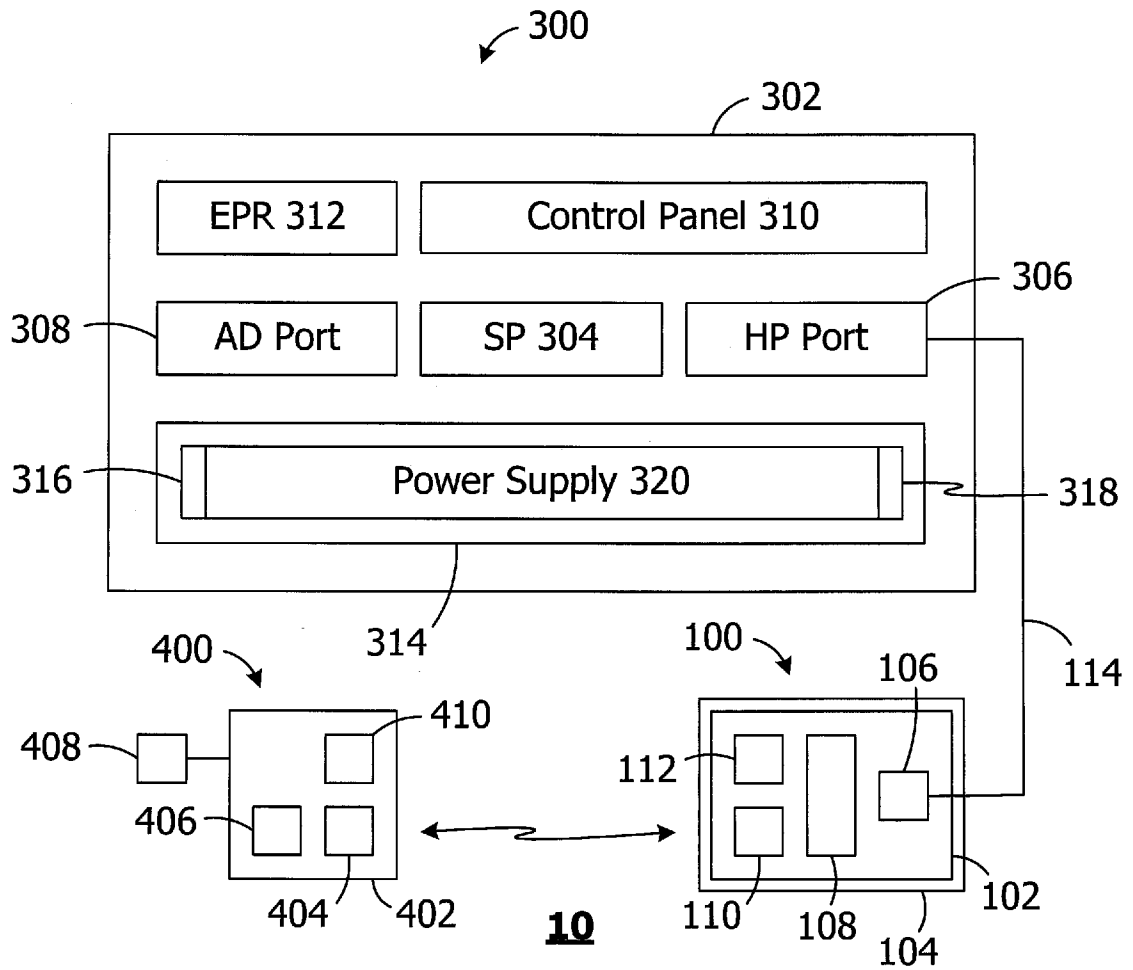


FIG. 1

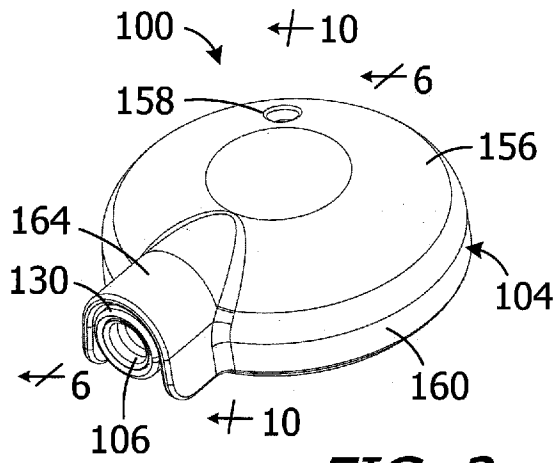


FIG. 2

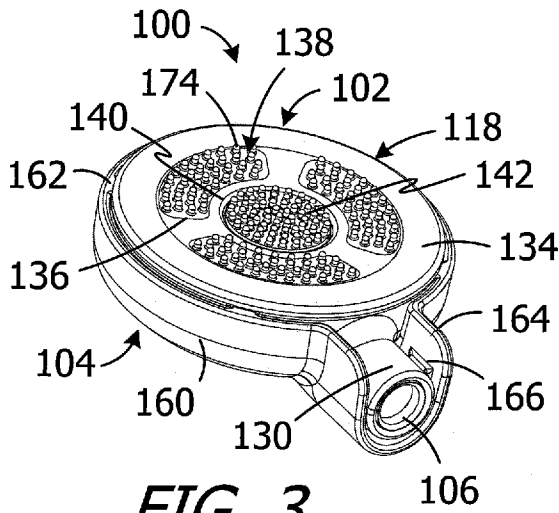


FIG. 3

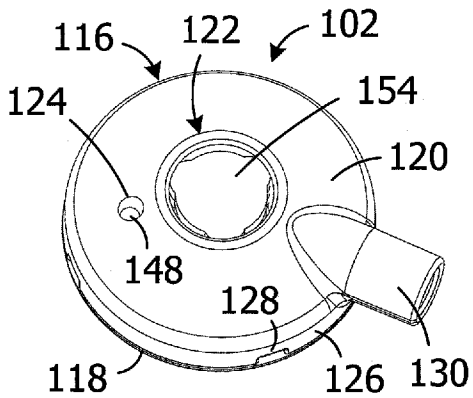


FIG. 4

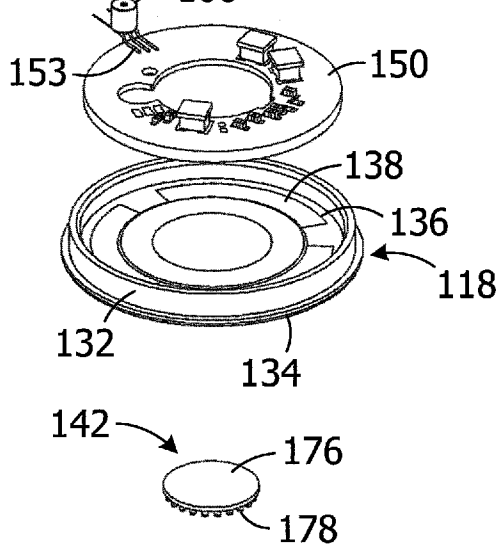
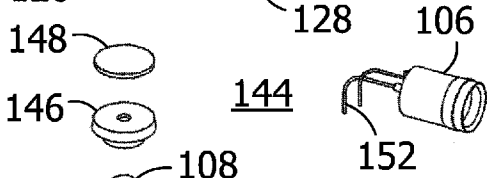
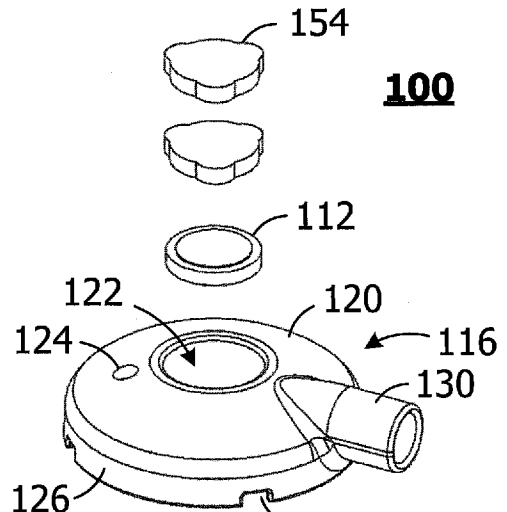
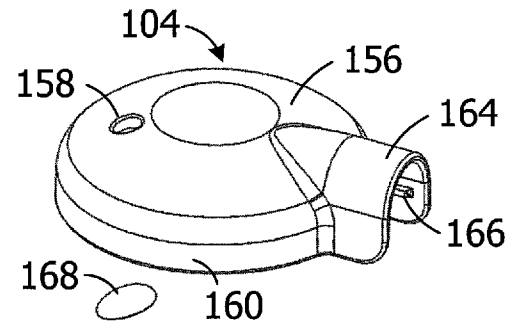


FIG. 5

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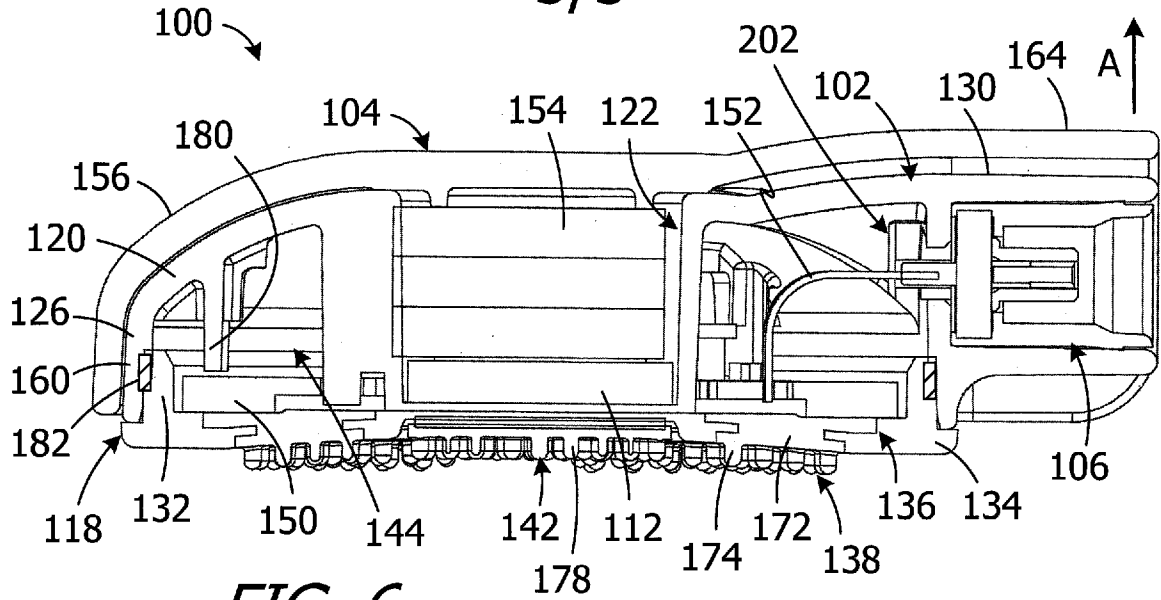


FIG. 6

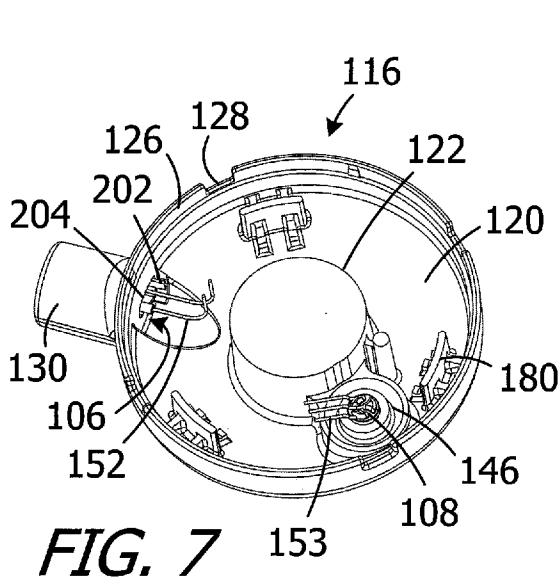


FIG. 7

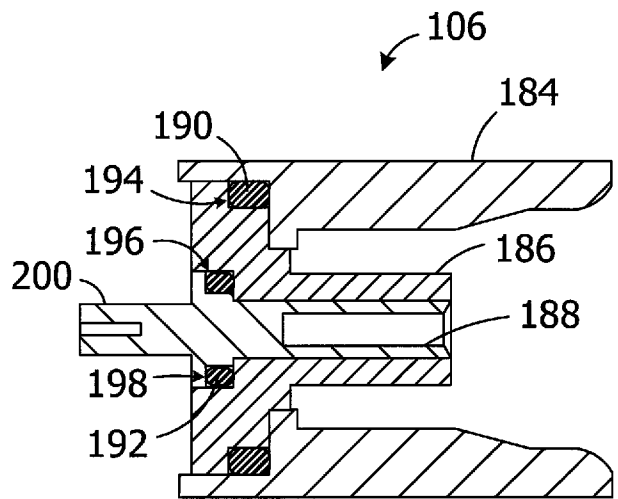


FIG. 8

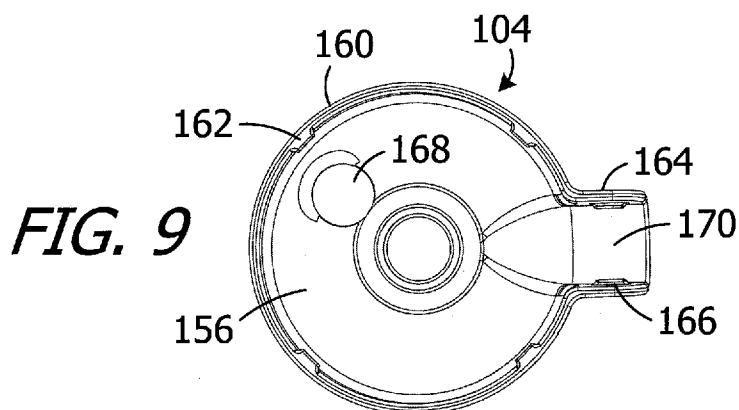
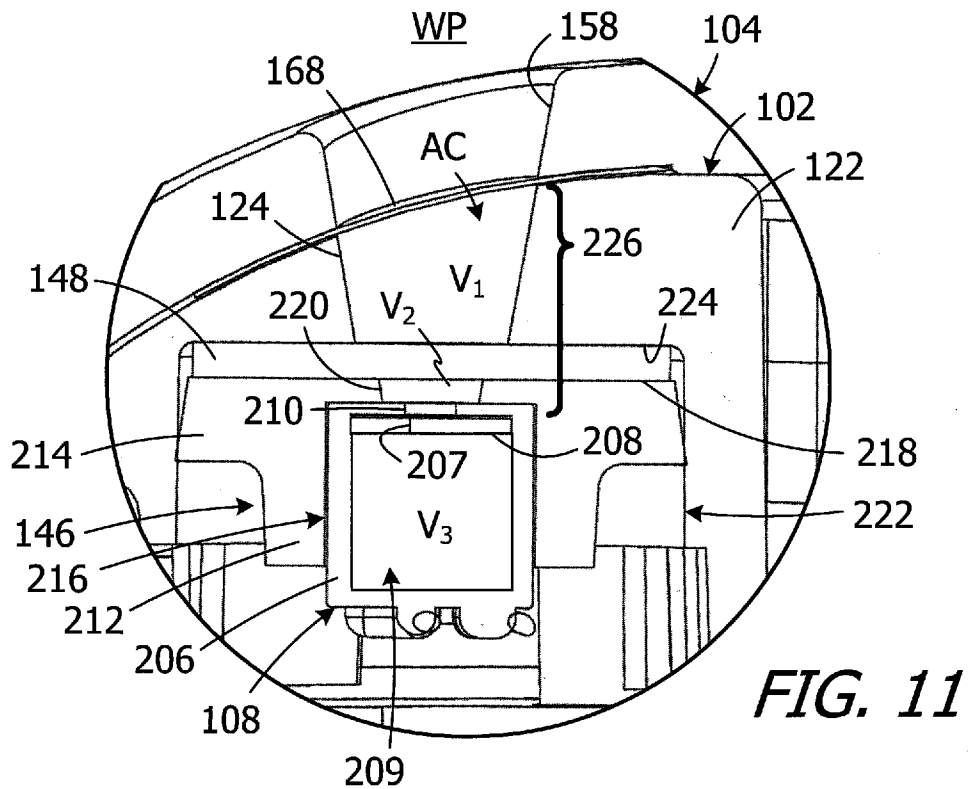
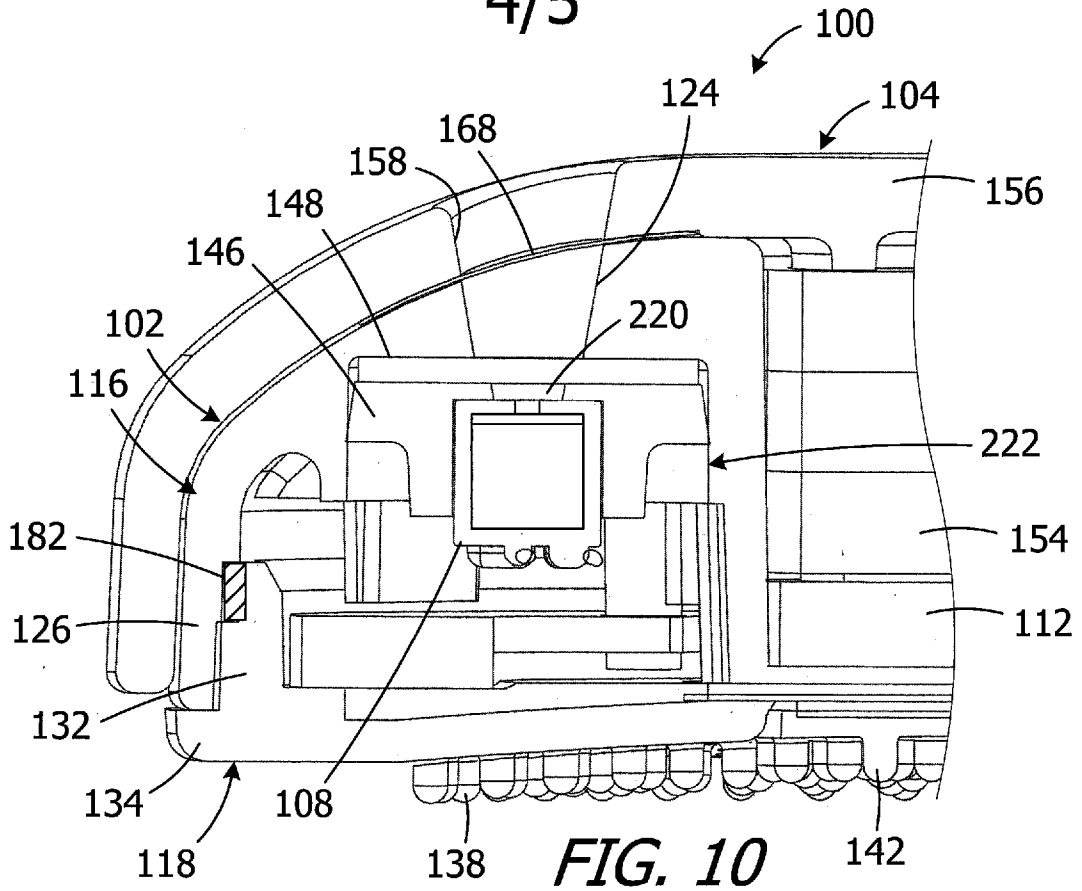


FIG. 9

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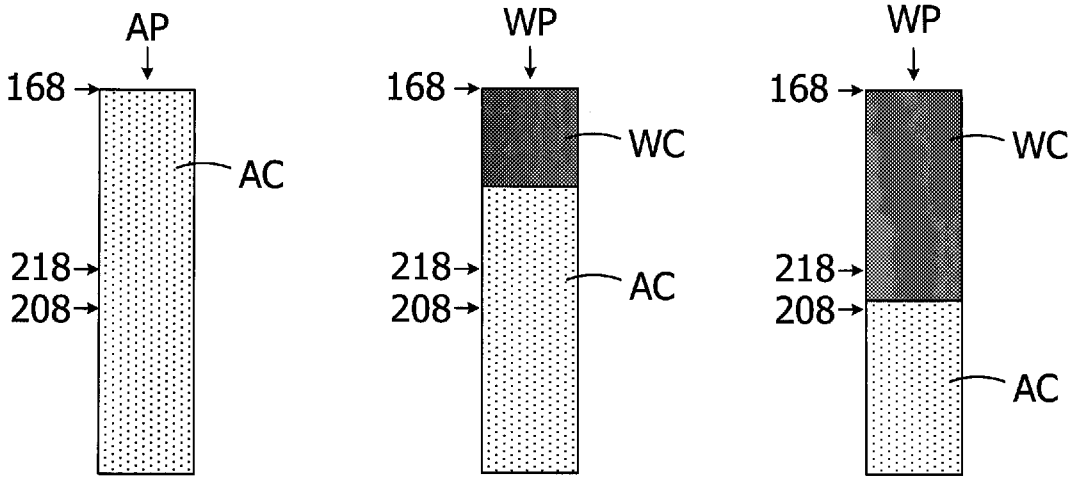
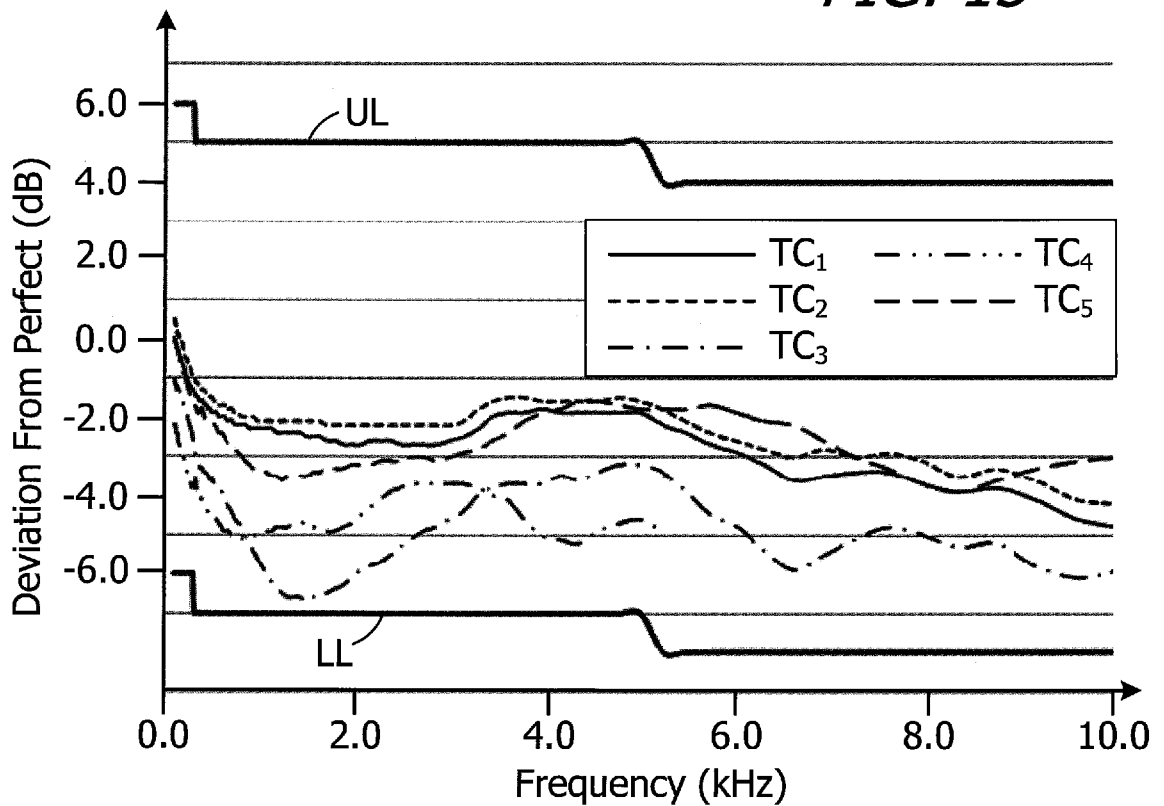


FIG. 12A

FIG. 12B

FIG. 12C

FIG. 13



INTERNATIONAL SEARCH REPORT

International application No PCT/US2012/020980

A. CLASSIFICATION OF SUBJECT MATTER INV. H04R1/08 H04R25/00 H01R13/52 H01R24/38 ADD. A61N1/36		
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 A61N H01R		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/147978 A1 (SAUER JOSEPH [DE] ET AL) 11 June 2009 (2009-06-11) paragraphs [0049] - [0055]; figures 1A-5 -----	1-14, 16, 22
X	US 4 987 597 A (HAERTL CHRISTOF [DE]) 22 January 1991 (1991-01-22) column 2, line 58 - column 4, line 61; figures 1, 2, 10-13 -----	1-14, 16, 22
X	DE 10 2007 027920 B3 (SIEMENS MEDICAL INSTR PTE LTD [SG]) 18 December 2008 (2008-12-18) paragraphs [0031] - [0035], [0046]; figures 1A-1C -----	1-3, 5, 11-14, 16, 22
X	US 2002/177883 A1 (TZIVISKOS GEORGE [US] ET AL) 28 November 2002 (2002-11-28) paragraphs [0026] - [0035]; figures 1-7 -----	22
Y		1-16
----- -/--		
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.	
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"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	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
19 June 2012	28/06/2012	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Fischer, Olivier	

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/020980

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/175203 A1 (KARAMUK ERDAL [CH]) 11 August 2005 (2005-08-11) paragraphs [0039] - [0054]; figures 1, 2, 5 -----	1-16
A	US 2006/215863 A1 (SAUER JOSEPH [DE]) 28 September 2006 (2006-09-28) paragraphs [0002], [0020] - [0023]; figures 1-3 -----	1-16
A	US 4 073 366 A (ESTES ROGER Q) 14 February 1978 (1978-02-14) column 2, line 4 - column 4, line 2; figures 1-4 -----	1-16
A	US 2003/142843 A1 (MEIER HILMAR [CH]) 31 July 2003 (2003-07-31) paragraphs [0019] - [0036]; figures 1-5 -----	1-16
Y	US 7 729 774 B1 (LYNCH DOUGLAS P [US] ET AL) 1 June 2010 (2010-06-01) column 3, line 40 - column 5, line 37; figures 1-3, 5-16 -----	17-21
Y	EP 0 768 736 A2 (KABELMETAL ELECTRO GMBH [DE]) 16 April 1997 (1997-04-16) column 3, line 27 - column 5, line 21; figures 1-4 -----	17-21

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/020980

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-16

Cochlear headpiece comprising a housing, a microphone within the housing, a membrane between the housing and the microphone and a removably connectable cap including a sound port and a shield, the membrane and the cap protecting against particulate and moisture ingress.

2. claims: 17-21

Cochlear headpiece comprising a housing, a transmitter and a connector operably connected to the transmitter, the connector including an electrically conductive barrel, an electrically conductive socket, an electrical insulator between the barrel and the socket, a first seal compressed between the barrel and the insulator, and a second seal compressed between the socket and the insulator.

3. claim: 22

A method of manufacturing a cochlear implant headpiece, including a microphone aperture and a microphone having an internal volume mounted adjacent to the microphone aperture, that can be submerged in water without damage to the microphone to a predetermined maximum depth, the method comprising the steps of calculating the volume of the microphone aperture according to a specific involving the microphone aperture volume, the water pressure at the predetermined maximum depth, atmospheric pressure, and the internal microphone volume; and forming a microphone aperture of the calculated size.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2012/020980

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009147978 A1	11-06-2009	DE 102007058987 B3 EP 2068587 A2 US 2009147978 A1	16-07-2009 10-06-2009 11-06-2009

US 4987597 A	22-01-1991	AU 2336788 A CA 1296797 C DE 8713369 U1 DK 552888 A EP 0310866 A1 JP H0157898 U US 4987597 A	06-04-1989 03-03-1992 09-02-1989 06-04-1989 12-04-1989 11-04-1989 22-01-1991

DE 102007027920 B3	18-12-2008	NONE	

US 2002177883 A1	28-11-2002	NONE	

US 2005175203 A1	11-08-2005	NONE	

US 2006215863 A1	28-09-2006	DE 102005012149 B3 EP 1703771 A2 US 2006215863 A1	21-09-2006 20-09-2006 28-09-2006

US 4073366 A	14-02-1978	NONE	

US 2003142843 A1	31-07-2003	NONE	

US 7729774 B1	01-06-2010	NONE	

EP 0768736 A2	16-04-1997	AU 6801796 A EP 0768736 A2 NZ 299557 A	24-04-1997 16-04-1997 27-05-1998
