



- (51) International Patent Classification: *H04R 11/04* (2006.01) *H04R 31/00* (2006.01)
- (21) International Application Number: PCT/US2013/037689
- (22) International Filing Date: 23 April 2013 (23.04.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 61/638,644 26 April 2012 (26.04.2012) US
- (71) Applicant: **MED-EL ELEKTROMEDIZINISCHE GERAETE GMBH** [AT/US]; Fuerstenweg 77, A-6020 Innsbruck (AT).
- (72) Inventors: **EINBERGER, Tobias**; Innrain 36b, A-6220 Innsbruck (AT). **BAUMGARTNER, Josef**; Außerdorf 65, A-6179 Ranggen (AT).
- (74) Agents: **SANDVOS, Jay** et al.; Sunstein Kann Murphy & Timbers LLP, 125 Summer Street, Boston, Massachusetts 02110-1618 (US).
- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

[Continued on next page]

(54) Title: NON-PRESSURE SENSITIVE IMPLANTABLE MICROPHONE

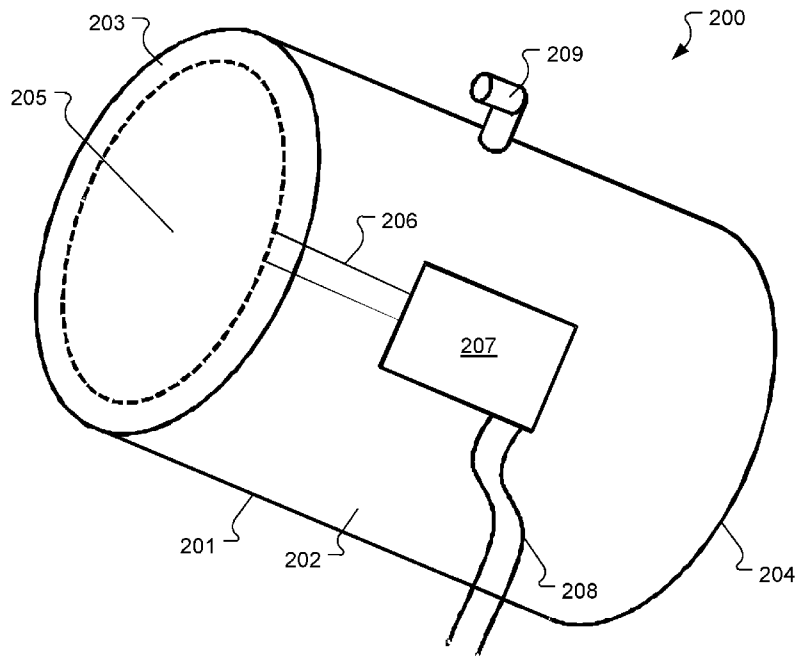


Fig. 2

(57) Abstract: An implantable microphone is described for use in hearing prosthesis systems. A cylindrical microphone housing has opposing circular cylinder ends and an interior volume containing an incompressible housing liquid. At least one housing membrane is on one of the cylinder ends and is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing. An acoustic-electric transducer is coupled to the housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.

WO 2013/163115 A1

MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

— *before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))*

Published:

— *with international search report (Art. 21(3))*

TITLE

Non-Pressure Sensitive Implantable Microphone

[0001] This application claims priority from U.S. Provisional Application 61/638,644, filed April 26, 2012, which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to an implantable microphone for a hearing prosthesis system such as a cochlear implant system.

BACKGROUND ART

[0003] A normal ear transmits sounds as shown in Figure 1 through the outer ear **101** to the tympanic membrane **102** which moves the bones of the middle ear **103** that vibrate the oval window opening of the cochlea **104**. The cochlea **104** is a long narrow duct that is wound spirally about a central axis for approximately two and a half turns. It includes an upper channel known as the scala vestibuli and a lower channel known as the scala tympani, which are connected by the cochlear duct. The cochlea **104** forms an upright spiraling cone with a center called the modiolar where the spiral ganglion cells of the acoustic nerve **113** reside. In response to received sounds transmitted by the middle ear **103**, the fluid-filled cochlea **104** functions as a transducer to generate electric pulses which are transmitted to the cochlear nerve **113**, and ultimately to the brain.

[0004] Hearing is impaired when there are problems in the ear's ability to transduce external sounds into meaningful action potentials along the neural substrate of the cochlea **104**. To improve impaired hearing, hearing prostheses have been developed. For example, when the impairment is related to operation of the middle ear **103**, a conventional hearing aid may be used to provide acoustic-mechanical stimulation to the auditory system in the form of amplified sound. Or when the impairment is associated with the cochlea **104**, a cochlear implant with an implanted stimulation electrode can electrically stimulate auditory nerve tissue with small currents delivered by multiple electrode contacts distributed along the electrode.

[0005] Figure 1 also shows some components of a typical cochlear implant system. An external microphone provides an audio signal input to an external signal processor **111** where various signal processing schemes can be implemented. The processed signal is then converted into a digital data format such as a sequence of data frames for transmission into an implanted stimulator **108**. Besides receiving the processed audio information, the implanted stimulator **108** may also perform additional signal processing such as error correction, pulse formation, etc. and produces stimulation signals (based on the extracted audio information) that is sent through an electrode lead **109** to an implanted electrode array **112**. The electrode array **112** includes multiple electrode contacts **110** on its surface that deliver the stimulation signals to adjacent neural tissue of the cochlea **104** which the brain interprets as sound. The individual electrode contacts **110** may be activated sequentially, or simultaneously in one or more groups of electrode contacts **110**.

[0006] Though existing commercial products generally use an external microphone to sense the acoustic environment, there would be an advantage to an implantable microphone. Among other things, an implantable microphone needs to be hermetically sealed from the environment of the adjacent tissue. This makes implantable microphones very sensitive to pressure changes such as those that occur on an airplane flight. For high acoustic sensitivity, a good acoustic impedance match to the surrounding tissue is necessary, which due to the required hermeticity is achieved using thin metal membranes. Pressure changes on the outside of the microphone relative to the hermetic inside of the microphone then can cause a deformation of the membrane, which produces bad microphone characteristics or even a total microphone failure. This problem can be mitigated somewhat by increasing the pressure inside the hermetic microphone housing and thus shifting the pressure range. But the change with pressure in the microphone characteristics remains unsolved.

SUMMARY

[0007] Embodiments of the present invention are directed to an implantable microphone for use in hearing prosthesis systems. A cylindrical microphone housing has opposing circular cylinder ends and an interior volume containing an incompressible housing liquid. At least one housing membrane is on one of the cylinder ends and is in contact with the

housing liquid and moveable in response to an acoustic signal outside the housing. An acoustic-electric transducer is coupled to the housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.

[0008] Embodiments of the present invention also are directed to an implantable microphone for use in hearing prosthesis systems. A microphone housing has a double cone shape with opposing circular cone ends and an interior volume containing an incompressible housing liquid, wherein the double cone shape is narrower in the middle and wider towards the ends. At least one housing membrane is on one of the cone ends that is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing. An acoustic-electric transducer is coupled to the housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.

[0009] In further specific embodiments, there may be housing membranes on each cylinder end, with an acoustic-electric transducer coupled to each housing membrane. There also may be an interior membrane within the interior volume of the microphone housing between the at least one housing membrane and the acoustic-electric transducer for coupling the movement of the housing membrane to the acoustic-electric transducer. In some such embodiments, there may be a bypass tube that provides a fluid passage across the interior membrane. There may also be a microphone signal module for developing the microphone signal and coupling the microphone signal as an electrical output from the microphone housing. For example, the microphone signal module may be located in the incompressible liquid within the interior volume. And there may be an attachment pad located on the outer surface of the microphone housing for connecting the microphone housing to adjacent bone in the implanted patient.

[0010] Embodiments of the present invention also include an implantable hearing prosthesis system having an implantable microphone according to any of the foregoing. For example, the implantable hearing prosthesis system may be a cochlear implant system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1 shows various anatomical structures in a normal human ear and various

elements of a typical cochlear implant system.

[0012] Figure 2 shows an example of an implantable microphone according to one specific embodiment of the present invention.

[0013] Figure 3 shows another example of an implantable microphone according to another specific embodiment of the present invention.

DETAILED DESCRIPTION

[0014] Various embodiments of the present invention are directed to an implantable microphone with improved handling of pressure changes. The interior volume of the microphone is filled with an incompressible liquid. The use of an incompressible liquid results in the microphone being uninfluenced by pressure changes.

[0015] Fig. 2 shows one specific embodiment of such an implantable microphone **200** for use in hearing prosthesis systems. A cylindrical microphone housing **201** has an interior volume **202** that contains an incompressible housing liquid such as an oil, silicone-based fluid, or a fluid dispersion (water-based or not). There are housing membranes **203** and **204** at either cylindrical end of the microphone housing **201** which are in contact with the housing liquid. The housing membranes **203** and **204** are moveable in response to an acoustic signal outside the microphone housing **201**.

[0016] An acoustic-electric transducer **205** is coupled to one or both of the housing membranes **203** or **204** for converting the acoustic generated movement of the housing membrane into a corresponding electrical microphone signal. Using two opposing housing membranes **203** and **204** helps provide a good acoustic impedance match to the surrounding tissue and enables the acoustic wave to travel through the liquid-filled interior volume **201** of the microphone **200**. The acoustic-electric transducer **205** may be a piezo element attached to one of the housing membranes **203** and/or **204**, but some other kind of acoustic-electric transducer **205** also can be used. In some embodiments, there may be an acoustic-electric transducer **205** on each of the housing membranes **203** and **204** whose signals may be summed together in an advantageous way.

[0017] The output sensing signal of the acoustic-electric transducer **205** may be coupled by one or more transducer wires **206** to a microphone signal module **207** with the microphone housing **201** to perform signal conditioning/pre-processing of the transducer sensing signal. Depending on the specific properties of the housing liquid (e.g. if the liquid is electrically conductive) a microphone sensing module **207** may be encapsulated in protective material or enclosed in its own module housing within the interior volume **202**. The processed microphone output signal from the microphone sensing module **207** is coupled out from the microphone **200** by one or more microphone output wires **208** (e.g., to an implanted stimulator **108** for further signal processing, etc.).

[0018] Figure 3 shows another example of another implantable microphone **300** in which the microphone housing **301** has a double cone shape which is narrower in the middle and wider towards the opposing circular cone ends. The microphone housing **301** has an interior volume **302** that contains an incompressible housing liquid that results in the desired improvement in response to exterior pressure changes. There are housing membranes **303** and **304** located at the cone ends of the microphone housing **301**.

[0019] In the embodiment shown in Fig. 3, an interior intermediate membrane **310** is located within the interior volume **302** of the microphone housing **301** with an acoustic-electric transducer **305** mounted thereto. Due to the double cone shape of the microphone housing **301**, the outer housing membranes **303** and **304** are larger than the intermediate membrane **310** which results in amplification of the acoustic signal sensed by the acoustic-electric transducer **305** at the intermediate membrane **310**. The intermediate membrane **310** can be optimized to meet the specific needs of the acoustic-electric transducer **305** (e.g. non-conductive), while the outer end housing membranes **303** and **304** can be optimized to best ensure hermeticity and impedance matching. The interior intermediate membrane **310** also protected against mechanical impact.

[0020] The use of an intermediate membrane **310** could result in an undesirable pre-load which could alter the microphone characteristic. Thus, the microphone **300** shown in Fig. 3 has a bypass tube **311** that provides a fluid passage across the intermediate membrane

305. Another fluid bypass option is to provide a small hole in the intermediate membrane **310** to avoid a pre-load.

[0021] Microphone signal module **307** is located in the incompressible liquid within the interior volume **301** and receives the transducer sensing signal from the acoustic-electric transducer **305** via one or more transducer wires **306** and produces an output microphone signal that is coupled by one or more microphone output wires **308** as an electrical output from the microphone housing **301**.

[0022] Relative movement is needed between the microphone housing and the microphone to develop a sensing signal. Thus in general the mass of the microphone housing should be larger than the mass of the incompressible liquid within the interior volume of the microphone housing, or else the microphone housing should be securely fixed to a large mass such as the skull bone. Thus some embodiments of an implantable microphone may include an attachment pad in between the housing membrane and the bone site that provides a good acoustic impedance match. Due to the tapered middle part, the double cone-shaped microphone **300** has the advantage that the mass of the interior liquid is reduced compared to the cylinder shaped microphone **200**. Additionally the tissue between the cones effectively increases the mass of the housing.

[0023] Embodiments of an implantable microphone containing an incompressible liquid thus are less sensitive to changes in pressure than conventional microphones. In addition, there is an improved acoustic impedance match since the acoustic impedance of the liquid is closer to the impedance of the surrounding tissue as compared to air. But for a condenser microphone or electret microphone, the higher permittivity of a liquid compared to air may reduce the acoustic-electric transducer factor, so a liquid with low permittivity should be used. Moreover, the interior liquid should be compatible to the transducer material and to possible electronics within the microphone.

[0024] Although various exemplary embodiments of the invention have been disclosed, it should be apparent to those skilled in the art that various changes and modifications can

be made which will achieve some of the advantages of the invention without departing from the true scope of the invention.

CLAIMS

What is claimed is:

1. An implantable microphone for use in hearing prosthesis systems, the microphone comprising:
 - a cylindrical microphone housing with opposing circular cylinder ends and having an interior volume containing an incompressible housing liquid;
 - at least one housing membrane on one of the cylinder ends that is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing; and
 - an acoustic-electric transducer coupled to the at least one housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.
2. An implantable microphone according to claim 1, wherein there are housing membranes on each cylinder end, and wherein an acoustic-electric transducer is coupled to each housing membrane.
3. An implantable microphone according to claim 1, further comprising:
 - an interior membrane within the interior volume of the microphone housing between the at least one housing membrane and the acoustic-electric transducer for coupling the movement of the housing membrane to the acoustic-electric transducer.
4. An implantable microphone according to claim 3, further comprising:
 - a bypass tube providing a fluid passage across the interior membrane.
5. An implantable microphone according to claim 1, further comprising:
 - a microphone signal module for developing the microphone signal and coupling the microphone signal as an electrical output from the microphone housing.
6. An implantable microphone according to claim 5, wherein the microphone signal module is located in the incompressible liquid within the interior volume.
7. An implantable microphone according to claim 1, further comprising:

an attachment pad located on the outer surface of the microphone housing for connecting the microphone housing to adjacent bone in the implanted patient.

8. An implantable hearing prosthesis system having an implantable microphone according to any of claims 1-7.
9. An implantable microphone for use in hearing prosthesis systems, the microphone comprising:
 - a microphone housing having a double cone shape with opposing circular cone ends and having an interior volume containing an incompressible housing liquid, wherein the double cone shape is narrower in the middle and wider towards the ends;
 - at least one housing membrane on one of the cone ends that is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing; and
 - an acoustic-electric transducer coupled to the at least one housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.
10. An implantable microphone according to claim 9, wherein there are housing membranes on each cone end, and wherein an acoustic-electric transducer is coupled to each housing membrane.
11. An implantable microphone according to claim 9, further comprising:
 - an interior membrane within the interior volume of the microphone housing between the at least one housing membrane and the acoustic-electric transducer for coupling the movement of the housing membrane to the acoustic-electric transducer.
12. An implantable microphone according to claim 11, further comprising:
 - a bypass tube providing a fluid passage across the interior membrane.
13. An implantable microphone according to claim 9, further comprising:
 - a microphone signal module for developing the microphone signal and coupling the microphone signal as an electrical output from the microphone housing.

14. An implantable microphone according to claim 13, wherein the microphone signal module is located in the incompressible liquid within the interior volume.

15. An implantable microphone according to claim 9, further comprising:
an attachment pad located on the outer surface of the microphone housing for connecting the microphone housing to adjacent bone in the implanted patient.

16. An implantable hearing prosthesis system having an implantable microphone according to any of claims 9-15.

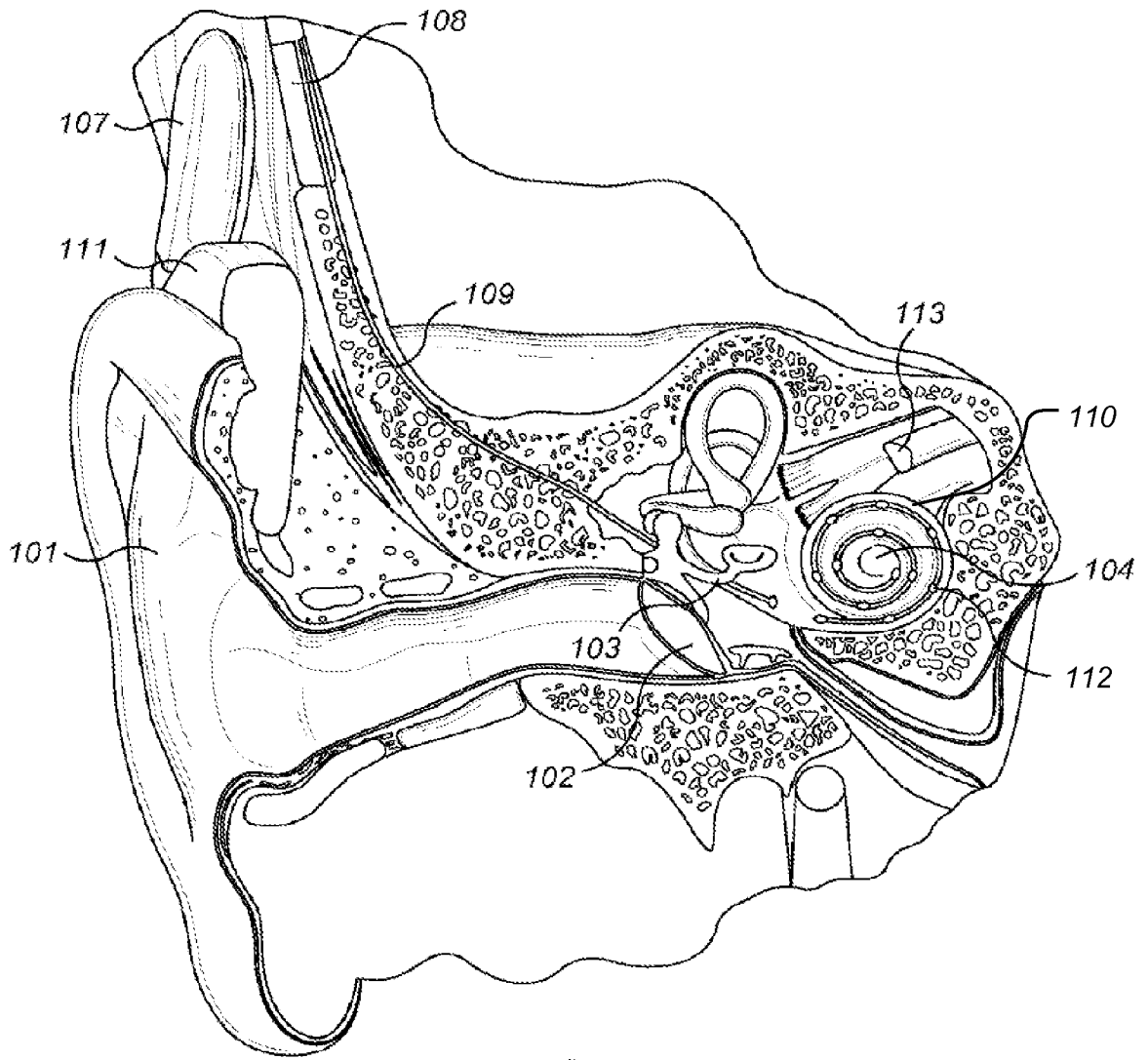


FIG. 1

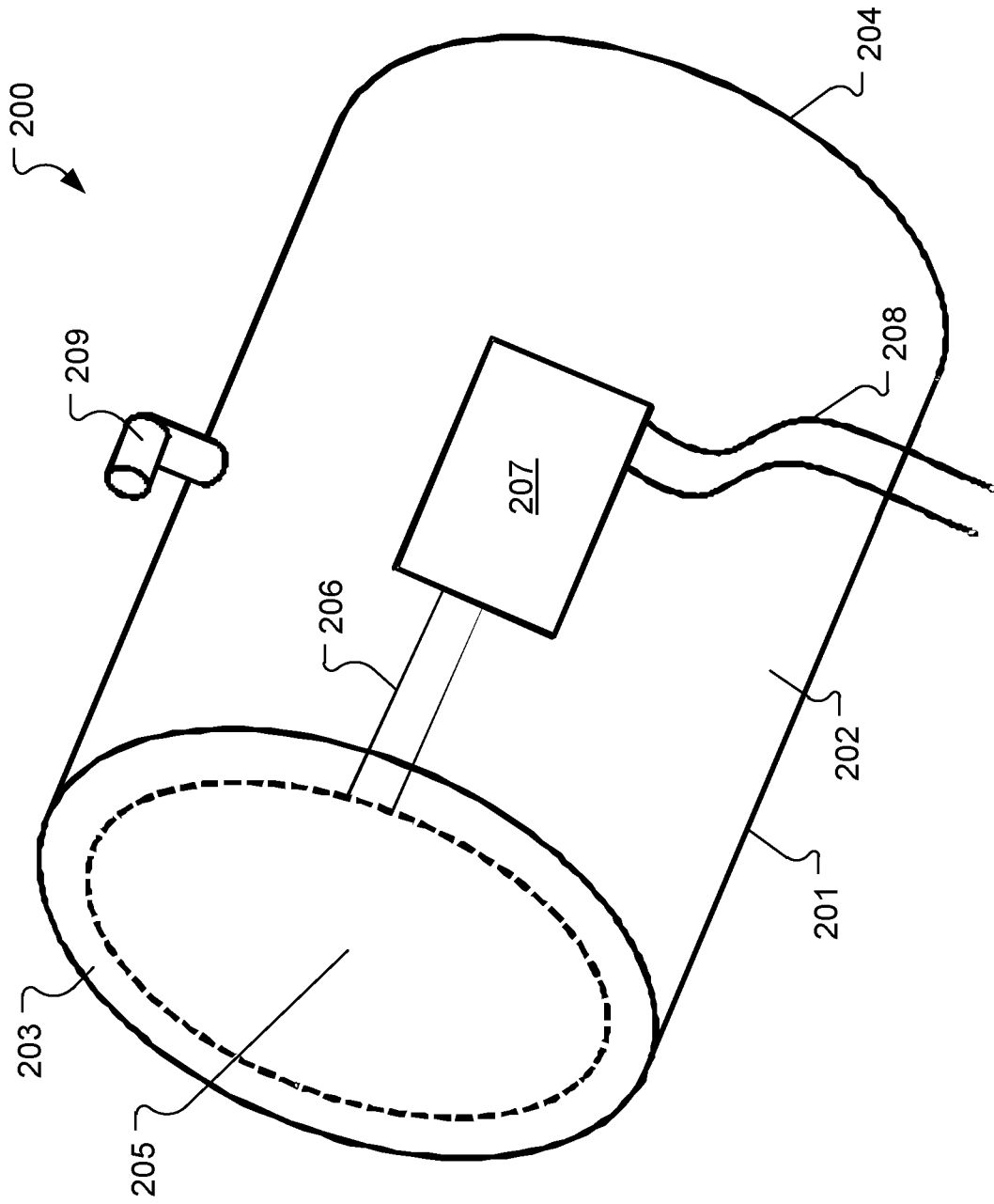


Fig. 2

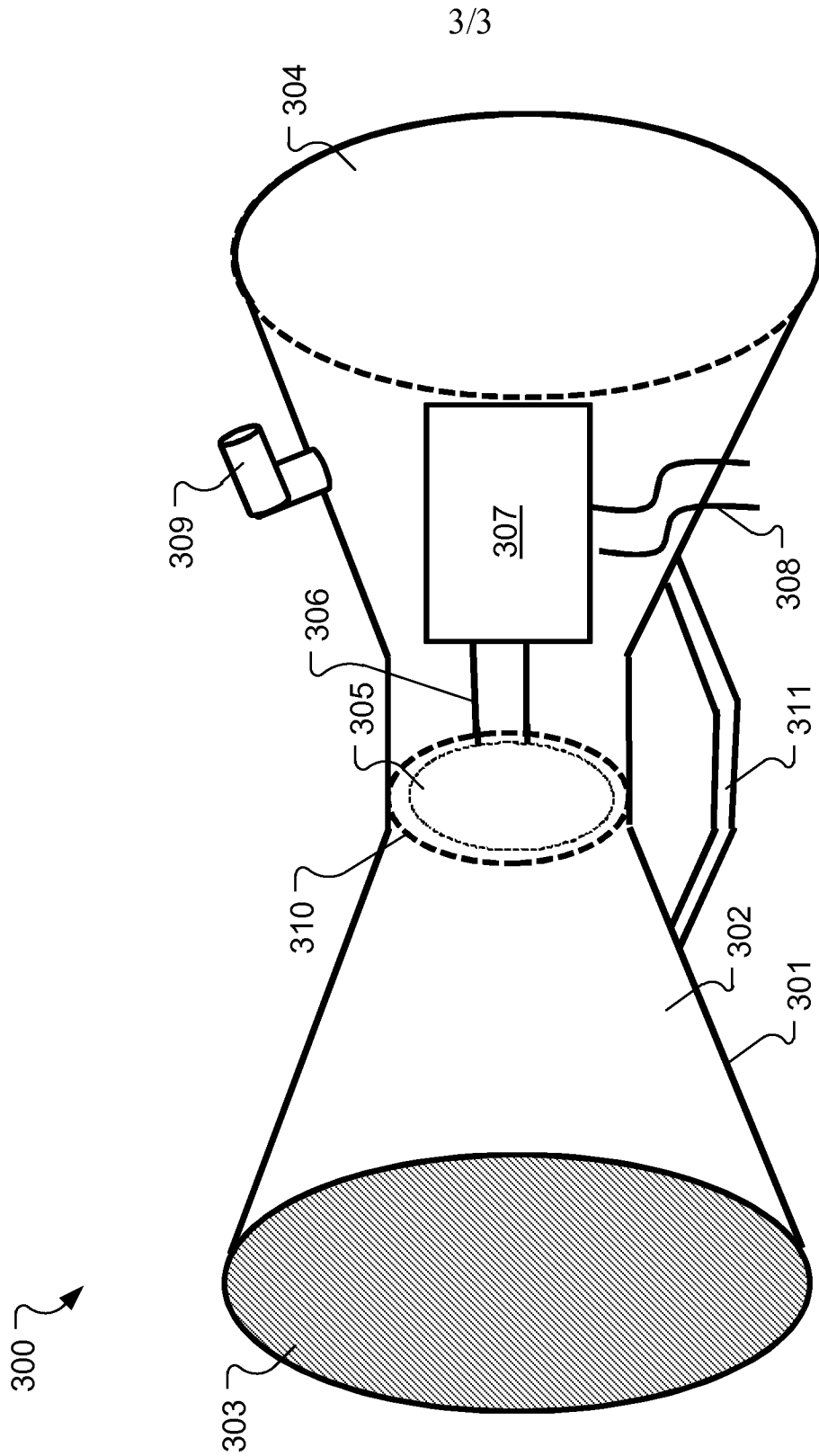


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/37689

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - H04R 11/04; 31/00 (2013.01)
 USPC - 600/25; 607/55, 56, 57, 136, 137; 381/364, 361, 355, 150
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 IPC(8): H04R 11/04; 31/00 (2013.01)
 USPC: 600/25; 607/55, 56, 57, 136, 137; 381/364, 361, 355, 150

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)
 MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); IP.com; PubMed/MEDLINE;
 Google/Google Scholar: ear, cochlear, implant, prosthesis, incompressible, fluid, liquid, bypass, cylinder, microphone, transducer,
 hearing, acoustic, auditory.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 5772575 A (LESINSKI, SG et al.) June 30, 1998; abstract; column 6, lines 23-26; column 9, lines 15-30; column 11, lines 33-36 ;column 14, lines 48-59; column 15, lines 1-2;	1, 5-6, 8/1, 8/5-6 2-3, 7, 8/2, 8/3, 8/7, 9-11, 13-15, 16/9-11, 16/13-15
Y	US 5977689 A (NEUKERMANS, AP) November 2, 1999; figure 6B; column 9, lines 9-32	2-3, 8/2, 8/3, 10-11, 16/10, 16/11
Y	US 7722524 B2 (LUPIN, AJ et al.) May 25, 2010; column 6, lines 4-20	7, 8/7, 15, 16/15
Y	US 2009/0022353 A1 (GOLDSTEIN, SW et al.) January 22, 2009; figures 2, 5; paragraphs [0026], [0028]	9-11, 13-15, 16/9-11, 16/13-15

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search 06 September 2013 (06.09.2013)	Date of mailing of the international search report 13 SEP 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

~~13/US/009 13.07.2013~~
 International application No.
 PCT/US13/37689

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 Supplemental 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 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.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/37689

--***Continued from Box III: Observations where unity of invention is lacking***--

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-7 and 8/1-7 are directed toward an implantable microphone for use in hearing prosthesis systems, the microphone comprising: a cylindrical microphone housing.

Group II: Claims 9-15 and 16/9-15 are directed toward an implantable microphone for use in hearing prosthesis systems, the microphone comprising: a microphone housing having a double cone shape with opposing circular cone ends.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical features of Group I include a cylindrical microphone housing with opposing circular cylinder ends; at least one housing membrane on one of the cylinder ends, which are not present in Group II; the special technical features of Group II include a microphone housing having a double cone shape with opposing circular cone ends; wherein the double cone shape is narrower in the middle and wider towards the ends; at least one housing membrane on one of the cone ends, which are not present in Group I.

The common technical features of Groups I and II are an implantable microphone for use in hearing prosthesis systems, the microphone comprising: a microphone housing with opposing ends and having an interior volume containing an incompressible housing liquid; at least one housing membrane on one of the ends that is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing; and an acoustic-electric transducer coupled to the at least one housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal.

This common technical features are disclosed by US 2010/0092021 A1 to Wiskerke, et al. (hereinafter 'Wiskerke'). Wiskerke discloses an implantable microphone for use in hearing prosthesis systems (an implantable microphone 302 for a hearing prosthesis; abstract; figure 3), the microphone comprising: a microphone housing with opposing ends (microphone comprises a housing 306 with opposing ends; abstract; figure 3) and having an interior volume containing an incompressible housing liquid (liquid form stiffening material 346 fills housing 306; figure 3; paragraph [0063]); at least one housing membrane on one of the ends that is in contact with the housing liquid and moveable in response to an acoustic signal outside the housing (diaphragm 340 (housing membrane) seals an aperture formed in housing 306 and vibrates in response to deflection volume 354 (acoustic; figure 3; paragraph [0046]); and an acoustic-electric transducer coupled to the at least one housing membrane for converting movement of the housing membrane into a corresponding electrical microphone signal (transducer or sensor 348 is configured to detect vibration of diaphragm 340 (housing membrane) and to generate electric signals based thereon; figure 3; paragraph [0047]).

Since the common technical features are previously disclosed by the Wiskerke reference, the common features are not special and so Groups I and II lack unity.