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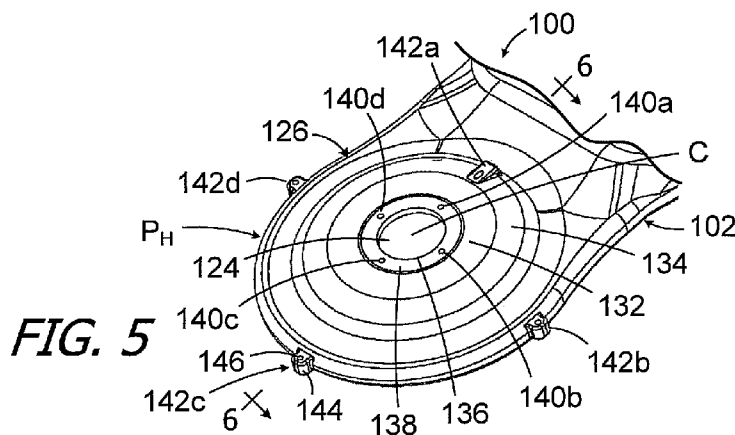
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(54) Title: COCHLEAR IMPLANT WITH A MAGNET RESTRAINT ANCHORED TO RESTRAINT ANCHORS AND A METHOD FOR SECURING A MAGNET



(57) Abstract: A cochlear implant (100) includes a cochlear lead, a housing (102) including a magnet pocket and a magnet aperture (136), an antenna within the housing and adjacent to the magnet pocket, a stimulation processor and a plurality of restraint anchors (140a-140d, 142a-142d) on the housing.

COCHLEAR IMPLANT WITH A MAGNET RESTRAINT ANCHORED TO RESTRAINT ANCHORS AND A METHOD FOR
SECURING A MAGNET**BACKGROUND****1. Field**

The present disclosure relates generally to the implantable portion of implantable cochlear stimulation (or "ICS") systems.

5 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
10 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
15 electrode combinations to create a perception of sound. The electrode array may, alternatively, be directly inserted into the cochlear nerve without residing in the cochlea. 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
20 reference in its entirety. Examples of commercially available ICS sound processors include, but are not limited to, the Advanced Bionics™ Harmony™ BTE sound processor, the Advanced Bionics™ Naida™ BTE sound processor and the Advanced Bionics™ Neptune™ body worn sound processor.

As alluded to above, some ICS systems include an implantable
25 cochlear stimulator (or "cochlear implant"), a sound processor unit (e.g., a body worn processor or behind-the-ear processor), and a microphone that is part of, or is in communication with, the sound processor unit. The cochlear implant communicates with the sound processor unit and, some ICS systems include a headpiece that is in communication with both the sound processor
30 unit and the cochlear implant. The headpiece communicates with the cochlear

implant by way of a transmitter (e.g., an antenna) on the headpiece and a receiver (e.g., an antenna) on the implant. Optimum communication is achieved when the transmitter and the receiver are aligned with one another. To that end, the headpiece and the cochlear implant may include respective
5 positioning magnets that are attracted to one another, and that maintain the position of the headpiece transmitter over the implant receiver. The implant magnet may, for example, be located within a pocket in the cochlear implant housing.

One example of a conventional cochlear implant (or “implantable
10 cochlear stimulator”) is the cochlear implant 10 illustrated in FIGS. 1 and 2. The cochlear implant 10 includes a flexible housing 12 formed from a silicone elastomer or other suitable material, a processor assembly 14, a cochlear lead 16 with a flexible body 18 and an electrode array 20, and an antenna 22 that may be used to receive data and power by way of an external antenna
15 that is associated with, for example, a sound processor unit. A positioning magnet 24, which is disk-shaped with north and south magnetic dipoles that are aligned in the axial direction of the disk, is located within the housing 12. The magnet 24 is used to maintain the position of a headpiece transmitter over the antenna 22.

It is sometimes necessary to remove the magnet from the cochlear
20 implant, and then reinsert the magnet, *in situ*, i.e., with the cochlear implant accessed by way of an incision in the skin. To that end, the positioning magnet 24 is carried within an internal magnet pocket 26 and can be inserted into, and removed from, the housing pocket by way of a magnet aperture 28
25 that extends through the housing top wall 30. The magnet 22 is larger than the magnet aperture 28, i.e., the outer diameter of the magnet is greater than the diameter of the magnet aperture. The portion of the top wall 30 between the aperture 28 and the outer edge 32 of the magnet 24 forms a retainer 34 that, absent deformation of the aperture and retainer, prevents the magnet
30 from coming out of the housing 12. During installation and removal, the aperture 28 and retainer 34 are stretched or otherwise deformed so that the magnet 24 can pass through the aperture 28.

The present inventors have determined that conventional cochlear implants are susceptible to improvement. For example, some conventional cochlear implants may not be compatible with magnetic resonance imaging ("MRI") systems. As illustrated in FIG. 3, the implant magnet 24 produces a magnetic field M in a direction that is perpendicular to the patient's skin and parallel to the axis A. This magnetic field direction is not aligned with, and may be perpendicular to (as shown), the direction of the MRI magnetic field B. The misalignment of the interacting magnetic fields M and B is problematic for a number of reasons. The dominant MRI magnetic field B (typically 1.5 Tesla or more) may generate a significant amount of torque T on the implant magnet 24. The torque T may be sufficient to deform the retainer 34 and dislodge the implant magnet 24 from the pocket 26 by way of the aperture 28 and/or reverse the magnet. One proposed solution involves surgically removing the implant magnet 24 prior to an MRI procedure and then surgically replacing the implant magnet thereafter. The present inventors have determined that a solution which allows an MRI procedure to be performed without magnet removal/replacement surgery, but which also permits magnet removal/replacement if otherwise necessary, would be desirable.

SUMMARY

A cochlear implant in accordance with one of the present inventions includes a cochlear lead, a housing defining an exterior and including a magnet pocket and a magnet aperture, an antenna within the housing, a stimulation processor within the housing, and a plurality of restraint anchors on the housing. The present inventions also include systems with such a cochlear implant in combination with a headpiece.

A method in accordance with one of the present inventions includes the step of securing a magnet within a cochlear implant housing that includes an exterior, a magnet pocket in which the magnet is located, and a magnet aperture that extends from the exterior to the magnet pocket, by anchoring a restraint to restraint anchors on the cochlear implant housing in such a manner that the restraint extends over the magnet aperture.

5 A cochlear implant in accordance with one of the present inventions includes a cochlear lead, a housing defining an exterior and including a magnet pocket and a magnet aperture, an antenna within the housing, a stimulation processor within the housing, and means for securing a restraint to the housing in such a manner that the restraint extends across the magnet aperture. The present inventions also include systems with such a cochlear implant in combination with a headpiece.

10 There are a number of advantages associated with such apparatus and methods. For example, the torque applied to the implant magnet by a strong magnetic field, such as an MRI magnetic field, will not dislodge the implant magnet from the within the housing and/or reverse the magnet. As a result, surgical removal of the cochlear implant magnet prior to an MRI procedure, and then surgical replacement thereafter, is not required. In those instances where removal is required, the restraints can be cut to permit magnet removal and later re-insertion, and the anchors facilitate replacement of the restraints. 15 These benefits are also achieved without anchoring the restraint(s) to tissue such as bone or fascia.

20 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.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a plan view of a conventional cochlear implant.

FIG. 2 is a section view taken along line 2-2 in FIG. 1.

FIG. 3 is a side view showing a conventional cochlear implant in an MRI magnetic field.

30 FIG. 4 is a plan view of a cochlear implant in accordance with one embodiment of a present invention.

FIG. 5 is a perspective view of portion of the cochlear implant illustrated in FIG. 4.

FIG. 6 is a section view taken along line 6-6 in FIG. 5.

FIG. 7 is a section view similar to FIG. 6 with the magnet removed.

FIG. 8 is a plan view of a portion of the cochlear implant illustrated in FIGS. 4-7 with a pair of restraints secured thereto.

5 FIG. 9 is a plan view of a portion of the cochlear implant illustrated in FIGS. 4-7 with a pair of restraints secured thereto.

FIG. 10 is a plan view of a portion of the cochlear implant illustrated in FIGS. 4-7 with a single restraint secured thereto.

10 FIG. 11 is a plan view of a portion of the cochlear implant illustrated in FIGS. 4-7 with a single restraint and a cover secured thereto.

FIG. 12 is a perspective view of a cochlear implant in accordance with one embodiment of a present invention.

FIG. 13 is a section view taken along line 13-13 in FIG. 12.

15 FIG. 14 is a plan view of a portion of the cochlear implant illustrated in FIGS. 12-13 with a pair of restraints secured thereto.

FIG. 15 is a perspective view of a cochlear implant in accordance with one embodiment of a present invention.

FIG. 16 is a section view taken along line 16-16 in FIG. 15.

20 FIG. 17 is a plan view of a portion of the cochlear implant illustrated in FIGS. 15-17 with three restraints secured thereto.

FIG. 18 is a block diagram of a cochlear implant system in accordance with one embodiment of a present invention.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

25 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.

30 One example of a cochlear implant (or “implantable cochlear stimulator”) in accordance with the present inventions is the cochlear implant 100 illustrated in FIGS. 4-7. Referring first to FIG. 4, the exemplary cochlear implant 100 includes a resilient flexible housing 102 formed from a silicone elastomer or other suitable material, a processor assembly 104, a cochlear lead 106, and

an antenna 108 that may be used to receive data and power by way of an external antenna that is associated with, for example, a sound processor unit. The cochlear lead 106 may include a flexible body 110, an electrode array 112 at one end of the flexible body 102, and a plurality of wires (not shown) that extend through the flexible body from the electrodes 114 (e.g., platinum electrodes) in the array 112 to the other end of the flexible body. The exemplary antenna 108 is a coil antenna with one or more loops (or “turns”), and three loops are shown in the illustrated embodiment. The exemplary processor assembly 104, which is connected to the electrode array 112 and antenna 108, includes a printed circuit board 116 with a stimulation processor 118 that is located within a hermetically sealed case 120. The stimulation processor 118 converts stimulation data into stimulation signals that stimulate the electrodes 114 of the electrode array 112. The hermetically sealed case 120 is located within a processor portion 122 of the housing 102. A positioning magnet 124 is located within an antenna portion 126 housing 102. The magnet 124, which is used to maintain the position of a headpiece transmitter over the antenna 108, is centered relative to the antenna 108.

Turning to FIGS. 5-7, the exemplary housing antenna portion 126 includes a magnet pocket 128 which is surrounded by a bottom wall 130 that is located under the magnet pocket (in the illustrated orientation), a top wall 132 that is located above the magnet pocket (in the illustrated orientation) and a side wall 134 that is lateral of, and extends around, the magnet pocket. During use, the housing bottom wall 130 faces the patient’s skull and the outer surface of the bottom wall defines a portion of the bottom surface of the cochlear implant 100, which is the surface of the cochlear implant that faces the patient’s skull. The magnet pocket 128 is disk-shaped in the illustrated implementation and, accordingly, the outer perimeter P_P of the magnet pocket is circular. The magnet 124 can be inserted into, and removed from, the magnet pocket 128 by way of a magnet aperture 136 that extends through the housing top wall 132. The magnet 124 is larger than the magnet aperture 136, i.e., the outer diameter of the magnet is greater than the diameter of the magnet aperture, and the portion of the top wall 132 between the aperture 136 and the outer edge of the magnet forms a retainer 138.

As the strength of the retainer 138 may be insufficient to prevent the magnet 124 from being dislodged during an MRI procedure, the present implant housing 102 includes a plurality of anchors (or “restraint anchors”) to which one or more magnet-holding restraints may be secured. The exemplary implementation illustrated in FIGS. 4-7 includes two sets of anchors. The first set of anchors, which includes anchors 140a-140d, is associated with the retainer 138. The anchors 140a-140d may simply be regions of the portion of the top wall 132 that forms the retainer 138 with apertures that extend through each region (as shown). So positioned, the anchors 140a-140d are located within the region of the top wall 132 that is defined by the outer perimeter P_P of the magnet pocket 128 (i.e., extends outwardly to the same extent as the outer perimeter P_P) and are adjacent to the magnet aperture 136. The apertures of the exemplary anchors 140a-140d extend from the top surface of the housing 102 to magnet pocket 128 (but not to the bottom surface of the implant 100). The second set of anchors, which includes anchors 142a-142d, is associated with the outer perimeter of the housing antenna portion 126. In particular, the anchors 142b-142d are located on the housing outer perimeter P_H , while the anchor 142a is located within the outer perimeter P_H . The distance between the anchors 142a-142d and the center C of the magnet aperture 136 is greater than the distance between the anchors 140a-140d and the center C. The exemplary anchors 142a-142d each include a base 144 that extends outwardly from the adjacent portion of the housing 102 (e.g., the side wall 134) and an aperture 146 that extends through the base. The apertures 146 of the anchors 142b-142d extend to the bottom surface of the cochlear implant 100, which in the illustrated embodiment includes the bottom surface of the housing 102 and the bottom surfaces of the bases 144 of the anchors 142b-142d, while the aperture 146 of the anchor 142a does not extend to the bottom surface of the cochlear implant 100.

The anchors 140a-140d and 142a-142d may be used in conjunction with one or more flexible restraints in, for example, the manner described below with reference to FIGS. 8-11. To that end, the anchors in each set are arranged such that a flexible restraint can extend from one anchor to another across the magnet aperture 136. Put another way, the anchors perform the

function of securing a restraint to the housing 102 in such a manner that the restraint extends across the magnet aperture 136. In the embodiment illustrated in FIGS. 4-7, pairs of anchors in each set are diametrically opposed, i.e. are offset from one another by 180° around the center C of the magnet aperture. A restraint associated with a pair of diametrically opposed anchors will pass over the center C of the magnet aperture 136. Other anchor arrangements are discussed below.

The flexible restraints may be slender lengths of flexible material such as suture threads, slender chords and the like. The thickness of the flexible restraints should be low enough that the flexible restraints do not substantially increase the distance between the implant magnet 124 and the headpiece magnet. For example, the thickness (e.g., diameter where the cross-section is circular) may be 1 mm or less. Suitable materials include, but are not limited to, biocompatible materials such as nylon, polyester, polyvinylidene fluoride, and polypropylene. In at least some instances, the restraints will be secured to the cochlear implant 100 by way of the anchors 140a-140d and/or anchors 142a-142d prior to implantation.

Referring first to FIG. 8, the cochlear implant 100 is shown in conjunction with first and second restraints 148 and 150. The restraints 148 and 150 are secured to the anchors 142a-142d, thereby securing the restraints to the housing 102, and simply pass over the anchors 140a-140d. The restraints 148 and 150 pass through the aperture 146 (FIGS. 5-7) in each of the anchors 142a-142d. A knot 152 is formed at the ends of each restraint 148 and 150 (only one visible in FIG. 8), and a short piece 154 of the restraint may extend from each knot. The first and second restraints 148 and 150 may, alternatively, be only secured to the anchors 140a-140d. In both of these instances, as well as in the other restraint anchoring techniques described below, the restraints 148 and 150 are anchored to (i.e., secured to) a portion of the cochlear implant 100 and not to tissue such as bone or fascia. It should also be noted that, because the width of the restraints 148 and 158 is far less than the size (e.g., diameter) of the magnet aperture 136, the restraints only cover a small portion of the magnet aperture as they pass over the center C.

Turning to FIG. 9, the cochlear implant 100 is again shown in conjunction with the first and second restraints 148 and 150. Here, however, the restraints 148 and 150 pass through the anchors 140a-140d and are secured to the anchors 142a-142d. The restraints 148 and 150 are secured to the anchors 142a-142d with knots 152 (only one visible in FIG. 9), and a short piece 154 of the restraint extends from each knot.

As illustrated in FIG. 10, a single restraint may be secured to the cochlear implant housing 102. By way of example, but not limitation, the restraint 148 extends from anchor 140a to anchor 140c, then from anchor 140c to anchor 140d, and then from anchor 140d to anchor 140b. The restraint 148 passes through anchors 140c and 140d and is secured to the anchors 140a and 140b with knots 152. Alternatively, or in addition, a single restraint may be employed in similar fashion in conjunction with anchors 142a-142d.

The present anchors may also be used to secure a cover 156 over the magnet aperture 136. Referring for example to FIG. 11, the restraint 148 is stitched through the cover 156 in addition to passing through the anchors 140a-140d and being secured to the anchors 140a and 140b in the manner described above with reference to FIG. 10. The cover 156 may be formed from a flexible material such as a surgical cloth or an implantable mesh (as shown).

As illustrated above, the anchors 140a-140d and 142a-142d perform the function of connecting one or more restraints to the housing 102 in a manner that prevents the magnet 124 from being partially or completely dislodged from the magnet pocket 128 through the aperture 136. As a result, the torque generated by an MRI magnetic field will not dislodge the magnet 124 from the housing 102 and/or reverse the magnet within the housing in the manner described above with reference to FIGS. 1-3. Nevertheless, if necessary, the magnet 124 may be removed in situ by simply cutting the restraints 148 and 150 and then pulling the restraints out of the anchors (and the patient) in a manner similar to sutures. The magnet 124 may also be replaced in situ, and then new restraints may be passed through and secured to the appropriate anchors using conventional suturing techniques. One

example of a device that may be used to remove the magnet 124 after the restraints have been cut and removed, and then to replace the magnet, is disclosed in PCT Pub. No. WO2014/164023.

Although the present inventions are not so limited, the exemplary magnet 124 includes a magnetic disk 158 (FIG. 6) or magnetic object of some other shape formed from a ferromagnetic material and a thin hermetically sealed housing 160 formed from, for example, biocompatible metals and/or plastics. Such housing materials may, in some instances, be non-magnetic or paramagnetic. Suitable materials include, but are not limited to, titanium or titanium alloys, polyether ether ketone (PEEK), low-density polyethylene (LDPE), high-density polyethylene (HDPE) and polyamide. In particular, exemplary metals include commercially pure titanium (e.g., Grade 2) and the titanium alloy Ti-6Al-4V (Grade 5). With respect to size and shape, and although the present inventions are not so limited, the magnet 124 may have an overall size and shape similar to that of conventional cochlear implant magnets. In some implementations, the diameter that may range from 9 mm to 16 mm and the thickness may range from 1.5 mm to 3.0 mm. The diameter of the magnet 124 is 10.5 mm, and the thickness is 2.2 mm, in the illustrated embodiment. The dimensions of the magnet pocket 128 may be equal to those of the magnet 124.

It should be noted here that the present anchor configurations are not limited to those illustrated in FIGS. 4-11. For example, either the anchors 140a-140d may be omitted, or the anchors 142a-142d may be omitted. The two sets of anchors may be rotated relative to one another about the center C (FIG. 5) of the magnet aperture 136 so that they are not aligned in the manner shown. The anchors 140a-140d and 142a-142d need not be arranged in diametrically opposed pairs. The number and configuration of the anchors may also be changed. The retainer 138 may be thickened in some implementations. The anchors, including those described below, may be integral with the housing 102 (as shown), may be reinforced, or may be separately manufactured structures that are secured to the housing.

The exemplary cochlear implant 100a illustrated in FIGS. 12-14 is substantially similar to cochlear implant 100 and similar elements are represented by similar reference numerals. Here, however the cochlear implant

100a includes anchors 160a-160d in place of anchors 140a-140d. The anchors 160a-160d each include a base 162 that extends outwardly from the adjacent portion of the housing 102 (e.g. the retainer 138) and an aperture 164 that extends through the base. The apertures 164 extend in directions that are transverse to, and may be perpendicular to, the axis A that extends through the center C of the magnet aperture 136. Referring more specifically to FIG. 14, first and second restraints 148 and 150 may be secured to the housing 102 by way of the anchors 160a-160d. Here too, a knot 152 is formed at each of the ends of each restraint 148 and 150, and a short piece 154 of the restraint may extend from each knot. The anchors 160a-160d are more robust than the anchors 140a-140d, and may also be used (or not used) in conjunction with one or more restraints in, for example, the manner described above with reference to FIGS. 8-11.

The exemplary cochlear implant 100b illustrated in FIGS. 15-17 is substantially similar to cochlear implant 100a and similar elements are represented by similar reference numerals. Here, however the cochlear implant 100b includes a set of six anchors on the retainer 138, i.e., anchors 160a-160f. Referring more specifically to FIG. 17, in one exemplary arrangement, first, second and third restraints 148, 150 and 151 may be employed in conjunction with the cochlear implant 100b and secured to the housing 102 by way of the anchors 142a-142d and 160a-160f. By way of example, but not limitation, the restraints 148 and 150 are secured to the anchors 142a-142d in the manner described above with reference to FIG. 8. The restraint 151 extends from anchor 160e to anchor 160b, then from anchor 160b to anchor 160a, then from anchor 160a to anchor 160d, then from anchor 160d to anchor 160c, and then from anchor 160c to anchor 160f. Knots 152 are formed at anchors 160e and 160f. The restraint 148 passes through anchors 140c and 140d and is secured to the anchors 140a and 140b with knots 152. As a result, restraints 150 and 151 both pass through anchors 160c and 160f.

As illustrated in FIG. 18, the exemplary cochlear implant system 50 includes the cochlear implant 100 (or one of the other cochlear implants 100a and 100b described above), a sound processor, such as the illustrated body

worn sound processor 200 or a behind-the-ear sound processor, and a headpiece 300.

The exemplary body worn sound processor 200 in the exemplary ICS system 50 includes a housing 202 in which and/or on which various components are supported. Such components may include, but are not limited to, sound processor circuitry 204, a headpiece port 206, an auxiliary device port 208 for an auxiliary device such as a mobile phone or a music player, a control panel 210, one or microphones 212, and a power supply receptacle 214 for a removable battery or other removable power supply 216 (e.g., rechargeable and disposable batteries or other electrochemical cells). The sound processor circuitry 204 converts electrical signals from the microphone 212 into stimulation data. The exemplary headpiece 300 includes a housing 302 and various components, e.g., a RF connector 304, a microphone 306, an antenna (or other transmitter) 308 and a positioning magnet apparatus 310, that are carried by the housing. The magnet apparatus 310 may consist of a single magnet or may consist of one or more magnets and a shim. The headpiece 300 may be connected to the sound processor headpiece port 206 by a cable 312. The positioning magnet apparatus 310 is attracted to the magnet 124 of the cochlear stimulator 100, thereby aligning the antenna 308 with the antenna 108. The stimulation data and, in many instances power, is supplied to the headpiece 300. The headpiece 300 transcutaneously transmits the stimulation data, and in many instances power, to the cochlear implant 100 by way of a wireless link between the antennas. The stimulation processor 118 converts the stimulation data into stimulation signals that stimulate the electrodes 114 of the electrode array 112.

In at least some implementations, the cable 312 will be configured for forward telemetry and power signals at 49 MHz 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. Additionally, given the presence of the microphone(s) 212 on the sound processor 200, the microphone 306 may be also be omitted in some instances. The functionality of the sound processor 200 and headpiece 300 may also be combined into a

single head wearable sound processor. Examples of head wearable sound processors are illustrated and described in U.S. Patent Nos. 8,811,643 and 8,983,102, which are incorporated herein by reference in their entirety.

5 Although the inventions disclosed herein have been described in terms
of the preferred embodiments above, numerous modifications and/or
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
10 described. 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 by the claims set forth below.

We claim:

1 1. A cochlear implant, comprising:
2 a cochlear lead including a plurality of electrodes;
3 a housing defining an exterior and including a magnet pocket, a
4 top wall above the magnet pocket, and a magnet aperture that extends
5 through the top wall to the magnet pocket;
6 an antenna within the housing and adjacent to the magnet
7 pocket;
8 a stimulation processor within the housing operably connected
9 to the antenna and to the cochlear lead; and
10 a plurality of restraint anchors on the housing;
11 wherein the cochlear implant defines a bottom surface; and
12 wherein at least one of the restraint anchors includes an
13 aperture that extends to the magnet pocket and/or at least one of the restraint
14 anchors includes an aperture that does not extend to the bottom surface of
15 the cochlear implant.

1 2. A cochlear implant as claimed in claim 1, wherein
2 the housing comprises a flexible housing; and
3 the antenna and the stimulation processor are embedded within
4 a flexible housing.

1 3. A cochlear implant as claimed in claim 2, wherein
2 the housing is formed from a silicone elastomer.

1 4. A cochlear implant as claimed in claim 1, wherein
2 the magnet aperture defines a center; and
3 at least two of the restraint anchors are aligned with the magnet
4 aperture center and are diametrically opposed to one another.

1 5. A cochlear implant as claimed in claim 1, wherein

2 the magnet aperture defines a center; and
3 the plurality of restraint anchors comprising a first set of restraint
4 anchors and a second set of restraint anchors, the first set of restraint anchors
5 being closer to the magnet aperture center than the second set of restraint
6 anchors.

1 6. A cochlear implant as claimed in claim 5, wherein
2 the first set of restraint anchors and the second set of restraint
3 anchors include an equal number of restraint anchors.

1 7. A cochlear implant as claimed in claim 5, wherein
2 the first set of restraint anchors is aligned with the second set of
3 restraint anchors relative to the magnet aperture center.

1 8. A cochlear implant as claimed in claim 1, wherein
2 at least one of the restraint anchors comprises an anchor
3 aperture that extends through the housing top wall at a location adjacent to
4 the magnet aperture.

1 9. A cochlear implant as claimed in claim 1, wherein
2 at least one of the restraint anchors comprises a base that
3 extends from the housing and an anchor aperture that extends through the
4 base.

1 10. A cochlear implant as claimed in claim 9, wherein
2 the magnet aperture defines a center and an axis that extends
3 through the center; and
4 the anchor aperture extends through the base in a direction that
5 is transverse to the axis.

1 11. A cochlear implant as claimed in any one of claims 1-10, further
2 comprising:
3 a magnet located within the magnet pocket.

1 12. A cochlear implant as claimed in any one of claims 1-11, further
2 comprising:

3 a magnet restraint extending from one restraint anchor to
4 another restraint anchor.

1 13. A system, comprising
2 a cochlear implant as claimed in any one of claims 1-12; and
3 a headpiece including
4 an antenna, and
5 a headpiece magnet associated with the antenna that is
6 attracted to the implant magnet.

1 14. A method, comprising:
2 securing a magnet within a cochlear implant housing that
3 includes an exterior, a magnet pocket in which the magnet is located, and a
4 magnet aperture that extends from the exterior to the magnet pocket, by
5 anchoring a restraint to restraint anchors on the cochlear implant housing in
6 such a manner that the restraint extends over the magnet aperture.

1 15. A method as claimed in claim 14, wherein
2 anchoring a restraint comprises anchoring a restraint to restraint
3 anchors that are respectively located at two diametrically opposed locations
4 on the cochlear implant housing.

1 16. A method as claimed in claim 14, wherein the restrain anchors
2 define first restraint anchors and the restraint defines a first restraint, the
3 method further comprising the step of:
4 anchoring a second restraint to second restraint anchors on the
5 cochlear implant housing in such a manner that the second restraint extends
6 over the magnet aperture.

1 17. A method as claimed in claim 16, wherein
2 the first and second restraints are offset from one another.

1 18. A method as claimed in claim 14, wherein
2 the restraint comprises a slender length of flexible material.

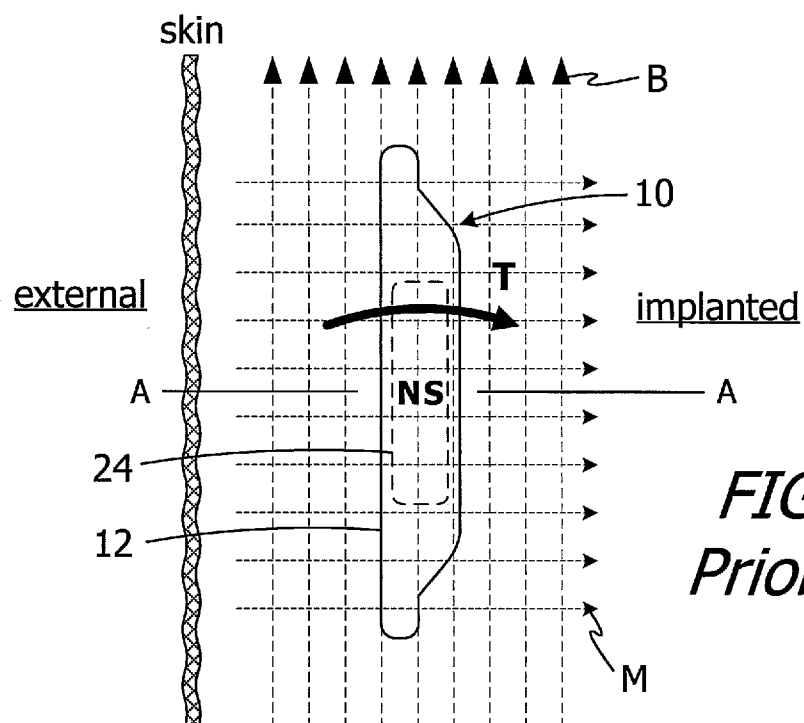
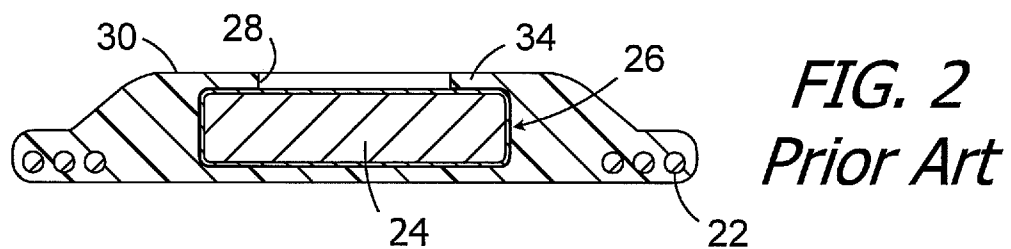
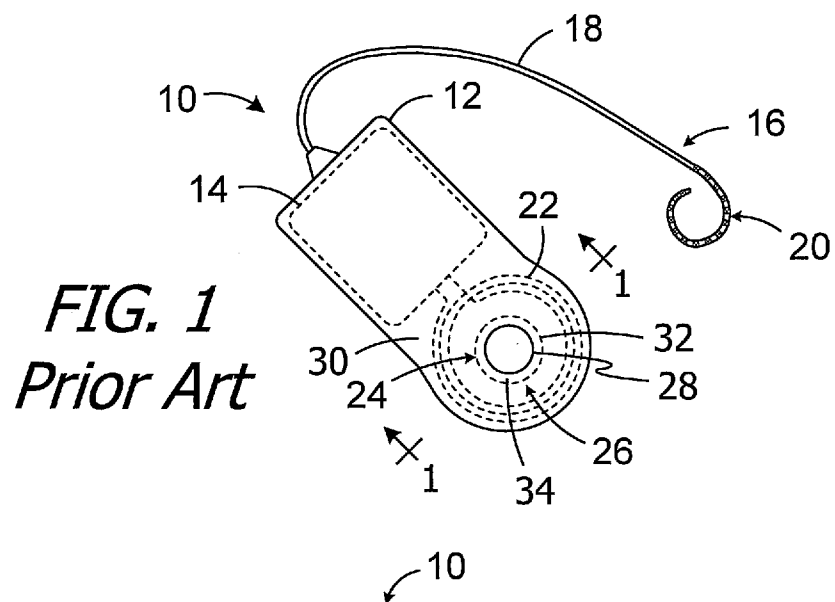
1 19. A method as claimed in claim 14, further comprising the steps
2 of:
3 removing the restraint and the magnet from the cochlear implant
4 housing while the cochlear implant housing is within a patient;
5 reinserting the magnet into the magnet pocket while the
6 cochlear implant housing is within the patient; and
7 after the magnet has been reinserted, anchoring a restraint to
8 restraint anchors on the cochlear implant housing in such a manner that the
9 restraint extends over the magnet aperture.

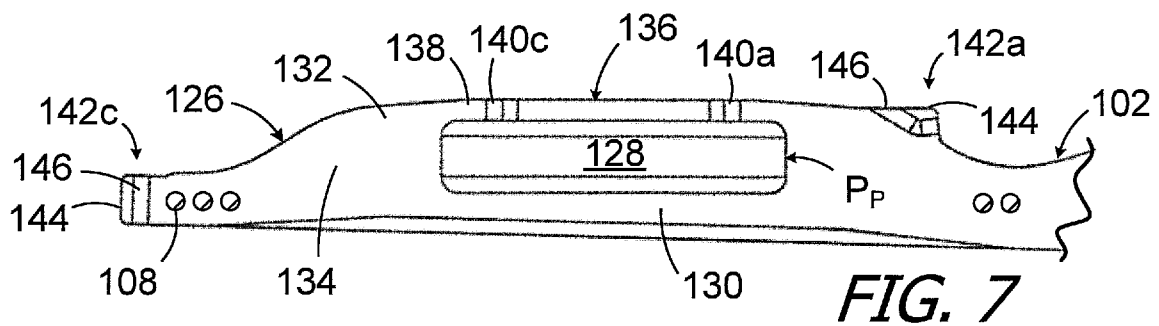
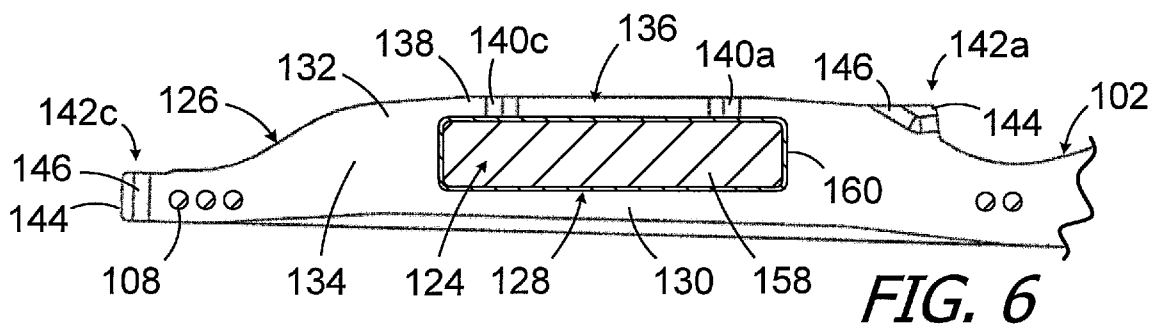
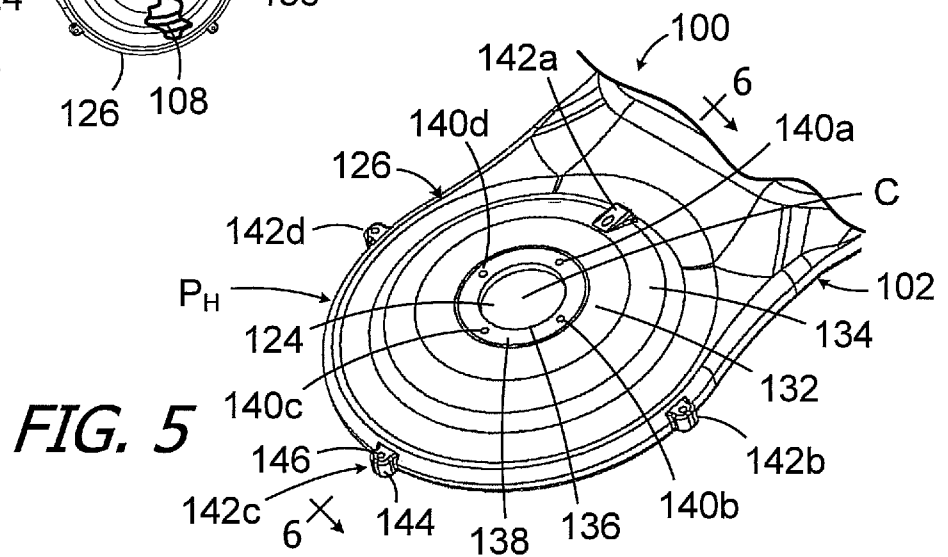
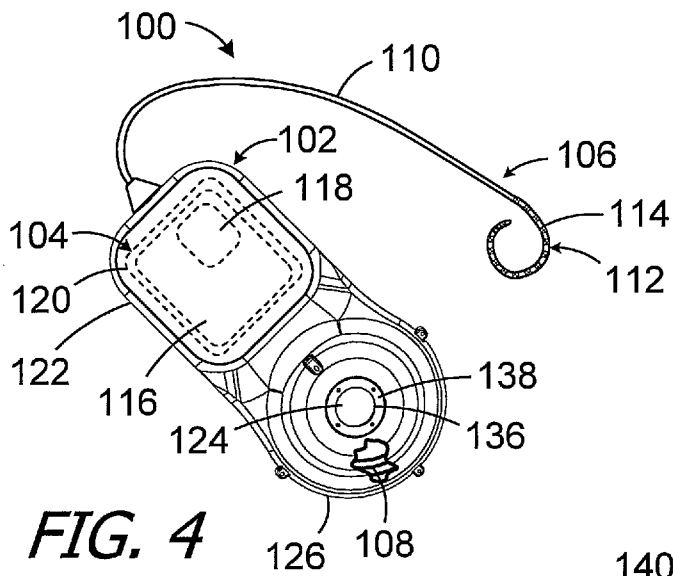
1 20. A method as claimed in claim 14, wherein
2 anchoring a restraint comprises anchoring a restraint to restraint
3 anchors on the cochlear implant housing without anchoring the restraint to
4 tissue.

1 21. A cochlear implant, comprising:
2 a cochlear lead including a plurality of electrodes;
3 a housing defining an exterior and including a magnet pocket, a
4 top wall above the magnet pocket, and a magnet aperture that extends
5 through the top wall to the magnet pocket;
6 an antenna within the housing and adjacent to the magnet
7 pocket;
8 a stimulation processor within the housing operably connected
9 to the antenna and to the cochlear lead; and
10 means for securing a restraint to the housing in such a manner
11 that the restraint extends across the magnet aperture.

1 22. A cochlear implant as claimed in claim 21, wherein
2 the housing comprises a flexible housing; and
3 the antenna and the stimulation processor are embedded within
4 a flexible housing.

- 1 23. A cochlear implant as claimed in claim 22, wherein
2 the housing is formed from a silicone elastomer.
- 1 24. A cochlear implant as claimed in any one of claims 21-23,
2 further comprising:
3 a magnet located within the magnet pocket.
- 1 25. A cochlear implant as claimed in any one of claims 21-24,
2 further comprising:
3 a restraint secured to the housing by the means for securing a
4 restraint.
- 1 26. A system, comprising
2 a cochlear implant as claimed in any one of claims 21-25; and
3 a headpiece including
4 an antenna, and
5 a headpiece magnet associated with the antenna that is
6 attracted to the implant magnet.





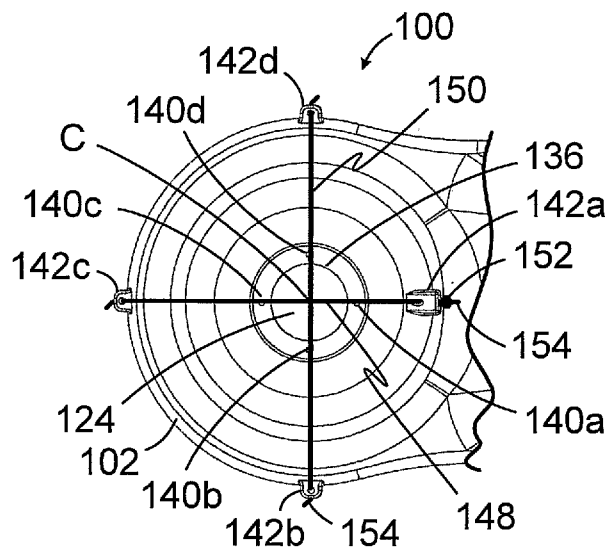


FIG. 8

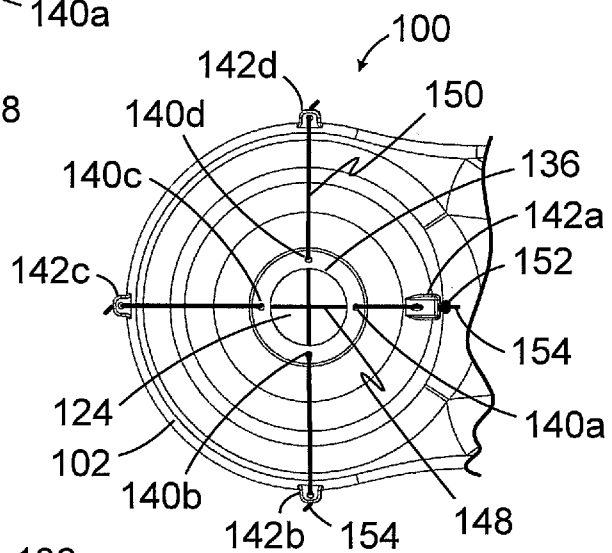


FIG. 9

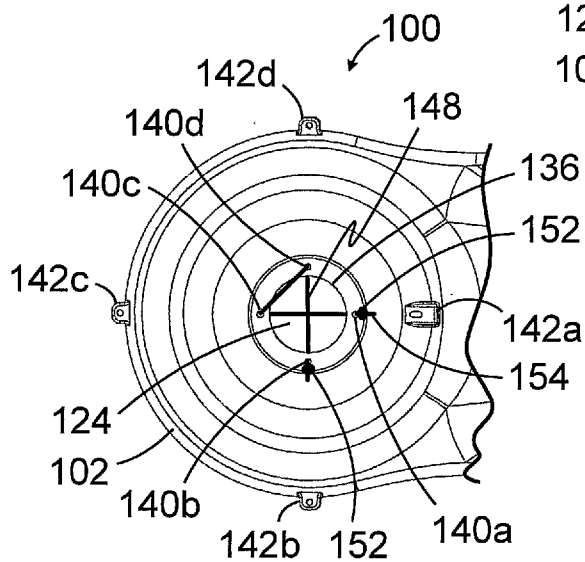


FIG. 10

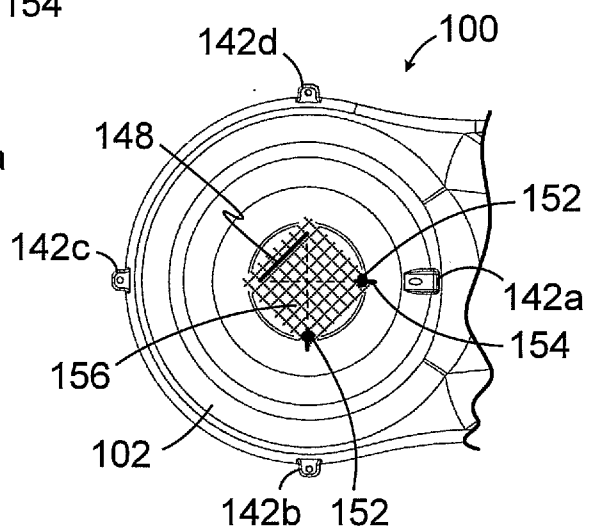
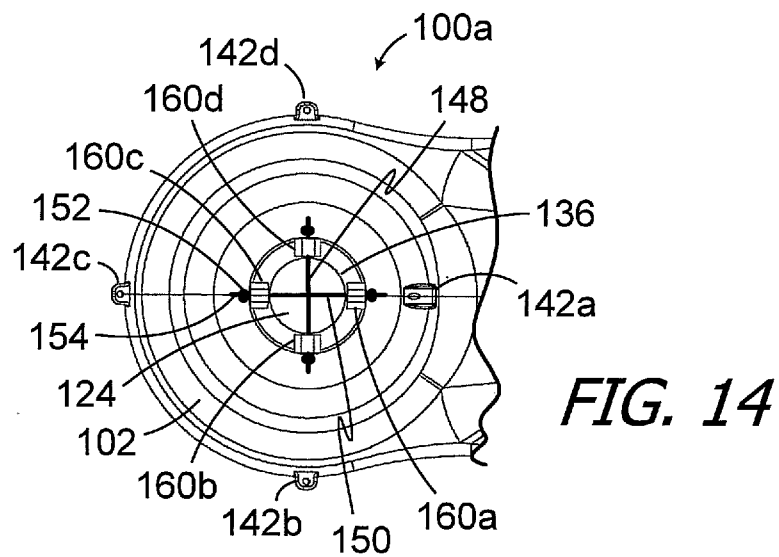
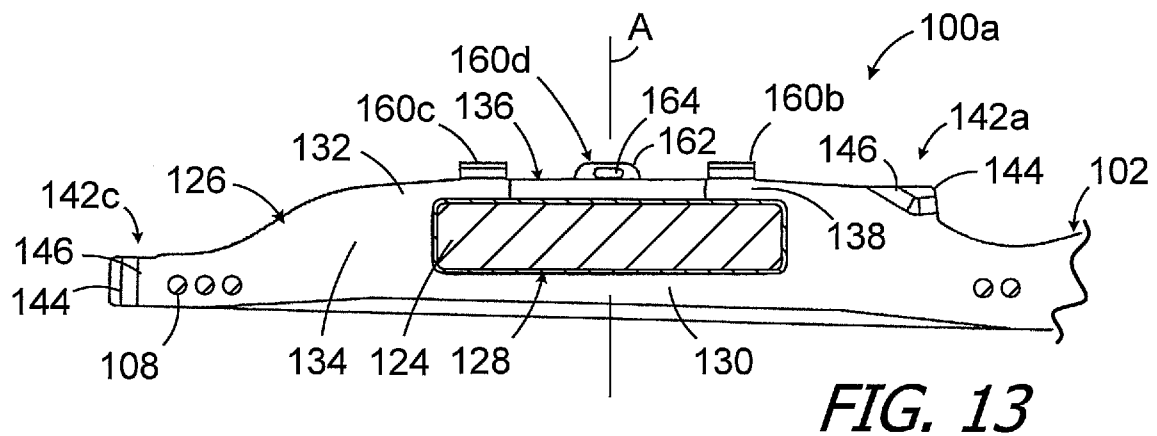
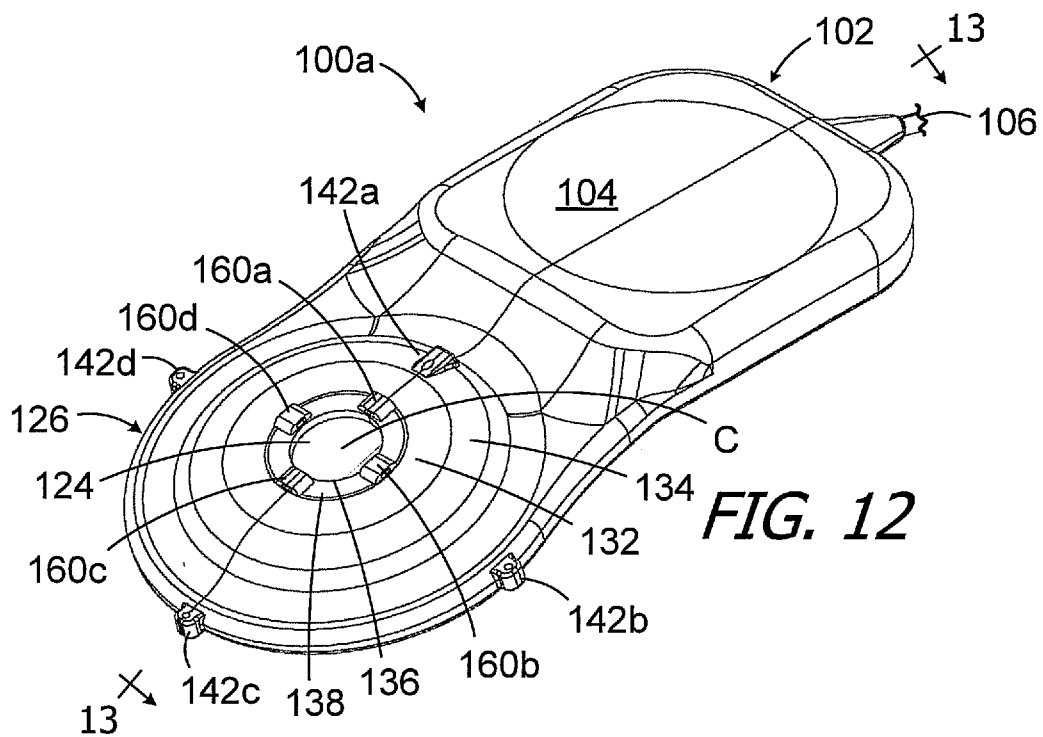
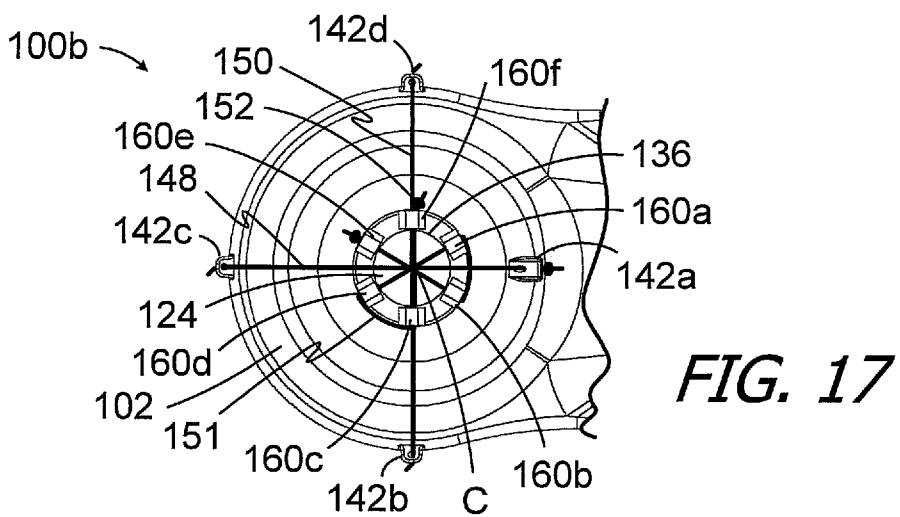
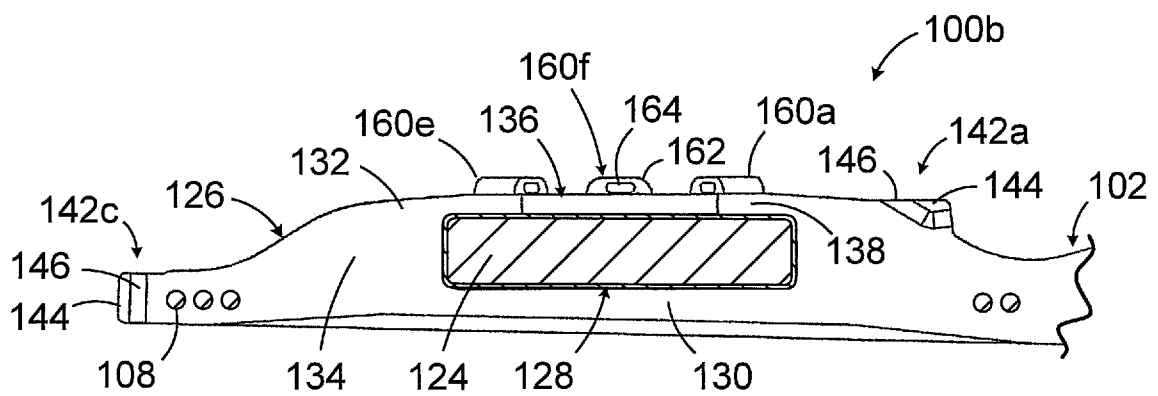
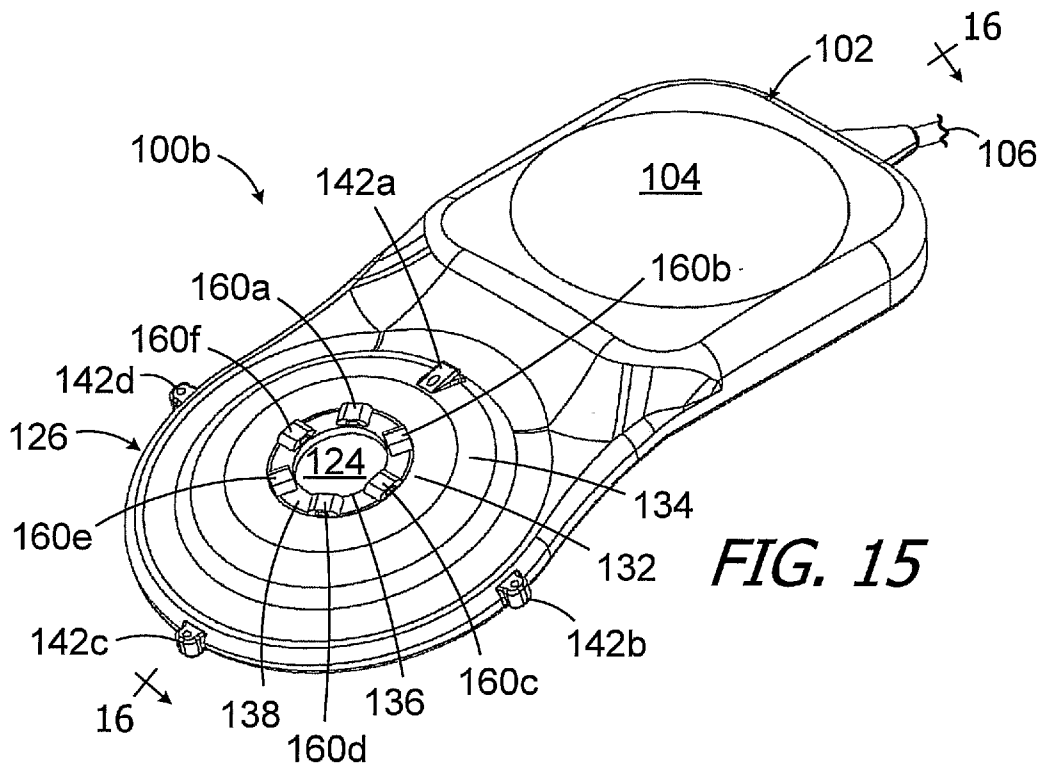
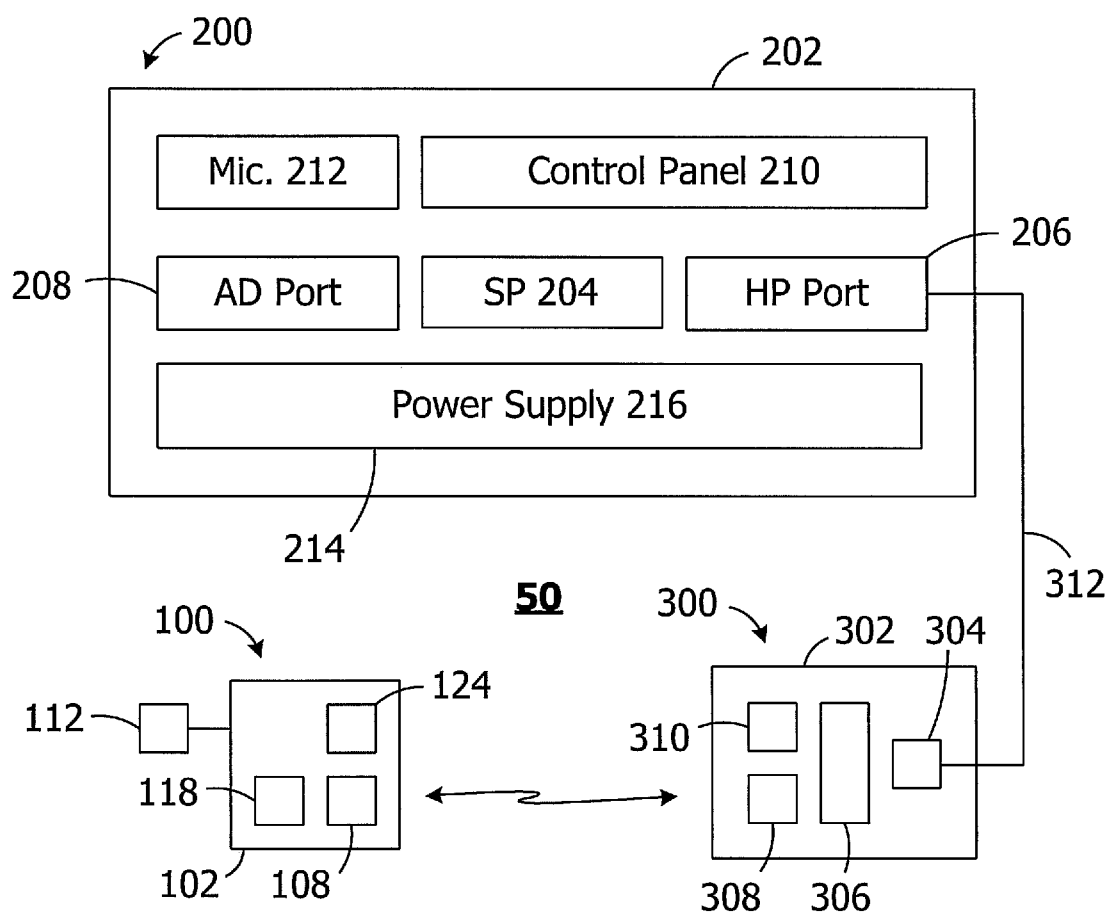


FIG. 11





**FIG. 18**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/046403

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61N1/36

ADD.

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)

A61N

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)

EP0-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	WO 03/092326 A1 (COCHLEAR LTD [AU]; GIBSON PETER [AU]) 6 November 2003 (2003-11-06)	1-6,8, 11-18, 20-26 7,9,10
A	page 4, line 10 - line 16 page 6, line 6 - line 13 page 8, line 29 - page 9, line 7 page 10, line 30 - page 11, line 18 page 11, line 31 - page 12, line 18; figures 1, 4, 6	
A	----- US 5 290 281 A (TSCHAKALOFF ALEXANDER [DE]) 1 March 1994 (1994-03-01) column 1, line 16 - line 38 column 10, line 47 - column 11, line 35; figures 6A-6F ----- -/--	5-7



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 May 2016

Date of mailing of the international search report

31/05/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Sigurd, Karin

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/046403

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/343626 A1 (THENUWARA CHULADATTA [US] ET AL) 20 November 2014 (2014-11-20) paragraph [0058] - paragraph [0067] paragraph [0075] paragraph [0096] - paragraph [0101]; figures 3, 17-19 -----	1-18, 20-26
A	US 2009/287278 A1 (CHARVIN GUY [FR]) 19 November 2009 (2009-11-19) paragraph [0019] - paragraph [0022] paragraph [0043] - paragraph [0046]; figures 3, 4A -----	1-18, 20-26

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/046403

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.: 19
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210
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:

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

Continuation of Box II.1

Claims Nos.: 19

Dependent claim 19 relates to a method comprising the step of removing a restraint and a magnet from a cochlear implant housing while the cochlear implant housing is within a patient. As this is a method for treatment of the human or animal body by surgery, the International Searching Authority is not required to search the subject-matter of dependent claim 19 according to Rule 39.1(iv) PCT.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/046403

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 03092326	A1	06-11-2003	NONE	

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			US 5290281 A	01-03-1994
			US 5459298 A	17-10-1995
			US 5607427 A	04-03-1997

US 2014343626	A1	20-11-2014	EP 2758125 A1	30-07-2014
			US 2014343626 A1	20-11-2014
			WO 2013043176 A1	28-03-2013

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			EP 2119474 A2	18-11-2009
			FR 2931076 A1	20-11-2009
			US 2009287278 A1	19-11-2009
